New and Revised Stratigraphic Names in the Santa Rita Mountains of Southeastern Arizona

By HARALD DREWES

CONTRIBUTIONS TO STRATIGRAPHY

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A stratigraphic column is presented for the Santa Rita Mountains, and formations are defined or revised. Their ages are supported by radiometric determinations

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CONTRIBUTIONS TO STRATIGRAPHY

NEW AND REVISED STRATIGRAPHIC NAMES IN THE SANTA RITA MOUNTAINS OF SOUTHEASTERN ARIZONA

By HARALD DREWES

Abstract

Recent work provides the basis for establishing a stratigraphic column in the Santa Rita Mountains of Santa Cruz and Pima Counties of southeastern Arizona. Thirteen formations of this column are here defined and one is revised. One new formation is a Precambrian granodiorite. Ten new formations are Mesozoic units that include plutonic, volcanic, and continental sedimentary rocks. The revised formation is the Upper Cretaceous Fort Crittenden Formation of Stoyanow (1949), dominantly a sedimentary unit. Two new formations are volcanic and sedimentary rocks of Tertiary age. Many radiometric dates supplement the sparse fossil record in corroborating or redefining the ages that had been assigned to many units on the basis of their geologic relations and in establishing the ages of other units.

INTRODUCTION

Detailed geologic mapping and petrographic studies of the rocks in the Santa Rita Mountains since 1962 (Drewes, 1966) provide the basis for establishing a stratigraphic sequence in the area (fig. 1). The names of the Paleozoic formations and one of the Precambrian formations recognized in the Santa Rita Mountains have previously been used over much of southeastern Arizona and they are retained in this report. However, one additional Precambrian unit, many Mesozoic units, and two Cenozoic units are newly recognized in the report area, are of considerable areal extent and geologic importance, and are formally defined. In addition, the Upper Cretaceous Fort Crittenden Formation, originally described by Stoyanow (1949), is now seen to be a more complex unit that is several times the thickness of the original one and is herein revised.

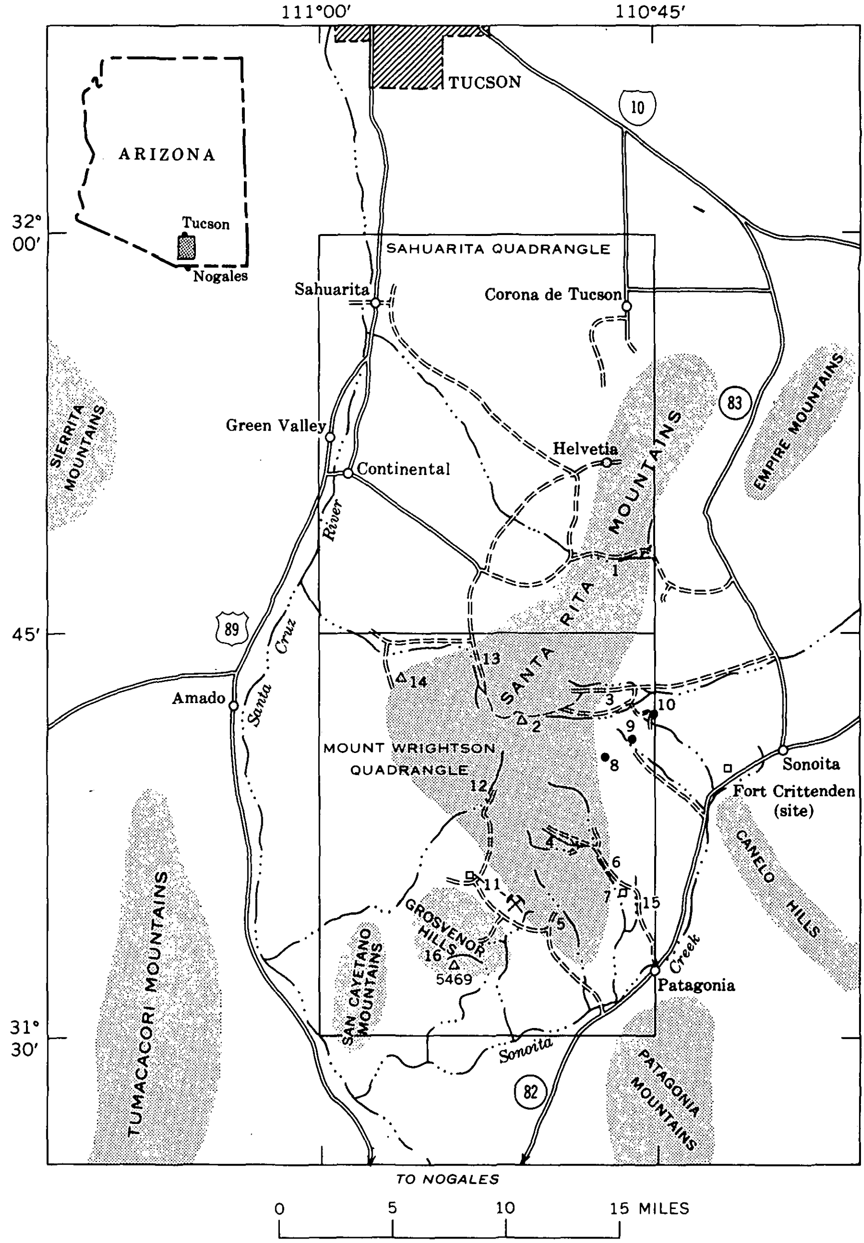

FIGURE 1.—Index map showing location of Santa Rita Mountains, Ariz. 1, Box Canyon; 2, Mount Wrightson; 3, Gardner Canyon to south and Cave Creek canyon to north; 4, Piper Gulch to north and Mansfield Canyon to south; 5, Squaw Gulch; 6, Temporal Gulch; 7, ranch; 8, Bathtub; 9, El Pilar Tank and Adobe Canyon; 10, bench mark YOUNG and Hog Canyon; 11, Salero ranch and mine; 12, Josephine Canyon; 13, Madera Canyon; 14, Elephant Head; 15, Gringo Gulch; 16, Cinigita Canyon to north and Coal Mine Canyon to south.

The Mesozoic and Cenozoic strata consist largely of continental sedimentary and volcanic rocks in which lateral facies changes are rapid and thicknesses highly variable. Large stocks and other bodies both intrude these strata and, in places where the Paleozoic rocks are absent, underlie them. Radiometric ages of the intrusives have provided many critical data on this sparsely fossiliferous sequence.

Many of the formations extend into ranges adjacent to the report area where they commonly are less complete and less well dated or are more intensely altered and faulted than in the Santa Rita Mountains. Some geologic relations, however, have been clarified or substantiated by studies in these adjacent areas (fig. 1). These studies include the work in the Patagonia Mountains to the south and southeast by F. S. Simons; in the Canelo Hills to the east by R. B. Raup; in the Empire Mountains, also to the east, by Tommy Finnell; and in the Sierrita Mountains to the northwest by J. R. Cooper. Enough is known of the geology of the Rincon and Santa Catalina Mountains to the north, just beyond the area shown in figure 1, to indicate that rocks of those mountains present essentially a different problem; enough is also known of the rocks of the Tumacacori Mountains to the southwest to show that mid-Tertiary volcanics cover most of the older rocks, which leaves a very sparse and fragmentary record. As a result, the general stratigraphic results of the present study will probably not be appreciably augmented by additional work, although further refinement of the facies and subdivisions of the units and more complete and accurate dating may be possible.

This report serves to introduce the new formations and their geologic relations. Their typical lithology and location are described briefly here. Descriptions in greater detail, along with regional correlations and tectonic implications, are being prepared as a series of topical reports.

PRECAMBRIAN ROCKS

CONTINENTAL GRANODIORITE

A coarsely porphyritic Precambrian granodiorite underlies much of the northern part of the Santa Rita Mountains. It intrudes gneissic rocks, contains inclusions of schistose rock probably correlative with the Pinal Schist, is overlain along a fault contact by Paleozoic rocks, and lies unconformably beneath the Lower Cretaceous Bisbee Formation. The contact with the Paleozoic rocks probably was once an unconformity, as it still is in many nearby ranges, along which the faulting took place. The rock is

TABLE 1.—*Sequence and ages of rocks in the Santa Rita Mountains of southeastern Arizona*

[Names marked by double asterisk are new in this report. Name marked by asterisk is redefined and newly accepted for usage by the U.S. Geol. Survey]

Age	*Stratigraphic unit and description*
Cenozoic:	
Recent to Pliocene	Fine gravel and silt units, unnamed, thickness unknown.
Pliocene and Miocene	Gravel of Nogales, more abundant to south.
Late(?) Oligocene	Quartz monzonite stock and rhyodacite dike swarm and laccoliths of a single genetic sequence (K-Ar, 26–27 m.y.).
	Grosvenor Hills Volcanics:** rhyolite and rhyodacite volcanics, also of the above genetic sequence.
Eocene(?)	Quartz vein swarm; mineralized.
Paleocene	Quartz latite porphyry dike swarms and small stocks; associated with mineralization (K-Ar, 56 m.y.).
	Quartz monzonite stocks (K-Ar, 54–60 m.y.).
Paleocene(?)	Gringo Gulch Volcanics:** largely rhyolitic to dacitic volcanics.
Mesozoic:	
Late Cretaceous	Elephant Head Quartz Monzonite:** fine- and coarse-grained quartz monzonite, two large stocks (K-Ar, 68–69 m.y.; Pb-alpha, 188 m.y.).
	Madera Canyon Granodiorite:** leucocratic and melanocratic granodiorite and porphyritic granodiorite (K-Ar, 68 m.y.).
	Josephine Canyon Diorite:** medium-coarse-grained diorite and quartz diorite (K-Ar, 67 m.y.; Pb-alpha, 62–63 m.y.).
	Salero Formation:** rhyodacite to dacite volcanics, arkose and other sedimentary rocks (K-Ar, 72 m.y.).
	Fort Crittenden Formation:* conglomerate, sandstone, and shale; Santonian to Maestrichtian fauna.
Early Cretaceous	Bisbee Formation: sandstone, arkose, siltstone, conglomerate, and limestone; Aptian-Albian fauna in type area.
	Bathtub Formation:** rhyolitic to andesitic volcanics and conglomerate.
	Temporal Formation:** rhyolitic to andesitic volcanics and conglomerate.
Jurassic	Squaw Gulch Granite:** coarse-grained granite and quartz monzonite (K-Ar, 145 m.y.; Pb-alpha, 160–161 m.y.).
Triassic	Piper Gulch Monzonite:** very coarse grained monzonite (Pb-alpha, 184 m.y.).
	Gardner Canyon Formation:** red beds, arkose, and dacite volcanics (Pb-alpha, 192 m.y.).
	Mount Wrightson Formation:** rhyolitic to dacitic volcanics and eolian sandstone (Pb-alpha, 220 m.y.).

TABLE 1.—*Sequence and ages of rocks in the Santa Rita Mountains of southeastern Arizona*—Continued

Age	*Stratigraphic unit and description*
Paleozoic:	
Permian	Rainvalley Formation: limestone, dolomite, and sandstone.
	Concha Limestone: cherty thick-bedded limestone.
	Scherrer Formation: quartzite and dolomite.
	Epitaph Dolomite: dolomite, marl, and limestone.
	Colina Limestone: dark-gray moderately thick bedded limestone.
Permian and Pennsylvanian	Earp Formation: red siltstone and limestone.
Pennsylvanian	Horquilla Limestone: light-gray limestone and siltstone.
Mississippian	Escabrosa Limestone: massive coarsely crystalline limestone.
Devonian	Martin Limestone: limestone, dolomite, and sandstone.
Cambrian	Abrigo Limestone: sandstone, siltstone, and limestone.
	Bolsa Quartzite: quartzite and conglomerate.
Precambrian	Continental Granodiorite:** coarse-grained porphyritic granodiorite and quartz monzonite (Rb-Sr, 800 m.y.; Pb-alpha, 1,360–1,450 m.y.).
	Pinal Schist: schist and gneiss.

here named the Continental Granodiorite for its extensive exposures in the hills east of the town of Continental. The type area for the granodiorite is along Box Canyon (fig. 1, No. 1), a few miles east of Continental, where there are excellent exposures along both canyon bottom and road.

The Continental Granodiorite ranges in composition from granodiorite to quartz monzonite, and numerous small bodies of leucocratic quartz monzonite and aplite form a separately mappable phase of the formation. Granophyric and myrmekitic textures are common, and the large crystals, as much as a few centimeters long, are porphyroblasts. The approximate mode of the rock, given in percent, is: quartz, 10–20; orthoclase or microcline, 10–40; plagioclase, 25–55; biotite or chlorite, 10; and amphibole, magnetite, sphene, apatite, and zircon in smaller amounts. One sample of the rock is radiometrically dated at 800±80 m.y. (million years), by means of the Rb-Sr method on whole rock (Zell Peterman, written commun., 1966) and at 1,450±160 m.y., by the Pb-alpha method on zircon (T. W. Stern, written commun., 1966). Zircon from an additional sample of the rock was dated, also by means of the Pb-alpha method, at 1,360 m.y.±20 percent (T.W. Stern, written commun., 1968), and, by means of the K-Ar method, biotite from that sample was dated at 56 m.y. (R. F. Marvin, H. H. Mehnert, and Violet Merritt, written commun., 1967). Recrystallization textures in the rock indicate that at the collection locality the rock was metamorphosed, presumably by the nearby Paleocene intrusives.

TRIASSIC ROCKS

MOUNT WRIGHTSON FORMATION

The name Mount Wrightson Formation is given to a sequence, at least 8,500 feet thick, of Triassic volcanic and sedimentary rocks that underlie the crest and upper part of the east flank of the Santa Rita Mountains. Mount Wrightson (fig. 1, No. 2), the highest peak in the range, is a resistant mass of rhyolitic rock that is part of the middle member of the formation. The type area of the Mount Wrightson Formation includes a stretch along the trail between Madera (fig. 1, No. 13) and Gardner (fig. 1, No. 3) Canyons where the lower and middle members are well exposed, and the north slope of Cave Creek canyon at the end of the road where the upper member is well exposed. The base of the formation is unexposed, for plutonic rocks intrude it everywhere; however, the change from a sequence of Paleozoic rocks of marine origin to a sequence of Mesozoic rocks of continental origin, such as occurs in the report area, is presumably marked by an unconformity. Likewise, the top of the Mount Wrightson is everywhere a fault contact in the Santa Rita Mountains, but in the south fork of Monkey Canyon of the northern Canelo Hills rocks of similar lithology lie beneath red beds correlated with the Gardner Canyon Formation.

The Mount Wrightson Formation is divided into three members. The lowest member, at least 1,500 feet thick, is made up largely of dacitic to andesitic rocks but also includes some rhyolitic rocks and intercalated thin lenses of quartzite and sandstone. Some of the andesitic rocks are amygdaloidal and vesicular; others are coarsely porphyritic and resemble the Tertiary rock of the Tucson area that is locally referred to as the "turkey track" andesite. In the middle member, about 5,000 feet thick, rhyolite and latite are dominant over dacitic volcanics; in addition, lenses of sandstone and quartzite are abundant, and of conglomerate, sparse. The volcanics of this member are mostly well indurated, grayish red, finely flow laminated, and finely porphyritic; some, however, are nonlaminated or spherulitic. Near the type area, flows are most common; but to the north, welded tuff is dominant over flows, and to the south, flow breccia and tuff breccia are most abundant. The upper member, at least 2,000 feet thick, contains andesitic and rhyolitic volcanics and thick bodies of eolian sandstone. The andesites include both pillow lavas and amygdaloidal flows. A zircon concentrate from a lava flow of the middle member was radiometrically dated by the Pb-alpha method as 220±30 m.y. (T. W. Stern, written commun., 1966).

GARDNER CANYON FORMATION

Triassic red beds and intercalated conglomerate, limestone, and volcanic rocks, totaling at least 1,000 feet in thickness, crop out along a major fault zone that strikes northwestward across the Santa Rita Mountains. These rocks are named the Gardner Canyon Formation for their excellent exposures along Gardner Canyon and adjacent parts of Cave Creek (fig. 1, No. 3), which are designated as the type area. The formation lies unconformably on various Permian formations, and conglomerate in the red beds contains pebbles of the Mount Wrightson Formation. In the Santa Rita Mountains the top of the formation is everywhere a fault contact, but to the southeast, in the northern Canelo Hills, it is overlain by tuffs of the lower unit of the Canelo Hills Volcanics of Triassic and Jurassic age (Hayes and others, 1965, p. M3). This contact is now believed by Raup to be an unconformity.

The Gardner Canyon Formation in its type area consists of two members. The lower member, about 200 feet thick, is a siltstone that contains lenses of well-rounded pebble conglomerate and two thin beds of limestone. Plant fragments were collected from a coaly pocket in one of the limestone beds but were unidentifiable; fossil pollen was looked for but not found. The upper member is a red mudstone that contains some beds of sandstone, conglomerate, and dacite flows and tuff, along with some small dacite bodies that probably were intruded at shallow depths. A radiometric age calculated as 192 m.y. and presented by T. W. Stern (written commun., 1965) as 190±20 m.y. was obtained for a zircon concentrate from a dacite flow.

PIPER GULCH MONZONITE

A very coarse grained dark-gray monzonite of Triassic age forms a string of bodies that lie roughly along the crest of the southern part of the Santa Rita Mountains. This rock intrudes the Mount Wrightson Formation and is intruded by the Jurassic Squaw Gulch Granite and younger plutonic rocks, in which it forms large northwest-alined inclusions and septa. The rock is named Piper Gulch Monzonite for its exposures near the jeep road in Piper Gulch, the type locality (fig. 1, No. 4), a tributary gulch to Mansfield Canyon. This monzonite seems to be unique in age and composition to this part of southeastern Arizona.

The Piper Gulch Monzonite typically has a grain size of 7–15 mm (millimeters), and it is finely myrmekitic. Its approximate modal composition, in percent, is: quartz, 1–10; orthoclase, 10–40; plagioclase, 30–55; amphibole, 2–20; pyroxene, 0–7; magnetite 3–6; and sphene, biotite, apatite, and rutile(?), all in small amounts. The plagioclase ranges in composition from calcic oligoclase to sodic labradorite. A zircon concentrate from the Piper Gulch was radiometrically dated at 184 m.y. by the Pb-alpha method (reported as 180±20 m.y., T. W. Stern, written commun., 1966).

JURASSIC ROCKS

SQUAW GULCH GRANITE

Much of the south-central part of the Santa Rita Mountains is underlain by a coarse-grained pink granite that is assigned a Jurassic age. Similar granite forms a large stock in the Patagonia Mountains and other stocks of this age appear in more distant ranges to the east. The rock of the Santa Rita Mountains is here named the Squaw Gulch Granite for Squaw Gulch. The type area lies along the middle reaches of Squaw Gulch (fig. 1, No. 5) east of the Salero mine and is accessible from the Salero road. The granite intrudes rocks as young as the Piper Gulch Monzonite and is unconformably overlain by the Temporal Formation.

The Squaw Gulch Granite is a myrmekitic and in part granophyric rock that ranges in composition from a true granite to a sodic quartz monzonite. Its modal composition, in percent, is: quartz, 25–35; orthoclase, 25–50; albite plagioclase, 10–35; accessory biotite or chlorite is sparse and magnetite, apatite, and zircon appear in trace amounts. Biotite from the rock has been radiometrically dated by the K-Ar method as 145±4 m.y. (H. H. Mehnert, R. F. Marvin, and Wayne Mountjoy, written commun., 1965) and by the Pb-alpha method, on zircon concentrates of two specimens, as 160±20 m.y. (T. W. Stern, written commun., 1965) and as 161±20 m.y. (reported as 160±20 m.y., T. W. Stern, written commun., 1964). The zircon, whose age is calculated as 160 m.y., was obtained from the same specimen that provided the datable biotite.

LOWER CRETACEOUS ROCKS

TEMPORAL FORMATION

The unit here designated the Temporal Formation is of Early Cretaceous age and crops out low along the southeast flank of the

Santa Rita Mountains. It is the lower of two sequences of volcanic and sedimentary rocks that rest on the Squaw Gulch Granite and underlie the Lower Cretaceous Bisbee Formation. The Temporal is 1,000–2,000 feet thick and overlies the Jurassic and Triassic rocks on an unconformity that shows a local rugged paleocanyon topography. The sequence is named for its excellent exposures (fig. 1, No. 6) along a readily accessible part of Temporal Gulch between the mouth of Mansfield Canyon and the ranch (fig. 1, No. 7) in Temporal Gulch. Some of the lenticular units of the formation are absent, however, from the type area. A composite section of all the lenticular units of this formation would be about 3,800 feet thick. The formation is overlain with minor unconformity by the Bathtub Formation.

The Temporal Formation consists of three members. The lowest member contains subunits of rhyolitic to andesitic tuff, welded tuffs, lava flows, arkosic fanglomerate, and polymictic conglomerate. The middle member also consists of conglomerate and rhyolitic tuff, as well as porphyritic latite flows. Locally the lowest and middle members grade laterally into a thick unit of andesite flows and volcanic breccia. The uppermost member consists of a thick wedge of boulder-and-cobble conglomerate, rhyodacite breccia, and small lenses of other volcanic rock. Zircon concentrated from a welded tuff at the base of the formation gives a radiometric age comparable with that of the underlying granite and may actually have been picked up from the weathered granite by the tuff when it flowed across the granite. The formation is assigned to the early Early Cretaceous, but it may be slightly older.

BATHTUB FORMATION

The upper of the two post-Squaw Gulch and pre-Bisbee sequences on the southeast flank of the mountains also consists of volcanic and sedimentary rocks and is 1,500–2,300 feet thick. This sequence is named the Bathtub Formation after a small natural basin called the Bathtub (fig. 1, No. 8), which is located a mile west of Adobe Canyon. Its type area lies in an unnamed valley tributary to Temporal Gulch and on the southeast flank of that valley immediately southeast of the ranch (fig. 1, No. 7) in Temporal Gulch (sec. 23, T. 21 S., R. 15 E.) and is a locality in which much of the formation is relatively accessible. The formation rests with general disconformity, but locally with slight angular unconformity, on the Temporal Formation and is unconformably overlain by the basal conglomerate of the Lower Cretaceous Bisbee Formation.

The Bathtub Formation consists of three members, each of mixed lithology. The lowest member contains mappable units of a coarse polymictic boulder conglomerate and volcanic sandstone. The middle member is a rhyolite tuff breccia in the northern part of the area and andesite flows in the southern. The uppermost member is largely dacite volcanic breccia but contains some small units of rhyolitic tuff and flows. Additional subdivisions of the members have been mapped. The formation is assigned an Early Cretaceous age, inasmuch as it lies between two units also of that age.

UPPER CRETACEOUS ROCKS

FORT CRITTENDEN FORMATION

A sequence of fossiliferous black shale, sandstone, and conglomerate in the Adobe Canyon area low on the east flank of the Santa Rita Mountains was originally described by Stoyanow (1949) as the Fort Crittenden Formation. This formation, along with an underlying Fort Buchanan Formation, comprised his Sonoita Group. The Fort Buchanan Formation is now recognized by me to be the upper part of the Bisbee Formation; a subtle angular unconformity separates those rocks of late Early Cretaceous age from the overlying ones of late Late Cretaceous age. Consequently, I propose that the names Sonoita Group and Fort Buchanan Formation be dropped from stratigraphic nomenclature; the name Fort Crittenden Formation is retained but is here revised to include not only the 1,000-foot sequence originally described but also the overlying sequence, about 3,500 feet thick, of conglomerate, sandstone, and siltstone. A composite stratigraphic section of the revised formation that lies roughly between El Pilar Tank (fig. 1, No. 9) in Adobe Canyon (SE¼NW¼ sec. 24, T. 20 S., R. 15 E., unsurveyed) and triangulation marker YOUNG, VABM 5510, on the east side of Hog Canyon (fig. 1, No. 10), is here designated the reference section. The revised formation, then, rests unconformably on the Bisbee and, on the west flank of the mountains where it has now also been recognized, it lies with probable conformity beneath the Salero Formation.

The Fort Crittenden Formation consists of five members, four of which are sedimentary rocks and one of which is a lens of volcanic rocks intercalated high in the sedimentary sequence. At the base is a shale member which contains, in subordinate amount to the shale, a thin lenticular basal conglomerate and a medial pelecypod-bearing siltstone unit, essentially unit 3 of Stoyanow

(1949, p. 60). A lower red conglomerate member overlies the shale and contains some thin beds of red siltstone. This is overlain by, and locally interfingers with, a brown conglomerate member, which contains some thin units of brown sandstone and red conglomerate and siltstone. The highest member is an upper red conglomerate member; it contains only a few brown beds and is distinguished by the presence of clasts much coarser and more angular than those of the lower red conglomerate member. A tuff member forms a thick sheet in the upper red conglomerate on the west flank of the mountains, and it appears as thin marker beds near the base of that member and near the top of the brown conglomerate member on the east flank of the mountains. The fauna of the shale member, described by Stoyanow (1949), Miller (1964 and 1966), and H. W. Miller, Jr., and K. W. Schwab (written commun., 1967), is of late Late Cretaceous age.

SALERO FORMATION

Another sequence of Upper Cretaceous volcanic and sedimentary rocks that have a composite maximum thickness of about 5,000 feet crops out in much of the southwestern part of the Santa Rita Mountains and in some parts of the northern end. Only parts of this sequence crop out in any one area because the rocks lie subhorizontally and the relief is only moderate. The rocks are named the Salero Formation for the Salero ranch and mine (fig. 1, No. 11), near which three of the five members are fairly accessible. This locality serves as type area and is reached by the Salero road. Locally the formation rests conformably on the Fort Crittenden Formation, and over extensive areas it lies unconformably on the Squaw Gulch Granite; it is intruded by several plutons of latest Cretaceous age.

Four of the members of the Salero Formation form a vertical sequence and the other is a strongly developed lateral facies. The lowest member consists of dacitic flows and a little tuff breccia. This is overlain by an exotic block member, consisting of a dacitic volcanic flow breccia that contains a great many blocks, as much as 1,000 feet long, of assorted Jurassic and older rocks. A welded tuff member of rhyodacitic composition overlies the exotic block member, probably with minor unconformity. The arkose member consists of arkosic fanglomerate, conglomerate, sandstone, and tuff. It forms a lateral facies, largely equivalent to the welded tuff member but also in part to slightly older and younger rocks. It lies between the welded tuff and the Squaw Gulch Granite, which it overlies unconformably. The uppermost member is of mixed volcanic and sedimentary rocks, including much tuffaceous sandstone, tuff breccia, agglomerate, and conglomerate, and some quartzite and red beds. Biotite from the welded tuff has been radiometrically dated by the K-Ar method as 72.5±2.2 m.y. (H. H. Mehnert, R. F. Marvin, and Wayne Mountjoy, written commun., 1965).

JOSEPHINE CANYON DIORITE

The largest body of Upper Cretaceous plutonic rock is a diorite that extends from Madera Canyon (fig. 1, No. 13) south to the flank of the Patagonia Mountains and reappears in the structural block of the San Cayetano Mountains. The diorite is extensively exposed along the upper reaches of Josephine Canyon, for which it is here named and which serves as its type area (fig. 1, No. 12). The terrain underlain by the diorite is gently rolling to moderately steep and is covered with dark-brown soil typically containing residual rounded blocks 4–8 inches across.

The rock intrudes formations as young as the Salero; it is probably intruded by the other large plutons of Late Cretaceous age and is cut by dikes of Paleocene(?) age and by other dikes and a pluton of late(?) Oligocene age. It is unconformably overlain by the Gringo Gulch Volcanics of Paleocene(?) age.

The Josephine Canyon Diorite is a dark-gray moderately coarse grained subophitic rock ranging in composition from diorite to quartz diorite and to some granodiorite. It also contains a separately mapped late phase of fine-grained quartz monzonite. The approximate modal composition of the diorite, in percent, is: quartz, 3–15 (to 25 in late phase); orthoclase, 5–25; labradorite plagioclase, 35–65; hornblende, 5–18; biotite, 2–18; and pyroxene, 0–3; and accessory magnetite, sphene, apatite, and zircon. The diorite is more intensely chloritized than the other Laramide plutonic rocks. Biotite concentrated from the diorite is dated, by means of the K-Ar method, as 67.1 m.y. (S. C. Creasey, written commun., 1964). Zircon from the diorite is dated by the Pb-alpha method as 63.0 m.y. (reported as 60±10 m.y., T. W. Stern, written commun., 1964) and from the quartz monzonite phase, also by the Pb-alpha method, as 61.3 m.y. (reported as 60±20 m.y., T. W. Stern, written commun., 1965).

MADERA CANYON GRANODIORITE

Much of the north-central part of the Santa Rita Mountains is underlain by a large stock of granodiorite of Late Cretaceous age. This rock is named the Madera Canyon Granodiorite for its exposures along Madera Canyon, the lower reaches of which serve as type area (fig. 1, No. 13). The granodiorite locally cuts the Josephine Canyon Diorite and is cut by the upper(?) Oligocene rhyolite porphyry dikes; its relations to the Elephant Head Quartz Monzonite are unclear.

The Madera Canyon Granodiorite is mapped as a light-gray or main phase, a dark-gray melanocratic phase, and a porphyritic phase. The modal composition of the main and porphyritic phases, in percent, is about: quartz, 18; orthoclase, 25; plagioclase, 44; hornblende, 5; and biotite, 5. Sphene, magnetite, apatite, and zircon are the accessory minerals. The dark minerals of the melanocratic phase make up 15–20 percent of the rock and commonly are clustered; the quartz content is only about 10 percent. Phenocrysts in the porphyritic phase are as much as 5 cm (centimeters) long and make up 1–5 percent of the rock. They are typically smaller than the porphyroblasts in the Continental Granodiorite. The rock is very little altered. Biotite from rock here identified as the main phase was dated by the K-Ar method as 67.9±2.1 m.y. (P. E. Damon, written commun., 1964).

ELEPHANT HEAD QUARTZ MONZONITE

The youngest rock of the large stocks of Late Cretaceous age is a coarse-grained quartz monzonite that forms much of the west-central part of the Santa Rita Mountains. The rock is here named for the prominent knob of that name, on whose flanks it is typically exposed (fig. 1, No. 14); this area is designated as the type area. Much of the terrain underlain by this rock forms rugged knobs, serrate ridges, and deep narrow canyons, but some of it is gentler and is veneered with grus. The formation probably cuts the diorite pluton and is intruded by the upper(?) Oligocene rhyolite porphyry dikes.

The Elephant Head Quartz Monzonite forms two stocks; a smaller stock at Elephant Head intrudes the larger one to the east. A quartz monzonite mass northeast of Madera Canyon may be either a separate pluton or a cupola of the larger stock. A fine-grained phase of the larger stock lies along parts of its flanks and intrudes its core. The modal composition of the rock, in percent, is roughly: quartz, 22; orthoclase, 27; plagioclase, 45; biotite and amphibole, each 2; magnetite, 1; and traces of apatite, sphene, zircon, and allanite. Two K-Ar radiometric ages on biotite of the main stock are 68.2±2.4 m.y. (R. F. Marvin, H. H. Mehnert, and Wayne Mountjoy, written commun., 1965) and 69.0±2.1 m.y. (Marvin, Mehnert, and Violet Merritt, written commun., 1967). A Pb-alpha age on zircon concentrated from the same rock whose biotite is 69 m.y. old is dated as 188 m.y. (reported as 190 m.y. ±20 percent by T. W. Stern, written commun., 1968). A zircon counterpart of the other biotite concentrate is being dated. The apparently anomalous zircon age may suggest that this quartz monzonite was initially the Jurassic Squaw Gulch Granite, which was completely recrystallized during the Late Cretaceous. Chemical and petrographic data permit, but do not require, such a geologic history.

PALEOCENE(?) ROCKS

GRINGO GULCH VOLCANICS

A sequence largely of rhyolitic to dacitic volcanic rocks 1,500–2,000 feet thick underlies the southeastern part of the Santa Rita Mountains and extends into the Patagonia Mountains to the south and east. It also contains a little sedimentary rock derived mainly from the volcanics. This sequence is named the Gringo Gulch Volcanics for its type area along Gringo Gulch (fig. 1, No. 15), 2–3 miles north-northwest of Patagonia ($E\frac{1}{2}W\frac{1}{2}$ sec. 25, T. 21 S., R. 15 E.). The volcanics unconformably overlie rocks as young as the Josephine Canyon Diorite and are intruded by upper(?) Oligocene rhyolite porphyry dikes, Eocene(?) quartz veins, and possibly also by a hornblende dacite porphyry of late Laramide (Paleocene) age.

The Gringo Gulch Volcanics consist of two members. The lower member contains much dacitic lava, dacitic sandstone, and conglomerate, and a little rhyolite lava and tuff, overlain by a very pale orange tuff, an indurated tuff, and a locally welded tuff. A thin but conspicuous bluish-gray welded to nonwelded tuff forms the base of the upper member and is overlain successively by light-colored tuff, tuffaceous sandstone, and a capping andesitic flow. No minerals suitable for radiometric dating were found because the rocks are slightly altered. Inasmuch as the formation postdates upper Upper Cretaceous intrusives and predates some or all of the middle and lower Tertiary intrusives, it is assigned to the Paleocene(?).

UPPER(?) OLIGOCENE ROCKS

GROSVENOR HILLS VOLCANICS

Vitric volcanics are exposed in an extensive area on the southwest flank of the Santa Rita Mountains and in the Grosvenor Hills, where they are about 2,000 feet thick. They are here named the Grosvenor Hills Volcanics and their type area is designated as the basins of the uppermost parts of Coal Mine and Cinigita Canyons (fig. 1, No. 16). On the southwest flank of the basins a relatively complete and little-faulted section underlies the northeast spur of the highest peak (5,469-ft altitude) in the hills. The formation lies unconformably on Cretaceous and older rocks, is unconformably overlain by the gravels of Nogales, and is intruded by rhyodacite dikes and laccoliths. These intrusive rocks are genetically associated with the Grosvenor Hills Volcanics and are roughly coeval with them.

The Grosvenor Hills Volcanics consist of a basal gravel and silt member, a rhyolite member, and a capping rhyodacite member. The basal beds are very lenticular, are rarely more than 100 feet thick, and are made up of poorly consolidated pale-red silt containing stringers of well-rounded small pebbles. The rhyolite member is dominantly tuff and tuffaceous sandstone, but it also contains some small pinkish-gray lava flows. The rhyodacite member is complex, containing several vitrophyre flows, agglomerate sheets, and both welded and nonwelded tuff. Fossil pine wood and pine pollen have been reported from the formation by Damon and Miller (1963) and by E. B. Leopold (written commun., 1964) but indicate only a Cretaceous or Cenozoic age. Biotite from a rhyodacite laccolith intruding the formation, however, is radiometrically dated by the K-Ar method as 26.0 m.y., and hornblende from a second laccolith is dated by that method as 27.3 m.y. (S. C. Creasey, written commun., 1964). Zircon from the second laccolith is also dated as 40 ± 10 m.y. (T. W. Stern, written commun., 1964); this age determination is considered less reliable than the other dates in this young time range. The combined evidence, then, suggests that the formation is late(?) Oligocene.

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