GEOLOGIC MAP OF THE PALOMAS MOUNTAINS, YUMA COUNTY, ARIZONA

by

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INTRODUCTION

The Palomas Mountains are located approximately 70 miles northeast of Yuma, Arizona, and about 15 miles north of the town of Dateland in eastern Yuma County (Figure 1). Across a narrow valley to the north are the Tank Mountains, which form a continuous belt of bedrock westward into the Kofa Mountains. To the west lies Neversweat Ridge, which is the eastern-most known exposure of Orocopia Schist. To the east and northeast is the Palomas Plain, and to the south is the Gila River.

Accessibility to the range is generally good. Most of the dirt roads are in good condition and can be partially traversed by a two-wheel drive vehicle. However, because they cross many sandy washes the roads are only passable with a four-wheel drive vehicle. The western half of the range lies within the Yuma Proving Ground and permission must be obtained before entering. Besides the current munitions testing on the Proving Ground most of the southern portion of the mountains was the site of military training during World War II. Rusted fragments of shrapnel, small craters, and tank and vehicle tracks are numerous. Two miles west of the curve in the paved road heading north from Dateland is a monument commemorating the training of the 81st Infantry Division.

Field work was carried out between December, 1993, and April, 1994, and was contemporaneous with mapping in the Tank Mountains. The study area encompasses parts of the following 1:24,000 U.S. Geological Survey topographic maps: Palomas Mountains SW, Palomas Mountains SE, Kofa, and Horn. Plate 1 uses these maps as a base. This project was jointly funded by the Arizona Geological Survey and the U.S. Geological Survey STATEMAP program, contract #1434-93-A-1144.

PREVIOUS INVESTIGATIONS

Previous geologic studies of the area include reconnaissance surveys incorporated into the State geologic map by Wilson and others (1969) and the Ajo 1° x 2° Quadrangle by Gray and others (1988). A study of the geology, geochronology and mineral resources by Bagby and others (1987) covered the adjacent Kofa National Wildlife Refuge and included three K-Ar dates of rocks in the Palomas Mountains. Wilson (1933) also briefly described the geology and mineralization of the area within and surrounding Yuma County.

GEOLOGIC SETTING

The Palomas Mountains are within the Basin and Range physiographic province. Bedrock geology includes a Miocene granitic pluton dated at 23.2 ± 0.5 Ma (biotite K-Ar date from Bagby et al., 1987) overlain by felsic and mafic Miocene volcanic rocks (Plate 1; Figures 2 and 3). A myriad of northwest-trending dikes intrude the granite, as does a northwest-striking, southwest-dipping sheet-like body of pegmatitic granite. Exposures of unfoliated hornblende-biotite granite in the southern Tank Mountains may be related to the granite in the Palomas Mountains. Locally exposed banded gneiss and porphyritic granite/quartz monzonite are possibly related to similar rocks in the Tank Mountains. They occur below the volcanic section north of the central wash and as small lenses within the granite in the west.

The range is surrounded by gently sloping piedmonts of various ages. To the southeast basin-fill deposits form raised terraces which are extensively dissected. These deposits are horizontally stratified and have developed a dark, coarse lag gravel on the upper surfaces. Locally, the younger fans are very thin, revealing granite pediments below. The northwest end of the range is underlain by gently northeast-dipping older Tertiary basin-fill deposits. These deposits are conglomerates and debris flows composed almost entirely of the youngest andesite unit, and dip 3°-10° northeast. The southern edge of the deposit is defined by an abrupt slope several hundred feet high.

On the north and northeast sides of the mountains, many relatively flat caliche-capped terraces overlie basalt hills (not shown on map). It is not clear if the terraces represent separate older erosion surfaces or one surface which has been faulted prior to deposition of the youngest andesite lavas. In sec. 1, T. 5 S., R. 14 W., andesite lavas overlap a steep, northwest-facing slope in the underlying basalt. The slope may represent a degraded fault scarp or may simply be an erosional feature.

DIKES

Most of the dikes are well-exposed in the Tertiary granite and the older metamorphic rocks. Although two types are shown on the map there are variations of each. The felsic dikes include feldspar porphyry and quartz-feldspar porphyry dikes. Each includes variable amounts of either biotite and hornblende or both. The porphyry dikes are coarser-grained toward the cores where they are commonly granitic. The mafic dikes include dark aphanitic basalt and grey-green medium- to fine-grained plagioclase-hornblende dikes. In general, the mafic dikes appear to be older than the felsic dikes, but cross-cutting relationships are rare and often equivocal. In many areas swarms of thin mafic dikes appear to be intruded by wider felsic dikes. In some areas, particularly to the east, felsic dikes appear to be emplaced along the margins of earlier mafic dikes. A K-Ar biotite date of 22.6 ± 0.4 Ma was obtained from one felsic dike (Bagby et al., 1987).

The strikes of the dikes are predominantly northwest-southeast but strike closer to north-south progressively to the west. This trend appears to continue to the northwest outside the study area at Neversweat Ridge (Grubensky, Haxel and Demsey, in press) where north-northwest-trending mafic dikes intrude Orocopia schist. Locally, in the west-central part of the granitic body, felsic dikes strike nearly north-south and dip very gently to the west. Their attitudes suggest that they may be of a different age than northeast- and east-dipping dikes to the east. The number and thickness of dikes decreases to the west. The dips of the dikes vary from about 75°-80° NE in the northeast to 20°-40° NE in the southwest.

STRUCTURE

Most of the exposed faults are northwest-trending high-angle normal faults. Where discernable, offsets are less than 100 meters, and typically are expressed as small horsts and grabens. No detachment faults were recognized, though there is a large, high-angle normal fault juxtaposing the Tertiary volcanic sequence and Mesozoic or Proterozoic rocks on the northeast with Miocene granite on the southwest. The fault projects through the narrow alluvial-filled valley running through the center of the mountain range. It is not clear how much offset has occurred on this fault. Many of the faults have been filled with dark carbonate (possibly siderite or manganiferous calcite), locally intergrown with quartz. Slickensides in the carbonate indicate that faulting continued during or after deposition of the calcite. The carbonate is locally more resistant than the granite and forms small resistant ridges. Because the older tuffs and basalts dip more steeply to the north-northeast than do the younger units, most of the faulting in the area appears to have occurred prior to deposition of the younger cliff-forming basalt. However, the younger andesite lavas, which overlie the younger basalts, cover a steep slope in the underlying basalt. Local Accumulations of tuff and breccia associated with the andesite show that the slope existed before deposition of the andesite. It is not clear if the slope was formed by erosion or by faulting of the upper basalt.

The Tertiary supracrustal rocks all appear to dip to the north-northeast. Most of the volcanic rocks in the Palomas Mountains crop out north of the Miocene granitic pluton and are separated from it by a major north-side-down fault. Volcanic rocks also exist south of the fault but only near the western end of the range. The Tertiary volcanic rocks, both north and south of the fault, dip about 5°-20° to the northeast. However, south of the major fault to the east, where supracrustal rocks are absent, it is difficult to determine the direction and magnitude of tilting. The relationship between the dikes and pegmatite sill within the granitic body may be of use in approaching the problem. The dikes and pegmatite are everywhere oriented at high angles to each other, typically greater than 80 degrees, and the pegmatite is locally oriented parallel to a crude magmatic layering within the granite. The implication of these observations is that the pegmatite was originally emplaced as a subhorizontal sill-like body and later intruded by subvertical dikes, and the current orientations of these bodies may indicate the direction and magnitude of tilt that the rocks have undergone. The dip of the dikes decreases to the southwest whereas the dip of the pegmatite increases, suggesting that, to the southwest, the granite may be broken into southwest-dipping blocks bounded by north-side-down normal faults. This sense of tilting (to the southwest) is opposite to that of the volcanic rocks to the northeast.

The timing of faulting is not well-constrained. Talus and alluvium obscure much of the bedrock and make it impossible to visually follow faults for long distances. Tertiary supracrustal rocks west of the major fault are much thinner than that to the northeast, and basalt (map units Tbu + Tbm) and the Tuff of Ten Ewe Mountain (Tte) rest directly on Miocene granite. The two basalt map units are attenuated with respect to the same units on the northeast side of the fault. The absence of older units suggests that the major fault is a growth fault. The older volcanic units may have been removed by erosion prior to deposition of the Tuff of Ten Ewe Mountain and the younger basalt.

Map unit Ttv is the youngest unit visibly cut by the main fault. However, a smaller fault on the north side of the main fault cuts the Tuff of Ten Ewe Mountain (map unit Tte) and possibly the upper basalt (map unit Tbu). Because the smaller fault is cut by the main fault, faulting along the main fault ended after deposition of the Tuff of Ten Ewe Mountain and possibly after earliest eruption of the overlying basalt. Faulting ceased before the andesite (map unit Ta) was deposited.

The shallow dip of the rocks and the relatively minor offsets of the faults indicates that the Palomas Mountains have undergone relatively little extension compared to areas farther south, such as the Mohawk Mountains (Mueller et al., 1982), and to the north and east as in the Little Horn and Gila Bend Mountains (Grubensky and Demsey, 1991, and Gilbert et al., 1992).

MINERALIZATION

Almost all of the mineralization occurs along the northern margin of the Tertiary granite and foliated granitic rocks. Many small prospects and adits have been dug at the contacts between the granitic rocks and mafic dikes where mineralization includes chrysocolla, malachite, hematite, quartz, and triangular facets of probably pseudomorphs of limonite after pyrite. Individual pseudomorphs are commonly surrounded by a rim of chrysocolla. At the England Mine (or Engles/Adams Mine) chrysocolla and malachite mineralization occurs at the junction of a quartz-feldspar porphyry dike and a basaltic dike. Workings include several short tunnels, two thirty-foot shafts on the Charles Engles claims and two shafts, 50 and 100 feet deep, on the Henry Adams Group (Wilson, 1933). Farther west of the England Mine there are only a few small pits associated with mafic and felsic dikes.

Locally, in the eastern end of the range, in sec. 7, T. 5 S., R. 12 W., dikes of manganese oxides (probably psilomelane) fill fractures cross-cutting andesitic to dacitic volcanic rocks (Figure 4). The exposure is limited to one small ravine but it is well-exposed. The manganese is laminated and intimately associated with fine-grained white quartz and calcite. The dikes are nearly vertical, trend N35°W and vary in thickness from between several millimeters to almost a meter.

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DESCRIPTION OF MAP UNITS

Qs **Surficial deposits (Quaternary)** -- Includes talus, colluvium, caliche-cemented, rubble-forming terraces, and unconsolidated alluvial deposits.

Tsy **Younger sedimentary deposits (Tertiary)** -- Gently north- and northeast-dipping tan-colored conglomerate and sandstone. The unit is weakly to strongly consolidated and composed of intercalated layers of moderately sorted pebbly sandstone and conglomerate, and very poorly sorted sandy boulder conglomerate. Clasts are almost exclusively of map unit Ta, with rare basalt clasts. The individual clasts are angular to subrounded, and the matrix is tan-colored sand and silt. All conglomerate is clast-supported. Layers generally form lens-like bodies and may represent avalanche or debris flow deposits. Outcrops of conglomerate are commonly covered with desert varnish and are darker than adjacent finer-grained layers. Where good exposures exist, the surface exfoliates into curved blocks and caves. Locally, high-angle joints or faults with unknown offset trend N15°W through well-exposed deposits.

Ta **Andesite (Tertiary)** -- Interbedded blocky and massive flows of moderately crystal-rich mafic lavas with up to 20% phenocrysts of plagioclase and 1% phenocrysts of pyroxene. The uppermost part of this unit is massive, columnar jointed, strongly flow-banded lava (or possibly a welded tuff) with characteristic rounded, fine-grain mafic clots up to 5 cm in diameter. The clots show no preferential orientation or evidence of flattening, and they appear to overprint a highly compacted or flow-banded texture. The andesite is very resistant and typically forms steep, grayish-tan blocky hills and tall cliffs.

Tax **Andesite breccia (Tertiary)** -- Local accumulations of poorly sorted, angular, monolithic breccia at the base of andesite flows. It is possibly a flow breccia.

Tta **Tuff (Tertiary)** -- Local accumulations of bedded tuff and tuffaceous sandstone at the base of the andesite unit (Ta).

Tbu **Upper Basalt (Tertiary)** -- Dark blue-grey basalt lava flows that varies from crystal-poor olivine and pyroxene basalt to moderately crystal-rich plagioclase-only basalt. This basalt forms resistant mesas and steep cliffs. Locally, flows are interbedded with thin intervening tuffs and sandstones. The basalt is generally vesicular and is locally crumbly.

Tt **Tuff (Tertiary)** -- Local accumulations of yellow, bedded lapilli tuff at the base of the upper basalt.

Tte **Tuff of Ten Ewe Mountain (Tertiary)** -- Peach-colored, densely welded, moderately crystal-poor ash-flow tuff, and locally entirely or partly unwelded bedded and/or massive tuffs, all 0-20 meters thick. Phenocrysts consist of very rare quartz, feldspar, and abundant biotite. The eastern-most extent of this unit is a 1 to 3 meter-thick sequence of unwelded, faintly bedded tuffs that separates basalt lavas (Tbu and Tbm) in the southern half of sec. 15, T. 5 S., R. 13 W. To the west, the unit thickens and includes a densely welded zone and a 10 meter-thick unwelded base. The densely welded zone in this area is characterized by orange-colored pumice fragments with a distinctive pattern of axiolitic needle growth such that, in cross-section, the pumice resemble closed zippers. The unit weathers into light pink and peach-colored rounded hills. This tuff probably correlates with the tuff of Ten Ewe Mountain as mapped by Grubensky and others (in press).

Tsc **Sandstone and conglomerate (Tertiary)** -- Volcaniclastic sandstone and conglomerate up to 20 meters thick that locally underlies the Tte unit. The sandstones may be eolian at eastern-most exposures of this unit in section 13, T. 5 S., R. 13 W.

Tr **Rhyolite (Tertiary)** -- Light grey to pink rhyolite lavas that contain small phenocrysts of biotite, feldspar, quartz, and rare hornblende 1 to 5 mm long. Flow-banded locally and commonly vitrophyric and brecciated. Exposed only on one hill north of Snyder's Well in section 25, T. 4 S., R. 13 W. near the northeastern end of the range.

Trd **Rhyodacite lava (Tertiary)** -- Grey moderately crystal-poor lava with up to 15% feldspar phenocrysts and little or no quartz, and rare mafic minerals. This unit is of limited extent, only present in the west half of section 15 and east half of section 16, T. 5 S, R. 13 W.

Tbm **Middle basalt (Tertiary)** -- Basalt lava with phenocrysts of olivine, pyroxene, and variable amounts of plagioclase. Dark grey and commonly vesicular. Directly overlies dacite (map unit Td) in section 15, T. 5 S., R. 13 W. and is only distinguishable from a very thick sequence of younger basalt because of intervening felsic lavas and/or ash-flow tuffs.

Td **Younger dacite lava (Tertiary)** -- Crystal-rich locally flow-banded lavas containing phenocrysts of biotite (1-5 mm), hornblende (1-5 mm) and plagioclase (2-10 mm). Light to medium tan to blue-grey on fresh and weathered surfaces. The plagioclase phenocrysts commonly stand out in relief on weathered surfaces and give the rock a frothy appearance. Locally vitrophyric and dark grey. Generally very resistant and forms prominent cliffs and steep hills.

Tdx **Dacite autobreccia (Tertiary)** -- Light yellow monolithic breccia composed of angular, poorly sorted clasts of low-density yellow dacite (probably tuffaceous). The clasts contain fresh subhedral to euhedral phenocrysts of biotite, hornblende and clear feldspar (possibly sanidine) and are surrounded by a slightly darker yellow tuffaceous matrix with a similar phenocryst assemblage. The unit is mostly massive but the base is thinly-bedded, and the autobreccia grades upward into dacite (Td). Not as resistant as the dacite and forms steep slopes.

Tcv **Volcaniclastic conglomerate (Tertiary)** -- Moderately well-sorted conglomerate containing subangular clasts of grey pre-Tertiary crystalline rocks and red to tan mafic and felsic volcanic rocks. Most clasts are 1 to 2 cm in diameter and are surrounded by dark brown matrix. Locally exhibits a dark desert varnish and forms a small ledge 2-3 meters thick. Only exposed in the eastern side of section 7, T. 5 S., R. 13 W.

Tsv **Volcaniclastic sandstone (Tertiary)** -- Finely-bedded tan to red sandstone composed of subrounded clasts of mafic and felsic volcanic rocks. Base not exposed, but overlain by basalt (Tbl) locally. Erodes into small ledges that dip about 10 degrees northwest. Exposed only in the eastern side of section 7, T. 5 S., R. 13 W.

Ttu **Unwelded tuff (Tertiary)** -- Unwelded lithic tuffs and locally interbedded basalt or basaltic andesite flows totaling 15-50 meters thick. The tuffs are medium- to thick-bedded, with up to 30% lithic fragments, and include medium- to thin-bedded ash-fall and surge deposit units. Locally, they contain very small (less than 1 mm) phenocrysts of feldspar, biotite and hornblende. The thin-bedded deposits are brown-colored, contrasting with the light tan color of the thicker deposits. The tuffs are commonly lithic-rich, locally clast-supported, and are generally reddish-brown in color. Lithic fragments are angular to subrounded and include basalt, older dacite, and less common granitic gneiss. Mafic flows, if present, typically occur in the middle of the unit.

Tbl **Older basalts (Tertiary)** -- Dark purple to dark grey basalt flows containing relict olivine phenocrysts less than 1 mm in diameter altered to red opaques and light green talc or serpentine, and local clear, fine-grained phenocrysts of plagioclase or quartz. The lavas are typically very fine-grain and commonly vesicular. Forms rounded slopes with round clasts. Commonly vesicular. Some vesicles are filled with white calcite. Locally contains small 5 to 20 cm diameter masses of radiating quartz crystals and globular chalcedony.

Tx **Monolithic breccia (Tertiary)** -- Clast-supported monolithic breccia containing clasts of porphyritic to megacrystic K-feldspar granite up to 2 meters in diameter. Clasts are subrounded to angular and surrounded by a fine-grained sandy, granitic matrix.

Ttv **Lithic tuff (Tertiary)** -- Lithic, unwelded tuffs associated with dacite lavas (Tdl).

Tdl **Older dacite lava (Tertiary)** -- Dark red-brown, moderately crystal-rich dacite lava with small (< 2 mm) white, tabular plagioclase phenocrysts and less abundant biotite and hornblende phenocrysts. The mafic minerals have been mostly altered to hematite. At one locality green vitrophyre at the base of the unit overlies a green tuff (Ttg). Weathers dark and gnarly. The unit is typically highly fractured. In the west it is locally intruded by dark carbonate veins. In the east it is intruded by dark quartz-carbonate-manganese veins (section 7, T. 5 S., R. 12 W.).

Tdt **Tan-colored dacite (Tertiary)** -- Fine-grained dacite lava containing 1-3 mm phenocrysts of hornblende, biotite and plagioclase. This unit can be distinguished from Tva by its light tan color and relatively smooth to platy outcrops. Exposed only along the eastern escarpment of the range.

Ttg **Green tuff (Tertiary)** -- Light green unwelded to incipiently welded lithic ash-flow tuff 0-10 meters thick. This unit has been recognized only in the southwest corner of section 8, T. 5. S, R. 13. W, where it is in probable depositional contact with Proterozoic granitic rocks.

Tf **Felsic volcanic rocks (Tertiary)** -- Limited exposures of several different types of felsic volcanic rocks with obscure contacts. Contains light purple-tan aphyric, brecciated volcanic rock cross-cut by thin 1-2 mm calcite veins; light purple fine-grained dacite breccia; and medium grey, relatively porphyritic dacite containing mostly white, tabular plagioclase phenocrysts 1 to 3 mm long and rare mafic minerals altered to hematite. Exposures are limited to the middle of section 12, T. 5 S., R. 13 W., and form tan to light purple slopes.

Tc **Conglomerate (Tertiary)** -- Poorly sorted conglomerate containing only well-rounded clasts of pre-Tertiary medium-grained biotite granite, granitic gneisses, purple slate, amphibolite, yellow-green metarhyolite, muscovite schist, and chlorite schist. The unit is clast-supported, moderately to strongly consolidated, and cemented by a red, sandy matrix. It crops out only in section 7, T. 5 S., R. 12 W.

Intrusive and Metamorphic Rocks

Tif **Felsic dikes (Tertiary)** -- Undifferentiated fine-grained felsic dikes, quartz-feldspar porphyry dikes, and less abundant quartz porphyry dikes. The quartz-feldspar porphyry dikes are the most common and typically exhibit granitic textures in the centers of larger dikes. All dikes contain variable amounts of quartz, biotite and hornblende. Phenocrysts are typically subhedral and between 1 and 4 mm in diameter. Dikes with less quartz commonly contain zoned plagioclase. Felsic dikes are tan to pink on fresh and weathered surfaces and are generally more resistant than the granitic host rock, forming long ridges. The dikes range from several centimeters to 10 meters thick.

Tim **Mafic dikes (Tertiary)** -- Includes fine-grained basalt/microdiorite and coarse-grained hornblende-plagioclase dikes, with rare phenocrysts of quartz. The thickness of these dikes is fairly consistent, between 1 and 3 meters, though locally they are up to 5 meters wide. Many are only a few tens of meters long or shorter and occur in left-stepping *en echelon* swarms, particularly visible in section 22, T. 5 S., R. 13 W.). They are dark grey-green and form prominent stripes across the granitic rocks.

Tgp **Granite pegmatite sill (Tertiary)** -- Medium- to coarse-grained pegmatitic granite or syenogranite with less than 5% biotite. Miarolitic cavities are present locally and are commonly lined with fine-grained greenish-white mica and quartz. Biotite locally occurs in euhedral books up to 1 cm wide and is commonly copper-colored. Graphic textures are common in coarser-grained varieties.

Tg **Granite (Tertiary)** -- Relatively fresh, nonfoliated, equigranular, medium- to fine-grained (1-4 mm) quartz monzonite to monzogranite and granodiorite. Contains phenocrysts of quartz, white feldspar, euhedral biotite, and tabular hornblende. Generally massive, even-textured, and of consistent composition, but rarely weakly foliated in the vicinity of the pegmatite sheet. Also in the vicinity of the pegmatite sheet, the granite may consist of a mixture of leucocratic and melanocratic varieties. Locally forms smooth outcrops of low relief but typically forms very steep mountains Commonly erodes spheroidally and appears orangish tan on weathered surfaces.

TXg **Foliated granite (Proterozoic or Tertiary)** -- Weakly to moderately foliated, equigranular monzogranite/granodiorite to quartz monzonite. The foliation is defined by preferential alignment of feldspars and mafic minerals. The composition is very similar to Tg. In most places the unit is separated from Tg by biotite schist/gneiss. The contact is very irregular, but on a small scale it is very sharp (where visible). Blocks of TXg are within Tg. Both rocks are highly fractured and display many small faults. Many veins of Tg intrude TXg.

Xg **Granite (Proterozoic or Mesozoic)** -- A foliated, equigranular, medium-grained biotite-rich granite/quartz monzonite with between 10 and 30% biotite. Probably related to the porphyritic granite of map unit Xgp. This unit is likely a contact phase of Xgp because it usually occurs between the porphyritic phase and the banded gneiss.

Xgp **Porphyritic granite (Proterozoic or Mesozoic)** -- (A phase of Xg) A foliated, equigranular, coarse-grained granitoid containing 5 to 25% mafic minerals, mostly biotite. K-feldspar phenocrysts are between 1 and 3 cm in diameter and are light pink. Biotite occurs in dark felted masses. Quartz is clear to milky grey. Locally, biotite masses are aligned and K-feldspar phenocrysts are slightly rounded and deformed into augens.

Xs **Biotite schist/gneiss (Proterozoic or Mesozoic)** -- Strongly foliated biotite-rich schist or finely banded gneiss. Grey to light green-grey. The biotite-rich portions are very friable and locally strongly lineated with the lineation defined by an elongation of biotite and other minerals on the foliation plane. The protolith was probably sedimentary in origin because of the abundance of phylosilicates. Weathers into flaky platy outcrops.

Xgn **Banded gneiss (Proterozoic or Mesozoic)** -- Compositionally banded orthogneiss, generally dominated by a quartzofeldspathic leucosome with a subordinate biotite-rich melanosome. Younger open to close mesoscopic folds may be associated with a crenulation lineation in the melanosomes.

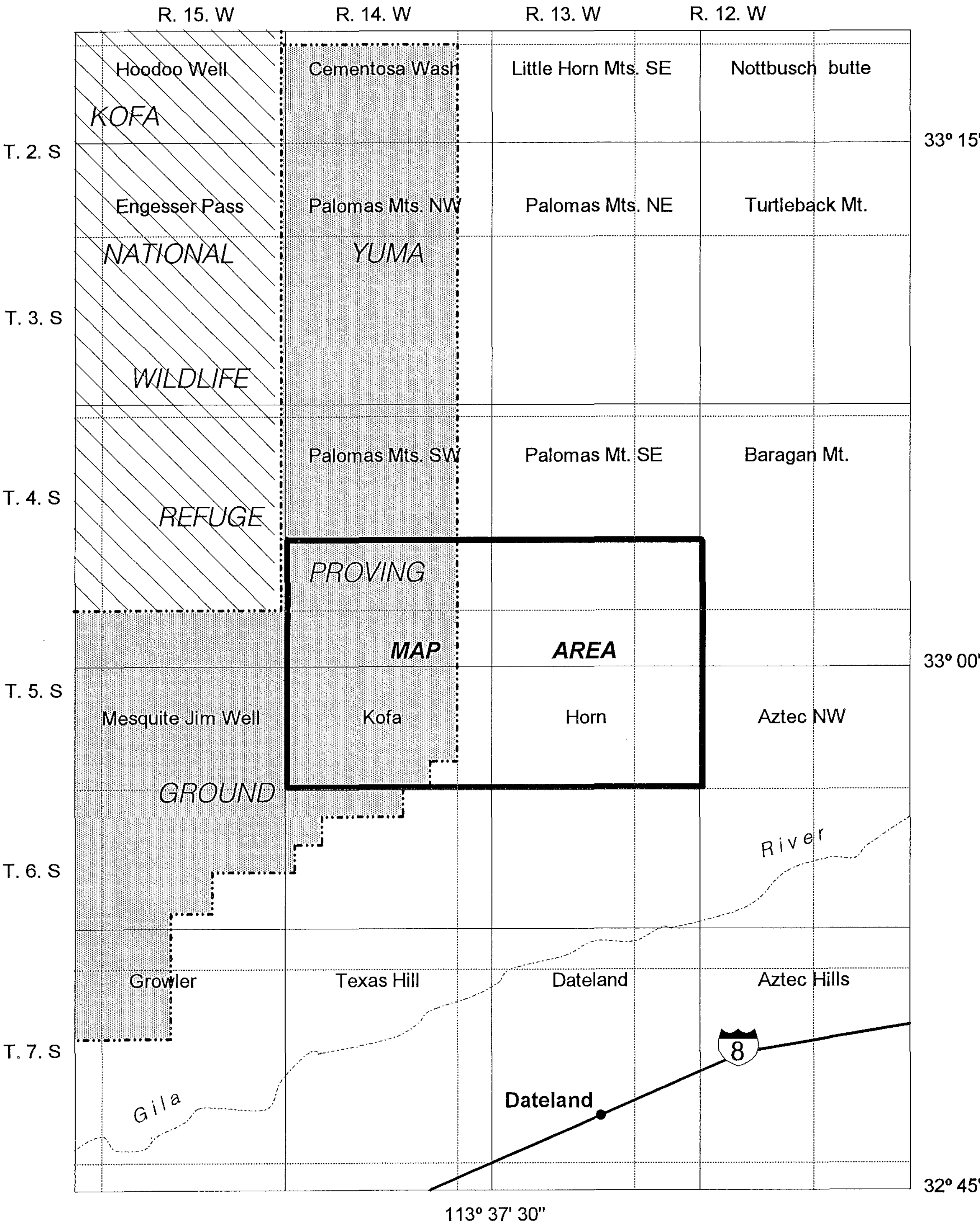

Figure 1. Location of study area, and locations and names of U.S.G.S. 7.5' topographic quadrangles.

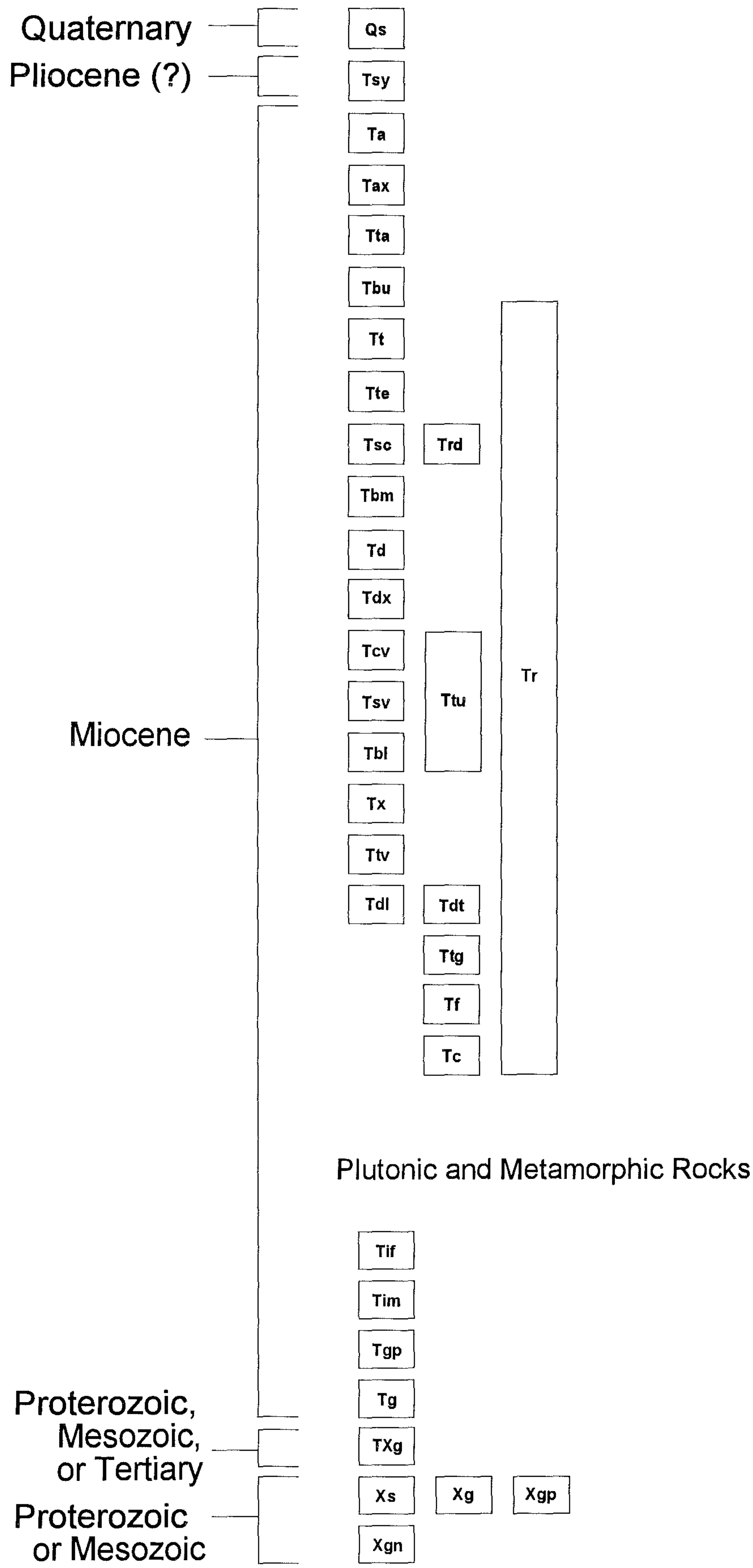

Figure 2. Correlation of map units in the Palomas Mountains.

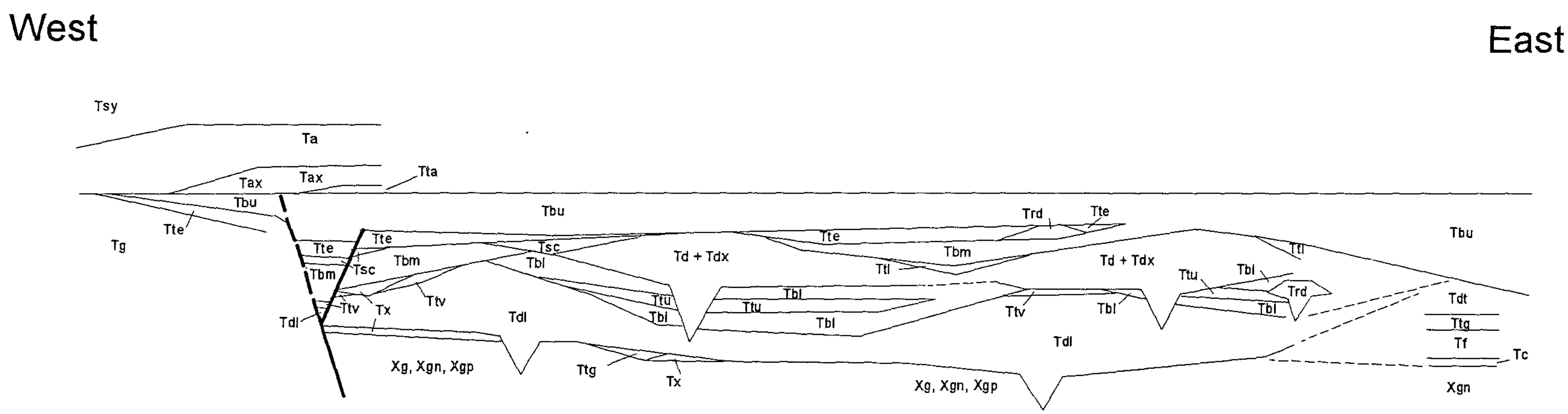

Figure 3. Diagramatic stratigraphic east-west cross-section through the Palomas Mountains.

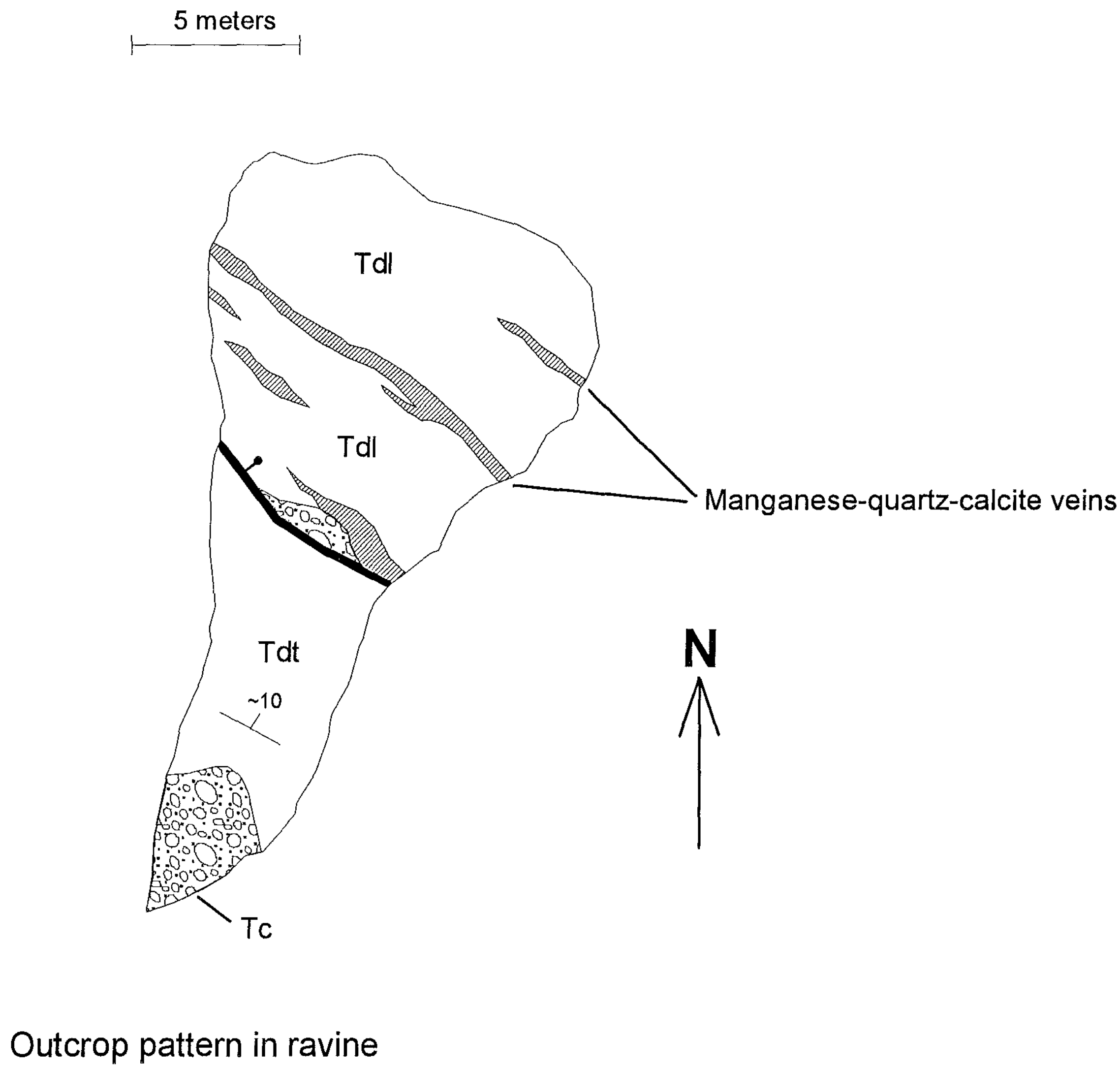

Figure 4. Exposure of manganese veins in eastern Palomas Mountains