Geology of the Cholla Tank and northern third of the Hoodoo Well quadrangles, northern Kofa Mountains, Yuma and La Paz Counties, Arizona

by

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INTRODUCTION

This study encompasses the western-most end of the Little Horn Mountains and the northeast end of the Kofa Mountains. Although relief in the area is less than 2000 feet, with elevations ranging from about 1500 feet in the northeast corner to 3348 feet at New Water (the peak west of Red Rock Pass), both ranges are extremely rugged. The physiography of the area is dominated by high basalt mesas flanked by steep-sided talus slopes. This is a very dry region in which saguaro, palo verde and ocotillo are abundant and seperated by land largely devoid of low brush. Abundant older Quaternary surfaces (Late Pleistocene and older) and talus deposits mantling dark basalt mesas all contain abundant basalt clasts covered with dark desert varnish. This abundant varnish gives the area a very dark, charred appearance. Desert pavements are well-developed on older surfaces.

Most of the bedrock exposures are Miocene volcanic rocks. They occur in three distinct sequences: (1) a series of ash-flow tuffs that depositionally overlie crystalline basement rocks, (2) a middle sequence of mafic to intermediate lava flows, and (3) a younger sequence of basalt lavas. The crystalline (granitic) basement rocks are exposed in the footwalls of several northwest-striking, south-side-down normal faults exposed north of Red Rock Pass. In the southern part of the study area, east and northeast of Hoodoo Well, slightly metamorphosed mafic(?) to silicic volcanic rocks and conglomerates of presumed Mesozoic age locally depositionally overlie granitic basement.

The study area includes all of the Cholla Tank USGS 7.5' topographic quadrangle and the northern third of the Hoodoo Well quadrangle. All of the region lies within the Kofa National Wildlife Refuge and, hence, several old dirt roads have been closed (including the Sheep Tank Mine Road). Although access to the central part of the study area requires a two or three hour hike, the Kofa-Manganese Road, which runs more or less north-south through Red Rock Pass, and the Red Raven Road in the southeast corner of the map area, provide good access to most of the region (with a 4-wheel drive).

PREVIOUS AND CONCURRENT STUDIES

Field work was carried out using 1:24,000 scale topographic base maps. The study area was mapped in reconnaissance as part of a USGS Wilderness Survey (Bagby et al., 1987). Shafiqullah and others (1980) reported radiometric dates of a few samples and noted that most of the tilting of the mid-Tertiary volcanic rocks occurred before the youngest mesa-capping basalt flows were erupted. The Owl Head and northern third of the Kofa Butte 7.5' quadrangles lie directly west of the study area and were mapped concurrently by Ferguson and Skotnicki (1996). The New Water Mountains to the north-northwest were mapped by Sherrod and others (1990) and areas of the Plomosa Mountains to the northwest were mapped by Richard and others (1993). To the south, our mapping overlaps slightly with the mapping of Grubensky (1987) and Grubensky and others (1995).

Preliminary results of current investigations by Jim Faulds and Steve Richard of the paleomagnetic properties of regional ash-flow tuffs in southwestern Arizona and southeastern California have helped constrain some of our correlations.

STRATIGRAPHY

Basement

Pre-volcanic basement is exposed as small slivers in the footwalls of faults in the west-central part of the map area north of Red Rock Pass, and in the south east of Hoodoo Well. North of Red Rock Pass the basement is composed entirely of medium-grained, equigranular to K-feldspar porphyritic quartz monzonite to granodiorite. The granitoid is almost everywhere propylitized and is slightly green-colored. East of Hoodoo Well the same granitic rocks crop out in association with weakly metamorphosed mafic to intermediate volcanic rocks interbedded with tuff beds and quartz-jasper pebble conglomerates. These

metamorphosed supracrustal rocks are probably Mesozoic in age and may be related to the McCoy Mountains Formation. The contact between the granite and the metamorphic rocks is sharp but highly irregular, suggesting an intrusive contact. The contact itself is covered with much debris but where it is well exposed it is ambiguous as to whether it is an intrusive contact or a depositional contact. However, because the contact is so irregular and because the volcanic rocks are locally weakly foliated but the granite is not, the granite probably intruded the supracrustal rocks. The granite and metamorphic rocks are intruded by a porphyritic, hypabyssal andesite, probably Miocene in age.

Tertiary volcanic rocks

The mid-Tertiary volcanic rocks of the northern Kofa and eastern Little Horn Mountains can be divided into three chronological sequences: (1) a lower sequence of welded ash-flow tuffs, herein referred to as the Kofa sequence, (2) a middle sequence of lavas, consisting principally of a thick pile of andesite lavas overlain and intruded by dacite and rhyodacite lavas, and (3) a younger sequence of basalt lavas. A detailed description of the Kofa sequence is given in Ferguson and Skotnicki (1996) and is not repeated here.

Older volcanic sequence--Kofa sequence

Welded tuffs of the Kofa sequence are exposed in three principle areas; north of Red Rock Pass, in the south near Hoodoo Well, and in the southeast near the Sheep Tank mine. North of Red Rock Pass most exposures of welded tuff have undergone argillic alteration and are altered to shades of red and green. In many areas farther to the north the welded tuffs are only slightly altered and it may in fact be possible to distinguish between the different tuffs in the Kofa sequence in the Red Rock Pass area with more work. Because exposures near Red Rock Pass outcrop in low, often altered hills surrounded by alluvium, making identification and correlation difficult, this is probably the least preferred place to begin a study of the welded tuffs. Unfortunately, we had the misfortune to begin our study in the Kofa and Little Horn Mountains in this very region. Therefore, the individual tuffs were not differentiated and instead most exposures were labeled Tk (Kofa sequence, undifferentiated). Near Sheep Tank Mine three distinct welded tuff layers seperated by thin basalt flows dip steeply to the southwest in a small ravine west of the mine. These welded tuffs are probably correlative to the Kofa sequence but the individual layers were not correlated with specific members. By far the best exposures of welded tuff occur in the southwest corner of the map west and northwest of Hoodoo Well. Here the tuff of Owl Head (map unit Tk_1) and the tuff of Hoodoo Well (map unit Tk_3) have shallow to moderate dips and the tuff of Owl Head is extensively intruded by andesite. It is not clear if the andesite (Ta) and the andesite porphyry (Tap) near the Sheep Tank Mine are correlative, but they appear to occupy the same stratigraphic position.

Middle volcanic sequence

The middle lava sequence consists mostly of two map units; a regionally extensive unit dominated by andesite lava called the Unit of Red Raven Wash, and a younger sequence of rhyodacite and dacite.

To the west of the study area, in the Owl Head and Kofa Butte quadrangles, the Unit of Red Raven Wash attains a thickness of at least three thousand feet (900 meters) and has been subdivided into an extensive andesite unit (Ta), an overlying dacite unit (Tad), and an underlying basaltic andesite to basalt unit (Tab). In the map area only the andesite unit is exposed. It intrudes and unconformably overlies tilted welded tuff on the west side of the study area.

Rhyodacite and dacite lavas are exposed in several places beneath the younger basalt mesas. Unlike the sequence to the west in the Owl Head quadrangle, here this sequence is composed of at least five and possibly more distinct felsic flows. Rhyodacite similar to that in the Owl Head quadrangle is confined to the southern half of the map area, where it is exposed south of the Sheep Tank Mine and east of Hoodoo Well. Near the Sheep Tank Mine the rhyodacite overlies tilted welded tuffs (Tk), is intruded by andesite porphyry (Tap), and is clearly overlain by dacite (Te) and dacite breccia (Teb). To the northwest the dacite

flows are overlain by younger basalt (Tby) [the lower contact is concealed]. In the southwest, the rhyodacite forms resistant light tan hills intruded (?) by andesite and overlain by basalt (Tb).

Bagby and others (1987) reported an age of 20.4 $\pm$ 0.4 Ma (K-Ar sanidine) from a sample of rhyodacite in the vacinity of Alamo Spring in the Owl Head quadrangle. Ferguson and Skotnicki (1996) reported a $^{40}Ar/^{39}Ar$ sanidine age of 22.42 + 0.13 Ma from a sample of the same unit collected farther west.

Younger volcanic sequence

The youngest volcanic rocks in the study area are fine-grained basalt lavas which cap the flat-topped mesas in most of the map area. The lavas occur in stacked sequences of relatively thin flows locally interbedded with rare reddish sandstones or the unwelded tuffs. The flows are subhorizontal to gently dipping and bury significant paleo topography. This paleo topography contact is well-exposed in the west-facing cliff face northeast of Red Rock Pass where dark blue-gray basalt flows contrast sharply with the underlying light gray to yellow dacite.

Two radiometric dates of this unit have been reported on samples from the adjoining Owl Head quadrangle. Shafiqullah and others (1980) reported a K-Ar whole rock age of 18.31 $\pm$ 0.42 Ma. Bagby and others (1987) reported a K-Ar whole rock age of 19.9 $\pm$ 0.4 Ma.

STRUCTURE

Pre-Tertiary structure

The structure of the pre-Tertiary rocks is obscure. Probable Mezosoic-age, steeply tilted, sedimentary and volcanic rocks east of Hoodoo Well were metamorphosed into the lower greenschist facies and deformed prior to an eposiode of uplift and erosion that preceeded eruption of the mid-Tertiary volcanic rocks. It is not clear if the supracrustal rocks were tilted before or during later Tertiary extension. Although it is also not clear if the granite-sedimentary contact is intrusive or depositional, it at least can be said that it is not a fault contact.

Tertiary Structure

The mid-Tertiary volcanic pile of the northern Kofa Mountains and northwestern Little Horn Mountains is dismembered by an extensive set of northwest-striking, southwest-side-down normal faults. Tilts of the volcanic strata range from a few degrees to steeply inclined. In the west, strata in the Kofa sequence and in the middle volcanic sequence are tilted towards the northeast, whereas strata of the younger basalts dip primarily to the southwest. In the east the older and younger rocks are all tilted to the southwest. There is a general decrease in magnitude of the tilts upwards through the volcanic pile, and southward within any given unit. Near Red Rock Pass the Kofa sequence dips between about 60° and 80°. Tuffs associated with dacite at the Sheep Tank Mine dip between about 40° and 60°. The younger basalt flows dip between about 0° and 20°.

Unfortunately most of the structure in the study area is obscured. Most of the older rocks in the study area have been buried by younger basalt flows, themselves half buried by obscuring talus. The older, middle, and younger sequences of volcanic rocks are exposed much better to the west of the map area in the Owl Head quadrangle. Three distinct episodes of faulting have been observed . They are (1) synvolcanic faulting during eruption of the ash-flow tuffs and continued faulting of the resultant welded tuffs, (2) faulting after deposition of the intermediate to felsic lavas of the middle volcanic sequence, and (3) faulting of the younger basalt flows.

North of Red Rock Pass northwest-striking low-angle normal faults (one with a measured dip of 36°) cut the Kofa sequence and granitic basement into narrow, parallel fault blocks. These faults are probably the oldest generation of faults in the region, but since all younger rocks were removed it cannot be said for certain that these faults did not cut them as well.

Faults of the second generation can be seen cutting dacite in very isolated exposures between 1.5 and 2 miles northeast of Red Rock Pass. Here, faulted dacite and interbedded tuff is unconformably overlain by unfaulted basalt flows. In the vicinity of the Sheep Tank Mine there are two exposed probable syn-volcanic faults. The fault exposed in the canyon southwest of the mine cuts welded tuffs and interbedded basalts of the Kofa sequence, as well as andesite porphyry (map unit Tap). The fault, however, is truncated by undisturbed dacite breccia and lava. Immediately south of the mine a fault displaces rhyodacite and andesite porphyry and projects at least part of the way upward into dacite lava.

Faults of the youngest generation are almost nowhere exposed. Only two small fault segments were observe, one in the northwest near White Tank and one in the center of the map area. At both localities the faults are high-angle and cut both the basalt and the underlying dacite and rhyodacite (and all of the buried older rocks as well). These high-angle faults (and others that are not exposed) strike to the northwest and have broken the younger basalt lavas into steep, gently southwest-dipping fault blocks.

Syn-volcanic structures

In the southwest corner of the map area near Hoodoo Well, horizontal to gently-dipping outflow(?) facies tuff of Hoodoo Well (map unit Tk_3) occurs at essentially the same level on both sides of Hoodoo Wash. On the north side of the wash the tuff overlies crystalline basement, but on the south side it overlies a "bottomless" (at least 300 meters thick) sequence of the tuff of Owl Head (map unit Tk_1). This difference in thickness is interpreted to be a result of a now-buried south-side-down fault roughly paralleling the course of Hoodoo Wash. This structure may represent a northern cauldron margin for the tuff of Owl Head, and in support of this interpretation lithic mesobreccias within the tuff of Owl Head occur along the south side of Hoodoo Wash.

MINERALIZATION

Sheep Tank Mine. This mine consists of several deep adits and tunnels, and a few smaller pits. Several buildings still stand. On the mine dumps there is an abundance of very fine-grained, dark grey, manganese-rich rock--possibly psilomelane. The psilomelane is intamitely associated with light to dark grey calcite. The calcite preferentially erodes and the psilomelane weathers into resistant bands and irregular masses. Where exposed in outcrops, psilomelane and calcite occurs as anastamosing veins within the highly-fractured host rock (andesite porphyry).

Red Rock Pass. Throughout the area north and south of Red Rock Pass, the tilted welded tuffs of the Kofa sequence and interbedded basalts all display marked discoloration. Some exposures of basalt have been bleached to light green and the mafic minerals have been altered to opaques. The welded tuffs display argillic alteration. Locally, the argillic alteration is so extreme that the rock has been altered to a very friable clay which easily erodes. Where the alteration is not so extreme the welded tuff is different hues of pink and cream. In these rocks most of the mafic minerals are no longer identifiable, nor are the feldspars. Quartz seems unaffected and stands out vividly in many outcrops, giving the impression of a quartz-rich volcanic rock.

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UNIT DESCRIPTIONS
FOR THE CHOLLA TANK AND NORTHERN
HOODOO WELL 7.5' QUADRANGLES

Quaternary Deposits

Qa, Qt (Quaternary): Surficial deposits of unconsolidated to poorly consolidated alluvium (Qa). Locally includes tongues of talus along steep mountain sides, and in some areas talus deposists were mapped separately as Qt. Map unit Qa is a general classification and includes several different ages of Quaternary and possibly late Tertiary surficial deposits.

Tertiary Rocks

Younger volcanic sequence

Tby **Younger basalt lava (Tertiary)**: moderately crystal-rich olivine and pyroxene bearing basalt with abundant plagioclase phenocrysts. Unit consists of numerous thin flows accumulating to a thickness of over 200 meters in some areas. The rock is dark grey and weathers into angular to subangular varnish-covered boulders that form steep talus slopes. Shafiqualla and others (1980) report a K-Ar whole rock age of 18.31 Ma.

Tsx **Undifferentiated breccia (Tertiary)**: Composed of poorly sorted, angular clasts derived from both the tuff of Ten Ewe Mountain and the tuff of Hoodoo Well. Exposed in the southeast corner of the map, south of Sheep Tank Mine. Possibly of fault-breccia origin but probably represent rock avalanche deposits.

Tsxt **Monolithic breccia of tuff of Ten Ewe Mountain (Tertiary)**: Lenses of poorly sorted breccias composed of greater than 90% angular clasts of tuff of Ten Ewe Mt. Clast size range from sand up to 3 meters.

Tsxh **Monolithic breccia of tuff of Hoodoo Well (Tertiary)**: Lenses of poorly sorted breccias composed of greater than 90% angular clasts of tuff of Hoodoo Well. Clasts size range from sand up to 3 meters.

Middle volcanic sequence

Tl **Limestone (Tertiary)**: Light grey, wavy laminated limestone. Based on position of limestone in the stratigraphic section to the east (Grubensky and Demsey, 1991) this unit may be younger than map unit Trd. This unit is exposed in only one saddle in the south-central part of the map area.

Teb **Dacite breccia (Tertiary)**: This unit is composed of poorly sorted, angular clasts of light grey dacite (map unit Te) strongly welded together. The clasts are commonly vitric and pumiceous.

Te **Dacite (Tertiary)**: Light grey, slightly vitric, fine-grained felsic lavas containing subhedral to euhedral phenocrysts of clear plagioclase, and fresh biotite and hornblende, all <2 mm wide in a light grey, aphanitic matrix. Weathers light grey to tan and has a chalky apperance. Locally, flow-foliation is very pronounced, and the base, where in contact with andesite porphyry (map unit Tap),

is defined by vitrophyre and yellow, devitrified lava. The dacite is brecciated locally. The unit is resistant and forms peaks and ridge tops in the Sheep Tank Mine area.

Trd **Rhyodacite lava (Tertiary)**: a moderately crystal-poor, quartz, feldspar, and biotite-bearing felsic lava (2-10% phenocrysts) displaying a wide variety of megascopic textures. The three principal morphologic types of lava are: massive crystalline-matrix flow-banded, vitric flow-banded, and vitric auto breccia. Locally spherulitic. Light tan in color and generally weathers into light grey to tan, slightly varnished, resistant knobs and hills in the southern part of the map area northeast of Hoodoo Well and south of the Sheep Tank Mine in the southeast corner of the study area. Though exposures may be blocky and steep, individual blocks are commonly slightly rounded. A K-Ar sanidine age of 20.4$\pm$0.4Ma (Shafiqualla and others, 1980), and an Ar/Ar sanidine age of 22.42$\pm$0.13Ma (McIntosh, personal communication) have been reported for this unit from exposures to the west in the west-central Owl Head 7.5' quadrangle.

Tt **Unwelded tuff (Tertiary)**: Generic unwelded, bedded and typically lithic-rich tuffaceous rocks interpreted as (in decreasing order of abundance) ash-flow tuffs, subaerial ash-fall tuffs, volcaniclastic sandstone (locally eolian), or surge units. This generic unit occurs within and between volcanic units throughout the map area.

Tap **Andesite porphyry (Tertiary)**: Dark purple volcanic rock containing large, light grey, subhedral plagioclase phenocrysts 1-10 mm long, and smaller subhedral biotite phenocrysts1-5 mm wide, in a purple, aphanitic matrix. The unit is crystal-rich--about 30% phenocrysts. The rock weathers into dark, gnarly cliffs and steep rugged hills with caves and overhangs near the Sheep Tank Mine in the south corner of the study area. The rock is commonly highly fractured and brecciated but is difficult to break with a rock hammer. This rock is similar to map unit Tai.

Tf_3 **Tan Dacite (Tertiary)**: Similar to map unit Tf_2, which it overlies, and map unit Tf_1. This unit is a light tan-colored, fine-grained dacite lava containing small phenocrysts of fresh plagioclase, possibly sanidine, and biotite, all less than 2 mm wide, in a tan, aphanitic matrix. Phenocrysts comprise about 3-5% of the rock. Locally flow-banded. It makes up the low, orange-tan-colored hills in the central part of the study area.

Tf_2 **Dacite (Tertiary)**: Light grey to yellow, fine-grained, crystal-rich dacite lava. Contains phenocrysts of clear plagioclase, fresh black hornblende and biotite, and minor quartz, all between 1-3 mm wide. Plagioclase crystals commonly stand out in relief on weathered surfaces. Outcrops are massive--no stratification is visible. Exposures commonly consist of large blocks of dacite welded together by yellow tuffaceous breccia. Locally vitrophyric. Forms steep, light-colored cliffs east of Red Rock Pass.

Tf_1 **Fine-grained rhyodacite (Tertiary)**: Locally flow-banded and commonly brecciated. Flow-banding is defined by grey and pink laminae between about 1-10 mm thick. It contains phenocrysts of subhedral quartz, plagioclase, biotite, and hornblende 1-4 mm wide. The hornblende has been mostly altered to red opaques. Phenocrysts constitute less than 5% of the rock. The unit form a dark brown, blocky, angular cliff below Tf_2 east-northeast of Red Rock Pass. May be equivalent to map unit Trd.

Tbi **Gabbro (Tertiary)**: Mafic sill intrudes near or at the base of the Kofa sequence between granite and welded tuff and within welded tuff (probably map unit Tk_1). It contains black anhedral to subhedral hornblende phenocrysts up to 1.5 cm long, and light grey plagioclase phenocrysts.

Td **Dacite (Tertiary)**: Irregular-shaped, light grey to light tan intrusive bodies of dacite porphyry containing about 25% phenocrysts of feldspar (mostly plagioclase), biotite, and hornblende. Locally flow-banded. Exposed in very small exposures slightly over two miles directly north of Red Rock Pass where it unconformably overlies andesite of the unit of Red Raven Wash, and possibly welded tuffs of the Kofa sequence.

Ta, Tai Unit of Red Raven Wash (Tertiary): a composite unit of lavas which may exceed 300 meters in some areas. It is dominated by flows of andesitic composition, most commonly a plagioclase-rich, pyroxene, and amphibole-bearing andesite with 10-25% phenocrysts. Fine-grained, crystal-poor basaltic andesites, olivine and pyroxene bearing basalts, and biotite-bearing dacitic lavas are also present. To the west of the study area (Ferguson and Skotnicki, 1995) individual lava flows were differentiated as Tab-basalt to basaltic andesite, or Tad-dacite. Lavas of this unit are also interbedded with thin (less than 20 meter-thick) lithic-rich, unwelded, bedded tuffs (Tat), and sandstones or pebbly sandstones (Tas). In the west end of the Kofa Butte and Owl Head 7.5' quadrangles, lavas of this unit are interbedded with west-thickening, welded ash-flow tuffs of the Tk_5 unit. In some areas, particularly west and southwest of Hoodoo Well andesites of this composition contain abundant, large 5-10 mm-wide, subhedral to euhedral light grey to partially clear to chalky plagioclase phenocrysts. Because of the size and abundance of phenocrysts, and the clear intrusive relationships between this unit and host rock (particularly map unit Tk_1) this unit was mapped locally as intrusive andesite (**Tai**).

Tb **Older basalt (Tertiary)**: olivine, pyroxene-bearing basalt lava flows interbedded with the ash-flow tuffs of the Kofa Sequence.

Older volcanic sequence--Kofa sequence

Tc **Conglomerate (Tertiary)**: Volcaniclastic conglomerate containing moderately well-sorted, subrounded sand- to pebble-size lithic clasts of basalt, tuff and welded tuff. Exposures are limited to three small outcrops about 2 miles north of Red Rock Pass.

Tk **Kofa sequence, undifferentiated (Tertiary)**: The Kofa sequence is a succession of at least 6, and probably 7 welded ash-flow tuffs separated by bedded tuffaceous sequences (both pyroclastic and epiclastic), and lava flows. Most, if not all, of these tuffs can be correlated with other welded ash-flow tuffs that have been described in the Kofa Mountains region. Most of the welded tuffs can be identified by their phenocryst assemblage, and in the field the sequence can in most places be broken into its individual units. Unfortunately, the phenocryst assemblage of feldspar and quartz with relatively abundant biotite and hornblende is fairly common, and the distinguishing phenocryst abundances and ratios are subtle enough that severly altered or areally limited exposures of these tuffs may not be assignable to individual units. Not all of the ash-flow tuffs of the Kofa sequence are differentiated in the study area.

Tk_5 **Tuff of Ten Ewe Mountain (Tertiary)**: A moderately crystal-poor to moderately crystal-rich (5-10% to 15-20%), densely welded, locally flow-banded ash-flow tuff containing phenocrysts of feldspar (mostly plagioclase?), a few percent quartz, very abundant (perhaps up to 1-2%) biotite,

and lesser amounts of hornblende. The tuff is characteristically grayish-purple in color, and its pumice fragments commonly display evidence of axiolitic devitrification textures. The only discernible zonation of this tuff is a general upwards increase in phenocryst content. Differentiated only immediately north of Red Rock, on the west edge of the map area.

Tk_3 **Tuff of Hoodoo Well (Tertiary)**: A crystal-poor, pumice-poor, vertically zoned, sanidine, plagioclase, and large resorbed quartz phenocryst-bearing tuff with a very sparse population of mafic phenocrysts. The unit is vertically zoned from only a few percent phenocrysts and pumice near its base to a tuff with 5% to 10%, and up to 10-15% pumice near its top. No obvious vertical zonation of phenocryst ratios is apparent in the field. The tuff is characteristically light-gray or pink-colored on fresh surfaces, massive and red-colored in outcrop, and typically high-standing relative to adjacent units. The more densely welded portion typically has a mottled appearance due to the presence of spherulites, many of which tend to grow around phenocrysts.

Tk_2 **Tuff of White Tanks? (Tertiary)**: Welded tuff that occurs between the tuff of Owl Head and tuff of Hoodoo Well in the Alamo Wash area in the Kofa Butte 7.5' quadrangle, and differentiated north of Red Rock in the Cholla Tank 7.5' quadrangle. In many areas it is separated from these two tuffs by thin basalt lava flows and/or bedded tuffaceous sequences. The tuff is zoned from very crystal-poor at the base to moderately crystal-poor at the top, and its phenocryst assemblage is dominated by feldspar, probably mostly sanidine. It also contains minor amounts of quartz, distinguishing it from Tk_3, and a very sparse population of mafic minerals, distinguishing it from the other welded tuffs. An upwards increase in biotite, from virtually absent to trace amounts, occurs at the very top of some sections. In the Alamo Wash area the densely welded upper portion is typically dark reddish-brown colored with a mottled appearance due to the presence of cm-scale spherulites, and it contains abundant elliptical, lithopysal cavaties up to 10 cm long. Tk_2 is tenatively correlated with the tuff of White Tanks (north-central Tank Mountains), a poorly to moderately welded tuff with a similar phenocryst assemblage.

Tk_1 **Tuff of Owl Head (Tertiary)**: A moderately crystal-rich (15%) to crystal-rich (30-40%), vertically zoned, welded ash-flow tuff. The phenocryst assemblage of feldspar (mostly plagioclase), quartz, and biotite changes from a quartz-rich, biotite-poor assemblage at the base to a quartz-poor, plagioclase and biotite-rich assemblage at the top. The appearance of very crystal-rich, plagioclase and biotite-bearing, dark-colored pumice in the upper half of the unit is also fairly diagnostic. Near its type locality at Owl Head, in the Kofa Butte 7.5' quadrangle, the welded tuff overlies a bedded tuff and volcaniclastic sandstone or cobbly sandstone sequence up to 15 meters thick, and the welded portion is capped by a complex, bedded, subaerial ash-fall tuff sequence. The outflow sequence in the Owl Head area ranges from 0 to 75 meters thick. In the Hoodoo Well area (Hoodoo Well 7.5' quadrangle), tuff of Owl Head fills a volcano-tectonic depression where it is at least 300 meters thick with no exposed base suggesting that this area lies within its source cauldron. The tuff in this area grades upward from a moderately to densely welded, quartz-poor, plagioclase and biotite-rich sequence with numerous prominent and sharp flow-breaks to a sequence dominated by medium-bedded ash-fall tuffs overlain by a basalt lava. The breaks are expressed as recessive zones and are interpreted as basal 2a layers.

Mesozoic Rocks

Mg **Granitoid (Mesozoic)**: Medium to fine-grained, equigranular to porphyritic granitoids ranging in composition from granite to diorite, and with an average compositon of quartz monzonite or granodiorite. Contains phenocrysts of light grey to white plagioclase, light grey to pink K-feldspar,

clear to milky quartz, and variable amounts of hornblende and/or biotite. The granitoids display a wide range of mafic mineral content from a few percent to over 25% and they are typically propyllitized. Locally the unit is K-feldspar- porphyritic. Outcrops are commonly highly fractured and locally brecciated. Most exposures are green-grey in color and form both blocky, resistant buttes and low, rounded hills. In the Kofa Butte 7.5' quadrangle the unit is locally foliated and contains minor banded quartzofeldspathic gneiss.

Mv **Metavolcanic rocks (Mesozoic)**: These rocks are mostly dark green, fine-grained phyllites and very locally muscovite schist. Within the phyllite very small (<1mm) dark porphyroblasts resemble hematite after magnetite. What appear to be stretched pummice fragments in a fine-grained green matrix are visble locally. The unit also locally contains several 2-20 cm thick, more resistant, silicic bands. Locally, there are very fissle/crumbly bands of pink to tan muscovite-rich phyllite 'interbedded' with green phyllite and may represent metamorphosed tuff layers. Also exposed are locallized outcrops of tuffaceous meta-volcaniclastic conglomerate containing green, phyllitic volcanic clasts in a tan-red sandy matrix. Very locally thin bands of sandstone are well-indurated yet fissle along foliation planes.

Mc **Conglomerate (Mesozoic)**: Moderately indurated conglomerate containing moderately well-sorted, well rounded clasts of quartz and jasper from pebble- to cobble-size, weakly to moderately cemented by a siliceous matrix. Outcrops are generally lighter colored than neighboring green phyllites and are covered by a loose lag of pebbles and cobbles.

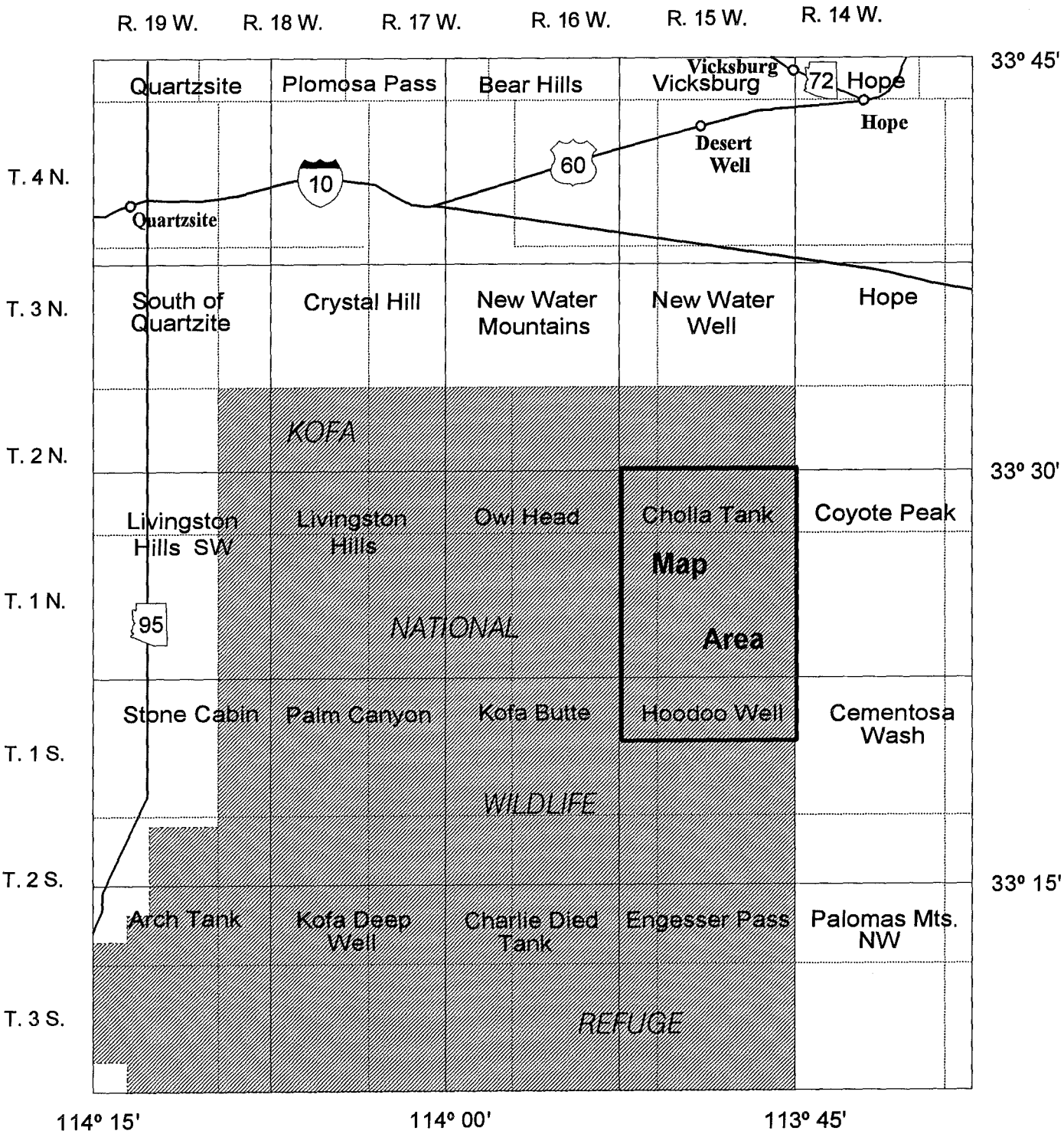

Figure 1. Index map showing the location of the map area and the U.S.G.S. 7.5' Quadrangles.

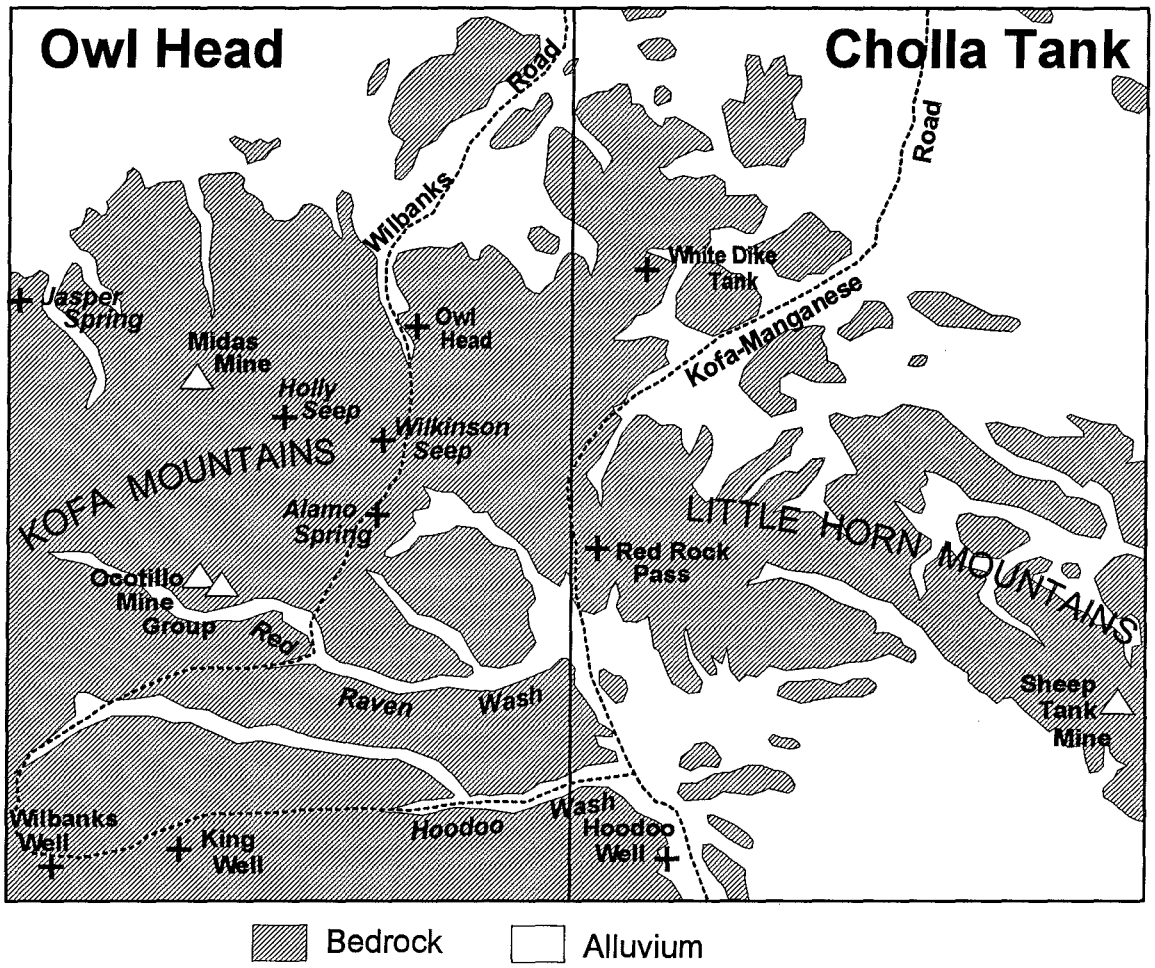

Figure 2. Index map of the northern Kofa Mountains showing place-names and geographic localities.

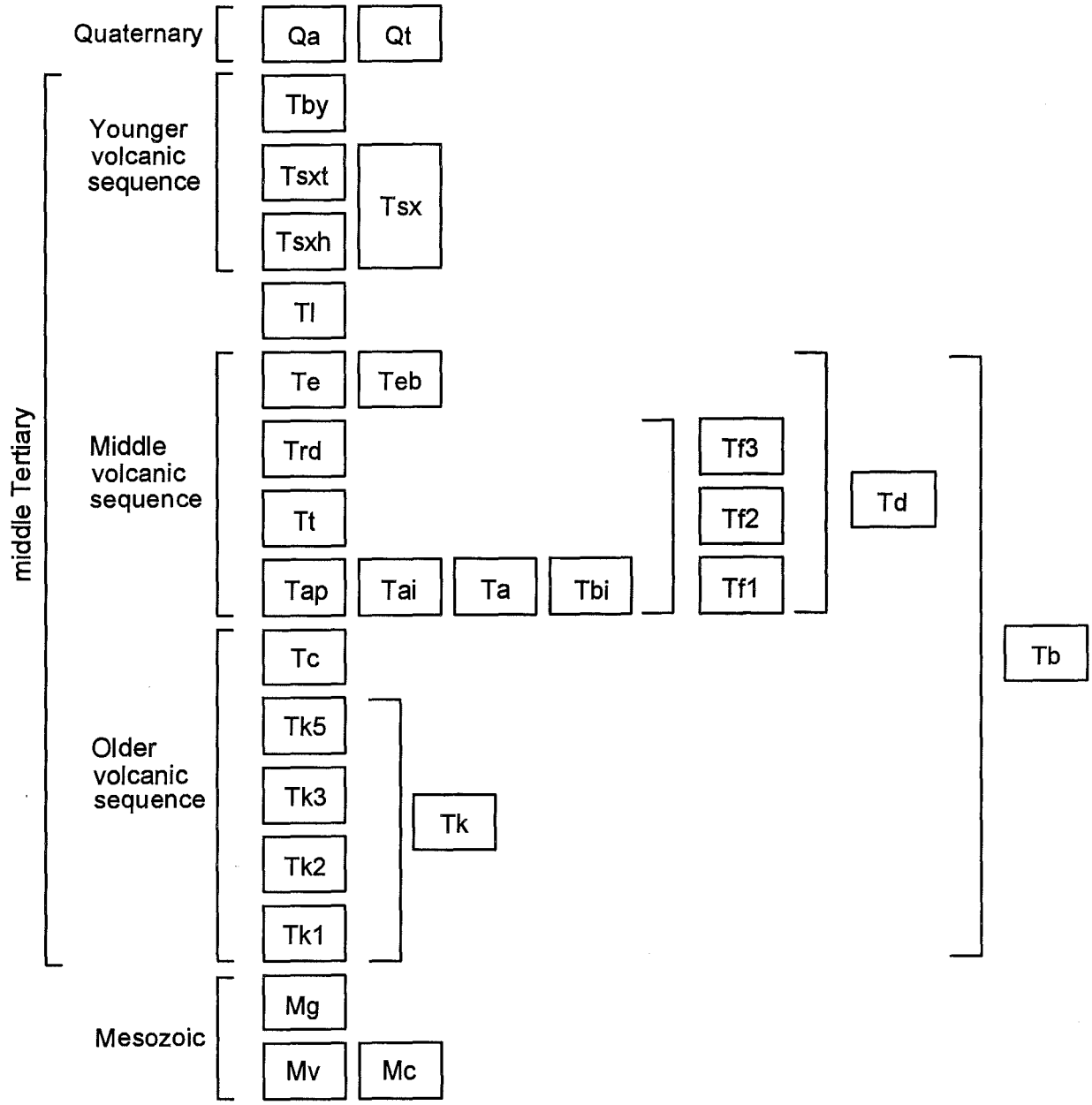

Figure 3. Correlation diagram for rocks in the Cholla Tank quadrangle and northern Hoodoo Well quadrangle, northern Kofa Mountains.