# Geologic Map of the Salome 30'x60' Quadrangle, West-central Arizona

by

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# MAP UNITS

## Late Tertiary and Quaternary deposits

Q Undivided surficial deposits. **(Quaternary)** Alluvium and talus, undifferentiated.

Qyc Active alluvium. **(Holocene)** Primarily sand and silt (hue 7.5 to 5 YR), confined to active and recently active deposits of major axial drainages. No soil development has occurred on any of the deposits.

Qye Eolian deposits. **(Holocene)** Fine-grained, non-indurated sand. Mapped where sand dunes, generally stabilized by vegetation, make up more than 50% of the surficial deposits.

Qy Young Alluvium. **(Holocene and late Pleistocene)** Surfaces primarily underlain by well-sorted sand and silt, with local occurrences of fine gravel. Surfaces are very slightly but abundantly dissected by active gullies and washes, with ≤0.5 m of relief. Remnant bar -and-swale topography is preserved locally. Surface material typically fine-grained, and surfaces appear smooth. Incipient to light desert varnish is developed on mafic clasts where a surface pavement is present. Surfaces exhibit minimal soil development; the most strongly developed profiles contain cambic horizons (hue 7.5 YR) over stage I to II calcic horizons [Machette, 1985]. Soils typically belong to Torriorthents, Calciorthids, or Camborthids great groups.

Qt Talus. **(Holocene and late Pleistocene)** Unconsolidated, poorly sorted, angular gravel to boulder-size sediment on steep slopes.

Qm Middle alluvium, undifferentiated. **(Late to middle Pleistocene)** Undivided younger and older middle alluvium (includes $Qm_1$ and $Qm_2$). Primarily represents surface remnants in which the two units are mixed to a degree that precludes differentiation at the scale of this map. In a few places this broader designation is used because of uncertainty in estimating the age of a particular remnant.

$Qm_2$ Younger middle alluvium. (Late to middle Pleistocene) Surfaces underlain by deposits of silt to coarse gravel, and slightly to moderately dissected with ~1 to 4 m of relief above active channels. Remnants have smooth and fine-grained surface or planar, gravelly pavement. Pavements commonly have moderate to dark desert varnish on mafic clasts. Soils on the remnants exhibit slightly of moderately developed textural B horizons (hue 7.5 to 5 YR), typically above a stage II or III calcic horizon. Soils are Camborthids to Haplargids.

$Qm_1$ Older middle alluvium. **(Middle Pleistocene)** Surfaces underlain by sand and fine gravel to large cobbles, generally moderately sorted. Surfaces are moderately dissected, with ~3 to 6 m of relief above active channels. Remnants are generally rounded by erosion near their edges, and have a gravelly to cobbly capping pavement. Mafic clasts in the pavement are consistently darkly varnished, and surface remnant are normally among the darkest on the piedmont. Underlying soils are characterized by moderately to very strongly developed argillic horizons (hue 5 to 2.5 YR), and commonly overlie a stage III to IV calcic horizon. Soils are Haplargids or Paleargids.

Qo Older alluvium. **(Middle to early Pleistocene)** Surfaces underlain by coarse gravel and cobbles to boulders, with minor amounts of finer-grained material. Commonly forms a 1-5 m thick veneer unconformably overlying older basin fill or bedrock. Surfaces are relatively deeply dissected, with ~7 to 10 m of relief above active channels. Remnants are comparatively small, and are found on well rounded ridges between entrenched channels. Pavement of the surfaces is not well preserved due to extensive erosion and/or clast weathering. Remnants are typically covered with abundant fragments of pedogenic carbonate, many of which are >5 mm thick, derived from brecciated laminar petrocalcic horizons and carbonate clast-coatings. The fragments and coated clasts commonly lend a lighter-colored appearance to these remnants. Soils are generally stripped by erosion to expose remnants of stage V or VI petrocalcic horizons (Paleorthids).

QTbx Breccia and Rubble. **(Quaternary or Tertiary)** Boulders and cobbles of shattered basalt or rhyolite mantle the surface of several hills on the NW side of the Eagletail Mountains. Exposure is too poor to determine the nature of the underlying deposit.

## Tertiary sedimentary and volcanic units

Tsy Younger sedimentary rocks. **(Pliocene or Miocene)** Polymict conglomerate with clasts up to 30 cm in diameter. Generally weakly to moderately indurated, very poorly bedded, and overlies Tertiary and pre-Tertiary rocks on an angular unconformity. Erosional unconformity typically separates Tsy from younger alluvium where the contact is well exposed. Clast types reflect rock types in adjacent outcrops. Clast size in conglomerate is generally coarser than in younger deposits, but as distance from bedrock outcrop increases, this distinction is difficult to make. Original surfaces are not preserved. Generally mapped morphologically because of poor outcrop; occurs as deeply dissected old alluvial fans with >10 m of relief above active channels.

Tsl Lacustrine sedimentary rocks. **(Miocene)** Primarily buff-colored, laminated tuffaceous mudstone that crops out east and west of Black Butte in the western Vulture Mountains. Locally includes silica nodules, gypsiferous beds, and gray colored beds that are celestite-bearing. Includes subordinate tuff and lapilli tuff.

Tsm Sedimentary rocks. **(Miocene)** Massive conglomerate, ranges from pebble and cobble conglomerate to boulder conglomerate with scattered large blocks up to about 5 m in diameter. A few thin sandstone units are interbedded. Generally buff colored, poorly to moderately indurated, and non-resistant. The unit commonly forms low hills with little or no outcrop, but steep cliffs a few meters high occasionally occur in washes. In the Big Horn Mountains, includes monolithologic sedimentary breccia and landslide megabreccia, and some overlying, less consolidated, sand and gravel deposits equivalent to unit Tsy. Clast composition reflects local source areas. The irregular distribution of the conglomerate in the southern Plomosa Mountains suggests that it was deposited on a steep paleotopography. Conglomerate in this unit is mostly coarse alluvial deposits and possible debris flow deposits. The thickness is highly variable; in the southern Plomosa Mountains a maximum of about 190 m of section is exposed. The deposits are flat lying to slightly tilted, and generally appear to have been deposited during the final stages of the early Miocene extension event.

Tbu Upper basalt. **(Miocene)** Vesicular basalt lavas with a dark gray very fine-grained groundmass of plagioclase, opaque oxides, and olivine and phenocrysts of pyroxene, plagioclase, and olivine (mostly altered to iddingsite) in varying amounts. Plagioclase phenocrysts are usually subordinate. Zeolite minerals and calcite partially fill vesicles and diktytaxitic voids. Includes Hot Rock basalt in Big Horn Mountains [Stimac et al., 1994], and basalt of Black Mesa in the southern Plomosa

Mountains [Sherrod et al., 1990]. These basalt lavas typically cap mesas and high hills, and are not tilted or are only very gently tilted. The maximum thickness is about 20 m at Hot Rock Mountain, and up to about 90 m on Black Mesa. Reported K-Ar dates from this unit include 15.01 ± 0.42 Ma from Hot Rock Mountain in the southern Big Horn Mountains [Shafiqullah et al., 1980]; 15.62 ± 0.35 Ma from Black Butte in the western Vulture Mountains [Scarborough and Wilt, 1979], and 17.23 ± 0.43 from Black Mesa in the southern Plomosa Mountains [Shafiqullah et al., 1980]

Tfu Upper felsic volcanic rocks. **(Miocene)** Consists of light gray to pink-colored, crystal-poor rhyolite flows, flow breccias, and lithic tuffs. Phenocrysts (<1 to 5%; <2 mm) are biotite, quartz, and opaque minerals. The groundmass exhibits a medium-grained granophyric texture. Some outcrops may be remnants of small domes. The maximum thickness of the flows is about 50 m. The lithic tuffs reach a maximum thickness of 20 m, and do not persist laterally beyond the limit of the overlying flows. This unit is equivalent to the Beer Bottle rhyolite member of the Big Horn volcanics of Stimac et al. [1994], which is the youngest volcanic rock in the central Big Horn Mountains. This rhyolite overlies older volcanic rocks (Tbl and Tf) with a significant angular unconformity. Age estimate is based on a K-Ar feldspar date of 16.4 ± 0.2 Ma [Capps et al., 1985].

Tf Felsic volcanic rocks. **(Miocene)** Includes dacitic to rhyolitic lavas and associated pyroclastic rocks, which form a major part of the Tertiary volcanic section in the Vulture, Big Horn, and Eagletail Mountains and the Bouse Hills. In most areas the lavas formed dome complexes with associated breccia rinds and block and ash deposits. Central parts of the complexes are typically light-colored, massive to flow-banded felsite with variable amounts of biotite, hornblende, quartz, sanidine and plagioclase crystals. These grade laterally into breccia and tuff, and the distal parts of each flow grade into light gray to white non-welded tuff. For more complete descriptions of the highly variable lithology and stratigraphy of this unit, see the descriptions in Grubensky [1989], Stimac et al [1994], Spencer et al. [1993], and Spencer and Reynolds [1990].

Tbx Megabreccia and sedimentary breccia. **(Miocene)** Includes monolithologic and polymict sedimentary breccia and megabreccia near the base of the Tertiary stratigraphic section in the Eagletail Mountains and near the top of the stratigraphic section in the Big Horn Mountains. Sedimentary breccia is massive angular-clast conglomerate with good evidence for mixing of clasts with epiclastic sandstone matrix, interpreted as landslide or debris flow deposits. Megabreccia consists of shattered and brecciated rock with little or no discernible epiclastic matrix, generally interpreted to be rock avalanche deposits. Lenses of megabreccia are typically interbedded with sedimentary breccia and conglomerate. In the Big Horn Mountains the Tbx unit interfingers with conglomerate and sandstone (unit Tsm), and breccia blocks consist of virtually all rock types present in the area as well as blocks of Paleozoic formations in the extreme western part of the range [Stimac et al., 1994]. In the Eagletail Mountains, the Tbx unit is present at the base of the section and is interbedded in its upper part with unit Tbl [Spencer et al., 1993]. Predominant clast types include granitoid resembling underlying crystalline rocks and Jurassic(?) quartz-feldspar porphyry similar to that exposed at the southern tip of the Little Harquahala Mountains (unit Jv) [Spencer et al., 1985], and less abundant Tertiary basalt, tuff, and Jurassic hypabyssal quartz porphyry with K-feldspar phenocrysts up to 50 mm long having white (plagioclase?) rims.

Tbm Middle basalt unit. **(Miocene)** Includes Burnt Mountain volcanic rocks of Stimac et al. [1994] in Big Horn Mountains. The Burnt Mountain Volcanics consists of several members including the Moon Anchor andesite, Pump Mine Wash andesite, Upper mafic flows, and andesite lavas and lahars of Burnt Mountain. Burnt Mountain, at the southern tip of the Big Horn Mountains, appears to be an andesitic volcanic center, and probably represent the source vent for part of the Burnt Mountain volcanics. Rock types include aphyric to crystal-poor, slightly vesicular basalt lava, gray and brown variably porphyritic and vesicular andesite lava flows, and associated tuffs, lahars, and breccia. The andesites contain up to about 30% crystals, including variable amounts of plagioclase, biotite, pyroxene, amphibole, rare quartz and opaque minerals. These volcanic rocks overlie several different members of the Big Horn volcanic rocks of Stimac et al. [1994] (units Tf and Tbl on this map) either concordantly or with intervening erosional or angular unconformities, and are locally deposited directly on Pre-Tertiary rocks. Parts of this unit may be identical with rocks mapped in other areas as Tb, Tbl or Ta.

Tb Basalt, undifferentiated. **(Miocene or Oligocene)** Basalt to andesite lavas and local hypabyssal intrusive rocks equivalent to Tbu, Tbm, Tbl, and Tmi. Mapped where data are insufficient to determine correlation.

Tbl Lower basaltic volcanic rocks. **(Miocene or Oligocene)** Includes mafic volcanic rocks that typically predominate in the lower part of the Tertiary volcanic sections throughout the map area. Unit is mapped in the Bouse Hills, Big Horn Mountains, Eagletail Mountains, and along the eastern edge of the Harquahala Mountains. In the Bouse Hills includes vesicular to amygdaloidal lavas ranging in composition from andesite to basalt. Crystals of pyroxene or olivine altered to iddingsite are visible in many of the lavas. The rocks are widely altered, and is nearly completely replaced by brown to tan calcite in some areas. The unit includes interbedded brown to reddish-brown sandstone, felsic tuff, conglomerate, monolithologic breccia and sparse gray limestone with orangish Fe-stained siliceous layers.

In the Eagletail Mountains consists of a thin interval of dark gray basalt, basaltic andesite and andesite lavas that contain tiny crystals of plagioclase, pyroxene and olivine. The mafic volcanic rocks are interbedded with sedimentary breccia at the base and overlain by felsic lavas and associated tuffaceous rocks.

The unit is thickest and most extensive in the Big Horn Mountains, where this unit includes rocks mapped as Dead Horse formation by Stimac et al. [1994]. The Dead Horse formation consists of 0 to >300 m of mafic lavas with subordinate tuff and clastic rocks. Typical rocks are dark-gray, dark-green, and reddish-brown, vesicular to massive, porphyritic to nearly aphyric basalt lava flows, flow breccias, and cinder beds. Basalts contain 2 to 20% phenocrysts, including 2 to 10% olivine, 2 to 15% clinopyroxene, 2 to 5% plagioclase, and more rarely <3% orthopyroxene. Opaque oxides and fine-grained olivine are abundant in a matrix of flow-foliated plagioclase laths. Glomerophenocrysts consisting of olivine, clinopyroxene, biotite, and plagioclase are present in a few flows. Red, reddish-brown, brown, and green-gray massive to vesicular, platy, andesite lava flows and breccias form much of the unit in the Big Horn Peak area. The andesites contain <2 to 15% phenocrysts including of biotite, amphibole, clinopyroxene, plagioclase, and opaque oxides in a groundmass dominated by flow foliated plagioclase microphenocrysts. The mafic lavas are interbedded with and overlain by felsic lavas and associated tuffaceous rocks (unit Tf and Tfu). Interbedded tuff and tuffaceous sedimentary rocks are welded to nonwelded, typically contain phenocrysts of sanidine, quartz, and biotite, and form thin ridges and ledges. Feldspathic to arkosic sandstone and conglomerate are interbedded with basalt lavas, particularly in the NW Big Horn Mountains, where 30-40% of the exposed section is clastic rocks. The sandstone and conglomerate contain abundant clast of pre-Tertiary igneous and metamorphic rocks that can not be matched with rocks in the Big Horn or Harquahala Mountains, and cobbles to boulders of welded ash-flow tuff containing sanidine, plagioclase, and quartz. An interbedded tuff in the Bouse Hills yielded a K-Ar biotite date of 22.5±0.7 Ma [R. Miller, written communication to J. E. Spencer, 1986]

Tt Ash flow tuff and tuff. **(Miocene or Oligocene)** Welded to non-welded tuff in the southern Plomosa Mountains, western Vulture Mountains and Bouse Hills. Tuffs in the southern Plomosa Mountains include the tuff of Twin Peaks and tuff of Felipe Pass [Sherrod et al., 1990]. In the Vulture Mountains, includes the lower lithic tuff and Lucky Cuss tuff of Grubensky [1989]. In the Bouse Hills includes hornblende-biotite tuff [Spencer and Reynolds, 1990]. Except for the tuff of Felipe Pass, which appears to have a wide distribution to the south and west [e.g. Sherrod and Tosdal, 1991], these tuffs appear to be locally derived, and are probably related to nearby felsic dome complexes (unit Tf). Similar tuffs are included in unit Tf, particularly in the Big Horn Mountains, where the tuff units have not been broken out in order to simplify the map pattern.

Tts Tuff and associated sedimentary rocks. **(Miocene or Oligocene)** Interbedded tuff, tuffaceous sandstone, and conglomerate units present in various parts of the Tertiary section.

Buff to white thin to medium bedded massive tuff and laminated reworked or air-fall tuff. Crystal and lithic content is variable. The thickness is highly variable depending on proximity to sources. In the canyon on the southeast side of Black Mesa (SW corner of the map area), the lower part of the Tts section, with a maximum thickness of approximately 65 m, dips 30-50° to the S or SW; dips decrease up section, and on the order of 60 m of non-tilted tuff underlies the basalt of Black Mesa. The tuffaceous rocks overlying Tsm in the southern Plomosa Mountains thicken to the east to a maximum of about 100m thick at the SE edge of the map area. In the Eagletail Mountains Tts is interbedded with felsic lavas and breccias, and probably represents pyroclastic aprons erupted from adjacent dome complexes. In the western Vulture Mountains, rocks mapped as Tts are equivalent to unit Ttv of Grubensky [1989], which consists of light-yellow, tuffaceous conglomeratic sandstone and volcaniclastic breccia interbedded with basalt lava (unit Tbu) on the south flank of Black Butte. Conglomeratic sandstone is thin to medium bedded (5-20 cm thick beds) and locally laminated. It contains subrounded pebbles and cobbles of rhyolite and basalt lava. Volcaniclastic breccia composed of angular fragments (as much as 80%) of porphyritic, stony rhyolite lava and subordinate basalt in a tuffaceous sandy matrix. Maximum clast dimensions vary from 1-50 cm. The unit is up to 180 m thick in the western Vulture Mountains.

Contacts with felsite (unit Tf) and welded tuff (Tt) are gradational zones of increasing welding. Other contacts are generally abrupt. Irregular and generally anomalously steeply dipping atitudes measured in this unit where it is deposited on pre-Tertiary rocks reflect pre-existing topography.

Ta Andesite. **(Miocene or Oligocene)** Intermediate composition lavas and hypabyssal intrusive rocks, with associated breccia and tuff. Typically includes dark red brown to gray massive volcanic rocks with crystals of altered mafic minerals (hornblende or biotite) and plagioclase, with less abundant pyroxene or rarely quartz or K-feldspar. Forms large masses in which bedding or flow foliation is highly variable, obscuring the original orientation of the deposit, and the intrusive or extrusive nature cannot be determined. The Ta unit in the southern Little Harquahala Mountains apparently represents a deeply dissected, but little deformed andesitic volcanic center. In the northwestern Eagletail Mountains, rocks mapped as Ta are distinguished from Tf by the absence of quartz or sanidine phenocrysts. The andesitic rocks in the northwestern Bear Hills (volcanic rocks of Bear Hills [Sherrod et al., 1990]) are the southeastern continuation of a large andesitic volcanic complex in the central Plomosa Mountains [see Miller, 1970]. In the Bouse Hills, Ta includes the 'medial felsic volcanic unit', 'feldspar porphyry' and 'tuff and andesite' units of Spencer and Reynolds [1990]; this unit includes a polymictic sedimentary breccia unit, several rhyolite lavas and tuffs in addition the more typical intermediate composition volcanic rocks. Rocks mapped as Ta are probably coeval in part with rocks mapped as Tbl, Tbm and Tf in other parts of the map.

## Tertiary intrusive rocks

Ti Hypabyssal Intrusive rocks. **(Miocene or Oligocene)** Undivided felsic to mafic hypabyssal intrusive rocks. Includes Tif and Tim.

Tif Felsic intrusive rocks. **(Miocene or Oligocene)** Light colored dikes and small intrusions that have an aphanitic groundmass and characteristically are light-colored and contain crystals of quartz or K-feldspar. The matrix of the dikes varies from fresh to extensively altered. Along the NE side of the NW Eagletail Mountains the mapped Tif units are thick dikes that have been tilted 30-40° to the southwest and are now like flatirons that form the steep buttresses with high peaks along the range front; these were probably feeder dikes for Tf in this area.

Tim Mafic to intermediate intrusive rocks. **(Miocene or Oligocene)** Dark green to olive, brown, and black-colored aphanitic to medium-grained basaltic, andesitic, and dioritic dikes and small irregular intrusions. Fresh dike rock consists of hornblende and plagioclase with an ophitic to intersertal texture. Grain size depends on dike thickness. Aphanitic chilled margins are generally 2-5 cm thick, dikes more than 1.5 to 2 m thick have a fine-grained core, and 3-5 m thick dikes have a medium-fine grained core. Most dikes are less that 2 m thick. These form a vertical to steeply NE-dipping, NW-trending dike swarm in the central Harquahala Mountains. Dikes are locally mineralized and altered. The alteration assemblage is generally sericite-chlorite-pyrite-earthy hematite (commonly after pyrite), with minor secondary copper minerals. In the Big Horn Mountains, these dikes are typically extensively altered, and poorly exposed, except in mine workings and washes.

Tg Granitoid. **(Miocene or Oligocene)** Fine- to medium-grained, equigranular, biotite±hornblende granitoid rocks exposed in the eastern Bouse Hills. Map-scale compositional layering characterizes this unit in the easternmost 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 NE 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 generally N-trending, resistant ridges. Gently dipping epidote-filled fractures are the dominant control of the ridge-crest morphology. No pegmatites were seen in this unit and no evidence of hydrothermal alteration or mineralization at the margins of this unit was recognized except rare and thin epidote- and hematite-filled fractures. Samples of this unit have yielded biotite K-Ar dates of 20.0±0.6 Ma, 20.2±0.5 Ma [Spencer et al., in press], and 16.5±0.5 Ma [Shafiqullah et al., 1980]. A ~20 Ma age for the pluton is supported by two of these three dates, and by a 19.7±0.5 Ma K-Ar biotite date on a silicic dike that is probably genetically related to the pluton [Spencer et al., in press].

## Cretaceous and Jurassic intrusive rocks

Kg Leucocratic granitoids

$Kg_1$ Tank Pass Granite. **(Cretaceous)** The Tank Pass granite is a light colored, medium-grained, equigranular to slightly porphyritic granite to granodiorite. In the Granite Wash and western Harcuvar Mountains, it contains about 1 to 5% biotite and local sphene crystals up to 1 mm long. Quartz eyes 1 to 3 mm in diameter and plagioclase phenocrysts are also locally present. This phase contains distinctive disseminated biotite books that are 0.5 to 1 mm in diameter, and about 0.25 mm thick. Porphyritic outcrops contain scattered K-feldspar phenocrysts 0.5 to 2.5 cm in diameter. Leucocratic aplite to pegmatite dikes are associated with the granite; these are generally composed of quartz and predominantly alkali feldspar, with biotite, minor reddish-brown garnet, and rare muscovite. Some of the aplitic dikes have garnetiferous and pagmatitic bands parallel to their margins. A granodioritic border phase is locally present, especially where the pluton contains abundant inclusions of metamorphic rock.

In the west-central part of the Harcuvar Mountains, the Tank Pass granite consists mostly of a medium-grained equigranular biotite-muscovite granite, with abundant aplite and pegmatite. It is nearly white on fresh surfaces, but commonly weathers a tan to orangish-brown color. Muscovite (1-2%) and biotite (1-3%) are present as very thin platelets to discrete books 0.5 to 4 mm thick. This phase also contains <1% garnet in outcrops on the south flank of the range southwest of Cottonwood Pass. In the central part of the Harcuvar Mountains abundant sills of fine- to coarse-grained leucocratic granite, pegmatite and layered aplite-pegmatite locally coalesce into bodies of mappable dimension that consist mostly of granitoid. Similar sills are abundant in unit Xm. Most of the aplite-pegmatite dikes and sills are probably late-stage differentiates of the granite, but some may be younger than and unrelated to the Tank Pass granite.

$Kg_2$ Brown's Canyon granite. **(Cretaceous)** Light colored, fine-grained granitoid mapped as Brown's Canyon granite and Stone Corral Granite in the northeastern Harquahala Mountains [Richard, 1988]. The granite of Brown's Canyon is an equigranular, aplitic, fine to medium-fine grained monzogranite. The rock typically consists of sub-equal amounts of anhedral, interlocking microcline, plagioclase, quartz, 1-2% biotite and muscovite in varying proportions, sparse garnet, and accessory apatite and zircon. The grain size and distribution of micas and garnet are variable within the pluton. Small areas have been observed in which the rock consists of up to about 5% of 1 to 3 mm garnet. Muscovite grains commonly are ragged on edges of books, suggesting possible decomposition before complete crystallization of body. Abundant pegmatite dikes are associated with the Brown's Canyon granite, especially high on the southeast and along the northwest side of the pluton. The dikes increase in abundance towards the main body of the granite, but are not observed cutting the internal parts of the pluton. Swarms of garnet-muscovite pegmatite dikes flood the country rock above the pluton on its southeast side, and the contact between the granite and country rock is a mixed zone. Brown's Canyon pegmatites are generally planar and range in thickness from several centimeters to several meters. They are zoned, with alternations of very coarse and medium grained quartz, albite and muscovite; no systematic zoning pattern was discerned. Very fine-grained garnet is an ubiquitous component. The southwest side of the Brown's Canyon granite, near Sunset Canyon, is a steep, abrupt contact zone that sharply truncates fabrics in the wall rocks. Few pegmatites are observed in this area. The north side of the pluton is a strongly deformed injection complex in which numerous dikes and irregular bodies of leucocratic garnet-biotite granitoid have been transposed along with the pre-existing gneissic foliation in the country rocks into a moderately SW-dipping gneissic foliation. The concordant sills of leucogranite in this complex, near the Sunshine mine, are indistinguishable from foliated granite in the border zone of the pluton along its east side. The foliated granite in this border zone grades into unfoliated granite of the main phase in Brown's Canyon. On its east side, the bottom of the pluton is a Tertiary high strain zone localized along the intrusive contact of the pluton with underlying heterogeneous plutonic and metamorphic rocks. Igneous foliation within the Brown's Canyon granite, defined by grain size variations in undeformed rock, is parallel to SW-dipping syn-plutonic fabric. Hornblende from a small inclusion near the border of the Brown's Canyon granite yielded an $^{40}Ar/^{39}Ar$ maximum cooling age of 69 Ma, interpreted to indicate the minimum age of the granite. Granite cropping out below the bounding shear zone on the east side of the Brown's Canyon granite is lithologically very similar to the Brown's Canyon granite and is probably related. Richard [1988] referred to this phase as the Stone Corral granite. It consists of very light gray or tan, medium-grained, equigranular, biotite-garnet granite, and is locally slightly porphyritic with 1 cm K-feldspar phenocrysts. Garnet in is present in trace amounts, concentrated near leucocratic-pegmatitic bands. The pluton is generally weakly to moderately foliated. It grades into the mixed KXgn gneiss, which contains numerous sills of leucocratic granitoid resembling $Kg_2$.

Kgd Hornblende-biotite granodiorite units

$Kgd_1$ Big Horn granodiorite. **(Cretaceous)** Light-gray, gray, and tan coarse- to medium-grained granodiorite averaging approximately 30% plagioclase, 30% potassium feldspar, 5 to 12% biotite, >10% quartz, and trace amounts of sphene, opaque oxides, and other accessory minerals. Locally grades into gray, or pink equigranular medium- to fine-grained granite. In the southwestern part of the Big Horn Mountains, near Big Horn Peak, grades into porphyritic granite to monzogranite containing abundant K-feldspar megacrysts up to 4 cm long. This pluton has complex contacts with Proterozoic rocks, typically with a dioritic border phase along the northwest side and a granitic border phase along the northeast side. Numerous irregular apophyses of the intrusion project into adjacent Proterozoic metamorphic rocks. Sparse biotite-rich xenoliths are present. A sample of granodiorite from the Dead Horse Wash area yielded a K-Ar biotite date of $70.8 \pm 0.5$ Ma. K-Ar biotite dates of $63 \pm 1.9$ and $68 \pm 2.0$ Ma were determined for porphyritic granite phase in the Big Horn Mountains Wilderness Study Area [Miller and Gray, 1993, in prep.]. The pluton crops out in a ENE-trending belt through the northern part of the Big Horn Mountains. The unit forms very poor outcrops, typically making up small grus-covered hills and pediment.

$Kgd_2$ Granite Wash granodiorite. **(Cretaceous)** Light gray, medium-grained, equigranular granodiorite. Rock consists of 25-30% quartz, 50-65% plagioclase, 10-15% K-feldspar, 5-7% biotite in 1-2 mm diameter flakes, 1-5% hornblende in subhedral prisms up to 1.5 cm long, and accessory sphene. Biotite typically has chloritized rims, and hornblende is extensively but weakly altered to epidote, actinolite and biotite. Some outcrops SE of Winchester Peak in the southern Granite Wash Mountains contain repetitive 1-5 cm thick bands defined by subtle variations in mineralogy and grain size.

Kd Dioritic border phase. **(Cretaceous)** The Big Horn granodiorite and Granite Wash granodiorite both have dioritic border phases found near the margins of the plutons. The border phase is more abundant on the north side of both plutons (although the southern intrusive contact of the Big Horn granodiorite is mostly covered. In the Big Horn Mountains, the border phase forms small, irregular bodies in the Proterozoic country rock. The rock consists of hornblende and plagioclase; sphene is significantly more abundant than in main phase (Kgd). Grain size is quite variable, ranging to very coarse-grained hornblendite. Some small bodies are agmatitic. In the Granite Wash Mountains the border phase is found along contacts of the granodiorite, and forms most of the smaller apophyses. The dioritic rocks are characterized by lithologic diversity. Rock types observed include: 1) medium-grained, equigranular to slightly porphyritic granodiorite with 10-20% hornblende and biotite; 2) medium- to coarse-grained diorite or tonalite with 15-40% hornblende; 3) fine- to medium-grained porphyritic diorite with several percent hornblende phenocrysts that give the rock a spotted appearance; 4) hornblendite with less than 15% plagioclase; and 5) fine-grained microdiorite mostly composed of plagioclase and hornblende. Hornblende is typically more abundant than biotite, and scattered hornblende phenocrysts 0.5 to 2 cm long are present at least locally in all units.

KJgd Granodiorite. **(Cretaceous or Jurassic)** Fine grained dark gray equigranular to slightly porphyritic granodiorite containing sparse 1-2 cm long K-feldspar phenocrysts, subhedral plagioclase phenocrysts 3-4 mm in diameter in a groundmass of quartz, plagioclase, and biotite. Contains inclusions of Paleozoic quartzite. This rocks is unfoliated, but contains extensive weak sericitic alteration similar to pre-cleavage alteration in other parts of western Harquahala Mountains.

KJd Hypabyssal mafic rocks. **(Cretaceous or Jurassic)** Sills and irregular intrusions of fine to very fine-grained equigranular diorite or gabbro, consisting of altered hornblende or pyroxene and plagioclase. Hornblende is typically altered to chlorite and actinolite(?); plagioclase is commonly sericitized. In the western Granite Wash Mountains, some plagioclase feldspar crystals preserved calcic (~$An_{50}$) compositions, and pseudomorphs after olivine are present. Some sills are porphyritic with crystals of hornblende or plagioclase in varying proportions. These intrude Jurassic or Cretaceous sedimentary rocks (KJc, KJs, KJsh, KJsq, KJss) in the southern Plomosa and Granite Wash Mountains, forming sills up to about 135 m thick in the southern Plomosa Mountains. Contorted bedding and narrow zones of hornfels are present near many intrusive contacts. Vesicular and fragmental units are present in both the Ramsey Mine and Granite Wash sections, indicating that some of these rocks are extrusive or possibly intruded wet, unlithified sediments. Geochemical analysis [Laubach et al., 1987] of rocks from the Granite Wash Mountains reveal that these rocks are slightly alkalic and have trace-element affinity to "within-plate basalts" of Pearce and Cann [1973]

Jg Granodiorite or monzogranite. **(Jurassic)** Porphyritic biotite granitoid and leucogranite in the Granite Wash Mountains The porphyritic granitoid contains 1-2 cm long, pink K-feldspar in a groundmass of blocky 2-4 mm plagioclase, 1-2 mm anhedral quartz, and 3-6% biotite. The leucogranite is fine-grained, and mostly equigranular, but 2-4 mm-diameter quartz phenocrysts are locally present. Both granitoids intrude Paleozoic rocks in the western Granite Wash Mountains. Age interpretation is based on lithologic similarity with dated plutonic rocks of the Jurassic Trigo Peaks superunit [Tosdal et al., 1989] and contrast with lithology of known Cretaceous or Tertiary plutonic rocks.

$Jg_1$ Granitoid porphyry. **(Jurassic)** Medium grained, ubiquitously altered, porphyritic monzogranite; contains 1-3 cm long, elongate K-feldspar phenocrysts in a groundmass of 10-20% quartz in 2-3 mm 'eyes', 60-70% altered plagioclase, 2-3% 2-3 mm clots of chloritized biotite, and a trace of accessory sphene. The granitoid is mostly undeformed, but is cut by sparse, thin mylonite zones. Grades to southeast into hypabyssal quartz-feldspar porphyry included in unit Jv. The gradational contact with Jv suggests a Jurassic age similar to that for the Black Rock volcanics.

$Jg_2$ Granodiorite to diorite. **(Jurassic(?))** Dark gray equigranular to porphyritic monzodiorite, diorite, and granodiorite in the western Harquahala and northern Little Harquahala Mountains. Abundant dikes and small irregular bodies of aplitic leucogranite are ubiquitous throughout the unit. In the northern Little Harquahala Mountains, is a porphyritic monzodiorite consisting of 10-20% potassium feldspar phenocrysts up to 3 cm in diameter, 50-60% plagioclase in 3-5 mm subhedral, blocky crystals, 10% quartz in equant 1-3 mm grains, 15% biotite, and abundant accessory euhedral apatite and anhedral sphene. Plagioclase is nearly completely replaced by sericite and epidote. A very fine-grained, recrystallized aggregate of biotite, quartz, albite(?), and epidote forms a groundmass between the larger feldspar and quartz crystals. Some biotite-epidote-plagioclase clots with aligned biotite crystals appear to pseudomorph hornblende prisms. The monzodiorite becomes more equigranular (resembling the granodiorite phase in the western Harquahala Mountains) to the south, and the contact into the mixed Proterozoic-Jurassic crystalline rocks (JXi) is gradational.

In the western Harquahala Mountains, the unit consists mostly of equigranular diorite at the western end of the range, intruded by granodiorite on the east. The diorite phase is mostly medium-fine grained and texturally and compositionally variable, ranging from gabbro(?) to granodiorite. Granodioritic zones are locally porphyritic and rare megacrystic phases strongly resemble the monzodiorite phase of the northern Little Harquahala Mountains. The dioritic phase is metamorphosed and deformed to a biotite-plagioclase-quartz semi-schist in the 'S' Mountain area. Leucogranite dikes and intrusions truncate some foliation in this area. Small pods of massive to weakly foliated, texturally and compositionally variable dioritoid are common in adjacent rock units (YXgg, Xgn, Xgp); these may be related to $Jg_2$ or to unit JYd.

Granodiorite intrudes the diorite phase on the east; the contact is variably sharp or gradational. The granodiorite is equigranular, dark gray, medium-grained and consists of 65-75% plagioclase, 10-20% quartz, and 7-10% biotite in very fine-grained recrystallized aggregates with epidote and plagioclase. It is locally slightly porphyritic with K-feldspar phenocrysts up to 1 cm in diameter. The granodiorite is interleaved with augen gneiss (Xgp) at its eastern contact, but inclusions of augen gneiss in granodiorite indicate that the granodiorite intrudes the augen gneiss. A single zircon fraction from a monzodiorite sample (04-10-85-16), collected at 33°43.60'N, 113°25.05'W in the northern Little Harquahala Mountains, yielded U-Pb ages of $^{206}Pb/^{238}U$: 165.5Ma, $^{207}Pb/^{235}U$: 166.6; $^{207}Pb/^{206}Pb$: 182Ma (N.R.Riggs and S. M. Richard, unpublished data, 1987); w.r. Rb/Sr analysis of one sample yielded an $^{87}Sr/^{86}Sr$ ratio of .70766±.00004, with a Rb/Sr ratio of 0.4166 (P. Damon and M Shafiqullah, written communication, 1984). Rb/Sr model ages are older than 200 Ma if the assumed initial ratio is less than 0.7065. These data strongly indicate that the monzodiorite is Jurassic, probably crystallized at about 165 Ma.

$Jg_3$ Sore Fingers granite. **(Jurassic)** Coarsely porphyritic biotite granite (monzogranite) consisting of 20-50% K-feldspar in 2-3 cm blocky, equant phenocrysts, 30-40% plagioclase in 2-5 mm subhedral, blocky crystal, 20-25% 2-5 mm rounded quartz grains, and 5-10% biotite. K-feldspar crystals are locally up to 8 cm in diameter, and are irregularly distributed in the rock body; some cumulate zones consist of >50% phenocrysts. A few equigranular, non-porphyritic zones are also present. Minor hornblende is present in the outcrops in the Eagletail Mountains. Only one small area was found in the southern Little Harquahala Mountains where igneous hornblende was preserved; throughout the rest of the body there, igneous hornblende and biotite have been recrystallized to fine-grained aggregates of secondary biotite, epidote and plagioclase. Ubiquitous weak alteration in the granite is concentrated along joints filled with chlorite and epidote. Alteration becomes more intense in parts of the southern Little Harquahala Mountains. In the most intensly altered areas, the granitoid becomes a dense, black, silicified rock in which the igneous texture is obliterated and biotite clots surround sparse relict quartz and feldspar crystals. Sparse aplite dikes intrude the Sore Fingers granite. The sore Fingers granite intrudes foliated porphyritic granitoid to augen gneiss (unit JXi) on the north. The contact is subtle, but sharp where it is not disrupted by minor faulting. A K-Ar biotite date of 140±4 Ma was reported by Shafiqullah et al. [1980]; sample location 33°38.2'N, 113°29.9'W. Lithologic similarity of the most mafic parts of this unit with the porphrytic monzodiorite phase of the diorite-granodiorite unit ($Jg_2$) suggest that these are part of the same plutonic suite.

## Mesozoic and Paleozoic supracrustal rocks

### <u>**Jurassic or Cretaceous clastic rocks.**</u>

Middle to late Mesozoic clastic rocks, including mostly brown to gray lithic-feldspathic sandstone, siltstone, conglomerate and minor limestone, are exposed in three major stratigraphic packages on the Salome 1:100000 sheet. These will be referred to as the Ramsey Mine [Sherrod and Koch, 1987; Richard and Spencer, 1994], Granite Wash [Laubach et al, 1987] and Little Harquahala [Richard et al., 1987] sections. Other less complete sections are exposed at the southern tip of the Harquahala Mountain and in isolated hills in the northern part of the Harquahala Plain [Richard et al., 1987]. The age and correlation of these clastic rocks remains unresolved in detail because of the lack of fossils and distinctive, laterally continuous marker units, but they most likely correlate with some part of the McCoy Mountains Formation [Harding and Coney, 1985; Tosdal and Stone, 1994, and references cited above]. One lithologically distinctive unit is present in the McCoy Mountains Formation--the basal unit one of Harding and Coney [1985] (Jksq on this map), but an angular unconformity separates this unit from overlying rocks in the southern Plomosa Mountains just west of this map area. Outcrops of lithologically identical rocks in this map area are faulted against all adjacent pre-Tertiary rocks, so their stratigraphic position is indeterminate. Formalization of stratigraphic nomenclature for these rocks awaits a consensus on their age and correlation from range to range. In light of these difficulties, the Jurassic or Cretaceous clastic rocks have been mapped on a purely lithologic basis on this map.

Kc Conglomerate. **(Cretaceous)** Approximately 300 m of brown, calcite-cemented, feldspathic sandstone, conglomeratic sandstone, and boulder conglomerate are exposed in the Red Hills in the northern part of the Harquahala Plain. Fine-grained sandstone is interbedded with coarse-grained sandstone and conglomeratic grit in thin to thick beds. Low-angle cross-beds are locally present. Massive conglomerates include clasts of unmetamorphosed rocks from all parts of the Paleozoic section in the Little Harquahala Mountains, a variety of granitic rocks, and rounded vitreous quartzite. The granitic clasts, such as those of equigranular, medium- to fine-grained muscovite leucogranite, correspond to rock types present in the Harquahala Mountains. Boulder beds in the conglomerate are derived from different sources; some contain predominantly Paleozoic rock types, others contain mostly granitic rocks. Granitic clasts up to 70 cm in diameter and Kaibab Limestone clasts up to 2 m in diameter are present. Detrital K-feldspar and muscovite are present in the sand matrix of the conglomerate. These rocks have been informally named the Red Hills conglomerate and correlated with the conglomerate member of the McCoy Mountains Formation [Harding and Coney, 1985], based on the abundance of locally derived basement clasts and relatively weak diagenesis of this conglomerate [Richard et al., 1987].

KJc Conglomerate. **(Cretaceous or Jurassic)** Massive pebble to boulder conglomerate is present in the lower part of the Little Harquahala section, as a thick wedge in the lower middle part of the Ramsey mine section, and as a thin maker bed in the Granite Wash Section. Clasts include varying proportions of predominantly Jurassic volcanic rocks (Jv), upper Paleozoic sedimentary rocks (gray crystalline carbonate, laminated quartzite, calcareous sandstone, siltstone), and Proterozoic(?) tan vitreous quartzite. Conglomerate in the Ramsey Mine section contains sparse lithofeldspathic sandstone (recycled Mesozoic?) and possible Jkd clasts. Bedding is rarely indicated by thin sandstone lenses. Clasts are rounded to sub-rounded. The conglomerate in the Ramsey Mine section disappears abruptly along strike; whether this is due to rapid stratigraphic variation or to structural removal cannot be determined. In the southern Little Harquahala Mountains the conglomerate thins rapidly to the northwest and grades laterally into an interval of shale with minor interbedded gypsum. Thickness is up to 160 m in the Ramsey Mine section, 200 m in the southern Little Harquahala Mountains, and 5-10 m in the Granite Wash section.

KJsh Fine-grained clastic rocks. **(Cretaceous or Jurassic)** Composed predominantly of siliceous gray shale (now phyllite and slate), but also includes thin layers of fine-grained calcareous siliciclastic rock, calcareous feldspathic siltstone, lithic-feldspathic sandstone, and rare conglomerate layers with 2-4 cm diameter clasts. Sandstone in the unit is dominantly composed of volcanic lithic grains, plagioclase feldspar, and quartz. Load casts are present at the base of some thin sandstone beds. Grades upward into overlying sandstone and conglomerate (Kc). Fine-grained rocks form a thick enough section to map separately only in the Granite Wash Mountains, but similar fine-grained units, too thin to show on this map, are present interbedded in the Ramsey Mine section and in the upper part of the southern Little Harquahala section. These fine-grained sediments are generally very thin bedded, locally laminated, mudstone, siltstone and very fine-grained lithofeldspathic sandstone, with sparse, thin, interbedded cobble conglomerate. They are light tan-gray to gray-green weathering. In the Ramsey Mine section, thick fine-grained intervals are invariably adjacent to thick conglomerate lenses, except in the stratigraphically highest part of the section. Poorly preserved Branchiopod conchonstraca (identified by R. Forrester, personal communication, 1985), belonging to the "nodose-rib type", and resembling Estheriella (Estheriella) cf evadridgian, Upper Jurassic of Zaire (Paul Tasch, written communication, 1985) are present in a shale bed in the upper part of the Little Harquahala section (see photo in Richard et al., 1987). These fossils indicate a nonmarine depositional environment with temporary bodies of standing water. Miller [1966] reported the presence of branchiopods in the southern Plomosa Mountains sections (location not given specifically), but non have been found in the course of recent mapping in the area [Richard et al, 1993; Richard and Spencer, 1994]

KJsq Quartzite, quartzite cobble and maroon mudstone. **(Cretaceous or Jurassic)** Interbedded, thin- to thick-bedded, quartzite-cobble conglomerate, quartzite, calcareous quartz arenite, and purple siltstone or mudstone. Crops out south of the Ramsey Mine section in the southern Plomosa Mountains, in isolated inselbergs along the northeastern side of the New Water Mountains, and in the Little Harquahala Mountains. Quartzite units range from tan or white orthoquartzite, becoming tan to dark brown weathering with increasing calcareous cement; sand is fine- to coarse-grained. Clasts in conglomerate are sub-rounded to well rounded, and consist mostly of light-colored, vitreous quartzite of uncertain provenance. Clasts of Bolsa and Coconino quartzite can also be recognized, along with black or red chert clasts, microporphyritic to aphyric white felsite and rare intermediate-composition volcanic rocks. Conglomerate clasts are typically cobbles, although clasts up to about 40 cm are present in thick conglomerate beds in the northern Black Rock Hills (southern Little Harquahala Mountains). Although conglomerate, sandstone and mudstone are interbedded throughout, 50-100 m-thick intervals of finer-grained rock, in which mudstone predominates and conglomerate is uncommon, alternate with coarser-grained intervals in which sandstone predominates and conglomerate is common. This unit is equivalent to the continental red bed deposits of Miller [1970] in the adjacent Quartzsite quadrangle, with basal unit one of the McCoy Mountains Formation [Harding and Coney, 1985; Stone, 1990; Tosdal and Stone, 1994], and with Crystal Hill formation, an informal name proposed by Richard et al. [1993]. The unit is a minimum of 530 m thick in the southwestern part of the map area.

KJs Sandstone. **(Cretaceous or Jurassic)** Most of the Jurassic or Cretaceous clastic section consists of thin- to thick-bedded brown to drab-gray weathering lithic-feldspathic sandstone, interbedded with mudstone, siltstone, and conglomerate. The stratigraphy tends to be laterally variable. Sandstone:conglomerate:mudstone ratios vary irregularly, with fining-up and coarsening-up sequences on scales ranging from 10's to 100's of meters. Coarser grained parts of the section typically consist of medium to thick bedded, massive to vaguely laminated sandstone, conglomeratic sandstone and conglomerate, with thin, discontinuous mudstone or siltstone partings. Conglomerate lenses up to 20 m thick may be present. One such conglomerate bed forms a continuously mappable marker horizon in the Granite Wash section, indicated on the map by an ornamented line. Finer grained parts of the section typically consists of thin- to very thin-bedded sandstone, often with sedimentary structures including plane lamination, small-scale cross bedding and sole marks on the base of beds, interbedded with laminated to massive mudstone and siltstone. Mudstone may make up >70% of the section over 10-20 m thick intervals. The finer grained intervals have rhythmic bedding and sedimentary structures suggestive of deposition by sediment gravity flow, particularly in parts of the Granite Wash and Ramsey Mine sections. Mudstone rip-up clasts are common near the base of sandstone beds. Poorly preserved fossil plant(?) material has been observed on bedding planes in many of the fine-grained units. Laminated, medium to dark gray limestone beds are present in the fine-grained parts of the sections.

## Jurassic and older volcanic and sedimentary rocks

Jvs Sedimentary rocks derived from volcanic rocks. **(Jurassic)** Jurassic volcanic rocks are overlain by volcanic-lithic sandstone and conglomerate that ranges in thickness from ~20 m above the Black Rock volcanics in the southern Little Harquahala Mountains, to a minimum of 1400 m in the rocks of Harquar in the central Little Harquahala Mountains. These sediments are greenish gray volcanic lithic sandstone consisting of quartz and feldspar grains derived from volcanic phenocrysts and various microcrystalline volcanic rock fragments. Clasts in conglomerate are sub-round to angular and include a wide variety of volcanic rock-types representative of the underlying volcanic units. Sparse vitreous tan quartzite and gray crystalline carbonate clasts are also present; these are typically sub-rounded to well rounded. Bedding in sandstone is rarely visible as faint lamination, fine-grained partings or grain-size variations, but parts of the upper sandstone unit of the rocks of Harquar are well bedded with mudstone partings; mud cracks and mudstone rip up clasts are common in this unit. The lower contact with volcanic rocks is gradational, and in strongly deformed sections (Granite Wash and at the western end of the Harquahala Mountains), the contact between volcaniclastic and epiclastic rocks is virtually impossible to define precisely (Jv and Jvs are not differentiated in these areas for this reason). Where the sediments derived from volcanic rocks are overlain by lithofeldspathic sandstone of unit JKs, the contact is a gradation over 5-10 m of section in most places, but along part of the contact in the southern Little Harquahala section (at the top of the Needle formation of Spencer et al. [1985]) 20-30 m of gypsiferous shale separate the volcanic-lithic and lithofeldspathic sandstones. Where the quartz arenite-rich unit of the basal McCoy Mountains Formation (unit KJsq) overlies Jvs, the contact is generally sharp.

Jv Volcanic rocks. **(Jurassic)** Jurassic volcanic rocks crop out in nearly all the ranges where pre-Tertiary rocks are exposed in the map area, except for the Harcuvar and Big Horn Mountains and Bouse Hills. The most common rock type is a massive, light gray, quartz-feldspar porphyry, with 3-7% chloritized biotite. Quartz phenocrysts, forming 5-20% of the rock, are typically 2-3 mm diameter 'eyes', but in some units may be up to 1 cm in diameter. Plagioclase is the most abundant feldspar, but K-feldspar is present in some units. Phenocrysts form 5-30% of the rock, and are typically 2-4 mm in diameter, but in the Granite Wash Mountains a porphyry unit contains zoned plagioclase megacrysts up to 5 cm in diameter. The groundmass is typically a very fine-grained aggregate or recrystallized quartz, plagioclase, sericite, epidote and very fine-grained green biotite or chlorite. Secondary calcite is often abundant. Possible relict fiamme and lithic fragments are rare. This sort of quartz-feldspar porphyry forms massive, homogeneous stratiform units in all the Jurassic volcanic sections within the map area; these include three separate units in the Ramsey Mine section, with maximum thicknesses ranging from 70 to ~800 m [Richard and Spencer, 1994], the lower volcanic sequence (up to 1 km thick) in the Granite Wash Section [Reynolds et al.,1989]; the upper volcanic unit of the Needle formation (335 m maximum thickness), a large part of the Black Rock Volcanics, and the silicic subunit of the Hovatter volcanic unit in the Little Harquahala Mountains [Spencer et al., 1985], and the Jv unit at the western end of the Harquahala Mountains. In the Little Harquahala Mountains, and the Ramsey Mine section in the Plomosa Mountain, the Jv unit includes some more intermediate-composition lavas and fragmental rocks. These include dark gray andesitic rocks with sparse phenocrysts of plagioclase and chloritized mafic minerals and purplish to greenish-gray lava, tuff, and breccia with 1-3 mm plagioclase phenocrysts. The Jurassic volcanic rocks grade up section into epiclastic rocks derived from the volcanic rocks (Jvs).

MzPzS Sedimentary rocks, undivided. **(Mesozoic and Paleozoic)** Mixed Cambrian through lower Jurassic(?) sedimentary rocks in structurally complex areas.

JTrs Buckskin and Vampire Formations, undivided. **(Jurassic or Triassic)** Lower Mesozoic clastic rocks are present between Permian carbonate rocks and Jurassic volcanic rocks in the Little Harquahala, western Harquahala and Granite Wash Mountains. This unit typically consists of tan, orange and brown-weathering quartzose sandstone, quartzite-cobble conglomerate and sparse red-brown mudstone. Sandstones are typically calcareous, and range from quartz arenite to feldspathic quartz arenite; detrital chert, K-feldspar and mica are present. Fine-grained sandstone beds are typically well sorted, and the degree of sorting decreases with increasing grain size. Conglomeratic sandstone is very poorly sorted. Cobbles in conglomerate are Paleozoic limestone and quartzite or vitreous quartzite of uncertain origin. In the Granite Wash Mountains, the unit contains calc-silicate rocks and small lenses and pods of brown and gray crystalline carbonate. Gypsiferous zones in this section are associated with greenish, fine-grained quartz arenite, greenish phyllite, and cream-colored limestone, and are generally found near the base of the section. These sediments are correlated with the Buckskin formation of the Buckskin Mountains [Reynolds et al., 1987] based on lithologic similarity and similar stratigraphic position. Overlying quartzite and sparse massive conglomerate with cobbles to boulders of quartzite and Proterozoic igneous and metamorphic rocks is correlated with the Vampire Formation of the Buckskin Mountains [Reynolds et al.,1987] on the same basis. A similar quartzite and conglomerate unit overlies Cambrian quartzite on the west face of Salome Peak in the Granite Wash Mountains.

Pzs Sedimentary rocks, undivided. **(Paleozoic)** Units Pzl and Pzu, undivided.

Pzu Upper Paleozoic sediments, undivided. **(Permian and Pennsylvanian)** Includes Supai formation, Coconino Quartzite, and Kaibab Limestone. The Supai formation consists of interbedded white, vitreous quartzite, calcareous sandstone, maroon mudstone, limestone and dolomite. Sandstone is nearly pure quartz arenite, and is uniformly fine-grained and well sorted. Beds are .5 to 3 m thick, and can be trace along strike for 10's of meters in the least deformed section (southern Little Harquahala Mountains). Plane lamination and medium-scale troughy cross bedding is present in undeformed sandstone beds. The unit forms prominently banded dark-brown desert-varnished outcrops. At the base of the unit is a red brown to dark gray shale and siltstone unit that contains discontinuous chert pebble to cobble conglomerate beds.

The Coconino quartzite is a white orthoquartzite with prominent lamination. The sand is fine- to very fine-grained and well sorted. Mudstone laminations produce a prominent parting, which persists even in very deformed quartzite.

The Kaibab formation consists of medium to thick bedded variably fossiliferous or cherty limestone and dolomite. The unit can be divided into 5 units in the southern Little Harquahala Mountains. From the base, these are: Unit 1- Basal sandy dolomite, which grades up into cherty, fossiliferous dolomitic limestone with large crinoid columnals, echnoid spines and brachiopods; capped by a tan, silty sandstone; probable Toroweap Formation equivalent; Unit 2- Massive, cherty, medium gray limestone; crinoid grainstone; large Productid brachiopods abundant in the upper part; Unit 3- Even, medium-bedded dark-gray limestone; poorly preserved fusilinids and large gastropods present; Unit 4- Thick-bedded light gray, cherty and fossiliferous limestone; abundant chert at top. Fossils include Chaetetes corals and brachiopods; Unit 5- Tan silty sandstone overlain by cherty, light pink-gray limestone [Richard, 1983]. In more metamorphosed sections, the unit consists of light gray to white calcite marble, with local lenses of dolomite-tremolite marble along the contact with Coconino Quartzite. One or two 1-3 m thick dark gray marble markers units are present in the middle of the unit; these may be relicts of unit 3 in the unmetamorphosed Kaibab. Aligned siliceous clots and color variations define foliation; foliation is commonly contorted with abundant, showy intrafolial isoclinal folds.

Pzl Lower Paleozoic sediments, undivided. **(Mississippian through Cambrian)** Includes Bolsa Quartzite, Abrigo Formation, Martin Formation, and Redwall limestone. Bolsa Quartzite consists of maroon-gray feldspathic sandstone. Grit and pebble conglomerate at the base grade up into medium- to fine-grained sandstone with siltstone partings up section. The Bolsa quartzite-Abrigo formation transition is a gradation into dark gray, maroon and gray-green sandy shale with a few thin, locally bioturbated siltstone beds. Planar tabular cross beds are common in quartzite beds in the lower part. In more metamorphosed sections (NE Harquahala Mountains, Granite Wash Mountains), the fine- to coarse-grained feldspathic quartzite is generally massive in the lower part, but phyllite partings with slaty cleavage are common in the upper part; bedding is rarely visible as magnetite-rich laminations. This grades into fine-grained muscovite-epidote-quartz-biotite schist and phyllite with a well developed slaty cleavage in the Abrigo interval.

The Martin formation consists of medium-bedded gray and tan dolomite and dolomitic limestone. The lower part is dark gray, medium bedded dolomite. This is overlain by a poorly exposed interval of about 5 m of light pink gray calcareous fine-grained sandstone. Above this is interbedded massive medium to dark gray dolomite and finely laminated light to medium gray dolomite.

The Redwall limestone consists of massive limestone with lenticular stratiform chert nodules, which is variably dolomitized in its lower part. In the least-deformed and recrystallized sections, concentric structure within these nodules is preserved. At the top of the section a paleo-karst zone is preserved, with carbonate cemented breccias and irregular (cavern-filling?) pods of purple mudstone. In more metamorphosed sections, the dolomite marbles of the Martin formation cannot be differentiated from the dolomite marble of the lower Redwall formation, and the upper Redwall forms a prominent unit of white calcite marble with siliceous lenses.

## Proterozoic igneous and metamorphic rocks

Ygm Muscovite granitoid. **(Middle Proterozoic)** Medium grained monzogranite in western Harquahala Mountains; consists of 20-30% anhedral quartz 1-3 mm, plagioclase, K-feldspar, 1-4% biotite in very fine grained aggregates, and up to 4% muscovite in .5-2 mm flakes. Equigranular in general, but grades into porphyritic phases with elongate K-feldspar phenocrysts up to 3 cm long. Rock near margins of pluton is texturally variable fine to medium fine-grained aplitic granite with 1-2% biotite. Intrudes Yg5 as dikes near contact north of Socorro Peak. Inclusions of Yg5 are present in the aplitic border zone in the San Marcos Mine area.

Yg Middle Proterozoic granitoid. **(Middle Proterozoic)** Undivided equigranular to porphyritic biotite monzogranite to granodiorite. These granitoids lack pre-Mesozoic tectonic fabric. Where mapped in the Little Harquahala Mountains consists mostly of mixed megacrystic and porphyritic biotite granite ($Yg_5$) and muscovite granite (Ygm).

$Yg_1$ Blue Tank granite. **(Middle Proterozoic)** Medium-grained, porphyritic biotite granitoid consisting of: 2-4% biotite, normally in 1-3 mm very fine-grained aggregates, but in least altered and recrystallized rock occurs as 2-3 mm diameter books; subequal parts of microcline, in 2 to 3 cm long, elongate phenocrysts, and anhedral plagioclase and quartz; abundant accessory sphene in 1 mm crystals. Sphene is visible only in unaltered rock; it is replaced by leucoxene in altered samples. Silicified alteration zones are commonly present near the contacts of the Blue Tank granite, and obscure contact relations. When exposed in unaltered rock, the contact is sharp and abrupt. Contact with $Xg_1$ is sheared, but sharp intrusive contacts are preserved in low strain zones. The main phase of the Blue Tank granite is very similar to the porphyritic biotite granite of the Socorro suite ($Yg_5$); it is doubtful if a contact could be mapped between these rocks if they were in direct contact. However, the two granites are associated with different suites of intrusive rocks.

$Yg_2$ Harquahala granite. **(Middle Proterozoic)** Megacrystic biotite granodiorite to granite. 5-30% equant, blocky K-feldspar phenocrysts up to 5 cm in diameter; 5-7% biotite in very fine-grained aggregates; 10-20% quartz; accessory magnetite; rare accessory sphene only in westernmost exposures. Variably foliated and recrystallized parts of the unit in the central Harquahala Mountains typically have 1-3% of 1-2 mm muscovite grains, which are probably secondary. A border phase along the western margin of the unit consists of medium- to medium fine-grained, equigranular to slightly porphyritic granitodiorite with 15% quartz in 1-5 mm grains, 7% biotite in very fine-grained aggregates, plagioclase in 2-4 mm grains, and sparse K-feldspar in elongate 1-3 cm phenocrysts. The relationship between the Harquahala and Socorro ($Yg_5$) granites is obscured by alteration. The Harquahala granite generally contains more biotite and less quartz than Socorro granite, and its texture is more distinctly porphyritic. The Harquahala granite grades into fine-grained equigranular granodiorite (YXgg) on the southwest, and is overlain depositionally by Cambrian Bolsa Quartzite on the south. The contact with Xgs NE of Harquahala Mountain is complexly interdigitated due to deformation superimposed on an irregular intrusive contact. Sparse inclusions of Xgs in Harquahala granite indicate that it intrudes Ygs. Harquahala granite is intruded by fine-grained biotite granitoid ($Yg_3$) north of Harquahala Mountain, but the contact is locally gradational.

$Yg_3$ Fine-grained granitoids. **(Middle Proterozoic)** Fine-grained, equigranular monzogranite consisting of subequal amounts of anhedral microcline, plagioclase, and quartz, and 1-2% biotite and muscovite. Also includes medium fine-grained slightly porphyritic monzogranite body on ridge NW of Harquahala Mountain. Muscovite-biotite ratio ranges from 0 to 1. Plagioclase is mostly untwinned and difficult to distinguish from quartz in thin section. Fine-grained monzogranite intrudes the Harquahala granite as dikes, locally grading to homogeneous bodies; much of the unit is irregularly mixed with Harquahala granite ($Yg_2$). The slightly porphyritic monzogranite has sharp intrusive contacts. Similarity of trace-element chemistry and spatial association suggests that this unit is related to the Harquahala granite ($Yg_2$) (Richard and DeWitt, unpublished data, 1987).

$Yg_4$ Blue Tank granite, fine-grained phases. **(Middle Proterozoic)** Includes two medium- to fine-grained granitoid phases associated with the Blue Tank granite ($Yg_1$). The northern outcrops mapped as $Yg_4$ are a medium- to fine-grained, slightly porphyritic biotite granodiorite to monzogranite. This rock consist of 20-30% equant, subhedral to euhedral K-feldspar, 3-7 mm in diameter; 5-7% biotite in very fine-grained recrystallized clots; 20-30% quartz in 2-3 mm diameter, granular, irregular clots and as sparse 4 mm rounded 'eyes'; about 30-40% plagioclase in 2-4 mm anhedral and weakly to moderately sericitized grains; ~1 mm diameter muscovite grains are a sparse but ubiquitous accessory. The southern part of the area mapped as $Yg_4$ is an equigranular, fine-grained, hypidiomorphic-granular, biotite monzogranite to two-mica granite. Potassium feldspar in this rock is distinctly more euhedral than the recrystallized plagioclase and quartz with which it is intergrown; biotite occurs as very fine-grained aggregates, and rarely as 0.5-2 mm diameter flakes. This rock type forms a border zone along parts of the margin of the Blue Tank granite ($Yg_1$), and also along the margins of the slightly porphyritic biotite granite phase of this unit. The contacts of both of these units are commonly zones of silicification and chloritization, obscuring the field relationships in the contact zones.

$Yg_5$ Biotite granitoid of the Socorro suite. **(Middle Proterozoic)** Includes the Socorro granite of Varga [1977] and the porphyritic biotite granite of the Centennial plate [Richard, 1988; Spencer et al., 1985]. The porphyritic biotite granite of the Centennial plate consists of 20-25% quartz up to 8 mm in diameter, K-feldspar in elongate ('boxcar') phenocrysts up to 2 cm long, plagioclase, 5% biotite in very fine-grained clots up to 2 mm in diameter and locally as 1-2 mm flakes. Generally medium to dark gray even when altered. Locally grades to quartz-feldspar porphyry . Resembles deformed biotite granitoid phase of the augen gneiss unit (Xgp). The border zone is medium fine-grained equigranular leucogranite. The Socorro granite consists of medium- to coarse-grained porphyritic granitoid consisting of 20-30% anhedral quartz up to 7 mm diameter, plagioclase up to 1 cm diameter, K-feldspar in blocky, equant phenocrysts 2-4 cm in diameter, and 2-4% biotite. Locally it is equigranular. The Socorro granite is generally coarser-grained, contains more quartz, and phenocrysts are more equant than porphyritic granitoid of Centennial plate; also, the grain size difference between the phenocrysts and groundmass is not as great. Thin dikes of aplitic leucogranite are common. The contact between Socorro granite and porphyritic granitoid of Centennial plate is gradational. Medium- to fine-grained leucogranites are present near contacts north-northeast of Socorro Peak; fine-grained leucogranites contain 2-4 mm rounded quartz phenocrysts. The Socorro granite is overlain depositionally by Bolsa Quartzite.

YXg Porphyritic granodiorite. **(Middle or Early Proterozoic)** Moderately to strongly deformed biotite granitoid of uncertain affinity in the northwestern Granite Wash Mountains and eastern Harquahala Mountains. In the Granite Wash Mountains the unit includes scattered fault-bounded outcrops. The most widespread forms the western face and northern half of Butler Ridge (the NW tip of the Granite Wash Mountains). It varies from a medium- to coarse-grained, porphyritic, biotite granite to a medium-grained, nonporphyritic to porphyritic biotite granodiorite. Phenocrysts in the pluton include K-feldspar up to 2 cm long, and bluish-gray quartz 3-6 mm in diameter. Where the granite is overlain by Cambrian quartzite, its upper 1-2 m is particularly micaceous and has pronounced quartz eyes, possibly due to weathering of feldspar prior to burial. A single whole-rock Rb-Sr analysis indicates a Proterozoic age for the granite [Reynolds et al., 1989]. Similar rocks are present on the isolated ridge SW of Butler Ridge (Sec. 10&11, T6N, R15W), but here the unit includes medium- to coarse-grained biotite granite and granodiorite with quartz eyes as large as 6 mm in diameter. This granite is very porphyritic and contains up to 40% rectangular feldspar phenocrysts 5 to 15 mm wide and 1-2 cm long, about 10% biotite, and numerous pods of biotite schist. A similar, but generally coarser-grained granite underlies Cambrian quartzite and Mesozoic sandstone on the west slope of Salome Peak. The isolated outcrop north of the Cobralla Mine (north of the eastern Granite Wash Mountains) includes abundant pegmatite.

In the eastern Harquahala Mountains, the unit consists of medium- to medium fine-grained, porphyritic granodiorite to hypidiomorphic granular monzogranite. Monzogranite consists of 3-4 mm subequant K-feldspar (25-40%) in fine grained quartz (20%)-feldspar-biotite groundmass; 3-7 % biotite, locally 1% muscovite (metamorphic?), and sparse 1-2 mm blocky opaque grains (illmenite?). Quartz locally forms 3-4 mm granular eyes. The porphyritic phase contains 1-2 cm K-feldspar phenocrysts and 7-10% biotite. Variations in the original igneous texture and subsequent strain make the character of the unit highly variable. This unit resembles Harquahala granite ($Yg_2$), coarser phases of Blue Tank granite ($Yg_1$), and porphyritic phases of Weldon Hill granite ($Xg_1$). Isolated outcrops and strong deformation make definite correlation based on field observations impossible. Mafic gneiss (Xma) is interleaved with the granitoid at their contact. Contains locally abundant inclusions/screens of biotite-muscovite quartzo-feldspathic gneiss and muscovite schist. Intruded by Kbc pegmatites

YXgm Muscovite granitoid. **(Middle or Early Proterozoic)** Light gray medium grained equigranular to slightly porphyritic granite, consisting of about 40% moderately to strongly sericitized plagioclase, 10-15% 0.5-1.5 cm blocky K-feldspar phenocrysts and 10-30% subhedral to anhedral K-feldspar grains 2-4 mm in diameter, 20-25% quartz in 2-3 mm rounded grains; 3-5% biotite in very fine-grained secondary clots. Intrudes Weldon Hill granite ($Xg_1$), and is distinctly less foliated. Aplitic/fine grained phase near contact on SW.

YXgg Deformed granitoid and augen gneiss. **(Middle or Early Proterozoic)** Mostly deformed porphyrytic biotite monzogranite that consists of elongate ('boxcar') K-feldspar phenocrysts to 4 cm long, 10-20% quartz in 2-4 mm equant/round to 5 mm anhedral irregular grains, ubiquitously sericitized plagioclase, and 5-10% biotite in very fine-grained aggregates to 2 mm flakes. Contains fine-grained mafic enclaves to 0.5 m long. Augen gneiss is a minor component; it consists of rounded to blocky 2-4 cm K-feldspar augen, commonly with ragged, corroded margins, enclosed in recrystallized groundmass of 20-30% quartz in 3-10 mm anhedral grains, anhedral plagioclase in 3-10 mm-diameter grains, and 5-10% very fine-grained clots of biotite 3-5 mm in diameter. Resembles Socorro granite (coarse-grained phase of $Yg_5$). In Tenahatchipi Pass the unit grades into mixed metamorphosed and deformed biotite granitoids, including fine-grained equigranular granodiorite or quartz diorite, Socorro granite, deformed Socorro granite or augen gneiss, porphyritic biotite monzogranite and irregular pods of diorite and leucogranite. Rocks in this area are extensively chloritically altered and poorly exposed.

XYgs Foliated biotite granitoid and pelitic gneiss. **(Middle and Early Proterozoic)** Mixed biotite granitoid and quartz-feldspar-biotite-muscovite schist in the northeastern Harquahala Mountains. In the thin sheet within $Kg_2$ at the northeast end of the range, the granitoid phase is variably foliated (ranging to augen gneiss), medium gray granodiorite, with 1-2 cm diameter K-feldspar augen and 5-7% biotite. This granitoid locally resembles the Harquahala granite ($Yg_2$) or the porphyritic granodiorite unit (YXg) exposed on the southwest and south side of the Brown's Canyon granite. Dark gray biotite-rich schist includes quartzo-feldspathic layers that may represent granitic melt or the product of metamorphic segregation; the schist resembles biotite schist inclusions common in the Sunset Canyon granite ($Xg_2$ and Xgs). Moderately to strongly retrograded garnet or staurolite(?) are locally present in the schist. Variably foliated, fine-grained to pegmatitic leucogranite forms a significant component of the NE outcrop area; it is generally equigranular with 1-2% fine-grained biotite, sparse muscovite and trace of garnet. This leucogranite is interpreted to be a foliated early phase of the Brown's Canyon granite ($Kg_2$). Dark gray amphibole-plagioclase pods are a sparse but ubiquitous component of the assemblage. The granitoid component in outcrops on the NE side of lower Sunset Canyon is less strongly foliated and is probably equivalent to Harquahala granite ($Yg_2$); leucogranite is much less abundant in these outcrops. Contacts with $Kg_2$ in the NE outcrop area are Tertiary(?) high strain zones interpreted to be deformed intrusive contacts.

Xg Granitoid. **(Early Proterozoic)** In the western Vulture Mountains consists of two strongly foliated varieties: 1) A leucocratic variety that consists of light-gray, coarse-grained, equigranular, biotite or garnet granitoid with 1-3% garnet, 15-20% mostly chloritized biotite, 30-35% quartz, <5% epidote, and two feldspars; and 2) a mafic variety that consist of medium-gray, mesocratic, medium- to coarse-grained, quartz-poor, equigranular granitoid with 15-35% biotite, amphibole, and epidote, and saussuritized feldspar. The mafic variety also includes amphibole-rich melanocratic granitoid interleaved with biotite-amphibole schist on a scale of approximately 30 m. A small outcrop of granite mapped in the NW Big Horn Mountains is similar to the leucocratic variety, and the assemblage of granitoid phases in this unit is similar to the granitoid phase of unit Xga in the NW Big Horn Mountains.

In the NE Harquahala Mountains, granitoid mapped as Xg in the area N of Sunset Pass consists of biotite granitoid, abundantly intruded by dikes and irregular masses of aplite to pegmatite related to the Brown's Canyon granite ($Kg_2$). The biotite granitoid is fine- to medium fine-grained with 20-25% blocky to rounded, equant K-feldspar, in a groundmass of granular, anhedral, 1 mm-diameter quartz and plagioclase, with 2-5% biotite in 1 mm diameter flakes and recrystallized aggregates, a trace of muscovite, and sparse but ubiquitous 2-3 mm blocky opaque grains (illmenite?). The biotite granitoid is texturally variable; in some places it strongly resembles Sunset Canyon granite ($Xg_2$), in other places it resembles Weldon Hill granite ($Xg_1$), and sparse, more porphyritic phases are very similar to the porphyritic granodiorite (YXg) south of the Brown's Canyon granite ($Kg_2$). The blocky opaque grains are distinctive.

$Xg_1$ Weldon Hill granite. **(Early Proterozoic)** Medium- to medium fine-grained, equigranular biotite monzogranite to granodiorite. Named for a low hill in the south-central Harquahala Mountains underlain mostly by this rock. Most of the rock consists of recrystallized anhedral plagioclase and potassium feldspar; 6-9% biotite is present in 2-3 mm very fine-grained aggregates, along with 5-10 % quartz in 2-7 mm granular aggregates. Quartz grains are commonly very round, giving the rock a "quartz-eye" look. The rock is locally slightly porphyritic with .5 to 1 cm long K-feldspar phenocrysts. Dark gray, fine-grained, quartz-feldspar-biotite enclaves are ubiquitous. Intrusive contacts are mixed zones, but in general the pluton is more homogeneous and more biotite-rich than the Sunset Canyon granite ($Xg_2$). The Weldon Hill granite is associated with mostly mafic-gneiss (Xma) wall rocks, whereas the Sunset Canyon granite intrudes pelitic gneisses and contains much more abundant screens of the gneissic wall rocks. Mixed-contact style, and equigranular texture suggest this is an Early Proterozoic rock, but the biotite-rich petrography and local gradations into porphyritic phases is like Middle Proterozoic granitoids.

$Xg_2$ Sunset Canyon granite. **(Early Proterozoic)** Foliated, fine-grained, equigranular granodiorite to granite in the central Harquahala Mountains. Named for outcrops along the NE and SW sides of lower Sunset Canyon. The mineralogy varies considerably from a local hornblende-diorite border phase in the upper part of Arrastre Gulch to muscovite-biotite granite. Superimposed deformation and metamorphism obscure the primary igneous mineralogy. The Sunset Canyon granite is characterized by fine to medium-fine grained equigranular texture; recrystallization generally obscures igneous textures. Typically contains 1-3% very fine-grained biotite, and a trace to 3% of muscovite. Locally the unit is slightly porphyritic. Internal contacts between different phases can be mapped for short distances, but the various phases grade into one another, and relative ages based on the lithology of cross-cutting dikes are inconsistent, indicating that these phases are all related. Faint to strong, laminated differentiated foliation is characteristic; this foliation is concordant with that in the ubiquitous screens of biotite schist and gneiss. Contacts are typically zones of mixed igneous and metamorphic rock.

$Xg_3$ Equigranular biotite granitoid. **(Early Proterozoic)** In the northern Granite Wash Mountains, corresponds to unit Xgd [Reynolds et al., 1989] or Xg [Reynolds et al., 1991]. This unit consists of deformed medium-grained, equigranular to slightly porphyritic granodiorite and feldspar-quartz-biotite±hornblende schist interpreted to be its deformed equivalent. The rocks are medium gray and homogeneous in composition over entire outcrops, but the composition varies between adjacent thrust slices. The granitoid generally contains 15-20% biotite, 15-25% quartz, and 60% feldspar. Where strongly deformed it becomes schistose, in some places with laminated compositional differentiation.

$Xg_4$ Equigranular biotite granitoid. **(Early Proterozoic)** Crops out in the northern Big Horn Mountains, where it consists of tan, fine to medium fine-grained, equigranular granitoid with about 5% biotite in flakes up to 2 mm in diameter. The rock has a weak foliation, and spheroidal weathering when not altered. It forms a relatively large (2 km$^2$) and homogeneous pluton in the Pegrin well area. Contains 5-10% amphibolite inclusions as discrete xenoliths. Very weakly foliated pegmatite dikes intrude the granite. Near its borders the granitoid becomes texturally more variable and more leucocratic (~1% biotite) and resembles the leucogranite phase of unit Xga. Intrudes compositional banding in wall rock-gneisses; foliation in this pluton corresponds to $S_2$ fabric observed in gneisses in vicinity of the contact.

Xgm Hyduke leucogranite and pegmatite. **(Early Proterozoic)** Medium fine- to fine-grained, equigranular muscovite leucogranite. Named for outcrops along Hyduke Canyon in the central Harquahala Mountains. Although the modal mineralogy of these granitoids makes them granodiorites, the petrographic texture of the potassium feldspar suggests abundant albitization. Primary plagioclase occurs in anhedral, twinned grains and is albite or oligoclase. Potassium feldspars occur within very fine-grained aggregates of untwinned plagioclase (albite?), white mica, epidote and quartz; the potassium feldspar is commonly in crystallographic continuity with the plagioclase. If these aggregates were originally potassium feldspar grains, the rock would have been a monzogranite. Muscovite ranges in abundance from about 2% to 10%, and occurs as 1 to 3 mm flakes. The granite occurs in mixed zones with the pelitic schist unit (Xms), and in many areas the two units cannot be mapped separately. Contacts with unit Xms indicate where schists predominate over the leucogranite. More homogeneous bodies of muscovite leucogranite intrude the heterogeneous gneiss unit (Xgn); contacts of these bodies are sharp with much less mixing of rock. Voluminous pegmatites are associated with the leucogranite; these are especially prominent in the pelitic schist, and on the ridge west of Harquahala Mountain. Pegmatites consist of quartz, albite, muscovite, and minor microcline; they intrude as irregular, unzoned sills and dikes.

Xm Metamorphic rocks, undifferentiated. **(Early Proterozoic)** Diverse gneiss, schist, amphibolite, and granitoid throughout the northeastern half of the map area. In the SE Granite Wash Mountains includes quartz-feldspar-biotite gneiss, biotite schist, amphibolite, quartzite and quartz-rich gneiss, granitic gneiss and foliated granitoid, and leucogranite. One distinctive phase is a foliated porphyritic granite containing several percent of large K-feldspar phenocrysts and 10-15% biotite in shreddy, irregular clots; around the margins of the granite are less deformed fine-grained leucogranite and pegmatite, some of which is muscovite-bearing. In the northern Granite Wash Mountains, includes quartzo-feldspathic gneiss, mica schist and foliated granitoid, with a steep gneissic foliation; some thin zones of amphibolite, biotite schist derived from amphibolite and dioritic rocks are present.

In the Harcuvar Mountains includes compositionally diverse metamorphic and deformed plutonic rocks. Common rock types are: 1) Gneiss that consists of interleaved mica schist, amphibolite, granitic gneiss and quartzo-feldspathic 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, with thin (<0.5 m) banded quartzite layers and quartz-feldspar segregations up to 1 cm thick that define the gneissic layering. Protolith is probably sedimentary. 4) Granitic gneiss and various metaplutonic rocks, including aplite, pegmatite and foliated leucogranite containing 1-5% biotite. 5) Foliated granite and light-gray foliated granodiorite to granite with 5% scattered biotite, and rare phenocrysts of feldspar. Early steeply dipping layering in this phase is concordant with that in adjacent gneisses. 6) Foliated granodiorite and quartz diorite locally similar to rocks mapped as JXg. 7) Fine-grained siliceous gneiss, schist and laminated tan-buff quartzite. Rocks mapped as Xm NE of Big Horn Peak in the Big Horn Mountains have not been described.

Xgn Heterogeneous gneiss. **(Early Proterozoic)** Generally intermediate-composition (Quartz-feldspar-biotite±hornblende) gneisses in the central and southwestern Harquahala Mountains and northwestern Big Horn Mountains In the central Harquahala Mountains, the unit is characterized by quartz-feldspar-biotite gneiss, but a wide variety of other rock types are present. These include pelitic schist, actinolitic hornblende-feldspar-quartz gneiss, biotite-epidote-amphibole-rich gneiss, and rare quartz-magnetite granofels. To the northeast the rocks grade into mostly dark gray, biotite-muscovite-feldspar-quartz schist and gneiss. In the southwestern part of the Harquahala plate, the foliation defined by mineralogical and textural variations is generally regular and planar. The gneisses become migmatitic to the northeast, and the foliation becomes contorted. Chlorite is common in the southwestern part of the Harquahala plate but is absent in the Harquahala Mountain area. Small, irregular bodies of medium-grained biotite granitoid are present in the southwest. Mineral assemblages indicate upper greenschist to lower amphibolite facies metamorphism.

In the southwestern Harquahala Mountains, includes rocks informally referred to as Tenahatchipi gneiss [Richard, 1988], named for outcrops in Tenahatchipi Pass. In this area, the gneiss includes heterogeneous, fine-grained, quartzo-feldspathic to mafic gneiss. Quartz-feldspar-muscovite-biotite gneiss contains 2-20 cm-thick banding defined by mineralogical and textural variations, especially biotite concentrations; abundant leucogranite injections are discordant to subconcordant with this fabric. A superimposed schistosity related to the Centennial thrust in the outcrops northwest of Tenahatchipi Pass results in 'pencil' weathering. This unit is interleaved with augen gneiss (Xpg) over 10-20 m at the contact. On top of Twin Peaks contains lenses of highly deformed medium-grained equigranular biotite granitoid. Gneissic foliation is highly contorted on northern side of Twin Peaks, but becomes more planar and regular to south.

In the Big Horn Mountains consists of feldspar-quartz-biotite-amphibole gneiss to quartz-feldspar- biotite gneiss. In the SW part of the outcrop area, consists of mineralogically variable, fine-grained, feldspar-quartz-biotite-amphibole gneiss, grading into amphibolite gneiss, which forms a significant component of the assemblage. All of these variants are probably part of the same original protolith assemblage. A minor component in this assemblage is fine-grained, quartz-feldspar gneiss with 1-3% biotite, and irregular, nebulitic foliation. To the northeast, two sorts or quartz-feldspar-biotite gneiss become prominent. Both are fine-grained and contain 25-35% quartz, 40-60% plagioclase, minor K-feldspar, and 3-5% biotite. One is slightly finer-grained (1-2 mm), and contains a foliation defined by anastomosing, discontinuous biotite-rich laminations spaced 1-10 cm; rare K-feldspar porphyroblasts are present. The other consists of 2-3 mm grains, possibly with slightly more K-feldspar, and a foliation defined by more planar and continuous biotite laminations; plagioclase in this gneiss weathers white to give weathered surfaces a characteristic speckled look. Both types of gneiss contain highly flattened inclusions of amphibolite and intermediate gneiss that resemble deformed igneous xenoliths. These gneisses are interpreted to be highly deformed and metamorphosed granodioritic plutons that intruded the older gneiss assemblage represented by the feldspar-quartz-biotite-amphibole gneisses in the southwestern part on the unit. Textural reworking and mixing of these compositionally similar rock bodies during metamorphism and deformation makes separation of the units on the map impractical. The protolith is interpreted to be a mafic to intermediate volcanic and plutonic rocks. These rocks experienced intense deformation and metamorphism before and during intrusion of the igneous complex represented by the leucogranite and biotite granite phases of unit Xga.

Xga Mixed granitoids and amphibolite. **(Early Proterozoic)** Heterogeneous complex consisting of varying proportions of leucogranite, biotite granitoid, and amphibole-rich gneiss in the northwestern Big Horn Mountains. The leucogranite phase consists of fine-grained equigranular monzogranite (mapped as Xlg on Stimac et al., 1994), which contains 1-2% biotite, 25-35% quartz, 20-35% K-feldspar, 40-55% plagioclase and has an aplitic texture. The leucogranite intrudes the more mafic phases of this complex as thin dikes or small irregular plutons. It rarely forms relatively homogeneous bodies (with <~10% inclusions) larger than several 10's of m. In general it is characterized by abundant wall rock inclusions and textural and compositional gradation to more mafic phases. Weak foliation is defined by biotite alignment, and by compositional and textural variations.

Contact zones between leucogranite and gneissic wall rocks commonly contain abundant pegmatite as irregular pods and stringers. The pegmatites consist of quartz and feldspar, with little muscovite.

The biotite granitoid phase consists of medium- to medium fine-grained, equigranular, biotite monzogranite to granodiorite (mapped as Xbg by Stimac et al., 1994). This phase consists of 30-40% quartz, 10-20% potassium feldspar, 40-60% plagioclase, 4-10% biotite, and a trace of sphene. Relatively unfoliated zones weather spheroidally. As with the leucogranite, it rarely occurs as homogeneous masses, but normally crops out in heterogeneous, texturally variable mixed zones with abundant wall rock inclusions, many of which are partially resorbed. Rare, sharp contacts vary from concordant to discordant in different areas. Gradational mixed contacts are the most common; compositions grade both to gneissic diorite (amphibole-rich gneiss phase) and to leucogranite. Foliation is variably developed, ranging from weak and irregular to a well developed, uniform shape fabric and biotite schistosity.

The amphibole-rich gneiss component (mapped as Xag by Stimac et al., 1994) is fine-grained amphibole-plagioclase gneiss with well developed planar fabric defined by aligned amphibole and laminated compositional banding of amphibole- or plagioclase-rich layers, or locally by 1-15 cm thick quartzo-feldspathic layers. Ranges from homogeneous amphibolite gneiss to mixed amphibolite and amphibole-plagioclase-biotite-(quartz) gneiss with concordant and discordant granitic lithosomes. In the area near the Lion's Den Mine, grades into a massive to gneissic diorite or gabbro. Other small gabbroic pods scattered through the complex are typically agmatitic.

Xms Pelitic metasedimentary rocks. **(Early Proterozoic)** Muscovite-quartz-biotite-feldspar schists are the major component of this unit. In the southwestern part of the Harquahala Plate, the unit consists of muscovite schist and fine-grained quartz-feldspar-mica schists; primary sedimentary features are locally preserved. The typical mineral assemblage in the southwest is quartz-muscovite-chlorite-biotite indicating lower greenschist facies metamorphism. Staurolite and garnet are common in Proterozoic pelitic schists in the Sunset Canyon area, but because Mesozoic schists with similar compositions contain the same assemblages, the higher grade observed in Proterozoic rocks may be a result of Mesozoic metamorphism. To the north and northeast, the schists become more biotite rich; the large screens associated with the Sunset Canyon granite typically consist of biotite-muscovite-feldspar-quartz-garnet-staurolite schist and are dark gray instead of silvery in color. The muscovite-rich and biotite-rich schists have not been differentiated, but they may have different protoliths.

On the north side of the Brown's Canyon granite, consists of light tan-gray fine-grained feldspathic quartzite, commonly with abundant very fine-grained epidote; medium gray, fine grained elephant-hide weathering marble, and quartz-feldspar-rich psammitic schist to coarse-grained muscovite-biotite-garnet schist. Concordant to cross cutting leucogranite (Kg?) intrusions are abundant. This is the oldest component of the gneiss complex north of the Brown's Canyon granite.

In the western Bouse Hills, consists of black-weathering, variably micaceous, locally and variably calcareous and quartzose schist. Steep, east- to NE-striking foliation is defined by schistosity and by compositional layering. The protolith of these metamorphic rocks is interpreted to be siltstone, calcareous siltstone, and quartzose sandstone.

In the east central Big Horn Mountains includes fine- to medium-grained, muscovite-rich schist and phyllite, feldspar-muscovite-chlorite-epidote schist, plagioclase-chlorite schist, calc-silicate gneiss or hornfels; and less abundant ferruginous-quartzite layers a few meters thick. The protolith includes silicic to intermediate volcanic rocks, volcaniclastic units, quartzose feldspathic-lithic sandstones, pelitic rocks, and ferruginous cherts. Relict depositional structures (bedding?, fragmental textures) are rarely visible. A well-developed, northeast-striking, steep continuous cleavage is present throughout in the micaceous units. The unit is commonly monotonous on a 1-10 m scale, but displays significant lithologic variation on a larger scale. Similar pelitic and quartz-rich metasedimentary rocks are exposed at the SE corner of the map area. There are the northern end of more extensive exposures of metasedimentary rocks between the Big Horn Mountains and Saddle Mountain [Ort and Skotnicki, 1993]

Xma Mafic gneiss. **(Early Proterozoic)** Mafic gneiss includes compositionally banded hornblende-rich gneisses ranging from amphibolite to plagioclase-biotite-hornblende gneiss. The typical gneiss is fine-grained and equigranular, with 2-15 cm thick bands defined by plagioclase-rich and plagioclase-poor layers. The foliation is generally quite regular. Foliated gabbro or diorite bodies and aphanitic to very fine-grained white quartz-feldspar granofels that contain sparse 2-3 mm quartz porphyroclasts are a minor component; these are especially abundant in the canyon southwest of Blue Tank Canyon in the central Harquahala Mountains.

Xa Mafic to intermediate metavolcanic rocks. **(Early Proterozoic)** Dark-green and greenish-gray to black, massive, fine-grained hornblende schist, consisting of 50-80% hornblende with variable amounts of plagioclase, chlorite, epidote and biotite. Light-greenish quartz-epidote layers and lenses of muscovite-rich schist are locally present. Grades to the northwest into Xga unit with increasing metamorphic grade and granitoid intrusion.

Xgs Sunset Pass complex. **(Early Proterozoic)** Sunset Canyon granite ($Xg_2$) with concordant inclusions of schist and gneiss from several meters to several hundred meters long. Schist and gneiss are very similar to unit Xgn on the southwest side of Harquahala Mountain. These are mostly fine- to medium-grained biotite-muscovite-quartz-feldspar-garnet-staurolite schist and gneiss. The rock contains a differentiated foliation that ranges from lamination in schistose layers to quartzo-feldspathic layers 10 to 20 cm thick. Foliation is normally irregularly planar, but in some areas is quite contorted. Fine-grained amphibolite pods are locally present; these may be relict dikes.

Xpg Augen gneiss. **(Early Proterozoic)** Dark gray weathering augen gneiss containing 2-3 cm diameter, rounded K-feldspar augen with irregular, corroded margins. Augen are commonly fractured with quartz filling, or have quartz and feldspar inclusions. The groundmass is an aggregate of granular quartz and feldspar with disseminated very fine-grained biotite. About 15-25% of rock is quartz, mostly in 1-3 mm granular aggregates and anhedral grains in a mat of sericitized plagioclase, chloritized biotite and microgranular epidote. Some quartz aggregates are up to 7 mm in diameter. Plagioclase is moderately to strongly sericitized. Medium to fine-grained leucogranite dikes and concordant pods and lenses of medium grained diorite or gabbro are common. Strongly resembles foliated Socorro granite (coarse phase of $Yg_5$), but contains less quartz and more biotite. Interleaved with Tenahatchipi gneiss at the contact. Intruded by diorite/granodiorite of $Jg_2$.

## Phanerozoic or Proterozoic crystalline rocks

TXgg Crystalline rocks. **(Tertiary, Cretaceous, and Proterozoic)** Heterogeneous igneous and metamorphic rocks in the central Bouse Hills. Includes granitoid rocks similar to TXg and their foliated equivalents, medium-grained leucocratic muscovite granite, and quartzo-feldspathic gneiss. Tertiary siliceous dikes become progressively more abundant towards the contact with unit Tg, and form most of TXgg near the contact. Weak, NE-striking, steeply dipping crystalloblastic foliation is present in granitoid rocks in some areas; quartz veins up to 10 cm thick, oriented parallel to foliation, are present in some areas. Local shear zones contain protomylonitic to weak crystalloblastic foliation. Compositionally variable granitoids within these zones are gneissic. Granitoid rocks of this unit also contain local inclusions (up to many meters in diameter) of compositionally layered metasedimentary rocks. In the southeastern exposures of this unit, distinctive porphyritic granite consists of plagioclase, 10 to 50% K-feldspar phenocrysts up to 2 cm long, 20 to 40% quartz, and 2 to 10% biotite that is commonly altered or associated with epidote.

KXg Granitoid rocks. **(Tertiary, Cretaceous, and Proterozoic)** Fine- to coarse-grained equigranular to porphyritic, medium- to light-gray, biotite granite or granodiorite with local fine-grained leucocratic phases. Exposed only in the Bouse Hills. Porphyritic varieties contain 1- to 2-cm-diameter, stubby potassium-feldspar phenocrysts. Plagioclase is variably sericitized. Zone of mixed granitoids near contacts of Tertiary granite in Bouse Hills.

KXgd Gneissic to unfoliated granitoid. **(Cretaceous, Jurassic, or Proterozoic)** Includes fine-grained, foliated to gneissic granodiorite, and unfoliated granodiorite to monzogranite in the western Harquahala Mountains. Unfoliated parts resemble both the Jurassic or Cretaceous fine-grained granodiorite (unit KJgd), and the hypidiomorphic-granular granodiorite to monzogranite border phase associated with the Harquahala granite ($Yg_2$). Foliated to gneissic phases resemble equigranular granodiorite of probable early Proterozoic age exposed in the hanging wall of the Harquahala Thrust ($Xg_1$, parts of Xgs). Contacts between the various phases are subtle.

KXgn Quartzo-feldspathic to amphibolite gneiss. **(Cretaceous, Jurassic and Proterozoic)** Heterogeneous assemblage consisting mostly of intermediate to mafic gneiss injected by massive to gneissic leucocratic granitoid, mapped along the northern side of the NE Harquahala Mountains. Gneiss is typically fine-grained, and consists of feldspar, quartz, biotite, and hornblende, with thin to laminated banding defined by variations in mafic mineral content. Nearly massive hornblende-plagioclase gneiss dominates the assemblage NE of the Linda Mine. The leucogranite injection component is aplitic to pegmatitic granodiorite to granite related to the Brown's Canyon granite ($Kg_2$), and contains 1-4% biotite, muscovite or garnet. North of Brown's Canyon, lenses of porphyritic biotite granitoid, ($Yg_2$?) are relatively common. Along the northern edge of the Harquahala Mountains, a variety of biotite granitoids are more abundant than the older gneiss component in the complex. Some of these are lithologically identical to rocks mapped as Xg on the NW ridge of the mountain drained by Brown's Canyon. Equigranular fine- to medium-fine-grained biotite and hornblende-biotite granitoids in this assemblage contain more mafic minerals and clots of opaque grains than Brown's Canyon granite ($Kg_2$), but are lighter colored and finer grained than the typical Proterozoic(?) granitoid (Xg). One distinctive phase is an equigranular leucogranodiorite with .7-1 cm long hornblende crystals that crops out in NE sec. 7, T N, R9W. These rocks have not been studied in detail. The general appearance of the assemblage is highly variable due to variations in the degree of deformation related to three foliation-forming events recognized in these rocks: 1) Proterozoic metamorphism and deformation that formed the primary gneissic foliation in the older gneiss component. 2) Cretaceous(?) metamorphism and deformation that has largely transposed this older fabric. Brown's Canyon granite dikes are concordant or discordant to this foliation, and in a few places can be observed cutting the older gneissic foliation where it can be distinguished from the Cretaceous(?) fabric. 3) Tertiary mylonitization and retrogression that has largely transposed both older fabrics along the northern edge of the range. Miocene(?) mafic dikes (Tim) are mostly broken up and rotated to near parallel with the mylonitic foliation, but a few cross-cutting mafic dikes were observed. To the SW, the unit grades into a mixed biotite granitoid complex (Xg). Granitoids in this complex intrude the older gneiss component in KXgn.

JYd Hypabyssal mafic rocks. **(Jurassic or Middle Proterozoic)** Includes a small fine-grained dioritoid intrusion in the east-central Little Harquahala Mountains, and older mafic dikes in the central Harquahala Mountains. The body in the Little Harquahala Mountains consists of equigranular, fine- to medium-grained plagioclase, chloritized mafic minerals (hornblende or biotite?), and minor quartz. Secondary epidote is abundant. Older mafic dikes in the central Harquahala Mountains consist of very fine-grained, cleaved, biotite-chlorite-sericite-plagioclase-quartz semi-schist. Sparse hornblende phenocrysts replaced by biotite are present. These dikes lack evidence of chilled margins characteristic of Tertiary mafic dikes (Tim). The body in the Little Harquahala Mountains intrudes JXi along its southern contact. The older dikes in the central Harquahala Mountains intrude a variety of Proterozoic crystalline rocks.

JXg Undivided granitoid rocks. **(Jurassic or Early Proterozoic)** Heterogeneous, typically granodioritic and equigranular, massive to gneissic granitoid mapped in the western Harcuvar, southeasternmost Little Harquahala and Eagletail Mountains. In the western Harcuvar Mountains consists of variably deformed and metamorphosed tonalite to granite. Less deformed outcrops in this area are generally equigranular to slightly porphyritic hornblende-bearing granodiorite or tonalite containing 5-10% mafic minerals, including both biotite and hornblende. Epidote is very common. A porphyritic granodiorite phase contains plagioclase and quartz phenocrysts 0.5 to 2 cm in diameter; the most porphyritic phases are also the coarsest grained. A local porphyritic granite phase contains 10% 1-3 cm diameter K-feldspar phenocrysts. Less common rock types included in this unit are fine-grained equigranular granodiorite, quartz diorite, quartz diorite gneiss, miscellaneous gneiss and schist, and rare amphibolite. Exposures of deformed granitoids are generally homogeneous over large outcrops. In high-strain zones this unit is deformed and metamorphosed to a medium- to dark-gray, strongly foliated feldspar-quartz-biotite-amphibole schist, commonly with a gneissic aspect due to the presence of 0.1 to 5 cm-thick feldspar segregations. Schistose, mylonitic, muscovite-rich granodiorite is present directly beneath the Cottonwood Pass thrust. These igneous rocks are probably Proterozoic or Jurassic, but the structural fabric is probably Cretaceous. Leucogranite becomes more abundant to the west and this unit grades into JXl or Jxi.

The northwesternmost ridge of the Granite Wash Mountains is underlain by medium-grained, equigranular to locally porphyritic, foliated granodiorite containing 5-7% biotite. Feldspar phenocrysts up to 1 cm in diameter are locally present. This unit is complexly interleaved with Paleozoic to lower Mesozoic metasedimentary rocks (MzPzs) to the southeast along a pre-metamorphic contact that may be an older fault, an intrusive contact or, less likely, an unconformity.

Rocks mapped as JXg on Lone Mountain on the west side of the Harquahala Plain are a compositionally variable, medium- to fine-grained, equigranular diorite(?) to granodiorite plutonic suite, locally grading into a granitic phase with approximately equal parts of plagioclase and K-feldspar. Pegmatite dikes intrude this complex. Anhedral apatite and sphene, 1-2 mm in diameter are ubiquitous in the less leucocratic phases. More felsic members of this suite are apparently younger.

Moderately to strongly chloritized, sericitized and hematite stained aplitic leucogranite, locally with a laminated mineralogical differentiation foliation, and slightly porphyritic medium-grained biotite granodiorite, mapped as JXg, crop out over a small area in the northern Eagletail Mountains. These rocks are faulted against quartz-feldspar porphyry that is lithologically identical to the Black Rock volcanics (Jv).

JXh Hypabyssal rocks. **(Jurassic or Early Proterozoic)** Hornfels, consisting of a dark gray, aphanitic groundmass containing white to pinkish, broken-appearing, 1-4 mm diameter K-feldspar crystals. Rock unit is probably related to Jv, but origin is unclear. Exposed on 2 small hills on pediment north of Lone Mountain.

JXi Granitoid and gneiss. **(Jurassic or Early Proterozoic)** Mixed augen gneiss, granite to granodiorite and leucogranite. Similar to JXg, but typically includes equigranular to megacrystic biotite granite to granodiorite as a major component with leucogranite. In the northern Granite Wash Mountains consists of mixed aplitic leucogranite, pegmatite, and megacrystic, variably foliated to gneissic biotite granitoid with K-feldspar phenocrysts or augen up to 4 cm in diameter. In the northern Little Harquahala Mountains consists of 40-60% fine- to medium-grained leucogranite, intruding amphibolite gneiss and less abundant biotite granitoid. In the southern Little Harquahala Mountains consists of weakly to moderately foliated porphyritic biotite granite with 1 to 3 cm rounded K-feldspar phenocrysts or augen, intruded by abundant dikes and small irregular bodies of fine-grained equigranular leucogranite and medium grained, equigranular biotite granite; a minor component of this assemblage is metasedimentary gneiss or schist. Jurassic granite ($Jg_3$) intrudes JXi in the southern Little Harquahala Mountains.

JXl Leucogranite. **(Jurassic or Early Proterozoic)** Aplitic leucogranite and pegmatite, typically in mixed assemblages with older gneissic rocks and biotite granitoids. Leucocratic end of a continuum from JXl to JXi to JXg with decreasing leucogranite and increasing diorite to granodiorite in mixed granitoid assemblages. JXl is mapped in the Little Harquahala and Granite Wash Mountains. The leucogranite is medium to fine-grained, equigranular, and contains 1-3% biotite and, in the Granite Wash Mountains, 1-2% muscovite.

JXmi Mixed orthogneiss and paragneiss. **(Jurassic through Early Proterozoic)** Paleozoic and lower to middle Mesozoic metasedimentary rocks (MzPzs) structurally interleaved with Jurassic or Proterozoic metaplutonic rocks (JXl, JXg) and Proterozoic metamorphic rocks (Xm)

## GEOCHRONOLOGY

Available isotopic age dates for rocks within the map area are located on the map. Each point on the map is labeled with an idetifying number, a two letter code for the isotopic system used to obtain the date, an apparent age, and an uncertainty. Where two or more mineral fractions from the same sample were analyzed, these are show on consectutive lines. Table1 provides more information about these ages dates. Abbreviations used on the map are explained below the table.

Table 1. Isotopic dates from the Salome Quadrangle

| Map # | Sample ID | Rock type | Unit | method | material | Date | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **1** | 86WAG001 | rhyodacite tuff | Hummingbird mbr, Big Horn volcanics | KA | biot | 20.0 ±0.6 | 33° 32.37' | 113° 3.33' | Miller and Gray, in press |
| **2** | 86WAG002 | andesite | Burnt Mountain volcanics | KA | w.r. | 17.7 ±0.6 | 33° 32.37' | 113° 3.50' | Miller and Gray, in press |
| **3** | UAKA-73-107 | basalt | Eagletail volcanics | KA | w.r. | 20.9 ±0.5 | 33° 32.92' | 113° 26.50' | Shafiqullah and others, 1980 |
| **4** | 84WAM73 | rhyolite | Hummingbird mbr, Big Horn volcanics | KA | biot | 20.2 ±0.8 | 33° 34.83' | 113° 6.32' | Miller and Gray, in press |
| **5** | 84WAB140 | basalt | Deadhorse basalt | KA | w.r. | 19.8 ±0.8 | 33° 36.00' | 113° 7.33' | Miller and Gray, in press |
| **6** | 84WAB17 | monzonite | Big Horn granodiorite(?) | KA | biot | 68.1 ±2.0 | 33° 37.67' | 113° 7.68' | Miller and Gray, in press |
| **7** | UAKA-73-20 | granite | Sore Fingers granite | KA | biot | 140.0 ±4.0 | 33° 38.20' | 113° 29.90' | Shafiqullah and others, 1980 |
| **8** | 84WAM23 | rhyolite | Hummingbird member | KA | biot | 18.5 ±0.6 | 33° 38.55' | 113° 10.75' | Miller and Gray, in press |
| | | | Big Horn volcanics | KA | sani | 19.4 ±0.5 | | | |
| **9** | 85WAM40 | leucocratic granite | Big Horn granodiorite? | KA | biot | 63.0 ±1.9 | 33° 38.63' | 113° 8.78' | Miller and Gray, in press |
| **10** | 84WAM30 | basalt | | KA | w.r. | 18.8 ±0.5 | 33° 38.75' | 113° 6.92' | Miller and Gray, in press |
| **11** | BHC-212 | rhyolite | | KA | biot | 20.3 ±0.2 | 33° 39.26' | 113° 5.03' | Spencer et al., 1995 |
| **12** | 1-15-88-7 | tuff | | KA | fl_c | 19.6 ±0.4 | 33° 39.42' | 113° 39.26' | Spencer et al., 1995 |
| | | | | KA | biot | 21.5 ±0.5 | | | |
| **13** | 12-16-88-4 | basalt | | KA | pl_c | 19.4 ±0.4 | 33° 40.05' | 113° 40.87' | Spencer et al., 1995 |
| **14** | BH-89 | basalt | | KA | pl_c | 16.1 ±0.2 | 33° 41.44' | 113° 5.68' | Spencer et al., 1995 |
| **15** | LHA-1 | porphyritic granite | Little Harquahala monzodiorite | KA | biot | 66.0 ±2.2 | 33° 43.00' | 113° 36.30' | Shafiqullah and others, 1980 |
| **16** | BHC-213 | rhyolite | | KA | biot | 21.4 ±0.3 | 33° 43.28' | 113° 5.31' | Spencer et al., 1995 |
| **17** | 4-10-85-16 | diorite | Sore Fingers | AA max | k-sp | 60.0 ±0.5 | 33° 43.60' | 113° 36.95' | Richard et al., 1995 |
| | | | monzodiorite | FT | apat | 19.0 ±2.0 | | | |
| **18** | 1-31-84-1 | granite | Socorro suite, | AA max | musc | 1144.9 ±6.4 | 33° 44.46' | 113° 30.36' | Richard et al., 1995 |
| | | | muscovite granite | AA max | k-sp | 54.6 ±0.6 | | | |
| **19** | BHC-215 | rhyodacite | | KA | biot | 19.6 ±0.2 | 33° 44.59' | 113° 1.88' | Spencer et al., 1995 |
| **20** | 3-2-86 | granodiorite | Granite Wash | AA tg | biot | 65.5 ±0.4 | 33° 44.51' | 113° 40.45' | Richard et al., 1995 |
| | | | granodiorite | AA max | k-sp | 51.0 ±0.3 | | | |
| | | | | AA ms | horn | 80.0 ±0.4 | | | |
| **22** | 89-09 | | Granite Wash granodiorite | FT | apat | 21.0 ±2.0 | 33° 44.73' | 113° 40.42' | Foster et al., 1993 |

| Map # | Sample ID | Rock type | Unit | method | material | Date | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **23** | ES:94 | granodiorite | Granite Wash granodiorite | KA | biot | 70.8 ±0.0 | 33° 44.76' | 113° 40.45' | Eberly and Stanley, 1978 |
| **24** | UAKA-66-03 | granodiorite | Granite Wash granodiorite | KA | biot | 66.5 ±3.6 | 33° 45.00' | 113° 40.50' | Shafiqullah and others, 1980 |
| **25** | HLA-2 | diorite dike | | KA<br>KA | biot<br>horn | 22.1 ±1.3<br>28.6 ±1.9 | 33° 45.70' | 113° 17.80' | Shafiqullah and others, 1980 |
| **26** | 4-1a-86 | Meta granodiorite | Sore Fingers plutonic suite(?) | AA ms | biot | 55.7 ±0.4 | 33° 45.71' | 113° 32.40' | Richard et al., 1995 |
| **27** | 4-28-85-2 | granite | Blue Tank Suite, border phase | AA tg<br>AA max | biot<br>musc | 55.7<br>692.8 ±4.8 | 33° 45.96' | 113° 21.78' | Richard et al., 1995 |
| **28** | 853-26-1A | granodiorite | | KA | biot | 70.8 ±0.5 | 33° 46.14' | 113° 3.00' | Spencer et al., 1995 |
| **29** | UAKA-77-64 | phyllite | McCoy Mtns. Fm. | KA | w.r. | 67.1 ±1.4 | 33° 46.80' | 113° 44.00' | Shafiqullah and others, 1980 |
| **30** | 4-24-85-3 | Quartz-feldspar-biotite schist | Abrigo Formation | AA ms | biot | 42.7 ±0.3 | 33° 46.97' | 113° 18.53' | Richard et al., 1995 |
| **31** | 83-11-8-3 | alaskite-pegmatite | White Marble Mine pegmatite | KA | musc | 573.0 ±19.0 | 33° 47.04' | 113° 24.37' | Hardy, 1984 |
| **32** | HVR-1 | mica schist | Calcite Mine schist | KA | musc | 64.6 ±1.5 | 33° 47.00' | 113° 41.30' | Shafiqullah and others, 1980 |
| **33** | 83-11-8-2 | gneiss | | KA | biot | 58.4 ±2.2 | 33° 47.15' | 113° 24.47' | Hardy, 1984 |
| **34** | 4-26-85-1 | mafic dike | | AA is | horn | 22.3 ±2.0 | 33° 47.24' | 113° 17.30' | Richard et al., 1995 |
| **35** | 4-15-85-6 | amphibilite gneiss | | AA tg | horn | 96.2 | 33° 47.20' | 113° 23.17' | Richard et al., 1995 |
| **36** | 83-11-8-4 | mylonitic schist | Harquahala thrust zone | KA | musc | 62.5 ±2.3 | 33° 47.44' | 113° 24.88' | Hardy, 1984 |
| **37** | 83-11-8-5 | mylonitic schist | Harquahala thrust zone | KA | biot | 56.1 ±2.1 | 33° 47.44' | 113° 24.88' | Hardy, 1984 |
| **38** | D4-11-84-1d | gneiss | | AA tg | horn | 188.2 | 33° 47.64' | 113° 16.40' | Richard et al., 1995 |
| **39** | 4-5-86-1 | amphibolite gneiss | Proterozoic amphibolite | AA max | horn | 133.1 ±3.0 | 33° 47.82' | 113° 15.49' | Richard et al., 1995 |
| **40** | 83-11-8-1 | porphyritic granite | Harquahala granite | KA | biot | 49.5 ±1.9 | 33° 47.99' | 113° 25.04' | Hardy, 1984 |
| **41** | 4-5-85-2 | granite | Harquahala granite | AA ms<br>AA max<br>AA tg<br>FT | musc<br>k-sp<br>biot<br>apat | 54.8 ±0.4<br>76.9 ±1.0<br>51.8<br>20.0 ±2.0 | 33° 48.03' | 113° 25.05' | Richard et al., 1995<br><br><br>Foster et al., 1993 |
| **42** | 2-18-86-3 | schist | Proterozoic schist | AA ms<br>AA max | biot<br>musc | 26.0 ±0.1<br>48.5 ±0.6 | 33° 48.18' | 113° 18.08' | Richard et al., 1995 |
| **43** | 4-2-86-3 | metadiorite | | AA tg | horn | 219.7 | 33° 48.13' | 113° 41.89' | Richard et al., 1995 |

| Map # | Sample ID | Rock type | Unit | method | material | Date | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|
| **44** | 1-1-86 | schist | Sunset Pass assemblage | AA tg | biot | 21.4 ±0.2 | 33° 48.62' | 113° 17.72' | Richard et al., 1995 |
| **45** | 11-28-84-7 | pegmatite | | AA max | musc | 100.3 ±0.6 | 33° 48.78' | 113° 21.82' | Richard et al., 1995 |
| **46** | AWL-7-83 | felsic dike | Salome dike | KA | feld | 56.5 ±2.3 | 33° 49.10' | 113° 44.20' | Kress and others, 1985 |
| **47** | 11-27-84-3 | Amphibolite gneiss | | AA ms | horn | 72.2 | 33° 49.39' | 113° 20.90' | Richard et al., 1995 |
| **48** | 3-5-84-4 | granite | two mica granite (Harquahala suite?) | AA max<br>AA tg<br>AA pl | k-sp<br>biot<br>musc | 37.2 ±0.6<br>43.5 ±0.3<br>51.8 ±0.3 | 33° 49.55' | 113° 22.37' | Richard et al., 1995 |
| **49** | 11-27-84-6 | pegmatite | Brown's Canyon granite | AA pl | musc | 51.1 ±0.3 | 33° 49.64' | 113° 21.15' | Richard et al., 1995 |
| **50** | 2-1-86 | granite | Brown's Canyon granite | AA tg<br>AA is | biot<br>musc | 20.0 ±0.2<br>30.0 ±0.1 | 33° 49.95' | 113° 14.04' | Richard et al., 1995 |
| **51** | 2-2-86 | granite | Brown's Canyon granite | AA max | musc | 26.9 ±0.2 | 33° 50.20' | 113° 14.11' | Richard et al., 1995 |
| **52** | UAKA-73-126 | granite | Tank Pass granite | KA | biot | 47.5 ±1.0 | 33° 50.67' | 113° 41.55' | Shafiqullah and others, 1980 |
| **53** | UAKA-78-31 | basalt | Black Butte basalt | KA | w.r. | 15.6 ±0.4 | 33° 50.76' | 113° 1.87' | Scarborough and Wilt, 1979 |
| **54** | 2-19-86-3 | amphibolite | Brown's Canyon granite | AA tg | horn | 64.4 | 33° 50.70' | 113° 14.51' | Richard et al., 1995 |
| **55** | 17-1 TO 17-3 | granite | Sunset Pass two-mica granite | SR<br>SR | musc<br>w.r. | 50.3 ±0.4<br>53.0 ±0.4 | 33° 50.76' | 113° 20.52' | Rehrig, 1981 |
| **56** | UAKA-77-63 | granite | Tank Pass granite | KA | biot | 55.0 ±1.2 | 33° 51.20' | 113° 45.10' | Shafiqullah and others, 1980 |
| **57** | D11-22-84-2 | granite | Brown's Canyon granite | AA tg<br>AA max<br>AA max | biot<br>musc<br>k-sp | 20.3 ±0.1<br>32.5 ±0.2<br>26.0 ±0.5 | 33° 51.35' | 113° 16.68' | Richard et al., 1995 |
| **58** | D4-5-84-2 | amphibolite | | AA ms | horn | 68.9 ±0.4 | 33° 51.59' | 113° 16.05' | Richard et al., 1995 |
| **59** | D4-9-84-2 | amphibolite | | AA tg | horn | 93.8 | 33° 51.53' | 113° 20.40' | Richard et al., 1995 |
| **60** | UAKA-78-48 | basalt | Vulture volcanics | KA | w.r. | 20.0 ±0.4 | 33° 51.62' | 113° 2.80' | Scarborough and Wilt, 1979 |
| **61** | 2-23-86-2 | amphibolite | Brown's Canyon granite | AA pl | horn | 67.9 ±0.4 | 33° 51.63' | 113° 12.30' | Richard et al., 1995 |
| **62** | 9-2-86 | amphibolite | Brown's Canyon granite | AA ms | horn | 63.5 ±0.3 | 33° 51.62' | 113° 12.32' | Richard et al., 1995 |
| **63** | HVR-2 | granite | Tank Pass granite | KA | biot | 44.1 ±1.3 | 33° 52.00' | 113° 41.30' | Shafiqullah and others, 1980 |
| **64** | 9-1a-86 | granite | Brown's Canyon | AA tg | biot | 13.7 ±0.1 | 33° 52.16' | 113° 11.97' | Richard et al., 1995 |

| Map # | Sample ID | Rock type | Unit | method | material | Date | Latitude | Longitude | Reference |
|---|---|---|---|---|---|---|---|---|---|
| | | | granite | AA max | k-sp | 22.4 ±0.5 | | | |
| **65** | 89-12 | | | FT | apat | 16.0 ±2.0 | 33° 53.08' | 113° 37.88' | Foster et al., 1993 |
| **66** | 87G16 | | | AA is | musc | 55.4 ±0.7 | 33° 53.00' | 113° 43.50' | Knapp and Heizler, 1990 |
| **67** | 87G29 | granitoid | JXg | AA is | biot | 45.5 ±3.8 | 33° 53.00' | 113° 44.00' | Knapp and Heizler, 1990 |
| **68** | 87G36 | granitoid | JXg | AA is | biot | 37.1 ±3.4 | 33° 53.00' | 113° 46.00' | Knapp and Heizler, 1990 |
| | | | | AA is | k-sp | 21.3 ±0.3 | | | |
| **69** | UAKA-77-65 | granite | Tank Pass granite | KA | biot | 51.0 ±1.1 | 33° 53.10' | 113° 37.80' | Shafiqullah and others, 1980 |
| **70** | 87G30 | granitoid | JXg | AA is | horn | 129.0 ±5.0 | 33° 53.30' | 113° 44.00' | Knapp and Heizler, 1990 |
| **71** | 4-8-85-5 | mafic dike | | AA tg | horn | 32.3 | 33° 55.10' | 113° 9.62' | Richard et al., 1995 |
| **72** | 12-12-88-5 | granite | | KA | biot | 20.0 ±0.6 | 33° 55.27' | 113° 50.92' | Spencer et al., 1995 |
| **73** | 89-14 | | | FT | apat | 17.0 ±2.0 | 33° 55.32' | 113° 37.17' | Foster et al., 1993 |
| **74** | 12-6-84-3 | tuff | | KA | horn | 18.4 ±0.5 | 33° 55.93' | 113° 55.28' | Spencer et al., 1995 |
| | | | | KA | biot | 21.5 ±0.5 | | | |
| **75** | 2-10-85-1 | basalt | | KA | w.r. | 19.5 ±0.3 | 33° 56.07' | 113° 55.00' | Spencer et al., 1995 |
| **76** | ES:90 | andesite | Bouse Hills andesite | KA | biot | 20.5 ±1.1 | 33° 56.62' | 113° 55.52' | Eberly and Stanley, 1978 |
| **77** | 853-11-2 | tuff | | KA | biot | 22.5 ±0.7 | 33° 57.37' | 113° 58.82' | Spencer et al., 1995 |
| **84** | 32-2-85 | | | FT | apat | 18.9 ±6.5 | 33° 57.48' | 113° 36.63' | Bryant et al., 1991 |
| | | | | FT | zirc | 18.0 ±1.4 | | | |
| **78** | 853-11-1 | tuff | | KA | biot | 24.0 ±0.7 | 33° 57.48' | 113° 58.75' | Spencer et al., 1995 |
| **79** | UAKA-73-127 | granodiorite | Bouse Hills granodiorite | KA | biot | 16.5 ±0.5 | 33° 58.10' | 113° 49.80' | Shafiqullah and others, 1980 |
| **80** | SJR-HV-78-1 | amphibolite | Cunningham Pass gneiss | KA | horn | 70.3 ±2.9 | 33° 58.94' | 113° 33.67' | Shafiqullah and others, 1980 |
| **81** | UAKA-75-107 | gneissic granite | Harcuvar gneissic granite | KA | biot | 25.3 ±0.5 | 33° 59.00' | 113° 34.00' | Shafiqullah and others, 1980 |
| **82** | 12-14-88-4 | dike | | KA | biot | 19.7 ±0.5 | 33° 59.24' | 113° 54.05' | Spencer et al., 1995 |
| **83** | 12-14-88-3 | granite | | KA | biot | 20.2 ±0.5 | 33° 59.88' | 113° 50.75' | Spencer et al., 1995 |
| **85** | 4-8-83-1 | rhyolite | Black Rock Volcanics | U-Pb | zirc | 160.0 | 33° 4.00' | 113° 37.50' | Reynolds et al., 1987 |

Abbreviations: Dating methods: AA-$^{40}Ar/^{39}Ar$ method (is-isochron age; tg-total gas age; ms-mean of several steps; max or min-of age gradient; pl-plateau); KA-potassium argon; SR--rubidium-strontium; U-Pb-uranium-lead; FT-Fission track.

Material dated: apat-apatite; biot--biotite; feld-feldspar; pl_c--plagioclase concentrate; sani--sanidine; w.r.--whole rock; zirc-zircon.

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# Salome 30'×60' Quadrangle
# Correlation of map units