DAVID BLOOM

Correlation of the Peach Springs Tuff, a large-volume Miocene ignimbrite sheet in California and Arizona

Allen F. Glazner
U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025
and Department of Geology, University of North Carolina, Chapel Hill, North Carolina 27514

Jane E. Nielson, Keith A. Howard, David M. Miller
U.S. Geological Survey, 345 Middlefield Road, Menlo Park, California 94025

ABSTRACT

The Peach Springs Tuff is a distinctive early Miocene ignimbrite deposit that was first recognized in western Arizona. Recent field studies and phenocryst analyses indicate that adjacent outcrops of similar tuff in the central and easten Mojave Desert may be correlative. This proposed correlation implies that outcrops of the tuff are scattered over an area of at least 35 000 km^2 from the western Colorado Plateau to Barstow, California, and that the erupted volume, allowing for posteruption crustal extension, was at least several hundred cubic kilometres. Thus, the Peach Springs Tuff may be a regional stratigraphic marker, useful for determining regional paleogeography and the time and extent of Tertiary crustal extension.

INTRODUCTION

A single welded rhyolite tuff containing conspicuous chatoyant sanidine phenocrysts occurs in the Tertiary section in many mountain ranges in western Arizona and the Mojave Desert. Here we offer evidence that these scattered outcrops represent part of a single enormous early Miocene outflow sheet. Because we have been unable to find any significant petrographic, field, or chemical differences between these outcrops, the descriptions below pertain to all the outcrops in our proposed correlation.

The tuff is exposed discontinuously in a region stretching from Barstow, California, to the Colorado Plateau at Peach Springs, Arizona (Fig. 1). In most ranges it is the only welded tuff in the Tertiary section. The tuff was originally recognized over an area of about 5200 km^2 between Kingman and Peach Springs, where it was named (Young, 1966; Young and Brennan, 1974; Goff et al., 1983). Recent mapping in the Colorado River trough region extended the correlation westward into tilted Miocene sections on both sides of the Colorado River (W. J. Carr's mapping compiled by Stone and Howard, 1979; Carr et al., 1980; Dickey et al., 1980; Carr and Dickey, 1980; Suneson, 1980; Carr, 1981; Young, 1981; Howard et al., 1982; John, 1982; Pike and Hansen, 1982; Nielson-Pike, 1984).

Petrographically identical tuff occurs in most of the ranges of the central Mojave Desert. Durrell (1953) mapped chatoyant sanidine tuff near celestite deposits in the southeastern Cady Mountains. Bassett and Kupfer (1964) mapped outcrops of chatoyant sanidine tuff in the Bristol Mountains, Old Dad Mountains, Cady Mountains, and Bullion Mountains. They noted the lithologic similarities between the outcrops and suggested that they might be correlative. T. W. Dibblee, Jr. and A. M. Bassett mapped similar tuffs as unit QTr in the Bristol Mountains and Bullion Mountains, as unit Trt in the Cady Mountains, and as unit Tst in the Newberry Mountains (Kane Wash) and on Daggett Ridge (Dibblee, 1964a, 1964b, 1966, 1967a, 1967b, 1970; Dibblee and Bassett, 1966). Our recent mapping and reconnaissance in the Bristol Mountains, Cady Mountains, Marble Mountains, and Ship Mountains (Miller and Glazner, unpub. data) indicate that these units represent part of the same extensive tuff. Additional mapping in the Providence Mountains area (Goldfarb et al., 1986) and New York Mountains (Miller et al., 1986) has resulted in discoveries of similar tuff.

Correlation of the tuff would make it an exceptionally valuable stratigraphic and tectonic marker horizon because of (1) its presence in otherwise difficult-to-correlate local stratigraphic sections, (2) its deposition during a time of regional extension, and (3) its wide geographic distribution across Neogene tectonic-province boundaries.

PETROGRAPHIC AND FIELD ASPECTS OF THE TUFF OUTCROPS

The tuff is characterized by abundant large (up to 5 mm) and clear sanidine phenocrysts that commonly exhibit blue chatoyance. Sanidine makes up 70–90 vol% of the phenocryst assemblage; subequal amounts of plagioclase, biotite, hornblende, and sphene compose the remainder. Quartz is rare. Phenocrysts compose 10–20 vol% of the total rock. Lithic clasts are as large as 10 cm or more and are generally locally derived.

In outcrop, the tuff is generally strongly to moderately welded, although weakly welded facies are locally present, especially at the edges of the known distribution. Two cliffs of Peach Springs Tuff are exposed in roadcuts along U.S. Interstate 40 at Kingman. Buesch and Valentine (1986) ascribed these cliffs to variations in the degrees of welding and vapor-phase crystallization within a single cooling unit. We have not found multiple cooling units in our studies of proposed equivalent tuffs in California.

In some localities in the central Mojave Desert, the unit contains a black vitrophyre layer

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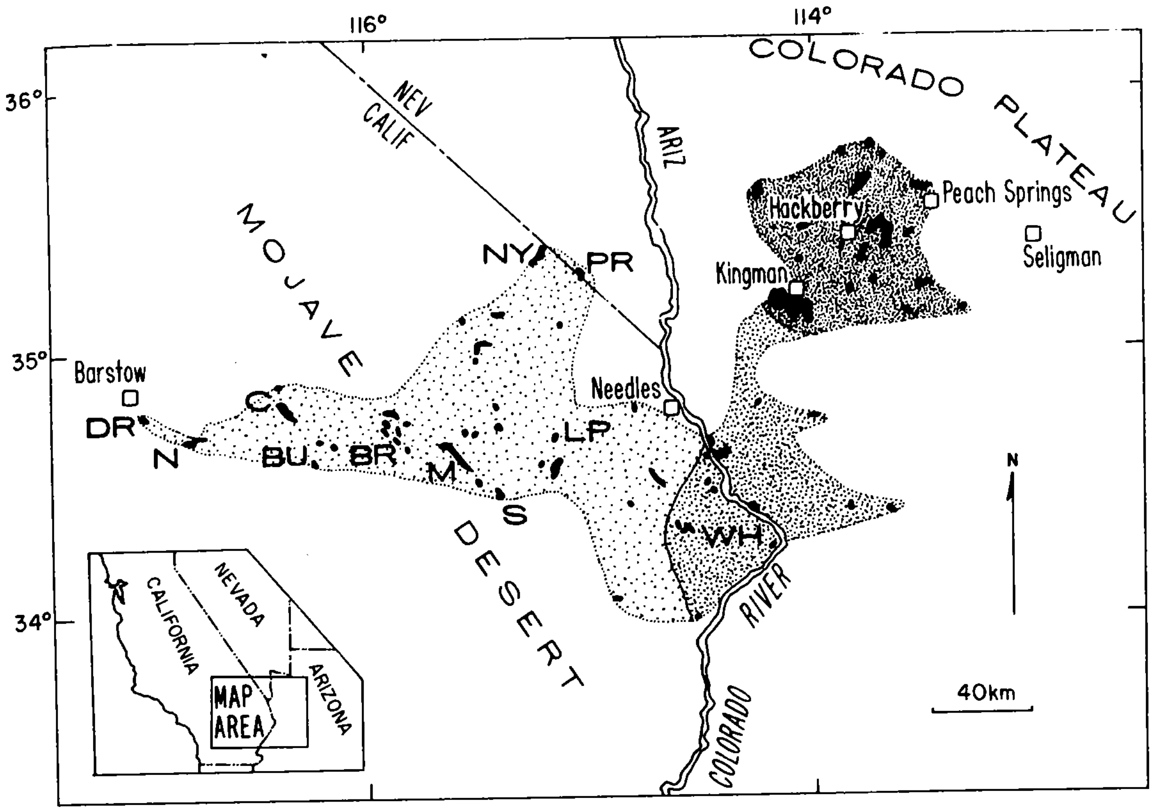

Figure 1. Outcrops (black) and known distribution (stipple) of Peach Springs Tuff and proposed equivalents. Young (1966) and Young and Brennan (1974) originally defined tuff in region between Kingman and Peach Springs (heavy stipple). W. J. Carr and coworkers and Young (1981) extended distributions to ranges bordering both sides of Colorado River (medium stipple). We propose to extend correlation from Colorado River westward to Barstow (light stipple). BR = Bristol Mountains, BU = Bullion Mountains, C = Cady Mountains, DR = Daggett Ridge, LP = Little Piute Mountains, M = Marble Mountains, N = Newberry Mountains, NY = New York Mountains, PR = Piute Range, S = Ship Mountains, WH = Whipple Mountains.

(about 1 m thick) that occurs several metres above the base and that has the same mineralogy as the main welded tuff, including chatoyant sanidine. Buesch and Valentine's (1986) studies of Peach Springs Tuff in the Kingman area have shown that vitrophyre there occurs within the densely welded zone. Buesch and Valentine (1986) also found that at Kingman, vitrophyre occurs in the "edge facies" and is absent from the "open-valley facies" of the Peach Springs Tuff. These observations indicate the extent of paleotopographic control on deposition and welding of the tuff. Color of the tuff is highly variable and includes buff, chocolate brown, salmon pink, gray, and bluish gray, depending on the degree of welding, alteration, and desert varnish. Pumice clasts are generally gray and are not glassy black in densely welded tuffs.

In the region between the Colorado Plateau and the central Mojave Desert (Fig. 1), the tuff is present locally in every range where the appropriate part of the stratigraphic column is exposed. The thickness of the tuff is highly variable, presumably because of a topographically irregular substrate (as can be seen at Kingman) and postdepositional erosion. In general, however, maximum thicknesses increase from distal exposures toward the Colorado River trough. Our observations and published measurements (Young and Brennan, 1974; Buesch and Valentine, 1986; Knoll et al., 1986) indicate that maximum thickness of the tuff increases from 10–15 m in distal exposures (Barstow; Peach Springs) to 65–85 m at Kingman and 130 m in the Little Piute Mountains.

PROPOSED CORRELATION

On the basis of stratigraphic position, lithology, petrography, and phenocryst compositions, we propose that the chatoyant sanidine tuff of the central Mojave Desert is part of the Peach Springs Tuff outflow sheet. The main lines of evidence are summarized below.

1. A single welded tuff that is petrographically indistinguishable from the Peach Springs Tuff exposed at Kingman occurs in most Tertiary stratigraphic sections between Barstow, California, and Peach Springs, Arizona. In no range have two welded tuffs with Peach Springs mineralogy been found. In most of the ranges in California, the proposed Peach Springs Tuff is the *only* welded tuff in the Tertiary section.

2. Major-element compositions of sanidine, plagioclase, biotite, and hornblende phenocrysts in tuff from the central Mojave Desert are identical to those from the Peach Springs Tuff at Kingman. These data are summarized in Table 1. Compositional differences between localities are smaller than the relatively small scatter of compositions found within a single thin section. Whole-rock, major- and trace-element compositions overlap but show far more scatter than the phenocryst data, presumably because of alteration of the volcanic glass and the presence of exotic lithic components.

3. Although the stratigraphic setting of the tuff varies, it consistently overlies pre-Miocene or lower Miocene rocks and underlies middle Miocene and younger rocks. At and south of the latitude of Barstow and Needles, the main pulse of volcanic rocks was erupted at about 20 Ma (Glazner and Supplee, 1982), and the tuff consistently lies at or near the top of the Tertiary section. North of this latitude (for example, Piute Range, Fig. 1), the main pulse of volcanism occurred at 12–15 Ma, and the tuff lies near the base of the Tertiary section.

4. The mean magnetic direction measured in nine widely scattered outcrops of relatively flat-lying tuff from the central Mojave Desert is indistinguishable from that measured in the Peach Springs Tuff in the Kingman area (Wells and Hillhouse, 1986). This direction has an unusually low inclination and a large declination ($I = 42.8°$, $D = 32.3°$, $\alpha_{95} = 4.4°$ at Kingman; Young and Brennan, 1974) and is therefore distinctive.

5. A mineralogic study by Sharon Gusa

TABLE 1. COMPARISON OF PHENOCRYST COMPOSITIONS: PEACH SPRINGS TUFF AND PROPOSED EQUIVALENT TUFF FROM COLORADO RIVER TROUGH AND CENTRAL MOJAVE DESERT

	sanidine			plagioclase			biotite			hornblende		
	CM	CR	PS	CM	CR	PS	CM	CR	PS	CM	CR	PS
SiO_2	65.7, 3	65.4, 4	65.4, 3	64.2, 6	64.1, 4	63.4, 9	38, 2	38.6, 1	39.1, -	47.4, 7	46.7, 4	47.4, 5
Al_2O_3	18.8, 3	18.9, 1	18.5, 1	21.7, 5	21.9, 1	21.8, 6	12.6, 8	12.7, 1	12.8, -	6.5, 4	7.0, 2	6.9, 2
FeO							14, 1	14.9, 8	14.3, -	12.7, 2	13.0, 3	13.1, 2
MnO							0.6, 1	0.6, 1	0.6, -	1.1, 1	1.0, 1	1.1, 1
MgO							16, 1	16.2, 1	16.7, -	14.9, 4	14.7, 3	15.0, 3
CaO	0.4, 2	0.5, 1	0.4, 1	3.1, 4	3.2, 3	3.5, 5	0	0	0	10.9, 6	10.8, 4	11.3, 2
Na_2O	5.3, 4	5.3, 3	5.1, 1	8.8, 3	8.6, 2	8.8, 2	0.6, 1	0.6, 0	0.6, -	2.2, 1	2.2, 0	2.2, 1
K_2O	9.2, 6	9.0, 5	9.4, 2	1.6, 2	1.7, 3	1.3, 3	9.2, 6	9.7, 2	9.6, -	0.9, 1	1.0, 0	1.0, 1
n	19	11	4	14	6	4	9	2	1	3	3	2

Note: numbers after commas give standard deviations of point analyses (in terms of units of last digit; i.e., 12.6, 8 indicates a mean of 12.6 with a standard deviation of 0.8); n = number of point analyses. CM = central Mojave (4 samples, from Bullion Mountains, Marble Mountains, southeastern Cady Mountains, and northern Cady Mountains); CR = Colorado River trough area (2 samples, from Mohave and Chemehuevi Mountains); PS = Peach Springs Tuff from Kingman area (1 sample). Samples of CM, CR, and PS were alternated during analysis. Core and rim analyzed on most grains. All analyses by A. F. Glazner on the UCLA Cameca microprobe, January 1985.

of the U.S. Geological Survey (1986, written commun.) showed that heavy mineral suites of the Peach Springs Tuff and proposed equivalents are dominated by sphene and contrast sharply with suites from several more local Miocene ash-flow tuffs in the region, including the Hole in the Wall Tuff (McCurry, 1986), the Cook Canyon Tuff of Buesch and Valentine (1986), and a tuff in the Turtle Mountains reported by Howard et al. (1982, Table 3, no. 11). Gusa's study found no evidence of significant vertical mineralogic zonation in the Peach Springs Tuff.

TABLE 2. K-AR DATES ON PEACH SPRINGS TUFF AND PROPOSED EQUIVALENT TUFF IN MOJAVE DESERT

age (Ma)	Mineral	Locality	Reference
18.8 ±0.6*	san	Milkweed Canyon	P. E. Damon, in Young and Brennan (1974)
17.3 ±0.4*	san	Kingman	
18.2 ±0.4, 18.8 ±0.5	san, bio	Whipple Mountains	Dickey et al. (1980)
20.0 ±1.0	san	Cady Mountains	Glazner (1981)
18.1 ±0.6	san	Chemehuevi Mountains	Howard et al. (1982)
18.3 ±0.6	san	Little Piute Mountains	"
20.0 ±0.5, 18.8 ±0.5	san, bio	Woods Mountains	Goldfarb et al. (1986)
19.2 ±0.6, 20.1 ±0.5	san, bio	Bristol Mountains	Unpublished
16.5 ±0.4	san	"	"
18.0 ±0.5	san	"	"
20.5 ±0.5	san	Pinto Mountain	"
16.2 ±0.4	san	Marble Mountains	"
16.7 ±0.3, 17.8 ±0.4	san, san	Mohave Mountains	"
17.4 ±0.2	san	"	"
18.0 ±0.5	san	"	"
18.6 ±0.6	san	Piute Mountains	"
17.5 ±0.4	san	Ship Mountains	"
18.3 ±1.2†			

Note: san=sanidine, bio=biotite; ± refers to stated analytical precision. Unpublished dates determined by M. A. Pernokas, J. K. Nakata, and R. F. Marvin in U.S. Geological Survey laboratories on samples collected by the authors.

*Corrected to new decay constants (Dalrymple, 1979).

†Mean and standard deviation.

AGE OF THE TUFF

The Peach Springs Tuff and its proposed Mojave Desert equivalent are characterized by discrepant K-Ar dates. Available data are summarized in Table 2. Ages determined on sanidine, the mineral most often used for dating, range from 16.2 to 20.0 Ma; the mean is 18.2 Ma. The source of the variation is unknown, but it probably is not a result of dating different units because the variation occurs within single ranges as well as between ranges.

Three samples, from the Whipple Mountains, Bristol Mountains, and Providence Mountains, have yielded concordant sanidine-biotite ages that average 18.5, 19.6, and 19.4 Ma, respectively.

SOURCE OF THE TUFF

The tuff in our proposed correlation lacks a known source. Young and Brennan (1974, p. 84) stated, "The trend of outcrop thicknesses indicates that the source of the [Peach Springs Tuff] deposits was somewhere west of the Cerbat Mountains, most likely in or near the Black Mountains" (Fig. 1). Our thickness data corroborate the assumption that the source was somewhere in the Colorado River trough area, near the southern tip of Nevada.

SUMMARY

Similarities in stratigraphic position, field appearance, petrography, isotopic ages, paleomagnetic directions, and phenocryst compositions indicate that outcrops of chatoyant sanidine ash-flow tuff in the central Mojave Desert may be equivalent to the Peach Springs Tuff. If this correlation is confirmed, then outcrops of the Peach Springs Tuff are currently scattered over an area of at least 35 000 km^2. Even allowing for northeast-southwest crustal extension of as much as 100% across the region, this implies that the tuff had a volume of several hundred cubic kilometres—the first ash-flow tuff of such magnitude recognized in southern California.

Because it may be so widely distributed, the tuff offers a method for correlating isolated Tertiary stratigraphic sections in the Mojave Desert and western Arizona (Nielson-Pike, 1984). In addition, the tuff is generally flat-lying on the Colorado Plateau, moderately tilted in the Colorado River trough, and gently tilted in the central Mojave Desert; in many areas Tertiary strata beneath the tuff are tilted more steeply (Nielson and Glazner, 1986). These relations make the tuff an excellent marker bed for studying the timing and progress of extension across the region. On the basis of its apparent presence in most lower Miocene sections in the region, the tuff was deposited on a surface of relatively low relief, with few obvious large topographic irregularities such as block-faulted ranges.

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