MAP GQ-1109

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE PUTNAM WASH QUADRANGLE, PINAL COUNTY, ARIZONA

By Medora H. Krieger

GEOLOGIC QUADRANGLE MAP
Published by the U.S. Geological Survey, 1974
Washington, D.C. 20244

KRIEGER—PUTNAM WASH QUADRANGLE, ARIZ. 1:24,000 MAP GQ-1109

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

TO ACCOMPANY MAP GQ-1109

GEOLOGIC MAP OF THE PUTNAM WASH QUADRANGLE, PINAL COUNTY, ARIZONA

By Medora H. Krieger

REGIONAL GEOLOGIC SETTING

The broad regional geologic and structural setting of the Winkelman 15-minute quadrangle, of which the Putnam Wash quadrangle is the southeast part, is discussed by Krieger (1974). Rocks within the general area range in age from Precambrian to Holocene. At least half of the area of the Putnam Wash quadrangle is probably underlain by early(?) Miocene alluvial and playa deposits that dip steeply eastward and have been involved in a major gravity slide and later cut by high-angle faults.

STRATIGRAPHY

The oldest Precambrian rocks in the area of the larger scale index map are the Pinal Schist and intrusive rocks, largely the Ruin Granite (Oracle Granite of Peterson, 1938). Batholithic masses of Ruin Granite (1,430 m.y.) were intruded after a period of intense deformation that produced near-vertical east-trending foliation and bedding in the schist. The schist and granite are overlain with profound angular unconformity by Precambrian sedimentary rocks--the Apache Group and the disconformably overlying Troy Quartzite. Diabase, about 1,200 m.y. old (Silver, 1960; Damon and others, 1962), forms sills in the Apache Group and Troy Quartzite, sill-like masses in the schist and granite generally parallel to, and not more than 500 feet below, the pre-Apache surface (Shride, 1967, p. 56), and some dikes. The sills inflated, but did not perceptibly tilt,the Precambrian sedimentary rocks.

After a long period of erosion, Paleozoic formations were deposited paraconformably on the Precambrian sedimentary rocks and diabase sills.

Volcanic rocks of Late Cretaceous age disconformably overlie older rocks in the area of the larger scale index map. A small remnant of the Cloudburst Formation, of probable latitic composition, is present in the southwest corner of the Putnam Wash quadrangle. The Cloudburst Formation is included in the Late Cretaceous because Creasey (1967) considered it probably the same age as the volcanic rocks (Williamson Canyon Volcanics) in the Christmas quadrangle. These volcanic rocks were considered Late Cretaceous by Willden (1964), or Late Cretaceous and(or) early Tertiary by Creasey (1965, 1967). In the Crozier Peak quadrangle the Williamson Canyon Volcanics is intruded by diorite that in the Winkelman quadrangle is dated at 65 m.y. (Late Cretaceous).

Cenozoic stratigraphy in eastern Pinal County has recently been revised by Krieger and others (1973). In the area of the larger scale index map,Tertiary sedimentary deposits, formerly called the Gila Conglomerate or Group, are now divided into three formations--in ascending order, the San Manuel, Big Dome, and Quiburis. In addition, Pleistocene and Holocene alluvial deposits, also formerly included in the Gila Conglomerate or Group, overlie these formations.

The San Manuel Formation consists of alluvial and playa deposits, and interbedded andesite and megabreccias. It is Miocene (probably early Miocene) in age. Discordant dates on biotite and sanidine from a rhyodacite tuff bed in its upper part in the Crozier Peak quadrangle are 18 and 24 m.y., respectively (Joan Engels, written commun., 1968). The San Manuel Formation is clearly unconformably overlain by the alluvial Big Dome Formation in the Kearny and Crozier Peak quadrangle. In the Kearny quadrangles (Cornwall and Krieger,1974)an interbedded nonwelded ash-flow tuff yields late Miocene K-Ar ages of 14 m.y. on biotite and 17 m.y. on hornblende (see also Banks and others, 1972). The youngest of these formations, the Quiburis Formation, which consists of an alluvial and a lakebed facies, was deposited in the basin now occupied by San Pedro River. It contains Hemphillian vertebrate fossils (see Krieger, 1974a), indicating a middle Pliocene age.

STRUCTURE

The major structural features in the Winkelman 15-minute quadrangle southwest of the Gila and San Pedro River are high-angle faults, north-northwest-trending en echelon ridges of steeply dipping to overturned Precambrian and Paleozoic sedimentary rocks and diabase, and low-angle gravity slides. Portions of the en echelon ridges are exposed near the eastern edge of the quadrangle, north of Putnam Wash, and in the center of the northern edge of the quadrangle, the southern tip of a ridge that extends completely across the Winkelman 7½-minute quadrangle. As the tops of the beds in the en echelon ridges always face east, the structures are interpreted as partly eroded roots of a single monoclinal fold later separated by faults, or possibly as a series of monoclinal folds. Locally, the section within an individual ridge is repeated along what appear on a map as high-angle faults, but which are inferred to be tilted thrusts. Some of the faulting, monoclinal folding, tilting of the thrusts, uplift, and erosion of large areas now stripped of Precambrian and Paleozoic sedimentary rocks occurred before deposition of the San Manuel Formation, for the oldest unit in that formation in the Putnam Wash quadrangle is composed largely of Precambrian granite clasts. Intense deformation also occurred after deposition of the San Manuel Formation, for adjacent to the monoclinal ridges, the formation dips steeply, although somewhat less than the older rocks.

The faults can be divided into those that predate and those that postdate the San Manuel Formation, although renewed movement probably occurred on some of the earlier faults in post-San Manuel time. Those that predate the San Manuel are the thrusts, now

tilted to vertical or overturned, and some of the high-angle faults that trend east-northeast and north.

Faults that postdate the San Manuel Formation are west-dipping, low-angle gravity slides, high-angle, north-northwest-trending faults, and a few east-northeast-trending faults. Some high-angle faults, or some of the movement on them, also postdate the Big Dome Formation; a few postdate the Quiburis Formation.

The Camp Grant fault, a major gravity slide feature, is well exposed on the north side of Camp Grant Wash about 2,000 feet southwest of its junction with Putnam Wash. The gravity slide surface, dipping 20° W., is exposed between Ruin Granite on the east and the San Manuel Formation on the west. The surface on granite is remarkably smooth. A few inches of conglomeratic gouge separates the granite from the overlying conglomerate. Fracture cleavage in the gouge indicates that the upper block moved from east to west. The conglomerate, which dips steeply northeast, is cut by subparallel cycloidal (in section) faults and by steeper west-dipping faults. The steeper faults end downward at the gravity slide surface, or at the cycloidal faults. Camp Grant fault has been cut by north-northwest-trending high-angle faults, notably the Cowhead Well fault. North of Putnam Wash, the Camp Grant fault may have been offset to the west by east-northeast-trending faults (exposed near the corner of sections 3, 4, 9, 10, T. 7 S., R. 15 E.), possibly by renewed movement along earlier strike-slip faults.

MINERALIZATION

The Winkelman 15-minute quadrangle, of which the Putnam Wash is a part, is adjacent to three major copper deposits: the San Manuel to the southeast, the Christmas to the northeast, and the Ray to the northwest. Although no economic deposits have yet been found within the 15-minute quadrangle, numerous prospect pits, shafts, and adits have explored the principal mineralized areas, which are in granitic rocks in the southeast corner and in the north-central and northwestern parts of the 15-minute quadrangle.

Mineralization in the Putnam Wash quadrangle is most intense in the southeast corner of the quadrangle. Narrow silicified, limonitic, brecciated, and sheared zones in general trend northwest and contain quartz, pyrite, malachite, azurite, chrysocolla, fluorite, wulfenite, and manganese oxides. This mineralization may be related to the Laramide mineralization at the San Manuel copper mine, about 5 miles to the southeast. Near the center of the east edge of the quadrangle, manganese, manganese-calcite, and dark-gray manganiferous calcite veins have been explored by prospect pits. They probably are Tertiary in age. Little evidence of mineralization was noted in the Ruin Granite in the northwest part of the quadrangle. It consists of a little quartz-pyrite mineralization and many noneconomic tourmaline and tourmaline-quartz veins.

DESCRIPTION OF MAP UNITS

SURFICIAL DEPOSITS

Alluvium (0-15 ft exposed).—Flood-plain deposits along valley bottoms, composed of clay, silt, sand, and some gravel; largely unconsolidated.

Travertine (0-10 ft).—Two small remnants on southeast side of Camp Grant Wash (NE¼ sec. 24, T. 7 S., R. 14 E.). Deposited before wash cut down to its present level; indicates location of former falls. Many gulches on south side of wash, near and upstream from the travertine, enter the wash as "hanging valleys."

Talus (0 - about 10 ft exposed).—Veneer of rock debris derived from adjacent bedrock; only those in northeast part of sec. 12, T. 7 S., R. 15 E. are large enough to map.

Soil and gravel veneer on pediments and younger terraces (0-25 ft.)—Subangular pebbles and cobbles in a generally reddish-brown, fine- to coarse-grained matrix. Clasts largely nongranitic in eastern half and granitic in western half of quadrangle. Pediments somewhat dissected and include younger colluvial material on slopes and alluvial material on shallow valley bottoms. The dark-red-brown soils were developed during one of the pre-Wisconsin interglaciations.

Undifferentiated gravels (0-10 ft exposed).—Talus and alluvium. Along Camp Grant Wash near the southern border of the map area, it consists of light-gray, well-cemented gravels composed of granitic and nongranitic pebbles in a matrix of sand and very small pebbles derived from granitic rocks. Deposited in channels in San Manuel Formation and locally overlain by fine-grained brown alluvium.

SAND AND GRAVEL (0-AT LEAST 200 FT)

Covers the southwestern third of the map area, mostly west of the underground pipeline, and caps ridgetops in many other places. In northeastern 6 square miles of the quadrangle, where it is difficult to separate the gravel and sand from older deposits, questionable outcrops are assigned to the Pleistocene sand and gravel. Unit consists of poorly exposed, essentially unconsolidated alluvial sand and gravel composed largely of fragments derived from granitic rocks, except in eastern part south of Putnam Wash, where material was derived largely from nongranitic rocks. Ridgetop gravel and sand generally have the same composition as the underlying formations, making separation difficult. Some may represent weathered, leached, and slumped older gravels, not a younger deposit. The ridgetop gravels have been separated largely on the basis of appearance on areal photographs and absence of exposures of dipping gravels. One exposure (near center S.½ sec. 13, T. 7 S., R. 15 E.), however, shows ridgetop gravels that lack the reddish color, large granitic cobbles and boulders, and scattered clasts of andesite that are characteristic of the underlying San Manuel Formation. Locally, gravels tentatively correlated with ridgetop gravels clearly fill channels in San Manuel Formation (see NW¼ sec. 14, T. 4 S., R. 15 E.). The underground pipeline may mark the approximate position of the buried fault scarp against which gravels to the west were deposited.

QUIBURIS FORMATION (0-MORE THAN 100 FT EXPOSED)

Named by Heindl (1963); see also Krieger and others (1973); Krieger (1974a); called Gila Conglomerate by Krieger (1968c, d); and Creasey (1965, 1967). The formation consists of two facies. The lakebed facies lies along San Pedro Valley east and north of the quadrangle. The alluvial facies crops out in the northeast corner of the map area. It consists of pale- to light-brown, medium-light-brownish-gray, and pale-red pebble-conglomerate and interbedded sandy and silty beds. Clasts are subangular to subrounded, generally less than 4 in. in longest dimension; composed mostly of nongranitic Precambrian rocks but includes some granite. Channeling common; bedding rather poorly developed. Contacts with underlying Big Dome Formation and with overlying gravel and sand are poorly exposed and very arbitrarily placed.

BIG DOME(?) FORMATION

Thickness unknown, probably not more than a few hundred feet in this area. Named by Krieger and others (1973). Questionably correlated with the type Big Dome Formation in the Sonora quadrangle, where it was mapped, but not named, by Cornwall and others, (1971). May locally include the younger granitic alluvial deposits of the San Manuel Formation, alluvial facies of the Quiburis Formation, and Pleistocene sand and gravel. Yellowish gray, pale olive to grayish orange pink; largely derived from Ruin Granite and related rocks.

SAN MANUEL FORMATION (0-POSSIBLY 10,000 FT)

Named by Heindl (1963). The formation, which is well exposed along Putnam and Camp Grant Washes and their tributaries, crops out in about one-third of the quadrangle but probably overlies more than half of it. Although the formation has not been mapped southward along Cowhead Well fault to the exposures in the west-central part of the Mammoth 7½-minute quadrangle, because of lithologic similarities and structural relations, I believe that the correlation is justified (see Heindl, 1963, also lower member of the Gila Conglomerate, Creasey, 1965). The formation is divided in this quadrangle into 5 units that in part interfinger.

Granitic playa(?) deposits (0 - at least 2,500 ft, if unfaulted).—Crops out in central part of quadrangle. Best exposures along Putnam Wash at and for about a mile east of Beehive Well. Thin and well bedded, yellowish gray to pale olive and light shades of brown sandstone and conglomerate; composed largely of clasts of light-colored granitic rocks, some andesite, and scattered nongranitic, mostly Precambrian rocks concentrated in local beds or lenses. Massive to thinly laminated white rhyolite tuff beds, ¼ to 1 ft thick, some of them composed entirely of altered pumice shards. Beds 6 to 12 in. thick with pebble- to cobble-sized clasts show no evidence of channeling of underlying fine-grained beds. The lateral extent of pebble to cobble beds, extent and smoothness of surfaces on which thin beds of tuff were deposited, and absence of channeling are characteristic of this unit. These same bedding features are typical of some of the deposits in the Kearny quadrangle, where the abundance of mud cracks and curled mud chips prove a playa origin for that part of the San Manuel Formation. Mud chips were not observed in the Putnam Wash quadrangle, but the other bedding features are so similar that it is probable that this unit also was deposited in a playa. Possibly some of the conglomerates formed as mudflows into temporary lakes. Local channeling and crossbedding in sandstone may indicate fluvial deposits. The unit is underlain conformably to the west by older granitic alluvial deposits and overlain to the east, north, and south of Bloodsucker Wash, by nongranitic alluvial deposits. Elsewhere the unit may interfinger with, or be in fault contact with, other units.

Nongranitic alluvial deposits (possibly 3,000 - 4,000 ft).—Crops out extensively in the eastern half of the map area and in two areas in northwest part. Mostly shades of brown and yellowish to olive gray; alternating beds of sandstone, siltstone, pebble to cobble conglomerate with local boulders as much as 5 ft long, some rhyolite and lapilli tuff, and concretionary tuffaceous sandstone. Clasts are of Pinal Schist, diabase, Precambrian and Paleozoic sedimentary rocks, and Tertiary and older(?) andesite; few granitic clasts. Bedding mostly thin to very thin; locally thick to massive; thinly laminated in silty beds. Locally much channeled, especially in eastern exposures between Camp Grant and Putnam Washes, where much of the unit is coarse grained.

The various blocks mapped as nongranitic alluvial deposits do not all represent the same stratigraphic unit. Very similar deposits that may represent the same units are in (1) the southeastern part of the mapped area, (2) in the northeastern part north of Putnam Wash, and (3) in the northwestern part east of the older granitic gravels. The outcrops on the west side of the older granitic gravels, east of Antelope Peak, probably are a lens or tongue at the base of the older granitic gravels. The lens south of the north-central area of Pinal Schist may also represent intertonguing of granitic and nongranitic material at the top of the older granitic unit and the base of the younger granitic alluvial deposits. Gravels composed largely of Escabrosa Limestone that surround small outcrops of Paleozoic rocks in the northeast part of the area (sec. 2, T. 7 S., R. 15 E.) are included in this unit. Four small lenses in the central part of the area north of Bloodsucker Wash are discussed under megabreccia.

Younger granitic alluvial deposits (thickness unknown, probably less than 1,000 ft).—Mostly poorly exposed and poorly bedded, light-gray, pebble to boulder conglomerate in a sandy matrix; composed of clasts of granitic rocks, some andesite, and locally a little Pinal Schist.

Older granitic alluvial deposits (maximum more than 5,000 ft, if not repeated by faults).—Crops out from near north edge of quadrangle, east of Antelope Peak to southern border, just west of Camp Grant Wash. Poorly exposed and poorly consolidated, coarse- to fine-grained alluvial and fanglomeratic deposits; pale red and light shades of yellowish, olive, and brownish gray. Composed largely of clasts of granitic rocks, considerable amount of Cretaceous(?) andesite, and local beds and lenses of Pinal Schist, and Precambrian and Paleozoic sedimentary rocks. Unit becomes coarser grained and more poorly exposed westward, with local boulders as much as 12 ft long. In eastern exposures (west of Beehive Well) thin beds (a few inches thick) of light-colored sand and silt 100 or more feet long may be due to local ponding. These fine-grained beds are intercalated with beds containing granules and pebbles and with thicker beds containing widely scattered cobbles and small boulders. Sorting mostly poor, except in some fine-grained lenses. West of Beehive Well contact with granitic playa(?) deposits is easily mapped; elsewhere this contact is approximately located.

Nongranitic red alluvial deposits (maximum of at least 3,500 ft if not faulted).—The unit crops out from just north of Putnam Wash to the granite outcrops south of Camp Grant Wash in the eastern part of the map area. Maroon-colored (shades of red and reddish brown) conglomerate, sandstone, and some mudstone. Well to poorly sorted, well indurated, thin to thick bedded; bedding generally pronounced, in spite of coarseness; considerable channeling in some areas. Sorting varies from very poor to good. Sand-filled mud cracks noted in maroon mudstone and conglomeratic mudstone in western outcrops just north of Camp Grant Wash. Clasts range in size from granules to boulders locally 10 ft across; derived from Pinal Schist, diabase, Precambrian and Paleozoic sedimentary rocks, andesite, and rhyolite identical to a rhyolite dike of Miocene age (see below). Granitic clasts, mostly red, are concentrated near south-

east margin, but locally are abundant elsewhere; clasts of light-colored granite are sparsely represented. Appears to be gradationally overlain on east by nongranitic alluvial deposits. It is in fault contact with similar deposits and with granitic playa(?) deposits on the west.

Andesitic volcanic rocks.—Small outcrops of andesite resting on Ruin Granite crop out in SW¼ sec. 28 and SE¼ sec. 29, T. 7 S., R. 15 E., and near center sec. 12, T. 7 S., R. 14 E. (three small flow remnants and one east-northeast-trending discontinuous dike). Dark-brownish-gray rock contains small phenocrysts of altered olivine. As the outcrops in secs. 28 and 29 are overlain by the older granitic alluvial deposits, the andesite is tentatively included in the San Manuel Formation. It may, however, be an older formation, but it is not considered part of the Cloudburst(?) Formation, as it is not as altered as the volcanic rocks of the type Cloudburst.

Megabreccia.—Small lenses of megabreccia are intercalated at several horizons in granitic and nongranitic alluvial deposits. Also included is the larger granitic breccia mass along the contact between Ruin Granite and nongranitic alluvial deposits south of Camp Grant Wash. Individual lenses range in length from a few feet to about 1,500 ft and have a maximum width of about 200 ft. Some of the lenses are compound, but lithologic types are not mixed. Fragments in the breccias are largely angular, locally somewhat rounded. The matrix consists of small angular fragments and rock flour similar in composition to the larger fragments in an individual lens. Breccias of limestone and quartzite generally are extremely well indurated; those of other lithologic types may be less well indurated. The breccias probably formed as landslide blocks. They occur in the following places (1) The andesite in sec. 23, T. 7 S., R. 15 E., is considered a monolithologic breccia because of the presence in the area of breccias of other lithologic types, but admittedly it is difficult to distinguish a sedimentary volcanic breccia from a flow breccia. The western part of the western mass resembles a flow breccia, but the contact with underlying gravels, which might have revealed baking, was not exposed. Alluvial deposits both above and below the lens contain andesite clasts. (2) On the east edge of the map area, 900 ft southeast of number 30 of sec. 30, T. 7 S., R. 15 E., a small outcrop of Troy Quartzite breccia on the boundary between the Lookout Mountain and Putnam Wash quadrangles was mapped as conglomerate in the base of the Pioneer Formation (3) Two low dark hills, surrounded by granitic playa(?) deposits, north of Bloodsucker Wash near the center of the quadrangle, consist of a western part of brecciated white quartzite and brown dolomitic sandstone (middle and upper members) of the Abrigo Formation and some blocks of Escabrosa Limestone and an eastern part of nongranitic alluvial deposits composed of clasts from the Apache Group, Pinal Schist, Abrigo and Escabrosa Formations in a dark-red matrix. The two lenses may be separated by faults. Two lenses of nongranitic alluvial deposits, one north and one south of the lenses just described, contain blocks as much as 6 ft long of brecciated and nonbrecciated Precambrian and Paleozoic sedimentary rocks and andesite. (4) The breccia masses south of Camp Grant Wash include small lenses of sedimentary breccia derived from the middle and Barnes Conglomerate Members of the Dipping Spring Quartzite, diabase, and granite, and larger masses of granite breccia, some of which probably is of sedimentary origin and some of tectonic(?) origin; some resembles talus deposits. Granite near the contact is badly brecciated and appears to grade into talus and sedimentary breccia, both of which intertongue with the alluvial deposits. (5) A small west-dipping lens of Bolsa Quartzite in NE¼ sec. 2, T. 7 S., R. 15 E., rests on east-dipping Bolsa Quartzite.

INTRUSIVE RHYOLITE

Forms dikes and a small lenticular plug(?) in Pinal Schist, Ruin Granite, and diabase along eastern edge of quadrangle. The largest dike, north of Putnam Wash, is a very light gray porphyritic rock with abundant phenocrysts (as much as 4 mm) of quartz, sanidine, plagioclase, biotite, and rare magnetite in a microcrystalline, locally spherulitic groundmass of quartz, K-feldspar laths, chalcedony, and finely disseminated hematite. K-Ar determination on biotite from a sample near the north end of the dike gave an indicated age of 22.3±0.7 m.y. (Miocene) according to Richard Marvin (U.S. Geol. Survey, written commun., 1966). Dike extends 1½ miles southeast into the Lookout Mountain quadrangle, where it had been assigned a Late Cretaceous and(or) early Tertiary age. Other dikes, similar in abundance and size of phenocrysts, but with less biotite, may be rhyodacite in composition; they are light brownish to olive gray, possibly reflecting greater abundance of Fe oxides in groundmass. Chemical and normative compositions of the sample that was analyzed for age are given in table 1.

TABLE 1.—*Chemical and normative compositions of intrusive rhyolite*

[Analysis under the direction of Leonard Shapiro, methods given in U.S. Geol. Survey Bull. 1144-A]

Field No. W-10			
Chemical composition (in percent)		CIPW norm (wt percent)	
SiO_2	76.20	Q	40.2
Al_2O_3	12.8	c	1.8
Fe_2O_3	.87	or	26.9
FeO	.12	ab	25.7
MgO	.25	an	3.5
CaO	.72	en	.6
Na_2O	3.0	mt	.03
K_2O	4.5	hm	.9
H_2O-	.35	il	.3
H_2O+	.65	ap	.05
TiO_2	.18		
P_2O_5	.02	Total [1]	99.98
MnO	.05		
CO_2	< .05	Salic	98.1
		Femic	1.9
Total	100		

[1] In calculating the norms, H_2O- and H_2O+ were omitted

DIKES UNCLASSIFIED

Six small dikes in Ruin Granite in the northwestern and eastern parts of the quadrangle are probably related to Late Cretaceous and(or) early Tertiary dikes in adjacent quadrangles (Krieger, 1974a,b,c). Some are similar to the medium-gray to olive-gray, equigranular fine-grained diorite dikes in the Winkelman quadrangle; some resemble rhyodacite porphyry and hornblende porphyry

dikes in the Crozier Peak quadrangle. None are more than a few feet wide.

CLOUDBURST FORMATION

Named by Pelletier (1957). Present only in the southwest corner of the map area, where it is represented only by volcanic rocks and where it forms the northern tip of a larger mass that extends westward and northwestward into the southeastern part of the Black Mountain quadrangle (Krieger, 1974c). Volcanic rocks of latitic composition, are dark-gray to brownish- and purplish-gray flows and agglomerates with fairly abundant 2-mm phenocrysts of altered mafic minerals.

PALEOZOIC FORMATIONS

All named by Ransome (1904). Limited to three small exposures in northeastern part of the quadrangle.

ESCABROSA LIMESTONE

Massive, mostly thick-bedded, coarse-grained light-gray and yellowish- to greenish-gray limestone. Exposure in sec. 6, T. 7 S., R. 16 E., is western tip of a larger mass.

MARTIN FORMATION (100 FT EXPOSED)

Olive-gray to reddish-brown shale with a few feet of interbedded limestone at the top. Forms a slope.

ABRIGO FORMATION

The formation consists of three members in quadrangles east of the San Pedro River (Krieger, 1968a, b, d, e).

Upper member (less than 100 ft exposed).—Dark-brown-weathering, thin- to thick-bedded, medium- to coarse-grained, poorly sorted, crossbedded dolomitic and glauconitic sandstone.

Middle member (not exposed in this quadrangle, but represented on section A-A'; probably about 200 ft. thick).—Cliff-forming, light-yellowish-gray, poorly sorted sandstone.

Lower member (over 200 ft exposed).—Thin-bedded brown mudstone and sandstone.

BOLSA QUARTZITE (170 FT EXPOSED)

Medium- to fine-grained, well-bedded quartzite.

DIABASE

Abundant as sills in Apache Group and as sill-like masses in Pinal Schist, parallel to the pre-Apache surface, in northeastern part of map area; also present as irregular masses in Ruin Granite in northwest and southeast part. The diabase is dark gray to dark greenish or olive gray, and fine to coarse grained, with diabasic to ophitic texture; composed of plagioclase, pyroxene, olivine, magnetite, and ilmenite. Felsic dikes with hornblende needles, probably a differentiate of the diabase, intrude it in sec. 13, T. 7 S., R. 14 E. Diabase well below the pre-Apache surface probably owes its present position to unrecognized faults.

TROY QUARTZITE

Named by Ransome (1915). Present only as megabreccia (Tsbt) in the San Manuel Formation, where it consists of gray to pale-red conglomerate and sandstone of the lower member.

APACHE GROUP (MAXIMUM OF ABOUT 300 FT EXPOSED)

Group, formations, and members named by Ransome (1903), except for Mescal Limestone (Ransome, 1915) and for the siltstone and arkose members of the Dripping Spring Quartzite (Shride, 1967). The Apache Group includes, in ascending order, the Pioneer Formation and Dripping Spring Quartzite,both of which crop out in the northeastern part of the quadrangle; and the Mescal Limestone, which crops out a short distance east of the map area.

DRIPPING SPRING QUARTZITE (ABOUT 400 FT THICK)

The formation consists of three members; the siltstone and arkose members were not mapped separately in this area.

Siltstone and arkose members.—The siltstone member is thin-bedded (¼-12 in.) siltstone to very fine grained, feldspathic to arkosic quartzite that is shades of gray, brown, red, and yellow. The arkose member is medium grained, thin to very thick bedded (2 to 12 ft) and crossbedded, red to pink feldspathic to arkosic quartzite. Lower one-third of member in this area is buff-colored, fine-grained quartzite and sandstone and grayish-red-purple siltstone and fine-grained sandstone; superficially resembles some beds in Pioneer Formation.

Barnes Conglomerate Member (0-10 ft).—Ellipsoidal, extremely well rounded pebbles (¼ - 6 in) of quartzite, quartz, and red jasper, mostly closely packed, locally sparsely scattered, in a matrix of red to gray, arkosic sandstone and quartzite.

PIONEER FORMATION (0-ABOUT 100 FT)

Upper member, dark-red to purple siltstone and very fine grained sandstone with numerous pale-red to yellowish-gray elliptical leached spots; light-colored and reddish-orange, fine- to medium-grained, crossbedded sandstone; some dark-red to purple, coarse-grained sandstone. Many beds are tuffaceous. *Scanlan Conglomerate Member,* represented by only a few widely scattered, angular clasts of quartz in a few inches or feet of red or brown arkosic matrix, except in northernmost outcrops, where it consists of as much as 5 ft of dark conglomerate composed of cobbles, as much as 1 ft in diameter, of jasper-magnetite or quartz-hematite replacement beds from the Pinal Schist, overlain by a few feet of conglomerate composed of schist pebbles about 1 in. in diameter.

APLITE

Aplite and, locally, pegmatite dikes cut Ruin Granite, granodiorite, and Pinal Schist. Only a few have been mapped. In southwest corner (west of muscovite granite), closely spaced shear zones in Ruin Granite strike N. 40°W., and dip 25°-45° E. These zones are intruded by pegmatite and have a layered appearance. Pegmatites are a few inches to 10 ft thick, are zoned, and contain some aplite. Most pegmatites are probably closely related to muscovite granite; many aplites probably are related to Ruin Granite.

MUSCOVITE GRANITE

White to very light gray rock composed of quartz, microcline, plagioclase, light-gray to yellowish-brown and olive-gray muscovite books, and minor amounts of opaque minerals. It forms two small masses near the western edge of the quadrangle. Numerous aplites and pegmatites, apparently related to the muscovite granite, cut Ruin Granite in the northern area and west of the lens of Pinal Schist(?) in the southwestern area. The large aplite dike in the southeast corner of the map area also probably is related. The complete absence of aplite in Ruin Granite east of the southwestern mass suggests a fault separation. The west side of this mass probably is a low-angle fault or gravity slide surface. K-Ar determinations on muscovite give an indicated age of 1,310±40 m.y., whereas a Rb-Sr whole rock determination gave 1,550±80 m.y., according to Richard Marvin (written commun., 1967). The younger age may indicate a degassing of the muscovite, possibly caused by intrusion of diabase. The Rb-Sr age, however, is

older than the 1,430-1,460 m.y. age suggested for the Ruin Granite by Silver (1968). Chemical and normative compositions of the muscovite granite are given in table 2.

TABLE 2.—*Chemical and normative compositions of muscovite granite*

[Analyses under the direction of Leonard Shapiro, methods given in U.S. Geol. Survey Bull. 1144-A]

Field No. W-38			
Chemical compositions (in percent)		CIPW norm (wt percent)	
SiO_2	77.6	Q	48.4
Al_2O_3	13.20	C	4.4
Fe_2O_3	.44	or	21.0
FeO	.12	ab	23.2
MgO	.12	an	1.7
CaO	.48	en	.3
Na_2O	2.70	mt	.2
K_2O	3.50	hm	.3
H_2O	.04	il	.2
H_2O+	.92	ap	.3
TiO_2	.11		
P_2O_5	.11	Total [1]	100.0
MnO	.03		
CO_2	.05	Salic	98.7
		Femic	1.3
Total	99.00		

[1] In calculating the norms, H_2O- and H_2O+ were omitted

RUIN GRANITE AND RELATED ROCKS

Named by Ransome (1903). Same as Oracle Granite of Peterson (1938). Coarse-grained, porphyritic, pinkish- to yellowish-gray quartz monzonite, speckled with dark biotite books (as large as 5 mm), and containing euhedral, somewhat poikilitic and perthitic phenocrysts of microcline and microperthite (as large as 4 x 2 cm, locally larger). Somewhat zoned plagioclase (mostly less than 1 cm, locally 3 cm), much of it sericitized; quartz as rounded crystals (about 6 mm) and as finer intergrowths with microcline; accessory magnetite and apatite; biotite locally altered to a mixture of magnetite and chlorite.

Associated with Ruin Granite are alaskite, aplitic alaskite, alaskite porphyry, and aplite, not mapped separately except for some of the aplites. Quartz monzonitic rocks appear to grade into alaskite with decrease in mafic mineral content, grain size, and size and abundance of microcline phenocrysts, increase in K-feldspar content, and change from light color to darker shades of red. Aplitic and porphyritic alaskite and aplite are grayish pink to very pale orange with phenocrysts of quartz and feldspar as much as 5 mm long in an aplitic or saccharoidal groundmass. These finer grained rocks riddle the Ruin Granite in many areas and from most of the ridgetops owing to greater resistance to erosion. Alaskite and at least some of the aplites appear to be closely related to, but slightly younger than, the Ruin Granite. Narrow tourmaline and quartz-tourmaline veins cut granitic rocks near Antelope Peak. Ruin Granite intrudes granodiorite and Pinal Schist. According to Silver (1968), the age of granite (quartz monzonite) in Arizona, based on U-Pb isotope systems in zircon is 1,430-1,460 m.y. Damon and others (1962) have dated the Ruin Granite near Oracle at 1,420 m.y.

GRANODIORITE

In southeast corner of map area. Very light gray and dark gray (salt and pepper), medium grained (less than 4 mm, mostly less than 1 mm); contains zoned and saussuritized plagioclase, somewhat strained quartz, biotite and hornblende (some of which are altered to chlorite), minor amounts of interstitial microcline, and accessory magnetite and sphene. It is intruded by Ruin Granite; both rocks in area are cut by numerous quartz veins and silicified zones. Relation to Pinal Schist is unknown, but it probably is younger. Granodiorite in southeastern Arizona is 1,650-1,700 m.y., according to Silver (1968).

PINAL SCHIST

Named by Ransome (1903). The formation crops out in the northeastern, north-central, northwestern, and southwestern parts of the quadrangle. The northeastern area is largely fine-grained, finely laminated, medium- to dark-gray and grayish-red quartz-sericite schist, probably of sedimentary origin. Some bedding is contorted; some well-developed slaty cleavage. Where the schist is hornfelsed locally near the Ruin Granite, andalusite metacrysts as much as 2 cm long, now largely altered to muscovite, have developed. A little tourmaline is present locally. The north-central area is olive-gray to greenish-gray, massive to bedded volcanic breccia and conglomerate, probably of andesitic composition, but with some finely laminated siliceous rock, and local slate with a pronounced pencil structure. The northwestern area is mostly dark-gray, massive, locally vesicular and amygdaloidal flow or flow breccia of andesitic or basaltic composition, with some bedded(?) tuffs and hematitic jasper or quartz-hematite replacement(?) veins. In southwest corner of map area, a narrow band of sheared(?) dark mafic volcanic and (or) intrusive rock is questionably included in the Pinal. On the east it is in contact with muscovite granite along an east-dipping low-angle fault or gravity slide surface.

JASPER-MAGNETITE OR QUARTZ-HEMATITE REPLACEMENT(?) VEINS

Dusky-red-purple; veined with white quartz, common in Pinal Schist, but not mapped separatedly in this quadrangle except for two small masses in Ruin Granite (NNE of Antelope Peak), which may be xenoliths of veins in the Pinal Schist.

REFERENCES

Banks, N.G., Cornwall, H.R., Creasey, S.C., and Marvin, R.F., 1972, Chronology of the intrusion and ore deposition at Ray, Arizona, Pt. 1, K-Ar ages : Econ. Geology, v. 67, no. 5, p. 864-878.

Cornwall, H.R., Banks, N.G., and Phillips, C.H., 1971, Geologic map of the Sonora quadrangle, Pinal and Gila Counties, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-1021, scale 1:24,000.

Cornwall, H.R., and Krieger, M.H., 1974, Geologic map of the Kearny quadrangle, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-1188, scale 1:24,000 (in press).

Creasey, S.C., 1965, Geology of the San Manuel area, Pinal County, Arizona: U.S. Geol. Survey Prof. Paper 471, 64 p.

———1967, General geology of the Mammoth quadrangle, Pinal County, Arizona: U.S. Geol. Survey Bull. 1218, 94 p.

Damon, P.E., Livingston, D.E., and Erickson, R.C., 1962, New K-Ar dates for the Precambrian of Pinal Gila, Yavapai, and Coconino Counties, Arizona, *in*

New Mexico Geol. Soc. Guidebook, 13th Field Conf., Mogollon Rim Region, east-central Arizona, p. 56-67.
Heindl, L.A., 1963, Cenozoic geology in the Mammoth area, Pinal County, Arizona: U.S. Geol. Survey Bull. 1141-E, 41 p.
Krieger, M.H., 1968a, Geologic map of the Brandenburg Mountain quadrangle, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-668, scale 1:24,000.
———1968b, Geologic map of the Holy Joe Peak quadrangle, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-669, scale 1:24,000.
———1968c, Geologic map of the Lookout Mountain, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-670, scale 1:24,000.
———1968d, Geologic map of the Saddle Mountain quadrangle, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-671, scale 1:24,000.
———1968e, Stratigraphic relations of the Troy Quartzite (younger Precambrian) and the Cambrian formations in southeastern Arizona: *in* Southern Arizona Guidebook III (Geol. Soc. America, Cordilleran Sec., 64th. Ann. Mtg., Tucson, 1968): Tucson, Ariz., Arizona Geol. Soc., p. 22-32.
———1974a, Geologic map of the Winkelman quadrangle, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-1106, scale 1:24,000.
———1974b, Geologic map of the Crozier Peak quadrangle, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-1107, scale 1:24,000.
———1974c, Geologic map of the Black Mountain quadrangle, Pinal County, Arizona: U.S. Geol. Survey Geol. Quad. Map GQ-1108, scale 1:24,000.
Krieger, 1974d, Regional geologic and structural setting of the Winkelman 15-minute quadrangle, Arizona: U.S. Geol. Survey Jour. Research, v 2 (in press).
Krieger, M.H., Cornwall, H.R., and Banks, N.G., 1973, The Big Dome Formation and revised Tertiary stratigraphy in the Ray-San Manuel area, Arizona: *in* Changes in stratigraphic nomenclature. U.S. Geol. Survey Bull. 1394-A, p. 100.
Pelletier, J.D., 1957, Geol. of the San Manuel mine (Arizona): Mining Eng., v. 9, no. 7, p. 760-762.
Peterson, N.P., 1938, Geology and ore deposits of the Mammoth mining camp area, Pinal County, Arizona: Arizona Bur. Mines Bull. 144, geol. ser. 11 (Arizona Univ. Bull., v. 9, no. 2), 63 p.
Ransome, F.L., 1903, Geology of the Globe copper district, Arizona: U.S. Geol. Survey Prof. Paper 12, 168 p.
———1904, The geology and ore deposits of the Bisbee quadrangle, Arizona: U.S. Geol. Survey Prof. Paper 21, 168 p.
———1915, The Paleozoic section of the Ray quadrangle, Arizona: Washington Acad. Sci. Jour., v. 5, p. 380-385.
Shride, A.F., 1967, Younger Precambrian geology in southern Arizona: U.S. Geol. Survey Prof. Paper 566, 89 p.
Silver, L.T., 1960, Age determinations on Precambrian diabase differentiates in the Sierra Ancha, Gila County, Arizona [abs.]: Geol. Soc. America Bull., v. 71, no. 12, pt. 2, p. 1973-1974.
———1968, Precambrian batholiths of Arizona [abs.]: Geol. Soc. America, Cordilleran Sec., 64th Ann. Mtg., Tucson, Ariz., program, p. 109-110.
Willden, Ronald, 1964, Geology of the Christmas quadrangle, Gila and Pinal Counties, Arizona: U.S. Geol. Survey Bull. 1161-E, p. E1-E64.