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MAP UNITS AND SYMBOLS

MAP UNITS

Qs YOUNGER ALLUVIUM (Quaternary)
Qso OLDER ALLUVIUM (Quaternary)
QTs SEDIMENTARY ROCKS (Quaternary and (or) Tertiary)
Tf FANGLOMERATE (Tertiary)
Tsc CONGLOMERATE AND SANDSTONE (Tertiary)
Tbu UPPER BASALT FLOWS (Tertiary)
Tdf DEBRIS FLOWS (Tertiary)
Tif FELSIC DIKES AND PLUGS (Tertiary)
Tia INTERMEDIATE DIKES AND PLUGS (Tertiary)
Tim MAFIC DIKES AND PLUGS (Tertiary)
Td DACITIC INTRUSIVE AND EXTRUSIVE ROCKS (Tertiary)

RHYOLITIC ROCKS OF SAN DOMINGO WASH
- Trs RHYOLITE FLOWS, DOMES, SILLS, AND DIKES (Tertiary)
- Tts RHYOLITIC PYROCLASTIC ROCKS (Tertiary)

Tbl LOWER BASALT FLOWS (Tertiary)
Ts SANDSTONE AND CONGLOMERATE (Tertiary)
Kg GRANITE (Cretaceous)
Kgd GRANODIORITE (Cretaceous)
Kd DIORITE (Cretaceous)
Xs SCHIST (Precambrian X)
Xg BIOTITE QUARTZ MONZONITE TO MONZOGRANITE (Precambrian X)
Xsg SCHIST AND GNEISS (Precambrian X)
Xam AMPHIBOLITE (Precambrian X)

MAP SYMBOLS

GEOLOGIC CONTACT--Solid where crossed on a traverse; dashed where extended between traverses; dotted where buried.

FAULT--showing dip. Solid where crossed on a traverse; dashed where extended between traverses; dotted where buried. Bar and ball on downthrown block.

LOW-ANGLE FAULT--showing dip. Hachures on upper plate. Solid where crossed on a traverse; dashed where extended between traverses; dotted where buried.

STRIKE AND DIP OF BEDDING
- Horizontal
- Inclined
- Overturned

EUTAXITIC FOLIATION IN ASH FLOW TUFF

FLOW FOLIATION IN LAVA FLOWS AND INTRUSIONS

FOLIATION IN METAMORPHIC ROCKS
- Inclined, showing bearing and plunge of lineation.
- Vertical
- Horizontal

LINE OF CROSS SECTION

Mapped by Pacific Area, Geological Survey

This is an unedited copy of an original manuscript including field additions made in 1961

TRUE NORTH — MAGNETIC NORTH — 14½° — APPROXIMATE MEAN DECLINATION, 1961

SCALE 1:24000

1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

CONTOUR INTERVAL 40 FEET
DASHED LINES REPRESENT 20-FOOT CONTOURS
DATUM IS MEAN SEA LEVEL

WICKENBURG 2 NE., ARIZ.

Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1962. Field checked 1964

Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue
To place on the predicted North American Datum 1983 move the projection lines 1 meter south and 67 meters east as shown by dashed corner ticks

GN — MN — 0°56' 17 MILS — 14½° 258 MILS
UTM GRID AND 1964 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

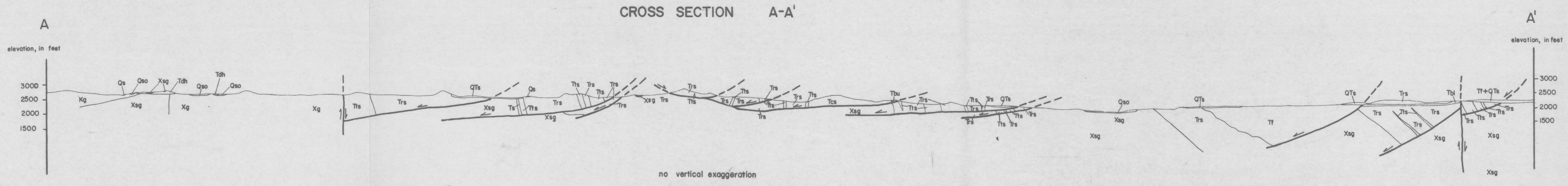
GEOLOGIC MAP OF THE NORTHEASTERN VULTURE MOUNTAINS AND VICINITY, CENTRAL ARIZONA.

by Michael J. Grubensky, James A. Stimac, Stephen J. Reynolds, Stephen M. Richard

1987

ARIZONA BUREAU OF GEOLOGY AND MINERAL TECHNOLOGY
OPEN-FILE REPORT 87-10

CROSS SECTION A-A'



GEOLOGIC MAP OF THE NORTHEASTERN VULTURE MOUNTAINS AND VICINITY, CENTRAL ARIZONA

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INTRODUCTION

This report presents 1:24,000-scale geologic mapping of the eastern Vulture Mountains and vicinity. This mapping, along with concurrent mapping of the Wickenburg Mountains and western Hieroglyphic Mountains (Stimac and others, 1987), was completed between January and April 1987 and was jointly funded by the U.S. Geological Survey and Arizona Bureau of Geology and Mineral Technology as part of the cost-sharing Cooperative Geologic Mapping Program (COGEOMAP). These areas were mapped because they were previously unmapped in detail, and were suspected to contain a highly faulted and potentially mineralized assemblage of Proterozoic crystalline rocks, Cretaceous granite, and middle Tertiary volcanic and sedimentary rocks. The Vulture Mountains represent an important link between previously studied middle Tertiary rocks and structures in the Big Horn Mountains (Capps and others, 1985; Stimac and others, 1987) and central Vulture Mountains (Rehrig and others, 1980) to the southwest and Hieroglyphic Mountains to the east (Capps and others, 1986). Together, the geologic studies in these mountain ranges provide a transect from the highly distended Basin and Range Province to the edge of the Transition Zone.

GEOLOGIC SETTING

The Vulture Mountains and vicinity are located within the Basin and Range Province in central Arizona, adjacent to the Transition Zone (Fig. 1). The area is topographically subdued compared to adjacent mountain ranges and consists of a series of north- to north-northwest-trending ridges, separated by areas with low, hummocky topography. Much of the area consists of broad pediments dotted with small inselbergs. The Vulture and Wickenburg Mountains are separated by the south-flowing Hassayampa River. The town of Wickenburg is located along the river.

The eastern Vulture Mountains contain more than 1.5 km of middle Tertiary volcanic and sedimentary rocks that rest unconformably on Proterozoic metamorphic and granitic rocks and Late Cretaceous granodiorite. Middle Miocene faulting has dissected the Tertiary volcanic rocks into a series of north-northwest-striking homoclines that dip steeply to the northeast or are vertical to slightly overturned. The steeply dipping Tertiary sections are truncated downward against pre-Tertiary crystalline rocks on a series of low-angle normal faults.

MIOCENE VOLCANIC COMPLEX IN THE EASTERN VULTURE MOUNTAINS

The Miocene volcanic rocks in the northeastern Vulture Mountains are almost exclusively the products of a moderately sized rhyolitic volcanic complex, whose products are informally referred to as the rhyolites of San Domingo Wash. The complex is constructed on a basement of Proterozoic and Cretaceous crystalline rocks overlain by conglomerates and basalt of Tertiary ages. Because all of the silicic volcanic rocks have steep northeastward to vertical dips, several transects through the stratigraphy of the volcanic complex are provided along the east-flowing drainages that feed the Hassayampa River. The relatively complete sections consist of as much as 1500m of interlayered rhyolite flows and hypabyssals, and pyroclastic deposits. Parts of the complex are also exposed between Cemetary Wash in the Vulture Mountains and the Hassayampa River.

Rhyolite lavas and irregularly shaped intrusions comprise as much as 70 percent of the Tertiary section, including as many as 7-9 lava flows. Some flows are up 300m thick, and most are separated from one another by pyroclastic deposits of air-fall or surge origin. Spherulitic devitrification is common near contacts with adjacent pyroclastic rocks, and locally flows and tuffs are intermixed or intertwinned with one another along complex intrusive contacts. Intrusive rhyolites are especially abundant along Cemetary Wash in the northeast Vulture Mountains. The more resistant lavas underlie north-south-striking ridges that dominate the topographic grain of the region. Intervening valleys and basins are underlain by pyroclastic rocks or intensely devitrified rhyolite.

The rhyolites of San Domingo Wash are crystal-poor, typically with 10 percent or fewer phenocrysts of sanadine and biotite. The youngest crystal-poor rhyolite flows have fresh-looking, euhedral phenocrysts of sanadine as much as 2mm across. Biotite occurs as <1mm plates that are in various degrees of oxidation to hematite. Phenocrysts are uncommon or absent in most of the pyroclastic deposits. The rhyolite lavas do not commonly include the lithic fragments that characterize the pyroclastic rocks. Flow banding with thin seams of vapor-phase quartz also help to distinguish flows from tuffs.

A variety of types of pyroclastic deposits are interlayered between the rhyolite flows and hypabyssal rocks. Most tuffaceous horizons are thinly to medium-bedded, unwelded, sorted lapillistones with abundant (5-20 percent) pebble-sized lithic fragments with volcanic textures. Most of the pumice lapilli is angular and free of phenocrysts. Sedimentary rocks are conspicuously absent. Normal and reverse grading of lithic fragments and pumice are common in lapilli tuffs. Monotonous layers of crystal-poor ash are interlayered with cross-bedded, lithic-poor tuffs. Welding is conspicuous only in one ash-flow tuff exposed along Cemetary Wash; this tuff is a partly to densely welded, sanadine-biotite phyric ash-flow tuff with abundant lithic fragments and basal vitrophyre up to 40m thick. Additional mapping may discover enough exposures of this tuff to warrant it as a separate map unit. Otherwise, all the tuffaceous deposits in the map area are probably air-fall or surge-related tuffs associated with the rhyolite flows with which they are interlayered.

The time period over which the rhyolites of San Domingo Wash were erupted is uncertain in part because our mapping does not yet include some radiometrically dated crystal-poor rhyolite flows that may or may not correlate with the rhyolites of San Domingo Wash. Rehrig and others (1980) obtained a 26 m.y. old date on biotite from rhyolite at the base of the Tertiary volcanic section at a location just west of our study area. They also obtained an 18.2 m.y. date from rhyolite near the top of the same section. Whole-rock K-Ar dates constrain basalt flows at the base of the Tertiary section in adjacent mountain ranges to be older than 21 to 18.7 Ma (Capps and others, 1985; Kortemier and others, 1986). In contrast to the eastern Vulture Mountains, crystal-poor rhyolite flows in the Big Horn Mountains are interbedded with basalt and andesite flows. Crystal-poor rhyolite flows and subordinate tuffs in the western Hieroglyphic Mountains are also interbedded with a basalt flow, mapped as lower basalt. At San Domingo Peak in the Wickenburg Mountains, a section of crystal-poor rhyolite that is 330 m thick is overlain by dacitic rocks of the Hells Gate volcanics, which yield K-Ar dates of 17.9, 17.4, and 16.1 m.y. (Shafiqullah and others, 1980; Capps and others, 1986; Kortemeier and others, 1986).

The immense 1.5 km thickness of rhyolite lavas and related tuffs on the west side of the Hassayampa River apparently represents a precipitous flow-dome complex. The presence of younger basalt directly on the rhyolites suggests this area was a local topographic high compared to areas east of the Hassayampa River where thick assemblages of sandstones and conglomerates overlie the volcanic rocks and underlie the upper basalt flows.

MAP UNIT DESCRIPTIONS

QUATERNARY SEDIMENTARY ROCKS

Qs: Younger alluvium

Unconsolidated sand and gravel in modern stream channels or on low terraces in or adjacent to these channels. This unit also includes thin aprons of colluvium found on some low slopes and spurs west of the Hassayampa River.

Qso: Older alluvium

Unconsolidated gravel-poor sand and sandy gravel deposits standing above modern stream channels and below partly consolidated alluvium of map unit QTs.

QTs: Sedimentary rocks

Unconsolidated to partly consolidated or caliche-cemented sands and gravels of dissected terraces standing more than 2 m above modern drainages. Deposits are generally flat-lying, although some deposits are dipping as much as 8°.

TERTIARY VOLCANIC AND SEDIMENTARY ROCKS

Tf: Fanglomerate

Brown- to buff-colored, consolidated to semi-consolidated conglomerate, sandstone, and siltstone with a discontinuous thin cover of QTs. Fanglomerate grades down into tilted sheet-flood deposits and debris flows with interbedded basalts and thin upper tuffs. Fanglomerate usually forms low hills with little or no outcrop, but steep cliffs 5 to 20 m high occur along major washes east of the Hassayampa River. These deposits are flat-lying to moderately tilted.

Tsc: Conglomerate and sandstone

Brown- to buff-colored, consolidated to poorly consolidated conglomerate, sandstone, and siltstone. This unit consists chiefly of matrix-supported, unsorted, conglomeratic arkose and arkose in beds that are 1m to 1cm thick, averaging 10-20cm, and are rarely graded and lack crossbeds. However, some of these deposits have clasts with diameters equal to the thickness the bed that contains them, and these may represent thin debris flows. Clasts consist of Proterozoic and Cretaceous crystalline rocks and Tertiary volcanic rocks. Exposures of these deposits are identical to fanglomerates found east of the Hassayampa River and are at least in part correlative in age.

Tbu: Upper basalt flows

Black to gray, vesicular, plagioclase-clinopyroxene-olivine phyric basalt in flows 2 m to 5 m thick. Maximum thickness of this map unit is 40m on a strike ridge north of the Hassayampa River. Total phenocryst content ranges between 1 percent and 25 percent. Unit unconformably overlies the rhyolites of San Domingo Wash in Turtleback Wash and in Cemetery Wash. Between Burg and the Hassayampa River, this basalt fills in channels at least 4m deep in map unit Tdf. This basalt is distinguished from the lower basalt (map unit Tbl) by the conspicuous phenocrysts of olivine that may reach 7mm across and comprise 10 percent of the rocks.

Tdf: Debris flows

Non resistant, massive deposits of unsorted boulders, cobbles, and pebbles of rhyolite and basalt, Cretaceous granitic rocks, and Proterozoic metamorphic rocks in a matrix of unsorted sand. In Mockingbird Wash, these debris flows grade downsection into several meters of well-layered, very thickly bedded arkosic and boulder conglomerates, which lie depositionally on rhyolitic rocks (map unit Trs). The lowest part of the map unit generally dips 45°, but dips decrease systematically upsection and are flat-lying in stratigraphically highest exposures.

Tif: Felsic dikes and plugs.

Tia: Intermediate dikes and plugs.

Tim: Mafic dikes and plugs.

Td: Dacitic intrusive and extrusive(?) rocks

Dikes and plugs of light- to dark-mauve-weathering, resistant, blocky weathering dacitic rocks with 10 percent to 30 percent phenocrysts of plagioclase, quartz, biotite, hornblende, and clinopyroxene. Conspicuous singular plagioclase phenocrysts and 2- and 3-grain aggregates of subhedral to euhedral plagioclase range up to 1 cm across and are typically chalky white colored, with a seive texture visible with a hand lens. Biotite occurs as altered books 2 to 3 mm across, whereas clinopyroxene occurs as fresh-looking grains about 1mm across. Xenoliths of fine-grained, phaneritic rock are scattered between the phenocrysts and range from 3 and 5 cm across. This unit occurs in or adjacent to low-angle normal faults between Tertiary volcanic rocks and Proterozoic or Cretaceous crystalline rocks. This lithology is texturally identical to dacitic rocks of the Hells Gate volcanics (map unit Tdh), which are common in Hieroglyphic Mountains.

San Domingo volcanics

The rhyolitic rocks of this rock unit have two members; rhyolitic igneous rocks (referred to as rhyolite) and associated rhyolitic pyroclastic rocks. These lithology are generally associated and complexly intermixed on the scale of tens of meters. The nature of each body of rhyolite is, more often than not, uncertain. Some are certainly intrusive because they crosscut and intrude the adjacent pyroclastic rocks, whereas others are texturally zoned lava flows with a basal vitrophyre and upper and lower spherulitic zone. Some exposures of massive intrusive(?) rhyolite arc more than 2km across and include only 1 to 2 m xenoliths of granite and schist.

Tr: Rhyolite flows, domes, sills, and dikes

Light-gray colored, resistant, flow-foliated, autobrecciated, +biotite-quartz-sandine phyric rhyolite that is interbedded with and intrudes associated pyroclastic rocks (map unit Tts). Spherulites are common in the lower portions of flows. Rhyolite flows low in the section are biotite-poor, whereas those high in the section have up to 3 percent biotite. The rhyolite contains 15 percent phenocrysts of sanadine and 5 percent quartz.

Ttl: Rhyolitic pyroclastic rocks

Light-yellow colored, nonresistant, thinly to thickly bedded, lapilli-poor, unwelded tuffs with variable amounts of pebble-sized lithic fragments of basalt, granitoid, and rhyolite. Lithic fragments compose only several percent of the tuffaceous exposures. Long-wavelength crossbeds in some horizons represent surge deposits. Well-sorted, ash-poor lapilli tuffs are also common and probably represent air-fall deposits. Some tuffaceous horizons contain 15 to 20 percent phenocrysts of 1 to 5 mm glomeroporphyritic aggregates of plagioclase and biotite, whereas others are aphanitic. Along Cemetary Wash, the unit includes massive, quartz-sanadine phyric ash flow tuff, which is locally welded and includes a basal vitrophyre over 10m thick.

Tbl: Lower basalt flows

Dark gray, reddish weathering, nonresistant flows of plagioclase-clinopyroxene-olivine phyric basalt and red-brown colored, nonresistant aphanitic scoria. Olivine, which is consistently altered to iddingsite, occurs as phenocrysts typically less than 1mm across and also occurs as a groundmass phase. Basalt also contains less than one percent clinopyroxene phenocrysts 1-2mm across, and white to clear and iron-stained plagioclase as sparse 1-3mm grains.

Tss: Conglomeratic arkose

Dark-red-brown-colored, variably resistant sedimentary rocks including conglomerate, conglomeratic arkose, and arkose. A particularly good section is exposed in Cemetary Wash, where the unit is an upward-fining sequence that is roughly 5m thick and bedded on the scale of 30 to 60m. Arkose in the upper half of the unit is in plane-parallel beds with few crossbeds. Elsewhere the redbeds are massive or inconspicuously layered, consisting of matrix-supported conglomerate with subangular clasts of quartz-rocks ranging in size from 3 to 10cm across, and finer grained clasts of granitoid and schist. The hematitic character of the unit increases toward the lower unconformable contact with metamorphic rocks, which are also hematitic within a few meters of the contact.

CRETACEOUS ROCKS

Kg: Granite

Light-colored, medium-grained, equigranular, leucocratic,biotite granite, which is locally flow foliated along intrusive contacts with Proterozoic schist (map unit Xs). Phenocrysts include pinkish K-spar, white plagioclase, clear quartz grains, and biotite that occurs as fine-grained pads up to 0.5mm across and 0.2mm wide, which define the foliation.

PROTEROZOIC ROCKS

Xg: Biotite quartz-monzonite to monzogranite

Orange-brown, light-gray- to white-colored, medium- and fine-grained, foliated, leucocratic, biotite granite. Phenocrysts include 15 percent quartz, 50 percent plagioclase, 30 percent K-spar (which can be slightly porphyritic grains 5mm to 1cm across), and 2-3 percent biotite. Biotite-muscovite-bearing varieties are common along Turtleback Wash where schist (map unit Xs) and the monzogranite are tectonically interleaved on the scale of decimeters. Zoned bodies of this unit in Cemetery Wash grade outward from a medium-grained core to a fine-grained border phase into a mixed zone with inclusions of amphibolite and dikes of aplite and pegmatite.

Xs: Schist

This unit is predominantly nonresistant, fine- to medium-grained schist of two varieties distinguished by the presence or absence of metamorphic muscovite. One variety with muscovite includes quartz and may include garnet, staurolite, biotite or chloritoid with an uneven distribution of staurolite, garnet, and chloritoid. Staurolite megacrysts are present near intrusive contacts with Proterozoic granite (map unit Xmg). Tourmaline-rich zones occur locally. The variety of schist without muscovite is gray-green in color, nonresistant, mesocratic, fine- to medium-grained, even-grained, biotite quartzo-feldspathic schist. Metaconglomerate with clasts of granitoid and black silica is also present. Map unit includes dikes of rhyolite, dacite, and basalt (map units Trs, Td, and Tbl or Tbu, respectively). The biotite- and muscovite-rich, pelitic varieties of this map units are mineralogically identical to schists in the southern Bradshaw Mountains, rocks correlated with the correlative with the Proterozoic Yavapai Supergroup.

Xam: Amphibolite

Very dark-gray to dark-greenish-gray, foliated, strongly lineated, fine- to medium-grained, ±plagioclase feldspar-epidote-amphibole schist, which occurs as lenticular pods within the biotite-rich schist (map unit Xs).

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GEOLOGIC MAP OF THE SOUTHEASTERN VULTURE MOUNTAINS, WEST-CENTRAL ARIZONA

by

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Arizona Geological Survey
Open File Report 88-9

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INTRODUCTION

The Vulture Mountains are situated in west-central Arizona, between the Big Horn and Harquahala Mountains on the west, and the Wickenburg Mountains on the east. Although a range of low relief, the Vulture Mountains are sufficiently areally extensive in that they cover all or part of eight individual 7.5 minute quadrangles. The geologic map of the southeastern Vulture Mountains (Fig. 1), a product of this study, covers the northern part of the Wickenburg SW 7.5 minute quadrangle. Most of the few precipitous bluffs and ridges of the range are in the eastern quarter of the range, and have roughly 200 m of relief. Detailed geologic mapping in the Vulture Mountains has been limited to the northeastern part (Grubensky and others, 1987). Geochronologic studies of rocks in the central and northern Vulture Mountains (Rehrig and others, 1980) provide the only available K-Ar dates of any of the rocks in the range. This report is considered preliminary and is part of an ongoing project to map and study the entire Vulture Mountains.

The Vulture Mountains are important for three fundamental reasons. The first is that the Vulture Mountains are, at present, largely unmapped. Second, the Vulture Mountains contain an excellent record of the mid-Tertiary structural and volcanic history of the region, which is of general interest to the geologic community. Third, central and western Arizona are of increasing interest to the mining industry because of the potential for undiscovered ore deposits in southwestern Arizona (for example, Bagby and others, 1987). This report is an attempt to meet some of these needs with a new geologic map and a brief summary of the geologic setting of the range. In the course of mapping we have also noted areas where the rocks have been altered and(or) mineralized; areas which may or may not prove to have high mineral potential.

Our understanding of the geologic context of the Vulture Mountains is enhanced by geologic mapping in adjacent ranges conducted by the Arizona Geological Survey (formerly the Bureau of Geology and Mineral Technology). This and other mapping studies have been jointly funded by the Arizona Survey and the U.S. Geological Survey as part of a cost-sharing, cooperative geologic mapping (COGEOMAP) program (see inset, Fig. 1). Base materials for this study included 1:24,000-scale topographic maps and aerial photographs, which were supplied by Ray Brady of the U.S. Bureau of Lands Management.

GEOLOGIC OVERVIEW

The Vulture Mountains are one of several mountain ranges in west-central and central Arizona composed almost exclusively of two pre-Quaternary rock types; (1) pre-Tertiary metamorphic and plutonic rocks, and (2) mid-Tertiary volcanic and sedimentary rocks. The oldest unit in many of the ranges is gneiss and schist similar to rocks of the Yavapai Supergroup, a sedimentary and volcanic sequence that accumulated at the edge of the Proterozoic North American craton. Stratigraphically overlying Paleozoic and Mesozoic supracrustal rocks are preserved in some ranges, but were removed from the Vulture Mountains by pre-middle Tertiary erosion. Cretaceous granitic rocks intrude the Proterozoic crystalline rocks and are the youngest rocks exposed beneath the widespread unconformity onto which a mid-Tertiary volcanic sequence was deposited. The association of Proterozoic and Cretaceous rocks beneath the volcanic rocks throughout central and western Arizona, including the Vulture Mountains, indicates that the substrates of now widely separated mountain ranges have a common geologic history prior to mid-Tertiary deformation.

The petrologic and lithologic diversity of mid-Tertiary volcanic rocks across Arizona is discernible because the rocks postdate regional metamorphic events and have not been buried. Thick packages of calc-alkaline rocks of Oligocene(?) to Miocene age are exposed in most of the Basin and Range Province. The Tertiary volcanic record in most of the mountain ranges in the Transition Zone consists of basalt with lesser amounts of rhyolite, dacite, and latite. Closely spaced rhyolite domes and related thick lava flows and pyroclastic aprons indicate the existence of one or more rhyolitic volcanic centers in the eastern Vulture Mountains (Grubensky and others, 1987). Unlike the adjacent volcanic fields, however, the eastern Vulture Mountains are barren of intermediate lavas.

Mid-Tertiary, post-volcanic, regional extension has since modified the rocks in west-central Arizona. The structure of some ranges, like the Vulture Mountains, consists of numerous, consistently northwest-striking homoclines that dip either to the northeast or to the southwest. Other ranges, including the Big Horn Mountains, have a volcanic section with bedding attitudes that reflect more complex extensional deformation (Capps and others, 1985; Allen, 1985). The structure of the Vulture Mountains is more straightforward.

LITHOLOGY

PROTEROZOIC METAMORPHIC ROCKS

The structurally and stratigraphically lowest rocks of the southeastern Vulture Mountains are Proterozoic metasedimentary and metavolcanic rocks of greenschist to amphibolite facies. These rocks are located in fault-bounded blocks in the eastern Vulture Mountains and also in northeast-dipping homoclines in the Wickenburg and Hieroglyphics Mountains to the east. The protolith for these rocks is considered to be early Proterozoic(?) in age based on lithologic and textural similarity to the Yavapai Supergroup (1.70-1.85 b.y.), which is exposed in the Bradshaw Mountains (Anderson and others, 1971). The metamorphism is probably also early Proterozoic in age, although some metamorphism in the Vulture Mountains could also be Mesozoic in age. Unfoliated granitic plutons of Cretaceous age intrude the schist in the northeastern Vulture Mountains (Grubensky and others, 1987).

Several metamorphic lithologies are present including pelitic and psammitic schist and amphibolite. The schist contains compositional layering defined by alternating bands of quartzofeldspathic and mafic-bearing schist. Compositional banding is on the order of 2 to 10 cm thick and is primarily defined by changes in biotite abundance and the biotite/quartz ratio. Compositional banding does not everywhere parallel foliation. Amphibolites consisting of minor quartz, epidote, plagioclase feldspar, and amphibole are less abundant. Lenses, boudins, and massive irregular-shaped bodies of amphibolite are both concordant and discordant to a strong, east-west striking foliation in the map area. The least abundant lithologies consist of metamorphic assemblages of andalusite+muscovite+ biotite, andalusite+muscovite+quartz, and biotite+muscovite+ quartz. Most of the schist is fine or medium grained: some pelitic schists, however, include anhedral to subhedral porphyroblasts of andalusite up to 1 cm across. The protolith for the quartzofeldspathic schists is probably thin-bedded sandstone, although sedimentary structures other than possible plane bedding are not well preserved. Amphibolites are probably derived from mafic flows and dikes, whereas muscovite schists are likely derived from clays or tuffaceous rocks. Stratigraphic and structural relations between each of these mineralogically discrete assemblages is still uncertain.

The schistose rocks are exposed in structural windows in and along subhorizontal mid-Tertiary normal faults in the southeastern Vulture Mountains. In several places they are intruded by abundant east-west-trending rhyolite dikes and plugs (unit Trs), and the overlying unconformity with Tertiary sedimentary rocks (unit Ts) is repeatedly exposed in adjacent fault-blocks. Precipitous hillsides of schist in sections 7 and

18, T. 6 N., R. 4 W. flank abundant, resistant rhyolitic dikes. A regional metamorphic foliation that is east-west striking and steeply dipping is typical of schists. Lineation directions defined by aligned hornblende phenocrysts or elongated feldspars are less systematic. Unlike Proterozoic rocks in the northeastern Vulture and Buckhorn Mountains, the schists in the map area are not intruded by or associated with fine-grained, quartzofeldspathic gneiss or pegmatites (Grubensky and others, 1987; Jahns, 1952); unmetamorphosed Cretaceous granite and granodiorite of the Wickenburg batholith of Rehrig and others (1980) are also absent.

TERTIARY SEDIMENTARY ROCKS

The stratigraphically lowest Tertiary unit consists of as much as 100 m of red arkosic sandstone and conglomerate of Oligocene(?) and Miocene age. These rocks were deposited on an unconformity that is constrained to be younger than late Cretaceous and older than middle Miocene. The unconformity is regional in extent, overlies rocks as young as Cretaceous granite, and is overlain by rocks as old as late Oligocene in some other ranges (Shafiqullah and others, 1980). The arkosic rocks are, in part, locally derived because they contain clasts of Cretaceous granodiorite and Proterozoic schist, however clasts of Proterozoic quartzite are probably derived from the Buckhorn Mountains. The arkose, although the thickness may be as little as 5 m, is always present at the unconformity unless it has been intruded by rhyolite. The horizon was apparently one of low relief.

The basal arkosic rocks in the map area consist of approximately 10 meters of a fining-upward sequence of conglomerate, conglomeratic sandstone, and arkose with pebbles and cobbles that are between 2 cm and 15 cm in diameter. Clasts of Proterozoic rocks are well rounded and typically matrix supported. Cut-and-fill crossbedding is common on the horizontal scale of a meter as are gravel-filled channels. This sequence includes well-bedded, thickly layered, unsorted conglomerate and thin horizons of well-sorted, coarse-grained sandstone, in part pebbly. The arkose is locally, but dramatically, interbedded with basalt flows of unit Tbl at the common corner of sections 9, 10, 16, and 15, T. 6 N. R. 4 W. There, the arkose is uncharacteristically greenish colored and partly tuffaceous with bedsets that are 3 to 6 m thick. Clasts in this conglomerate are derived solely from unmetamorphosed (Cretaceous?) granitoid and are as large as 15 cm. Plane parallel beds in this unit are approximately 10 cm thick. These rocks are poorly sorted and poorly bedded, and lack obvious channels.

TERTIARY VOLCANIC AND HYPABYSSAL ROCKS

Tertiary volcanic rocks of the southeastern Vulture Mountains are dominated by a sequence of rhyolite at least 1 km thick. These crystal-poor rhyolite flows and domes and associated pyroclastic rocks are now referred to, informally, as the San Domingo rhyolites. The less specific name of San Domingo volcanics was used previous to this report (Stimac and others, 1987; Grubensky and others, 1987), but additional mapping has shown that this unit consists strictly of rhyolite to the exclusion of volcanic rocks of other compositions. K-Ar dates on some rhyolites in the central Vulture Mountains indicate the San Domingo rhyolites are approximately 18 m.y. old (Rehrig and others, 1980). Basalt flows lie above and below the rhyolite sequence. The lower basalt (unit Tbl) is correlative to the Deadhorse basalt, which is dated at approximately 20 Ma (Capps and others, 1985), and the upper basalt is correlative to basalts dated at 14.5 Ma in adjacent areas (Capps and others, 1985; S.J. Reynolds, unpublished data). In two places, the lower basalt is intercalated with crystal-rich dacite (unit Td).

The San Domingo rhyolite complex was erupted through at most 100 m of basalt flows (unit Tbl). These lower basalts are steel-gray, nonresistant, aphyric flows that are uncommonly vesicular. They are interbedded with conglomerate and arkosic sandstone of unit Ts in the northeastern corner of the map area. Locally a parting cleavage has developed in the basalt flows. Scoria is not common. In the southern part of the map area, the lower basalts include at least three varieties: (1) clinopyroxene-olivine-plagioclase-phyric basalts with up to 20% phenocrysts. Clinopyroxene is green, locally altered and present as 1-3 mm euhedral grains, which are singular or as aggregates with plagioclase. Olivine phenocrysts are 1-2 mm across and altered to Fe-oxide. Plagioclase phenocrysts are 1-5 mm euhedral laths or as groundmass microlites; (2) dark gray, aphyric basalt locally including phenocrysts of plagioclase; and (3) olivine-phyric variety that is reddish gray and massive, with a plagioclase microphyric groundmass. Flow thicknesses average between 3 m and 5 m, and flow breccias are only locally developed along flow bases.

Lava flows of the San Domingo rhyolites are characterized by 1-5 mm phenocrysts of sanidine and finer grained biotite set in a devitrified or perlite matrix. Phenocrysts constitute less than approximately 5% of the rock. Rhyolite flows typically have autobrecciated margins and flow-foliated, massive cores. Devitrification of flow matrix to microcrystalline quartz and alkali-feldspar and spherulites between 5 mm and 1 cm are features ubiquitous in the rhyolite flows except for some basal vitrophyres. Interbedded pyroclastic rocks include mostly very well sorted tuffs and lapilli tuffs (air-falls) deposited in beds that are generally 10 cm thick. These are associated with laminated surge-related tuffs with crossbedding, reverse grading, and fine ash-sized grains, and 1-m-thick beds of poorly sorted, unwelded pyroclastic flows. Lithic fragments less than 1 cm are characteristic, except in the western half of section 22, T.6 N., R.4 W., where the tuffaceous rocks have angular fragments up to 1 m across, beds up to 4 m thick, and some welding an autoclastic facies (within a volcanic vent).

Rotation of large fault blocks has provided substantial structural relief through the Tertiary volcanic section. One fault block (including secs. 17, 18, 19, 20,; T. 6 N., R. 4 W.) provides an additional 2 km of vertical section through the schist substrate and a Tertiary rhyolite dike swarm (unit Trs). Several rhyolite dikes that intrude the schist across the width of this fault block grade structurally upward into extrusive, flow banded rhyolite; this fault block, therefore, provides an upturned cross-section through a volcanic center and its hypabyssal feeders. This intrusive network consists of 1- to 20-m-thick dikes, most of which strike east-west, dip steeply, and are, in most places, parallel to the metamorphic foliation in the schist. The Tertiary-pre-Tertiary contact exposed near the Queen of Sheba mine (SE 1/4, sec. 8; T. 6 N., R. 4 W.) has been locally intruded by Tertiary rhyolite dikes. In general, mineralogic and textural differences between and within dikes are very subtle. Locally, individual dikes display sharp zoning between two phases; the marginal (older?) phase is a dark, almost glassy hornblende- and K-feldspar-phyric rhyolite that is separated from the inner phase by a sharp contact or a selvage of schist. The inner phase is typically hematite stained and thoroughly devitrified or altered, such that both hornblende and sanidine are altered to hematite and clays, respectively.

In the northern part of the eastern Vulture Mountains, the tilted volcanic complex is overlain by conglomerate and sandstone associated with the development of half grabens developed on rotating fault blocks. These sedimentary rocks have been removed in most of the map area. Basalt flows of unit Tbu are exposed in isolated pediment outcrops south of the main part of the mountain range. Where unaltered, the flows are plagioclase microphyric basalt or basaltic andesite with local aggregates of clinopyroxene 1-3 mm across. Vesicles and calcite amygdules up to 2 cm across are both common. One flow is underlain by a heterogeneous deposit of unsorted blocks (unit Tdf), which may represent debris flows mapped in adjacent areas (Grubensky and others, 1987).

QUATERNARY SEDIMENTS AND SEDIMENTARY ROCKS

Rocks along the southern margin of the Vulture Mountains are overlain unconformably by poorly to unlithified sediments and sedimentary rocks of Quaternary age that are essentially flat-lying. The Hassayampa Plain includes the area between Black Butte, in the southwestern Vulture Mountains, and the Hassayampa River along the eastern margin of the study area (inset, Fig. 1). Drainages in the eastern half of the map area feed the Hassayampa River directly, whereas runoff from the western half is diverted through a drainage network across the Hassayampa Plain. Isolated outcrops of Tertiary volcanic rocks are present on the northernmost part of the plain. Broad alluvial fans extend southward from the southern flank of the Vulture Mountains. The entire mountain range is one of comparatively low relief amidst the precipitous Harquahala, Big Horn, and Hieroglyphics Mountains. Isolated bedrock exposures suggest that the pediment for the southeastern Vulture Mountains extends at least 3 miles south of the last continuous outcrops within the range.

The Quaternary geology for the western half of the study areas differs from that in the eastern half. The western half is dominated by alluvial fans. West of secs. 32, 29, 20, 17, lies a broad, irregular plain of alluvium with scattered exposures of bedrock pediment. As much as 30 m of poorly lithified gravel (unit Qg) defines a paleoriver channel much broader than the present day Hassayampa River. River. These gravels are exposed 2 miles from the modern Hassayampa River beneath a thin veneer of alluvium and soil. Modern drainages have incised these gravels, which are composed of well-bedded sandy conglomerate and sandstone. Most clasts are light-colored Cretaceous(?) granite and granodiorite. The gravels are characterized by bedform crossbeds, shallow channels, and interbedded, well-sorted, planar laminated sandstone. The components of older river gravels contrast markedly with those of alluvial (Qal units) because of its better sorting, well-rounded clasts, clast-supported nature, and well-developed bedding surfaces. Also, the gravels weather to conspicuous steep-walled arroyos. Interfluves are underlain by poorly developed soils less than 1 m thick that form conspicuous flats, or surfaces, associated with an immature desert pavement. Pavement clasts are primarily of rhyolite. The blufflike topographic expression indicative of the gravels can be traced into areas south of the study area.

Three types of alluvium (subdivisions of unit Qal) are distinguished in the western half of the map. To varying degrees, alluvium of units Qal_o, Qal_m, and Qal_y is incised by modern drainages (units Qs and Qso), and as a result, patterns of drainage and their textures seen in photographs provide information rough criteria for their distinction. The alluvium of unit Qal_o is exposed along the foot of the SE Vulture Mountains and is associated with a relatively large amount of relief within arroyos that dissect it. The deep arroyos in this poorly consolidated alluvium define a high density, dendritic drainage network characterized by well-developed main channels, and short, subsidiary channels. High drainage density suggests that these rocks are less permeable than Qal_y or Qal_m. Many of the modern channels in Qal_o are floored by bedrock.

At the contact of Qal_o and Qal_y, runoff is distributed into a low-density, parallel dendritic, drainage network with shallow gullies. Interfluves in Qal_y are covered by silts and fine-grained sands probably associated with sheet flooding. Few drainages in Qal_y incise down into bedrock.

Map unit Qal_m is less widespread than either Qal_o or Qal_y, and is intermediate in age. The characteristic reddish color of the unit reflects a high proportion of Tertiary rhyolite clasts. Qal_m overlies Qal_o in section 31, T.6 N., R.4 W. and is distinguished from it by its lower density, dendritic drainage pattern, and smooth texture along interfluves. Qal_m, like Qal_o, is rather deeply incised by arroyos.

STRUCTURE

Pre-Tertiary Structure

Proterozoic schists in the southeast Vulture Mountains record one or more dynamothermal, regional metamorphic events of pre-Cretaceous age that have produced moderate-grade metamorphic assemblages. Although protolith grain shapes, phenocrysts, and sedimentary bedforms are not preserved, relict bedding in the metasedimentary rocks is locally preserved as changes in composition and grain size. Bedding has been folded and locally transposed into parallelism with foliation. Amphibolite schists that form lozenge-shaped bodies parallel to foliation are possibly metamorphosed, dismembered mafic dikes. Some mesoscopic layering in schists might be better referred to as compositional banding rather than bedding, which implies a sedimentary origin.

The emplacement of Late Cretaceous plutons (the Wickenburg batholith of Rehrig and others, 1980) crosscuts the metamorphic fabrics, although the plutons locally show a weak flow(?) foliation. Mesozoic fabrics related to either Cretaceous plutonism or tectonism (Reynolds and others, 1980) are recognized in this area; several crosscutting foliations and cleavages have been mapped in the northeastern Vulture Mountains (Grubensky and others, 1987).

Tertiary Structure

A period of Miocene rotational normal faulting occurred after emplacement of the San Domingo rhyolites. The faulting dissects the rhyolite volcanic complex along a duplex of several, sub-parallel, sub-horizontal normal-faults. The Tertiary units are vertical or locally overturned to the west. This duplex is apparently unlike any mapped in Tertiary rocks in west-central Arizona thus far. Klippe of Tertiary volcanic rocks and small fensters into schist through subhorizontal normal faults are otherwise uncommon in a region of high- to moderate-angle mid-Tertiary normal faults. The mid-Tertiary deformation was not associated with metamorphism in the Vulture Mountains because these rocks were and probably have remained at shallow crustal levels throughout the deformation. Miocene faulting has not reoriented the east-west trending foliation in the schist because the axis of rotation was approximately perpendicular to the foliation.

Exposures of subhorizontal faults generally include a resistant upper plate of Miocene volcanic rocks, usually rhyolite flows, and a less resistant lower plate of Proterozoic schist. Rocks in the fault zone were pervasively sheared and cataclasized to a fault breccia. Gouge is uncommon or confined to very narrow zones along fault planes. Upper-plate rocks are typically silicified and pervasively stained with hematite for as much as 10 m above the fault surface, whereas the underlying schists are commonly unmineralized or are recemented with black calcite. Black manganese staining can be present in the upper plate rocks. The striated fault surface is commonly preserved on Miocene rhyolite and usually dips more steeply than the trace of the contact implies, probably because of additional rotation along minor, more closely spaced, later high-angle normal faults with small separation. Lower-plate schists have locally developed a fault-parallel cleavage.

Faulting occurred largely or entirely after deposition of the San Domingo rhyolite based on two observations: (1) debris flows and conglomerates indicative of synvolcanic tectonism are not interbedded with the rhyolite, only with the younger basalts of unit Tbu, and (2) bedding has approximately the same dip within most fault blocks--decreases in dip upsection in some fault blocks are probably inherited from the flanks of a volcanic edifice. Normal faulting continued for probably 5 to 6 m.y., until the eruption of flat-lying younger basalts (unit Tbu) that are dated at approximately 14 Ma. Coarse-grained conglomerates and sedimentary debris flows that fill many of the half grabens, are exposed north of the map area along the Hassayampa River (Grubensky and others, 1987).

The numerous subhorizontal normal faults in the Vulture Mountains are significant because they imply a larger amount of crustal extension than in adjacent mountain ranges. The faults have much shallower dip than in the adjacent Big Horn or Hieroglyphics Mountains, and the Miocene rocks within each fault block in the eastern Vulture Mountains are consistently near vertical to overturned. The present vertical thickness of each fault block is also quite thin, commonly 100 m. Because the lithologic units are vertical and the faults are subhorizontal, the amount of dip separation across several of the larger faults can be measured directly from the geologic map in Fig. 1. The major faults must have 1 to 2 km top-to-the-west motion in order to restore similar volcanic sections between adjacent fault blocks. The total amount of extension across the southeastern Vulture Mountains is approximately the width of the map area (6 km.

The development of flat faults in the eastern Vulture Mountains has been a complex process. The faults probably formed as a series of high-angle normal faults structurally above a regionally developed feature, such as a detachment fault. As the rhyolite flows and tuffs of the Vulture Mountains were extended, beds rotated to moderate eastward dips as faults rotated to moderate westward dips; the angle between faults and bedding remained approximately at right angles during deformation. An additional (secondary) set of younger high-angle faults crosscut the package when rotation along the primary faults had resulted in gentle dips of faults and steep dips of beds. With continued extension, most additional rotation was probably accommodated on the younger, initially high-angle secondary faults (Fryxell and others, 1987). Some beds of volcanic rocks are rotated to vertical or overturned dips as a result of continued extension, and primary faults associated with such beds dip shallowly eastward, although there was little movement, if any, along these faults in this orientation. All generations of faults consistently place younger rocks over older rocks. Late-stage high-angle faults are probably the youngest structures present that are related to Miocene deformation.

ALTERATION AND MINERALIZATION

During the course of geologic mapping, several areas of altered and mineralized rock have been noted. The main types of alteration and mineralization include the following; (1) widespread hematite- and limonite-staining, which may include the presence of Cu-oxide and -carbonate, and relict sulphides; (2) intense silicification, with and without alunite and montmorillonite, and (3) intense or closely spaced veins or irregularly shaped solution-fillings of black calcite. Each of the alteration-mineralization types is shown on the geologic map by a patterned overlay (Fig. 1). The significance of each of these types of alteration and mineralization is uncertain, although a majority of zones of alteration and mineralization in the map area are spatially associated with and probably related to normal-faults. Age relations between types of alteration are unknown. No one lithology seems more favorable for alteration, except hematization is more commonly associated with Tertiary rhyolite.

MAP UNIT DESCRIPTIONS

QUATERNARY SEDIMENTARY ROCKS

Qs: Sediments

Unconsolidated sand and gravel in modern stream channels or on low terraces in or adjacent to these channels. This unit also includes thin aprons of colluvium found on some low slopes and spurs west of the Hassayampa River.

Qso: Older sediments

Unconsolidated gravel-poor sand and sandy gravel deposits standing above modern stream channels and below partly consolidated alluvium of map unit QTs.

Qt: Talus

Includes unconsolidated material shed from steep slopes.

Qal: Alluvium, undivided

Unconsolidated to partly consolidated or caliche-cemented sands and gravels of dissected terraces standing more than 2 m above modern drainages. Deposits are essentially flat lying and form south-directed alluvial fans along the southern front of the Vulture Mountains. Unit is locally divided into three different members based on superposition and texture, drainage density, and color in aerial photographs.

Qal_y: Younger alluvium--characterized by high drainage density, light color, and relatively shallow arroyos. Exposures of bedrock in arroyo bottoms are rare.

Qal_m: Middle alluvium--characterized by low drainage density and light-colored interfluves capped by fine-grained deposits.

Qal_o: Older alluvium--characterized by high drainage density, deep arroyos, bedrock exposures in arroyo bottoms, and relative greater degree of consolidation.

Qss:

Poorly consolidated, coarse-grained, poorly sorted alluvium and colluvium that overlies conglomerate and sandstone (unit Qg) in the eastern portion of the map area. Characterized by a desert pavement that is substantially more resistant to erosion than underlying sedimentary rocks. Unit is generally not more than 1 m thick. Composed primarily of clasts of Miocene rhyolite (unit Trs) shed from hillsides and talus in secs. 32 and 29, T.6 N., R.4 W.

Qg: Conglomerate and sandstone

Light-colored, nonresistant, poorly consolidated, well-bedded, well-sorted conglomerate and interbedded sandstone.

Clast lithology locally dominated by unfoliated (Cretaceous (?)) granitoid. Conglomerates are clast supported and commonly form shallow channels. Sandstones have crossbeds and planar laminations, and are commonly size-graded beds ranging in thickness between 2 cm and 30 cm. Pebbly sandstone beds are common.

TERTIARY VOLCANIC AND SEDIMENTARY ROCKS

Tbu: Upper basalt flows

Black to gray, vesicular, plagioclase-clinopyroxene-olivine-phyric basalt in flows 2 m to 5 m thick. Total phenocryst content ranges between 1 percent and 25 percent. Unit unconformably overlies the rhyolites of San Domingo Wash along the Hassayampa River. This basalt is distinguished from the lower basalt (map unit Tbl) by the conspicuous phenocrysts of olivine that may reach 7 mm across and comprise 10 percent of the rocks.

Tdf: Debris flows

Nonresistant, massive deposits of unsorted boulders, cobbles, and pebbles of rhyolite, and basalt, and Proterozoic metamorphic rocks.

Tsc: Conglomerate and sandstone

Brown- to buff-colored, consolidated to poorly consolidated conglomerate, sandstone, and siltstone. This unit consists chiefly of matrix-supported, unsorted, conglomeratic arkose and arkose in beds that are 1 cm to 1 m thick, averaging 10-20 cm, and, that are rarely graded and lack crossbeds. However, some of these deposits have clasts with diameters equal to the thickness of the bed that contains them, and these may represent thin debris flows. Clasts consist of Proterozoic and Cretaceous crystalline rocks and Tertiary volcanic rocks.

Tdh: Hell's Gate dacite

Dikes and plugs of light- to dark-mauve-weathering, resistant, blocky-weathering dacitic rocks with 10 to 30 percent phenocrysts of plagioclase, quartz, biotite, hornblende, and clinopyroxene. Conspicuous singular plagioclase phenocrysts and 2- and 3-grain aggregates of subhedral to euhedral plagioclase range up to 1 cm across and are typically chalky-white colored, with a sieve-texture visible with a hand lens. Biotite occurs as altered books 2 to 3 mm across, whereas clinopyroxene occurs as fresh-looking grains about 1 mm across. Xenoliths of fine-grained, phaneritic rock are scattered between the phenocrysts and range from 3 and 5 cm across. This unit occurs in or adjacent to low-angle normal faults between Tertiary volcanic rocks and Proterozoic crystalline rocks. This lithology is texturally identical to dacitic rocks of the Hells Gate volcanics (map unit Tdh), which are common in Hieroglyphic and Wickenburg Mountains (Capps and others, 1986; Stimac and others, 1987).

San Domingo Wash rhyolites

This unit has two members; rhyolitic igneous rocks (referred to as simply rhyolite) and associated rhyolitic pyroclastic rocks. These lithologies are generally associated with one another and are complexly intermixed on the scale of tens of meters. The nature of each body of rhyolite is, more often than not, uncertain. Some are certainly intrusive because they crosscut and intrude the adjacent pyroclastic rocks, whereas others are texturally zoned lava flows with a basal vitrophyre and upper and lower spherultic zones.

Trs: Rhyolite flows, domes, sills, and dikes

Light-gray, resistant, flow-foliated, autobrecciated, ±biotite-quartz-sanidine-phyric rhyolite that is interbedded with and intrudes associated pyroclastic rocks (map unit Tts). Spherulites are common in the lower portions of flows. Rhyolite flows low in the section are biotite-poor, whereas those high in the section have up to 3 percent biotite. The rhyolite contains 15 percent phenocrysts of sanidine and 5 percent quartz.

Tts: Rhyolitic pyroclastic rocks

Light-yellow, nonresistant, thinly to thickly bedded, lapilli-poor, unwelded tuffs with variable amounts of pebble-sized lithic fragments of basalt, granitoid, and rhyolite. Lithic fragments compose only several percent of the tuff. Long-wavelength crossbeds in some horizons represent surge deposits. Well-sorted, ash-poor lapilli tuffs are also common and probably represent air-fall deposits. Some tuffaceous horizons are aphanitic, but others contain 15 to 20 percent phenocrysts, including aggregates of plagioclase and biotite 1 to 5 mm in diameter.

Tbl: Lower basalt flows

Dark-gray, reddish-weathering, nonresistant flows of plagioclase-clinopyroxene-olivine-phyric basalt and, locally, red-brown-colored, nonresistant aphanitic scoria. Olivine, which is consistently altered to iddingsite, occurs as phenocrysts typically less than 1 mm across and also occurs as a groundmass phase. Basalt also contains less than one percent clinopyroxene phenocrysts 1 to 2 mm across, and white to clear and iron-stained plagioclase as sparse 1 to 3 mm in diameter.

Td: Dacite flows

Lavender-colored, nonresistant, biotite-hornblende-plagioclase-phyric flows(?) intimately interlayered with lower basalt (unit Tbl).

Ts: Conglomeratic arkose

Dark-red-brown, variably resistant, arkosic sedimentary rocks including conglomerate, conglomeratic sandstone, and sandstone. Commonly consists of an upward-fining sequence that is roughly 10 m thick and bedded on the scale of 30 to 60 cm. Arkose in the upper half of the unit is in plane-parallel beds with few crossbeds. Elsewhere the redbeds are massive or inconspicuously layered, consisting of matrix-supported conglomerate with subangular clasts of vein quartz ranging in size from 3 to 10 cm across, and finer grained clasts of granitoid and schist. The hematitic character of the unit increases toward the lower unconformable contact with metamorphic rocks, which are also hematitic within a few meters of the contact.

PROTEROZOIC(?) ROCKS

Xs: Schist

Nonresistant, fine- to medium-grained quartzofeldspathic schist of two varieties distinguished by the presence or absence of metamorphic muscovite. One variety with muscovite includes quartz and locally includes garnet, andalusite, and biotite. The second variety, muscovite-poor schist, is gray-green, mesocratic, fine- to medium-grained, even-grained, biotite quartzofeldspathic schist. Map unit includes dikes of rhyolite, dacite, and basalt (map units Trs, Td, and Tbl or Tbu, respectively). The biotite- and muscovite-rich, pelitic varieties of this map units are mineralogically similar to schists in the southern Bradshaw Mountains (Jagger and Palache, 1905) of the Proterozoic Yavapai Supergroup (Anderson and others, 1971). Unit also includes very dark-gray to dark-greenish-gray, foliated, strongly lineated, fine- to medium-grained, ±plagioclase-epidote-amphibole schist, which occurs as lenticular pods within the biotite-rich schist.

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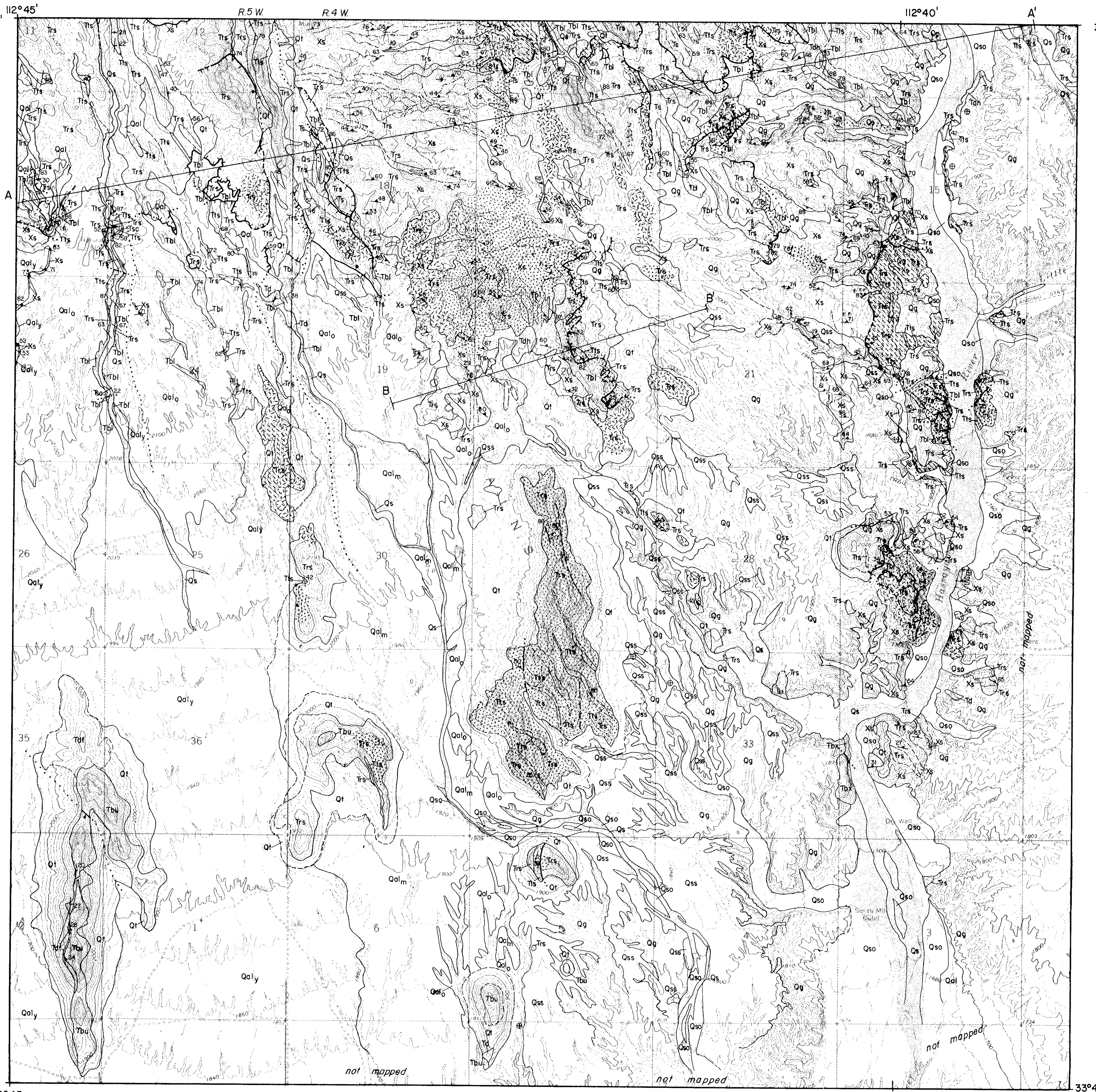


Base from U.S. Geological Survey, Wickenburg SW 7.5 min. quadrangle, 1965.

Geology by M.J. Grubensky, Nov. 1987 to Jan. 1988.

-N-

1 0.5 0 1 mile

1 0.5 0 1 km

Contour interval 20 feet

MAP LOCATION

GEOLOGIC MAP OF THE SOUTHEASTERN VULTURE MOUNTAINS, WEST-CENTRAL ARIZONA

by

Michael J. Grubensky and Stephen J. Reynolds

1988

CORRELATION OF MAP UNITS

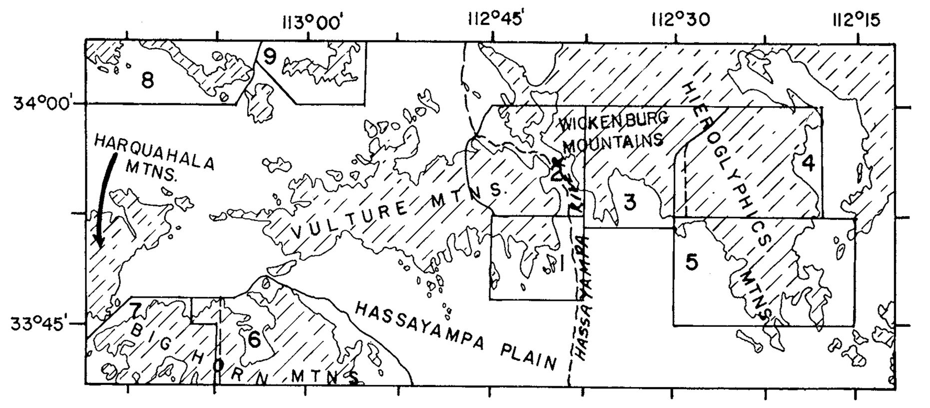
Qs, Qt, Qso; Qal, Qaly, Qalm, Qalo; Qg	Pleistocene to Holocene	Quaternary
Tbu; Tdf, Tsc; Tdh; Trs, Tts; Tbl, Td	Miocene	Tertiary
Ts	Oligocene	Tertiary
Xs		Proterozoic X

MAP UNITS

- Qs SEDIMENTS (Holocene)-
- Qso SEDIMENTS, FLOOD PLAIN (Holocene)-
- Qt TALUS (Holocene To Pleistocene)-
- Qal ALLUVIUM, UNDIVIDED (Holocene To Pleistocene)-
- Qal_y YOUNGER ALLUVIUM (Holocene To Pleistocene)-
- Qal_m MIDDLE ALLUVIUM (Holocene To Pleistocene)-
- Qal_o OLDER ALLUVIUM (Holocene To Pleistocene)-
- Qss ALLUVIUM (Holocene To Pleistocene)-
- Qg GRAVEL AND SAND (Holocene To Pleistocene)-
- Tbu BASALT, UPPER (Miocene)-
- Tdf DEBRIS FLOWS (Miocene)-
- Tsc SANDSTONE AND CONGLOMERATE (Miocene)-
- Tdh HELL'S GATE DACITE (Miocene)-
- Trs SAN DOMINGO RHYOLITE, FLOW MEMBER (Early Miocene)-
- Tts SAN DOMINGO RHYOLITE, PYROCLASTIC MEMBER (Early Miocene)-
- Tbl BASALT, UPPER (Early Miocene)-
- Td DACITE FLOWS (Early Miocene)-
- Ts ARKOSIC SEDIMENTARY ROCKS (Early Miocene to Oligocene)-
- Xs SCHIST (Proterozoic X)-

SYMBOLS

- Geologic contact; dashed where approximately located, dotted where buried.
- High-angle fault with dip; bar and ball on downthrown block; dashed where approximately located, dotted where buried.
- Low-angle fault with dip; hachures on upper plate; dashed where approximately located, dotted where buried.
- Bedding:
  - inclined
  - vertical
  - horizontal
  - overturned
- Foliation in metamorphic rocks, with lineation:
  - inclined
  - vertical
  - horizontal
- Line of cross-section
- Alteration
  - hematite; locally including sulphides
  - clay + quartz + alunite
  - manganocalcite
- Mine shaft
- Prospect
- Rhyolite dikes (unit Trs)
- Dacite dikes (unit Tdh)



INDEX TO PUBLISHED GEOLOGIC MAPS

1. This report.
2. Grubensky and others, 1987.
3. Stimac and others, 1987.
4. Capps and others, 1986.
5. Wahl and others, 1988.
6. Capps and others, 1985.
7. Richard and others, in prep.
8. Reynolds and Spencer, 1984.
9. Reynolds and Spencer, 1985.

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Capps, R. C., Reynolds, S. J., Kortemeier, C. P., Stimac, J. A., Scott, E. A., and Allen, G. B., 1985, Preliminary geologic maps of the eastern Big Horn and Belmont Mountains, west-central Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report OFR 85-14, 26 p., scale 1:24,000, 2 sheets.

Capps, R. C., Reynolds, S. J., Kortemeier, C. P., and Scott, E. A., 1986, Geologic map of the northeastern Hieroglyphic Mountains, central Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report OFR 86-10, 16 p., scale 1:24,000, 1 sheet.

Grubensky, M. J., Stimac, J. A., Reynolds, S. J., and Richard, S. M., 1987, Geologic map of the northeastern Vulture Mountains and vicinity, central Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report OFR 87-10, 7 p., scale 1:24,000, 1 sheet.

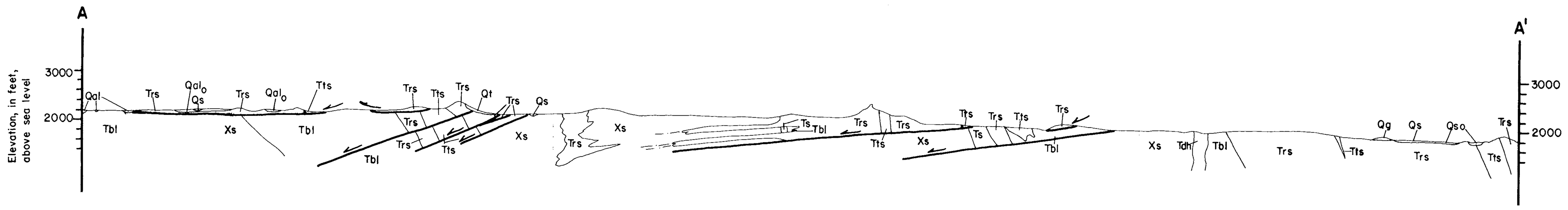
Reynolds, S. J., and Spencer J. E., 1984, Preliminary geologic map of the Aguila Ridge-Bullard Peak area (eastern Harcuvar Mountains), West central Arizona: Arizona Bureau of Geology and Mineral Technology, 2 p., scale 1:24,000.

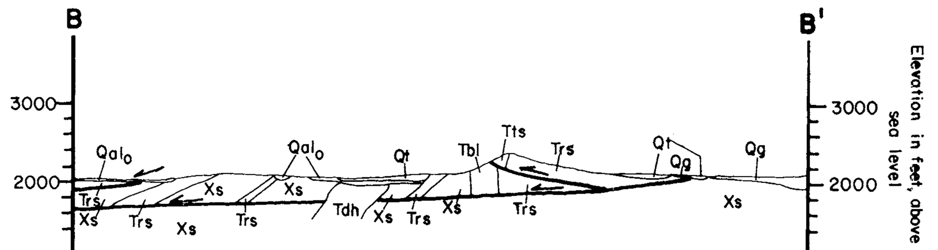
Reynolds, S. J., and Spencer, J. E., 1985, Reconnaissance geologic map of the Merritt Hills, southwestern Yavapai County, Arizona: Arizona Bureau of Geology and Mineral Technology, scale 1:24,000.

Stimac, J. A., Fryxell, J. E., Reynolds, S. J., Richard, S. M., Grubensky, M. J., and Scott, E. A., 1987, Geologic map of the Wickenburg, southern Buckhorn, and northwestern Hieroglyphic Mountains, central Arizona: Arizona Bureau of Geology and Mineral Technology, 13 p., scale 1:24,000, 2 sheets.

Wahl, D. E., Reynolds, S. J., Capps, R, C., Kortemeier, C. P., Grubensky, M. J., Scott, E. A., and Stimac, J. A., 1988, Geologic map of the southern Hieroglyphic Mountains, central Arizona: Arizona Bureau of Geology and Mineral Technology Open-File Report 88-1, 6 p., scale 1:24,000, 1 sheet.

PREPARED IN COOPERATION WITH THE U.S. GEOLOGICAL SURVEY COOPERATIVE GEOLOGIC MAPPING (COGEOMAP) PROGRAM #14-08-001-A0378





MINE AND PROSPECT FIELD VISIT DATA SUMMARY

COMMODITIES Copper, gold and silver

MILS ID No. ______ Date January 17, 1983

ENGINEER Ken A. Phillips

INFORMATION FROM: Property visit 1971 and Crowell, clarence A., yellow card

*See comments on back.

PROPERTY SUMMARY

I. MINE NAME Twin Buzzards OTHER POSSIBLE NAMES INCLUDING ANY CLAIM NAMES NOTED Ethel May 1-52

II. LOCATION: T 7N R 5W SEC(S) 28 & 29 MINE DISTRICT Vulture

ELEV. 2520' COUNTY Maricopa TOPO QUAD. Vulture 15"

DIRECTIONS ______

MAP ATTACHED Yes

III. OWNERSHIP: NAME Clarence Crowell PHONE ______

ADDRESS: P.O. Box 368, Aguila, Arizona 85320

COMPANY NAME IF ANY: ______

PERTINENT PEOPLE ______

IV. PROPERTY AND HOLDINGS: 52 unpatented claims

V. PAST PRODUCTION - NOTED, KNOWN, PROBABLE, UNKNOWN, NONE unknown

VI. CURRENT STATUS: Prospect

VII. WORKINGS: Pit in copper stained granitic rock 100' x 100' x 30' Maximum dimensions.

VIII. GEOLOGY AND MINERALOGY: DEPOSIT TYPE: ______

LENGTH: ______ WIDTH: ______ VEIN STRIKE ______

HOST ROCK: ______

ECONOMIC MINERALS: Copper oxides

COMMENTS: Pit in copper oxides, showy oxide material scattered about pit area.

IX. EQUIPMENT ON SIGHT: None

X. SAMPLING: NOTE TYPE IF ANY, DRILLING?

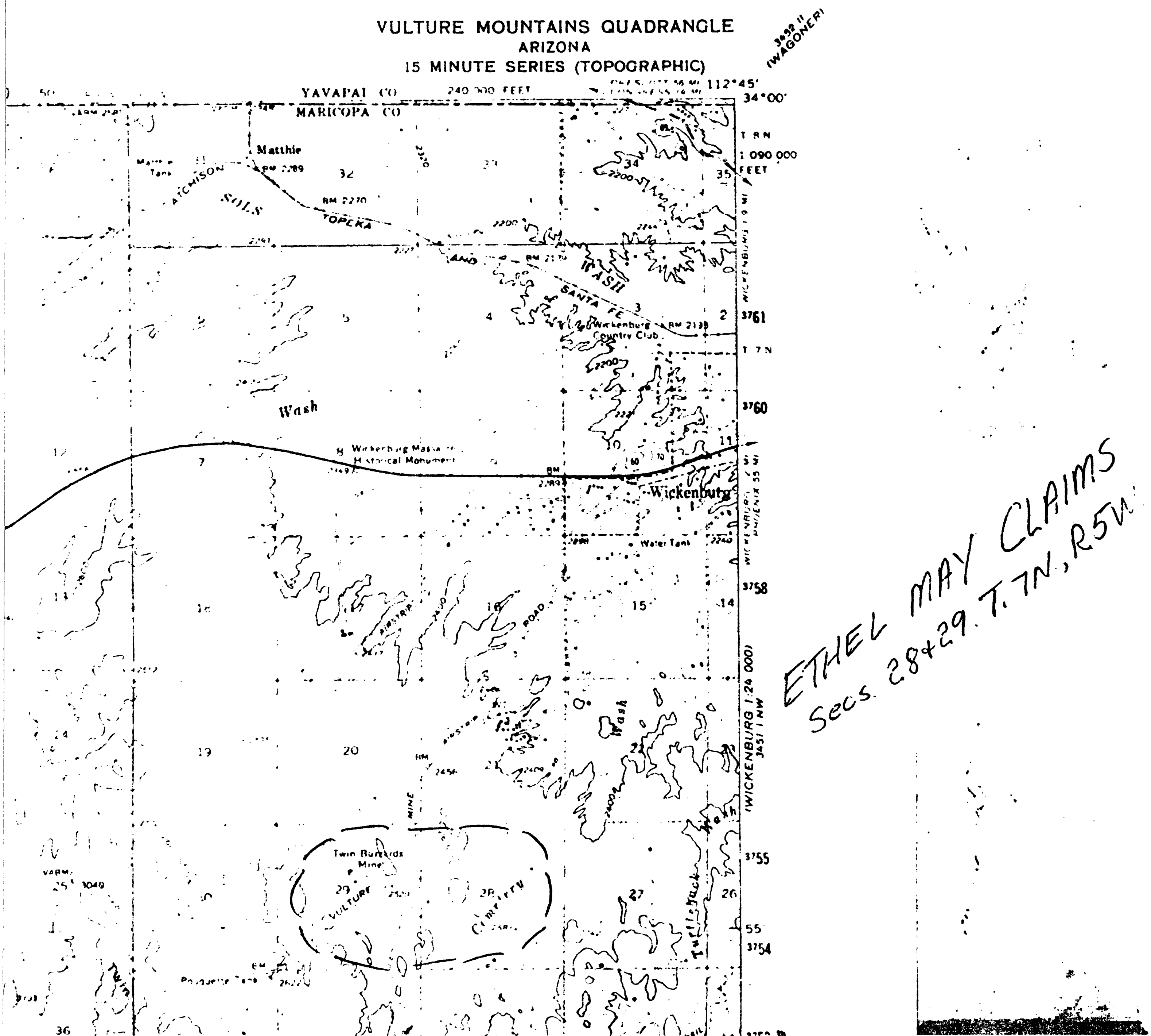
XI. REFERENCES AND REMARKS On January 17, 1983 Guy Mack, V.P. Operation Mgr., Contempo Realty and Investment Inc., 7100 E. Lincoln Drive, Suite D225, Scottsdale, Arizona 85253 was in to obtain information of Mr. Crowell's claims pursuent to listing the property for sale or soliciting investors. Mr. Mack had a data package assembled by Crowell which contained gold and silver assay results.

TWIN BUZZARDS

MARICOPA COUNTY

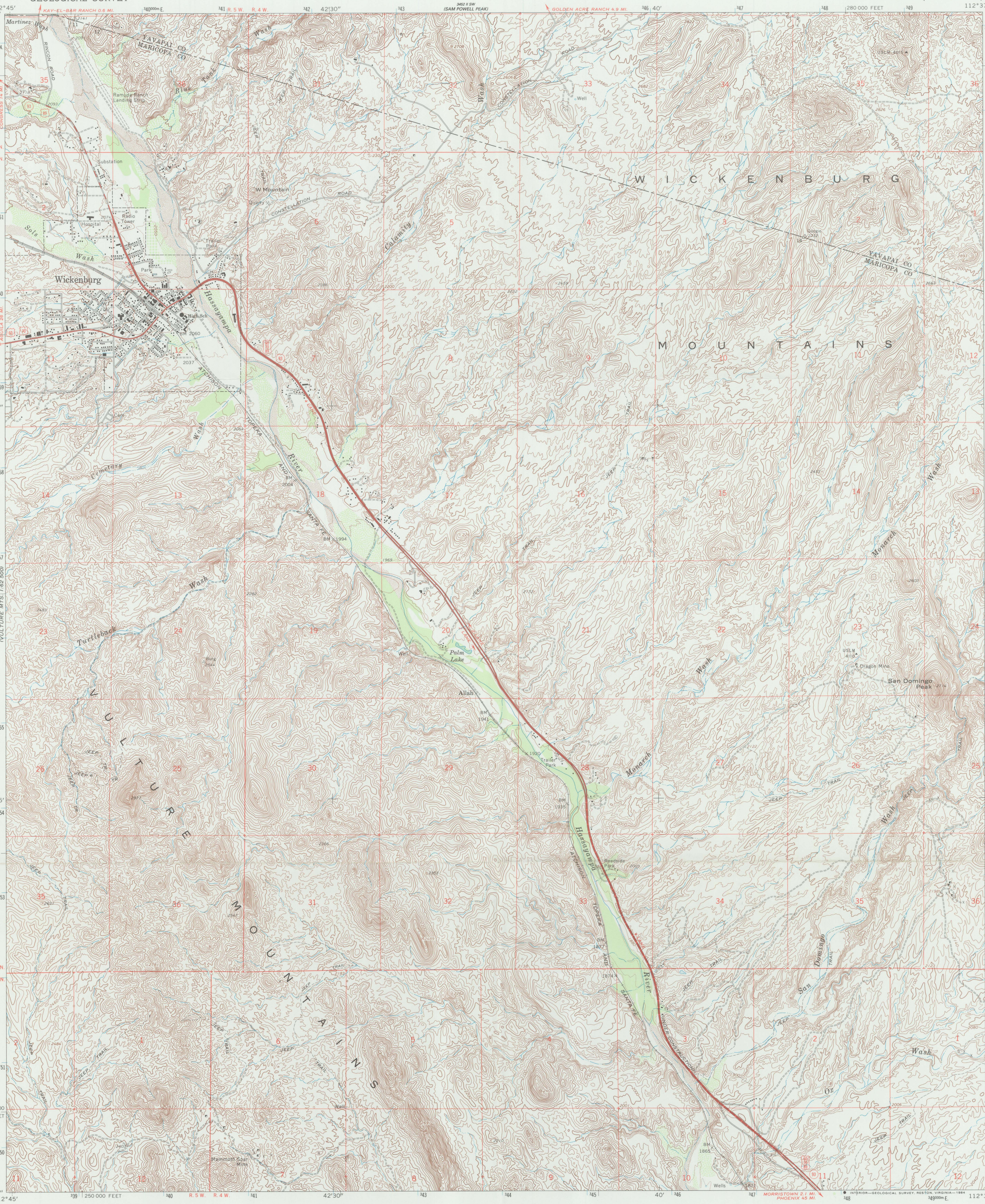
KAP WR 2/7/80: Reported by Mr. Clarence A. Crowell, Box 368, Aquila, Arizona 85320 that he has a group of claims which cover all of Section 29, west half of section 28 and west half of section 33 and one claims in section 32, T7N R5W. He feels that the granite which makes up half of the property may contain gold. He further reported that he has spent over $200 with Dr. Dean of ACM, plus he has talked with the Technical Resistration Board and Dr. Dean is not registered as an assayer or geologist but had performed assays for the $200 fee. Additionally, he has heard that Dr. Dean is not really a doctor. He intends to file a formal complaint.

VULTURE MOUNTAINS QUADRANGLE
ARIZONA
15 MINUTE SERIES (TOPOGRAPHIC)



UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

WICKENBURG QUADRANGLE
ARIZONA
7.5 MINUTE SERIES (TOPOGRAPHIC)



Mapped, edited, and published by the Geological Survey

Control by USGS and USC&GS

Topography by photogrammetric methods from aerial photographs taken 1962. Field checked 1964

Polyconic projection. 1927 North American datum
10,000-foot grid based on Arizona coordinate system, central zone
1000-meter Universal Transverse Mercator grid ticks, zone 12, shown in blue
To place on the predicted North American Datum 1983 move the projection lines 1 meter south and 67 meters east as shown by dashed corner ticks

UTM GRID AND 1964 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
DOTTED LINES REPRESENT 10-FOOT CONTOURS
NATIONAL GEODETIC VERTICAL DATUM OF 1929

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225, OR RESTON, VIRGINIA 22092
A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST

QUADRANGLE LOCATION

Map photoinspected 1978
No major culture or drainage changes observed

ROAD CLASSIFICATION

Heavy-duty — Light-duty
Medium-duty — Unimproved dirt
U. S. Route — State Route

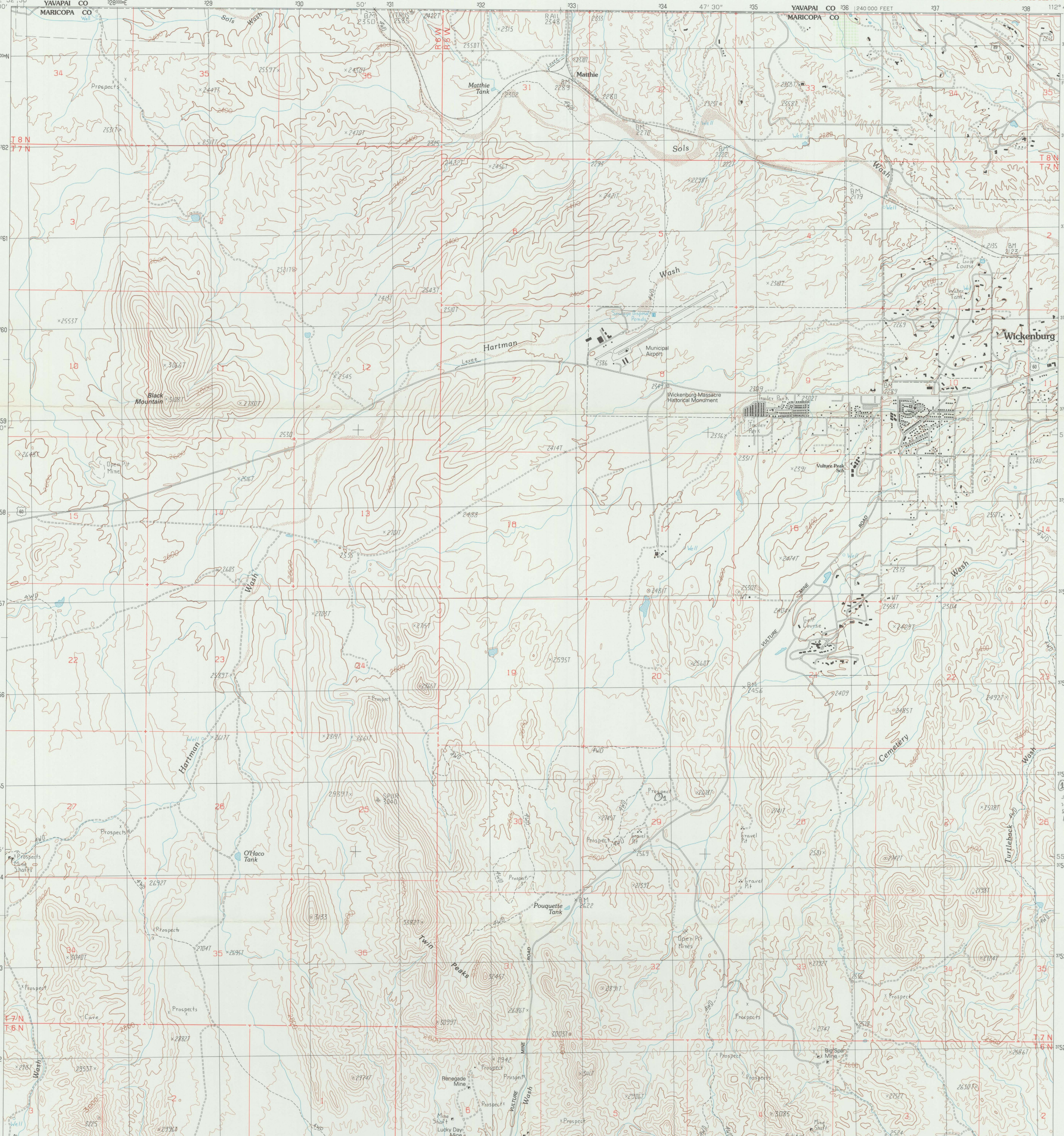
WICKENBURG, ARIZ.
N3352.5—W11237.5/7.5

1964
PHOTOINSPECTED 1978
DMA 3451 I NW—SERIES V898

INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1984

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

VULTURE PEAK QUADRANGLE
ARIZONA
7.5 MINUTE SERIES (TOPOGRAPHIC)



PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY . . . . USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN . . . . 1951 AND 1960
FIELD CHECKED 1961
LIMITED REVISION FROM AERIAL PHOTOGRAPHS TAKEN 1984
FIELD CHECKED . . . . 1986 MAP EDITED 1990
PROJECTION . . . . TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR . . . . ZONE 12
10,000-FOOT STATE GRID TICKS . . . . ARIZONA, CENTRAL ZONE
UTM GRID DECLINATION . . . . 1°01' WEST
1990 MAGNETIC NORTH DECLINATION . . . . 12°30' EAST
VERTICAL DATUM . . . . NATIONAL GEODETIC VERTICAL DATUM OF 1929
HORIZONTAL DATUM . . . . 1927 NORTH AMERICAN DATUM

To place on the predicted North American Datum of 1983, move the projection lines as shown by dashed corner ticks (1 meter south and 68 meters east)

There may be private inholdings within the boundaries of any Federal and State Reservations shown on this map

No distinction made between houses, barns, and other buildings

Public Land Survey System is shown as published in 1961 and verified or supplemented in 1986

NORTH

PROVISIONAL MAP
Produced from original manuscript drawings. Information shown as of date of field check. T

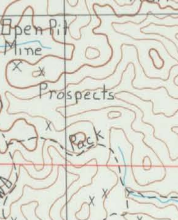
SCALE 1:24 000

CONTOUR INTERVAL 40 FEET

To convert feet to meters multiply by .3048
To convert meters to feet multiply by 3.2808

THIS MAP COMPLIES WITH NATIONAL MAP ACCURACY STANDARDS
FOR SALE BY U.S. GEOLOGICAL SURVEY, DENVER, COLORADO 80225
OR RESTON, VIRGINIA 22092

INTERIOR-GEOLOGICAL SURVEY, RESTON, VIRGINIA-1990



QUADRANGLE LOCATION

1	2	3
4		5
6	7	8

1 Congress SW
2 Flores
3 Sam Powell Peak
4 Outlaw Hill
5 Wickenburg
6 Wildcat Well
7 Vulture Mine
8 Wickenburg SW

ADJOINING 7.5' QUADRANGLE NAMES

ROAD LEGEND

Improved Road
Unimproved Road
Trail

Interstate Route · U.S. Route · State Route

VULTURE PEAK, ARIZONA
PROVISIONAL EDITION 1990

33112-H7-TF-024