GEOLOGIC QUADRANGLE MAP
Published by the U.S. Geological Survey, 1977
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
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<tr>
<td>Contact</td>
<td>Dashed where approximately located; short dashed where inferred; dotted where concealed</td>
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<tr>
<td>Fault</td>
<td>Dashed where approximately located; short dashed where inferred; dotted where concealed</td>
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<tr>
<td>Fault, showing dip</td>
<td>Ball and bar on downthrown side</td>
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<td>Normal fault</td>
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<td>Fault—Showing relative horizontal movement</td>
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<tr>
<td>Thrust fault</td>
<td>Sawteeth on upper plate</td>
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<td>Anticline—Showing direction of plunge; dashed where approximately located; dotted where concealed</td>
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<td>Asymmetric anticline—Short arrow indicates steeper limb</td>
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<td>Overturned anticline—Showing direction of dip of limbs</td>
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<td>Syncline—Showing direction of plunge; dashed where approximately located; dotted where concealed</td>
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<td>Asymmetric syncline—Short arrow indicates steeper limb</td>
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<td>Overturned syncline—Showing direction of dip of limbs</td>
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<td>Monocline—Showing direction of plunge of axis</td>
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<td>Minor anticline—Showing plunge of axis</td>
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<td>Minor syncline—Showing plunge of axis</td>
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<tr>
<td>Strike and dip of beds</td>
<td>Ball indicates top of beds known from sedimentary structures</td>
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<td>Strike and dip of foliation</td>
<td>Inclined @ Horizontal</td>
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<td>Strike and dip of cleavage</td>
<td>Inclined ← Vertical → Horizontal</td>
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<td>Bearing and plunge of lineation</td>
<td>Inclined → Vertical ← Horizontal</td>
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<tr>
<td>Strike and dip of joints</td>
<td>Inclined ← Vertical → Horizontal</td>
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Note: Planar symbols (strike and dip of beds, foliation or schistosity, and cleavage) may be combined with linear symbols to record data observed at same locality by superimposed symbols at point of observation. Coexisting planar symbols are shown intersecting at point of observation.

<table>
<thead>
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<tr>
<td>Shafts</td>
<td>Vertical Inclined</td>
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<td>Adit, tunnel, or slope</td>
<td>Accessible Inaccessible</td>
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<td>Prospect</td>
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<td>Quarry</td>
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<td>Gravel pit</td>
<td>Active Abandoned</td>
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<tr>
<td>Oil wells</td>
<td>Drilling Shut-in Dry hole,</td>
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<tr>
<td>Gas</td>
<td>Show of gas abandoned</td>
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<tr>
<td>Oil</td>
<td>Show of oil</td>
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GENERAL GEOLOGY

The main physiographic feature of the Hayden quadrangle is the Dripping Spring Mountains, which trend northwest-southeast through the center of the map area and consist of Precambrian, Paleozoic, and Cretaceous rocks that are intruded by a wide variety of Cretaceous and Tertiary dikes and sills. The range is bounded on the north by the Dripping Spring Valley and on the south by the Gila River Valley. Both valleys were depositional basins for thick colluvial and lake sediments of Miocene age. Oligocene sediments have been exposed by faulting and erosion on the Gila River Valley but not in the Dripping Spring Valley. Complexly faulted Precambrian rocks crop out in the southwest corner of the quadrangle.

The oldest rock exposed in the quadrangle is the Ruin Granite of Precambrian Y age. It is unconformably overlain by Precambrian Y sedimentary and volcanic rocks of the Apache Group and the Troy Quartzite, which were deposited mainly in shallow marine environments; significant unconformities exist in this section. These Precambrian rocks are intruded by Precambrian Y diabase sills and dikes. Faulting accompanying intrusion of the sills did not appreciably tilt the large blocks of intruded sedimentary rock. Topographic relief developed by the intrusion and faulting during the Precambrian was greatly subdued but not entirely removed by erosion prior to Middle and Late Cambrian deposition of the Bolsa Quartzite and Abrigo Formation in shallow marine waters. Erosion and probable non-deposition during Ordovician, Silurian, and Early Devonian time removed only part of the relief remaining after deposition of the Cambrian sedimentary rocks; this resulted in a variable lithology and thickness for the Late Devonian Martin Formation. Slight tilting and faulting occurred during the long interval of early Paleozoic erosion. Dominance of stromatolitic structures and sublithographic dolomite in the Martin Formation suggests that it was deposited primarily near, or in, the intertidal zone. The overlying Upper Devonian Percha Shale (Schumacher and others, 1976) was deposited in a deeper marine environment.

The overlying Mississippian Escabrosa Limestone is locally slightly clastic and does not contain age-diagnostic fossils in its basal few meters, but above this interval, Osagean fossils have been identified (A. K. Armstrong, written commun., 1973), suggesting that a measurable period of erosion occurred in latest Devonian and earliest Mississippian time. Perceptible tilting did not occur during this erosional interval. Dominance of micritic and fine-grained limestone in the lower half of the Escabrosa Limestone suggests that it was deposited in relatively quiet, perhaps deep marine waters; bioclastic debris is much more abundant in the upper part of the formation, which suggests a comparatively more turbulent, perhaps shallower, marine environment during its deposition. Incomplete dolomitization occurs locally in both the basal and upper beds of the formation; dominance of saccharoidal dolomite and bleached and recrystallized chert in the basal dolomite beds suggests that the required magnesium solutions had a hydrothermal source, whereas sublithographic dolomite and pristine chert in the upper beds suggest that the upper incomplete dolomitization occurred by seepage reflux, perhaps from Pennsylvanian seawater. Silification and local solution brecciation of the uppermost beds-(deposited in Meramecian time; A. K. Armstrong, written commun., 1973) occurred during late Mississippian or earliest Pennsylvanian erosion but was not accompanied by tilting or faulting.

The erosion produced topographic relief on the Escabrosa Limestone and a varied lithology and thickness in the basal parts of the overlying sedimentary rocks, which contain no age-diagnostic macrofossils or fusulinids. S. B. Keith (oral commun., 1975) reports Late Mississippian conodonts for these basal beds. Overlying beds of the Naco Limestone were deposited during Morrowan (A. K. Armstrong, written commun., 1973) and perhaps through earliest Permian (Peterson and Swanson, 1956) time in a marine environment that fluctuated between conditions favorable to shale deposition and conditions favorable to deposition of chert-bearing carbonates. The Permian parts of these sedimentary rocks, if deposited in the quadrangle, were removed by erosion prior to deposition of the Late Cretaceous basaltic Williamson Canyon Volcanics. During this erosional period or during eruption of the volcanic rocks, olivine basalt locally intruded the Paleozoic section, preferentially forming sills a few meters to tens of meters thick at specific horizons of the Abrigo and Martin Formations and the Escabrosa and Naco Limestones.

Eruption of the Williamson Canyon Volcanics was dominated by explosive activity. As indicated by mega-brecia slides of Naco Limestone and older rocks in the volcanic pile in sec. 13, T. 4 S., R. 15 E., it also must have been accompanied or preceded by folding and faulting, perhaps along some of the major north-striking and north-west-striking faults used earlier for access by the Precambrian diabase. Deposition of the volcanic rocks was followed, and perhaps in part accompanied, by the development of a large number of generally east-striking faults, fissure faults, and generally northwest-oriented folds, by intrusion of dikes and sills of andesitic to quartz latitic rock, and only locally by development of intrusive breccias and pebble dikes. Field relations and correlation of petrologically identical rocks in this quadrangle with those in adjoining quadrangles suggest that deposition of the major sulfide...
ore bodies in the quadrangle occurred after most of these intrusive rocks were emplaced, or about 60 m.y. ago (Banks and others, 1972; Banks and Stuckless, 1973).

Tilting of the layered strata and movement on the major north-striking faults and on some of the east-west-striking faults recurred after deposition of ore but prior to deposition of the thick Oligocene and Miocene sedimentary formations—the San Manuel Formation, the Big Dome Formation, and the deposits in the Dripping Spring Valley. On some of these faults, movement and tilting of strata also occurred during, and between, and after deposition of the Tertiary formations in the Gila River Valley.

Post-Miocene events recorded in the rocks of the quadrangle include erosion, faulting, development and then dissection of several pediment surfaces; deposition of several thin clastic units; deposition of travertine along some faults; and development of present drainage and accompanying older and younger alluvial deposits.

**STRUCTURE**

Geologic structure in the Dripping Spring Mountains is dominated by an intricately patterned fault mosaic superimposed on a gently dipping sequence of rocks that have been arched into a broad, open anticline, plunging to the southeast (see also Eastlick, 1968). This general structure can be further classified into (1) the major northwest-southeast-oriented anticline, (2) minor folds with axial planes also oriented generally northwest-southeast, (3) four major north-south fault systems, (4) two major northwest-southeast-trending fault systems parallel to and near the Miocene sedimentary basins, and (5) many faults oriented 0°-35° north and south of east-west. Tilting of adjacent fault blocks during the faulting resulted in the extremely complex geologic relations of the range; the east-westerly faults provided the major channelways for emplacement of the Laramide igneous rocks.

From west to east across the quadrangle, the major north-south fault systems are the Cowboy, Kelly Springs, Keystone, and O'Carroll faults. The occurrence of Precambrian diabase sills at different stratigraphic horizons across the first three of these fault systems suggests that they were active during emplacement of the diabase, but data neither determine nor negate Precambrian movement on the O'Carroll fault. Combined Precambrian to post-Laramide normal displacement on these north-south fault systems may have resulted from a right-lateral shear couple along the north-south faults. However, large lateral movement on the range-front faults is not compatible with slight offset of Laramide dikes and Precambrian contacts across the Gila River—Mineral Creek Valley (Cornwall, Brooks, and Phillips, 1971). East of the town of Hayden, the range-front fault on the southwest side of the mountains displaces the Miocene Big Dome Formation, but significant post-Miocene displacement did not occur on this fault north of Keystone Canyon or along the range-front fault north of the mountains.

Displacement along the many faults oriented 0°-35° north and south of east-west are much smaller than the major north-south-striking and range-front faults discussed above, and many are fissure fractures with little or no displacement. Most of these east-westerly faults apparently developed during Laramide time because many are both parallel to and intruded by the Laramide dikes. Thus, both the major and minor fault systems, and the major northwest-southeast-oriented folds whose hinge regions were intruded by Laramide dikes, had major development during Laramide time. These structures therefore provided ground preparation for fluid (magma and hydrothermal) access during the time that sulfide ore bodies developed in this and the adjacent quadrangles, and interpretation of the stress responsible for their formation is of potential economic interest.

The thin east-westerly dikes did not have enough thermal energy to stop their way through at least 600 m of carbonate rocks in the exposed section, and they do not show evidence of calcium-magnesium assimilation (no pyroxene). They likewise show only rare evidence of forceful intrusion. Thus, their abundance, lateral continuity, and narrowness suggest that they were most likely intruded in a tectonic environment involving northwest-southeast extension or tension. This condition could have resulted from generally northwest-southeast directed right-lateral tectonic shearing or approximately east-directed compression. However, the left lateral offset of the Laramide dikes on the major north-south faults is not compatible with right lateral movement on the range-front faults, and east-west compression is supported by the observed northwesterly folds and the general anticlinal character of the Dripping Spring Mountains. It also is suggested on a more
regional scale by similar orientation of dike sets and sulfide veinlets in nearby quadrangles and elsewhere in Arizona (Cornwall and others, 1971; Cornwall and Krieger, 1975a, b; Krieger, 1974a, b; Wilden, 1964; Rehrig and Heidrick, 1972) and by northwest-striking thrust faults to the southwest (Krieger, 1974c). This approximately east-directed compression might have originated in movement of lithospheric plates in Laramide time. Because each dike set in the Hayden quadrangle has its own particular northeast and northwest orientations that are not matched exactly by those of the next younger dike set, the orientation of regional stress probably fluctuated with time during Laramide igneous and structural activity. Thus, both dike sets and sulfide veinlets may occupy tensional features, and exploration basinward along projections of the most extensive dike swarms, which indicate potentially favorable channelways for deep fluid sources, could be profitable. Alternatively, because the sulfide veinlets cut the Laramide rocks, the sulfide-bearing fluids might have traveled still another set of fractures oriented east-west but not necessarily on or parallel to the particular set of dikes on which a deposit might center. Thus, if all the Laramide sulfide deposits in the quadrangle developed at approximately the same time, the zone of major fluid access might have extended N. 80° W. from Christmas mine through the New Year, Chilito, and 79 mines, which suggests possible exploration ground N. 80° W. of 79 mine and N. 100° E. of Christmas mine. It is noteworthy that N. 80° W. of the 79 mine in Miocene alluvial deposits are manganese oxide-barite-jasperoid deposits (presumably hot springs deposits) that carry base metal anomalies and, as expected, that base metal anomalies in the bedrock parallel the zone occupied by the major known sulfide deposits rather than any particular dike swarm (N. G. Banks and R. D. Dockter, unpub. data).

Only a small part of the Tortilla Mountains occurs in the Hayden quadrangle (southwest corner). The structure of complexly faulted bedrock in this part of the quadrangle is discussed by Krieger (1974c).

MINERAL DEPOSITS

Some of the metallization and alteration associated with the Christmas deposit, owned by Inspiration Consolidated Copper Co., occurs at the east-central edge of the quadrangle in secs. 19, and 30, T. 4 S., R. 15 E. (unsurveyed). From discovery through 1974, the deposit produced 279,250,300 pounds of copper (J. T. Eastlick, written commun., 1975), first in surface and underground mining of replacement beds in the Martin Formation, and the Escabrosa and Naco Limestones and later by open-pit mining, part of which includes stockwork mineralization. More detailed descriptions of the deposit are found in Eastlick (1968), Wilden (1964), Peterson and Swanson (1956), and Ross (1925).

About 3 km northwest of the Christmas deposit in SW cor. sec. 13 and NW cor. sec. 24, T. 4 S., R. 15 E., is Santa Monica Camp (originally the Premier mining group reported by Ross, 1925). About 400 m of adits and drifts have been made in the area, and about $70,000 worth of gold was reportedly produced from one of the main workings (J. T. Eastlick, written commun., 1975). The gold occurs as native gold in thin seams with iron and manganese oxides. The copper mineralization occurs as oxidized veins and replacement ore bodies immediately adjacent to the veins. At the surface, these veins are mostly jasper or spongy quartz, heavily stained with hematite, jarosite, and goethite; some veins show one or more of the following: manganese oxides, cerussite, anglesite, galena, copper carbonates, wulfenite, vanadinite, and hemimorphite.

The New Year mine, about 2.5 km N. 80° W. of Christmas mine, produced about 1,000 tons of lead ore and about 50 tons of zinc ore according to Ross (1925); there are four or more shafts including the Curtain shaft (reportedly 100 m deep, J. T. Eastlick, written commun., 1975), several adits, many prospect pits, and other surface workings. Alteration minerals in igneous rocks of the area include quartz-sericite, kaolinite, and propylitic minerals (epidote, chlorite, carbonate), and carbonate rocks have been variably converted to skarn. Eastlick (1968) reports galena, anglesite, cerussite, and hemimorphite as the major ore minerals.

About 1.5 km N. 80° W. of New Year mine is the Chilito mine (Kennecott Copper Corp.), a small- to medium-sized stockwork-vein-disseminated porphyry copper deposit presently (1975) worked under contract to provide silica flux for the Kennecott Copper Corp. smelter at Hayden. Alteration minerals include hydrothermal biotite, quartz-sericite, epidote, chlorite, and carbonate minerals. Hypogene chalcopyrite, pyrite, molybdenite, and anhydrite are present in the relatively oxidized parts; at least $200,000 of supergene galena-calcite ore was produced from the Schneider claims prior to 1913 (Ransome, 1923) in secondarily enriched pyrite in replaced beds of the Mescal Limestone west of the present open pit. Chilito produced about $1/4 million worth of ore during World War I (Eastlick, 1941).

Mineralization probably associated with Chilito encouraged development of small producing mines 1 km northeast (Apex or San Bernardo Jr. mine), and also east, southeast (Lavell mines), and south (London-Arizona mine) of Chilito along the east side of Schneider Canyon. Most of this mining activity focused on the upper beds of the Abrigo Formation and in the O'Carroll bed (local name) in the Martin Formation. The largest producer was the London-Arizona mine (about $1 million; Eastlick, 1968). The Lavell mines are said to have produced about $10,000 worth of gold ore (Ransome, 1923); the Apex mine produced about $20,000 worth of gold from oxidized lead ore and also some high-grade gold ore (Ross, 1925); and the London-Arizona produced at least 15,000 tons of ore averaging 4.5 percent copper. Minerals associated with these deposits include chalcopyrite, pyrite, pyrrhotite, copper carbonates, cuprite, chalcocite, cerussite, galena, wulfenite, native gold, andradite, specularite, quartz, idocrase, magnetite, serpentine, and anhydrite.

A few small adits and prospect pits that probably shipped no ore occur within 1 km to the northwest and southwest of Chilito mine. A little over 1 km southwest of London-Arizona mine, some workings in the upper Abrigo Formation and lower Martin Formation may have produced a few carloads of ore (probably gold) from oxidized veins and replacement bodies; the Hogvall prospect (Ross, 1925) is among these workings.

The 79 mine, in the approximate center of the quadrangle, was discovered in 1879 and worked intermittently through the 1950's. Production prior to 1947 was about 110,000 tons of mixed oxide and sulfide ore valued at between $3 million and $4 million (Kiersch, 1947). The ore came from vein and bedding replacement
ore primarily in the Martin Formation and Naco Lime­stone (Eastlick, 1968; Keith, 1972). In addition to
surface workings, the mine includes the main incline,
seven levels, and over 3,000 m of tunnels and stopes
(Keith, 1972). Near the surface is oxidized galena ore
with cerussite, anglesite, sphalerite, chalcopyrite, des­
cloizite, vanadinite, wulfenite, hematite, and some pyrite
and copper carbonates. The zinc content of the ore
increases with depth (Eastlick, 1968). The ore deposits
at the mine are discussed in detail by Kiersch (1947),
and a more complete list of minerals present in the
mine is presented by Keith (1972). Many prospect
pits, small shafts, and adits are scattered in sec. 21
and along its border with sec. 22, T. 4 S., R. 15 E., to
the north of the main 79 mine workings.

Along Keystone Canyon, 1½ km south of 79 mine,
are the Regan Camp prospects. Kiersch (1947) reported
that several carloads of oxidized lead ore were produced
from the irregular and scattered workings, mostly in
replacement ore bodies and veins along a fault cutting
Naco Limestone, south of Keystone Canyon. In addition
to the oxidized galena ore, wulfenite, vanadinite, and
copper carbonates occur on the prospect dumpes. Similar
minerals and also manganese oxides occur on the dump
of the Overland mine near SE cor. sec. 28, T. 4 S., R. 15
E.; this mine consists of a main shaft and probably a few
short tunnels that may have produced one or two car­
loads of oxidized lead ore.

Just north of the quadrangle is the Barbarosa mine,
reported by Ransome (1923) to have produced $2,000-
$3,000 worth of gold by dry washing alluvium deposited
on Troy Quartzite on gully slopes. Associated workings
occur in this quadrangle in and east of sec. 36, T. 3 S., R.
14 E. The gold most likely came from vein and re­
placement ore in the overlying Abrigo Formation and
Martin Formation. Several prospects in Mescal Lime­
stone, south of the Barbarosa mine in this quadrangle,
show oxidized lead-zinc minerals.

Extensive jasperoid-barite reefs and associated cross­
cutting manganese oxide and carbonate veins and bed­
ding replacement bodies occur in the Miocene Big Dome
Formation in an area of over a square mile centered in
NW cor. sec. 19, T. 4 S., R. 15 E. Both the jasperoid­
barite and manganese-carbonate mineralization extends
into nearby older rocks. The strongest veining is oriented
northwest-southeast. The mineralization carries base
metal and vanadium-tungsten anomalies, and copper
staining was observed at several localities (N. G. Banks
and R. D. Dockter, unpub. data). Prospecting of the
deposit has been extensive, but it is estimated that less
than 1,000 tons of high-grade manganese ore has been
shipped from the properties. High-grade manganese ore
is better developed in the southeast part of the deposit
relative to the northwest part. The geologic location,
cofolorm banding of the jasperoid and manganese,
mineralogy, open vugs, and a mercury-antimony anomaly
favor a hot-spring origin for the deposit. Its position
westward along the projection of a chain of Laramide
sulfide deposits suggests that remobilized Laramide
sulfides might account for the base metal anomaly.

About ½ km northeast of Kelly Springs are several
prospects and minor shafts with oxidized galena, spha­
erite, smithsonite, and minor amounts of copper carbo­
nate. Silver concentrations of 1,100 ppm were detected
in a sample of lead-rich rock from the dump of one
prospect.

Scattered prospects on generally weak shows of min­
eralization are peripheral to each of the mining localities
described above. Mineral showings in addition to those
described above occur east of Hayden on the north and
south sides of the Gila River and also along epido­
tite alteration zones in the volcanic rocks southwest of the
Christmas mine.

ACKNOWLEDGMENTS

The writers are very grateful to the Inspiration Con­
solidated Copper Co., particularly Chief Geologist, John
T. Eastlick, for access to its properties, drill hole infor­
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mines, and for maps, history, and production of
workings between the Christmas and Chilito mines.
The management and geologic staff of Kenneocott Copper
Corp., Ray Mines Division, in particular Neil A. Gambell,
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concerning the jasperoid-manganese deposit south of
Steamboat Mountain and the Chilito properties.Bernardo
and Connie Velasco provided friendship and access to
and information about their properties north of Chilito
mine. We are also grateful for the access granted us by
the several ranchers in and near the quadrangle, particu­
larly to Walter and Wynonna Barrup who provided a
site and facilities for one season's base camp.

Augustus K. Armstrong provided us with his unpub­
lished fossil and stratigraphic data from the Escabrosa
and Naco Limestones and also correlated several fossil
collections from the Naco Limestone with his sections.
Randolph A. Koski provided some thin sections from
the Williamson Canyon Volcanics.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qd MINE DUMP — Waste from open-pit mining oper­
atons
Qal ALLUVIUM — Gravel, sand, and silt deposits in
stream channels and on young low-lying
teraces along streams
Qt TALUS — Accumulations of large to small angular
blocks at or near the base of cliffs and
steep slopes
Qls LANDSLIDE DEPOSITS — Several slides of Naco
Limestone in sections 35 and 36, T. 4 S.,
R. 15 E., and one coherent slide block and
accompanying debris along the Gila River
(Sec. 12, T. 5 S., R. 15 E.)
Qtr TRAVERTINE — Calcium carbonate deposits oc­
curring along faults in Steamboat Wash (secs.
1 and 12, T. 4 S., R. 14 E.) and east of
Hayden townsite
Qp SOIL AND GRAVEL VENEER (0-8 m) — Reddish­
brown soil and gravel with subangular to sub­
rounded pebble to boulder clasts from older
rocks. Deposited on terrace surfaces of several
ages along the Gila River Valley, Dripping
Spring Wash, and major drainages out of the
Dripping Spring Mountains. Limestone clasts
are rare even where deposits overlie carbonate
rocks or limestone conglomerate
Qog OLDER GRAVELS (0-15 m) — Grayish to yel­
lowish-white carbonate-cemented gravels and
conglomerates deposited along but at higher
levels than present channels, streams, and washes. Clasts are subrounded pebbles, cobbles, and small boulders of older rocks exposed along adjacent drainage. Includes deposits of several ages

**QTv VEINS** — Red jasperoid-barite-manganese oxide and manganese oxide-calcite veins and replacement bodies with local base metal anomalies

**DEPOSITS IN DRIPPING SPRING VALLEY (0–460 m)** — Interfingering alluvial and lakebed deposits exposed in the Dripping Spring Valley; age unknown, tentatively correlated with Big Dome Formation on the basis of lithology but part might be as young as Quiburis Formation (Miocene or Pliocene age) of San Pedro Valley

**Tgv CONGLOMERATE (0–150 m)** — Facies dominated by angular to subangular pebble- to boulder-size clasts of Williamson Canyon Volcanics and Cretaceous and Tertiary intrusive rocks. Matrix is greenish gray, sand size, and composed mainly of decomposed volcanic and intrusive rocks. Induration is poor to slight

**Tg CONGLOMERATE (0–460 m)** — Conglomerate facies with subangular to subrounded clasts representing all pre-Miocene rocks in proportions and size that vary with proximity to and composition of the adjacent bedrock exposures. Matrix of silt- to small-pebble-size material (varying with composition of adjacent bedrock) is well cemented, particularly near bedrock, and is light olive gray to light tans and browns. Poorly sorted and bedded near bedrock; moderately well sorted and bedded in transitional facies with lakebed facies

**TI CLAY, SILT, AND SAND (0–unknown but at least 300 m)** — Lakebed facies; interbedded clay, silt, and fine sand. Clay-rich beds, locally with lenses and veins of gypsum, are most abundant near and south of SE cor. sec. 35, T. 3 S., R. 15 E. The clay-rich beds, probably representing the center of the depositional basin, are orange pink to very pale brown and grade southwestward and northeastward into grayish beds containing progressively more silt and then progressively more sand; beds of freshwater limestone are present and become increasingly abundant on the east side of the basin. Interbedded tuffs (<3 m) are most apparent north of Dripping Spring Wash; alteration of the tuffs is variable; glass shards in one tuff have a refractive index slightly greater than 1.495

**BIG DOME FORMATION (0–460 m)** — An alluvial deposit having four facies in this quadrangle (see also Krieger and others, 1974; Cornwall and Krieger, 1975a) and two interbedded tuffs, one of which gives K-Ar ages of 14 m.y. (biotite) and 17 m.y. (hornblende) (Cornwall and others, 1971; Banks and others, 1972)

**Tbg CONGLOMERATE (0–300 m)** — Facies dominated by subangular pebble- to boulder-size clasts of Ruin Granite and variable amounts of other pre-Miocene rocks; few clasts of Miocene Apache Leap Tuff (Peterson, 1969) and Paleozoic limestone except near boundary with sandstone and conglomerate facies. Matrix is pale-yellowish-brown to yellowish-gray sand-size material derived from decomposed and abraded granite. The clast/matrix ratio generally decreases northeastward. Beds are poorly indurated, bedded, and sorted. Shallow channeling is common. The main source area for this facies was to the west or south

**Tbs SANDSTONE AND INTERBEDDED CONGLOMERATE (0–300 m)** — Facies with arkosic, poorly indurated sandstone and interbedded conglomerate. The clasts consist of variable amounts of all pre-Miocene rocks. Matrix of the conglomerate is arkosic, calcareous, and sand sized. Large well-rounded clasts of Apache Leap Tuff (derived from northwest of the quadrangle) are common, and locally abundant; conglomerate beds with limestone clasts dominant are abundant in basal beds. Facies occupies approximate center of the Big Dome Formation depositional basin

**Tbl CONGLOMERATE (0–460 m)** — Facies dominated by subrounded pebble- to boulder-size clasts of Paleozoic limestone and variable, mostly minor, amounts of other pre-Miocene rocks. Matrix is light-gray, calcareous, and well-indurated sand- to granule-size material derived mostly from disintegration of Precambrian and Paleozoic sedimentary rocks

**Tbv CONGLOMERATE (0–400 m)** — Facies dominated by angular to subangular pebble- to boulder-size clasts of Williamson Canyon Volcanics with locally abundant clasts of Cretaceous and Tertiary intrusive rocks. Clasts of Precambrian and Paleozoic sedimentary rocks are present but in amounts especially close to bedrock outcrops. Clasts become smaller and less abundant relative to matrix southwestward from the bedrock contact. Matrix is greenish gray, sand size, and composed mainly of disintegrated volcanic and intrusive rocks. Induration is poor. Contains a few thin, highly altered white tuff beds that include clinoptilolite, a zeolite

**Tbtl LAPILLI TUFF (9 m)** — Series of beds of thinly laminated to massive, white to tan, rhyolitic tuff, tuffaceous sandstone, and pumice lapilli tuff and interbedded sandstone and conglomerate lenses. Some shards and pumice lapilli are altered to clay minerals; glass in unaltered shards is rhyolitic (refractive index of 1.496). The lapilli are white (altered) or light gray (unaltered) and generally are 1–4 mm in diameter, although they are as much as 3 cm in diameter in middle bed where they are closely packed. Exposed in the SW¼ sec. 12, T. 4 S., R. 14 E.; widely exposed in adjacent Kearney quadrangle (Cornwall and Krieger, 1975a)

**Tbql QUARTZ LATITE ASH-FLOW TUFF (6 m)** — Nonwelded to partly welded ash-flow tuff; pinkish
gray to pale red; basal 1 m is grayish white to grayish pink. Crops out in NW¼ sec. 1, T. 5 S., R. 14 E., and intersected in drill hole SE¼ sec. 12, T. 4 S., R. 14 E. (Neil Gambell, written commun., 1971). Phenocrysts and crystal fragments 0.5-1 mm in diameter are relatively abundant and, in order of decreasing relative abundance, they are sanidine, plagioclase (An28), biotite, quartz, magnetite, hornblende, and sphene. Pumice lapilli, usually less than 5 mm long, are sparse. X-ray analysis of the groundmass in the upper pink part indicates only traces of cristobalite and sanidine, suggesting relatively little devitrification and alteration, whereas at least half of the glass in the lower white part and in 1-mm- to 1-cm-thick rings surrounding lithophysae has been altered to clay minerals. Glass and much of the plagioclase in specimens from the drill hole have been altered to calcium-rich montmorillonite

**SAN MANUEL FORMATION (0->600 m) —** Alluvial and playa deposits with several facies (Krieger and others, 1974; Cornwall and Krieger, 1975a) and interbedded tuffs. Several K-Ar ages for samples in the upper part of the formation, 17 m.y. for biotite from one tuff, Cornwall and Krieger (1975a); 18 m.y. for biotite and 24 m.y. for sanidine from another (Krieger, 1974a) indicate a late Oligocene and early Miocene age for the formation. Overlain on an angular unconformity by the Big Dome Formation

**Tsda DARK CONGLOMERATE (0->450 m) —** Well-bedded and indurated conglomerate with subangular to subrounded pebble- to cobble-size (locally boulder) clasts of Williamson Canyon Volcanics, Late Cretaceous and Tertiary intrusive rocks, Precambrian sedimentary rocks and diabase, and, locally abundant, Paleozoic limestone; clasts of Ruin Granite are present but nowhere dominate. Matrix is calcareous, light olive gray to pale brown, and composed of silt- to granule-size material that varies in composition. Bedding ranges from about 1 cm to 2 m; a few thinner beds lack clasts. Channels with crossbedded sandstone are common

**Tst RHYOLITE(?) TUFF (about 0.2 m) —** White fine-grained tuff and medium- to coarse-grained tuffaceous sandstone and sandy tuff of probable rhyolitic composition; contains biotite, hornblende, plagioclase, sanidine(?), and quartz, with traces to 1 part in 10 of clay. Glass shards and matrix have been completely altered to clinoptilolite

**LARAMIDE INTRUSIVE ROCKS —** Laramide intrusive rocks in the area range in chemical composition from diorite to quartz monzonite. Because of their aphanitic to very fine grained groundmass they are termed herein andesite to quartz latite, but equally applicable terminology would be hornblende diorite porphyry, granodiorite porphyry, and quartz monzonite porphyry. The rock types and compositions were determined by counting from stained rock slabs and thin sections and by chemical analyses of petrologically identical rocks in adjacent quadrangles (Banks and others, 1972; Ransome, 1919). Potassium-argon and fission-track dating in the adjacent quadrangles (Banks and others, 1972; Banks and Stuckless, 1973; Damon and others, 1970; Creasy and Kistler, 1962; Damon and Bikerman, 1964) suggests ages of 63-60 m.y. for the Laramide rocks designated as Tertiary. All rock types are variable in composition and appearance, even along and across individual dikes, making classification of some of the dikes difficult. The dikes occupy fractures, faults, and, in places, fold hinges; some dikes terminate upward before traversing the entire geologic section, and some abut against other dikes without cutting them. In general, intrusion appears to have been passive; the exceptions are the intrusive breccia (Kb) in and adjoining sec. 31, T. 3 S., R. 15 E., parts of the contacts around the plug of Tr2, at Chilito, a breccia pipe (3-5 m across) just south of New Year mine (breccia also in drill core), and pebble dikes in the NW¼ sec. 7, T. 5 S., R. 16 E. Skarn occurs in limestone wallrock near some of the intrusive bodies, but it may locally also replace the igneous rock (endoskarn); it is better developed at sill bases than at sill tops. These observations and the variable, and in many places negligible, amount of skarn or calcium silicate metamorphism along the same dike suggest that the fluids involved did not directly evolve from the dikes or sills

**Tha HORNBLENSE ANDESITE PORPHYRY —** One dike exposed in two localities (northern parts of secs. 14 and 15, T. 4 S., R. 15 E.) oriented N. 80° W., cuts Tr2a. Phenocrysts make up about 43 percent of the rock as follows: subhedral to euhedral, lath and blocky plagioclase 1-3 mm long, with some plagioclase crystals totally altered to sericite (about 20 percent); euhedral 1-7-mm-long laths of hornblende (about 20 percent), totally altered to chlorite, calcite, and hematite clots; subhedral magnetite, as much as 1/3 mm in diameter (about 2-3 percent). The hornblende occurs in pigeon-track-like arrangements. The aphanitic groundmass composes about 57 percent of the rock; it is greyish gray to greenish gray, and consists of 0.08 mm laths of highly altered plagioclase and opaque clots; sericite, calcite, clays, chlorite, and quartz are interstitial. The dike is foliated parallel to its margins

**Tr3 RHYODACITE PORPHYRY —** Four dikes (located in SW¼ sec. 6 and NE¼ sec. 7, T. 4 S., R. 15 E.; and northern and southern parts of sec. 12, T. 5 S., R. 14 E.) that are generally similar to Tr3 of Cornwall and others (1971). One dike (NE¼ sec. 7, T. 4 S., R. 15 E.) cuts Tr2a+ dike; lacking crosscutting relations, the other three dikes might be equivalent to rhyodacite porphyry (TKr) of Cornwall and
Tq11 QUARTZ LATITE PORPHYRY — Spear-shaped (point to the southwest) dike swarm up to 2 km wide extending from west of the 79 mine, in the center of the quadrangle, to the east edge of the Dripping Spring Mountains; main dike orientations are N. 60° E., E-W±10°, and a few N. 30° E.; main orientation of the dike swarm changes from northeasterly to east-westerly in the approximate middle of the fault block between the Keystone and O’Carroll faults. Commonly cut by sulfide veinslets near major mining camps. Best exposed relations with next older rock (Tr2a) occur in the NE¼ sec. 15, T. 4 S., R. 15 E.; cuts rhyodacite porphyry (TRKl) at many localities. Phenocrysts compose 30-70 percent of the rock as follows: euhedral blocky oligoclase-andesine, ½-5 mm long, with some glomerocrysts to 12 mm (20-45 percent), euhedral to resorbed and embayed quartz dipyramids, ½-6 mm in diameter, with glomerocrysts to 10 mm in diameter (8-15 percent), euhedral orthoclase, 1-10 mm long (highly variable in amount across, along, and between dikes; relative to dikes 1-10 percent, relative to hand specimens 0-30 percent); euhedral biotite, ½-8 mm in diameter (5-15 percent); euhedral to resorbed magnetite (having sphene rims in some specimens) as much as 0.5 mm (usually less than 1 percent). Groundmass makes up 30-70 percent of the rock, is white to yellowish cream, is aphanitic to vitric with polycrystalline to aphanitic texture and grain sizes of 0.02-0.03 mm, and has an approximate composition relative to the whole rock of 2-6 percent plagioclase, 8-20 percent quartz, 15-45 percent orthoclase; 1-2 percent biotite and opaque minerals. Accessory minerals are apatite, zircon, and, locally, sphene. Plagioclase is moderately to highly altered to sericite, montmorillonite, kaolinite, calcite, K-feldspar, and epidote. Biotite is almost totally altered to chlorite, phengite, quartz, epidote, and titanium minerals. The orthoclase phenocrysts are intensely altered locally to kaolinite. This dike type is lithologically identical to and correlated with the Teapot Mountain Porphyry of Cornwall and others (1971) and Cornwall and Krieger (1975a). On the basis of geologic relations and fission-track and K-Ar dating of older and younger units (Banks and others, 1972; Banks and Stuckless, 1973), this rock type is probably younger than about 62 m.y. and older than about 60 m.y.

RHYODACITE PORPHYRIES — There are two main varieties of older rhyodacite porphyry. The first is a quartz-phenocryst-bearing variety that correlates with the rhyodacite porphyry in the Sonora quadrangle (unit TRk2) of Cornwall and others (1971) and the Kearny and Grayback quadrangles (unit TR2) of Cornwall and Krieger (1975a, 1975b). The second is a quartz-phenocryst-poor or quartz-phenocryst-free variety (TRK1).
that correlates with unit TKr1 of Cornwall and others (1971). In this report the first or quartz-bearing variety is further divided into four types (Tr2, Tr2a, Tr2b, and Tr2c), on the basis of restricted geographic occurrences of several petrologically distinguishable types. The differences between the four quartz-bearing rhyodacite porphyries include the number, size, and relative amounts of the main phenocryst minerals and the amount, color, grain size, and texture of the groundmass material.

Crosscutting relations between the four quartz-bearing types are unknown because of their separate geographic locations, and most of the crosscutting relations indicated between the quartz-bearing type (Tr2) and the quartz-poor or quartz-free variety (TKr1) are questionable or interpretive because mutually similar facies (quartz-bearing TKr1, indicated by TKr1*), poor exposures, and moderate to intense alteration in areas of mineralization make identification of rock types and contacts difficult. Examples of questionable or interpretive crosscutting relations of TKr1 type by Tr2 type are north of Tornado Peak, in the New Year mine area, and in the area west of Christmas mine (unsurveyed sec. 30, T. 4 S., R. 16 E.). The southernmost Tr2 dike (flagged with a dagger - t -) crosscuts a sill of TKr1 type rock in sec. 26, T. 4 S., R. 15 E. The chilled selvages of this dike are thicker but otherwise similar to those of other Tr2 dikes, and the dike has comparatively fewer quartz phenocrysts, particularly in outcrops where the dike thins. Otherwise, it is petrologically similar to and is intruded parallel to the other Tr2 dikes.

Some of the dikes of units Tr2a and Tr2b are also designated with a dagger (†), indicating lower than normal counts of quartz phenocrysts. Some of the Tr2a† dikes might be equally well classified as TKr1 dikes. Geologic relations between the various rhyodacite dikes and even the older hornblende andesite porphyry (Kha) dikes are not always clear cut because of mutually similar facies or alteration. Examples are found in the NE¼ sec. 12, T. 5 S., R. 15 E., where Tr2b cuts Tr2b†, and it is not certain whether the Tr2b† dike might not be a Kha dike. At another locality (sec. 7, T. 5 S., R. 16 E.), it is not certain that the Tr2b† dike cutting the hornblende andesite porphyry sill might not be a Tr2b dike in which quartz is present but was not observed. In addition, highly altered hornblende andesite porphyry is very similar to altered rhyodacite porphyry (unit TKr1), such as near New Year and Christmas mines.

**Tr2 RHYODACITE PORPHYRY** — Four or more dikes composing a dike set located south of the Tq11 dike swarm and trending about N. 80° W. from the Christmas mine through the New Year mine area to the Chilito mine area; this rock makes up the Chilito intrusive and the Christmas intrusive; heavily mineralized by sulfides at the Christmas, New Year, and Chilito mines and also south of Schneider Canyon to the west of the Keystone fault. Like the Tq11 dike swarm, this dike set changes orientation in the approximate center of the fault block between the Keystone and O'Carroll faults. Phenocrysts make up 35-65 percent of the rock as follows: euhedral blocky andesine-labradorite, ¾-9 mm long with common glomerocrysts to 10 mm in diameter (20-50 percent; lower values in dike selvages); euhedral to embayed quartz dipyramids, ¾-9 mm in diameter (<1-15 percent; low values in Tr2†, and in dike selvages); euhedral to subhedral lathlike to acicular hornblende, ¾-4 mm long, sometimes glomerocrystic (5-20 percent; higher values in dike selvages); euhedral to subhedral biotite, ¾-5 mm in diameter (<1-10 percent; lower values in dike selvages); euhedral to resorbed blocky magnetite, less than 1 mm in diameter (<1-2 percent); and a few large euhedral apatite grains. Groundmass makes up 35-65 percent of the rock; is light brownish or greenish gray or cream (chilled margins are medium gray to cream); is very fine grained to aphanitic with aplitic to hypidiomorphic texture and grain sizes of 0.01-0.04 mm; and has the approximate composition relative to the whole rock of 10-20 percent plagioclase, 15-20 percent K-feldspar, 10-15 percent quartz, and 1-10 percent mafic silicates and opaque minerals. Accessories are apatite, zircon, and rarely sphene and allanite. Plagioclase is variably altered to sericite, montmorillonite, K-feldspar, calcite, and epidote. Biotite usually is completely altered to chlorite, epidote, quartz, and titanium minerals. Near the Chilito deposit, the primary biotite and some of the groundmass is converted to intergrown aggregates of hydrothermal biotite and, locally, to phengite. Hornblende is usually less altered than primary biotite, being partially converted to epidote and carbonate, except near the Chilito deposit where it is converted to hydrothermal biotite. Magnetite usually is marginally oxidized to hematite. K-feldspar in the groundmass appears slightly altered, except in highly altered rock near the Chilito deposit where it is absent and possibly replaced by hydrothermal biotite. This rock has been dated in nearby quarangles; the K-Ar method on biotite at 62 m.y. (Creasey and Kistler, 1962), 63.1 m.y. (Damon and others, 1970), and 62.1 m.y. (Banks and others, 1972). A representative chemical analysis of the rock is given in Ransom (p. 66, 1919).

**Tr2a RHYODACITE PORPHYRY** — One dike set trending about N. 80° E. across the Dripping Spring Mountain from just north of Steamboat Mountain and one 2.2-km-wide dike swarm located north of the Tq11 dike swarm and trending about N. 60°-65° E. in the fault block west of Keystone fault and about N. 60°-80° E. in the block east of Keystone
fault. The dike type is locally cut by sulfide veins and is very similar to the Tr2c dike type but differs from it in having generally more abundant and smaller plagioclase phenocrysts. As exposed, these dikes do not crosscut older Laramide rocks, and their relations with Tq12 in sec. 17, T. 4 S., R. 15 E. are not exposed. Quartz-poor dikes are flagged with a dagger (†). Phenocrysts make up 45–70 percent of the rock as follows: euhedral blocky andesine, \(\frac{3}{4}\)-4 mm long with common glomerocrysts to 7 mm in diameter (35–55 percent); euhedral to embayed quartz dipyramids, \(\frac{3}{4}\)-5 mm in diameter (trace–15 percent); euhedral biotite, \(\frac{3}{4}\)-3 or 4 mm in diameter (2–15 percent); euhedral lathlike to acicular hornblende, \(\frac{3}{4}\)-3 mm (0–8 percent); euhedral magnetite, 0.1–0.2 mm in diameter (<1 percent); and a few large apatite grains. Groundmass makes up 30–55 percent of the rock; has various colors, such as very light tan to pale brown, pale yellowish white, pale yellowish green, pale to medium flesh, and light pinkish or greenish gray; is aphanitic to very fine grained with aplitic to hypidiomorphic granular textures (trachytic in dike selvages); has grain sizes of 0.03–0.06 mm; and has approximate composition relative to the whole rock of 15–25 percent plagioclase, 15–20 percent K-feldspar, 8–15 percent quartz, 4–7 percent mafic minerals, and 1–2 percent opaque minerals. Accessory minerals are apatite, zircon, and locally allanite. Plagioclase is slightly to heavily altered to sericite, carbonate, and montmorillonite. Hornblende is slightly to totally altered to carbonate, chlorite, iron oxides, and phengite. Biotite is heavily to totally altered to chlorite and titanium minerals. Magnetite is marginally altered to hematite.

Tr2c RHYODACITE PORPHYRY — Several dikes trending N. 70°–80° E. occur in the northwest corner of the quadrangle north of the Tr2a dikes and one dike occurs in the southeast part of the quadrangle along the Gila River. Dikes are cut by sulfide veins and the dike along the Gila River cuts a hornblende andesite porphyry dike (Kha); relations with other Tertiary or Cretaceous igneous rocks are not exposed in the quadrangle. Phenocrysts make up 45–60 percent of the rock as follows: euhedral blocky andesine \(\frac{3}{4}\)-5 mm long, abundant glomerocrysts up to 15 mm in diameter (35–50 percent); euhedral to embayed quartz dipyramids, \(\frac{3}{4}\)-6 mm in diameter (5–15 percent); stubby laths of euhedral hornblende, \(\frac{3}{4}\)-3 mm long (4–7 percent); euhedral biotite, \(\frac{3}{4}\)-3 mm in diameter (3–15 percent); euhedral magnetite up to 0.3 mm in diameter (<1 percent); and a few euhedral apatite grains up to 0.4 mm long. Groundmass composes 50–65 percent of the rock, is light tan to light grayish brown or brownish gray, is aphanitic to aplite texture and grain sizes of 0.01–0.02 mm, and has the approximate composition relative to the whole rock of 15–20 percent plagioclase, 15–20 percent K-feldspar, and 10–15 percent quartz. Accessory minerals are apatite and zircon. Plagioclase is heavily altered to carbonate, sericite, and montmorillonite. Hornblende is heavily altered to carbonate, chlorite, phengite, and iron oxides. Biotite is heavily altered to chlorite and titanium minerals.

Tr2b RHYODACITE PORPHYRY — Dike swarm in southeast corner of quadrangle; dikes trend N. 50°–65° E., N. 30°–45° W., and N. 80° W.; dikes crosscut sills and dikes of hornblende andesite porphyry (unit Kha) at many localities, but as noted above, the rock is geographically juxtaposed with, and petrologically similar to, hornblende andesite porphyry. Quartz-poor varieties (flagged by †) are most similar to hornblende andesite porphyry. Dikes are cut by sulfide veins. Phenocrysts make up 30–60 percent of the rock as follows: euhedral to stubby laths of calcic andesine, \(\frac{3}{4}\)-5 mm long with abundant glomerocrysts to 8 mm in diameter (25–50 percent); rounded, embayed, and resorbed quartz dipyramids up to 6 mm in diameter (0–6 percent, usually only in center of dikes); euhedral acicular to stubby laths of hornblende, \(\frac{3}{4}\)-2 mm long (15–25 percent); euhedral biotite (0–2 percent; absent in many dikes and always absent in dike selvages); euhedral magnetite, up to 0.4 mm in diameter (<1–2 percent); and euhedral apatite up to 0.6 mm long (about 1 percent). Groundmass makes up 40–70 percent of the rock; has various colors, such as olive tan, dark to pale brown, with shades of pink to green, and pinkish medium to dark gray; is aphanitic but is more commonly fine grained with aplite to hypidiomorphic granular textures (trachytic in dike selvages); has grain sizes of 0.03–0.06 mm; and has approximate composition relative to the whole rock of 15–25 percent plagioclase, 15–20 percent K-feldspar, 8–15 percent quartz, 4–7 percent mafic minerals, and 1–2 percent opaque minerals. Accessory minerals are apatite, zircon, and locally allanite. Plagioclase is slightly to heavily altered to sericite, carbonate, and montmorillonite. Hornblende is slightly to totally altered to carbonate, chlorite, iron oxides, and phengite. Biotite is heavily to totally altered to chlorite and titanium minerals. Magnetite is marginally altered to hematite.

TKr1 RHYODACITE PORPHYRY — Sills and relatively few connecting and feeding dikes occurring in a 4-km-wide zone, trending N. 65°–70° E. in the center of the quadrangle; age relations with younger igneous rocks discussed above; relations with Cretaceous intrusive rocks not exposed in quadrangle; petrology and field relations allow correlation with the Rattler Granodiorite (of Late Cretaceous age) or with unit TKr1 of Cornwall and others (1971) which may be younger.
than the Rattler Granodiorite; cut by sulfide veinlets at many localities; sills most commonly occur 60-90 m above the base of the Escabrosa Limestone and at or near the contact between the Williamson Canyon Volcanics and Naco Limestone. Phenocrysts make up 45-55 percent of the rock as follows: euhedral blocky to stubby laths of andesine-labradorite ¼-7 mm long, abundant glomerocrysts as much as 12 mm in diameter (30-45 percent); rare embayed and rounded quartz dipyramids up to 1 mm in diameter (0-2 percent); euhedral to subhedral stubby laths of hornblende ¼-3 mm (rarely 7 mm) in length (6-22 percent); euhedral biotite ¼-3 mm in diameter (0-4 percent); euhedral magnetite up to 0.3 mm in diameter (1-2 percent); and sparse euhedral apatite up to 0.7 mm long. Groundmass makes up 45-55 percent of the rock; has various colors such as off white, pale greenish to grayish brown, and medium gray to olive medium gray; is aphanitic to phanitic, with aplitic texture and grain sizes of 0.02-0.05 mm; and has the approximate composition relative to the whole rock of 20-25 percent plagioclase, 20-35 percent K-feldspar, 10-12 percent quartz, 0-2 percent mafic minerals, and <1 percent magnetite. Accessory minerals are apatite, zircon, and, rarely, sphene. Plagioclase is moderately to heavily altered to sericite, kaolinite, carbonate, epidote, and montmorillonite; hornblende is moderately altered to carbonate, chlorite, and iron oxides; and biotite is heavily altered to chlorite, epidote, and titanium minerals.

Kha HORNBLENDE ANDESITE PORPHYRY – Sills and feeder dikes in the south half of the Dripping Spring Mountains; the thickest sills occur in the Naco Limestone, here of Pennsylvanian age, and the dikes usually strike N. 55°-60° E. and N. 65° W.; cut by Tr2b and Tr2b+ dikes and sulfide veinlets. Phenocrysts make up 20-55 percent of the rock (higher figure for dike and sill centers) as follows: subhedral stubby laths of labradorite ¼-3 mm long, abundant glomerocrysts up to 4-5 mm in diameter (15-40 percent; more abundant toward centers of dikes and sills); rounded grains and aggregates of quartz that are in part vesicle fillings (0-2 percent); euhedral and glomerocryst augite up to 1.5 cm long (0-20 percent, only at base of some sills); euhedral to subhedral needles and stubby laths of hornblende ¼-4 mm long (locally, as much as 8 mm long, 10-20 percent; more abundant in center of dikes and sills); euhedral to glomerocryst magnetite as much as 1 mm in diameter but usually less than 0.5 mm in diameter (1-2 percent); and euhedral apatite grains as much as 0.6 mm long (<1 percent). Groundmass makes up 45-80 percent of the rock; has various colors, such as dark to light gray, brownish light gray to light grayish brown; is fine grained to aphanitic with aplitic, hyalopilitic, and trachytic textures with grain sizes of the plagioclase laths ranging from 0.04 to 0.08 mm; and has variable composition. In dike and sill selvages, the groundmass has the approximate composition relative to the whole rock of about 15 percent plagioclase laths, 2-8 percent magnetite, and about 50 percent devitrified glass that stains with sodium cobaltinitrite solution. In thick dikes and away from selvages of thin dikes, the groundmass has the approximate composition relative to the whole rock of about 25 percent plagioclase laths, 5 percent hornblende laths, 2 percent magnetite, and 10-15 percent quartz, K-feldspar, and devitrified glass. Accessory minerals are apatite, and, rarely, allanite. Plagioclase is moderately to heavily altered to sericite, clinozoisite, epidote, carbonate, kaolinite, montmorillonite, and K-feldspar. Hornblende is slightly to totally altered to carbonate, chlorite, epidote or clinozoisite, and iron oxides. The interstitial glass is everywhere devitrified and in part chloritized. This rock is petrologically identical to, and is correlated with, hornblende andesite porphyry (Kha) in the Sonora and Crozier Peak quadrangles (Cornwall and others, 1971; Krieger, 1974a). Chemical analyses are presented by Banks and others (no. 1, Table 1, 1972) and Krieger (W-149, Table 2, 1974a). The reported hornblende K-Ar age of 128 m.y. (no. 1, Table 2; Banks and others, 1972) for this rock is, as suspected by Banks, Cornwall, Silberman, and Marvin of Banks and others (1972), anomalously old because the rock cuts the Upper Cretaceous Williamson Canyon Volcanics.

Kb BASALT INTRUSIVE BRECCIA – A dike, sill, and a small, faulted, elongate plug in the center of the Dripping Spring Mountains at the north boundary of the quadrangle; offset of plug is apparently left lateral along the Cowboy fault. The plug is an intrusive breccia or breccia pipe with clasts ranging from crystal fragments to mappable blocks 30 m in diameter; the clasts include Devonian rocks derived from higher in the section than the present level of erosion. The dike, sill, and matrix of the plug are composed of grayish green to greenish purple devitrified glass (40-60 percent) and ¼-1 mm phenocrysts of anhedral to subhedral labradorite-bytownite laths (25-30 percent), anhedral augite (8-10 percent), and anhedral opaque minerals (4-5 percent). The rock and intrusive breccia are very similar to, and are tentatively correlated with, the Williamson Canyon Volcanics. Parts of the matrix of the plug are fine grained, and this variant is more properly called a pyroxene gabbro than a basalt. Apatite is the accessory mineral.

Kw WILLIAMSON CANYON VOLCANICS – Medium- to dark-gray and greenish-gray flows, flow breccias, volcaniclastics, and minor tuffs. Flows, fragments, and matrix are porphyritic, feldspathic, hyalopilitic pyroxene basalt or,
rarely, hornblende andesite. Phenocrysts compose 50–70 percent of the basalt as follows: euhedral stubby laths or blocky crystals of labradorite-biotovite, as much as 2 mm long (35–50 percent), either stubby subhedral laths of hornblende or, most commonly, subhedral to euhedral blocky augite, as much as 2 mm in maximum dimension (5–25 percent), euhedral to subhedral opaque minerals, as much as 1 mm in diameter (1–4 percent). The glass matrix is devitrified or heavily altered and locally is opaque from abundant disseminated opaque minerals. Plagioclase is moderately to heavily altered to sericite, kaolinite, calcite, and epidote; hornblende is commonly epidotized. Pyroxene is locally chloritized and uralitized. Quartz, and calcite-filled vesicles pose of the formation is characterized by 1 or goethite. Mzb BASALT — Sills and a few dikes of dark-gray to olive-gray basalt in the Martin Formation and Escabrosa Limestone in sec. 36, T. 3 S., R. 14 E., on and near Steamboat Mountain, in the NE cor. sec. 12, T. 4 S., R. 14 E., and in N½ sec. 21, T. 4 S., R. 15 E. Subhedral ½–1 mm long laths of labradorite make up 55–60 percent of the rock; subhedral augite and minor pigeonite up to 2 mm in diameter make up 25–30 percent of the rock; euhedral to subhedral olivine as much as 2 mm in diameter makes up 10–15 percent of the rock. Subhedral to euhedral opaque minerals less than 1 mm in diameter make up about 5 percent of the rock, and biotite, mostly rimming the opaque minerals, locally composes 5 percent of the rock. Apatite is the accessory mineral. The plagioclase is partially sericitized and kaolinitized; the pyroxenes are slightly chloritized, and the olivine is variably altered to antigorite or talc, opaque minerals, and minor amounts of bowlingite and iddingsite. Limestone overlying the sills is commonly silicified and contains abundant hematite or goethite. On cursory examination this rock is similar to and was mistaken for Precambrian diabase in older publications on the area.

Pn NACO LIMESTONE (180 to at least 260 m) — Higher figure is from drill hole information in the New Year mine area (J. T. Eastick, written commun., 1975) and from a composite section correlated with microfossil assemblages (A. K. Armstrong, written commun., 1975). Formation is characterized by fairly regularly spaced thin to medium (0.3–3.0 m) beds of resistant limestone and less resistant shale or shaly and silty limestone. The lithology of the basal unit varies in response to relief on the underlying Escabrosa Limestone. Most commonly, the basal unit (up to 3 m thick) is purple to reddish-purple shale with fragments or cobbles of black or red chert. Along the Gila River at the southern boundary of the quadrangle and south of Tornado Peak in Sec. 35, T. 4 S., R. 15 E., this basal unit is separated from the first white-weathering, fusilinid-bearing bed by 30 m of alternating 0.1–2-m-thick beds of purple shale and gray fine-grained dolomite. S. B. Keith (oral commun., 1975) reports upper Mississippian conodonts in these beds. At other localities, such as in the east center of sec. 16, T. 4 S., R. 15 E., less than 3 m of this dolomite and shale unit occurs, and in sec. 13, T. 4 S., R. 14 E., yellow dolomitic shale with reddish chert on bedding and fractures substitutes for the purple basal shale and the gray dolomite and shale unit. Above and including the first white-weathering, fusilinid-bearing, bioclastic limestone are about 70 m of 0.3–3.0 m beds of bioclastic to micritic to nodular, brown to flesh-colored (white-weathering) limestone (with variable, locally extremely abundant, amounts of red chert nodules, stringers, and layers) alternating with red to purple shale and siltstone. Intraformational disconformities and limestone and chert conglomerates are common in this interval, microfossils indicate that deposition occurred from Morrowan through Atokan time (A. K. Armstrong, written commun., 1973). Chert and shale in the upper 150 m of the formation tend to be black rather than red and purple, and the limestone tends to weather more to gray rather than white; the shale is less abundant than in the lower 110 m. Otherwise, similar to the rest of the formation, the limestone in upper 150 m is bioclastic, micritic, and nodular, is brown to gray, and contains intraformational breccias and a large variety of well-preserved silicified macrofossils, the microfossil assemblage indicates deposition in Desmoinesian and perhaps younger Pennsylvanian time (A. K. Armstrong, written commun., 1975). Peterson and Swanson (1956) report fusilinids in the uppermost beds, near the Christmas mine where the section is about 300 m thick, are characteristic of uppermost Pennsylvanian or lowermost Permian, but farther east, in the Mescal Mountains, Wilden (1964) reports Pennsylvanian fusilinids occur to at least 450 m above the base of the formation.

Me ESCABROSALIMESTONE (120 m in northwestern part of quadrangle, 160–170 m on and south of Tornado Peak)—Lowermost 5 m of limestone or dolomite, locally with basal 5–10 cm of sandstone, is yellowish and contains silt and clay reworked from disconformably underlying Percha Shale. Overlying 65 m consists of medium- to dark-gray, laminated,
Dpm PERCHA SHALE AND MARTIN FORMATION (60-115 m)—Thicknesses of the formations and the lithology of individual mappable units in each formation vary, presumably in response to relief on the erosional surface on which the Martin Formation was deposited and subsequent erosion of the Percha Shale. Percha Shale is everywhere present but was not mapped separately. In the NE ¼ sec. 23, T. 4 S., R. 15 E., where the Martin Formation lies on Abrigo Formation, local relief on the pre-Martin surface is very small and the basal unit is sparsely sandy dolomite (< 1 m thick), whereas in the NW ¼ sec. 2, T. 5 S., R. 15 E., a basal sandstone channel of 3-12 m into the underlying Abrigo Formation, and the SE ¼ sec. 12, T. 4 S., R. 14 E., it channels the Abrigo Formation as much as 6 m. In sec. 1, T. 4 S., R. 14 E., the Martin Formation locally rests on Troy Quartzite. A 100-m-thick measured section of the two Devonian formations in the SW ¼ sec. 6, T. 4 S., R. 15 E., is as follows: (a) Martin Formation; basal 4 m of tan to light-brown medium-grained dolomitic quartzite with bedding of 2-10 mm and vague crossbedding; overlain by 3.3 m of light-brown sandy dolomite with poorly sorted sand grains and rounded quartzite pebbles as much as 1.5 cm in diameter, grades less sandy upward; overlain by 6.7 m of dark- and light-gray laminated (2-20 mm) dolomite, splitting 2-4 cm, withstromatolitic and slump contortions of laminae and several 1-2 cm horizons of nodular and layer black chert, locally known as the O’Carroll bed; overlain by 47 m of alternating yellow-gray and medium-gray, fine-grained dolomite units, 2 cm-1 m thick; overlain by a 1.5-m-thick, red-brown to buff, fine-grained dolomitic quartzite with fucoid-like molds; overlain by a distinctive cliff-forming, 4.5-m-thick, fossiliferous, bioclastic, fine-grained, laminated, gray to medium-olive-gray limestone with wavy clay partings that weather grayish orange (fossils including Cyrtospirifer, Stropheodonta, Atrypa, small spiriferoids, crinoid stems, and bryozoa occur primarily in this and the overlying units); (b) Percha Shale, divided into a basal 18 m of thin-bedded orange-yellow, mainly dolomite that weathers to rounded pebble-and cobble-sized blocks and an overlying 15 m of olive to yellow-olive fissile shale. In the NE ¼ sec. 8, T. 4 S., R. 15 E., the total thickness of the two formations is about 60 m and the basal sandy units, and the distinctive limestone unit of the Martin Formation are very thin. In the NW ¼ sec. 2, T. 5 S., R. 15 E., a basal 3- to 12-m-thick sandstone of the Martin Formation is overlain by a 7-m-thick yellow-gray dolomite; the distinctive limestone unit is missing, and the quartzite that elsewhere underlies the limestone is thickened to a 6-m unit of sandy dolomite and interbedded quartzite which is directly overlain by 25 m of Percha Shale. The formations are locally intruded by one or more <1 m thick sills of andesite or basalt (unmapped).

€a ABRIGO FORMATION (0-60 m)—Like the Martin Formation, the thickness and lithology of this formation varies from locality to locality in the quadrangle. It is absent locally in sec. 1, T. 4 S., R. 14 E., is thickest on the north slope of Tornado Peak, and is most clastic in the NW ¼ sec. 2, T. 5 S., R. 15 E., where it consists wholly of thin-bedded brown quartzite. In sec. 12, T. 4 S., R. 14 E., in a 26-m-thick measured section, the formation may be divided into a basal 15 m of paper-thin yellow-brown siltstone, interbedded with 6- to 10-mm-thick dark-reddish-brown arkosic quartzite lenses and beds, and an upper 11 m of 6- to 20-mm-thick beds of brown arenaceous to argillaceous dolomite with phosphatic brachiopod fragments, and interbedded paper-thin yellow-brown siltstone and rare quartzite beds that are similar to those of the lower unit. In the NW ¼ sec. 7, T. 4 S., R. 15 E., the section is similar, but the lower unit contains an additional 12 m of coarse hematitic dirty sandstone, and in the north-central part of sec. 12, T. 4 S., R. 14 E., a 1- to 3-m-thick chocolate-brown sandy dolomite occurs in the approximate middle of the formation. In the east-central edge of sec. 20, T. 4 S., R. 15 E., the formation consists of a basal 30 m of thin-beded, brownish, dirty sandstone and quartzite, and an upper 25 m of yellow-brown mudstone. Many of the siltstone and mudstone beds have fucoids and other evidence of biogenic reworking of the beds. Unmapped basalt and andesite sills (<1 m thick) locally intrude the formation.

€b BOLSA QUARTZITE (0-55 m)—Variable thickness and locally absent throughout the quad-
range. In a 15-m-thick measured section in the SW cor. sec. 6, T. 4 S., R. 15 E., the formation may be divided into two units: a basal 7.5 m of 0.2- to 1-mm-bedded, massive-splitting, white to light-tan quartzite with abundant lioesgang banding in the basal 3 m and abundant Scolithus at the top; and an upper 7.5-m unit very similar to the lower unit except for the presence of low-angle crossbedding recurring on about 3-cm intervals. In the SE¼ sec. 17, T. 4 S., R. 15 E., the formation is an estimated 50 m thick, channels the underlying Troy Quartzite, and consists in ascending order of 3 m of drab, red pebble-conglomerate with a coarse sand matrix, followed by 15 m of medium-grained white quartzite with maroon spots up to 8 mm in diameter, and then 11 m of lavender, medium-grained, laminated to crossbedded quartzite, and finally 25 m of thin-bedded, white to buff, medium-grained quartzitic sandstone.

Yb DIABASE—Dikes and sills, <1 m to 180 m thick where exposed (composite of all the sills in drill core near Chilito mine is 410 m (D. S. Fountain, oral commun., 1970); intrudes all other Precambrian rocks, but in particular the Mescal Limestone and Dripping Spring Quartzite. Fresh diabase is dark- to very-dark gray, holocrystalline, fine- to coarse-grained, with diabasic to ophitic texture, and composed of plagioclase An35-70), faintly brownish augite (up to 2 cm in diameter) that is sometimes rimmed or substituted by a blue-green hornblende, olivine, and opaque minerals such as magnetite and ilmenite, and lesser amounts of pyrite, chalcopyrite, pyrrhotite, and rarely marcasite. Apatite is locally abundant and red-brown biotite or sphene are local accessory minerals. Some specimens have interstitial micrographic quartz and K-feldspar. Associated pegmatitic schlieren and irregular masses cut some of the sills. Chemical analyses of samples collected near the quadrangle are reported by Ransom (1919, p. 54) and Krieger (1974a, b); radiometric dating of samples from other localities suggests a general 1.15 billion year age for the diabase (Silver, 1963; Damon and others, 1962). The rock weathers to a greenish to olive-gray, granular material with pea- to boulder-sized masses of resistant rock with nodular surfaces. Metamorphism of the surrounding host rocks is most obvious in the Mescal Limestone where tremolite, forsterite, talc, and diopside occur; the Pioneer Formation becomes hornfelsed near the sills. The plagioclase is commonly sericitized or kaolinitized and locally contains carbonate, epidote, and clinzoisite; ferromagnesium minerals alter to serpentine, talc, chlorite, bowlingite, iddingsite, opaque minerals, and fibrous to massive or aggregate greenish hornblende; at the Chilito mine area, hydrothermal biotite replaces the primary ferromagnesium minerals.

Yt TROY QUARTZITE (0-300 m)—Formation is thickest in the northwest part of quadrangle; thins southward, both by depositional thinning of the lowermost units and by erosion of the upper units prior to Cambrian time; locally absent beneath Cambrian in NE¼ sec. 22, T. 4 S., R. 15 E. In the NW¼ sec. 8, T. 4 S., R. 15 E., the formation is 220 m thick, is typical of exposures throughout the quadrangle, and in ascending order consists of 10 m of cliff-forming poorly sorted cobble to pebble conglomerate with subrounded to subangular clasts of basalt, quartzite, red jasper, black chert, and white chert in a dark-purple to dusky-maroon quartzite matrix (½-2 mm grain size); disconformably overlain by 5.5 m of slope-forming, light-rose to tan, 2-4 cm alternating beds of coarse-grained quartzite and pebble conglomerate (splitting ½-1 m); 12 m of cliff-forming interbedded (0.15-1 m) yellowish-white poorly sorted pebble-bearing convoluted sandstone, and yellow to rose-gray poorly sorted coarse-grained quartzite with locally abundant pebbles; 22 m of slope-forming 0.3-1.3 m beds of reddish pebbly quartzite and pebble conglomerate, upper 10 m with better rounding of pebbles and more yellow and buff colors; 1 m of coarse pebble to cobble conglomerate; 25 m of ledge-forming interbedded (5-20 cm) greenish to yellowish-white medium-grained quartzite and light-yellowish buff poorly sorted coarse quartzite with locally abundant pebbles, paper-thin shale on bedding surfaces and convolution in many beds; 7 m of cliff-forming 1-3 cm beds (3 m splitting) of granule to fine-grained gray-white crossbedded (low angle) quartzite with a basal 1/3 m cobble conglomerate (sparse 1- to 2 cm clasts of white quartz); 20 m of ledge-forming, thin- to medium-bedded (1-8 cm), coarse-grained white convoluted quartzite; 2.5 m of cliff of lavender, crossbedded (low angle), fine-grained to granule quartzite with an upper conglomerate; 61 m of slope-forming, interbedded (4 cm-3 m), white, fine- to medium-grained, convoluted quartzite and reddish-brown, medium-grained to granule, crossbedded (low angle) quartzite, a distinctive, red gritty sandstone to pebble conglomerate occurs 40 m above the base; 12 m of slope-forming, yellowish, pebbly, medium-grained quartzite beds (6-12 cm thick); and 42 m of clean white crossbedded (low angle) fine-grained quartzite with some pebbles and granules.

APACHE GROUP

Yb BASALT (0-12 m)—One or more flows of porphyritic basalt, dusky-dark-brown to reddish-black, abundant flattened vesicles filled with sericite, calcite, or epidote. Sodic labradorite phenocrysts, 2-8 mm long, are set in very fine grained, highly altered groundmass of labradorite laths and interstitial pyroxene, olivine, and opaque minerals.

Ym MESCAL LIMESTONE (25-60 m)—Variations in thickness, caused by erosion after deposition.
of the basalt but prior to deposition of Troy Quartzite; upper beds are locally silicified and have solution collapse breccias formed during this weathering. Formation consists of light- to pinkish-brown and grayish-white, laminated to thin-bedded, partly calcareous, sublithographic to fine-grained and locally coarse-grained dolomite. Generally black chert forms 5- to 20-mm-thick layers and lenses, locally in great abundance, throughout the formation. Algal stromatolitic structures occur only in the uppermost parts of the thicker sections.

Ybm BASALT AND UNDERLYING MESCAL LIMESTONE

Ymd MESCAL LIMESTONE AND DIABASE SILLS

Yds DRIPPING SPRING QUARTZITE (about 220 m, from composite in drill hole near Chilito mine, corrected for dip)—The formation is everywhere too intensely faulted and intruded by diabase to provide a satisfactory locality for a continuous measured section, but one or more of four units comprising the formation (described below in descending order) were recognized in individual fault blocks:

Siltstone unit (about 120 m)—Siltstone and fine- to very-fine-grained sandstone and quartzite, feldspathic to arkosic, thin-bedded to laminated, locally with thin cross-laminated sets; thin-splitting, ledge- or slope-forming; light- to dark-gray, olive-green, dusky-brown, yellowish-brown, and grayish-red colors, often in irregular patterns associated with joints; subrounded feldspar and quartz with mafic or clay minerals in siliceous cement, locally abundant pyrite; more quartzitic upward; grades into underlying shale unit.

Shale unit (as much as 30 m)—Thin to medium interbeds of gray to buff, medium- to fine-grained quartzite and red to dark-purplish micaceous shale; slope-forming; common ripple marks and mudcracks; grades into underlying arkose unit.

Arkose unit (about 55 m)—Arkosic to feldspathic quartzite; thin-bedded to laminated with local low-angle thin- to medium-sets of cross laminae, cliff- or ledge-forming; thick- to massive-splitting; medium- to fine-grained; light-buff, off-white to grayish-pale colors; grades into underlying Barnes Conglomerate Member.

Barnes Conglomerate Member (variable thickness, 1-15 m)—Pebble and cobble conglomerate; well-rounded, ellipsoidal, closely to loosely packed clasts of white, gray, and black quartzite, schist, quartz, and red Jasper; light-gray to brown feldspathic medium- to coarse-grained matrix; medium- to thick-bedding and splitting, forms cliff or ledges.

Yp PIONEER FORMATION (30-55 m)—Formation consists of the basal Scanlan Conglomerate Member, overlain by a tuffaceous siltstone and interbedded arkosic sandstone unit.

Tuffaceous siltstone and arkosic sandstone unit (30-50 m)—Tuffaceous siltstone and very fine grained sandstone; laminated with local thin sets of cross laminae, slope-forming, dark- to orange-red to dark-purple; ovoid to round grayish-green and white spots common; subrounded K-feldspar, quartz, plagioclase, and dark minerals with hematitic devitrified glass shards. Interbedded 1-cm- to 1-m-thick sandstone is tuffaceous, reddish gray to buff, arkosic to feldspathic, and locally cross laminated.

Scanlan Conglomerate Member (0.1-3 m)—Conglomerate, well-rounded, ellipsoidal, large pebbles and cobbles of white to gray quartz, schist, and jasper with subangular to angular smaller pebbles and granules of quartz, schist, and mineral fragments in medium- to very-coarse-grained, arkosic quartzite or sandstone matrix; locally only the matrix material and crystal fragments from underlying Ruin Granite make up the member.

Yr RUIN GRANITE—Very coarse and coarse-grained (southwest of Gila River) to coarse- and medium-grained (in Dripping Spring Mountains), porphyritic to seriate porphyrritic quartz monzonite. Pink, poikilitic orthoclase and perthitic microcline are largest (1-2 cm) of the constituent minerals (25-35 percent); oligoclase-andesine is as much as 1.5 cm across (30-45 percent); quartz is less than 1 cm in diameter (25-35 percent). Biotite and magnetite (3-8 percent) are the dark minerals; and sphene, apatite, and zircon are accessory minerals. Plagioclase is always partially altered to sericite; biotite is partly chloritized.

Xp PINAL SCHIST—Not exposed but reported as a 150-m-thick slab penetrated by two drill holes in the Chilito mine area (D. S. Fountain, oral commun., 1970; Neil Gambell, written commun., 1975) as shown in cross section D-D' only.

REFERENCES


