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Geologic Map of the San Carlos Indian Reservation, Arizona

By Chester T. Wrucke, Calvin S. Bromfield, Frank S. Simons, Robert C. Greene, Brenda B. Houser, Robert J. Miller, and Floyd Gray

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INTRODUCTION

This map is a result of a study of the geology and mineral resource potential of the San Carlos Indian Reservation (Reservation) for the San Carlos Apache Tribe. The map provides new information on the geology of an area that contains the boundary between the Basin and Range Province on the south and the mountainous terrain that, in this part of Arizona, borders the southern structural margin of the Colorado Plateaus Province (herein referred to as the Colorado Plateau) on the north. In particular the map shows the great variety of Tertiary volcanic and sedimentary rocks typical of the northern part of the Basin and Range Province in east-central Arizona and the structural complications resulting from Cenozoic extension. Geology depicted in this map may aid in the interpretation of mineral resources between the copper mining areas of the Globe-Miami district to the west of the Reservation and the Morenci district to the east.

The San Carlos Indian Reservation, nearly 7,400 km^2 in size and extending a maximum of about 115 km east-west and 95 km north-south, is located in east-central Arizona 190 km east of Phoenix. Most of the Reservation consists of northwest-trending mountains and valleys, including the extensive area of mountains and plateaus along the Salt and Black Rivers at the north border. Drainage is mostly into the Gila River, which crosses the southern part of the Reservation. However, the northern part of the Reservation drains into the Salt and Black Rivers, and a small area at the southwest corner is in the drainage of the San Pedro River. A great variety of rocks is exposed on the Reservation. They range in age from Proterozoic to Quaternary and include Paleozoic strata, a few units of Mesozoic age, and extensive sedimentary and volcanic rocks and a granitic pluton of Cenozoic age. Isotopic ages are provided for many rock units (table 1, sheet 2).

The geology of the area was mapped during the period 1983-1988, mainly by detailed reconnaissance but in some areas in considerable detail. Previously published detailed mapping (Lindgren, 1905; Willden, 1964; Krieger, 1968a,b; Simons, 1964, 1987a,b; Houser and others, 1985; Ferguson and Enders, 2000) is included in the map. The area along the north border between Chiricahua Butte and the Black River Pumping Station was mapped in reconnaissance in 1999.

To facilitate discussion of the geology, the map area is divided into four areas (fig. 1, sheet 1)—northern, central, southern, and eastern—based on distinctive geology and topography of each area. Each of these areas includes adjacent land outside of the Reservation. The northern area consists of mountainous highlands along the north margin of the Reservation and extends from the west border approximately to the eastern edge of the Natanes Mountains. To the south is the central area, trending east-southeast and composed mostly of mountains and intervening basins of the Basin and Range Province but also has the north boundary of that province. In the eastern area, which parallels the east border of the Reservation, the northern boundary of the Basin and Range Province continues southeasterly from the central area and has high plains as well as mountainous terrain to the northeast of that boundary and the basin of Bonita Creek to the southwest. The Gila Mountains are at the southern margin of the eastern area. The southern area, containing high mountains, is divided from the central area by lowlands northwest of San Carlos Reservoir and along the Gila River.

PROTEROZOIC ROCKS

The oldest rocks on the San Carlos Reservation are Paleoproterozoic in age. They consist of gneiss (Ᵽ$_P$g) near the south border south of Bylas and the Pinal Schist (Ᵽ$_P$g) at scattered localities in the Gila Mountains and eastern and southern areas of the Reservation. The Paleoproterozoic age of the gneisses is inferred from their strongly foliated and gneissic character, which is typical of rocks of this age in southeastern Arizona. The Pinal Schist is known to be about 1,700-1,600 Ma (Conway and others, 1987).

Rocks considered to be of Mesoproterozoic age include a mostly undated assemblage of basic to felsic intrusive bodies at Mt. Turnbull near the south border of the Reservation: widespread granitic rocks (Ᵽ$_M$g) correlated with the 1,460-1,430 Ma Ruin Granite of central Arizona, the Apache Group (Ᵽ$_M$am, Ᵽ$_M$ad, Ᵽ$_M$ap) and basalt (Ᵽ$_M$ab), and the Troy Quartzite (Ᵽ$_M$t) above the Apache Group. Strata of the Apache Group and Troy Quartzite rest depositionally on the Mesoproterozoic granite (Ᵽ$_M$g) and are intruded by diabase (Ᵽ$_M$d) dated at about 1,100 Ma (Damon and others, 1962; Banks and others, 1972; Silver, 1963, 1978). Zircons from tuffaceous beds in the Pioneer Shale (Ᵽ$_M$ap) at the base of the Apache Group have yielded a recently determined age of 1,328 Ma (Stewart and others, 2001), and zircons from the Dripping Spring Quartzite (Ᵽ$_M$ad) higher in the Apache Group and from the overlying Troy Quartzite (Ᵽ$_M$t) have given ages, respectively, of 1,264 Ma and 1,256 Ma. The zircons from the Dripping Spring and the Troy are thought to represent volcanism approximately contemporaneous with deposition of these formations (Stewart and others, 2001). The northeasternmost exposures of the Apache Group, basalt, Troy Quartzite, and the diabase known in Arizona are on the Reservation.

PALEOZOIC ROCKS

Paleozoic strata on the San Carlos Reservation consist of marine sedimentary rocks that range in age from Cambrian to Pennsylvanian. Beds of Silurian age are missing. The section is thickest in the southern area where it attains a thickness of about 1,500 m, whereas the section is about half that thick in northern areas of the Reservation. Cambrian strata thin to the north and northeast, and some Cambrian units change in composition and become time-transgressive (Hayes, 1975). Ordovician strata are found at the eastern end of the Nantac Rim and on Pistol Creek near its junction with Eagle Creek at the east border of the Reservation. Elsewhere to the west, strata of this age are absent. Devonian and Pennsylvanian strata vary locally in composition and thickness. Compositional variations are less apparent in the Mississippian rocks, though they thin greatly from south to north.

MESOZOIC ROCKS

Rocks of Mesozoic (Cretaceous) age crop out near the southwest corner of the Reservation and in the Clifton-Morenci area east of the Reservation. Sedimentary rocks (Ks) at the southwest corner of the Reservation include sandstone, conglomerate, and minor amounts of limestone, siltstone, shale, and coal (Kc); these are overlain by andesite flows (Kv). The sedimentary section is 90-460 m thick, and the volcanic rocks are estimated to be 600-900 m thick. Some of the sedimentary rocks have been converted to garnetite and hornfels adjacent to the Santa Teresa Granite (Tst) of Tertiary age. Andesitic plugs, sills, and dikes of Cretaceous age intrude the sedimentary and volcanic rocks. Nearby to the north in Granite Basin, a Cretaceous dacite porphyry laccolith (Ki) intrudes the Pennsylvanian Horquilla Limestone (ℙMu). Mesozoic sedimentary rocks in the Clifton-Morenci area consist of shale and sandstone of the Pinkard Formation (Kp).

TERTIARY OR CRETACEOUS ROCKS

Rocks assigned to the Cretaceous or Tertiary Periods crop out in three small areas of the Reservation, one near the east border and two near the west border. On the west side of lower Bonita Creek, at the southeast corner of the Reservation, a small outcrop of propylitically altered rocks (TKv), perhaps in part epiclastic, is correlated with a larger area of Cretaceous or Tertiary volcanic rocks a few kilometers south of the Reservation, north of Safford (fig. 1, sheet 1). Although dates from these rocks are inconclusive, they suggest that these volcanic rocks and associated quartz monzonitic and granodioritic porphyries (TKg) span the interval between the Late Cretaceous and early Tertiary (70-50 Ma) (Houser and others, 1985).

On the west side of the Reservation, two small stocks of granodiorite (TKgp) and associated dikes crop out west of Sevenmile Wash, a few kilometers east and southeast of Chrome Butte. The rocks intrude the Apache Group and are strongly altered. Their age is uncertain but they resemble porphyries of Cretaceous or Tertiary age in the Sonora quadrangle southwest of the Reservation (Cornwall and others, 1971), the Globe-Miami district west of the Reservation (Peterson, 1962), and the Christmas area adjacent to the Reservation on the southwest (Koski and Cook, 1982). A porphyry dike 10 km north of Coolidge Dam also may be of Tertiary or Cretaceous age.

CENOZOIC ROCKS

A great variety of sedimentary and igneous rocks, amounting to roughly two-thirds of the exposed bedrock in the Reservation, accumulated during the Cenozoic Era. Rocks from each epoch of the Tertiary Period are represented. Isotopic ages are available for many of the igneous rocks. A small rhyolite intrusive body (Tr) near the southwest corner of the Reservation and four small intrusive bodies in the Clifton-Morenci area (Tpu, Tgp, Tmp, Tdp) are the only rocks of Paleocene age. An intrusive breccia (Tibx) near Morenci is Eocene in age, and a few andesite flows and breccias, basalt and dacite flows (Tawf), and intrusive rocks (Tawi) near the northeast corner may be of Eocene age. In contrast to rocks of Paleocene and Eocene age, rocks of Oligocene age are abundant. Locally in the central and southern areas of the Reservation the Whitetail Conglomerate(?) (Tw) crops out at the base of the Oligocene section, though in the northern area of the Reservation the Whitetail underlies volcanic rocks of Miocene age (Tbn). The Whitetail contains clasts of Proterozoic and Paleozoic rocks and either no volcanic material or locally a volcaniclastic matrix. Volcanic rocks of Oligocene age are numerous (see Correlation of Map Units) and widespread and consist of thick accumulations of andesitic and basaltic lavas (Tab, Tabv, Tgad) together with less extensive intrusive and extrusive dacite (Tda, Tsv, Tdpf, Tdpw, Tdpi, Tad, Tvd, Tdr, Tvs, Tvu), rhyolite (Tsv, Tir, Tirs, Tem, Ttnu, Ttnl, Tta, Tvr, Tvrb, Tgr, Tvs, Tvu), laharic breccia (Tl), and silicic rocks of uncertain composition (Tgh, Tvt). These Oligocene rocks and overlying andesite (Tpt, Tab, Tgua), basalt and basaltic andesite (Tbn, Tab, Tvu) of early Miocene age constitute the most extensive rocks of Cenozoic age on the Reservation. The Tertiary volcanic rocks have been classified according to the system adopted by the International Union of Geological Sciences (Le Bas and Streckeisen, 1991). Chemical analyses (fig. 2; table 2, sheet 2) from rocks extensively exposed across the northern, central, and eastern areas of the Reservation have an alkaline trend. This alkaline trend is typical of mid-Tertiary volcanic rocks in the Basin and Range Province and mountainous terrain of Arizona (Nealey and Sheridan, 1989). Oligocene and Miocene andesitic rocks also are widely exposed in southern Arizona and adjacent parts of New Mexico (Dickinson, 1989). An analysis of one representative example of these rocks from the Guthrie quadrangle southeast of the Reservation (fig. 2; table 2) also is alkaline and plots as trachyandesite (fig. 2). A batholith composed of the Santa Teresa Granite (Tst, Tstp, Tstb) of late Oligocene age that crops out in the southern

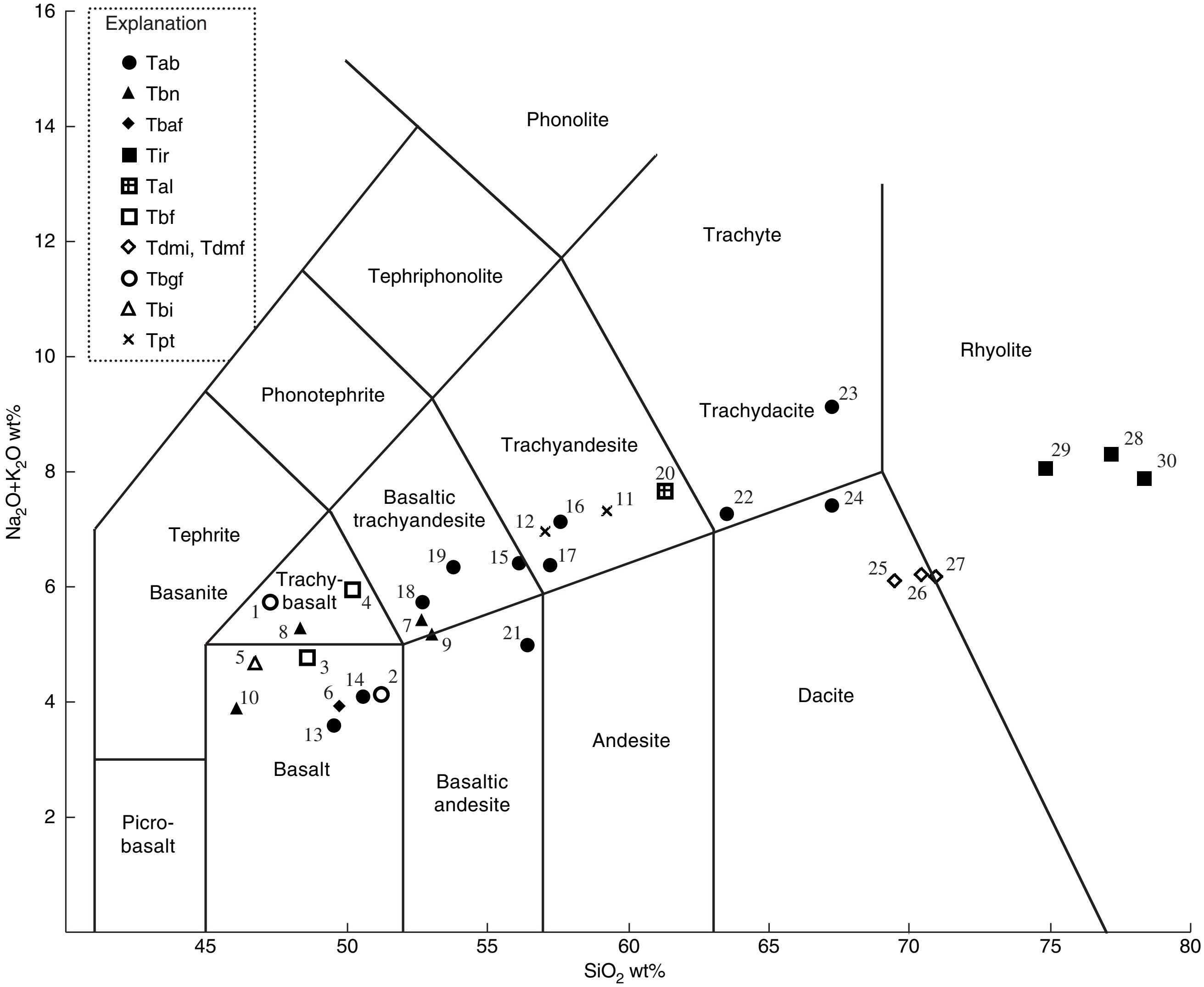

Figure 2. Na_2O+K_2O vs. SiO_2 variation diagram of the volcanic rocks north of the Gila River on the San Carlos Indian Reservation and of the Guthrie quadrangle, Arizona (fig. 1, sheet 1). Numbers refer to table 2 and location on geologic map. Discrimination lines are based on IUGS systematics of igneous rocks (LeBas and Streckheisen, 1991). Symbols plotted using analyses recalculated volatile-free.

area of the Reservation south of Mt. Turnbull is the largest Cenozoic intrusive body on the Reservation.

A variety of igneous and sedimentary rocks of Miocene to Pliocene age also crop out throughout the Reservation. These include dacite flows (Tdf, Tda, Tdmf, Tdft) and intrusive bodies (Tdf) and the physiographically prominent dacite plugs (Tdmi) at Mt. Triplet in the central area of the Reservation. The Gila Conglomerate (QTga,Tgs, Tgc, Tgcb, Tgsb, Tgls, Tgv Tgl, Tgcm, Tgm) of Miocene, Pliocene, and Pleistocene(?) age, exposed mainly along the Gila River, the San Carlos River, Bonita Creek, Eagle Creek and in the northeastern part of the area is the most widespread sedimentary unit on the Reservation. In most basins of the San Carlos Reservation, the Gila Conglomerate consists chiefly of proximal through distal alluvial-fan facies sedimentary rocks derived from the adjacent ranges, though axial stream deposits are present at the top of the sedimentary section in Bonita Creek basin. In the Gila River valley and on the east side of the San Carlos River valley, distal-fan facies rocks grade to and are interbedded with calcareous basin-center facies rocks consisting of shoreline, playa, and lacustrine facies. The lacustrine facies rocks are highly calcareous and in places are made up entirely of microbial mats or stromatolites. Lacustrine deposits indicate that a large shallow lake covered many square kilometers from northeast of Peridot southeast almost to Bylas. Basalt flows, interbedded with all facies of the Gila Conglomerate, locally are common in the central and southern parts of the Reservation but are absent in the eastern part.

In nearby basins in southeastern Arizona and southwestern New Mexico, the Gila Conglomerate commonly is composed of two major sedimentary packages that have been termed lower basin fill and upper basin fill. This separation is based on age, degree of consolidation, and amount of deformation (Houser and Gettings, 2000). Lower basin-fill deposits generally are middle to late Miocene in age, moderately consolidated, slightly to moderately deformed with dips of as much as 15˚ (higher adjacent to faults), and broken by numerous faults. Upper basin-fill deposits generally are Pliocene and Pleistocene in age, poorly consolidated, flat lying or nearly so, and broken by only a few faults. The two deposits are separated by an unconformity representing a hiatus of several million years.

Both deposits are present on the Reservation but in most areas were not differentiated in the field and, in areas where they were differentiated, are not shown separately on the map. The muddy sandstone and conglomerate member of the Gila Conglomerate (Tgm) in Bonita Creek basin consists of lower and upper basin fill separated by an unconformity or paraconformity. The other basin-fill unit, the conglomerate and associated sedimentary rocks member (Tgc), was not investigated with regard to the presence of upper and lower basin fill. Well-indurated, dipping and faulted limestone beds (Tgls) exposed along Highway 70 south of Mt. Triplet are upper basin-fill rocks deformed by nearby volcanic activity.

Pliocene volcanic rocks include extensive basalt flows on Antelope Flats (Tbgf) northeast of San Carlos and in the Bronco Gulch area northeast of San Carlos. Numerous basaltic diatremes (Tbv) of Pliocene age crop out in lowlands in the central part of the Reservation. The basalt of Bronco Gulch (Tbgf) of late Pliocene age (2.0±0.1 Ma) flowed down channels cut into basin-fill deposits of the Gila Conglomerate (Tgc) and its contained basalt flows (Tbf) and limestone deposits (Tgls, Tgl), suggesting that the modern through-flowing drainage system of the Gila River began about this time in this area. Pleistocene basalt flows (Qbpf) immediately southwest of San Carlos contain numerous olivine-rich peridotite nodules and are the youngest Cenozoic volcanic rocks on the Reservation. Other Quaternary deposits consist of basalt flows (QTb), piedmont gravels (Qp), terrace gravels (Qg), alluvial and colluvial sand, silt, and gravel (Qsg), calcareous tufa (Qct), landslide masses (Ql), talus (Qt), and stream alluvium (Qa).

STRUCTURAL GEOLOGY

The San Carlos Reservation straddles the boundary between the structural continuation of the Colorado Plateaus Province in the northern part of the Reservation and the Basin and Range Province in the southern part. The mountainous area in the Reservation north of the boundary includes the Natanes Plateau, the Nantac Rim, and the Sevenmile Mountains (fig. 1, sheet 1) and is included in the Mountain Region by Ransome (1904, 1923) and the Transition Zone by Bromfield and Shride (1956) and Wilson and Moore (1959). Sharp (1940) recognized that the Transition Zone has flat-lying strata and relatively few faults characteristic of the Colorado Plateau but extends south of the Mogollon Rim, which defines the physiographic southern margin of the Colorado Plateau in central Arizona. The Mogollon Rim is approximately 50 km north of the Reservation.

Northwest trends of the mountain ranges and major faults and the tilt of the mountain blocks are principal features of the structural geology of the Reservation. Northeast of a line from Chrome Butte southeast to Bylas on the Gila River (fig. 1), the mountain blocks tilt to the northeast, whereas southwest of that line the blocks tilt to the southwest. Major faults northeast of this line are sparse, but those that have been identified dip to the southwest and the sense of displacement is down to the southwest. In the area southwest of the line, most of the major faults dip to the northeast and have displacements down to the northeast. Many of the larger faults are here considered to have a listric geometry. The Deer Creek Syncline near the southwest corner of the Reservation is the most prominent fold in the Reservation.

A few thrust faults of Tertiary age are present in the Hayes Mountains (fig. 1), and low-angle normal faults are present on a small butte immediately south of the Sevenmile Mountains, near the east end of the low unnamed ridge that trends southesterly from Chrome Butte at the west border of the Reservation, and at scattered localities in the southern part of the southern area. Paleozoic rocks at the east end of the unnamed ridge may have traveled more than 15 km, the distance northward to a small remnant slice of possibly structurally related Devonian rock above a low-angle fault on an isolated butte near the base of the Sevenmile Mountains. The largest out-of-place rock masses in the southern part of the Reservation are 2 km in longest dimension and adjacent to the east side of the Santa Teresa pluton at Fiddler Camp Spring and White Spring. These are the Fiddler Camp Spring and White Spring klippen. Their origin is obscure. They and smaller displaced masses in the southern area are not associated with regional thrust faults or extensive low-angle normal faults. The bodies at Fiddler Camp Spring and White Spring contain the same kinds of Proterozoic rocks that crop out nearby, but they also contain Paleozoic rocks whose nearest exposures are more than 10 km to the west across the ridge that exposes the Santa Teresa Granite. Those Paleozoic rocks undoubtedly extended farther east into the region now occupied by the granite. The Fiddler Camp and White Spring bodies and adjacent smaller dislocated masses may have slid off a rising and partly denuded pluton before the granite mass reached its present height and cut off the supply of Paleozoic rocks to the west. Judged by the proximity of Proterozoic rocks to the north, the White Spring mass slid onto granite close to its upper contact.

Restricted basins were developed beginning in the early Oligocene with the onset of volcanism. Indirect evidence for a deep basin on the Reservation in the Oligocene and early Miocene is provided by volcanic rocks as thick as 3,000 m in the southern part of the reservation compared to a thickness of 1,000 m in the northern part.

Basin and range block faulting, which created the present topography of the Reservation, began in southeastern Arizona between about 18 and 12 Ma (Houser and others, 1985). The various members of the Gila Conglomerate of late Miocene, Pliocene, and Pleistocene age were deposited in basins south of the Nantac Rim and lap onto tilted fault blocks containing rocks as young as early Miocene in age. These basins developed after eruption of the basalt of the Natanes Plateau (fig. 1), which has been displaced down to the south by basin and range faults and has yielded an age as young as 16.7±0.4 Ma. By the time the oldest basalt interbedded with the Gila Conglomerate in the Hayes Mountains had erupted at 7.8±0.3 Ma, the Gila basin was well developed.

As mentioned above, the Gila Conglomerate consists of lower and upper basin-fill units separated by an unconformity representing a hiatus of several million years. In other basins of southeastern Arizona and southwestern New Mexico, radiometric dates indicate the hiatus lasted about 4 Ma, from about 10 Ma to 6 Ma (Houser and Gettings, 2000). The regional extent of the unconformity and the difference in the amount of deformation between lower and upper basin-fill units suggest that a significant change in tectonic activity occurred at the end of the Miocene in part of the southern Basin and Range Province, followed by renewed subsidence of the basins during the Pliocene.

DESCRIPTION OF MAP UNITS

[Some unit exposures on the printed or plotted map are too small to distinguish the color for unit identification. These units are labeled where possible, and unlabeled units are attributed in the database]

NORTHERN AREA

Qa **Alluvium (Holocene)**—Unconsolidated silt, sand, and gravel in stream channels and washes. Includes terrace deposits as much as 3 m above stream and wash bottoms

Ql **Landslide deposits (Holocene)**—Blocky rubble and dislocated masses

Qg **Gravel (Quaternary)**—Unconsolidated alluvial debris. Consists of terrace deposits along major streams and isolated areas of gravel of local origin

QTb **Basalt (Quaternary and Tertiary)**—Thin intracanyon olivine basalt flows on bench about 120 m above Salt River near junction of Carrizo Creek, near northwest corner of Reservation. Thickness 30 m. May correlate with 1.76-1.90 Ma intracanyon basalt 27 km north-northeast on Corduroy Creek on Fort Apache Indian Reservation (Peirce and others, 1979) or 1.47-2.05 Ma basalt 53 km northeast in White River drainage of that reservation (Condit and Shafiqullah, 1985)

Tdf **Dacite flows and plugs (Miocene)**—Light-brownish-gray to pale-red porphyro-aphanitic flows on Chiricahua Butte and areas to northwest and southwest. Commonly contain abundant plagioclase phenocrysts, sparse hornblende and hypersthene phenocrysts, and local quartz phenocrysts. Pale red and microporphyritic northwest of Chiricahua Butte. Form thick, poorly defined flows, locally flow banded and containing flow breccia. May include intrusives on Chiricahua Butte and area to northwest. Thickness of layered sections at least 180 m

Tbn **Basalt of Natanes Plateau (Miocene)**—Extensive flows of basalt, trachybasalt, and basaltic trachyandesite capping mountainous region and Natanes Plateau across northern part of reservation. Consists of dark- to medium-gray, fine-grained, locally vesicular flows commonly containing flow breccia and locally cinder agglutinate and interbeds of reddish basaltic sand. Contains olivine basalt in minor but undetermined amounts. Rests unconformably on a variety of Tertiary, Paleozoic, and Proterozoic rocks. Thickness at least 300 m. Whole-rock K-Ar age of 18.8±0.4 Ma from locality N1 (map and table 1)

Tpt **Porphyritic trachyandesite (Miocene)**—Widespread trachyandesitic (turkey-track) flows containing abundant conspicuous plagioclase phenocrysts commonly 1-2 cm long in a pattern resembling turkey tracks. Locally contains flows resembling basalt of Natanes Plateau (Tbn). In texture and chemistry greatly resembles widespread trachyandesite in southern Arizona, as at Dos Cabezas, Tucson, Bryce, Sierrita, Del Bac Mountains, and Peloncillo Mountains (L.D. Nealey, written commun., 1988; Nealey and Sheridan, 1989). Maximum thickness at least 490 m. Whole rock K-Ar age of 20.0±0.4 Ma from locality N2 (map and table 1)

Tab **Andesite and basalt (Miocene and Oligocene)**—Principally flows of andesitic rock, probably mostly trachyandesite, with locally abundant basalt in canyon of San Carlos River and tributaries 2-4 km northeast of San Carlos. Have local interlayers of siltstone, sandstone, and conglomerate containing clasts of basalt scoria and pumice lapilli. Only higher parts of unit exposed. Maximum exposed thickness 300 m

Tda **Dacite (Oligocene)**—Light-gray to grayish-red dacite exposed in Nantac Rim. Overlies tuff of Nantac Rim (Ttnu). Consists of abundant euhedral to subhedral plagioclase phenocrysts commonly 0.5-2.5 mm long and rare biotite, oxidized hornblende, and clinopyroxene phenocrysts in aphanitic groundmass. Mostly massive, but locally flow banded, platy, or brecciated. Thickness 0-200 m

Tsv **Siliceous volcanic rocks (Oligocene)**—Light-gray to pale-pinkish-gray rhyolite flows and flow breccias exposed northwest of Ash Flat

Tuff of Nantac Rim (Oligocene)—In this area consists of upper member only

Ttnu **Upper member**—Pale-brownish-gray to very pale yellowish gray densely welded rhyolite ash-flow tuff interlayered with weakly welded tuff and tuff breccia on escarpment of Nantac Rim. More widely exposed to northeast and east. Thickness 150 m; base not exposed

Tw **Whitetail Conglomerate(?) (Oligocene)**—Weakly consolidated gravel resting on Proterozoic and Paleozoic rocks and lying beneath basalt of Natanes Plateau (Tbn) of Miocene age. Extensively exposed for many kilometers in cliffs above Salt River and locally elsewhere in northern area of Reservation. Consists of angular to subrounded pebbles and cobbles of Proterozoic quartzite, diabase, and granite and Paleozoic limestone in sandy matrix. Thickness locally as much as 180 m. See description for central area of Reservation for information on age

IPn **Naco Formation (Pennsylvanian)**—Light-gray to light-brownish-gray limestone and interbedded gray to red silty shale along Salt River and its tributaries in northwestern part of Reservation. Limestone is medium bedded to nodular and has gray to grayish-red partings and chert nodules. Grayish-red shale and limestone breccia common near base. Maximum thickness 180 m east of Popcorn Canyon

Me **Escabrosa Limestone (Mississippian)**—Light-gray to light-yellowish-gray cliff-forming limestone extensively exposed along Salt River and locally on south flank of mountains north of San Carlos. Mostly thick bedded. Contains abundant fossil debris and nodular to bedded chert; locally oolitic. Locally has fractures filled with red siltstone and zones of limestone breccia with red siltstone matrix. Thickness 58-90 m

Dm **Martin Formation (Devonian)**—Dolomite, sandstone, and limestone along Salt River and at numerous localities in mountains north of San Carlos. Mostly light-brownish to yellowish- and medium-gray to gray, thin- to medium-bedded dolomite interbedded with lesser amounts of brown to gray sandstone, sandy dolomite, and minor limestone. Some dolomite has petroliferous odor. Thickness of most complete sections along Salt River is 83-85 m

Ꞓt **Tapeats Sandstone (Cambrian)**—Grayish-red and pinkish-gray to light-gray arkosic sandstone exposed only near northwest corner of Reservation. Medium to very coarse grained, poorly sorted, and in lenticular beds, commonly cross stratified. Beds typically weather differentially to ledges and indentations, with prominent local overhangs and rare caves. Thickness 0-36 m

₽$_M$d **Diabase (Mesoproterozoic)**—Exposed extensively near northwest corner of area and locally elsewhere. For details see description for central area of Reservation

₽$_M$t **Troy Quartzite (Mesoproterozoic)**—Pinkish-gray, light- to brownish-gray, and grayish-red sandstone and minor conglomerate in western part of northern area. Sandstone commonly medium to coarse grained but can be fine grained to very coarse grained and pebbly. Beds commonly thick and planar but may be thin; some are lenticular; some are crossbedded. Pebbly conglomerate beds present throughout section. Rests unconformably on Mescal Limestone (₽$_M$am) and Dripping Spring Quartzite (₽$_M$ad). Thickness 0-106 m

Apache Group (Mesoproterozoic)

₽$_M$ab **Basalt**—Dark-yellowish-grayish- and reddish-brown flow rock. In northern area of Reservation, exposed only in Bear Canyon and mountains to north. Aphanitic to fine grained, locally brecciated and amygdaloidal. Thoroughly altered. See description for central area of Reservation. Thickness about 25 m

$Ꝑ_M$am **Mescal Limestone**—Mostly light gray limestone and cherty limestone but contains gray to brown and red dolomite and minor amounts of siltstone and shale. Crops out at scattered localities in Salt River canyon and along west and south flanks of Natanes Plateau. Upper part consists of siltstone overlying stromatolitic carbonate rock. Lower part cherty and thin- to medium-bedded carbonate rock in planar to wavy beds. Consists of dolomite east of Bear Canyon. Deeply eroded prior to deposition of Troy Quartzite ($Ꝑ_M$t) in area between Cassadore Spring and Upper Highway Tank 24 km to north-northwest, where unit consists only of chert, siltstone, and sandstone erosional remnants. Commonly intruded by sills of diabase ($Ꝑ_M$d). Thickness 1-20 m

$Ꝑ_M$ad **Dripping Spring Quartzite**—Mostly gray, red, and brown sandstone and siltstone widely exposed west and south of Natanes Plateau and along Salt River. Upper member consists of arkosic sandstone, siltstone, and minor shale in thin lenticular beds; lower member consists of fine- to medium-grained, medium- to thick-bedded and crossbedded, locally pebbly arkosic sandstone. Basal Barnes Conglomerate Member, 0-1 m thick, consists of clasts of white quartz and brown quartzite. Thickness about 180 m. For information on age, see description for central area of Reservation

$Ꝑ_M$ap **Pioneer Shale**—Maroon siltstone, red sandstone, and conglomerate exposed along south margin of mountains in western part of area. Upper one-third to two-thirds consists of maroon siltstone with gray spots. Beneath siltstone are medium- to coarse-grained arkosic sandstone and conglomerate in lower one-fourth of formation. Thin Scanlan Conglomerate Member at base contains clasts of quartz and quartzite. Thickness commonly 75 m, locally as much as 140 m. See description for central area of Reservation for information on age

$Ꝑ_M$g **Granite (Mesoproterozoic)**—Light-gray to pale-reddish-brown, generally coarse grained granite locally containing large potassium feldspar phenocrysts. Exposed at and near west boundary of Reservation

CENTRAL AREA

Qa **Alluvium (Holocene)**—Unconsolidated silt, sand, and gravel in stream channels and washes. Includes terrace deposits as much as 3 m above stream and wash bottoms

Qt **Talus (Holocene)**—Rubble on steep slopes

Ql **Landslide deposits (Holocene)**—Blocky rubble and dislocated masses. Common and locally 1 km or more across in areas of Pliocene basalt flows capping or interlayered with alluvial and tuffaceous deposits northeast of San Carlos

Qg **Gravel (Quaternary)**—Unconsolidated alluvial debris. In basin of San Carlos River consists of pebbles and cobbles derived from older alluvial deposits and nearby bedrock, commonly basalt. Thickness as much as 75 m

Qp **Piedmont deposits (Quaternary)**—Loosely consolidated, locally caliche cemented, massively to lenticularly bedded silt, sand, pebbles, cobbles, and boulders. Pebbles, cobbles, and boulders commonly subrounded to rounded. Form prominent surfaces 12-73 m above adjacent major streams. Abundant in basin of San Carlos River, Gilson Wash, and Gila River. Not mapped south of Gila River. Locally includes terrace deposits. As much as 15 m thick

Basalt of Peridot Mesa (Pleistocene)—Divided into flows and vents

Qbpf **Flows**—Dark-gray to black olivine basalt that caps Peridot Mesa southwest of San Carlos and smaller mesas southeast of San Carlos. Basal parts of flows on Peridot Mesa contain peridotite inclusions commonly 2-15 cm in diameter that locally make up 50 percent or more of the rock. Many inclusions contain peridot, gem quality olivine. Thickness about 18 m. K-Ar ages of 0.93±0.08 Ma (Shafiqullah and others, 1980) and 0.58±0.12 Ma (Bernatowicz, 1981) reported for whole-rock samples from locality C1 (map and table 1). Surfaces of flows about 75 m above San Carlos River

Qbpv **Vent deposits**—Basalt cinders, agglutinated basalt fragments, and minor intrusive basalt. Parts of deposits are red, others black. Vent is source of flows of basalt of Peridot Mesa (Qbpf)

QTf **Fanglomerate (Quaternary or Tertiary)**—Unsorted pebble, cobble, and blocky bouldery debris of basalt and silicic volcanic rocks mixed with finer materials. Derived from escarpment of Nantac Rim

Basalt of Bronco Gulch (Pliocene)—Divided into flows and vents

Tbgf **Flows**—Gray to black olivine basalt and trachybasalt widely exposed in and mainly north of Gila Mountains. Locally has concentrations of peridotite nodules, particularly near vents in central part of area where exposed. Nodules commonly less than 7 cm in size. Thickness 12-24 m. Whole-rock sample from locality C4 (map and table 1) yielded K-Ar age of 2.0±0.1 Ma

Tbgv **Vent deposits**—Dark-red to black agglutinated basalt scoria, bombs, blocks, and scoriaceous flows at numerous localities associated with flows of basalt of Bronco Gulch (Tbgf). Most vents are cinder cones about 0.8 km in diameter

Gila Conglomerate (Pliocene and Miocene)—Divided into six members

Tgs **Siltstone, sandstone, and minor conglomerate member (Pliocene)**—Local deposits northeast and east of San Carlos. Generally finer grained equivalent of conglomerate and associated sedimentary rocks member (Tgc) and represents some of topographically highest basin-fill deposits in Gila Conglomerate in central area of Reservation. Weakly consolidated, light-brownish-gray conglomerate, sandstone, and siltstone. Rest on rock as young as basalt of Antelope Flat (Tbaf). Maximum thickness about 10 m

Tgc **Conglomerate and associated sedimentary rocks member (Pliocene and Miocene)**—Weakly consolidated chiefly alluvial deposits widely exposed in valley of Gila River and in basins of San Carlos River and along Gilson Wash. Generally pebble to cobble conglomerate near bedrock along margins of basins. Grades basinward to grayish-red sandstone, siltstone, and mudstone. Locally interlayered with basalt flows (Tbf) and unmapped limestone, gypsum deposits, and rhyolite and dacite tuffs. Contain prominent unconformity about 8 km west of San Carlos. Hornblende from pumiceous ash-fall tuff about 1 m thick interbedded with mudstone and muddy sandy limestone at locality C9 (map and table 1) northeast of Bylas gave $^{40}Ar/^{39}Ar$ age of 5.02±0.24 Ma. In closed basins in eastern Arizona and western New Mexico, the Gila Conglomerate is as young as Pleistocene (Houser and others, 1985; Drewes and others, 1985)

Tgsb **Sedimentary deposits and tuff member (Pliocene)**—Sandstone, siltstone, tuff, tuffaceous sandstone, and minor limestone equivalent to upper parts of limestone, siltstone, sandstone, and tuff member (Tgls). Interbedded with basalt flows (Tbf). Exposed northeast to southeast of San Carlos. Maximum thickness about 120 m

Tgls **Limestone, siltstone, sandstone, and tuff member (Pliocene)**—Interbedded deposits dominated by thin-bedded limestone in lower part and consisting of limestone, siltstone, sandstone, tuffaceous sandstone, and tuff in upper part. Contain diatomaceous earth in upper beds 3.8 km east-northeast of junction of Highway 70 and road to Ash Flat. Exposed in eastern part of San Carlos basin and in northern part of valley of Gila River. Limestone is porous to dense and contains microbial mats and stromatolites. Locally contains basaltic sand, chert, and diatomaceous earth. Deformed adjacent to dacite (Tdmi) plugs at Mount Triplet, east of San Carlos, and near plugs of intrusive basalt (Tib). Thickness 0-120 m

Tgv **Volcanic conglomerate member (Pliocene)**—Typically reddish-brown, locally gray, fine pebble to cobble, crudely bedded conglomerate or breccia centered 1.6 km south of Mount Triplet. Clasts are matrix supported and consist of oxidized dacite resembling intrusive phase of dacite of Mount Triplet (Tdmi), basalt, and limestone in variable proportions but generally about 90 percent dacite, 5 percent basalt, and 5 percent limestone. Most clasts angular to subangular, some subrounded. A few clasts, mostly basaltic bombs, as large as 30 cm in diameter. Matrix is volcanic sand. Thickness about 75 m

Tgl **Limestone member (Pliocene)**—Grayish-pink to yellowish-gray, porous, micritic to fine-grained, poorly bedded limestone exposed in upper reaches of Blue River south to San Carlos River and its tributaries, beginning about 6 km northeast of San Carlos. Thickness 0-120 m

Tbv **Vent deposits (Pliocene)**—Medium- to dark-gray, sand to fine pebble-size fragments of scoriaceous basalt in diatremes southeast and southwest of San Carlos and southeast of Bylas. Includes cinder cone 5 km south of Mount Triplet. Contain rare fragments of peridotite. Diatremes consist of crude but distinct, generally thin beds that dip gently to moderately toward center of vent. Basalt at locality C8 (map and table 1) in Bylas diatreme yielded K-Ar age of 2.49±0.06 Ma (Damon and others, 1997)

Tbaf **Basalt of Antelope Flat (Pliocene)**—Black olivine basalt capping Antelope Flats and other flats in central part of central area at altitudes of 360 m or more above San Carlos. See table 2 and figure 2 for information on chemistry. Thickness about 30 m. K-Ar age of 2.8±0.1 Ma obtained from whole-rock sample from locality C3 (map and table 1)

Dacite of Mount Triplet (Pliocene)—Divided into intrusives and flows

Tdmi **Intrusive dacite**—Dark- to light-gray and pale-grayish-red dacite containing abundant plagioclase and locally abundant hornblende phenocrysts. Matrix generally aphanitic but contains considerable glass. Commonly flow banded. Locally autobrecciated. Conspicuously glassy locally at margins. Forms prominent high-standing plugs at and near Mount Triplet. Hornblende from locality C2 (map and table 1) yielded K-Ar age of 3.4±0.5 Ma

Tdmf **Flows**—Medium-gray and pale-grayish-orange to pale-red massive to brecciated flows around Mount Triplet. Consist of abundant plagioclase and minor hornblende and pyroxene phenocrysts in aphanitic matrix. Locally contain beds of light-gray tuff. Thickness as great as 210 m

Tib **Intrusive basalt (Pliocene)**—Dark-gray to black massive olivine basalt in plugs a few kilometers south and southeast of Mount Triplet. Forms prominent Hackberry Draw ring dike 45-250 m thick and about 1.6 km in diameter in limestone, siltstone, sandstone, and tuff member (Tgls) of Gila Conglomerate 8 km south of Mount Triplet. Contacts of ring dike are subvertical

Tdft **Dacite flows and tuff (Pliocene)**—Light-gray, plagioclase-biotite-quartz-bearing ash-flow tuff at Chrome Butte and lava flow on west end of Ash Flat. Eruptive vents not known but could be at Mount Triplet. May correlate with dacitic rocks in conglomerate and associated sedimentary rocks member (Tgc) of Gila Conglomerate

Tirh **Intrusive rhyolite (Pliocene)**—Light- to medium-gray rhyolite south of Highway 70 and west of Hackberry Draw. Consists of phenocryst-poor glassy to aphanitic rock that has small plagioclase phenocrysts and trace amounts of small mafic phenocrysts. Forms cluster of mutually impinging domes that have strongly flow banded margins and weakly flow banded interiors. Locally brecciated. Steeply dipping silicic and basaltic breccia locally at margin of cluster

Tbf **Basalt flows (Pliocene and Miocene)**—Olivine basalt and basaltic trachyandesite flows in central and southwestern parts of central area interlayered with Gila Conglomerate (Tgc, Tgls, and Tgsb). Individual flows about a meter to several meters thick. Deformed adjacent to dacite (Tdmi) plug at Mount Triplet. K-Ar ages of whole-rock specimens are 7.46±0.59 Ma from locality C7 (map and table 1) (Shafiqullah and others, 1980) and 4.0±0.1 Ma from locality C5. See description of unit in southern area of Reservation for additional ages

Tbn **Basalt of Natanes Plateau (Miocene)**—Dark-gray to black olivine basalt at scattered localities along north border of central area northeast of San Carlos. See description for northern area of Reservation. Thickness 90 m or less

Tab **Andesite and basalt (Miocene and Oligocene)**—Mainly flows of trachyandesite and olivine-bearing basaltic trachyandesite and small amounts of porphyritic (turkey-track) trachyandesite in most extensive map unit in central area of Reservation. Commonly of purplish to reddish hue. Original flow layers poorly displayed. Contain widespread conglomerate composed of andesite and basaltic andesite pebbles and cobbles in sequences as much as 180 m thick and dacite flows in sections 120 m thick in western part of

Gila Mountains. Interlayered with rhyolite flows and tuffs of silicic volcanic rocks unit (Tsv) throughout Gila Mountains. Have intrusive andesitic rock in bodies 1-1.6 km wide in Bone Spring Canyon. Dikes of porphyritic trachyandesite locally abundant. Basaltic trachyandesite rocks have rare inclusions of peridotite and granitic gneiss. Thickness at least 600 m. K-Ar age of 20.4±0.5 Ma obtained from whole-rock andesite specimen from locality C6 (map and table 1). For additional information on ages, see description for eastern area of Reservation

Tpt **Porphyritic trachyandesite (Miocene)**—Trachyandesite to basaltic andesite flows with abundant large plagioclase phenocrysts exposed in Bronco Gulch and more widely in northern area of Reservation

Tda **Dacite (Oligocene)**—Light-gray to pale-brownish-gray massive flows west of Bronco Gulch. Porphyro-aphanitic with trace amounts of plagioclase, quartz, hornblende, biotite, and locally hypersthene phenocrysts. Basal tuff in Sweetmeat Draw has rounded quartz phenocrysts as large as 5 mm. Thickness 150 m, upper contact not exposed

Tsv **Siliceous volcanic rocks (Oligocene)**—Light-gray to pale-brownish-gray and pinkish-gray, rarely grayish-red flows and flow breccias, mostly of rhyolitic composition, in Gila Mountains. Small amount of dacite also present. Commonly flow banded and very fine grained. Local quartz and biotite phenocrysts. Thickness as much as 150 m

Tir **Intrusive rhyolite (Oligocene)**—Light- to medium-gray and purplish-gray plugs and rare dikes in Gila Mountains. Fine grained and aphyric or containing 1-2 mm quartz phenocrysts. Biotite, plagioclase, and hornblende phenocrysts uncommon to rare. Generally flow banded, commonly in intricate patterns. Black glass and intrusive breccia at outer margins of some bodies. Most plugs are 0.3-1.0 km in diameter, but one elongate body southwest of Ash Flat is 2.9 km long

Tirs **Intrusive rhyolite suite (Oligocene)**—Light-gray, pale-red, and grayish-red, fine-grained to glassy silicic lava flows and breccias, dikes, and irregular intrusives in northwest-trending belt about 900 m wide in Gila Mountains 10 km northeast of Bylas. Probably consists mostly of lava flows, but extrusive and intrusive rocks in many places cannot be distinguished. Mostly aphyric, but some rocks have small phenocrysts of alkali feldspar

Dacite of Paymaster Wash (Oligocene)—Divided into flows and tuff

Tdpf **Flows**—Pale-red to grayish-red-purple, brownish-gray, or pale-brown porphyritic lavas in higher part of Gila Mountains south of Ash Flat. Mostly massive but in part flow-layered, containing abundant euhedral plagioclase phenocrysts commonly 1-5 mm long, small amounts of biotite phenocrysts, and rare pyroxene and hornblende phenocrysts in glassy groundmass. Includes some rhyolitic lavas in Lower Fishhook Canyon. Thickness about 500 m

Tdpw **Welded tuff**—Grayish-red to pale-reddish-brown, moderately to densely welded ash-flow tuff interlayered with lava flows of dacite of Paymaster Wash in Lower Fishhook Canyon, northeast of Bylas. Contains abundant sanidine and biotite and sparse plagioclase and quartz phenocrysts in pumiceous, partly devitrified glassy matrix. Has sparse to abundant fragments of silicic and andesitic rocks. Thickness 0-75 m

Tw **Whitetail Conglomerate(?) (Oligocene)**—Crudely but distinctly bedded, pebble to boulder conglomerate at several localities in Wildhorse Canyon of Gila Mountains and 16-22 km north of San Carlos. Clasts, angular to subrounded, consist of variable proportions of Paleozoic limestone and Proterozoic granite in sandy matrix. Clasts about two-thirds limestone. No clasts of Tertiary rock found. Rests on Proterozoic and Paleozoic rocks. Lies beneath basalt of Natanes Plateau (Tbn) of Miocene age in northern part of central area of Reservation and below andesitic rocks (Tab) of Oligocene and Miocene age along Wild Horse Canyon. Thickness about 25 m. Age of tuff in Whitetail Conglomerate in Ray Mine area south of Globe (fig. 1) reported as 33.2±0.6 Ma (Oligocene) by Banks and others (1972) and Reynolds and others (1986) but 18.7±0.1 Ma (Miocene) by Richard and Spencer (1998). Stratigraphic position below andesite of Tab in central area of Reservation indicates conglomerate at least as old as Oligocene but makes correlation with Whitetail Conglomerate elsewhere in Arizona uncertain. However, Dickinson (2001) stated that Whitetail Conglomerate in Ray Mine area may be as old as late Oligocene in age

TKgp **Granitic porphyry (Tertiary or Cretaceous)**—Light- to medium-gray porphyritic rock in dikes, sheets, and small plutons, mostly intrusive in the Apache Group but locally in Paleozoic rocks. Exposed mainly a few kilometers east and southeast of Chrome Butte. Plutons 0.2-2.0 km in longest dimension. Phenocrysts consist of plagioclase, quartz, and biotite; plagioclase only; plagioclase and hornblende; or potassium feldspar, quartz, and biotite. Groundmass is microgranitic. Some bodies intensely altered and contain abundant white mica, others only weakly altered. Age uncertain but unit resembles descriptions of rocks of Cretaceous or Tertiary age in Sonora quadrangle (Cornwall and others, 1971) centered about 40 km west of Coolidge Dam and in Clifton-Morenci area (Lindgren, 1905) east of the Reservation near east edge of map

IPMu **Horquilla Limestone (Pennsylvanian) and Escabrosa Limestone (Mississippian), undivided**—Mapped along southern border of Gila Mountains north of Bylas

IPh **Horquilla Limestone (Pennsylvanian)**—Medium-gray to reddish- or purplish-gray, mostly medium bedded micritic limestone in Gila Mountains. Weathers medium gray, mottled, and commonly has pinkish to purplish hue. Gray to purplish-gray chert in nodules and thin beds makes up about 10 percent of rock and commonly weathers distinctive pale orange. Contains crinoid fragments, brachiopods, corals, and fusulinids. Deep-reddish-brown silty mudstone, locally at base, as thick as 9 m. Thickness 60 m, top not exposed

Me **Escabrosa Limestone (Mississippian)**—Dark- to medium-gray and brownish-gray, commonly micritic, thin- to thick-bedded cherty limestone exposed in Gila Mountains. Weathers light to medium gray and pale bluish to faintly pinkish gray. Conspicuous orange-weathering chert nodules and thin beds in some intervals. Contains crinoid debris, brachiopods, and corals. Some beds have abundant stylolites. Prominent purplish-red, fine-grained, calcareous sandstone about 1 m thick at base. Thickness about 85 m

Dm **Martin Formation (Devonian)**—Consists of upper unit of marl and shale 30 m thick and lower unit of dolomite, sandy dolomite, sandstone, and minor limestone 43-56 m thick. Marl and shale are gray to black at rare fresh exposures. Weathers to shades of gray, green, and brown. Lower unit mostly medium to dark gray, weathers yellowish gray and shades of brown (where sandy). Section 7 m thick of crossbedded sandstone above 5 m of fetid dolomite locally at base

€s **Sandstone (Cambrian)**–Dusky-red to grayish-red-purple sandstone and light-gray quartzite on south flank of Gila Mountains. In western part of mountains, upper one-fourth to one-third of formation consists of light-gray, fine- to coarse-grained, commonly cliff forming sandstone to orthoquartzite; lower part consists of reddish to red-purple, hematite-rich, poorly sorted feldspathic sandstone, locally with grit and fine pebbles, and commonly contains abundant worm tracks and *Scolithus* tubes. Locally has basal pebbly conglomerate as much as 2 m thick. Section east of Fivemile Wash generally resembles section farther west but locally is mostly light-gray quartz arenite containing worm tracks and *Scolithus* tubes and glauconite-bearing beds. Top and base east of Fivemile Wash not exposed. Thickness 0-90 m

Y_Md **Diabase (Mesoproterozoic)**—Dark and grayish-green sills in Troy Quartzite (Y_Mt) and rocks of Apache Group and irregular sheets in Proterozoic granite (Y_Mg). Extensively exposed in mountainous areas 15-30 km north and northwest of San Carlos. Fine grained at chilled margins; medium to coarse grained, mainly ophitically intergrown plagioclase and augite in interior of intrusive bodies. Locally intensely altered to chlorite and albite. Contains fine- to medium-grained gabbro intrusions west of Reservation boundary. Sills and sheets a few meters to several tens of meters thick. Age about 1,100 Ma (see Wrucke, 1989, for summary of age data)

Y_Mt **Troy Quartzite (Mesoproterozoic)**—Reddish-brown to dusky-red, light- to moderate-brown, and grayish-yellow to medium-gray sandstone in mountains north and northwest of San Carlos and on unnamed ridge southeast of Chrome Butte. Composition varies considerably.

Much is light colored, medium grained, well sorted, locally pebbly, slightly feldspathic, medium to thick bedded and crossbedded. Some stratigraphic intervals coarse grained and gritty and contain scattered fine pebbles. Bedding poor to distinct, planar to crossbedded. Many thick beds massive to planar, locally with contorted laminations. Thickness at least 120 m, locally could be twice as thick; top not exposed. Detrital zircons from Troy in Sierra Ancha (fig. 1) west of Reservation all give age of 1,256 Ma, suggesting nearby source because long distance transport likely would result in mixing of zircons of various ages (Stewart and others, 2001). Proximal source and locally abundant sericite of possible volcanic origin in Troy in Sierra Ancha suggest zircons represent volcanism of Troy age

Apache Group (Mesoproterozoic)

$Ᵽ_M$ab **Basalt**—Grayish-red flows on unnamed ridge southeast of Chrome Butte. Flows aphyric to porphyritic, locally amygdaloidal, and so thoroughly altered by weathering before deposition of Troy Quartzite (Shride, 1967) that no original minerals remain. Original phenocrysts plagioclase. Not lithologically distinguishable from basalt stratigraphically between limestone and argillite of Mescal Limestone ($Ᵽ_M$am) west of Reservation, but regional considerations suggest basalt on Reservation is younger than Mescal (Shride, 1967). Maximum thickness about 170 m

$Ᵽ_M$am **Mescal Limestone**—Where unmetamorphosed by diabase ($Ᵽ_M$d), as in south-central part of unnamed ridge southeast of Chrome Butte, consists of thin-bedded, commonly laminated, pale-brown to pale-reddish-brown dolomite and cherty dolomite divided into a stromatolite-bearing upper member and planar-bedded lower member. Elsewhere, southeast and east of Chrome Butte and north of San Carlos, metamorphosed to light-gray and chalky-white limestone preserving easily identified original bedding, laminations, stromatolites, and local chert nodules. Where metamorphosed contains sporadic seams of chrysotile asbestos in serpentinite; locally these have been mined and prospected (Bromfield and Shride, 1956). Thickness about 115 m

$Ᵽ_M$ad **Dripping Spring Quartzite**—Principally gray and reddish-brown to orangish-brown sandstone and siltstone and black siltstone widely but not extensively exposed in mountainous areas west, northwest, and north of San Carlos and in small exposures near Branaman Spring, 22 km east of San Carlos. Consists of upper member of thin-bedded, locally flaggy siltstone and fine-grained sandstone and lower member of fine- to medium-grained, medium- to thick-bedded, commonly crossbedded arkosic sandstone. Upper member locally spotted where metamorphosed by diabase. Upper beds of lower member locally calcareous. Pebble to cobble Barnes Conglomerate Member at base commonly about 1 m thick. Thickness about 180 m. Dominance of detrital zircons yielding age of 1,264 Ma from high in lower member in Sierra Ancha (fig. 1) west of Reservation may have come from nearby volcanic source (Stewart and others, 2001). Volcanic activity contemporaneous with deposition of Dripping Spring known from volcanic detritus and interbedded tuffs in Sierra Ancha, northwest of map area, (Nutt, 1981) supports this possibility

$Ᵽ_M$ap **Pioneer Shale**—Typically dusky-red to grayish-red-purple siltstone in mountains along west border of Reservation, east to Bear Canyon, and southeast to Gilson Wash. Planar and cross-laminated beds commonly 2-5 cm thick contain numerous light-gray reduction spots a few centimeters across. Very dark gray, almost black where metamorphosed by diabase. Dark-red, coarse-grained to gritty and fine-pebble arkose locally in lower 10 m above basal Scanlan Conglomerate Member, 0-2 m thick. Thickness about 76 m. Tuffaceous beds in Pioneer west of Globe (fig. 1) contain zircons of 1,328±5 Ma, considered to be derived from tuff or reworked tuff of Pioneer age (Stewart and others, 2001)

$Ᵽ_M$g **Granite (Mesoproterozoic)**—Mostly coarse grained gray to deep red granite widely exposed near west border of Reservation and Sevenmile Mountains and scattered localities as far east as Branaman Spring area, 21 km southeast of San Carlos. Mostly nonfoliated with blocky potassium feldspar phenocrysts as long as 5 cm, locally in trachytoid alignment, but contains some foliated rock with aligned mafic minerals and clots. Fine- to medium-grained granitic rocks, some with prominent quartz phenocrysts present locally

$P_{P}p$ **Pinal Schist (Paleoproterozoic)**—Metasedimentary and metaigneous rocks exposed 14 km northwest of San Carlos, near Branaman Spring, and 10.5-13.7 km northeast of Fort Thomas. Consists of quartz, white mica schist, chlorite schist, metarhyolite, and quartzite. At locality northwest of San Carlos and at Branaman Spring, forms inclusions as much as several tens of meters across in Mesoproterozoic granite ($P_{M}g$)

EASTERN AREA

Qa **Alluvium (Holocene)**—Unconsolidated silt, sand, and gravel in stream channels and washes. Includes terrace deposits as much as 3 m above stream and wash bottoms

Qt **Talus (Holocene)**—Rubble on steep slopes

Ql **Landslide deposits (Holocene)**—Blocky rubble and dislocated masses

Qg **Gravel (Quaternary)**—Unconsolidated alluvial debris. Consists of terrace deposits along major streams and isolated areas of gravel of local origin

Qsg **Sand, silt, and gravel (Quaternary)**—Unconsolidated alluvial and colluvial deposits, mostly silt and sand in extensive cover in eastern area of Reservation at Ash Flat and Big Prairie. Locally includes fine gravel. Rarely exposed

QTf **Fanglomerate (Quaternary or Tertiary)**—Unsorted pebble, cobble, and blocky bouldery debris of basalt and silicic volcanic rocks mixed with finer materials. Derived from escarpment of Nantac Rim

QToa **Older alluvial deposits (Pleistocene and Pliocene?)**—Alluvium of ancestral Eagle Creek (Ferguson and Enders, 2000). Consists of unconsolidated to caliche-cemented, poorly sorted sand to boulder gravel on terraces 240-320 m above Eagle Creek. Clasts rounded; dominantly basaltic andesite, rhyolite, and red granite, and lesser amounts of felsic porphyry, limestone, and shale. Thickness as much as 10 m

Gila Conglomerate (Pleistocene?, Pliocene, and Miocene)

QTga **Alluvium of Smuggler Canyon (Pleistocene? and Pliocene)**—Exposed in southern part of Clifton-Morenci area. Composed of unconsolidated to weakly consolidated, locally caliche-cemented sandstone, conglomerate, siltstone, and boulder gravel; clast composition highly variable reflecting local sources (Ferguson and Enders, 2000). Contains 1-15 percent black polished hematite and magnetite clasts and copper oxide-bearing clasts of skarn, porphyritic rock, quartzite, and granite. Forms rounded slopes with typically indistinct lower contact with underlying cliff-forming conglomerate of Buzzard Roost Canyon (Tgcb) and conglomerate of Midnight Canyon (Tgcm). Thickness 150 m

Tgcb **Conglomerate of Buzzard Roost Canyon (Pliocene)**—Extensively exposed along Eagle Creek and San Francisco River in Clifton-Morenci area (Ferguson and Enders, 2000); name from fluviatile deposits of Buzzard Roost Canyon of Richter and others (1983). Consists of tan, poorly sorted boulder conglomerate and interbedded siltstone and sandstone. Conglomerate clasts rounded to subrounded, dominantly of Tertiary andesite with lesser amounts of rhyolite and plutonic rocks, Paleozoic sedimentary rocks, and red Proterozoic granite. Locally has rare clasts of skarn, altered porphyry, and Proterozoic granite containing veins of oxidized copper sulfide minerals. Abundance of nonvolcanic clasts increases upward to 15-30 percent at top. Matrix largely altered to zeolite minerals, but calcite cement common locally. Strongly indurated, medium- to thick-bedded. Forms cliffs 80-100 m high along San Francisco River. Contact with underlying conglomerate of Midnight Canyon (Tgcm) gradational. Thickness at least 800 m

Tgm **Muddy sandstone and conglomerate member**—Fluvial conglomerate, sand, silt, and clay extensively exposed in the valley of Bonita Creek. Moderately to weakly consolidated. Lowest parts, well exposed in cliffs along Bonita Creek southeast of Bonita Well, consist of angular to subrounded pebbles to boulders as much as 1 m in diameter, chiefly of andesitic and subordinate siliceous volcanic rocks. Overlying section, well exposed north of Bonita Well, consists largely of pale-grayish-red poorly sorted clay to sand and less abundant interbedded conglomerate. Contains abundant volcanic material in addition to fragments of Paleozoic sedimentary rocks, and, above altitude of about 1,450 m, sparse clasts of Proterozoic granite derived from exposures to northeast. Forms thin- to thick-bedded ledge and slope topography. Accumulated in fans that prograded southwestward to center of valley of Bonita Creek, where ancestral streams carried sediments southeast to Safford basin south of Reservation. Deposits containing granitic clasts correlate with Pliocene gravel of Rail End Canyon and fluvial beds of 111 Ranch (Houser and others, 1985) in Safford quadrangle to south and were source of quartzite and red granite clasts in these units. Section beneath granite-bearing beds equivalent to strata mapped as conglomerate of Midnight Canyon of Pliocene and Miocene age by Ferguson and Enders (2000) in Clifton-Morenci area and by Houser and others (1985) in Safford quadrangle south of Reservation. Section above basal conglomerate locally well exposed in prominent cliffs on north side of Bonita valley. Thickness of conglomerate at base 50-75 m; thickness of higher parts as much as 300 m. Includes upper and lower basin-fill units found in southwestern New Mexico and southeastern Arizona; the lower unit typically as old as 16 Ma in Arizona

Tgc **Conglomerate and associated sedimentary rocks member**—Gravel deposits developed from alluvial fans in dissected shallow basins widespread in northeastern area of Reservation adjacent to Willow Mountain and along Willow Creek. Composed chiefly of locally derived debris, commonly volcanic, moderately to poorly sorted and moderately to weakly indurated. Contact with muddy sandstone and conglomerate member (Tgm) on north flank of Gila Mountains arbitrarily placed in area of constricted exposures where both units join. Incised through entire thickness in Willow Creek. Maximum thickness more than 120 m. See description for central area for information on age

Tgcm **Conglomerate of Midnight Canyon (Pliocene and Miocene)**—Light tan, massive, strongly indurated, fluvial, medium- to thick-bedded fluvial conglomerate in the Clifton-Morenci area (Ferguson and Enders, 2000). Contains clasts dominantly of basaltic andesite and sub-equal but highly variable amounts of rhyolite lava and tuff. Extensively exposed along lower reaches of Eagle Creek, where lower two-thirds forms vertical cliffs and hoodoos 80 to 100 m high. Consists mostly of matrix-supported pebbles to boulders in matrix of zeolite-cemented silt to coarse sand. Contact with underlying basaltic and andesitic conglomerate of Bonita Creek (Tcb) gradational. Thickness as much as 360 m. Mapped as rhyolite by Lindgren (1905), conglomerate and tuff by Heindl (1960), and gravel by Richter and Lawrence (QTg; 1981)

Tb **Basalt (Miocene)**—Medium- to dark-gray, fine-grained olivine basalt flows north of Dry Prong Creek. Thickness at least 300 m; stratigraphic top eroded. Whole-rock sample from high in unit at locality E1 (map and table 1) near Black River in northeast corner of Reservation yielded K-Ar age of 10.2±0.2 Ma

Tcb **Conglomerate of Bonita Creek (Miocene and Oligocene)**—Exposed along Bonita Creek and Midnight Creek near southeast corner of eastern area. Composed of angular to subrounded clasts, sand size to 1 m diameter, chiefly of andesite, basalt, and felsic volcanic rocks from Volcano of Bear Spring south of map area (Houser and others, 1985). Locally interbedded with andesitic rocks of andesite and basalt unit (Tab). Forms cliffs as much as 100 m high along Bonita Creek. Thickness about 100 m. Overlain in Midnight Creek area by 24.0±0.9 Ma ash-flow tuff of siliceous volcanic rocks unit (Tsv) at locality E18 (map and table 1). In Guthrie quadrangle east of Safford (fig. 1), unit interbedded with andesite flows having K-Ar ages of 23.7±0.5 Ma and 19.4±0.4 Ma and an ash flow with a K-Ar age of 19.1±0.4 Ma from sanidine (Richter and others, 1983)

Tcc **Conglomerate of Cienega Creek (Miocene)**—Pebble to boulder conglomerate south of Cienega Fault and Park Creek Fault. Clasts of volcanic rocks, chiefly basalt and rhyolite, with fragments of obsidian Apache tears and perlite conspicuous in some outcrops. Crudely bedded, poorly sorted, and moderately to well indurated. Exposed in cliffs 30-60 m high along Eagle Creek. Tilted along Cienega Creek Fault. Maximum thickness more than 60 m. May be equivalent to conglomerate of Bonita Creek (Tcb) but could be younger

Tbn **Basalt of Natanes Plateau (Miocene)**—Light- to dark-gray, fine-grained dense basalt, trachybasalt, and basaltic andesite flows mainly north of Nantac Rim. Outliers present to southeast as far as south side of Kane Spring Fault near southeast corner of Reservation. Overlies older volcanic rocks, apparently unconformably. Rests mainly on porphyritic trachyandesite (Tpt) but overlies tuff of Nantac Rim (Ttnu and Ttnl) east and southeast of Point of Pines. Farther southeast rests on andesite and basalt (Tab). Weathers dark brown. Top and base of flows vesicular. In Park Creek includes interbedded red to tan volcanic gravels and coarse sand. Thickness 120 m, stratigraphic top not exposed. Pyroxene-bearing basaltic andesite flows at locality E10 (map and table 1) near Midnight Tank south of Kane Spring fault yielded K-Ar age of 17.7±0.8 Ma and specimen collected at locality E3 near Dry Lake gave whole-rock K-Ar age of 16.7±0.4 Ma

Tem **Enebro Mountain Formation (Miocene and Oligocene)**—Widespread in northern part of Clifton-Morenci area; less extensive in eastern part of San Carlos Reservation. In Clifton-Morenci area consists of crystal-poor aphyric, high-silica rhyolite lava interbedded with nonwelded tuff and locally hypabyssal rhyolite in dikes, plugs, and sills (Ferguson and Enders, 2000). On Reservation includes tuff breccias, lahar deposits, lapilli tuffs, banded and contorted obsidian, and perlite containing Apache tear nodules. Also contains thick dense brownish flow-banded rhyolite, probably welded ash-flow tuff, that has basal vitrophyre. Thickness as much as 340 m. K-Ar age on obsidian nodules from locality E8 (map and table 1) southwest of Table Mountain near Eagle Creek gave age of 23.1±0.3 Ma. Isotopic ages from Clifton-Morenci area include $^{40}Ar/^{39}Ar$ age of 22.33±0.14 Ma from sanidine from locality E23 (Ferguson and Enders, 2000), and K-Ar ages of 20.9±0.8 Ma and 20.6±0.7 Ma from whole rocks from locality E22 (Marvin and others, 1987), 21.7 Ma (± not available) from biotite and 20.0 Ma from sanidine from locality E21 (Schroeder, 1996), and 19.70±0.42 Ma from sanidine from locality E20 (Damon and others, 1997)

Tpt **Porphyritic trachyandesite (Miocene)**—Flows extensively exposed north of Nantac Rim. Contains abundant platy or tabular plagioclase phenocrysts 5-10 cm long, in places as much as 2.5 cm long, in typical turkey-track pattern. Contains small scattered phenocrysts of olivine and, less commonly, clinopyroxene in dark-gray to black groundmass. Weathered surfaces red to purple or deep brown and yellow brown to pale orange. Locally forms large rounded boulders on weathered surfaces. Flow tops vesicular. Some flows less conspicuously porphyritic. Forms north-northeast-trending dikes along Nantac Rim near Barlow Pass. Thickness about 425 m on Nantac Rim near Tule Tubs, but thins eastward and is missing a short distance east of Park Creek. K-Ar age of 21.3±0.7 Ma (Marvin and others, 1987) from plagioclase from locality E6 (map and table 1) near Park Creek

Tab **Andesite and basalt (Miocene and Oligocene)**—Widespread dark-brown- to pale-purple-weathering flows 3-5 m thick, locally with oxidized and scoriaceous tops and bottoms. Flows fine grained, some with sparse small phenocrysts of reddish-brown iddingsite after olivine and sparse clinopyroxene phenocrysts. Less conspicuous but common plagioclase laths as much as 1 mm long. Contain beds of reddish flow breccia. Locally, as in Willow Creek, includes thin lenticular interbeds of red volcanic gravel. Composition ranges from alkalic andesite to alkalic basalt. Generally rest on mature paleotopography on rocks of Proterozoic to Mississippian age. Equivalent to andesite of Guthrie Peak-Turtle Mountain in Safford area (Houser and others, 1985). Maximum exposed thickness at least 300 m. Whole-rock K-Ar ages of 31.1±0.5 Ma from locality E13b (map and table 1) (Strangway and others, 1976), 27.6±1.4 Ma from locality E13a

(Strangway and others, 1976), 27.7±0.4 Ma from locality E9, 26.6±0.6 Ma from locality E16 (Houser and others, 1985), 26.1±0.9 Ma from locality E4 (Marvin and others, 1987; Bromfield and others, 1972), 25.6±0.4 Ma from locality E7, and 24.9±0.5 Ma from locality E2. See description for central area of Reservation for additional information on age

Tiab **Intrusive basalt (Miocene or Oligocene)**—Small chimneys of olivine basalt at Middle Prong Creek in northeastern part of eastern area of Reservation. May be feeders for flows in andesite and basalt unit (Tab)

Tuff of Nantac Rim

Ttnu **Upper member (Oligocene)**—Tan to pale-red, purple or reddish-brown rhyolite ash-flow tuffs along Nantac Rim and areas farther north. Contains two or three distinct cooling units, each with thin zone of densely welded tuff. Thins eastward and disappears east of Park Creek. Thickness as much as 150 m. K-Ar ages on biotite from locality E5 (map and table 1) are 24.9±0.9 Ma and 24.6±0.9 Ma (Bromfield and others, 1972)

Ttnl **Lower member (Oligocene)**—Tan to yellowish-brown rhyolite tuff-breccia that forms massive cliffs along Nantac Rim, but thins eastward and disappears east of Park Creek. Contains dark-purple and gray glassy rhyolitic fragments generally less than 2.5 mm in diameter. Uniformly bedded at base and near top. Thickness 150 m at Barlow Pass

Tta **Tuff of Angel Trail Spring (Oligocene)**—Rhyolite tuffs at south border of eastern area of Reservation and south of Reservation. Consists of medium-light-gray, cliff-forming, ash-flow tuff about 45 m thick overlying medium-gray and grayish- to orange-pink tuffs and dark-brown to black vitrophyre. Thickness 145 m. Thickens southward to at least 240 m. Sanidine from light-gray welded tuff from blocky columns along top of Table Mountain at locality E19 (map and table 1) gave $^{40}Ar/^{39}Ar$ age of 24.01±0.06 Ma. May correlate with tuff of Nantac Rim (Ttnu, Ttnl) and Enebro Mountain Formation (Tem)

Tsv **Siliceous volcanic rocks (Oligocene)**—Light-colored rhyolite lithic crystal tuffs, tuff breccias, and well-bedded pumice tuffs at scattered localities near east border of reservation north and south of Kane Spring Fault. Maximum thickness about 60 m. Relation to other rhyolitic tuff units uncertain. K-Ar age of 24.0±0.9 Ma (B.B. Houser, unpub. data) obtained from rock at locality E18 (map and table 1)

Volcanic rocks (Oligocene)—Equivalent to rocks mapped as Volcano of Bear Spring by Houser and others (1985) in Safford 15′ quadrangle southeast of Reservation

Tvr **Rhyolite of central dome**—Very light gray to light-brownish-gray, crystal-poor, low-silica rhyolite (Houser and others, 1985) in southeast corner of eastern area of Reservation and farther south. Emplaced in core of Bear Spring volcano. Generally massive, but locally contains highly contorted flow layers. Intrudes rhyolite breccia and flows unit (Tvrb) and numerous additional units of volcano as shown by Houser and others (1985)

Tvrb **Rhyolite breccia and flows**—Forms envelopes around rhyolite of central dome (Tvr) of Volcano of Bear Spring of Houser and others (1985). Exposed in southeast corner of Reservation and to south. Includes rhyolite breccia, air-fall tuffs, tuff breccias, thin-bedded ash, and vitrophyre. In general, shows quaquaversal dips away from rhyolite dome. Plagioclase and biotite from locality E17 (map and table 1) yielded K-Ar ages of 26.5±0.6 Ma and 24.5±0.6 Ma, respectively (Houser and others, 1985). Shown by Houser and others (1985) as older than 24.5 Ma

Tvd **Dacite flows and breccias**—Medium-gray to pale-yellowish-brown massive flows on north slopes of Bryce Mountain and east side of Bonita Creek. Consist of fine-grained rock containing small phenocrysts of plagioclase and oxyhornblende. Flow breccias at base of some flows. Include interbedded, pale-gray and brown andesite flows and breccias on north slopes of Bryce Mountain. Maximum thickness about 240 m. Oxyhornblende from locality E14 (map and table 1) gave K-Ar age of 25.9±0.6 Ma (Houser and others, 1985)

Tsp **Sandstone of Pine Flat Tank (Oligocene)**—Pale-gray and tan sandstone well exposed on north side of Cienega Creek northwest of Picket Corral Tank and extends 4 km northeast to vicinity of Pine Flat Tank. South end of exposures truncated by Cienega Creek Fault; pinches out at north end. Reappears 2 km northeast on benches as much as several tens of meters above Willow Creek. Medium to fine grained and friable. Contains large-scale eolian crossbedding in sets as thick as 25 m. Thickness about 30 m

Tabv **Andesite and basalt vent deposits (Oligocene)**—Andesite and basalt scoria along Park Creek and at Midnight Canyon eruptive center

Dacite of Paymaster Wash (Oligocene)—Divided into intrusive and flows

Tdpi **Intrusive dacite**—Medium- to dark-gray and dark-purplish-gray dacite in pluton 3 by 6 km in size west of Slaughter Mountain near south border of eastern area of Reservation. Consists of sparse to abundant blocky plagioclase phenocrysts 3-10 mm wide in dense groundmass of fine plagioclase, augite, and glass. Has flow layers of diverse attitudes, some contorted, 3-30 cm thick and conspicuous layers of coalescing red-brown-weathering spherulites commonly about 3 cm in diameter. Approximately one-half of body altered yellow brown to pale brownish yellow and brownish green

Tdpf **Dacite flows**—Reddish-brown to dusky-red-purple porphyritic dacite along southern border of area south of Ash Flat. See description for central area of Reservation

Tl **Lahars (Oligocene)**—Generally pale-yellow, tan, and pale-red laharic breccias well exposed in cliffs on east side of Lopez Canyon and in Deadman Canyon in Gila Mountains. Crudely bedded. Contains angular blocks to about 1 m across in mudstone matrix. Clasts range from light-gray to reddish-gray porphyritic dacite with hornblende, biotite, and plagioclase phenocrysts to dark-colored, fine-grained andesite and basalt. Biotite from tuff breccia matrix of lahar at lat 33°05.75′ W., long 109°03.30′ N. outside of Reservation south of Angel Trail Fault yielded $^{40}Ar/^{39}Ar$ age of 26.62±0.29 Ma (B.B. Houser, unpub. data, 2001). Thickness as great as about 200 m

Tdr **Dacite of Red Hills (Oligocene)**—Deep-reddish-gray to reddish-gray intrusive dacite in northeast-trending pluton 10 km long and as much as 3 km wide northeast of Fort Thomas. Weakly porphyritic with scattered small biotite phenocrysts and sparse sanidine phenocrysts in aphanitic groundmass. Contains abundant angular to subrounded fragments of volcanic rocks to 15 cm in diameter from underlying terrane. May be composite plug. Locally exogenous on west side with vitrophyre at base

Tad **Andesite and dacite of Coyote Wash (Oligocene)**—Flows at Pima Gap and south of Reservation north of Safford. Light-brownish-gray to medium-gray andesite and dacite flows containing abundant conspicuous blocky plagioclase phenocrysts 0.5-1.0 cm wide and less conspicuous pyroxene and hornblende phenocrysts. Correlation with dacite of Red Hills (Tdr) uncertain. Thickness about 60 m

Tw **Whitetail Conglomerate(?) (Oligocene)**—Crops out locally at base of Tertiary volcanic section. At Black Mesa, composed of boulders as much as 3 m across of Paleozoic carbonate rocks, sandstone, and quartzite and Proterozoic granite in red silty matrix; overlain by andesite and basalt (Tab) of Miocene and Oligocene age. No volcanic clasts found. Outcrops of similar gravel too small to map lie on east side of Park Creek. Gravel on west side of pluton of dacite of Red Hills (Tdr) northeast of Fort Thomas consists of clasts of Proterozoic rocks and smaller amounts of Paleozoic rocks but no Tertiary rocks. Thickness commonly about 60 m. For information on age, see description for central area of Reservation

Andesite of Willow Mountain (Eocene?)

Tawf **Flows and breccias**—Flows, flow breccias, and pyroclastic breccias of pyroxene andesite, hornblende andesite, basalt, and dacite east of Willow Mountain. Displays quaquaversal dips away from center of dioritic intrusive rock (Tawi) near Eagle Creek east of Willow Mountain. Propylitized (pattern on map) adjacent to intrusive body (Tawi). Maximum thickness more than 300 m. May correlate with pyroxene-hornblende andesite flows and breccias of Blue Range Primitive area northeast of reservation, where K-Ar hornblende ages are 38.3±3.9 Ma (Damon, 1970) and 36.1±2.7 Ma (Ratté and others, 1969)

Tawi **Intrusive rock**—Small stock of fine-grained equigranular diorite and pyroxene andesite at Reservation border east of Willow

Mountain. Stock bordered by zone of propylitic alteration in flows and breccias unit (Tawf)

Tibx **Intrusive breccia (Eocene)**—Fragmental rock in funnel-shaped body intruded into granite porphyry (Tgp) at Morenci Mine (Ferguson and Enders, 2000). Fragments are of Pinal Schist ($P_{P}p$), Mesoproterozoic granite ($P_{M}g$), and quartz-poor granite porphyry (Tgp) in matrix of quartz, white mica, and specularite. Smaller bodies, not shown, exposed in Morenci Mine. K-Ar age of 52.8±2.0 Ma from sericite in matrix from locality E24 (map and table 1; Bennett, 1975)

Tpu **Porphyries, undivided (Eocene)**—Undifferentiated granodiorite and diorite porphyries southwest, north, and north-northeast of the Morenci Mine. Mapped as undivided porphyry by Ferguson and Enders (2000), but not described in detail

Tgp **Granite porphyry (Paleocene)**—Gray, greenish-gray, and tan intrusive granitic porphyry consisting of older and younger granite porphyries of Ferguson and Enders (2000) in stock of highly irregular outline at Morenci Mine. All except center of unit is older porphyry, granodiorite to quartz monzonite in composition, containing quartz phenocrysts and highly abundant rectangular plagioclase and less abundant orthoclase phenocrysts in aphanitic groundmass of albite, quartz, and orthoclase. Older porphyry has well-developed quartz-sericite stockwork, pervasive quartz-sericite-pyrite alteration, and supergene minerals and occupies several plugs and dike swarm (not shown) in central part of Morenci district. Younger porphyry at center of stock occupies laccolith-shaped plug consisting of bipyramidal quartz, subordinate orthoclase, euhedral plagioclase, and chloritized biotite phenocrysts in very fine grained matrix of quartz, plagioclase, and sericite. Younger porphyry pervasively sericitized and argillized; lacks through-going veins and stockwork mineralization. K-Ar age of 57.6±2.2 Ma from biotite from locality E25 (map and table 1) reported for older porphyry (Bennett, 1975)

Tmp **Monzonite porphyry (Paleocene)**—Crops out as elongate stock at Morenci Mine and as dike swarm (not shown; Ferguson and Enders, 2000). Gray to greenish gray and brownish gray, consisting of abundant andesine to oligoclase phenocrysts, subordinate, variable amounts of biotite, and rare quartz in microcrystalline groundmass of feldspar and quartz. Biotite originally abundant but rarely preserved. Composition described by Ferguson and Enders as ranging from tonalite to granodiorite. Abundant quartz-sericite stockwork and pervasive quartz-pyrite alteration obscure original texture and chemistry. In mine area, secondary chalcocite mineralization and supergene alteration abundant in sulfide zone underlying oxidized and leached zone of iron oxides and local copper oxide minerals. K-Ar ages of 56.5±1.7 Ma from biotite from locality E11 (map and table 1; McDowell, 1971) and 61.7±2.8 from feldspar from unidentified locality in Morenci area (Ferguson and others, 2000)

Tdp **Diorite porphyry (Paleocene)**—Light-gray to greenish-gray hornblende diorite porphyry in southwestern part of Morenci Mine area (Ferguson and Enders, 2000). Forms thick sheet or laccolith and associated dikes (not shown). Has large phenocrysts of hornblende, plagioclase, and subordinate quartz and biotite in microcrystalline groundmass of chlorite, epidote, montmorillonite, and plagioclase. Ocillatory zoning in plagioclase from labradorite cores to oligoclase rims. K-Ar ages of 63.0±2.3 Ma and 64.8±6.3 Ma from hornblende from locality E12 (map and table 1; McDowell, 1971)

TKv **Volcanic rocks (Paleocene and Late Cretaceous)**—Dark-greenish-gray to olive-gray massive andesitic and dacitic fragmental rocks near Bonita Creek and south of Reservation. One small outcrop in Reservation west of Bonita Creek near southeast boundary of eastern area of Reservation. Includes flow breccias, avalanche deposits, and mudflows, all propylitically altered. Exposed thickness about 500 m (Houser and others, 1985). K-Ar age of 67.6±1.4 Ma obtained from hornblende from dike at locality E15 (map and table 1; Houser and others, 1985)

TKg **Granite (Paleocene and Late Cretaceous)**—Small plutons and dike-like bodies, largely quartz monzonite and granodiorite, with minor amounts of granite and quartz diorite porphyry south of Reservation (Houser and others, 1985). All rocks variously altered. Paleocene age suggested by isotopic ages reported by Houser and others (1985) as indicating possible late magmatic or alteration activity; Cretaceous age suggested by crosscuting dikes in unit dated as 67.6±1.4 Ma from hornblende from locality E15 (map and table 1)

Kp **Pinkard Formation (Late Cretaceous)**—Red, black, and brown shales and light-brown sandstone east of Reservation in southern part of Clifton-Morenci area. Upper 30 m interbedded shale and sandstone; lower part shale, mostly black. Thickness from exposed areas at least 50 m, but data from drill hole in hanging wall of Eagle Creek Fault indicates thickness greater than 238 m and potentially 430 m (Ferguson and Enders, 2000)

ⅡPMu **Horquilla Limestone (Pennsylvanian) and Escabrosa Limestone (Mississippian), undivided**—Exposed east of Reservation in northern Clifton-Morenci area. Gray and light-bluish-gray, thick-bedded, cherty, and fossiliferous limestone. Equivalent to Tule Spring Limestone of Lindgren (1905). Thickness about 210 m; at least upper 150 m Pennsylvanian in age

Me **Escabrosa Limestone (Mississippian)**—Very light gray limestone at scattered localities along Nantac Rim, north of Cienega Creek, and in Clifton-Morenci area east of Reservation. Mostly medium- to thick-bedded cherty and crinoidal limestone, in part coarse grained. Includes grayish-brown dolomitic limestone and quartzite in Clifton-Morenci area. Thickness as much as 120 m in Reservation, 49-55 m to east (Lindgren, 1905)

Dms **Morenci Shale (Devonian)**—Fissile shale and limestone at scattered localities along Nantac Rim, north of Cienega Creek, and east to Clifton-Morenci area. Shale calcareous, weathers pale red to greenish gray; fresh exposures black at Morenci. Upper part contains a few thin limestone beds, lower part blue-gray thin-bedded argillaceous limestone with red shale interbeds. Lindgren (1905) reported fine-grained dolomite in shale near top at Morenci. Thickness 15-60 m

O€e **El Paso Limestone (Ordvician and Cambrian)**—Limestone, dolomite, and sandstone along Nantac Rim, a few localities north of the rim, on Pistol Creek at Eagle River, and in Clifton-Morenci area east of Reservation. Upper part light-gray, thin- to medium-bedded dolomitic limestone and dolomite, in part sandy, and rusty-red, medium- to coarse-grained dolomitic sandstone. Lower part red to tan, thin-bedded, sandy and silty dolomite and dolomitic sandstone, in places glauconitic. In part resembles Abrigo Formation (€a) of southeastern Arizona and southwestern part of Reservation. Thickness 60-116 m

€c **Coronado Sandstone (Cambrian)**—Red, brown, and purple sandstone and siltstone along Nantac Rim, northeast of Park Creek, and in scattered localities east to Clifton-Morenci area east of Reservation. Upper part slope-forming, thin-bedded, planar and crossbedded sandstone and grit. Lower part slope-forming, thin-bedded, gritty limestone and sandstone. Thickness as much as 165 m, but thinner above paleohills of Proterozoic rocks, as near Pistol Creek, where formation consists of 0-30 m of pebble to cobble conglomerate of quartzite clasts

$Ꝑ_M$d **Diabase (Mesoproterozoic)**—Dark-olive-gray, fine- to coarse-grained, ophitic rock in small exposures near Black Mesa. Intrusive in Proterozoic granite ($Ꝑ_M$g). Weathers to olive-gray soil, flat areas, and gentle slopes. Age about 1,100 Ma (see Wrucke, 1989, for summary of age data)

$Ꝑ_M$g **Granite (Mesoproterozoic)**—Red to gray granite widely exposed east of Black Mesa and from Reservation border east to central Clifton-Morenci area. Biotite bearing, locally porphyritic from orthoclase megacrysts as large as several centimeters wide. Composition ranges from granite to monzogranite and granodiorite. Locally includes dikes and irregular bodies of red aplite and porphyritic granite (Ferguson and Enders, 2000). Weathers to grus

$Ꝑ_P$p **Pinal Schist (Paleoproterozoic)**—Quartzite and schist in Gila Mountains north of Fort Thomas, near east border east of Park Creek Fault, and schist in northeastern part of Clifton-Morenci area east of Reservation. Quartzite, light gray, fine grained, and massive, having no clearly defined bedding. Schistose rock, dark-purplish-red quartz-muscovite schist and phyllite; includes small bodies of amphibolite in Clifton-Morenci area.

Age about 1,700-1,600 Ma (Conway and others, 1987)

SOUTHERN AREA

Qa **Alluvium (Holocene)**—Unconsolidated silt, sand, and gravel in stream channels and washes. Includes terrace deposits as much as 3 m above stream and wash bottoms

Qt **Talus (Holocene)**—Rubble on steep slopes

Ql **Landslide deposits (Holocene)**—Blocky rubble and dislocated masses. Common and locally 1 km or more across in areas of Pliocene basalt flows capping or interlayered with alluvial and tuffaceous deposits northeast of San Carlos

Qct **Calcareous tufa (Holocene)**—Light-gray, cavernous, locally dense tufa in terraces deposited by Mescal Warm Spring along Mescal Creek Fault 10 km southwest of Coolidge Dam (fig. 1). Largest terrace is 0.8 km long and has maximum thickness of 120 m

Qg **Gravel (Quaternary)**—Unconsolidated alluvial debris. Consists of terrace deposits along major streams and isolated areas of gravel of local origin

Qp **Piedmont deposits (Quaternary)**—Loosely consolidated, locally caliche cemented, massively to lenticularly bedded silt, sand, pebbles, cobbles, and boulders. Pebbles, cobbles, and boulders commonly subrounded to round. Form prominent surfaces 12-73 m above adjacent major streams. Abundant in basin of San Carlos River, Gilson Wash, and Gila River. Not mapped south of Gila River. Locally includes terrace deposits. As much as 15 m thick

Gila Conglomerate (Pliocene and Miocene)

Tgc **Conglomerate and associated sedimentary rocks member**—Extensive deposits of mostly gently dipping, very coarse grained to fine-grained, weakly consolidated sedimentary deposits mainly on north flank of Santa Teresa and Mescal Mountains and along San Pedro River. Interbedded tephra deposit prominent in bluffs south of Bylas-Coolidge Dam road west of Bylas. Include unmapped Quaternary alluvial deposits. See description for central area of Reservation for information on age

Tbv **Vent deposits (Pliocene)**—Nearly flat lying coarse breccia of vesicular basalt in Bridge Washer Tank, Bylas, Nelson Well, and Ruin Diatremes. Contain breccia blocks as large as 2 m

Tbf **Basalt flows (Pliocene and Miocene)**—Thin flows in Mescal Mountains. Consist of vesicular, fine-grained olivine basalt intercalated with conglomerate and associated sedimentary rocks member (Tgc) of Gila Conglomerate. Aggregate thickness may be 300 m. Samples yielded whole-rock K-Ar age of 7.8±0.3 Ma from locality S1 (map and table 1), 5.28±0.13 Ma from locality S2 (Shafiqullah and others, 1980), and 3.6±0.4 Ma from locality S19 (Anderson, 1988). See description for central area of Reservation for additional ages

Thh **Hell Hole Conglomerate (Miocene)**—Light-colored, moderately indurated to well-indurated conglomerate and breccia south of Reservation, 5.6-14.1 km southwest of Stanley Butte. Mainly gently dipping but locally dips steeply to overturned. Thickness as much as 600 m

Tq **Quartz porphyry (Miocene)**—Light-gray to very light gray, conspicuously porphyritic intrusive rock composing oval-shaped plug about 1.6 km across, centered 4.5 km east of Stanley Butte, and smaller plug along Sycamore Gulch Fault. Consists of quartz and potassium feldspar phenocrysts in fine-grained groundmass

Tf **Felsic dikes (Miocene)**—Light-colored dikes mainly of quartz porphyry but also of feldspar porphyry widespread in southern area east of Hawk Canyon Fault. Many dikes 1.5 km or more long and as much as 60 m thick. Quartz and commonly sanidine phenocrysts in quartz porphyry dikes, locally with phenocrysts of plagioclase and biotite in fine-grained to aplitic groundmass. Composition probably ranges from dacite to rhyolite. Feldspar porphyry dikes contain only feldspar phenocrysts. Include dike of porphyritic hornblende dacite in Proterozoic rocks southeast of Beargrass Basin. Intrusive in rocks as young as lower Miocene

Ta **Andesite dikes (Miocene)**—Small dikes of coarsely porphyritic (turkey-track) andesite 1.4 km east and 5.7 km northeast of Mt. Turnbull. Includes small plug of dark-gray and greenish-gray, porphyritic, hornblende andesite 3.2 km southeast of Coolidge Dam

Tdi **Diabase dike (Miocene)**—Dike 1.5 m wide in Santa Teresa Granite (Tst) near Hinton Springs

Tvs **Silicic volcanic rocks (Miocene and Oligocene)**—Grayish pink to pale red, ranging in composition from rhyolite to dacite. Mapped separately around Mt. Geronimo, west of Stanley Butte, southwest and southeast of Mt. Turnbull, and at other scattered localities. Elsewhere included in volcanic rocks, undivided (Tvu). Prominent quartz and sanidine or sodic plagioclase phenocrysts in most rocks. Glassy matrix has prominent flow layers. Maximum thickness at least several tens of meters

Tvu **Volcanic rocks, undivided (Miocene and Oligocene)**—Form two extensive northwest-trending belts. Northern belt from Mt. Turnbull to Sycamore Gulch more than 11 km long and 1.5-5 km wide. Southwestern belt, in places nearly 6 km wide, extends more than 20 km from Stanley Butte to Gila River. Smaller areas present outside Reservation south of Stanley Butte. Composition ranges from olivine basalt to rhyolite in highly variable proportions. Includes lava flows and flow breccias, welded and nonwelded ash-flow tuffs and tuff breccia, and minor volcaniclastic sedimentary rocks. Rests on Proterozoic, Paleozoic, and Cretaceous rocks. Thickness, 1,200-1,800 m on Rawhide Mountain, as much as 4,300 m between Sycamore Gulch and Chittakow Draw, and 1,200-2,400 m on Mt. Turnbull. K-Ar ages: 23.3±0.4 Ma from sanidine from locality S8 (map and table 1), 22.8±0.9 and 22.5±0.3 Ma from whole rocks from localities S10 and S12, respectively, 21.8±0.4 Ma from plagioclase from locality S7, and 21.5±0.3 Ma from whole-rock from locality S9

Galiuro Volcanics (Miocene and Oligocene)

Tgua **Upper andesite member (Miocene)**—Dark-colored, dense, fine-grained, locally amygdaloidal andesite and agglomerate at south border of Reservation south of Red Rooster Fault. Includes flows of basalt and andesite unit of Willden (1964) north of Reed Basin near west border of southern area. Some flows contain millimeter-size plagioclase phenocrysts and grains of olivine (now iddingsite) 0.5-2 mm wide. Has vitric-lithic or vitric-crystal tuff 1-20 m thick locally at base. Thickness 30-130 m

Tga **Aspey Conglomerate Member (Miocene)**—Yellowish- to light-gray conglomerate exposed in area of many square kilometers centered 18 km northeast of southwest corner of Reservation. Thin bedded, consists mainly of volcanic clasts in well-indurated, sandy to tuffaceous matrix. Thickness as much as 120 m. Age of 22.78±0.48 Ma reported by Scarborough and Wilt (1979) and Reynolds and others (1986) for Holy Joe Peak quadrangle south of Reservation

Tgh **Hells Half Acre Tuff Member (Oligocene)**—Light-colored, cliff-forming silicic vitric tuff in widely scattered areas south of Deer Creek Syncline. Contains some crystal and lithic tuff and slightly welded ash-flow tuff. Thickness as much as 150 m. Ages of 25.30±0.70 Ma and 23.10±0.70 Ma reported by Creasey and Krieger (1978) for localities in Brandenburg Mountain quadrangle south of Reservation

Tgr **Rhyolite-obsidian member (Oligocene)**—Light- to dark-colored obsidian, obsidian conglomerate, vitrophyre, and lava flows extensively exposed south of Quartzite Mountain Fault. Locally conspicuously streaked and flow layered. Thickness as much as 200 m

Tgad **Andesite of Depression Canyon (Oligocene)**—Mostly olivine andesite flows mainly along south border of Reservation south of Deer Creek Syncline and northwest of Jackson Mountain. Flows as much as 30 m thick, locally interlayered with more silicic tuff. Includes andesite of andesite and conglomerate of Depression Canyon of Kreiger (1968a,b), upper andesite unit of Galiuro Volcanics (Simons, 1964, p. 89-90), and small area north of Deer Creek mapped as basalt by Willden (1964, p. E35). Maximum thickness about 180 m

Tst **Santa Teresa Granite (Oligocene)**—Light-gray to pinkish-gray, medium- to coarse-grained equigranular to porphyritic monzogranite in large batholith extending far to south of Reservation. Commonly hypidiomorphic granular and biotite bearing. Contains inclusions of mafic rocks possibly Proterozoic in age. Locally difficult or impossible to distinguish from Proterozoic granitic rocks (P_Mg). Biotite from granite yielded

K-Ar ages as follows at localities (map and table 1) indicated: 24.95±0.69 Ma at S18 (Shafiqullah and others, 1980), 23.5±0.4 Ma at S11, 23.3±0.5 Ma at S16, 23.0±0.8 Ma at S13, 22.9±0.4 Ma at S15, and 22.9±0.4 Ma at S17

Tstp **Porphyritic phase (Oligocene)**—Light-brownish-gray to pale-red porphyritic leucogranite only between Bee Spring and Mitchell Canyon Faults. Consists of feldspar phenocrysts and aggregates of quartz in fine- to medium-grained aplitic groundmass containing minor amounts of biotite. Lithologically similar to quartz porphyry dikes of felsic dikes unit (Tf)

Tstb **Granitic border rocks (Oligocene)**—Light-colored porphyritic rhyolite and rhyolite breccia, quartz porphyry, and microgranite only along Mitchell Canyon Fault 3 km southwest of Mt. Turnbull, where unit forms lenticular body about 760 m long and 150 m maximum width

Tvt **Tuffaceous volcanic rocks (Oligocene)**—Pale-red to grayish-red welded to non-welded tuff shown separately in belt of volcanic rocks, undivided (Tvu) that extends northwest beginning 3 km west of Stanley Butte. Welded ash-flow tuff beds on northeast flank of Rawhide Mountain contain phenocrysts of sanidine, sodic plagioclase, and biotite, with abundant lithic fragments. Thickness on flank of Rawhide Mountain 30-60 m. Biotite from locality S6 (map and table 1) near Mt. Geronimo yielded K-Ar age 23.6±0.6 Ma

Tw **Whitetail Conglomerate(?) (Oligocene)**—Consists of clasts of Horquilla and Escabrosa Limestones as much as 30 cm across and locally also of quartzite, chert, and granite in grayish-red volcaniclastic matrix. Crops out beneath volcanic rocks of Oligocene age nearly continuously for more than 13 km near southwest corner of reservation, where it rests on Paleozoic and Cretaceous rocks. Exposed for 1-5 km southeast of Mt. Turnbull, where it lies on Proterozoic rocks. Locally beneath volcanic rocks, undivided (Tvu) of Miocene and Oligocene age north and northwest of Mt. Turnbull, too small to show at map scale. Thickness irregular, from about 1 m to as much as 30 m. For information on age, see description for central area of Reservation

Tr **Rhyolite (Paleocene)**—Light-gray to pinkish-gray, flow-layered intrusive rhyolite 7.2 km northeast of southwest corner of Reservation. Contains small phenocrysts of biotite, quartz, and plagioclase in microcrystalline groundmass. Biotite from locality S5 (map and table 1) gave corrected K-Ar age of 62.63 Ma (Krieger, 1968b)

TKgp **Granite porphyry (Tertiary or Cretaceous)**—Light-gray feldspar porphyry dike in granite (E_Mg) 10 km north of Coolidge Dam. Consists of altered potassium feldspar phenocrysts 1-5 mm across and smaller fresh biotite phenocrysts in altered micrgranitic groundmass. See description for central area of Reservation

Ki **Intrusive rocks (Cretaceous)**—Medium gray, in small plugs in Cretaceous volcanic rocks (Kv) and sedimentary rocks (Ks) in upper Deer Creek and large laccolith in Granite Basin. May have been feeders for volcanic rocks (Kv). Consist of fine-grained feldspar porphyries with millimeter-size phenocrysts of clinopyroxene and altered plagioclase. Laccolith is dacite porphyry. Hornblende from laccolith at locality S4 (map and table 1) yielded age of 72.3±2.2 Ma (McKee and Koski, 1981); hornblende from dacite porphyry known as McDonald Stock at locality S3 yielded K-Ar age of 69.8±2.1 Ma (McKee and Koski, 1981)

Kv **Volcanic rocks (Cretaceous)**—Dominantly greenish-gray andesitic flows, flow breccias, and volcaniclastic rocks that crop out extensively in Deer Creek Syncline and southeast of Stanley Butte. Freshest rocks are gray, porphyritic hornblende andesite containing hornblende and plagioclase phenocrysts, but most rocks highly altered, saussuritic, and chlorite bearing. Rest unconformably on Horquilla Limestone (ℙh) and conformably on Cretaceous sedimentary rocks (Ks). Thickness estimated to be 600-900 m

Ks **Sedimentary rocks (Cretaceous)**—Interbedded brown, greenish-brown, gray and grayish-red sandstone, conglomerate and minor fossiliferous limestone, calcareous sandstone, siltstone, and shale. Exposed in nearly continuous, generally northwest-trending belt 24 km long that begins 6 km southeast of Stanley Butte. Other extensive exposures along flanks of Deer Creek Syncline. Impure sandstone, consists of quartzitic, tuffaceous, gritty, and pebbly phases. Locally contain abundant fossil wood and plant debris. Converted to garnetite and various kinds of hornfels east and southeast of Stanley Butte, presumably from contact metamorphism by Santa Teresa Granite (Tst). Where unmetamorphosed, weathers distinctive rusty orange. Rest unconformably on Horquilla Limestone (ℙh). Thickness 90-460 m in Deer Creek Syncline and 150-600 m elsewhere

Kc **Coal (Cretaceous)**—One small occurrence in upper Deer Creek near the east end of the Deer Creek Syncline. No outcrop, but small chips of coal in area underlain by brown, carbonaceous, arkosic carbonate-cemented sandstone

ℙMu **Horquilla(?) Limestone (Pennsylvanian) and Escabrosa(?) Limestone (Mississippian), undivided**—Highly brecciated and recemented gray limestone of uncertain correlation but probably Escabrosa or Horquilla Limestone, or both. Crops out along Bee Spring, Mitchell Canyon, and Sycamore Spring Faults

ℙh **Horquilla Limestone (Pennsylvanian)**—Gray, thin- to thick-bedded limestone, cherty limestone, dolomitic limestone, and minor dolomite. Widely exposed in several northwesterly trending belts in western two-thirds of area. Highest parts contain pink shaly limestone. Beds of pink, brown- to orange-weathering dolomite including a few beds of intraformational limestone conglomerate intercalated in lower part. Thin wavy layers of silty or sandy limestone and salmon-colored silicified fossils near base. Replaced by garnetite and quartz, locally with opal and fluorite, 3-5 km east of Stanley Butte. Thickness 270-500 m, commonly 300-360 m

Me **Escabrosa Limestone (Mississippian)**—Gray to brown limestone and gray dolomite exposed in same northwest-trending belts as disconformably overlying Horquilla Limestone (ℙh) and above low-angle normal faults at Fiddler Camp Spring and White Spring. Upper part consists mostly of gray, fine-grained, thick-bedded limestone and crinoidal limestone, cherty limestone, and brownish- to pinkish-gray dolomite and cherty dolomite; lower part gray, fine-grained to sugary, thick-bedded dolomite and cherty dolomite as much as 49-55 m thick. Conspicuous 3-m-thick bed of light-brown sandy dolomite commonly about 1 m above base. Thickness 120-150 m in northwestern part of southern area of Reservation, as thick as 240-300 m in southern part

DЄu **Martin Formation (Devonian) and sedimentary rocks (Cambrian), undivided**— Consists, from top downward, of 23-30 m of shale or marlstone and wavy-bedded limestone and 120-200 m of quartzite. Crops out in dislocated masses near White Spring and Fiddler Camp Spring and at scattered localities in east half of southern area of Reservation

Dm **Martin Formation (Devonian)**—In northwestern part of southern area of Reservation, consists of 15-23 m of green shale overlying 60 m of dolomite, limestone, and sandy dolomite and rests on Mesoproterozic rocks. In southern part of southern area of Reservation, shale 30-60 m thick rests on Cambrian rocks. Farther east, consists of 20-30 m of shale, calcareous shale, and marlstone

Єa **Abrigo Formation (Cambrian)**—Crops out only in southwestern part of southern area of Reservation. Consists of upper dolomitic member 27-32 m thick, middle sandstone member 46-67 m thick, and lower mudstone member 30-52 m thick

Єq **Quartzite (Cambrian)**—Light-brown, brown, reddish-brown, and gray quartzite of about same distribution as other Paleozoic rocks in southern area of Reservation. Quartzite is fine grained, thin to thick bedded, cross-bedded, and generally arkosic, but has beds of quartz arenite particularly in upper 30 m. Commonly has quartz granules and locally quartzite pebble conglomerate. Uppermost few meters contain glauconite and, locally, upper part contains tiny shell fragments. Thickness 150-200 m in most areas but thins to northwest and missing in northwestern part of southern area of Reservation. Thickness is 300 m at Crystal Peak, where older rocks included in unit

Ᵽ$_{M}$d **Diabase (Mesoproterozoic)**—Dark-green sills in sedimentary strata and sheets in granite (Ᵽ$_{M}$g) in west half of southern area of Reservation. Consists of variably altered plagioclase and pyroxene in ophitic texture. For information on age, see description for central area of Reservation

₽$_M$gd **Gabbro and diabase (Mesoproterozoic)**—Mainly gabbro but includes some diabase and diorite. Exposed mainly in four irregular bodies around Mt. Turnbull within 5 km of the summit and as prominent sheet in granite (₽$_M$g) northwest of Coolidge Dam. Gabbro medium dark gray to dark gray or dark greenish gray and medium to coarse grained, with allotriomorphic granular to ophitic textures. Consists of roughly equal amounts of plagioclase and clinopyroxene or hornblende

₽$_M$t **Troy Quartzite (Mesoproterozoic)**—Very light gray and reddish-brown to grayish-red sandstone exposed nearly continuously beneath Paleozoic rocks northward from about 10 km southwest of Coolidge Dam and in small area south of Red Rooster Fault. Typically poorly sorted, coarse-grained to gritty sandstone, locally with scattered pebbles. Beds medium to thick, planar to uneven, massive to laminated, and commonly crossbedded. Some beds have convolute laminations. Rarely contains well-sorted orthoquartzite. Thickness about 140 m and highly variable in short distances but as much as 270 m in northwestern part of southern area of Reservation. See description for central area of Reservation for information on age

Apache Group (Mesoproterozoic)

₽$_M$ab **Basalt**—Blackish-green and dark-gray flow rock exposed only in extreme northwestern part of southern area of Reservation. Fresh and weathered surfaces commonly of reddish hue from abundant hematite, locally bright red in vesicles. Rock aphyric and thoroughly altered from weathering before deposition of Troy Quartzite. See description for central area of Reservation. Thickness about 5-30 m

₽$_M$am **Mescal Limestone**—Exposed north of latitude of Coolidge Dam and in isolated remnants to south. Consists of pale-brown, gray, and pale-red, thin-bedded dolomite and cherty dolomite where unmetamorphosed. Upper part has prominent stromatolites. Consists of very light gray metalimestone locally containing thin layers of serpentinite where metamorphosed by diabase. Thickness as much as 60 m, but only about 1 m locally where deeply weathered prior to deposition of Troy Quartzite

₽$_M$ad **Dripping Spring Quartzite**—Mainly light-gray and brown to reddish-brown sandstone and siltstone exposed beneath Paleozoic rocks or with other Mesoproterozoic units west of longitude of Coolidge Dam. Upper member as thick as 15 m consists of fine-grained sandstone and siltstone in thin planar to lenticular beds and locally prominent black shale. Lower member consists of fine- to medium-grained, well-sorted, medium- to thick-bedded, crossbedded arkose and feldspathic sandstone. Basal Barnes Conglomerate Member commonly 3-5 m thick, locally 14 m. Thickness 140-150 m. Rests on granite (₽$_M$g) south of Gila River. For information on age, see description for central area of Reservation

₽$_M$ap **Pioneer Shale**—Dusky-red and dusky-reddish-purple siltstone and sandy siltstone beneath Dripping Spring Quartzite north of Gila River. Locally mapped with Dripping Spring. Commonly has light-colored spots, is thin bedded to laminated and finely cross-laminated. Scanlan Conglomerate Member at base present only locally as 30-100-cm-thick pebbly conglomerate. Thickness 0-50 m. For information on age, see description for central area of Reservation

₽$_M$g **Granite (Mesoproterozoic)**—Gray to reddish granite widely exposed along mountain front north of Gila River, north of Mt. Turnbull, and other localities beneath Proterozoic and Paleozoic strata. Largely medium- to coarse-grained, equigranular to porphyritic. Has inclusions of mafic rock several centimeters to several meters across. Difficult to distinguish from Santa Teresa Granite (Tst) in areas distant from Proterozoic or Paleozoic stratified rocks

₽$_M$mi **Mixed intrusive rocks (Mesoproterozoic)**—Mostly plutonic igneous rocks of various compositions exposed on steep north face of Mt. Turnbull. Most abundant rock types probably hornblende quartz diorite, diabase, gabbro, microgranite, and porphyritic granite. Contains rare pyroxenite. Contains scattered small bodies of metasedimentary and metavolcanic rocks. All rocks altered but do not show clear effects of metamorphism. Intruded by granite (₽$_M$g). K-Ar age of 892.4±9.2 Ma obtained from hornblende from quartz diorite at locality S14 (map and table 1) apparently reset

Pp **Pinal Schist (Paleoproterozoic)**—Metasedimentary and metavolcanic rocks in lower Squaw Canyon, south of Red Rooster Fault, at Cobre Grande Mountain, and in White Spring Klippe. Principal lithology is gray to dark-brown porphyroblastic quartz-feldspar-mica schist, probably mostly metarhyolite. Also present: chlorite schist, light- to dark-gray hornfels, and metasandstone and conglomerate. Age about 1,700-1,600 Ma (Conway and others, 1987)

Pg **Gneiss (Paleoproterozoic)**—Mainly light-gray, coarse-grained hornblende-biotite granite gneiss and augen gneiss in area of several square kilometers at Jackson Mountain, near southeast corner of southern area of Reservation. Also includes fine-grained equigranular gneiss, quartz-muscovite schist, microgranite, and sparse gabbro. Locally contains abundant pegmatite dikes and quartz veins

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