DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qsy — **Younger sediments (Holocene)** - Unconsolidated silt, sand, and gravel in arroyos; includes material along watercourse of Hassayampa River. Deposited during normal periods of precipitation.

Qso — **Older sediments (Holocene)** - Unconsolidated silt, sand, and gravel in arroyos and elevated slightly above deposits of younger sediments (unit **Qsy**). Exposed as partly eroded, sandbars or gravel bars along meanders in modern drainages. Includes narrow flood plain adjacent to active segments of Hassayampa River.

Qal — **Alluvium (Holocene to Pleistocene)** - Thin, unconsolidated to partly consolidated deposits of gravel, sand, silt, and mud that define preserved geomorphic surfaces. Underlain by pediment surfaces cut on bedrock or basin-fill-type deposits (unit **QTs**).

Qct — **Colluvium and talus (Holocene to Pleistocene)** - Colluvium, located on shallow slopes, includes unconsolidated sand-, silt-, and pebble-sized detritus deposited by sheetwash or downslope creep; locally includes some sediments (units **Qsy** and **Qso**). Talus, located beneath steep slopes and cliffs, consists of cones of loose detritus derived from fall and downslope creep; grades downslope into colluvium.

SEDIMENTARY ROCKS

Qg — **Gravels (Holocene to Pleistocene?)** - Light-gray, poorly consolidated fluvial deposits of channelized conglomerate and interbedded, cross-laminated arkosic sandstone in southeastern Vulture Mountains adjacent to Hassayampa River. Clast lithology is heterogeneous, but locally dominated by unfoliated granitoid (unit **Kg**?).

QTs — **Sedimentary rocks (Quaternary to Miocene)** - Weakly consolidated, heterogeneous sheet-flood deposits composed of conglomerate and sandstone. Characterized by discontinuous, unsorted, weakly stratified beds. Boulders and cobbles largely derived from basalt lava (unit **Tbu**). Locally includes alluvial deposits (units **Qsy**, **Qso**, and **Qal**).

Tsc — **Sandstone and conglomerate (Miocene)** - Slope-forming deposits of sandstone and conglomerate interbedded with or deposited adjacent to upper basalt lavas (units **Tbu** and **Tbul**). Beds locally dip as much as 70° or as little as 20°, decreasing with higher stratigraphic position. Steeply dipping beds locally intruded by rhyolite dikes (unit **Trp**). Clast dimensions average about 10 cm across, but locally exceed 30 to 40 cm; clast lithology consists of basalt (unit **Tbu**), foliated granitoid (unit **Xg**), and rhyolite lava (unit **Trf** or **Tro**).

Ttv — **Volcaniclastic rocks (Miocene)** - Light-yellow, tuffaceous conglomeratic sandstone and volcaniclastic breccia interbedded with basalt lava (unit **Tbu**) on south flank of Black Butte. Conglomeratic sandstone is thin to medium bedded (bed thickness is 5 to 20 cm) and locally laminated and contains subrounded pebbles and cobbles of rhyolite and basalt lava. Volcaniclastic breccia composed of angular fragments (as much as 80%) of porphyritic, stony rhyolite lava (unit **Trf**) and subordinate basalt in tuffaceous sandy matrix; maximum clast dimensions vary from 1 to 50 cm. Unit thickness is about 180 m.

Tbus — **Sedimentary rocks derived from basaltic volcanic rocks (Miocene)** - Massive to poorly bedded sandy conglomerate composed of angular cobbles of basaltic lava (unit **Tbul**?) in sandy epiclastic matrix. Forms unsorted clast-supported deposits, with clasts less than 60 cm across. Overlies lithic lapilli tuff (unit **Ttll**) along subhorizontal contact on east flank of Black Butte, southwestern Vulture Mountains. Maximum exposed thickness is about 5 m.

Tm — **Mudstone (Miocene)** - Primarily buff-colored, laminated tuffaceous mudstone east and west of Black Butte, southwestern Vulture Mountains. Locally includes silica nodules, gypsiferous beds, and gray-colored beds that are celestite bearing. Includes subordinate tuff and lapilli tuff. Decimeter-sized folds present in outcrops on southeast flank of Black Butte. Maximum thickness east of Black Butte is about 100 m.

Ts — **Sedimentary rocks and interbedded tuff, undivided (Miocene)** -

Tst — **Lapilli tuff** - Orange, massive, unwelded, biotite-sanidine-phyric lapilli tuff. Locally contains minor lenses of crystal tuff in upper portion. Contains granitic pebbles near upper and lower contact in exposures along Jimmie Wash in the central Vulture Mountains. Thickness is approximately 5 m.

Tsa — **Arkosic conglomerate** - Bright-orange to dark-red-brown, variably resistant, oxidized arkosic conglomerate, conglomeratic sandstone, and sandstone. Consists of upward-fining sequence bedded on a scale of 30 to 60 cm. Upper half of unit is plane-parallel bedded with few crossbeds. Massive or poorly layered lower half of unit consists of matrix-supported conglomerate with subangular clasts (between 3 and 10 cm across) of vein quartz, granitoid, and schist in sandy matrix.

VOLCANIC ROCKS

Basaltic Rocks

Tbu, Tbul — **Upper basalt (Miocene)** - Dark-gray, cliff-forming basalt and basaltic andesite lava flows, flow breccias, and scoria beds. Most common type of lava contains phenocrysts of plagioclase and olivine, large vesicles, an aphanitic groundmass, and as much as 15% euhedral olivine phenocrysts that measure 1 to 3 mm across. Subordinate lava type contains phenocrysts of clinopyroxene and plagioclase, few vesicles, a higher proportion and content of plagioclase phenocrysts (10% to 15%), and a microcrystalline groundmass. Interbedded with volcaniclastic rocks (unit **Ttv**) at Black Butte; separated from mineralogically similar lower flows (unit **Tbul**) by rhyolite lavas and tuffs (units **Trf**, **Ttlu**, **Ttll**) near Black Butte, or by 1 to 20 m of tuff (unit **Ttq**) in the central Vulture Mountains.

Tbs — **Pyroclastic rocks of basaltic composition (Miocene)** - Dark-brown, thin-bedded to laminated, pyroclastic surge deposits composed of fine-grained basaltic scoria and olivine and pyroxene phenocrysts. Form well-sorted, ungraded planar bedsets as much as 30 cm thick. Largely altered to palagonite. Locally interbedded with San Domingo rhyolite (unit **Trs**). Exposed thickness is typically 3 to 4 m.

Tbl — **Lower basalt (Miocene)** - Reddish-gray, nonresistant basaltic lava and scoria containing phenocrysts and microphenocrysts of plagioclase, clinopyroxene, and olivine. Olivine phenocrysts replaced by iddingsite; clinopyroxene phenocrysts altered to green clays. Locally interbedded with arkosic sedimentary rocks (unit **Ts**). Maximum exposed thickness is approximately 200 m.

Rhyolitic Rocks

Tt — **Tuff and tuffaceous sandstone (Miocene)** - White, thinly bedded tuff, lapilli tuff, and tuffaceous sandstone; tuff beds are locally glassy. Layering dips vary from subvertical in stratigraphically lower beds to subhorizontal in stratigraphically higher beds. Locally deposited on Proterozoic granitoid (unit **Xg**) or 1 to 3 m of red arkosic conglomerate (unit **Tsa**) with slight (10°) angular discordance. Locally includes rocks mapped as Quail Tank tuff (unit **Ttq**). Intercalated with basalt lava (unit **Tbu** and **Tbul**). Approximate thickness near Outlaw Tank is 200 m.

Ttlu — **Upper lithic tuff (Miocene)** - Yellow, medium-bedded, matrix-supported tuffaceous volcanic breccia. Exposed on southeast flank of Black Butte. Contains angular pebbles, cobbles, and boulders of crystal-poor rhyolite (unit **Trf**). Thickness is about 60 m.

Trf — **Rhyolite lava (Miocene)** - Light-brown-weathering, porphyritic rhyolite lava containing sanidine, biotite, and pyroxene phenocrysts, and mafic inclusions. Sanidine forms 2- to 3-mm euhedral crystals; biotite and pyroxene form 1-mm crystals. Flows are texturally zoned with basal vitrophyre, flow-foliated devitrified core, and capping pumiceous breccia. Unit dip varies from subhorizontal east of Black Butte to moderately dipping south of Black Butte. Unconformably overlies moderately dipping, lithic lapilli tuff (unit **Ttll**) and steeply dipping basalt lavas (unit **Tbl**) east of Black Butte; at Black Mountain, interbedded with basalt lava (unit **Tbu**). Exposed flow thicknesses vary from 35 to 70 m.

Ttll — **Lower lithic tuff (Miocene)** - Yellow, locally resistant, sparsely porphyritic, lithic lapilli tuff east of Black Butte. Phenocrysts consist of feldspar and biotite. Lithic fragments measure 3 to 70 cm across, are subangular, and are composed of porphyritic or sparsely porphyritic rhyolite lava or, rarely, basaltic lava. Basal 1 m contains pebbles of Proterozoic granitoid (unit **Xg**). Unwelded and weakly developed layering mantles topography on underlying contact. Cut by steep, west-dipping normal faults on east flank of Black Butte. Maximum thickness is 100 m.

Ttq — **Quail Tank tuff (Miocene)** - White, glassy, unwelded, lithic-bearing, porphyritic lapilli-tuff containing sanidine and biotite phenocrysts. Along north flank of Vulture Mountains. Interbedded with basalt lavas (unit **Tbu**); uppermost 5 m laminated or thinly bedded and probably reworked. Maximum exposed thickness is about 20 m. Unit is informally named for Quail Tank, which is in the northern Vulture Mountains.

Tro — **Outlaw rhyolite (Miocene)** - Gray, resistant, coarse-grained, porphyritic rhyolite plugs and one small flow near Outlaw Tank, northwestern Vulture Mountains. Composed of as much as 50% phenocrysts of quartz, sanidine, and biotite; sanidine and quartz form phenocrysts up to 7 mm across. Plugs attain 500-m diameter where circular and 1-km diameter where elongate. Minimum flow thickness is about 15 m. Unit is informally named for Outlaw Tank, which is in the northwestern Vulture Mountains.

San Domingo rhyolite (Miocene) - Interbedded rhyolite lavas, domes, and pyroclastic rocks. Exact nature of each extensive or unusually thick horizon of lava is locally uncertain; it could be either intrusive or extrusive. Maximum aggregate thickness is approximately 1,100 m. Unit was informally named for San Domingo Wash in the Wickenburg Mountains (Stimac and others, 1987). Divided into:

Trs — **Lava flows and domes** - Pinkish to reddish, sparsely porphyritic, rhyolite lava flows and domes containing phenocrysts of sanidine and clinopyroxene or biotite. Lavas texturally zoned from vitrophyric margins to flow-foliated and stony lava cores. Phenocrysts compose 5% to 15% of the rock; sanidine phenocrysts from 1 to 4 mm across. Individual flow thicknesses average 130 m.

Tts — **Pyroclastic rocks** - Yellow, unwelded, massive to thin-bedded and laminated, locally crossbedded tuff, lapilli tuff, and lithic lapilli tuff of pyroclastic flow-, fall-, and surge-related origin. Phenocrysts consist of sanidine and biotite. Angular lithic fragments of crystal-poor rhyolite (unit **Trs**) are locally 4 m across. Individual, interlava pyroclastic sequences typically have thicknesses of about 100 m.

Trj — **Jimmie Creek rhyolite (Miocene)** - Medium-brown-weathering flow breccias of sparsely porphyritic rhyolite containing less than 10% phenocrysts of feldspar and biotite. Distinguished from San Domingo rhyolite lava (unit **Trs**) by lack of flow zonation, absence of clinopyroxene phenocrysts, and abundant biotite phenocrysts. Maximum thickness is about 300 m east of Jimmie Creek. Unit is informally named for Jimmie Creek, which is in the central Vulture Mountains.

Trc — **Clinopyroxene-rich rhyolitic? lava (Miocene)** - Light-purplish-gray, moderately resistant, massive rhyolitic? lava containing phenocrysts of clinopyroxene and biotite. In fault blocks west of Vulture Mine Road and east of Jimmie Creek. Clots of clinopyroxene measure up to 5 mm across; phenocrysts compose 25% of rock. Thickness is about 10 m.

Ttb — **Welded tuff (Miocene)** - Red- to reddish-brown, welded, lithic lapilli tuff containing biotite and feldspar phenocrysts. In westernmost Vulture Mountains.

Ttlc — **Lucky Cuss tuff (Miocene)** - Dark-brown, very resistant, partly welded tuff containing phenocrysts of feldspar, quartz, and hornblende. Flattened pumice lapilli weather to 3- to 5-cm lenticular vugs in outcrop. Average thickness is about 3 m. Unit is informally named for Lucky Cuss mine, which is in northwestern Vulture Mountains.

HYPABYSSAL ROCKS

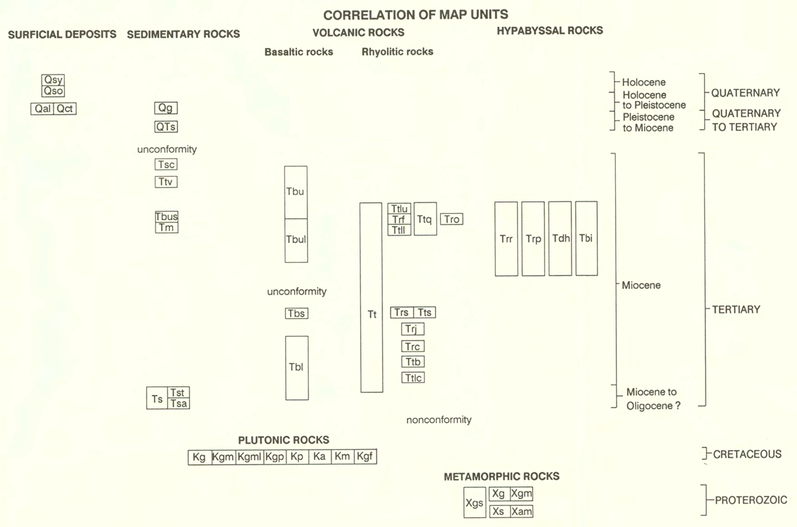
Trr — **Crystal-rich rhyolite dikes (Miocene)** - Purplish-brown, porphyritic dikes, largely rhyolite in composition, containing phenocrysts of feldspar, quartz, and biotite. Intruded along or parallel to low-angle normal faults. Texturally and compositionally zoned from margins of aphanitic basalt inward to fine-grained, plagioclase feldspar-phyric andesite(?), to fine- and medium-grained rhyolite, to a core of crystal-rich, medium- and coarse-grained rhyolite with about 30% to 35% phenocrysts of quartz and feldspar. Subangular inclusions of microphyric to aphanitic basalt are common in the interiors and average 2 cm across. Dikes generally strike N-S and dip between 5° and 30° west. Thickness is typically about 5 to 8 m.

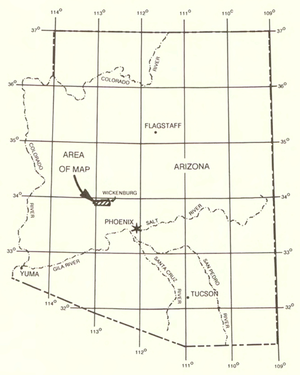
Trp — **Crystal-poor rhyolite dikes (Miocene)** - Dark-brown, resistant, compositionally homogeneous, sparsely porphyritic rhyolite dikes containing feldspar, trace quartz, and biotite phenocrysts; and basalt inclusions; contain 5% to 15% feldspar phenocrysts. Margins locally form flow-foliated zones. Mineralogically indistinguishable from San Domingo rhyolite dikes (unit **Trs**). Associated with and grades laterally into crystal-rich rhyolite dikes (unit **Trr**); dikes trend generally N-S and dip between 5° and 30° west. Thickness is typically 3 to 5 m.

Tdh — **Coarse-grained felsic dikes (Miocene)** - Light-purplish felsic dikes containing 10% to 35% phenocrysts of coarse-grained plagioclase, and fine- to medium-grained quartz, biotite, hornblende, and clinopyroxene. Plagioclase phenocrysts form two- and three-crystal aggregates as much as 1 cm across; fine-grained phaneritic xenoliths in matrix are 3 to 5 cm across. Intruded along low-angle normal faults between Tertiary volcanic and sedimentary rocks and Proterozoic rocks in areas east of Vulture Peak. Correlated with informally named Hells Gate latite in the Hieroglyphic Mountains (Capps and others, 1986).

Tbi — **Basaltic intrusions (Miocene)** - Dark-gray to dark-brown, nonresistant, aphanitic to fine-grained basalt dikes containing plagioclase feldspar microphenocrysts. Dike thicknesses are between 0.5 and 2 m. Intruded into Tertiary, low-angle, normal fault zones.

CORRELATION OF MAP UNITS





PLUTONIC ROCKS

Granitoid (Cretaceous) - Consists of a single, compositionally zoned pluton and several late phases of dikes and intrusive breccias, all of probable Cretaceous age. Intrudes schist and granitoid of inferred Proterozoic age; postdates metamorphic fabrics of host rocks. Middle Tertiary faulting has dismembered the pluton and tilted the fragments through approximately 90° of vertical rotation and onto their sides (top of pluton is to northeast); fault blocks provide vertical profiles through pluton. K-Ar age of 68.4 Ma on leucocratic phase (unit **Kg**; Rehrig and others, 1980). Divided into:

Kg — **Leucocratic granitoid** - Light-gray, medium-grained, equigranular biotite granitoid. Forms grus-covered erosional surfaces in central part of Vulture Mountains. Biotite composes approximately 10% to 15% of rock. Locally contains fine-grained melanocratic inclusions typically 2 cm across. Possible variant at the Vulture mine contains medium-grained muscovite, in part of secondary origin, and conspicuous quartz phenocrysts as large as 1 cm across (Reynolds and others, 1988).

Kgm — **Mesocratic granitoid** - Medium-gray, medium-grained, equigranular hornblende-biotite granitoid composed of about 15% biotite, less than 30% hornblende, and subequal amounts of quartz and two feldspars. Forms grusy outcrops along northern margin of pluton peripheral to leucocratic phase (unit **Kg**). Hornblende partly altered to epidote.

Kgml — **Melanocratic granitoid** - Heterogeneous assemblage of moderately resistant, dark-gray rocks composed of quartz diorites and hornblendites. Mineralogy consists of plagioclase feldspar and hornblende; locally very coarse grained and forms pegmatite; characterized by thumbnail-sized hornblende phenocrysts. Includes dikes and irregularly shaped bodies of plagioclase-rich aplite.

Kgp — **Mixed granitoid** - Light-gray, texturally diverse suite of granitoid dikes that intrude leucocratic phase of pluton (unit **Kg**) in south-central Vulture Mountains. Dike widths range from 5 to 20 m, strike E-NE, and are nearly vertical. Includes feldspar porphyritic granitoid, quartz-feldspar porphyry, and aplite granitoid. Characteristic feldspar-porphyritic type contains (up to 80%) 1- to 3-cm subhedral, lavender feldspar phenocrysts set in a matrix of 2- to 4-mm crystals of quartz, two feldspars, and fine-grained biotite.

Kp — **Quartz-feldspar porphyry** - Light-gray, leucocratic, biotite-bearing, quartz-feldspar-porphyry intrusive breccia southwest of South Tank, central Vulture Mountains. Fragments composed of conspicuous, rounded quartz crystals as much as 4 mm across, chloritized biotite, and relatively finer grained plagioclase in an aphanitic to fine-grained matrix. Breccia matrix exhibits mineralogy similar to fragments. Rare miarolitic cavities are lined with epidote.

Ka — **Aplite** - White, nonresistant, holocrystalline aplite dikes composed of fine-grained (1-mm) feldspar, sparse (<1%) biotite, conspicuous quartz crystals as much as 2 mm across, and pyrite cubes up to 1.5 mm across. Dike thickness is typically less than 1 m.

Km — **Muscovite-bearing aplite** - White, medium-grained aplite dikes containing plagioclase feldspar, quartz, muscovite, and pyrite.

Kgf — **Feldspar porphyry** - Leucocratic, holocrystalline, feldspar-porphyritic granitoid characterized by localized concentrations of subhedral feldspar phenocrysts up to 8 mm across. Matrix consists of medium-grained biotite and sparse 5-mm hornblende crystals, and subequal proportions of quartz and feldspar crystals.

METAMORPHIC ROCKS

Inferred Middle Proterozoic age based on regional considerations.

Xgs — **Granitoid and schist, mixed (Middle Proterozoic)** - Tectonically mixed, interfoliated biotite-amphibole schist, amphibolite, pegmatite, and medium- to fine-grained granitoid.

Xg — **Equigranular granitoid (Middle Proterozoic)** - Consists of two strongly foliated varieties: Leucocratic variety consists of light-gray, coarse-grained, equigranular, biotite or garnet granitoid composed of 1% to 3% garnet, 15% to 20% biotite, 30% to 35% quartz, and 5% or less epidote, and two feldspars; biotite largely altered to chlorite. Mafic variety consists of medium-gray, mesocratic, medium- to coarse-grained, quartz-poor, equigranular granitoid composed of 15% to 35% biotite, amphibole, and epidote, and saussuritized feldspar. Also includes amphibole-rich melanocratic granitoid interleaved with biotite-amphibole schist on a scale of approximately 30 m.

Xgm — **Megacrystic granitoid (Middle Proterozoic)** - Light-gray, nonresistant, coarse-grained porphyritic granitoid containing less than 1% biotite. Quartz aggregates compose 30% to 35% of the rock and weakly define a foliation. White, anhedral feldspar phenocrysts measure 1 to 2 cm long and lie within or slightly oblique to the foliation. Grades into coarse-grained nonporphyritic granitoid (unit **Xg**).

Xs — **Schist (Middle Proterozoic)** - Dark- to medium-gray, quartzo-feldspathic biotite schist and quartzofeldspathic andalusite-muscovite schist.

Xam — **Amphibolite (Middle Proterozoic)** - Dark-gray, lineated, plagioclase-amphibolite schist in eastern Vulture Mountains.

Contact - Dashed where approximately located

Fault - Dashed where approximately located, dotted where concealed; ball and bar on downthrown side

Low-angle normal fault - Dashed where approximately located, dotted where concealed; hachures on upper plate

Strike and dip of strata and tabular lava flows

- 70 inclined
- 68 overturned
- vertical
- horizontal

Strike and dip of foliation

- 79 inclined
- vertical

42 **Dip of fault, intrusive contact, or depositional contact**

A A' **Line of cross section**

Prospect

Shaft

Portal or adit

ALTERATION AND MINERALIZATION

Propylitic alteration

Massive quartz veins ± specular hematite ± chrysocolla

Banded quartz veins that locally form stockworks and that are associated with hematite staining in wall rocks

Manganocalcite veins and pervasive manganous alteration

Alunite + chalcedony + clay

Pervasive iron-oxide staining

Sericitic alteration

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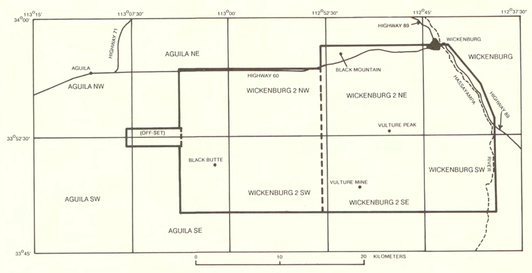
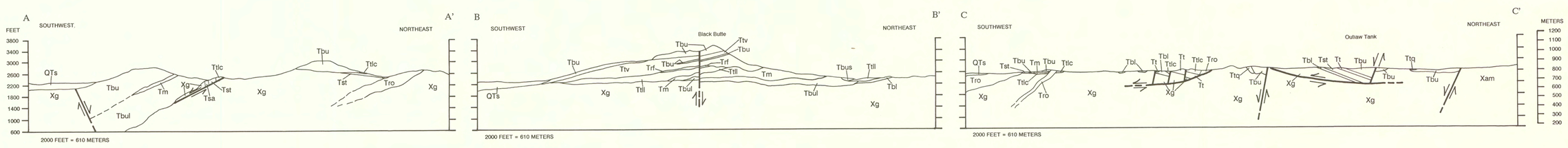
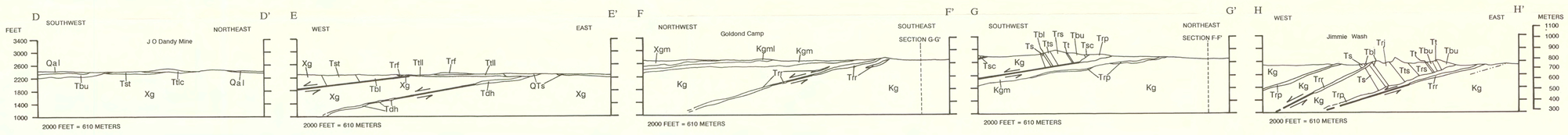
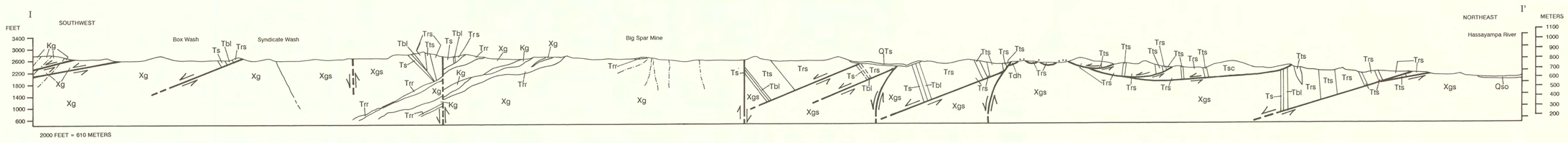


INDEX MAP SHOWING 7.5 MINUTE QUADRANGLES
COVERING THE STUDY AREA







SCALE 1:24 000

1 1/2 0 1 MILE

1 .5 0 1 KILOMETER

NO VERTICAL EXAGGERATION

CROSS SECTIONS

GEOLOGIC MAP OF THE VULTURE MOUNTAINS, WEST-CENTRAL ARIZONA

By

Michael J. Grubensky

1989

For sale by the Arizona Geological Survey,
845 N. Park Ave. #100, Tucson, AZ 85719