The Bates Mountain Tuff in Northern Nye County, Nevada

By K. A. SARGENT *and* E. H. McKEE

CONTRIBUTIONS TO STRATIGRAPHY

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By K. A. SARGENT and E. H. McKEE

ABSTRACT

The Bates Mountain Tuff, a widespread Miocene (K–Ar age about 22–24 million years) formation in central Nevada, crops out across a region of more than 1,900 square miles in northern Nye County, Nev. In the northwestern part of this region the formation comprises five cooling units, but only the upper two units can be traced eastward into east-central Nye County and only the upper unit can be found to the south in north-central Nye County.

INTRODUCTION

The Bates Mountain Tuff was named by Stewart and McKee (1968) for a lithologically distinctive sequence of Tertiary rhyolitic ash-flow tuffs that is well exposed in the vicinity of Bates Mountain in the Simpson Park Mountains, southern Lander County, Nev. To the south in the Spencer Hot Springs quadrangle, the formation, as mapped by McKee (1968), contains all the ash-flow units recognized at Bates Mountain as well as additional upper and lower units. This usage is retained in this paper.

The general distribution of the Bates Mountain Tuff in central Nevada and its stratigraphic relationship to other Tertiary units was outlined by McKee (1969). The Bates Mountain Tuff in northern Nye County and in the southernmost parts of Lander and Eureka Counties (fig. 1) is described in the present paper. The Bates Mountain Tuff is commonly the youngest ash-flow sequence in the northern part of the region, but to the south and east, in Nye County, it is locally overlain and underlain by tuffs and lavas from other volcanic centers. It is in this south and east area that the tuff is most useful as a unit for correlation. Like most widespread ash-flow tuffs, the Bates Mountain unconformably overlies various older tuffs, lavas, and sedimentary rocks.

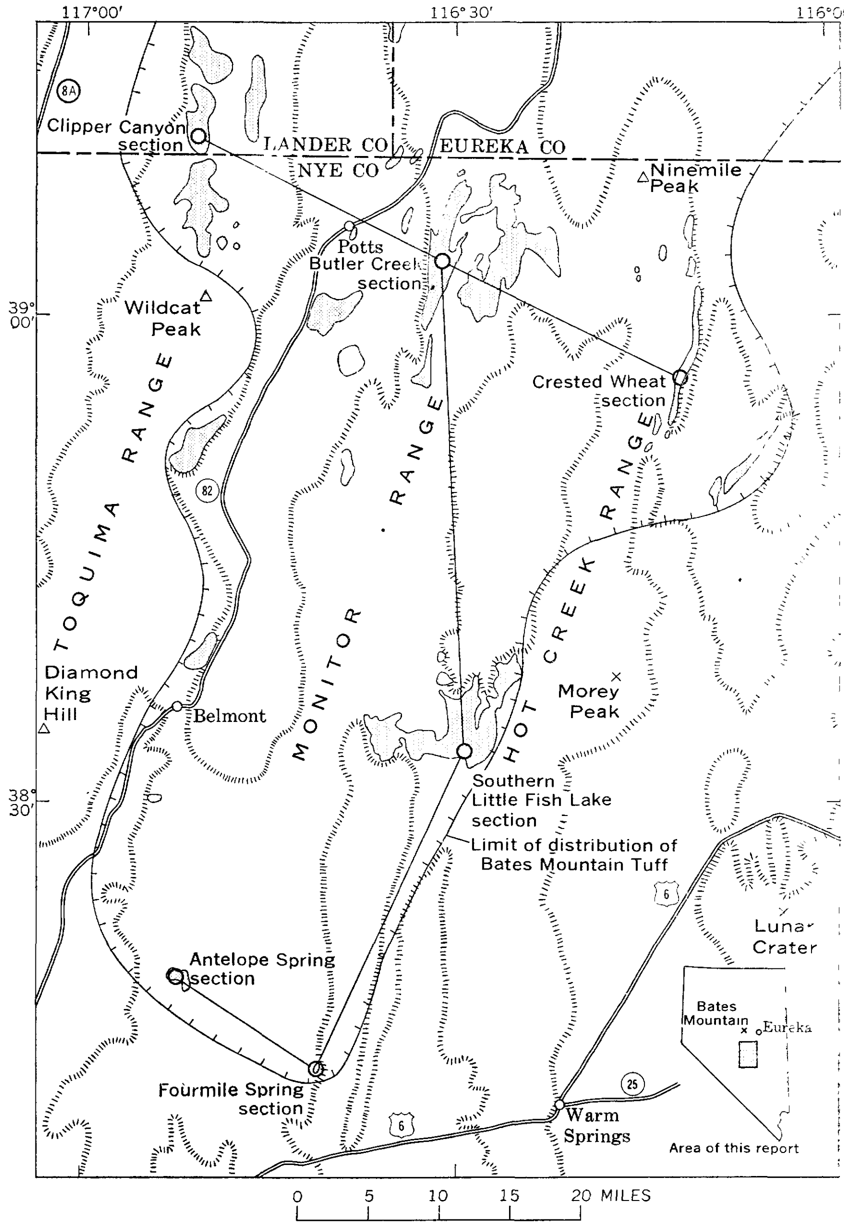

Figure 1.—Generalized map showing known distribution, areas of outcrop (stippled), and lines of sections of the Bates Mountain Tuff. Named sections are referred to in figures 2 and 3 and in the text.

LITHOLOGY AND PETROGRAPHY

In general, the Bates Mountain Tuff is characterized by phenocryst-poor ash flows that are grayish pink to buff where partly welded to nonwelded and pink to dark reddish brown where densely welded. Most flows contain less than 10 percent phenocrysts that consist dominantly of alkali feldspar (sanidine) but include less abundant plagioclase, quartz, accessory biotite, hornblende, clinopyroxene, orthopyroxene, and opaque oxides, and trace amounts of zircon, allanite, and apatite. All the phenocrysts are less than 3 mm in diameter, and commonly quartz is deeply embayed. The groundmass is shard rich, and most of it contains only sparse foreign lithic fragments of densely welded rhyolitic to quartz latitic tuff and (or) lava of intermediate composition.

The upper two cooling units of the Bates Mountain Tuff (Nos. 4 and 5) are especially distinctive. Both are characterized by dominant phenocrysts of sanidine, less common quartz, and sparse plagioclase relative to units 1, 2, and 3. In Nye County they appear to be more widespread than the lower three cooling units (1, 2, and 3), and the lower of the two (unit 4) is distinctive because of its ubiquitous gas cavities; this unit is informally called the "swiss cheese." Where the flows become punky owing to vapor-phase crystallization, prominent very light gray pumice, 0.5–2 inches long, is common in a brick-red groundmass.

Phenocryst mineralogy in cooling units 1, 2, and 3 indicates that units 1, and 2 are rhyolitic and that the overlying unit (unit 3) may be quartz latitic. The exact contact between cooling units 2 and 3 is difficult to find.

The vitrophyre from unit 2, as suggested by a whole-rock analysis (table 1), is a typical rhyolite.

TABLE 1.—*Analysis of black vitrophyre at base of densely welded part of unit 2, Bates Mountain Tuff, Clipper Canyon, Lander County, Nev.*

[Whole-rock analysis by U.S. Geol. Survey Lab., Leonard Shapiro, project leader]

Oxide	*Percent*	*Oxide*	*Percent*
SiO_2	73.6	H_2O-	.29
Al_2O_3	12.9	H_2O+	2.8
Fe_2O_3	.85	TiO_2	.11
FeO	.32	P_2O_5	.00
MgO	.16	MnO	.06
CaO	.50	CO_2	<.05
Na_2O	3.0		
K_2O	4.8	Sum	99.44

TABLE 2.—*Average phenocryst values, in volume percent, of five cooling units of the Bates Mountain Tuff at Clipper Canyon, northern Toquima Range*

[Tr., trace]

	Cooling unit				
	1	2	3	4	5
Total phenocrysts	10	5	7.5	2.7	5
Quartz	<1	30	24	<1	23
Alkali feldspar (sanidine)	55	44	17	88	60
Plagioclase	35	20	50	1	11
Biotite	<1	0	1	<1	4
Hornblende	Tr.	Tr.	Tr.	0	0
Pyroxene	Tr.	2	Tr.	Tr.	Tr.
Opaque oxides	3	3	6	4	1
Altered mafic minerals	6	1	2	6	1
Total	99+	100	100	99+	100

Table 2 summarizes the petrography of the five cooling units of the Bates Mountain Tuff. The phenocryst values given are averages from modal analyses of specimens taken at Clipper Canyon in the northern Toquima Range in the northwestern part of the region. The values are distinctive for the cooling units throughout their extent.

DISTRIBUTION AND THICKNESS

The Bates Mountain Tuff is known (fig. 1) in northern Nye County only north of U.S. Highway 6 and east of Nevada Highway 8A, which runs along the west side of the Toquima Range. The tuff is generally found in the stratigraphically high part of Tertiary fault blocks, although in many places it may have been eroded away. In the southern part of northern Nye County the Bates Mountain Tuff is seen only where erosion of paleotopographic lows has exposed the tuff under younger volcanic flows. The five cooling units of the Bates Mountain Tuff are 725 feet thick at Clipper Canyon, in Lander County about 1 mile north of Nye County. At Butler Creek, in the Monitor Range, where only the upper two cooling units were deposited, the formation is about 300 feet thick; south of Butler Creek, where only the upper unit was deposited, it is generally 50–100 feet thick (figs. 2, 3). Together the five cooling units cover about 1,900 square miles in northern Nye County alone and constitute a volume of about 30 cubic miles (average thickness about 80 ft). In the study region the upper cooling unit accounts for most of the distribution of the Bates Mountain Tuff (outlined in fig. 1); the fourth unit ("swiss cheese" unit) crops out across the northern part of the region, and the lower three units (units 1, 2, and 3) are found only in the northwestern part of the region (fig. 4).

Lines of sections showing thicknesses and general lithologies of the Bates Mountain and certain other Tertiary tuffs are presented in figures 2 and 3. Phenocryst mineralogy of most of the units is presented in tables 3 and 4. Figure 2 is a line of sections from Clipper Canyon on the northwest to the Hot Creek Range (Crested Wheat section) on the southeast. In the vicinity of the Crested Wheat section (Hot Creek Range), only the fourth ("swiss cheese") units is tentatively recognized.

Figure 3 is a line of sections from Butler Creek section on the north to the Antelope Spring section in the southern Monitor Range on the southwest. It shows the upper cooling unit (No. 5) of the Bates Mountain to be persistent southward and to be overridden by younger unrelated ash-flow tuffs.

REMANENT MAGNETISM

Data obtained by G. D. Bath, by J. D. Kibler, and independently by Sherman Grommé (written commun., 1969), all with the U.S. Geological Survey, on samples of Bates Mountain Tuff indicate that each cooling unit has a distinctive direction or remanent magnetism. In cooling unit 1 it is normal; in cooling units 2 and 3, reversed; in cooling unit 4, normal; and in cooling unit 5, nearly horizontal (table 5; figs. 2, 3). Table 5 shows the available data on cooling unit 5. Determinations of polarity as reported here are based on the methods used by G. D. Bath and J. D. Kibler. Polarity measurements were made on 1×1-inch vertically drilled cores which were demagnetized in alternating fields to remove the effects of lightning. Their attitudes have been corrected for dip of the flow.

AGE

The Bates Mountain Tuff is Miocene. As originally described, the formation was Oligocene or Miocene (Stewart and McKee, 1968), but redefinition of the Oligocene-Miocene boundary at 26 m.y. (million years) by the Geological Society of London (1964) suggests that the formation should be considered Miocene. Potassium-argon determinations made on sanidine mineral separates from seven localities in central Nevada (all north of the region described here) before those of this report indicate that an average age for the formation is about 24 m.y., which suggests early Miocene age. Of these analyses, that for the upper unit, dated at one locality near Eureka, Nev., gives an age which suggests that the unit is younger than the other cooling unit of the Bates Mountain; but overlap in age due to the plus-or-minus factor of analytical precision invalidates separation of cooling units

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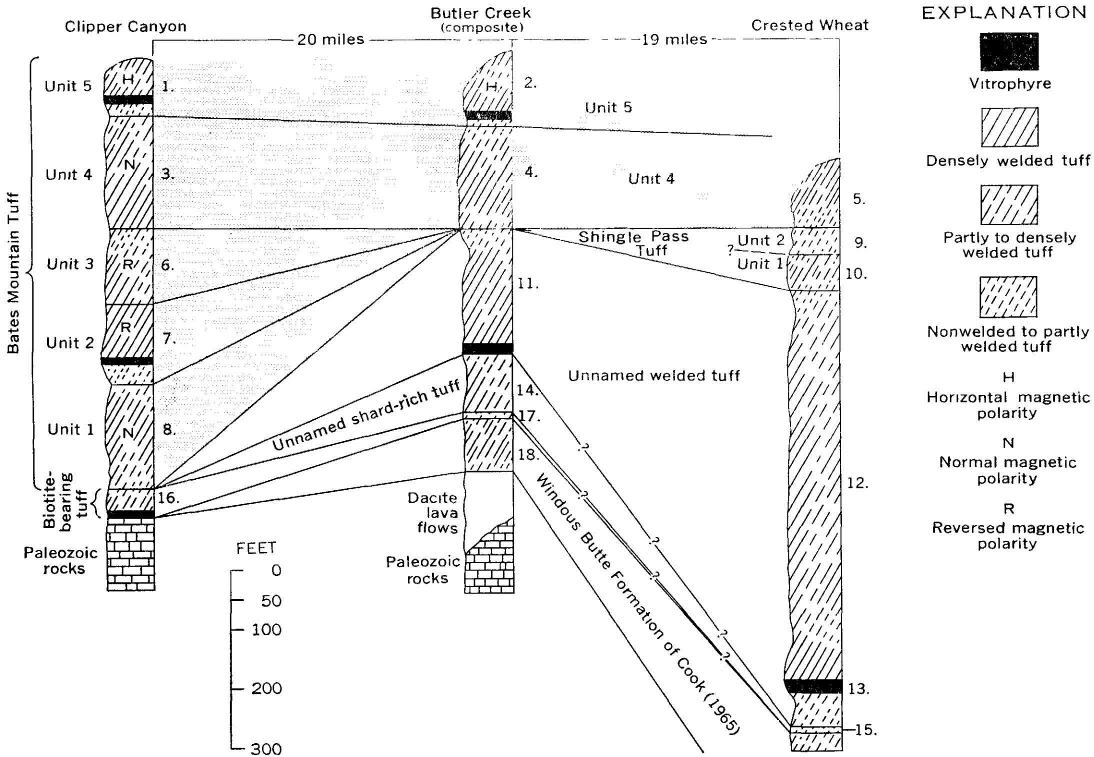

FIGURE 2.—Columnar sections from Clipper Canyon section in northern Toquima Range to Crested Wheat section in Hot Creek Range. Numbers to right of columns refer to phenocryst mineralogy of samples given in table 3. Line of section is shown in figure 1. Queries indicate questionable correlation.

TABLE 3.—*Phenocryst mineralogy, in percent, of Bates Mountain Tuff and older tuffs at section localities shown in figure 2*

[Tr., trace]

Rock unit	Sample No. in fig. 2	Quartz	Sanidine	Plagioclase	Biotite	Hornblende	Pyroxene	Opaque oxides	Unidentified altered mafic minerals	Total mafic minerals	Total phenocrysts
Bates Mountain Tuff:											
Unit 5	1	23.0	60.0	11.0	4.0	0	Tr.	1.0	1.0	6.0	5.0
	2	30.0	59.0	9.5	.4	Tr.	0	1.1	0	1.5	6.1
Unit 4	3	<1.0	88.0	1.0	<1.0	0	Tr.	4.0	6.0	10.0	3.0
	4	2.6	91.2	2.3	0	0	0	3.9	0	3.9	1.9
	5	6.7	70.0	15.0	1.8	.6	.6	2.7	1.4	7.1	4.8
Unit 3	6	24.0	17.0	50.0	1.0	Tr.	Tr.	6.0	2.0	9.0	7.5
Unit 2	7	30.0	44.0	20.0	0	Tr.	2.0	3.0	1.0	6.0	5.0
Unit 1	8	<1.0	55.0	35.0	<1.0	Tr.	Tr.	3.0	6.0	9.0	10.0
Shingle Pass Tuff:											
Unit 2	9	2.8	26.5	54.7	11.1	1.2	0	2.3	1.4	16.0	8.8
Unit 1	10	10.5	45.9	36.5	.9	Tr.	0	1.7	4.5	7.1	14.5
Unnamed welded tuff	11	22.4	23.4	43.5	8.2	1.9	0	.6	0	10.7	30.0
	12	27.7	20.9	42.4	6.6	1.5	Tr.	.5	.4	9.0	31.6
	13	23.7	36.2	34.5	4.8	Tr.	0	.7	.1	5.6	29.3
Unnamed shard-rich tuff	14	0	53.5	45.0	0	0	0	1.5	0	1.5	9.0
	15	Tr.	57.0	35.0	0	0	0	2.4	5.6	8.0	7.4
Biotite-bearing tuff	16	0	7.5	66.5	14.0	.5	10.0	1.0	0	26.0	25.0
	17	.5	13.0	72.0	12.5	0	0	2.0	0	14.5	13.0
Windous Butte Formation of Cook (1965)	18	20.0	42.0	32.0	1.0	0	0	2.0	3.0	6.0	46.0

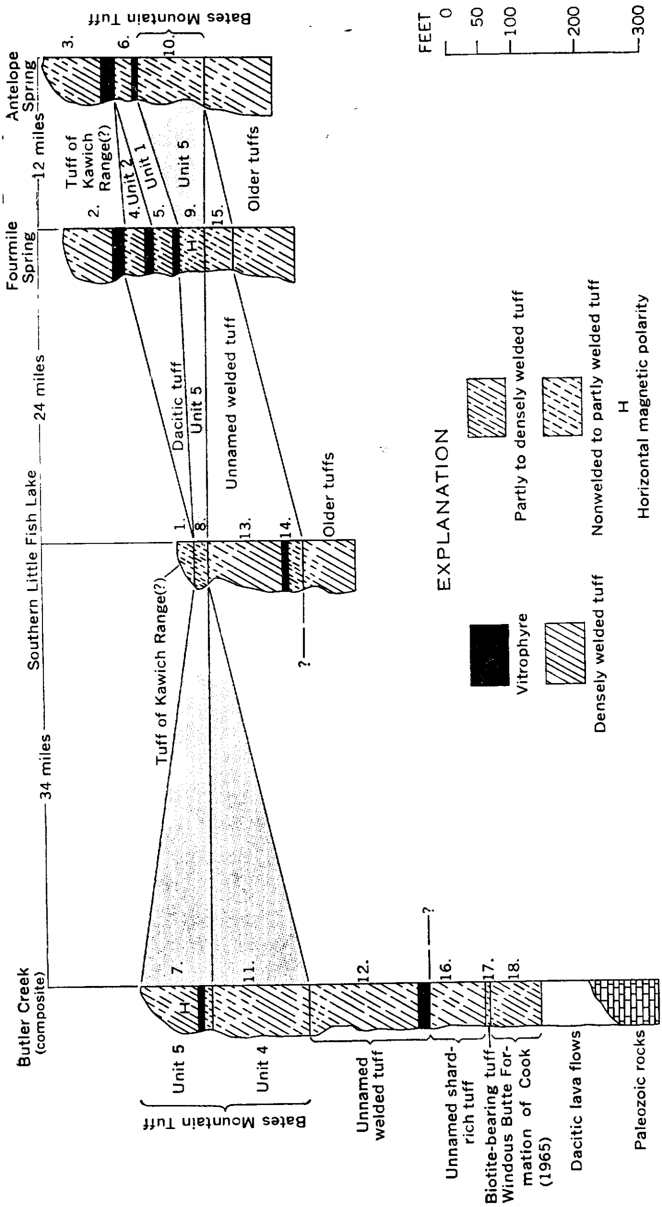

FIGURE 3.—Columnar sections from Butler Creek in central Monitor Range to Antelope Spring in southern Monitor Range. Numbers to right of columns refer to phenocryst mineralogy of samples given in table 4. Line of section is shown in figure 1.

TABLE 4.—*Phenocryst mineralogy, in percent, of Bates Mountain Tuff, younger tuffs, and certain older tuffs at section localities shown in figure 3*

[Tr., trace]

Rock unit	Sample No. in fig. 3	Quartz	Sanidine	Plagioclase	Biotite	Hornblende	Pyroxene	Opaque oxides	Unidentified altered mafic minerals	Total mafic minerals	Total phenocrysts
Tuff of Kawich Range(?)	1	21.0	36.0	37.0	6.0	0	0	0	0	6.0	22.0
	2	39.9	35.5	21.9	1.6	Tr.	0	1.1	0	2.7	28.6
	3	32.9	22.8	37.3	5.5	.8	0	.7	0	7.0	40.0
Dacitic tuff:											
Unit 2	4	0	1.5	78.9	0	0	16.0	3.6	0	19.6	17.0
Unit 1	5	2.9	5.4	74.8	0	Tr.	11.6	5.4	0	17.0	10.4
	6	4.0	1.0	76.0	1.0	0	14.0	4.0	0	19.0	8.0
Bates Mountain Tuff:											
Unit 5	7	30.0	59.0	9.5	.4	Tr.	0	1.1	0	1.5	6.1
	8	45.0	46.0	4.0	Tr.	0	0	1.6	3.0	5.0	5.7
	9	33.9	53.6	7.1	.3	Tr.	0	1.1	4.0	5.4	3.9
	10	24.8	62.2	8.9	.7	.4	.9	2.1	0	4.1	5.8
Unit 4	11	2.6	91.2	2.3	0	0	0	3.9	0	3.9	1.9
Unnamed welded tuff*	12	22.4	23.4	43.5	8.2	1.9	0	.6	0	10.7	30.0
Unnamed welded tuff*	13	17.0	14.0	54.0	10.6	3.5	0	.6	0	15.0	32.0
	14	8.0	44.0	32.0	11.0	3.0	0	2.0	0	16.0	14.0
	15	19.4	15.1	55.1	7.2	2.3	Tr.	.9	0	10.4	18.0
Unnamed shard-rich tuff	16	0	53.5	45.0	0	0	0	1.5	0	1.5	9.0
Biotite-bearing tuff	17	.5	13.0	72.0	12.5	0	0	2.0	0	14.5	13.0
Windous Butte Formation of Cook (1965)	18	20.0	42.0	32.0	1.0	0	0	2.0	3.0	6.0	46.0

*Units probably do not correlate.

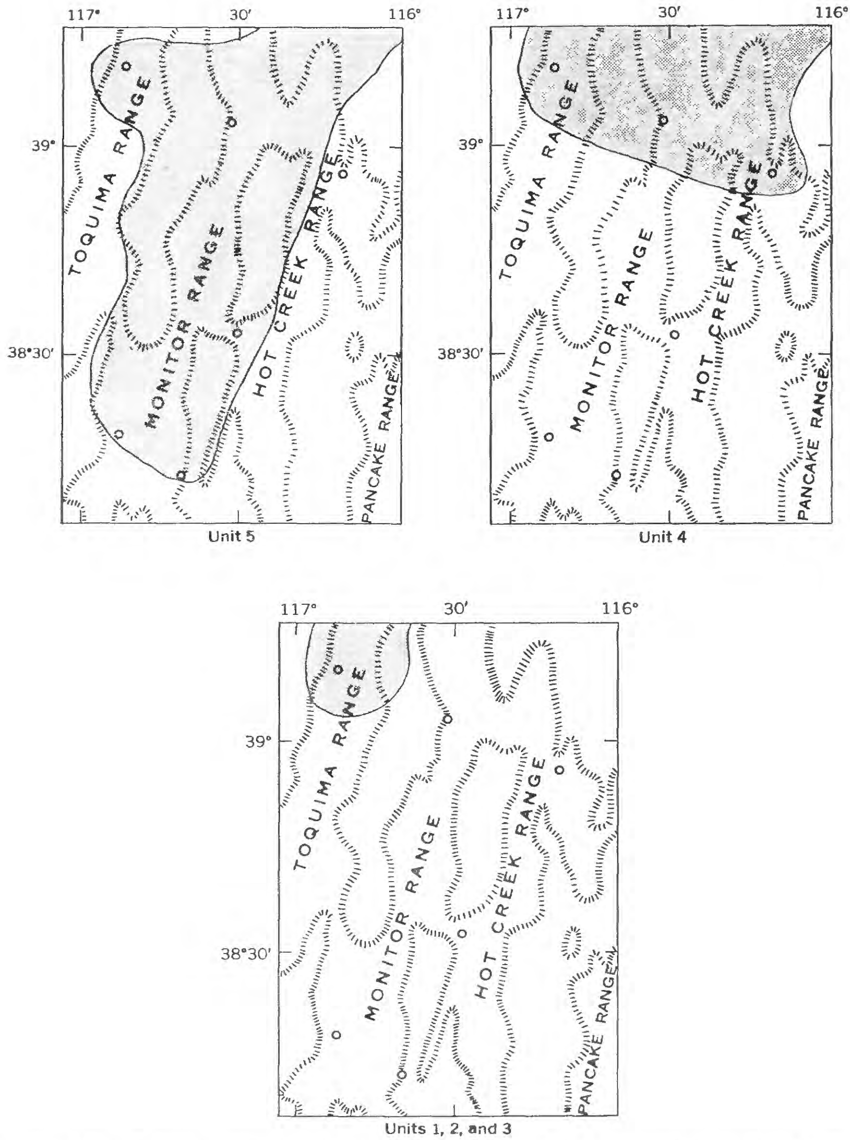

FIGURE 4.—Approximate distribution of units 1–5 of the Bates Mountain Tuff in northern Nye County, Nev. Small circles indicate section localities shown in figures 1, 2, and 3.

TABLE 5.—*Remanent-magnetism directions in samples collected from unit 5 of the Bates Mountain Tuff*

[Localities are at sections shown in figs. 1, 2, and 3. Monitor Range samples collected by J. D. Kibler; Toquima Range, by F. N. Houser]

Sample locality	Azimuth	Inclination
Butler Creek, Monitor Range	124	−2
	159	+2
	159	+3
Fourmile Spring, southern Monitor Range	135	+6
	143	+11
	143	+8
Clipper Canyon, Toquima Range	157	−2
	166	+22
	144	+18

by age. The determinations of this report agree with the earlier ones. Cooling unit 2 at Clipper Canyon in the northern Toquima Range has a K–Ar age of 23.7±1.0 m.y. (table 6, No. 3); the highest cooling unit (unit 5) from the same section has a K–Ar age of 22.2±0.9 m.y. (table 6, No. 1). At the Crested Wheat section in the Hot Creek Range the Bates Mountain Tuff, considered here to be unit 4, has a K–Ar age of 22.8±0.9 m.y. (table 6, No. 2).

TABLE 6.—K-Ar *age data on Bates Mountain Tuff and three underlying welded tuffs from Clipper Canyon section, Toquima Range, and from the Crested Wheat section, northern Hot Creek Range*

Sample No.	Unit and locality	Mineral analyzed	K_2O (weight percent)[1]	Ar^{40} (moles per g $\times 10^{-10}$)	Radiogenic argon (percent)	Apparent age (m.y.)
1	Unit 5, Clipper Canyon section	Sanidine	8.17	2.69	67.0	22.2±0.9
2	Unit 4, Crested Wheat section	do	7.77	2.63	54.0	22.8±0.9
3	Unit 2, Clipper Canyon section	do	10.47	3.69	84.0	23.7±1.0
4	Shingle Pass Tuff, unit 2, Crested Wheat section.	do	11.70	4.25	86.5	24.5±1.0
5	Shingle Pass Tuff, unit 1, Crested Wheat section.	do	11.36	4.24	81.1	25.1±1.0
6	Biotite-bearing tuff, Clipper Canyon section.	Biotite	7.68	3.50	70.8	30.6±1.2

[1] Average of duplicates.

Decay constants used for K^{40} are: $\lambda_\epsilon = 0.585 \times 10^{-10}$ yr^{-1}, $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}.
Atomic abundance of K^{40} is 1.19×10^{-4} moles per mole.

The Bates Mountain Tuff rests unconformably on rocks of Paleozoic, Mesozoic, and Cenozoic age. Some of the Tertiary units that lie directly beneath it at certain localities have been dated. At the Clipper Canyon section the Bates Mountain Tuff lies on a biotite-bearing tuff which yielded a K–Ar age on biotite of 30.6±1.2 m.y. (table 6, No. 6). This age suggests that the welded tuff is Oligocene (Geological Society of London, 1964). In the northern Hot Creek Range (Crested Wheat section), two units of Shingle Pass Tuff underlie the Bates Mountain (fig. 2). This is the only locality known to the authors where the

stratigraphic relationships between the Bates Mountain and Shingle Pass Tuffs can be observed. Units 2 and 1 of the Shingle Pass Tuff are 24.5±1.0 and 25.1±1.0 m.y. old, respectively (table 6, Nos. 4 and 5), and cannot be distinguished in age from the Bates Mountain Tuff within the precision of the K–Ar technique.

Analytical technique.—Argon analyses were made, by E. H. McKee, by standard isotope-dilution techniques on a Nier-type 6-inch-radius 60°-sector mass spectrometer. Potassium was analyzed by Lois B. Schlocker by flame photometer using a lithium internal standard. The errors shown as plus-or-minus values, which range from 3 to 4 percent of the calculated ages, represent the additive effects of uncertainties in the argon and potassium analyses, in the isotopic composition and concentration of the Ar^{38} tracer, and in the flame photometer standards.

REFERENCES CITED

Cook, E. F., 1965, Stratigraphy of Tertiary volcanic rocks in eastern Nevada: Nevada Bur. Mines Rept. 11, 61 p.

Geological Society of London, 1964, Summary of the Phanerozoic time-scale—Geological Society Phanerozoic time-scale 1964: Geol. Soc. London Quart. Jour., v. 120–S, p. 260–262.

McKee, E. H., 1968, Geologic map of the Spencer Hot Springs quadrangle, Lander County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–770.

——— 1969, The Bates Mountain Tuff of central Nevada, *in* Abstracts for 1968: Geol. Soc. America Spec. Paper 121, p. 530.

Stewart, J. H., and McKee, E. H., 1968, Geologic map of the Mount Callaghan quadrangle, Lander County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–730.

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