Lower Mesozoic Extrusive Rocks in Southeastern Arizona—the Canelo Hills Volcanics

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CONTRIBUTIONS TO STRATIGRAPHY

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By PHILIP T. HAYES, FRANK S. SIMONS, and ROBERT B. RAUP

ABSTRACT

The name Canelo Hills Volcanics is here given to rocks extensively exposed in southeastern Arizona. The formation includes thick units of rhyolitic lavas and tuffs and subordinate sedimentary rocks and is assigned to the Triassic and Jurassic. Other volcanic units of southern Arizona, previously thought to be younger, may also be of early Mesozoic age.

INTRODUCTION

A thick sequence of rhyolitic tuffs and lavas and interbedded volcanic sediments of early Mesozoic age has been identified by the writers in the Canelo Hills and nearby areas in eastern Santa Cruz and southwestern Cochise Counties, Ariz. This sequence of rocks is herein named the Canelo Hills Volcanics. The only other volcanic rocks of this age previously reported in southeastern Arizona—the Walnut Gap Volcanics—are poorly exposed in a few small outcrop areas in the Gunnison, Johnny Lyon, and Red Bird Hills, about 55 miles to the northeast (Cooper, 1959, 1960; Cooper and Silver, 1964). Volcanic rocks of possible Triassic or Jurassic age were mapped by Gilluly (1956, p. 68–69) near South Pass in the Dragoon Mountains, about 40 miles to the northeast, but local geologic relations do not permit definite dating of those rocks. Fieldwork of Simons in the Patagonia Mountains, 10 miles to the southwest, and of Harald Drewes (U.S. Geol. Survey, 1963, p. A92) near Mount Wrightson in the Santa Rita Mountains, about 15 miles to the northwest, indicates that thick sequences of post-Paleozoic and pre-Cretaceous volcanic rocks are present in those ranges. Elsewhere in southeastern Arizona, Sabins (1957, p. 506) and Gilluly (1956, p. 67) noted volcanic frag-

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ments in the basal conglomerate (Glance Conglomerate and equivalents) of the Lower Cretaceous Bisbee Group. These occurrences suggest that post-Paleozoic and pre-Cretaceous volcanic rocks once may have been widely distributed in southeastern Arizona. The sequence exposed in the southern Canelo Hills is the first yet discovered that can be dated with certainty on geologic evidence as younger than Early Permian and older than Early Cretaceous.

CANELO HILLS VOLCANICS

The Canelo Hills Volcanics is named for its exposures in the Canelo Hills (fig. 1), its type area. The formation is subdivided for descriptive purposes into three thick units: basal interbedded volcanic and sedimentary rocks, rhyolitic lavas, and an upper welded tuff. All three units, however, are not everywhere present.

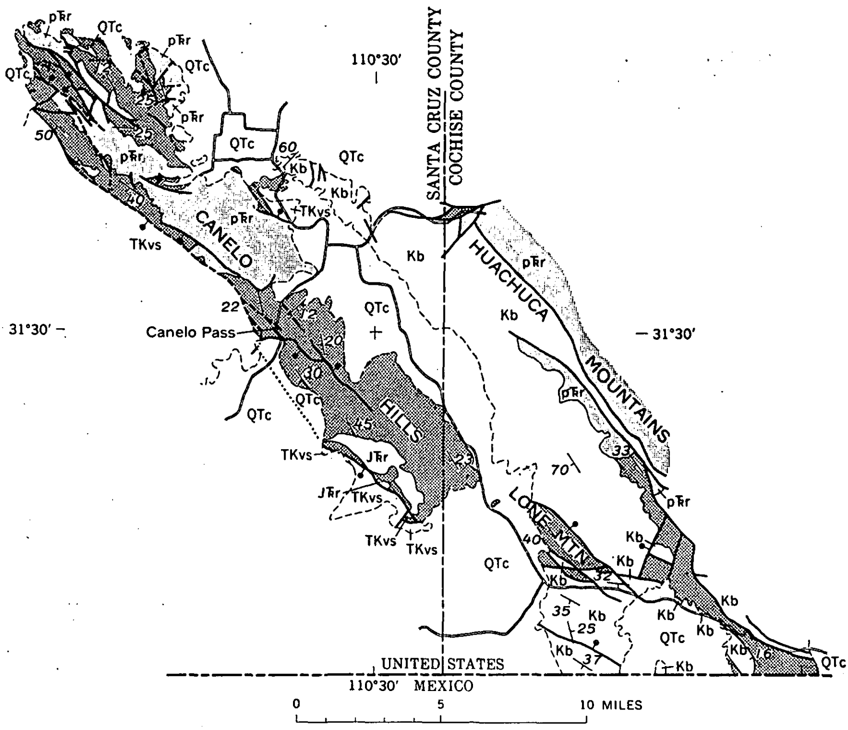

FIGURE 1.—Geology of Canelo Hills and vicinity. QTc—conglomerate, gravel, and alluvium (Quaternary and upper Tertiary); TKvs—post-Bisbee volcanic and sedimentary rocks (lower to middle Tertiary and Cretaceous); Kb—Bisbee Group (Lower Cretaceous); JTr, rhyolite porphyry (Jurassic and Triassic); stipple pattern—Canelo Hills Volcanics (Jurassic and Triassic); and pTr, pre-Canelo Hills Volcanics (mostly Paleozoic).

BASAL INTERBEDDED VOLCANIC AND SEDIMENTARY ROCKS

The basal unit is present at many places in the northern Canelo Hills, where it rests with marked unconformity on Paleozoic carbonate rocks and is as much as 2,000 feet thick. The lowest part of the unit shows much lateral variation. In the northernmost Canelo Hills, red beds such as those described by Feth (1948) as Canelo Redbeds, minor conglomerate, and sandstone are dominant at the base; southward, clastic rocks are subordinate and interbedded thin silicic flows and tuffs are dominant; and near Canelo Pass, thick limestone conglomerate overlies the Paleozoic rocks. Interlayered thin beds of volcanic and sedimentary rocks are typical of the upper part of the unit.

South of Canelo Pass the best exposures of rocks tentatively assigned to the basal unit are on the southwest side of Lone Mountain where nearly 2,000 feet of beds is exposed, apparently bounded on all sides by faults. Clastic sedimentary rocks probably make up more remainder. Sandstone is dominant, but conglomerate, siltstone, and than half of the basal unit, silicic tuffs and lavas constituting the shale are also present.

Volcanic rocks in the basal unit are rhyolitic to latitic in composition and consist of both pyroclastic and flow rocks. Tuffs, some weakly welded, are dominant. The lavas are porphyritic and most show poorly defined flow structure. The lavas are pale red to moderate red, and the tuffs are pinkish gray to moderate red. Conglomerate is made up of subangular to rounded fragments as much as several inches across of limestone, quartzite, and silicic volcanic rocks in a poorly sorted reddish-brown matrix. Some of the conglomerates are monolithologic. Sandstones are pale red to reddish brown and are generally tuffaceous. The siltstone and shale range from pale red to moderate red or reddish brown.

A striking feature of the basal unit is the presence of scattered exotic blocks of highly brecciated Paleozoic limestone as much as several thousand feet long. We regard these as ancient landslide blocks.

RHYOLITIC LAVAS

The rhyolitic lava unit crops out extensively along the northeast side of the southern Canelo Hills. Smaller outcrop areas are along the crest of the Canelo Hills, on Lone Mountain, and in the southeast part of the Huachuca Mountains. The greatest exposed thickness is on the northeast side of the Canelo Hills, about 5 miles east-southeast of Canelo Pass, where more than 1,000 feet is present.

The base of the unit is not exposed except possibly a short distance west of Canelo Pass and at the north end of Lone Mountain (fig. 1). At those places, the lava flows rest on Paleozoic limestone, outcrops of which are too small to be shown at the scale of figure 1. This limestone may have been bedrock of an area in which the basal unit of the Canelo Hills Volcanics was not deposited, but more likely it makes up large exotic blocks enclosed in lava. The lavas are overlain by welded tuff.

The lavas are sparsely porphyritic rocks that range from mainly pale to moderate red to grayish red and light gray. They characteristically display highly contorted flow layering and tend to split easily along the layers. Many flows were strongly brecciated. Gray spherulites a few centimenters in diameter and lithophysae as much as 1 foot across are abundant in some flows. Although probably more than 95 percent of the lava unit is made up of lava flows, it does contain a few tuff beds. Locally, red welded tuff similar to that in the overlying tuff unit seems to be interlayered with the lava flows.

All the lavas contain scattered phenocrysts of cloudy sanidine 1–2 mm across, and some also have sparse phenocrysts of quartz, sodic plagioclase, and(or) altered biotite. Phenocrysts make up less, ordinarily much less, than 10 percent of the rocks. The groundmass in all thin sections examined is patchily devitrified glass, usually spherulitic, and shows contorted flow layering.

WELDED TUFF

The upper unit of welded tuff makes up most of the southern Canelo Hills and also crops out extensively at the north end of the Canelo Hills, on and near Lone Mountain, and in several large areas in the southern part of the Huachuca Mountains. The greatest apparent thickness is along a southwest-trending section on the southwest side of the Canelo Hills about 4 miles southeast of Canelo Pass, where a thickness of about 6,400 feet is indicated without either base or top being exposed.

The welded tuff rests with apparent conformity on the rhyolitic lavas where they are present. Elsewhere, as in the Huachuca Mountains and northern Canelo Hills, the tuff lies unconformably on volcanic rocks of the lower unit or on Paleozoic formations. The tuff is unconformably overlain by various younger formations. The oldest rock overlying the tuff is conglomerate at the base of the Bisbee Group of Early Cretaceous age. This contact is well exposed at the south end of Lone Mountain near the center of sec. 36, T. 23 S., R. 19 E., and about 2 miles to the east in the Huachuca Mountains.

The welded tuff sequence in the northern Canelo Hills crops out no closer than about 5 miles from the dated tuff south of Canelo Pass. Correlation of these tuff sequences is based on similarities in their textural features, mineralogy, and geologic relations. The northern sequence is dominantly welded tuff, but unlike the southern sequence, it comprises several cooling units commonly separated by less welded ash beds and very thin flows. Lithic fragments in the tuffs tend to be more common in the northern sequence.

The welded tuff is a porphyritic rock ranging from moderate to grayish red to pale red or grayish pink. It invariably contains conspicuous 1- to 3-mm phenocrysts of clear quartz, pink to white feldspar, pumice lapilli, and lithic fragments. In many places the fragmental character of the rock is clear, and the attitude is indicated by pumice lentils; elsewhere, the tuff is so massive that it is almost unrecognizable as a layered rock.

The welded tuff is commonly separated from the underlying silicic lavas by light-gray and greenish-gray nonwelded tuff as much as 30 feet thick. In some places the nonwelded tuff is missing and in its place is a breccia composed of closely packed fragments of silicic lava as much as 6 inches across in a sparse sandy matrix of quartz, feldspar, and glass. Locally, the welded tuff may rest directly on lava. In one small area the tuff is welded to the underlying lava as if the tuff were very hot or the lava were still hot when the tuff was deposited. The dark vitrophyre zone so commonly found near the base of welded tuff cooling units is absent; this zone, if it ever existed, is unrecognizable now owing to devitrification.

Excellent exposures of the lower few hundred feet of welded tuff show a gradual change upward from soft, rather porous, and nonwelded tuff to hard and densely welded tuff, and an accompanying change in color from light greenish gray to grayish red. In thin section the densely welded tuff consists of euhedral crystals, embayed grains, and fragments of quartz and cloudy perthitic potassium feldspar 0.5–3 mm across, together with sparse much-altered biotite and lithic fragments, in a matrix of completely devitrified bent and compacted glass shards and highly flattened axiolitic pumice lentils.

Modal analyses of 14 samples of welded tuff from various places in and near the southern Canelo Hills gave the following results, in percent.

	Range	Average
Quartz	4.7–15.3	10.4
Potassium feldspar	9.9–33.5	14.6
Other minerals (biotite, iron ore)	.0– 8.1	1.6
Lithic fragments	.0– 3.5	.7
Groundmass	52.5–80.0	72.7
Total		100.0

Chemical analyses of densely welded tuff, together with Nockolds' (1954) average alkali rhyolite, are as follows:

	1	2		1	2
SiO_2	78.1	74.57	H_2O-	.19	-----
Al_2O_3	11	12.58	H_2O+	1	.66
Fe_2O_3	.75	1.3	TiO_2	.15	.17
FeO	.08	1.02	P_2O_5	0	.07
MgO	.2	.11	MnO	.04	.05
CaO	.07	.61	CO_2	<.05	-----
Na_2O	.92	4.13			
K_2O	7.4	4.73	Total	99.9	

NOTE.—Powder density, air pycnometer, 2.58.

1. Rhyolite welded tuff, center N½ sec. 34, T. 22 S., R. 18 E., Lochiel quadrangle, Arizona. Lab. No. 159243. Rapid rock analysis by P. L. D. Elmore, S. D. Botts, and G. W. Chloe, U.S. Geol. Survey.
2. Average alkali rhyolite plus rhyolite-obsidian (Nockolds, 1954, p. 1012, table 1, col. 4).

The fine-grained devitrified groundmass of the tuff obviously has approximately the composition of a mixture of slightly sodic potassium feldspar and quartz. The very small amounts of CaO and Na_2O are notable; rocks of such composition (CIPW class 1, order 3, rang 1, subrang 2) are represented in Washington (1917, p. 56–59) by only 10 analyses of rhyolites, 2 of pitchstones, and 1 of felsite.

RHYOLITE PORPHYRY

An irregular body of rhyolite porphyry intrudes the welded tuff unit on the southwest side of the Canelo Hills but is probably only slightly younger and may have come from the same magma chamber; the two rocks are certainly similar in composition. Fragments of the porphyry are locally present in the basal conglomerate of the Bisbee Group; so, the porphyry is older than the Bisbee, and probably pre-Cretaceous in age.

The contact between the tuff and the porphyry, although exposed in only a few places, seems to be roughly parallel to the strike of the tuff. Wherever exposed, the contact is frozen and the texture of the intrusive rock is porphyritic right to the contact, although the groundmass is slightly finer grained at contacts than elsewhere. In a few places the rhyolite porphyry shows vague flow layering within a few inches of a contact, but in general it has no apparent linear or planar structures. At one locality the porphyry near the contact is sheared and brecciated as if some movement had occurred during or slightly after consolidation.

The porphyry is a uniform rock composed of conspicuous phenocrysts as much as 5 mm across of quartz and pale-red to white feldspar set in a pale-red very fine grained to aplitic groundmass. In thin section, subhedral and embayed grains of quartz and very dusty phenocrysts of perthitic sanidine are enclosed in a fine-grained intergrowth of dusty potassium feldspar, quartz, and a little iron ore and much altered biotite(?). Modal analyses of three specimens gave the following results, in percent.

	Range	Average
Quartz	4.0– 8.1	6.5
Sanidine	21.2–26.5	23.2
Groundmass	68.7–70.7	69.8
Other	.3– .7	.5
Total	------------	100.0

The only contact metamorphic effect of the rhyolite porphyry on the welded tuff wallrock seems to have been the nearly complete destruction of shard outlines and eutaxitic texture, which elsewhere are generally recognizable even after thorough devitrification.

AGE OF CANELO HILLS VOLCANICS

The Canelo Hills Volcanics can be dated, on geologic evidence, as younger than Early Permian and older than Early Cretaceous. The formation unconformably overlies Lower Permian formations, and in several localities, large masses of Permian rock are included as exotic blocks in the lower two units of the Canelo Hills Volcanics. The earlier mentioned occurrences of the basal conglomerate of the Bisbee Group unconformably overlying the welded tuff unit indicate that the Canelo Hills Volcanics is probably of pre-Cretaceous age. The formation is here considered as Triassic and Jurassic.

This early Mesozoic age assignment for the Canelo Hills Volcanics is substantiated by a potassium-argon isotope age determination of biotite from the welded tuff unit 2 miles southeast of Canelo Pass in the northwest corner of the SE¼ sec. 29, T. 22 S., R. 18 E. The age, determined by S. C. Creasey of the U.S. Geological Survey (written commun., 1963), is 173±7 million years; thus, the welded tuff unit is probably Late Triassic or Early Jurassic in age.

REGIONAL CONSIDERATIONS

Although, as stated, certain volcanic units in southeastern Arizona have been assigned a tentative early Mesozoic age, and although volcanic detritus has been identified in the lowest Lower Cretaceous conglomerates, heretofore there has been no conclusive evidence for an early Mesozoic age assignment for volcanic rocks in the region. It seems possible, if not probable, that some of the volcanic rock units assigned a Late Cretaceous or early Tertiary age elsewhere in southern Arizona are early Mesozoic. Some previous ideas on structural relations might warrant reappraisal.

Volcanic rocks of Late Permian, Triassic, and Jurassic age are present at many places in the far Western United States (fig. 2). The nearest of these to southeastern Arizona is, to our knowledge, a few miles east of Soda Lake in San Bernardino County, Calif., about 400 miles northwest of the Canelo Hills. The Canelo Hills Volcanics and possible equivalent rocks elsewhere in southern Arizona may be the sources postulated by Stewart, Williams, Albee, and Raup (1959, p. 523) and Cadigan (1963) for volcanic detritus in the Upper Triassic Chinle Formation of northeastern Arizona.

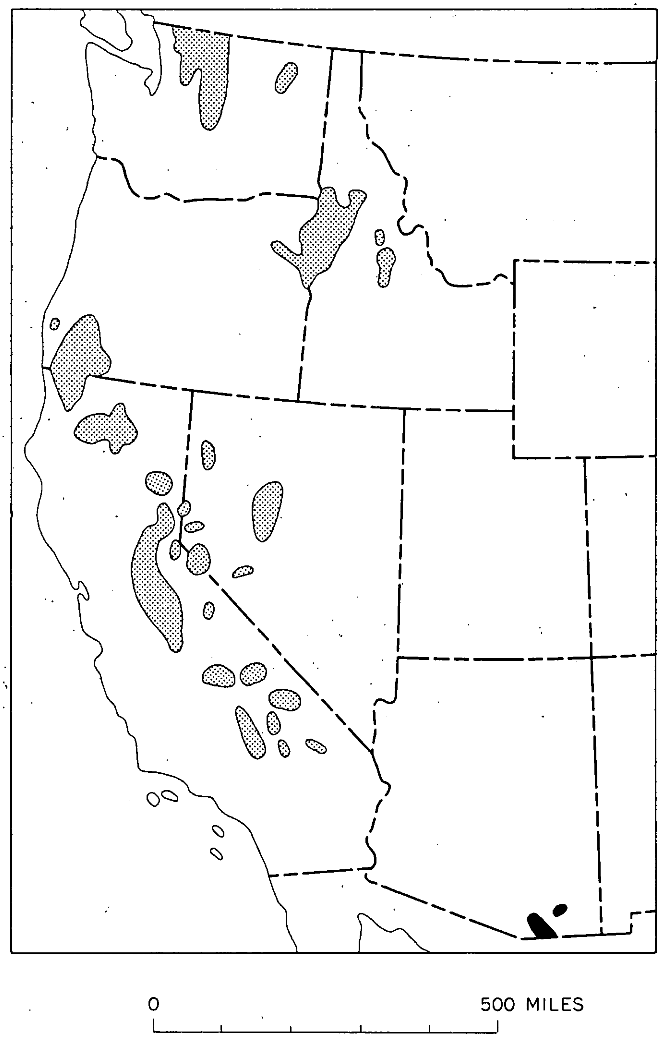

FIGURE 2.—Previously known distribution in Western United States of volcanic rocks of Late Permian, Triassic, and Jurassic age (stippled), and areas underlain by Canelo Hills (larger solid black area) and Walnut Gap (smaller solid black area) Volcanics in southeastern Arizona. Previously known areas from McKee and others (1956, 1959) and Gilluly (1963).

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