MAP GQ-1188

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE KEARNY QUADRANGLE, PINAL COUNTY, ARIZONA

By H. R. Cornwall and
M. H. Krieger

GEOLOGIC QUADRANGLE MAP
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CORNWALL AND KRIEGER—KEARNY, ARIZONA 1:24,000 MAP GQ-1188

GEOLOGIC MAP SYMBOLS

COMMONLY USED ON MAPS OF THE UNITED STATES GEOLOGICAL SURVEY

(Special symbols are shown in explanation)

Contact – Dashed where approximately located; short dashed where inferred; dotted where concealed

45

Contact – Showing dip; well exposed at triangle

Fault – Dashed where approximately located; short dashed where inferred; dotted where concealed

20

Fault, showing dip – Ball and bar on downthrown side

Normal fault – Hachured on downthrown side

Fault – Showing relative horizontal movement

Thrust fault – Sawteeth on upper plate

Anticline – Showing direction of plunge; dashed where approximately located; dotted where concealed

Asymmetric anticline – Short arrow indicates steeper limb

Overturned anticline – Showing direction of dip of limbs

Syncline – Showing direction of plunge; dashed where approximately located; dotted where concealed

Asymmetric syncline – Short arrow indicates steeper limb

Overturned syncline – Showing direction of dip of limbs

Monocline – Showing direction of plunge of axis

20 Minor anticline – Showing plunge of axis

60 Minor syncline – Showing plunge of axis

Strike and dip of beds – Ball indicates top of beds known from sedimentary structures

70 Inclined Horizontal

Vertical 40 Overturned

Strike and dip of foliation

20 Inclined Vertical Horizontal

Strike and dip of cleavage

15 Inclined Vertical Horizontal

Bearing and plunge of lineation

15 Inclined Vertical Horizontal

Strike and dip of joints

40 Inclined Vertical Horizontal

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.

Shafts

Vertical Inclined

Adit, tunnel, or slope

Accessible Inaccessible

x Prospect

Quarry

Active Abandoned

Gravel pit

Active Abandoned

Oil well

Drilling Shut-in Dry hole abandoned

Gas Show of gas

Oil Show of oil

GEOLOGIC MAP OF THE KEARNY QUADRANGLE, PINAL COUNTY, ARIZONA

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GEOLOGIC SETTING

The oldest rock in the Kearny quadrangle is the Ruin Granite of early Precambrian Y age; it is unconformably overlain by Precambrian Y sedimentary rocks, and all these units are intruded by late Precambrian Y diabase dikes and sills. These rocks are disconformably or unconformably overlain by Paleozoic sedimentary rocks and Mesozoic and Tertiary volcanic rocks. The entire sequence has been intruded by Late Cretaceous and Tertiary dikes and plutons. The dikes, mostly striking east-west, probably occupy faults and fissures that formed shortly before dike intrusion. Miocene alluvial and playa sediments with interbedded tuffs and megabreccias have been deposited in intermontane basins in the quadrangle and are overlain by Quaternary gravels and alluvium.

Paleozoic and older rocks in the northeastern part of the quadrangle are gently to moderately dipping and have been moderately to intensely deformed along high-angle normal faults. Rocks in the eastern part of the quadrangle are believed to be separated from rocks in the central and western parts by a major shear zone, largely concealed beneath the Gila River flood plain. In the central and western parts of the quadrangle, narrow linear belts of vertically dipping Paleozoic and Precambrian sedimentary rocks overlying the Ruin Granite to the west trend north-northwest and are believed to be parts of a monocline that developed partly in pre-Miocene time but was split later into several parts by high-angle transcurrent faults. These interpretations are supported by data from quadrangles to the south and southeast (Krieger, 1974a). Krieger has found evidence that some repetition of the linear belts was caused by thrust faulting nearly parallel to the sedimentary beds prior to formation of the monocline (Krieger, 1974a).

During the Tertiary, as Miocene intermontane basins formed along the areas now followed by the Gila River and Ripsey Wash, the intervening and bounding areas, particularly to the west, were uplifted, and debris from the bounding areas was shed into the basins. Large blocks, mainly of Paleozoic and Precambrian sedimentary rocks, slid eastward into the western side of the valley during the early Miocene, forming megabreccia plates in the alluvial and playa deposits of the San Manuel Formation. As the basins subsided, bounding normal faults developed along their margins and the San Manuel Formation was folded and tilted, the dips becoming progressively steeper toward the western margins.

During the late Miocene, debris continued to be shed into the basins from the surrounding highlands, depositing sediments that represent the Big Dome Formation unconformably above the San Manuel Formation. The Big Dome Formation has been moderately deformed by tilting along northwest-trending normal faults.

A breccia pipe, herein named the Riverside breccia pipe, crops out half a mile west of the Riverside. The pipe, 1,000 feet in diameter, is mostly in diabase but partly in Ruin Granite. There has been a little mixing of fragments such that some granite fragments occur in a diabase matrix and some diabase fragments occur in a granite matrix. The pipe is transected by dikes of the Paleocene Teapot Mountain Porphyry and the Late Cretaceous or early Tertiary rhyodacite porphyry and therefore is Paleocene or older.

ECONOMIC GEOLOGY

West of the Riverside breccia pipe in secs. 11, 12, and 13, T. 4 S., R. 13 E., east-trending mineralized veins occur in fissures as much as 20 feet wide in Ruin Granite. The veins contain quartz, limonite, chrysocolla, and malachite. The steeply dipping fissure zones have been trenched in several places, and seven diamond drill holes have been drilled to intersect the fissures at shallow depths. Most of this work was done by the Occidental Petroleum Co. in the 1960's.

The Florence mine, located in the SE¼ sec. 12, T. 5 S., R. 13 E., owned by Edward O. Ryden of Miami, Ariz., contains pyrite and silver-bearing galena in veins and as disseminated minerals in Paleozoic carbonate rocks. The Old Ripsey mine, located in the SW¼ sec. 12, T. 5 S., R. 13 E., is a small deposit of pyrite and copper sulfides as veinlets and disseminations in diabase and Ruin Granite.

Granite and diabase on the north and south sides of the hill in the NE¼ sec. 14, T. 5 S., R. 14 E., as well as some of the adjacent Precambrian sedimentary rocks, have been extensively brecciated and the fractures filled with carbonate and manganese oxide.

Several adits have been dug in megabreccias east and just southwest of the center of sec. 8, T. 5 S., R. 14 E., in part along shear zones that probably developed later than the emplacement of the breccias.

ACKNOWLEDGMENTS

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DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Qd *Mill tailings.* — In sec. 6, T. 4 S., R. 14E.

Qf *Alluvium of the Gila River flood plain.* — Largely fine sand and silt

Qal *Alluvium.* — Gravel, sand, and silt deposits in stream channels and higher terraces along the Gila River; contacts with Qf approximate

Qt *Talus.* — Large to small angular blocks at or near the base of cliffs and steep slopes

Qtr *Travertine.* — Deposited mostly along faults

Qp **PEDIMENT GRAVELS (0–10 ft).** — Subangular pebbles and cobbles in a generally reddish-brown, fine- to coarse-grained matrix. In contrast to the diverse types of clasts of older gravels, clasts are predominantly quartzite. The dark-red-brown soil developed on the gravel is probably pre-Wisconsin in age

Qog **OLDER GRAVELS.** — South of the Gila River, the unit is composed largely of sand, pebbles, and small cobbles derived from the Ruin Granite; north of the river, it consists chiefly of rounded limestone pebbles, cobbles, and small boulders. Caliche generally occurs at the base where the unit overlies the Big Dome Formation. Deposited mainly in channels cut in Miocene formations after development of the Gila river drainage

BIG DOME FORMATION (2,000+ ft). — An alluvial formation (Krieger and others, 1973) consisting of four gradational and interfingering members, deposited essentially simultaneously (see sec. *B–B'*) and two thin tuff beds that are time-stratigraphic units. In this quadrangle the formation lies mostly northeast of the Gila River except for an area northwest of Kearny and another in the southwestern part of the quadrangle, which is questionably correlated with the type Big Dome Formation. The unconformity between the Big Dome Formation and the underlying San Manuel Formation is well exposed below the railroad tunnel at the northern edge of sec. 7, T. 4 S., R. 14 E., just east of the Gila River. In this area both formations are alluvial and are similar lithologically except that clasts of the lower Miocene Apache Leap Tuff are found only in the Big Dome Formation. Biotite and hornblende from a tuff bed (Tbql) near the middle of the formation yield K-Ar ages of 14 and 17 m.y., respectively (Cornwall and others, 1971; Banks and others, 1972)

Tbl *Limestone conglomerate (±1,000 ft).* — Alluvial deposits composed largely of Paleozoic limestone clasts; well indurated with subrounded to locally subangular clasts, mostly cobbles with less abundant pebbles and boulders. The matrix is sand and granules in a calcareous cement. Other clasts include Precambrian sedimentary rocks, schist, and diabase, and Mesozoic or Tertiary intrusive rocks. Clasts of the Apache Leap Tuff are generally absent. No clasts of Ruin Granite have been observed in the member, which is mostly light gray. The source of the limestone clasts was probably the Dripping Spring Range to the northeast

Tbc *Conglomerate (±1,000 ft).* — Alluvial deposits of gravel and some sand, characterized by diverse types of clasts. The subangular to subrounded pebbles, cobbles, and boulders are of Precambrian schist, granite, sedimentary rocks, and diabase; Paleozoic sedimentary rocks; and Mesozoic and Tertiary intrusive and extrusive rocks. The abundance of each rock type varies from place to place. Color ranges from brown and yellowish brown to gray and olive gray. Many beds or lenses are packed with pebbles in a sandy matrix and may contain scattered cobbles and boulders; some beds are composed largely of sand and granules, with or without small pebbles. Where the conglomerate contains abundant limestone clasts with only a few sandy beds and little sandy matrix, it is well indurated and forms a rugged topography; elsewhere it forms a more subdued topography

Tblt *Lapilli tuff (0–40 ft).* — A thinly laminated to massive rhyolite tuff, tuffaceous sandstone, and pumice lapilli tuff that is generally separated into two parts by nontuffaceous pebble and cobble beds as much as 10 feet thick. Other conglomerate beds and lenses occur locally within the tuff units. Clasts are similar to those in adjacent conglomerates. The upper tuff consists of an upper part (0–15 ft) of thin-bedded to massive, grayish-orange-pink to white tuff with scattered small white pumice lapilli in a sandy matrix composed of shards and lithic fragments; a lower part (2–10 ft) of white massive tuff with closely packed pumice lapilli (1 mm to 4 cm) and a few light-gray lithic fragments in a shard matrix. Locally, pebbles of Pinal Schist are abundant; most are less than 2 cm long. The lower tuff (0–15 ft) is similar to the top of the upper tuff, but generally contains fewer and smaller pumice lapilli and may contain abundant lithic fragments. Most of the shards and pumice lapilli are altered to clay; unaltered pumice lapilli are very light gray. The tuff is largely reworked and bedded, but some is massive. The tuff was probably originally widely distributed; it has been partly removed by erosion

Tbs *Sandstone and conglomerate (±1,000 ft).* — Alluvial deposits composed of sand and gravel and characterized by diverse types of clasts: Precambrian schist, granite, sedimentary rocks, and diabase; Paleozoic sedimentary rocks; and

Mesozoic and Tertiary intrusive and volcanic rocks. Clasts of the Apache Leap Tuff are characteristic. The member contains abundant poorly indurated sandstone beds and lenses from a few inches to 15 or more feet thick and a few beds of brown claystone and siltstone, as much as 4 feet thick. Most of the interbedded pebble-, cobble-, and boulder-conglomerate beds have a sandy matrix. This member is easily distinguished from the overlying limestone conglomerate (Tbl) by its darker color and more subdued topographic relief

Tbql *Quartz-latite ash-flow tuff (0–20 ft).* — Nonwelded to slightly welded, pinkish-gray to pale-red ash-flow tuff; lower 10 feet locally contains abundant gravel. Common to abundant, partly broken phenocrysts, 0.5–1mm across, are sanidine, plagioclase (An_{28}), biotite, quartz, magnetite, hornblende, and sphene, in order of decreasing abundance. Pumice lapilli are sparsely distributed. The matrix consists mostly of glass shards partly devitrified to cristobalite and quartz. Lithophysae are common and are generally surrounded by a zone of white clay. Clay also makes up about 10 percent of the basal white zone, probably accounting for its lighter color. Chemical analysis and norm of a sample collected 1.5 miles north of Kearny are given in table 1. The ash-flow tuff is exposed intermittently in the northeastern part of the quadrangle and lies mostly within the granitic conglomerate (Tbg). The tuff, intensely altered to montmorillonite, was intersected in a drill hole in limestone conglomerate in SE¼ sec. 12, T. 4 S., R. 14 E., in the northwestern Hayden quadrangle.

TABLE 1. —*Chemical analysis and norm of quartz-latite ash-flow tuff, SE¼ sec. 16, T. 4 S., R. 14 E., Kearny quadrangle*

[Analysts, P. Elmore, G. Chloe, J. Kelsey, H. Smith]

Chemical composition (in percent)		CIPW norms (in percent)	
SiO_2	67.7	Q	32.7
Al_2O_3	14.5	C	3.2
Fe_2O_3	2.30	Z	.06
FeO	.26	Or	20.4
MgO	1.20	Ab	25.8
CaO	1.70	An	7.6
Na_2O	3.00	En	3
K_2O	3.40	Hm	2.3
H_2O	3.60	Il	.73
TiO_2	.44	Ru	.06
P_2O_5	.12	Ap	.29
MnO	.08	Cc	.11
ZrO_2	.04	Total	96.3
CO_2	.05	Salic	89.7
BaO	.10	Femic	6.6
Total	98.5		

Tbg *Granitic conglomerate (1,000–2,000 ft)* — Alluvial deposits largely composed of granitic clasts. The member contains pebbles, cobbles, and locally boulders, rarely as much as 5 ft in diameter, of Ruin Granite, with variable amounts of Precambrian sedimentary rocks, Laramide porphyries, and locally Pinal Schist, and rare clasts of Paleozoic limestone. The matrix is tan and consists largely of granitic sand. The formation is poorly indurated and poorly bedded and sorted. Shallow channels are common. The member becomes finer grained eastward near the sandstone and conglomerate member (Tbs). West of the Gila River, near the center of the quadrangle, the granitic conglomerate consist largely of coarse angular cobbles and boulders of granite. In the northwesternmost exposures (SE¼ sec. 36, T. 3 S., R. 13 E.) it is composed largely of clasts of Tortilla Quartz Diorite, which crops out near there. Exposures of this member in the southwestern part of the quadrangle are questionably correlated with the Big Done Formation

SAN MANUEL FORMATION (10,000+ ft). — Alluvial and playa deposits with interbedded megabreccias. The formation, first described by Heindl (1963) and later by Krieger (1974b,c,d), has been separated into nine members of this quadrangle. The age of the formation is probably slightly more than 20 m.y. as indicated by the absence of fragments of Apache Leap Tuff (20 m.y.), which crops out in the area, and K-Ar ages of 17–18 m.y. for biotites from two tuff beds and 24 m.y. for a sanidine from one of these tuffs. The single biotite separate came from a tuff at the top of the tuffaceous sandstone and conglomerate (Tst) in Ripsey Wash, the biotite and sanidine separates from a tuff near the top of the formation in the Crozier Peak quadrangle (Krieger, 1974c)

Tsg *Granitic conglomerate (0–at least 4,500 ft).* — Alluvial gravel and minor sand deposits, predominantly granitic, but with minor (locally abundant) Precambrian sedimentary rocks, diabase, and Mesozoic and Tertiary igneous rocks and, rarely, Paleozoic limestone. Color is grayish yellow, olive or red; bedding is thin to thick, poorly developed with common shallow channels. The conglomerate beds become progressively coarser grained westward toward the base of the exposed section on the west side of both the Gila River valley and Ripsey Wash. On the east side of Ripsey Wash, beds of this unit become progressively coarser grained upward as they do farther south in the syncline near the quadrangle boundary. Cobbles and pebbles of the Williamson Canyon Volcanics and other rocks typical of the dark playa deposits are present at the base of the granitic conglomerate in the syncline mentioned above and west of Kearny, where the conglomerate overlies the dark playa deposits (Tsdp). A few thin beds of freshwater limestone occur in the granitic conglomerate south-southeast of Kearny, where it is thin and well bedded. A few thin beds of felsic tuff are interbedded in granitic conglomerate in the syncline near the south edge of the quadrangle and east of Ripsey Wash

Tsda *Dark conglomerate (0–3,000 ft).* — Alluvial deposits of Cretaceous and Tertiary intrusive and volcanic rocks, including the Williamson Canyon Volcanics, Tortilla Quartz Diorite, andesite, rhyodacite, Paleozoic limestone (locally abundant), some diabase, and Precambrian sedimentary rocks. The conglomerate is mostly light olive gray to brown; finer grained beds are yellowish gray. The southernmost exposures, just east of Hackberry Wash, and south of the fault in sec. 10, T. 4 S., R. 14 E., are grayish red. Beds range from a few inches to 5 or more feet thick; most beds are at least 1 foot thick. Pebbles, cobbles, and boulders are sparsely distributed to closely packed in a granule to silt-sized matrix. Thin seams of silt and clay separate some beds. The conglomerate is well bedded close to the dark playa deposits (Tsdp) but poorly bedded and much channeled elsewhere. Local 2- to 3-foot deep channels are filled with crossbedded sands. A few thin beds of rhyolitic tuff were seen; only one (Tsrt), mostly less than 1 foot thick and about half a mile long, was mapped. The dark conglomerate represents a large tongue that spread northward into the playa basin. It is gradationally underlain and overlain by and interfingers with the dark playa deposits. Away from the playa deposits, the dark conglomerate becomes progressively coarser grained, bedding is less well developed, and channeling becomes more pronounced

Tsdp *Dark playa deposits (0–4,000 ft).* — Interbedded siltstone, sandstone, and conglomerate with clasts of Williamson Canyon Volcanics, Tortilla Quartz Diorite, andesite, rhyodacite, Paleozoic limestone and some diabase, and Precambrian sedimentary rocks. Mud cracks and curled mud chips are common along siltstone and claystone layers; conglomerate beds range from a few inches to 3 feet thick. Larger cobbles and boulders are generally concentrated in the middle of conglomerate beds, which rest with remarkably smooth planar surfaces on siltstone or sandstone beds. Bedding surfaces are only locally irregular, channeled, or lenticular. Rock color ranges from light gray and yellowish gray to grayish red; conglomerates are light olive gray. Small drag folds along faults with little displacements are common in this member. The dark playa deposits overlie gradationally and interfinger northward and eastward with playa claystone deposits (Tsc) and also interfinger northward with granitic conglomerate (Tsg). East of Hackberry Wash, and also to the south, the facies becomes coarser grained and thicker bedded as it interfingers with the dark conglomerate (Tsda)

Tst *Tuffaceous sandstone and conglomerate (0–800 ft).* — A lenticular body of tuffaceous sandstone with many thin, relatively pure tuff beds and 1- to 10-foot-thick beds of coarse angular nontuffaceous pebble, cobble, and local boulder conglomerate. Conglomerate is most abundant in upper and lower parts. Clasts in conglomerate beds are mostly of Ruin Granite and may be sparsely distributed to closely packed. The unit is white to pale orange and yellowish gray, except for the coarser beds, which commonly weather yellowish brown. The bedding is mostly thin and well developed with uniform planar surfaces over wide areas and only minor channeling. Some conglomerates are thick bedded. Curled mud chips, locally present, suggest that this unit was deposited in a playa environment, similar to the dark playa deposits (Tsdp) along Hackberry Wash. A little brown claystone that resembles the playa claystone (Tsc) in the Gila River valley was observed west of Ripsey Wash in the north-central part of sec. 2, T. 5 S., R. 13 E. Bedded tuff (Tsrt) marks the base and, in part, the top of this unit

Tsrt *Rhyolitic to dacitic tuff (0–4 ft).* — Thin beds of rhyolitic, rhyodactic, and dacitic tuff and tuffaceous sandstone are abundant in the tuffaceous sandstone (Tst) and in the underlying and overlying granitic conglomerate. A few of the more conspicuous beds have been mapped. They are mostly reworked bedded deposits that range from a few inches to about 4 feet in thickness. The longest one in this quadrangle was traced for more than 2 miles, but a lower tuff in the granitic conglomerate (Tsg) is more than 5 miles long, extending northwestward into the adjacent Grayback Mountain quadrangle. Most of the relatively pure tuff is white, but tuffaceous sandstone is pale orange to grayish orange pink. Small pumice lapilli are sparse to abundant. The 5-mile-long tuff is a conspicuous lapilli tuff with abundant large (1 to locally 4 cm) pumice lapilli and many small (mostly 1–2 cm) clasts of Pinal Schist. It is associated with some finer grained tuffs. Biotite from a tuff near the top of the tuffaceous sandstone and conglomerate (Tst) has given a K-Ar age of 17.1 m.y. (Jarel Von Essen, written commun., 1972). The chemical and normative composition of this tuff is given in table 2.

TABLE 2.— *Chemical analysis and norm of rhyodacite tuff, SE¼ SW¼ sec. 35, T. 4 S., R. 13 E.*

[Analysts, P. Elmore, G. Chloe, J. Kelsey, J. Glenn, H. Smith]

Chemical composition (in percent)		CIPW norms in percent)		
SiO_2	59.8	Q		30.8
Al_2O_3	14.2	C		1.8
Fe_2O_3	1.4	Or		8.5
FeO	.88	Ab		21.8
MgO	1.4	An		19.1
CaO	5.9	En		3.6
Na_2O	2.5	Fs		.023
K_2O	1.4	Mt		2.1
H_2O+	7.4	Il		.60
H_2O-	3	Ap		.24
TiO_2	.31	Cc		3.8
P_2O_5	.10		Total	92.4
MnO	.04		Salic	82.1
CO_2	1.6		Femic	10.3
Total	100			

The tuffs in the San Manuel Formation have been extensively altered, mostly to clinoptilolite. An unmapped tuff in the dark conglomerate (Tsda) has been altered almost completely to erionite. A little glass is present in some specimens, but most of the glass has been either zeolitized or altered to montmorillonite. Some specimens contain calcite; many are concretionary. Biotite in the altered tuff is largely fresh

Tsc *Playa claystone (0–2,000 ft).* — The claystone is brown to light brownish gray, very thin bedded (mostly ½–1 inch thick); contains some thin interbeds of gray sandstone and a few olive-gray beds of granule to pebble conglomerate, mostly less than 6 inches thick. The claystone contains, in addition to clay, silt to very fine sand-sized grains of quartz, feldspar, biotite, and some calcite. Gypsum beds and veins ½–4 inches thick occur in the claystone near the center of sec. 34 and west of the megabreccia near the boundary between sections 29 and 32, T. 4 S., R. 14 E., and about 1,500 feet north-northwest of the center of sec. 8, T. 5 S., R. 14 E. The claystone envelops the southern half of the northern megabreccia (Tsbe and Tsbm, 2 miles west of Kearny) and lies mostly west of (below) the southern megabreccia lenses (Tsbe, Tsbu, west of the north-trending part of Hackberry Wash)

Tsl *Limestone conglomerate.* — Two small lenses of gray limestone conglomerate crop out in secs. 18 and 19, T. 4 S., R. 14 E., 2 and 3 miles northwest of Kearny. Pebbles and cobbles of Williamson Canyon Volcanics, rhyodacite porphyries, diabase, Precambrian and Cambrian quartzite, and Ruin Granite are present in both lenses, but more abundant in the northern one. In many places the sandy matrix is pale brown. Limestone clasts, especially in the southern lens, are mostly angular; some are of boulder size

Tsb *Megabreccia (0–750 ft).* — Large landslide blocks, interbedded in playa and alluvial deposits of the San Manuel Formation, form tabular to lenslike masses a few feet to at least 750 feet thick and a few tens of feet to nearly 2½ miles long. The lenses are conformable to the enclosing sedimentary rocks. The breccias were derived from Precambrian, Paleozoic, Cretaceous, and lower Tertiary rocks. Some lenses are monolithologic; others consist of several formations still in stratigraphic sequence. In some lenses, lithologic units have been thinned or thickened during emplacement or the stratigraphic sequence has been repeated by imbrication or mixing during sliding. Some disruption of sequence may be due to earlier thrusting or faulting or to postemplacement faulting. Some of the breccia consists of angular fragments with little matrix—largely a crackled rock, which may grade into rocks with angular to rounded and rotated fragments and abundant matrix of finely comminuted material. Some breccias resemble debris flows; locally they grade into conglomerates. The breccia lenses probably were derived from highlands to the west. Several small breccia masses, which may be remnants of slides, rest on pre-Tertiary rocks in sec. 1, T. 5 S., R. 13 E., and sec. 8, T. 5 S., R. 14 E. Contact relations of the breccia lenses interbedded in the San Manuel Formation require that very low differential pressure existed on the underlying soft sand and clay, because no channeling or disruption of the bedding has been found

Tss *Playa sandstone (0–500).* — Light gray to yellowish gray, poorly indurated, thin bedded to thinly laminated, locally crossbedded. The sandstone is mostly fine to medium grained with a matrix of silt to clay-sized particles and is composed of quartz, feldspar, biotite, clay, and calcite cement. Thin beds and seams of brown claystone and layers of curled mud chips are common, and thin beds of granule and small pebble conglomerate are locally present. The unit has a strike length of 3 miles and underlies the northern two-thirds of the large megabreccia lenses except where claystone intervenes in the central part

Tsa *Quartzite conglomerate (0–1,300 ft).* — Grayish-red to pale-brown, pebble to boulder alluvial conglomerate with subangular to angular clasts derived from the Apache Group, mostly Dripping Spring Quartzite, and Barnes Conglomerate Member with variable amounts of Tortilla Quartz Diorite, Williamson Canyon Volcanics, rhyodacite, Ruin Granite, and Paleozoic limestone. Sandstone makes up much of the narrow bed that extends northward from the limestone conglomerate in sec. 19, T. 4 S., R. 14 E.

Tr3 **RHYODACITE PORPHYRY.** — Occurs as dikes that cut quartz latite and other rhyodacite porphyries. Composed of a light-brownish gray aphanitic groundmass. The phynocrysts and their abundance in the rock are as follows: plagioclase (andesine-labradorite) 1–5 mm long (6–12 percent), biotite, 1 mm in diameter, altered (3 percent), and quartz, 1–2 mm in diameter (< 1 percent)

Tql **QUARTZ LATITE PORPHYRY.** — Occurs as prominent vertical dikes in the northwest part of the quadrangle. One particularly prominent quartz latite dike, approximately 100 feet thick, extends west from Mineral Creek to the west edge of the quadrangle near the Gila River and thence west to southwest 5 miles across the Grayback quadrangle. Phenocrysts make up 10–20 percent of the rock and consist of abundant, partly glomeroporphyritic, sericitized and kaolinized oligoclase-andesine, 0.5–3 mm long; abundant quartz 0.2–2 mm in diameter; sparse to common magnetite and altered biotite 0.2 and 1 mm in diameter respectively; and accessory apatite and zircon. Groundmass is aphanitic, white to cream colored, and consists of intergrown K-feldspar, quartz, plagioclase, magnetite, apatite, and sericite

Ttm **TEAPOT MOUNTAIN PORPHYRY.** — One vertical dike extends eastward across sec. 36, T. 4 S., R. 13 E., into sec. 31, T. 4 S., R. 14 E. Contains sparse phenocrysts of K-feldspar 30 mm long and quartz 5 mm across in an aphanitic, cream to light-orange groundmass, which consists of intergrown plagioclase, K-feldspar, quartz, and minor biotite, hornblende, and magnetite. The feldspars are moderately to intensely altered to sericite, calcite, kaolinite, and montmorillonite, the biotite and hornblende to chlorite, epidote, and calcite

Tqm **QUARTZ MONZONITE.** — Occurs as a stock in sec. 36, T. 4 S., R. 13 E., intruding Ruin Granite and Tortilla Quartz Diorite, cut by a dike of Teapot Mountain Porphyry. Light brownish gray, fine to medium grained, and hypidiomorphic-granular. Modal analysis showed: plagioclase (39 percent), quartz (29 percent), K-feldspar (24 percent), biotite (7 percent), magnetite (1 percent), and accessory apatite, sphene, and epidote. Patches of disseminated pyrite occur locally. The plagioclase is oligoclase-andesine (An_{30-38}), slightly to moderately altered to sericite, kaolinite, and montmorillonite; biotite is partly chloritized. Aplite veins, locally present, typically have the following modal composition: oligoclase (24 percent), quartz (31 percent), K-feldspar (43 percent), biotite (1 percent), and accessory magnetite, apatite, hornblende, and iddingsite

Tr2 **RHYODACITE PORPHYRY.** — Forms vertical dikes throughout the quadrangle. Phenocrysts, which make up about half of the rock, are constituted: euhedral, partly glomeroporphyritic andesine 1–5 mm long, 25–35 percent; subhedral to rounded quartz 5 mm in diameter, 5–13 percent, biotite and hornblende 1–2 mm across, 1–17 percent; and subhedral magnetite-ilmenite 0.3 mm across, 1 percent. Groundmass is tan to cream colored, aphanitic, anhedral-granular, and consists of K-feldspar, plagioclase, quartz, biotite, hornblende, magnetite-ilmenite, and accessory apatite, zircon, allanite, and sphene. The feldspars, particularly plagioclase, commonly are partly altered to kaolinite, montmorillonite, sericite, and calcite; biotite and hornblende are partly altered to chlorite and epidote

TKmr **MELANOCRATIC RHYODACITE PORPHYRY.**— Occurs as vertical east-west striking dikes that crop out in the northern part of the quadrangle. Phenocrysts, which make up about 30 percent of the rock, are constituted in decreasing order of abundance: partly altered andesine, quartz, hornblende, altered biotite, and magnetite-ilmenite. The andesine and quartz are as much as 1.5 cm in longest dimension, the remaining phenocrysts less than 5 mm long. The groundmass is very fine grained and consists of hornblende, andesine, K-feldspar, quartz, magnetite-ilmenite, and accessory sphene, apatite, and zircon

TKr **RHYODACITE PORPHYRY.** — Forms vertical, east-west-striking dikes scattered throughout the quadrangle. Phenocrysts, 3 mm or less in length and making up about 35 percent of the rock, consist of andesine, hornblende, biotite, and sparse quartz in a very fine grained groundmass of the same minerals plus K-feldspar, magnetite-ilmenite, and apatite. The andesine has been partly to intensely altered to sericite, kaolinite, and montmorillonite; the hornblende and biotite have been largely altered to chlorite plus some epidote

TKrh **RHYODACITE PORPHYRY.** — These east-trending vertical dikes cut diabase in the northern part of the quadrangle. Prominent phenocrysts of plagioclase, hornblende, and minor biotite, 1–3 mm long, in a medium-gray aphanitic groundmass, make up about 25 percent of the rock. Texture is partly trachytic. Groundmass consists of plagioclase, quartz, K-feldspar, hornblende, biotite, magnetite-ilmenite, and minor apatite and calcite. The plagioclase has been largely replaced by sericite, clay minerals, and calcite; the biotite by chlorite. The hornblende has been partly altered to chlorite plus some calcite

TKa **ANDESITE.** — Forms two vertical, east-trending dikes in northwest part of quadrangle. Consists of very sparse altered hornblende phenocrysts 2 mm long in a greenish-gray aphanitic groundmass that has a microtrachytic texture composed of plagioclase and hornblende laths. Plagioclase is fresh; hornblende is partly altered to chlorite, epidote, calcite, and sphene. Contains irregular patches of interstitial quartz and K-feldspar plus some calcite, epidote, sphene, and limonitic magnetite.

Kgd **GRANODIORITE.** — Occurs as irregular stocks emplaced in Precambrian rocks near the southern border of quadrangle east of Ripsey Wash. Medium light gray with brownish tinge. Contains abundant plagioclase laths 1–5 mm long, biotite books 1–3 mm across, hornblende crystals 1–5 mm long, and small magnetite crystals. Groundmass consists of quartz, K-feldspar, plagioclase, and mafic and opaque minerals. Tentatively correlated with granodiorite in the Winkelman quadrangle (Krieger, 1974b), that contains biotite dated by the K-Ar method, at 66.0±2.0 m.y.

Kt **TORTILLA QUARTZ DIORITE.** — A number of small stocks of this quartz diorite crop out in the western part of the quadrangle and in the adjoining Sonora and Grayback Mountain quadrangles. A good exposure of a rather large stock in N½ sec. 2. T. 4. S., R. 13 E. in the northwest corner of the Kearny quadrangle has been designated its type section (Cornwall and others, 1971). Separate stocks range in composition from pyroxene-hornblende diorite through biotite-hornblende quartz diorite. Typically medium grained, hypidiomorphic-granular, fresh or slightly altered, and composed of (55–65 percent) plagioclase (An_{40-50}), hornblende (25–35 percent), clinopyroxene, and biotite in variable proportions, magnetite-ilmenite (3–5 percent), interstitial quartz and orthoclase (10–20 percent) and accessory apatite, zircon, and sphene. Local porphyritic patches with pyroxene and hornblende phenocrusts to 3 cm across are common. K-Ar ages of 71±2 m.y. and 83±2 m.y. were obtained on coexisting biotite and hornblende, respectively, these dates, though discordant, indicate a Late Cretaceous age (Banks and others, 1972).

Kw **WILLIAMSON CANYON VOLCANICS.** — A small mass in NW¼ sec. 8, T. 5 S., R 14 E., is medium-dark-gray porphyritic andesitic volcanic breccia with abundant xenoliths of Troy Quartzite and unidentified rock fragments. It is composed of equidimensional plagioclase crystals, mostly less than 1 mm in diameter, pyroxene, as much as 2 mm in diameter, and magnetite in a groundmass of plagioclase, mafic minerals, and magnetite. Some of this rock resembles Tortilla Quartz Diorite. The northern part of this mass is white due to extensive sericitization; some of it also shows extensive limonitic staining. The Williamson Canyon Volcanics in the megabreccia (Tsbw) includes grayish-purple to brownish-gray flow breccias and agglomerates and massive grayish-green andesitic flow rocks. Most of these rocks in the megabreccias are altered and locally epidotized

Mzbp **BASALT PORPHYRY.** — Forms three small sills and a few unmapped dikes in the Martin Limestone in the northeast corner of the quadrangle (secs. 2, 11, and 12, T. 4 S., R. 14 E.). An olive-gray, fine- to medium-grained porphyritic (plagioclase) to intergranular rock composed of plagioclase, augite, magnetite-ilmenite. The rock is moderately to intensely altered: plagioclase is sericitized and kaolinized; pigeonite and augite are slightly chloritized; olivine is altered to antigorite, bowlingite, and iddingsite; and magnetite-ilmenite is partly altered to limonite and sphene. Fresh biotite and apatite locally are abundant. Some interstitial quartz, K-feldspar, and calcite; calcite occurs in veinlets and replacing plagioclase

IPn **NACO LIMESTONE.** — Part of the formation is exposed in the northeastern part of the quadrangle. Units of resistant shaly limestone, each unit commonly about 5 feet thick. The formation contains a few beds of shale, calcareous shale, and siltstone. Lenses and nodules of chert locally prominent. The limestone is commonly aphanitic or fine grained, thin to thick bedded, light yellowish gray. The shale and calcareous shale or silstone beds are laminated, pale red to light olive gray. Contains fusulinids, brachiopods, corals, crinoids, Bryozoa, and ostracods

Me **ESCABROSA LIMESTONE.** — Crops out in the northeastern part of the quadrangle in sec. 33, T. 3 S., R. 14 E., and adjacent sections and in southwestern part in SE¼ sec. 12, T. 5 S., R. 13 E.; comprises two small flat-lying megabreccia bodies on Precambrian diabase in sec. 1, T. 5 S., R. 13 E., and large megabreccia masses interbedded in alluvial and playa deposits in the San Manuel Formation. Consists of several hundred feet of light- to dark-gray dolomite separated by slope-forming, gray, yellowish-gray, and black limestone and dolomite; fine to coarse grained; thin to thick bedded. Silicified fossils and chert nodules are common in parts of the formation. Base of formation consists of about 15 feet of pale-red dolomite, weathering orange or brown, fine grained, thin bedded, calcareous. Fossils include brachiopods, corals, and ostracods

Dm **MARTIN LIMESTONE.** — Partial exposures of the formation occur in the northeastern and southwestern parts of the quadrangle. Consists of several hundred feet of fine-grained dolomite, laminated to thin bedded, medium dark gray to light olive gray. A thick limestone layer, medium to light olive gray, occurs in the upper part of some exposures. A few sandstone and shaly limestone beds are scattered through the formation, and the base consists of 5–15 feet of dolomitic sandstone and sandy dolomite, grayish orange with rounded frosted quartz grains, prominent on weather surfaces. Brachiopods and crinoids are fairly common and brachiopods (*Atrypa reticularis*) in the upper part

Ꞓa **ABRIGO FORMATION.** — In the southwestern part of the quadrangle, the formation ranges in thickness from 110 to 220 feet; in the northeastern part, 60 to 80 feet. Slope-forming composite unit of interbedded mudstone, siltstone, sandstone, quartzite, and a little dolomite; laminated to thin bedded, some crossbedding. Reddish brown and grayish orange to light gray; composed of subangular quartz plus feldspar, glauconite, dark minerals, and phosphatic brachiopods in a well-cemented siliceous and ferruginous matrix. *Scolithus* and fucoids are locally abundant. Probably equivalent to Krieger's (1968) lower member of the Abrigo Formation.

Ꞓb **BOLSA QUARTZITE.** — Crops out in the northeast corner of the quadrangle. Normally less than 100 feet thick. White to pinkish-gray and light-brown, fine- to medium-grained quartzitic sandstone. Contains well-sorted subrounded to rounded quartz grains in a siliceous matrix that is partly ferruginous and kaolinitic. The strata are laminated to thin bedded, locally thick bedded. *Scolithus* abundant in upper part

db **DIABASE.** — Forms sills in Precambrian sedimentary rocks and sheets in Precambrian granite parallel to the pre-Apache surface. In the northeast corner of the quadrangle, a flat-lying 500-foot sill has intruded the lower part of the Mescal Limestone. In the western part of the quadrangle, discordant bodies and steeply dipping sheets have intruded the Ruin Granite. Dark gray to olive gray, fine to coarse grained with diabasic to ophitic texture. The fresh rocks are composed of plagioclase (An_{35-55}), augite, pigeonite, olivine, and magnetite-ilmenite. These minerals have been slightly to intensely altered to sericite, kaolinite, bowlingite, antigorite, limonite, iddingsite, hornblende, biotite, epidote, and pumpellyite. Locally the diabase contains intergrowths of quartz and K-feldspar. Thicker sills have pegmatitic schlieren

TROY QUARTZITE. — Sections exposed in the northeastern and southwestern parts of the quadrangle are 100–500 feet thick. Chiefly grayish pink and white to light brown and orange quartzite and sandstone composed of medium to coarse subangular to rounded quartz grains with variable amounts of feldspar, limonite, and dark minerals in a matrix of quartz with some clay. Beds range from laminated to very thin, arranged in thin to thick composite tabular to lenticular sets, locally crossbedded. Interbedded conglomerate at the base of the formation contains pebbles and cobbles of various sandstones, quartzites, cherts plus basalt, Mescal limestone, and Pinal schist

APACHE GROUP: Includes, in ascending order, the Pioneer Formation, Dripping Spring Quartzite, Mescal Limestone, and basalt

b BASALT. — Consists of one or more flows 0–60 feet thick. Porphyritic basalt, grayish to blackish red and brown with vesicular and amygdular tops. Phenocrysts, 2–8 mm long, are plagioclase. Groundmass is fine grained and consists of plagioclase (An_{50}), pyroxene, olivine, and magnetite-ilmenite intensely altered to chlorite, sericite, calcite, epidote, quartz, limonite, kaolinite, and some K-feldspar.

m MESCAL LIMESTONE. — The formation, 150–320 feet thick, crops out in the northeastern and southern parts of the quadrangle. Light-pink, brown, and brownish-gray dolomite, partly calcareous, thinly laminated to thin bedded, very fine grained to coarse grained. Some beds have abundant black, white, and pink chert in lenses and nodules. Stromatolitic algal beds occur above the middle of the formation, layers of sandstone and quartzite near the middle in some areas. The formation has been metamorphosed by diabase to marble and calc-silicates, and in many places contains layers of introduced magnetite

ds DRIPPING SPRING QUARTZITE. — Crops out in the northeastern and southern parts of the quadrangle. Ranges in thickness from 600 to about 700 feet. Includes the following members in descending order:

Siltstone member (400–500 feet). — Siltstone interbedded with shale and fine-grained arkosic sandstone, laminated to thin bedded with low-angle cross laminae; light to dark gray, olive gray, dusky brown, and grayish red. K-feldspar is abundant and pseudomorphs of small pyrite cubes are common. Individual laminae are fair to well sorted with subangular to subrounded quartz, K-feldspar, pyrite (limonite), and other dark minerals and siliceous cement. Forms slopes

Arkose member (150–200 feet). — **Arkose and feldspathic quartzite, fine to coarse grained, fair to well sorted, laminated to thin bedded with low-angle cross laminae, white, grayish orange, light pink and brown; forms ledges**

bc *Barnes Conglomerate Member (1–50 feet).* — **Well-rounded, ellipsoidal pebbles and cobbles of white, gray, and red quartz, red jasper, siltstone, quartzite, and schist in a matrix of light-gray, light-orange, and light-brown arkosic,** subrounded sand; well cemented, thick bedded, some crossbeds; forms ledges

p PIONEER FORMATION. — The formation ranges in thickness from 130 to 220 feet, crops out in the southern part of the quadrangle. Includes following members in descending order:

Tuffaceous siltstone and arkosic sandstone member. — Tuffaceous siltstone is grayish red and purple, partly mottled with bleached spots, laminated with low-angle cross laminae, composed of subrounded grains of K-feldspar, plagioclase, quartz, limonite, hematite, and glass shards devitrified to chalcedony and sericite. Arkosic sandstone is fine to medium grained, tuffaceous with devitrified shards, and similar in composition and color to the siltstone

sc *Scanlan Conglomerate Member.* — 1–10 feet of conglomerate and arkosic sandstone with angular to subrounded pebbles of white quartz in a fine- to very coarse-grained matrix of quartz, K-feldspar, plagioclase, dark minerals, sericite, and chalcedony. Ranges from white to speckled light gray and orange pink. Rock is well cemented with siliceous cement, laminated to thin bedded with low-angle cross laminae

Yr RUIN GRANITE. — Underlies large areas of the western and southern parts of the quadrangle. Yellowish-gray to grayish-orange, coarse-grained granite and quartz monzonite with pale-pink to orange-pink orthoclase and microcline phenocrysts, partly perthitic, in a coarse-grained groundmass of quartz, plagioclase (An_{8-35}), biotite, and minor zircon, sphene, and magnetite. The plagioclase is partly sericitized, the biotite partly chloritized. Contains dikes and lenses of fine- to medium-grained aplite composed of microcline, albite-oligoclase, quartz, muscovite, and minor magnetite

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