Stratigraphy and Potassium-Argon Ages of Some Tertiary Tuffs From Lander and Churchill Counties, Central Nevada

GEOLOGICAL SURVEY BULLETIN 1311-B

Prepared in cooperation with the Nevada Bureau of Mines

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By EDWIN H. McKEE *and* JOHN H. STEWART

CONTRIBUTIONS TO GENERAL GEOLOGY

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By EDWIN H. MCKEE and JOHN H. STEWART

ABSTRACT

Tertiary welded tuffs ranging in age from about 21 to 31 million years, according to potassium-argon dating, make up most of the Desatoya Mountains, New Pass Range, and the central part of the Shoshone Mountains in central Nevada. In the northern part of the region, 13 ash-flow-tuff cooling units are recognized. Five of these constitute the newly named Edwards Creek Tuff, the most widespread formation in this area. Its age is approximately 27 m.y. according to the potassium-argon dating. The Bates Mountain Tuff (approximately 24 m.y.) is commonly composed of three cooling units and forms the upper part of the section. Volcanic rock in the Desatoya Mountains consists of six welded tuffs. Only one of these tuffs is identified in other regions, and it is a distinctive biotite-bearing rock about 26 m.y. old. The most distinctive volcanic unit in the Desatoyas is the newly named New Pass Tuff, a single cooling unit which is about 22 m.y. old. This tuff is recognized eastward in the Shoshone Mountains but not to the north.

These rocks define the western part of a belt of late Oligocene and early Miocene silicic volcanism which seems to surround a core area of older (Oligocene) silicic volcanism in east-central Nevada.

INTRODUCTION

Tertiary rocks, mostly welded tuffs, constitute a large part of the northern Desatoya Mountains, the New Pass Range, and the central part of the Shoshone Mountains, a region of approximately 600 square miles in central Nevada (fig. 1). Two sequences of tuffs are distinguished in this region—a northern series which is mostly Oligocene in age, and a southern sequence which contains Oligocene and younger rocks (age assignment is based on 19 potassium-argon ages). Most of the units do not extend across the entire region nor

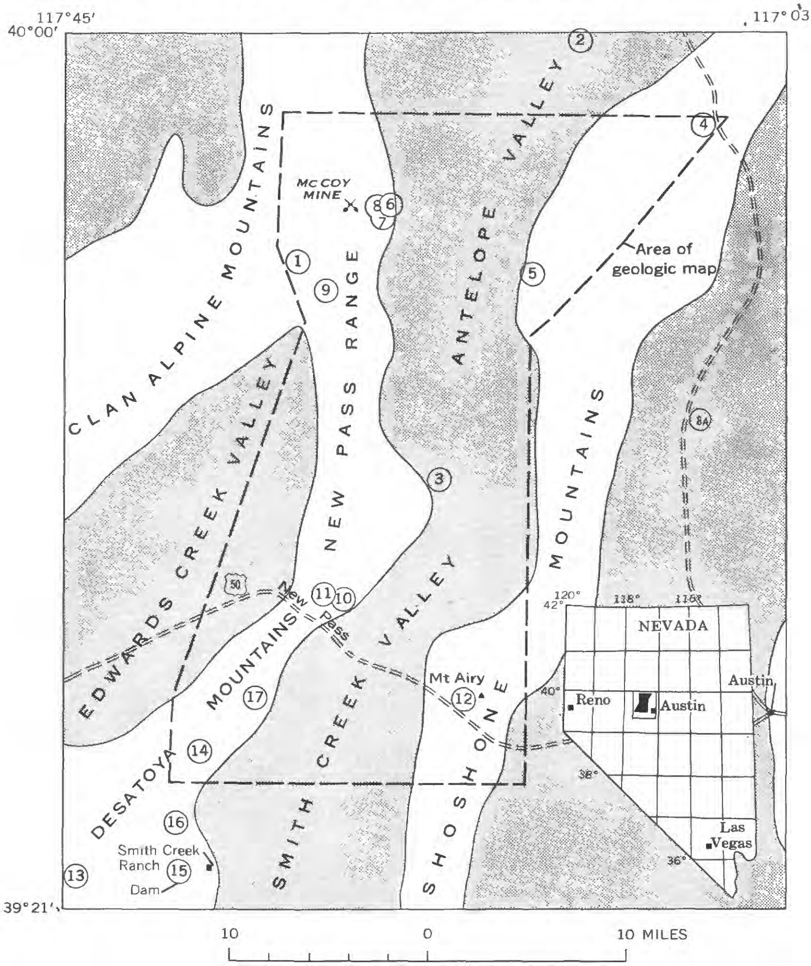


FIGURE 1.—Index map of Nevada and the region discussed in this paper. Circled numbers are potassium-argon localities.

are they found outside the region, except possibly to the west. The Bates Mountain Tuff, which is a part of the northern sequence, extends southeastward for at least 70 miles.

The source of these welded tuffs is not known, but most of them are presumed to have come from the west, possibly from the region of the Clan Alpine Mountains. The Desatoya Mountains south of the area described are underlain for about 15 miles by an unusually thick mass of welded tuff. This tuff may have accumulated near the source of one or more of the tuffs that crop out in the northern Desatoya Mountains; however, no tectonic features suggestive of a caldera or any other type of volcanic center in this area are apparent.

Most of the units are thin rhyolite welded tuffs, and several of them have distinctive lithologies which makes it possible to recognize and correlate them. In those places where only partial sections lacking marker units are exposed, correlation is uncertain. Here, potassium-argon ages are of help.

We appreciate Marvin A. Lanphere's help in the Geological Survey's potassium-argon laboratory at Menlo Park, Calif. Thanks are also due to C. Sherman Grommé and Joan C. Engels for review and helpful suggestions on the paper. The report was prepared in cooperation with the Nevada Bureau of Mines.

GEOLOGIC SETTING

The Desatoya Mountains and the New Pass Range form a continuous series of north-trending mountains approximately 50 miles long in central Nevada (fig. 1). The New Pass Range, which is the northern part of this chain, is composed of about equal amounts of upper Paleozoic to lower Mesozoic strata and Tertiary volcanic rock. The Desatoya Mountains to the south are composed of Tertiary volcanic rock and small amount of tuffaceous sedimentary rock. The central part of the Shoshone Mountains (between lat 39°27′ and 39°57′) is about 10 miles east of the Desatoya Mountains and New Pass Range and is separated from them by Smith Creek Valley in the south and Antelope Valley in the north. Low hills in these valleys disrupt the typical Basin and Range topography. The part of the central Shoshone Mountains described in this paper contains lower and upper Paleozoic strata and Tertiary volcanic and sedimentary rocks. Most of the volcanic rocks in the region are welded ash-flow tuffs.

All the Tertiary rocks in the region are broken by steeply dipping faults; the geologic map is a mosaic of fault blocks, most of which are tilted eastward (pl. 1). Stratification, however, is usually nearly horizontal, and dips greater than 25° are rare in the Tertiary units.

Most of the Tertiary rocks in the northern two-thirds of the region are different from those in the southern third. At the north end of the New Pass Range, a composite section of as many as 13 welded-tuff cooling units, which have a maximum thickness of about 1,300 feet, is well exposed (pl. 1 and fig. 3). Elsewhere in this area, only a part of this section is found. Units are missing from the base of the section at the regional pre-Tertiary unconformity or at other smaller unconformities in the sequence.

The southern third of the region—including the southern end of the New Pass Range, the northern part of the Desatoya Mountains, and the Mount Airy section of the Shoshone Mountains (fig. 1)—contains a sequence of welded tuffs and tuffaceous sedimentary rocks which are not found to the north. Correlation across this southern area is difficult, because the sedimentary units are lenticular and because some of the welded tuffs have limited distribution. One of the tuffs, however, can be traced across the area, and it serves as a useful datum plane. Correlation is substantiated by potassium-argon dates.

The thickest section in this subregion is in the northern Desatoya Mountains. Here, five welded tuffs have a total thickness of about 1,400 feet. At Mount Airy in the Shoshone Mountains, 10 miles to the east, six welded tuffs and two sedimentary units can be recognized. The total composite thickness of the Mount Airy section is about 1,000 feet. Only one or possibly two tuffs seem to be common to the two areas.

REGIONAL SIGNIFICANCE

All the welded tuffs except the Bates Mountain Tuff are from source areas at about the longitude of the map (fig. 1 and pl. 1; approx 117°30′) or perhaps as far west at long 118°15′. None of them, except the Bates Mountain Tuff, is recognized in east-central Nevada where welded tuffs have been described by Cook (1965), Blake, McKee, Marvin, and Nolan (1968), McKee (1968a), and others. The tuffs described in this report range in age from about 31 to 21 m.y. (million years), those in east-central Nevada include rocks as young as this, but are mostly 35 to 30 m.y. old. The distribution according to the age of silicic volcanic rocks in the Great Basin shows a concentric pattern, the oldest rocks being in east-central Nevada and increasingly younger rocks occurring at progressively greater distances from this "core area" (Armstrong and others, 1969). All the units dated here fit this generalized picture of time-space distribution; these silicic rocks form a belt which defines part of an imaginary second ring around the core area of older rocks as delineated by Armstrong, Ekren, McKee, and Noble (1969) (fig. 2). Westward migration of silicic volcanic activity in Nevada in time is substantiated by the ages of the welded tuffs of the Desatoya Mountains, New Pass Range, and central part of the Shoshone Mountains.

STRATIGRAPHY

NORTHERN PART OF THE REGION

Tertiary rocks are exposed across most of the northern New Pass Range, southern Antelope Valley, and central part of the Shoshone

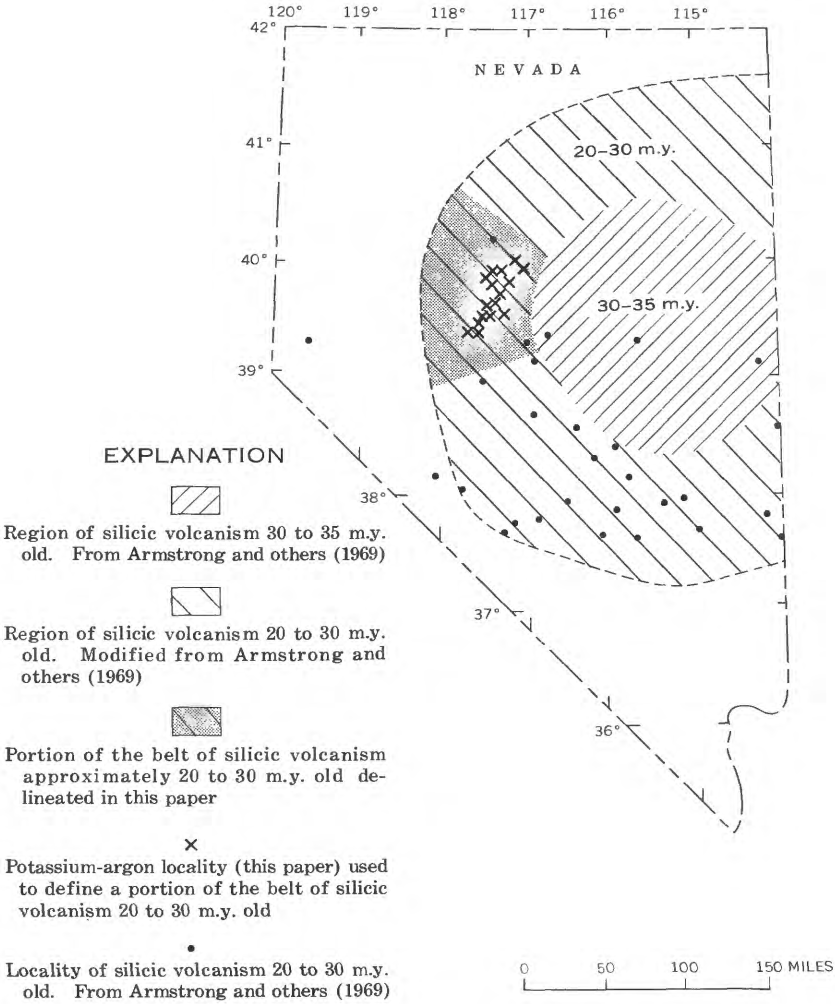
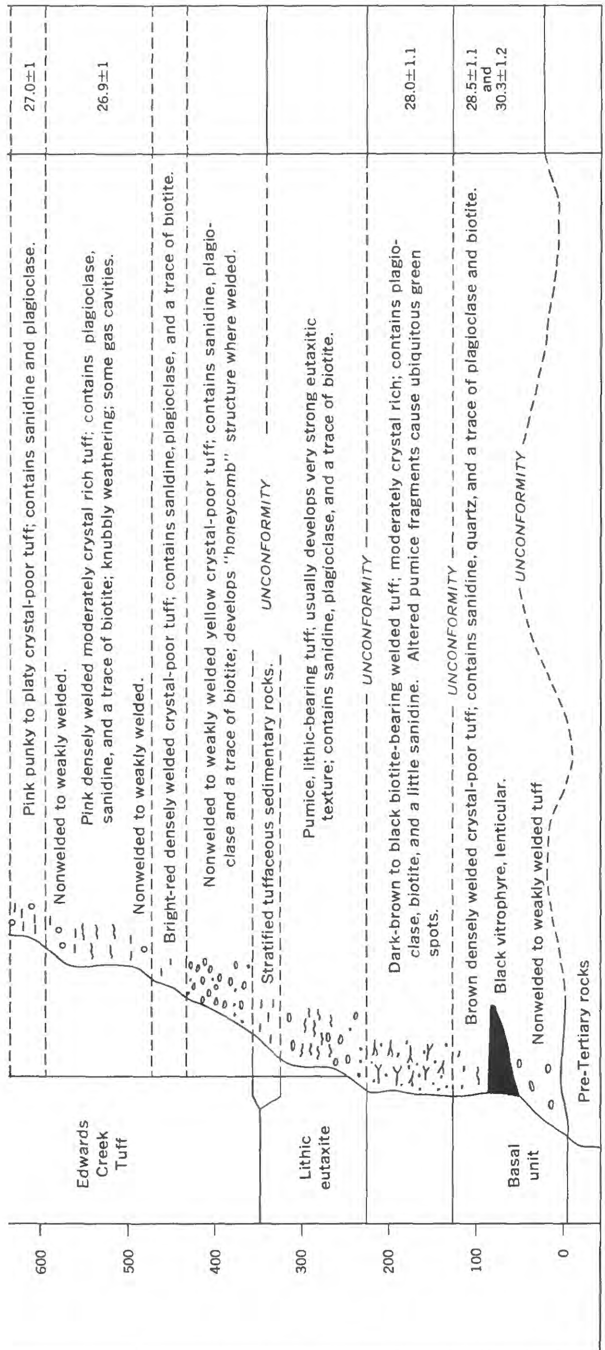


FIGURE 2.—Distribution of silicic volcanism in Nevada from 20 to 35 million years ago. Modified from Armstrong, Ekren, McKee, and Noble (1969, fig. 3).

Mountains (fig. 1 and pl. 1). In most areas these rocks are less than 500 feet thick and are composed of one to three welded-tuff cooling units. On the west side of the New Pass Range (loc. 1, pl. 1) and on the west side of the Shoshone Mountains (loc. 3, pl. 1), however, there are nearly identical continuous sections containing 10 cooling units each. A composite section of tuff that makes up a series of low hills in the vicinity of the McCoy mine (loc. 2, pl. 1)


Edwards Creek Tuff
Lithic eutaxite
Basal unit
600
500
400
300
200
100
0
Pink punky to platy crystal-poor tuff; contains sanidine and plagioclase.
Nonwelded to weakly welded.
Pink densely welded moderately crystal rich tuff; contains plagioclase, sanidine, and a trace of biotite; knubbly weathering; some gas cavities.
Nonwelded to weakly welded.
Bright-red densely welded crystal-poor tuff; contains sanidine, plagioclase, and a trace of biotite.
Nonwelded to weakly welded yellow crystal-poor tuff; contains sanidine, plagioclase and a trace of biotite; develops "honeycomb" structure where welded.
Stratified tuffaceous sedimentary rocks.
UNCONFORMITY
Pumice, lithic-bearing tuff; usually develops very strong eutaxitic texture; contains sanidine, plagioclase, and a trace of biotite.
UNCONFORMITY
Dark-brown to black biotite-bearing welded tuff; moderately crystal rich; contains plagioclase, biotite, and a little sanidine. Altered pumice fragments cause ubiquitous green spots.
UNCONFORMITY
Brown densely welded crystal-poor tuff; contains sanidine, quartz, and a trace of plagioclase and biotite.
Black vitrophyre, lenticular.
Nonwelded to weakly welded tuff
UNCONFORMITY
Pre-Tertiary rocks
27.0±1
26.9±1
28.0±1.1
28.5±1.1 and 30.3±1.2

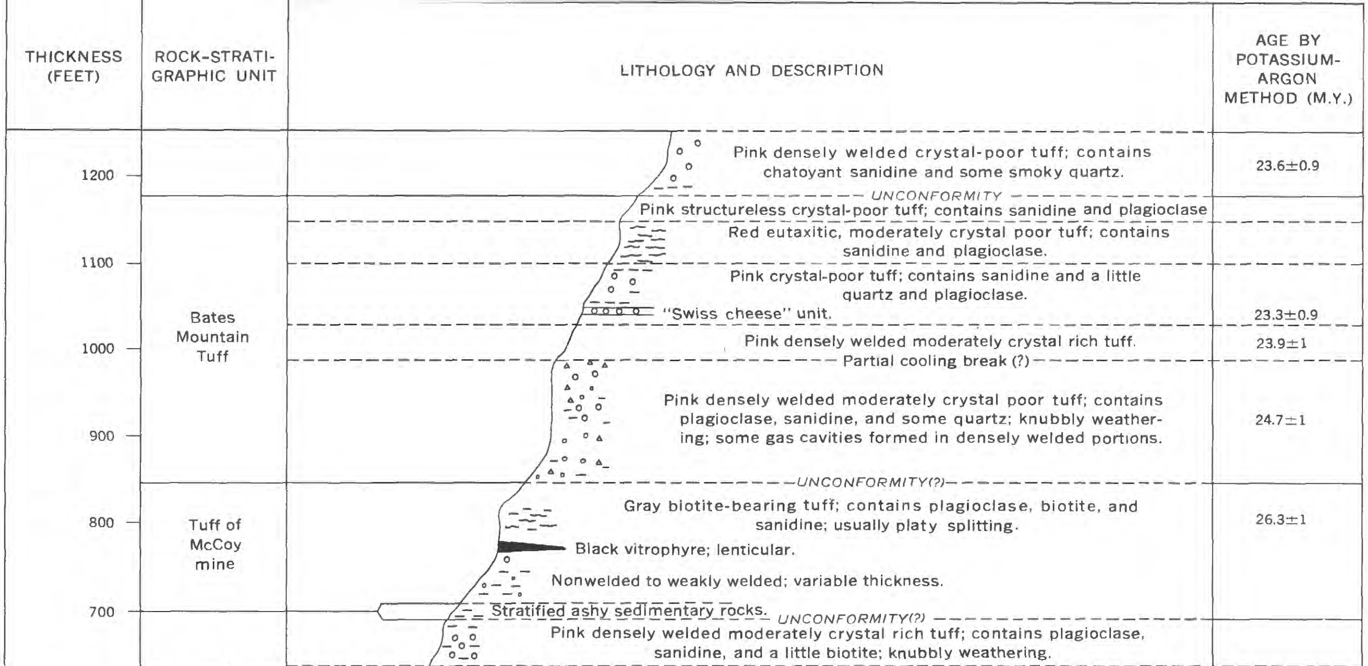


FIGURE 3.—Composite section of tuffs in the northern New Pass and central Shoshone Mountains.

contains 13 cooling units and is more than 1,300 feet thick (fig. 3). At a number of places lenticular tuffaceous sedimentary rocks and air-fall tuffs are interstratified with the welded tuffs.

Most of the welded tuffs are similar in general appearance. They are thin units (averaging less than 100 ft in thickness) in which the welded parts are well developed and the nonwelded parts are absent or poorly developed. The tuffs are usually pink to red rhyolite and range from crystal poor (less than 5 percent crystals) to moderately crystal poor (between 5 and 15 percent crystals). Sanidine, quartz, and plagioclase are common phenocrysts, and a few tuffs contain biotite. The presence or absence of biotite is used as a criteria for distinguishing these units. Lithic fragments, mostly of dacite and andesite, occur in several units, and one unit is distinguished by this feature. From one area to another each tuff seems to retain its lithologic character and shows little evidence of crystal sorting or other transitional changes. Features such as eutaxitic texture, gas cavities, platy structure, or degree of welding also seem to remain fairly constant in the different units. These features can also be used, in conjunction with crystal content and stratigraphic position, to distinguish each particular ash-flow tuff.

Four general groups of tuffs are recognized in the northern area. These are described in ascending order. (1) The oldest group consists of three lithologically different ash-flow tuffs. Each of these units is composed of a distinctive rock type and does not resemble any other tuff either in this region or in adjacent regions. The units overlie the Mesozoic and Paleozoic basement and are probably separated from each other by unconformities. Potassium-argon ages of two of these units are about 30 to 28 my., which is Oligocene (Harland and others, 1964). (2) The second group is the Edwards Creek Tuff (named in this paper). This formation contains five lithologically similar cooling units distinguished from each other mainly by texture. The K-Ar age of two of the cooling units is about 27 m.y. An Oligocene age (Harland and others, 1964) is indicated by the 27 m.y., but if the analytical uncertainty, which amounts to about 1 m.y., is taken into consideration, a Miocene age is possible. (3) Lying on the Edwards Creek Tuff at most places is a distinctive biotite-bearing welded tuff that serves as a useful marker unit in the region and that is informally called the tuff of McCoy mine. Its K-Ar age is 26.3± 1 m.y., which is Oligocene and Miocene (Harland and others, 1964). (4) The Bates Mountain Tuff (Stewart and McKee, 1968a; McKee, 1968a) is the fourth group, and in most of the area it is the youngest formation. It is approximately 24 m.y. old (this age is an average of five K-Ar dates, three reported in this paper, two unpublished). Although it was originally called Oligocene or Miocene by Stewart and McKee (1968a), it is considered here to be Miocene because of the redefinition of the Oligocene-Miocene boundary by Harland, Smith, and Wilcock (1964) from 25 m.y. to 26 m.y. It usually contains three cooling units that look a great deal like the Edwards Creek Tuff, but it can usually be distinguished either by subtle textural differences or by stratigraphic position. The Bates Mountain Tuff has been mapped outside the region and has tentatively been correlated with a tuff near Eureka, Nev., more than 80 miles to the southeast (Blake and others, 1968). At one locality southwest of the McCoy mine at the north end of the Clan Alpine Mountains, a single welded tuff overlies the upper cooling unit of the Bates Mountain. This tuff is 23.6± 0.9 m.y. old by K-Ar dating (sample 1, table 1).

All the ash-flow-tuff cooling units recognized in the northern area are found south and southwest of the McCoy mine, in the northern New Pass Range. A composite section of these units is shown in figure 3.

OLDER TUFFS

The oldest rock is a densely welded, crystal-poor ash-flow tuff found in a few localities southwest of the McCoy mine. It is discontinuous probably because it was the first Tertiary unit to be deposited on an old irregular erosional surface which developed during Triassic to Oligocene time, or it may have been eroded from parts of the area before the eruption of succeeding ash-flow sheets. It is a structureless brown to pink rock with phenocrysts of sanidine and quartz and a few of biotite and plagioclase. Crystals make up less than 10 percent of the rock. A few lithic fragments, less than a fourth of an inch in diameter, are scattered through the rock. At one place the lower part of the unit consists of about 60 feet of nonwelded to weakly welded tuff which grades upward into a 25-foot-thick black vitrophyre. The welded part of the tuff above the vitrophyre is about 40 feet thick. At other localities only the welded part crops out. The age of this tuff, determined by the K-Ar method on sanidine and biotite mineral separates, is 28.5± 1.1 m.y. and 30.3± 1.2 m.y., respectively (sample 9, table 1). This age is Oligocene (Harland and others, 1964).

The second oldest Tertiary unit is a distinctive dark-colored ash-flow tuff. At some places it lies on the tuff described above, and at other localities on pre-Tertiary rocks. It is dark brown to black and is easily distinguished on aerial photographs from other tuffs.

TABLE 1.—*Potassium-argon dates, analytical data, and location of welded tuffs*

[Potassium analyses by L. B. Schlocker. Argon analyses by E. H. McKee]

Sample (see fig. 1)	Page on which described	Unit and locality	Mineral analyzed	Average K_2O (weight percent: number in parentheses indicates number of analyses)	Ar^{40} rad × 10^{-10} mole per g	$\frac{Ar^{40}\text{ rad}}{Ar^{40}\text{ total}}$	Apparent age (m.y.) ± values explained in text
1	B16	Welded tuff overlying the Bates Mountain Tuff: northeast Clan Alpine Mountains: long 117°33′, lat 39°50′.	Sanidine	8.06(2)	2.84	81.1	23.6 ±0.9
2	16	Bates Mountain Tuff, so-called swiss cheese unit or 3rd cooling unit: north end Antelope Valley: long 117° 16′, lat 40° 0′.	do	7.57(2)	2.62	77.0	23.3 ±0.9
3	15	Bates Mountain Tuff 2nd cooling unit: south end Antelope Valley: long 117° 24′, lat 39° 40′.	do	10.39(2)	3.70	86.4	23.9 ±1.0
4	15	Bates Mountain Tuff, lowest cooling unit: south end canyon of Reese River at south end of Shoshone Mountains: long 117° 9′, lat 39° 56′.	do	10.05(2)	3.70	95.7	24.7 ±1.0
5	14	Tuff of McCoy mine: east edge Antelope Valley: long 117° 18′, lat 39° 49′.	Biotite	4.67(2)	1.83	67.2	26.3 ±1.0
6	13	Edwards Creek Tuff: 4th cooling unit: west edge Antelope Valley: long 117° 28′, lat 39° 52′.	Sanidine	8.94(2)	3.59	82.7	27.0 ±1.0
7	13	Edwards Creek Tuff, 3rd cooling unit: west edge Antelope Valley: long 117° 28′, lat 39° 52′.	do	9.05(2)	3.62	93.8	26.9 ±1.0
8	11	Biotite-bearing tuff, 2nd cooling unit beneath Edwards Creek Tuff: west edge Antelope Valley: long 117° 28′, lat 39° 52′.	Biotite	8.44(2)	3.52	38.5	28.0 ±1.1
9	9	Welded tuff basal unit: north New Pass Range: long 117° 30′, lat 39° 48′.	Biotite Sanidine	8.64(2) 11.22(2)	3.98 4.75	77.1 87.9	30.3 ±1.2 28.5 ±1.1
10	21	Post-New Pass Tuff, top unit: south New Pass Range: long 117° 29′, lat 39° 35′.	Biotite	7.48(2)	2.62	73.1	23.6 ±0.9
11	20	New Pass Tuff: northeast end of New Pass: long 117° 31′, lat 39° 34′.	Sanidine	8.32(2)	2.71	83.8	22.0 ±0.9
12	25	Tuff of McCoy mine (?): central Shoshone Mountains: southwest of Mount Airy: long 117° 22′, lat 39° 31′.	Biotite	7.60(1)	2.96	78.8	26.2 ±1.0
13	18	Welded tuff: approx 2 miles northeast highest peak Desatoya Mountains: long 117° 44′, lat 39° 23′.	do	6.89(2)	2.47	57.3	24.1 ±1.0
14	17	Welded tuff: central part of the Desatoya Mountains: long 117° 37′, lat 39° 28′.	Sanidine	9.87(2)	3.64	86.5	24.8 ±1.0
15	17	Welded tuff: Smith Creek dam, central part of the Desatoya Mountains: long 117° 38′, lat 39° 23′.	do	10.33(2)	3.86	92.9	25.1 ±1.0
16	17	Welded tuff: approx 2.5 miles north Smith Creek Ranch, central part of the Desatoya Mountains: long 117° 38′, lat 39° 25′.	do	10.50(2)	3.98	85.2	25.5 ±1.0
17	18	Biotite-bearing welded tuff, possibly the tuff of McCoy mine: north Desatoya Mountains: long 117° 34′, lat 39° 31′.	Biotite Sanidine	7.91(2) 11.05(2)	3.12 4.14	75.0 88.1	26.5 ±1.0 25.2 ±1.0

Lithologically it too is distinctive, for it contains large flakes of biotite. Crystals make up about 25 percent of the total rock and consist mostly of plagioclase with some biotite and a little sanidine. Small altered pumice fragments, which give the rock a greenish speckled appearance, are ubiquitous, and lithic fragments up to several inches across are scattered throughout. Eutaxitic texture is well developed and causes platy fracturing. This tuff ranges from 50 to 100 feet in thickness; nowhere have nonwelded, weakly welded, or vitrophyric portions been found. A K-Ar date on biotite from the unit is 28.0± 1.1 m.y. (sample 8, table 1). This age is Oligocene (Harland and others, 1964).

On top of the dark biotite-bearing tuff is a third ash-flow welded tuff which also is distinctive and easily recognized in the field. This unit usually lies on the biotite-bearing tuff, but in places it rests directly on pre-Tertiary strata. It is characterized by well-developed eutaxitic texture and numerous lithic fragments. A descriptive and useful name for the rock is a lithic eutaxite. About half the rock consists of pumice fragments as much as an inch in diameter that are flattened to some degree, or that are completely flattened to form large fiamme. Lithic fragments less than 1/8 inch to more than 2 inches in diameter make up about 10 percent of the rock. Thin sections show that crystals of sanidine and plagioclase and a trace of biotite make up 5–10 percent of the rock. In hand specimen the crystals are obscured by blebs of glass and lithic fragments. At most places this tuff is about 100 feet thick and consists of moderately to densely welded rock. At a few localities, nonwelded tuff at the base and top may constitute as much as half the unit.

Stratified air-fall tuff and tuffaceous sedimentary rock lie on top of the lithic eutaxite at some localities. These units are lenticular and cannot be traced along strike for more than about a mile.

EDWARDS CREEK TUFF

At most places the Edwards Creek Tuff lies on the lithic eutaxite with no obvious unconformity. The Edwards Creek Tuff is the most widespread Tertiary formation in the northern New Pass Range. It is here named from exposures along the northeast edge of Edwards Creek Valley. The type section is on the northwest edge of the New Pass Range (or the northeast side of Edwards Creek Valley) in sec. 5, T. 21 N., R. 40 E. The formation contains five ash-flow cooling units which are recognizable over an area of more than 400 square miles. A second good exposure, about 13 miles east of the type section, is on the eastern edge of Antelope Valley

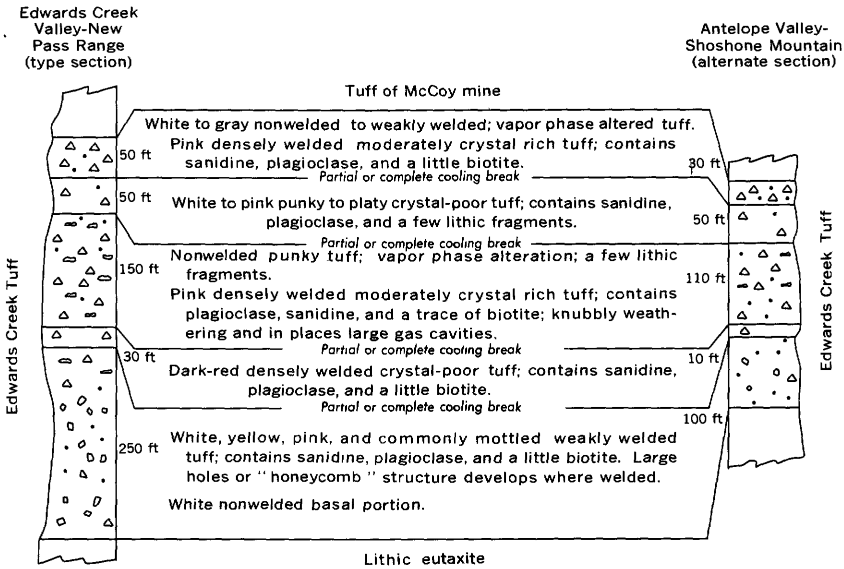


FIGURE 4.—Type and reference sections of the Edwards Creek Tuff.

(sec. 36, R. 41 E., T. 23 N.). The locations of the type and reference sections are shown in plate 1; the two sections are shown in figure 4.

The five cooling units are grouped together in one formation because they always seem to occur together and are similar lithologically. They are underlain and overlain by distinctive mappable welded tuffs. The ages of two of the cooling units, determined by the K-Ar method, are also essentially the same.

The lowest cooling unit is the most variable of the five in thickness and the most poorly exposed. At the type section it is more than 200 feet thick; at other sections it is about half that thickness. It is usually only weakly welded, and at places where it thickens, more than half of it may not be welded. Slopes formed by erosion of this relatively soft unit are usually covered by debris from the overlying densely welded tuffs, and outcrops are rare.

The rock is a white to yellowish tuff containing few crystals. In places large gas cavities give it a honeycomb appearance and cause it to form crumbly slopes. Phenocrysts, which reach a maximum of 2 mm across, consist mainly of sanidine, plagioclase, and a few flakes of biotite.

The second cooling unit is a thin (10–30 ft) densely welded tuff, recognizable because of its bright brick-red color. At a number of localities, however, this marker unit is obscured by debris from the thick tuff which overlies it. This unit is a hard structureless rock with less than 5 percent sanidine phenocrysts, a little plagioclase, and very sparse biotite. No nonwelded or weakly welded parts of the cooling unit can be distinguished.

The most conspicuous cooling unit of the Edwards Creek Tuff is the third unit, the welded portion of which forms a prominent cliff wherever it crops out. This ash-flow tuff ranges from 100 to 170 feet in thickness; the densely welded part is usually about 80 feet thick. The base, although nonwelded to weakly welded, often makes up part of the cliff formed by the overlying densely welded tuff. The upper part of the cooling unit consists of 10–20 feet of nonwelded tuff. This welded tuff is moderately rich in crystals of plagioclase and sanidine (crystals make up about 20 percent of the rock). Large biotite flakes are scattered sparsely throughout. The rock is structureless almost everywhere, but large cavities (½–1 in.) are developed at a few localities in the densely welded part. Except for the abundance of crystals and the presence of biotite, this ash flow looks like some of the units in the Bates Mountain Tuff—a formation that is also widespread in the same region. The age of this cooling unit, determined by the K-Ar method on a sanidine mineral separate, is 26.9± 1 m.y. (sample 7, table 1), which suggests that the rock is Oligocene or Miocene (Harland and others, 1964). The sample was collected about 2 miles east of the McCoy mine about midway between the type and the reference sections.

Above the prominent cliff-forming third cooling unit is a thinner tuff, the fourth cooling unit, which usually forms a low cliff from 10 to 30 feet high. This unit is easily distinguished from the underlying and overlying tuffs because it is platy where densely welded, whereas the densely welded parts of other units form knubbly massive outcrops. It can be distinguished in hand specimen by its low crystal content and lack of biotite. The phenocrysts, which make up 5 percent or less of the rock, are sanidine and plagioclase. Small pieces of magnetite, partially oxidized to limonite, commonly give the rock a speckled appearance. Lithic fragments occur sparsely at some localities. A K-Ar age determination on sanidine from a sample collected 2 miles east of the McCoy mine is 27.0± 1 m.y. (sample 6, table 1). This is the same age (within the limits of analytical uncertainity) as the underlying tuff from the same section and also suggests an Oligocene or Miocene age for this rock (Harland and others, 1964).

The top ash-flow cooling unit of the Edwards Creek Tuff forms a cliff which is usually about 30 feet high. Most of the rock is structureless except where gas cavities have developed, and it forms massive knubbly weathering outcrops. In hand specimen the rock looks like the third cooling unit—the main cliff former. It is moderately rich in plagioclase and sanidine phenocrysts and contains a little biotite. A few lithic fragments occur throughout.

TUFF OF McCOY MINE

The most easily distinguished and useful marker unit in the region is a welded tuff which overlies the Edwards Creek Tuff and underlies the Bates Mountain Tuff. It is informally called the tuff of McCoy mine because it crops out at a number of places a few miles south of the McCoy mine. This unit characteristically forms a cliff about 40 feet high; it may or may not have nonwelded to weaklywelded tuff associated with it. At several places the unit consists of about 150 feet of soft weakly welded tuff with a small thickness of densely welded rock. Locally a black vitrophyre up to 5 feet thick has formed at the base of the densely welded part.

The rock is distinctive because it is moderately rich in biotite. It usually develops platy structure, which is emphasized by the alinement of large biotite flakes on the platy surface. Crystals of plagioclase constitute 20–25 percent of the rock, and biotite and sanidine make up about 5 percent. A biotite mineral separate from a sample collected on the east side of Antelope Valley gave a K-Ar age of 26.3± 1 m.y. (sample 5, table 1). This age suggests that the tuff of McCoy mine is Oligocene or Miocene (Harland and others, 1964).

At a few places a lenticular zone of stratified air-fall tuff and tuffaceous sedimentary rock separates the tuff of McCoy mine from the older Edwards Creek Tuff. This local accumulation of sedimentary strata between the ash-flow sheets suggests that the time interval (26.9± 1 m.y. for the Edwards Creek Tuff and 26.3± 1 m.y. for tuff of McCoy mine) between the units is real, although the ages do overlap within the analytical uncertainity.

BATES MOUNTAIN TUFF

The youngest unit in most of the region is the Bates Mountain Tuff (Stewart and McKee, 1968a; McKee, 1968a), which consists of three to five cooling units. The total thickness of the formation ranges from 200 to 300 feet, depending on the thickness of nonwelded ash in the different cooling units and the number of units present. In most areas, the Bates Mountain Tuff is about 200 feet thick and contains three cooling units. The distribution of the cooling units suggests that the tuff is separated from older rocks by an unconformity and that unconformities may exist between some of the units. The difference in the K-Ar ages between the lowest cooling unit of the Bates Mountain Tuff (24.7± 1 m.y.) and the underlying tuff of McCoy mine (26.3± 1 m.y.), also suggests that there was a hiatus between these units, although the ages overlap within the analytical uncertainty. In the northern New Pass Range and parts of the Shoshone Mountains, the Bates Mountain Tuff rests on the tuff of McCoy mine, but in other places in the Shoshone Mountains it rests on older Tertiary lavas and tuffs or on Mesozoic and Paleozoic strata. The Bates Mountain Tuff has been traced almost continuously for at least 70 miles to the southeast of the central Shoshone Mountains (McKee, 1968a).

Several of the cooling units closely resemble units of the Edwards Creek Tuff but can usually be distinguished by subtle textural and lithologic differences. The lowest unit is a densely welded, knubbly weathering tuff moderately rich in crystals and similar in appearance to the third (the prominent cliff former) and upper units of the Edwards Creek Tuff. It differs from these tuffs in that it usually lacks biotite. It contains about 15–20 percent crystals—plagioclase, sanidine, and rarely quartz. Biotite is found at a few localities. Most of the unit is massive and megascopically structureless (although it shows well-developed eutaxitic texture under the microscope), but in the densely welded parts slightly flattened gas cavities are common. The ash flow is about 100 feet thick in most places. A sanidine separate from a specimen collected in the Shoshone Mountains yielded a K-Ar age of 24.7± 1 m.y. (sample 4, table 1). A date from a sanidine separate of a specimen collected in the New Pass Range was 23.9± 1 m.y. (sample 3, table 1). The latter specimen was from the unit directly above the tuff of McCoy mine, but it may be from one of the upper Bates Mountain cooling units. Both of these ages suggest that the Bates Mountain Tuff is Miocene (Harland and others, 1964). The formation was originally considered to be Oligocene or Miocene (Stewart and McKee, 1968a) but redefinition of the Oligocene-Miocene boundary by Harland, Smith, and Wilcock from 25 m.y. to 26 m.y., necessitates the change.

The second unit, which is similar to the lowest tuff, is separated at a break which lies within a sequence of nonwelded tuff. This contact cannot be located precisely and may represent a complete cooling break, or it may be a partial cooling break within a compound cooling unit. In either case the second tuff usually forms a low cliff separated from the basal cliff by 20–25 feet of nonwelded to weakly welded tuff. Since two densely welded units do not occur everywhere, the second unit, where it is developed, may well be the upper part of a compound cooling unit.

The most easily recognized cooling unit of the Bates Mountain Tuff is about 150–200 feet from the base of the formation. In the eastern part of the region, it is the top Tertiary unit and forms a low capping cliff (5–20 ft high) on much of the central part of the Shoshone Mountains. In the northern part of the New Pass Range to the west, it is overlain by two additional units. The unit is distinctive because the densely welded part is everywhere full of interconnecting holes ¼–1 inch in diameter. A rock with this texture obviously resembles swiss cheese, so the unit is informally called the swiss-cheese unit in the field. In most places only the densely welded swiss-cheese part is found, but in the area south of McCoy mine more than 50 feet of moderately welded eutaxitic tuff lies above the marker zone. The swiss-cheese unit contains 5 percent or less of crystals; these are sanidine, plagioclase, and quartz. The low crystal content helps distinguish it from the lower Bates Mountain cooling units. A K-Ar date on sanidine from a sample collected in Antelope Valley is 23.3± 0.9 m.y. (sample 2, table 1). This age suggests that the cooling unit is Miocene (Harland and others, 1964).

In the area approximately 5 miles west of the McCoy mine, two welded-tuff cooling units lie on top of the swiss-cheese unit. These are included in the Bates Mountain Tuff in this paper because they have a somewhat similar lithology, but they may be parts of unrelated younger tuffs. The lower of the two is a dark-red eutaxitic tuff about 50 feet thick with relatively few phenocrysts of sanidine and plagioclase. On top of this tuff is a structureless tuff with sparse crystals of sanidine and quartz. The tuff grades from punky and bricklike to hard and porcelainlike, depending on the degree of welding.

YOUNGEST TUFF

The youngest welded tuff in the northern area crops out on top of the Bates Mountain Tuff at one locality west of McCoy mine (loc. 4, pl. 1). This tuff has been mapped along the strike for about 2 miles and may be more widespread west of the region covered in this paper. It can be distinguished from all other rocks in the area because of the presence of large euhedral sanidine crystals which exhibit bright-blue chatoyance. A few crystals of smoky quartz are also present. Except for the chatoyant sanidine and smoky quartz, the unit is similar to a number of the other ash-flow tuffs in the region. Most of it is pink, densely welded, and crystal poor with only a little nonwelded to weakly welded tuff at its base. The unit rests directly on the uppermost cooling unit of the Bates Mountain Tuff; however, less than 2 miles away where stratified sedimentary rocks lie on the Bates Mountain, the chatoyant sanidine tuff is missing. This relationship suggests that an unconformity exists at the base of the unit. A K-Ar date on sanidine from the rock is 23.6± 0.9 m.y. (sample 1, table 1), which falls within the age range, considering the analytical precision, of the Bates Mountain Tuff.

SOUTHERN PART OF THE REGION

The northern part of the Desatoya Mountains, the southern end of the New Pass Range, and the Mount Airy part of the Shoshone Mountains contain a series of welded ash-flow tuffs, air-fall tuffs, and sedimentary units that differ from those directly to the north. The stratigraphy of the southern New Pass Range(approximately in the middle of the southern region) is transitional between the Mount Airy and Desatoya sections. Although the tuff stratigraphy of the southern New Pass Range is made complex by the lenticularity of the sedimentary units, one of the welded tuffs found in the Desatoya Mountains is recognized in the Mount Airy part of the Shoshone Mountains as well. The rocks from the Desatoya Mountains, southern New Pass Range, and the Mount Airy part of the Shoshone Mountains are described separately.

DESATOYA MOUNTAINS

The thickest stratigraphic section in the southern area is in the Desatoya Mountains. The maximum thickness of a composite section containing the five welded tuffs recognized in this area is more than 2,000 feet, but no single exposure contains more than about 1,400 feet. Unlike the welded tuffs from the northern area, all the tuffs are lenticular and vary widely in thickness; furthermore, they do not resemble each other in lithology. These features and their limited distribution suggest that they are the distal edges of tuffs from different sources.

TUFFS OF UNCERTAIN STRATIGRAPHIC POSITION

South of the area shown on the map, most of the Desatoya Mountains are underlain by a thick (probably more than 1,000 ft) welded tuff or series of similar welded tuffs that are very difficult to distinguish in the field. Vitrophyre pods, zones of partial welding, and zones with abundant lithic debris can only be traced a short distance along the strike. Where these markers are missing, the welded tuff is a uniform rhyolitic crystal-poor rock, with black fiamme in places where welding has not completely obliterated the pumice fragments. In an attempt to distinguish or correlate units, three samples were collected from different localities and K-Ar ages determined from sanidine mineral separates. All three ages are approximately 25 m.y. old (24.8± 1, 25.1± 1, 25.5± 1 m.y.; samples 14, 15, 16, table 1), suggesting that the entire mass of tuff is nearly contemporaneous. In the central part of the Desatoya Mountains (south of the map, pl. 1), this thick rhyolite tuff appears to be unconformably overlain by one or two lithologically different welded tuffs. A biotite separate from one of these overlying tuffs gave a K-Ar age of 24.1± 1 m.y. (sample 13, table 1), which is the same age, within the analytical uncertainity, as the thick underlying body of tuff. The relationship of the thick rhyolite tuff to the series of tuffs at the north end of the Desatoya Mountains is uncertain. The rhyolite tuff seems to thin abruptly at about the southern edge of the map (pl. 1) and may be represented by one of the thin crystal-poor tuffs midway in the section at the north end of the Desatoyas. Potassium-argon ages of units at the top and bottom of this section are younger and possibly older (22.0± 0.9 m.y., sample 11, table 1, and a mineral pair which is 26.5± 1 and 25.2± 1 m.y., sample 17, table 1) than the crystal-poor rhyolite to the south.

The series of readily distinguishable welded tuffs at the north end of the Desatoya Mountains contrasts with the thick homogeneous mass of tuff in the central part of the range. Five mappable ash-flow units make up the northern series (fig. 5). The units can be traced northward, but within less than 10 miles (in the vicinity of New Pass) three of them pinch out leaving one or two thick wedges of tuffaceous sedimentary rocks making up more than half of the section.

OLDER TUFFS

The basal unit of the welded tuff series from the northern part of the Desatoya Mountains is a pinkish tuff, which contains less than 5 percent plagioclase and sanidine phenocrysts. At most localities it is hard and densely welded, but large flattened pumice fragments show that some zones are only partly welded. This welded tuff does not seem to extend north as far as New Pass. Its probable temporal equivalent in the southern New Pass Range is a massive to stratified tuffaceous rock which forms extensive badland topography southwest of New Pass.

The second-oldest welded tuff is a distinctive biotite-bearing rock. It forms a cliff 50–100 feet high that can be traced on the ground or on aerial photographs throughout most of the northern Desatoyas and serves as a useful marker unit. Like most of the ash-flow tuffs in the region, the unit is densely welded throughout. It contains from 15 to 20 percent crystals, mainly sanidine, plagioclase, and a little quartz and biotite. The presence of biotite

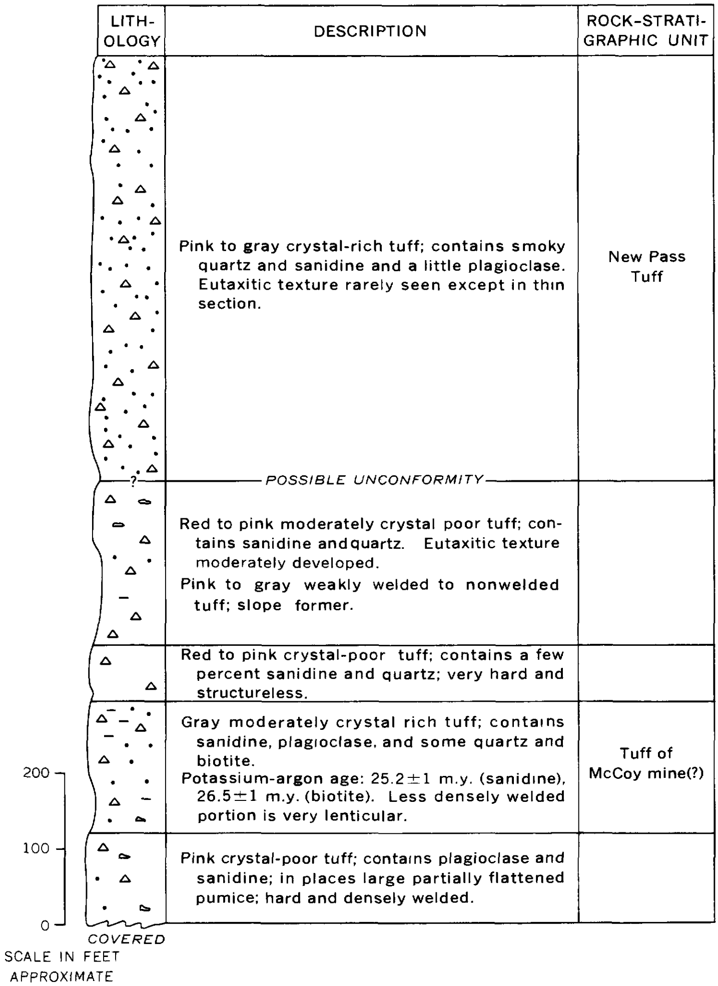


FIGURE 5.—Composite section, northern end Desatoya Mountains.

distinguishes it from all the other tuffs in the section. Potassium-argon ages were determined on the mineral pair biotite and sanidine from the same hand specimen. The ages are 25.2± 1 m.y. and 26.5± 1 m.y., respectively (sample 17, table 1). These ages suggest that the unit is Oligocene or Miocene (Harland and others, 1964). A similar welded tuff (see section on "Southern New Pass Range") of about the same age crops out in the Mount Airy region of the Shoshone Mountains 10 miles to the east, and these tuffs are tentatively correlated with the tuff of McCoy mine (see section on "Tuff of McCoy mine").

On top of the biotite-bearing tuff is a thin (25–50 ft) cliff-forming red to pink crystal-poor tuff. Most of this rock is very densely welded; no trace of eutaxitic texture is visible except in thin section. Slightly less welded parts contain occasional large gas cavities, but no welded texture is visible to the naked eye. Phenocrysts of sanidine and a few of quartz make up less than 5 percent of the rock.

A similar, but less densely welded tuff lies on top of the red unit. This ash flow is about 200 feet thick; the lower 120–150 feet forms a slope which steepens into a cliff about 50–75 feet high at the top of the unit. This cliff usually erodes into jagged spires or pinnacles. The slope-forming part of the tuff is weakly to moderately welded; the cliff is densely welded. All of the unit has eutaxitic texture, but it is best developed in the densely welded parts of the tuff. Between 5 and 10 percent of the rock is made up of phenocrysts of sanidine and a little quartz. Overlying this ash-flow unit is the New Pass Tuff which caps the Desatoya Mountains in this area.

NEW PASS TUFF

A thick distinctive crystal-rich welded tuff that serves as a useful stratigraphic marker is widespread in the northern Desatoya Mountains, the New Pass Range, and the Mount Airy part of the Shoshone Mountains. The unit is here named the New Pass Tuff for exposures in New Pass, the canyon which separates the Desatoya Mountains from the New Pass Range.

The exposures on both sides of New Pass in sec. 30, T. 20 N., R. 40 E. are designated the type locality. The northernmost peaks of the Desatoya Mountains (secs. 22 and 15, T. 19 N., R. 39 E.), considered a reference section, constitute equally good exposures. In neither of these sections, however, is the entire thickness of the formation present. The basal contact can be mapped for several miles at the reference section in the northern Desatoyas, but the upper contact has been eroded. In the vicinity of the type locality at New Pass, the upper contact is exposed beneath tuffaceous sedimentary rocks, but the basal contact is not exposed. In the western end of New Pass and in the northern Desatoyas, more than 400 feet of this unit crops out. East of New Pass the tuff thins to less than 100 feet, and at one locality approximately 4 miles east of New Pass, where both the top and bottom are exposed, the unit is only about 50 feet thick. The formation probably ranges from 50 to 500 feet in the area described in this paper.

The New Pass Tuff contains about 40 percent smoky quartz and slightly chatoyant sanidine phenocrysts in approximately equal amounts, and less than 5 percent plagioclase. Eutaxitic texture can rarely be seen, but flattened pumice fragments are visible in thin section. In most places the rock is pale red to lavender and is densely welded.

A K-Ar date on sanidine from a sample collected at the east end of New Pass is 22.0± 0.9 m.y. (sample 11, table 1), which suggests a Miocene age (Harland and others, 1964) for the New Pass Tuff.

SOUTHERN NEW PASS RANGE

A series of lenticular tuffaceous sedimentary rocks, air-fall tuffs, and nonwelded tuffs lie on top of the New Pass Tuff a short distance both north and south of New Pass (pl. 1, and fig. 6). The New Pass Tuff is also underlain by lenticular tuffaceous rocks and nonwelded tuffs a few miles east of New Pass, and it seems likely that both these underlying and overlying strata represent a continuing period of deposition interrupted by the New Pass Tuff. This sedimentary sequence in the vicinity of New Pass is capped by two other welded tuffs that form several small mesas in that area. The lower of these tuffs is a thin unit composed of lavender to pink rock that contains 5–15 percent phenocrysts of sanidine and quartz in about equal amounts. In places partially to com-

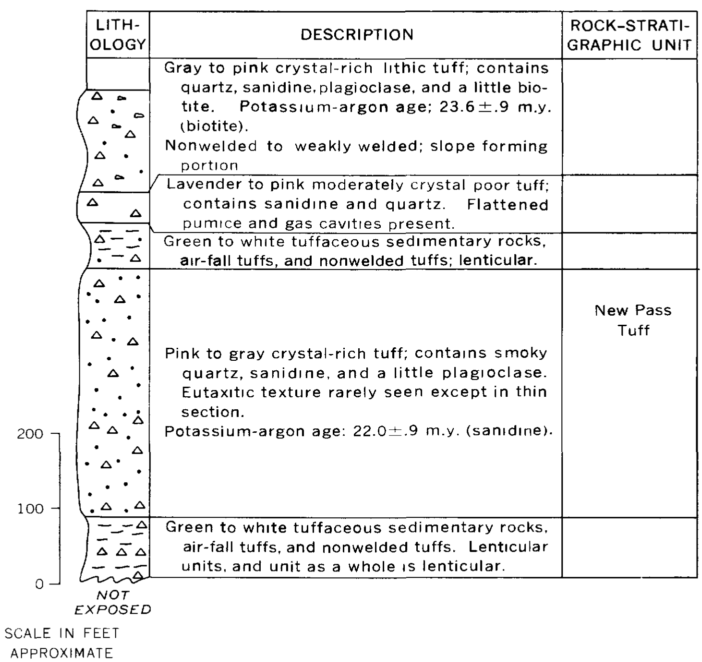


FIGURE 6.—Composite section, New Pass and vicinity.

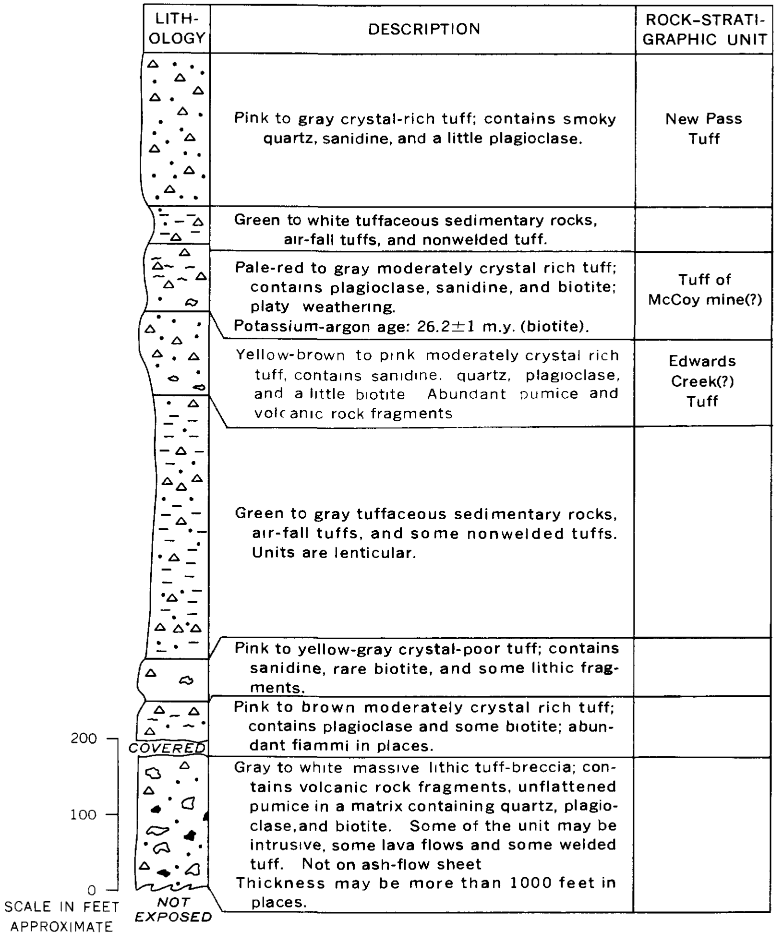


FIGURE 7.—Composite section, Mount Airy area in central part of the Shoshone Mountains.

pletely flattened pumice fragments are common, and more densely welded parts of the tuff contain numerous gas cavities. The second welded tuff forms a cliff less than 20 feet high capping most of the hills adjacent to New Pass. This tuff contains 40 percent or more crystals, including sanidine, quartz, and plagioclase in about equal amounts, and a little biotite. Lithic fragments are scattered throughout the rock. This welded tuff is the youngest rock in the region; it yielded a K-Ar date on a biotite separate of 23.6± 0.9 m.y. (sample 10, table 1), which overlaps (within the precision of the method) the age of the underlying New Pass Tuff. This age suggests that the unit is Miocene (Harland and others, 1964).

CENTRAL PART OF THE SHOSHONE MOUNTAINS (MOUNT AIRY AREA)

Near Mount Airy in the Shoshone Mountains, a series of six welded tuffs and two units of nonwelded tuff and tuffaceous sedimentary rock crop out (fig. 7). The total thickness of these rocks is about 1,000 feet; most of the welded tuffs are less than 200 feet thick. One of these—the New Pass Tuff—can be mapped westward into the southern end of the New Pass Range and farther to the southwest into the Desatoya Mountains. Another unit is correlated, on the basis of similiar lithology and K-Ar age, with the tuff of McCoy mine (see section on "Tuff of McCoy mine") and with the second oldest unit in the northern Desatoyas. The remaining welded tuffs are not recognized west of the Shoshone Mountains, and the sedimentary units are only tentatively correlated with tuffaceous strata west of the region. The source of most of these isolated tuffs is unknown.

OLDEST VOLCANIC ROCKS

The oldest unit is a thick massive body of slightly welded tuff that does not have the planar features that are typical of the other welded tuffs in the region. Most of the unit is a poorly sorted mass of debris made up of angular volcanic rock and pumice fragments, as much as 6 inches across, in a matrix containing a little quartz, plagioclase, and biotite. At most localities this rock is silicified or altered to a chalky siliceous material. The pumice fragments are flattened slightly, and a eutaxitic texture is weakly developed at only a few places. Associated with the non-stratified to poorly stratified lithic-pumice tuff-breccia are large structureless bodies of dense rock similar to the matrix of the tuff-breccia but containing a few lithic fragments and no pumice. The distribution and thickness of these bodies suggest that they are intrusive, although they grade into the tuff-breccias. These types of rock (massive intrusive(?) and lithic-pumice tuff-breccia) and associated thin rhyolite lava flows are exposed in the Shoshone Mountains approximately 15 miles south of the area shown on the map (see fig. 1) and are at least 1,000 feet thick at a number of places. It seems likely that all these rocks are related to a local volcanic center which is represented by intrusive domes and small extrusive flows. These volcanic rocks are in contrast to the widespread stratified ash-flow tuffs (all the other units described in this paper) that blanket most of the region.

OLDER TUFFS AND SEDIMENTARY ROCKS

On top of the massive tuff-breccia is the lowest unit in a series of thin welded tuffs exposed north of Highway 50 near Mount Airy (pl. 1). This welded tuff forms a ledge less than 40 feet high which projects from the alluvium at one locality on the east side of the range (loc. 5, pl. 1). Its total thickness is unknown because its basal contact is covered, but it probably is on the order of 100 feet. A thin layer of soft weakly welded tuff lies between the densely welded portions of this and the overlying tuff, and the contact is probably within this interval.

The tuff is pink to brown, and in places its eutaxitic texture is emphasized by abundant fiamme. Crystals make up about 20 percent of the rock and are mostly plagioclase with some biotite.

The second welded tuff also forms a low cliff about 20 feet high. This unit can be distinguished from the underlying tuff because of its low crystal content (about 10 percent) of sanidine and very rarely biotite. The sanidine is slightly chatoyant. The presence of a few scattered lithic fragments also helps to distinguish it from the older unit.

On top of the two thin welded tuffs is a sequence of nonwelded tuff and tuffaceous sedimentary rock which has a maximum thickness of about 400 feet. No attempt was made to map units within this sequence because most of them are lenticular and cannot be traced with certainty outside of the area. Most of these rocks are green to gray soft slope-forming units that resemble much of the Tertiary sedimentary rock throughout Nevada. They are tentatively correlated with the tuffaceous rock southwest of New Pass because of their stratigraphic position.

EDWARDS CREEK(?) TUFF

An ash-flow tuff overlies the tuffaceous strata, and its basal contact merges with these strata. The unit is about 100 feet thick, and midway in the unit the more densely welded parts of it form a cliff about 50 feet high. The weakly welded tuff of this ash flow is pink to white and has abundant pumice and volcanic rock fragments as well as a moderate number of crystal phenocrysts. The densely welded tuff is red to brown and is hard and structureless. The crystals make up 10–15 percent of the rock and are mostly sanidine with a lesser amount of quartz and plagioclase. A few small flakes of biotite can be seen in an average-sized hand specimen. The rock looks like Edwards Creek Tuff, and its position beneath a distinctive biotite-bearing welded tuff that has a K-Ar age of about 26 m.y. (the same age as the tuff of McCoy mine) suggests that it may be one of the cooling units of the Edwards Creek Tuff.

TUFF OF MC COY MINE(?)

The next youngest unit in the vicinity of Mount Airy is a welded tuff that is distinctive in that it contains a moderate amount of biotite. This mineral is particularly evident on the surfaces of slabby blocks. The tuff is between 40 and 100 feet thick, the upper half forming a cliff of moderately to densely welded rock. Thin sections show that the rock is moderately rich in crystals, containing 20–25 percent of plagioclase and sanidine and several percent of biotite. A K-Ar age of a biotite separate from this unit is 26.2± 1 m.y. (sample 12, table 1). This welded tuff is like the tuff of McCoy mine in that both have a high content of biotite, weather in the same slabby way, and have about the same K-Ar age (26.2± and 26.3± 1 m.y., respectively). This tuff also has about the same lithology and K-Ar age as the second oldest welded tuff in the northern Desatoya Mountains (see section on "Desatoya Mountains") with which it is tentatively correlated.

NEW PASS TUFF AND UNDERLYING SEDIMENTARY ROCKS

Between the biotite-bearing tuff and the New Pass Tuff is a thin sequence of tuffaceous sedimentary rocks and soft nonwelded tuff. These strata probably correlate with similar rocks beneath the New Pass Tuff near New Pass and are probably part of a continuous sequence represented by deposits on top of the New Pass Tuff as well. It seems likely that they are more nearly the age of the New Pass Tuff (22± 0.9 m.y.) than of the underlying biotite-bearing tuff (26.2± 1 m.y.), although they may have accumulated continuously throughout this 2–6-m.y. interval. The New Pass Tuff is the youngest unit in the vicinity of Mount Airy. However, 4 miles northeast to 5 miles northwest of Mount Airy there is a still higher unit consisting of a crystal-poor tuff containing sanidine and quartz (fig. 6). Locally a third tuff of uncertain affinities separates the New Pass Tuff from the top crystal-poor unit.

SUMMARY OF STRATIGRAPHY

As many as 19 ash-flow tuffs are recognized in the New Pass Range, the northern Desatoya Mountains, and the central part of the Shoshone Mountains. Four of these tuffs can be mapped across half or more of the region; the remaining units have more limited distribution. Lenses of sedimentary rock up to several hundred feet thick occur at various places between the ash-flow tuffs.

In the northern two-thirds of the region, 13 tuff cooling units are recognized. Most widespread and thickest of these is the Edwards Creek Tuff, consisting of as many as five cooling units. Directly on top of the Edwards Creek Tuff, is a thin, distinctive, biotite-bearing unit informally called the tuff of McCoy mine. This unit has about the same distribution as the Edwards Creek Tuff. The youngest unit in all but one place in the northern region is the Bates Mountain Tuff, usually made up of three cooling units. This formation has been mapped for at least 70 miles southeast of the area described here.

The Edwards Creek Tuff and the overlying tuff of McCoy mine are correlated with rocks in the vicinity of Mount Airy in the Shoshone Mountains. Other welded tuffs from Mount Airy bear little resemblance to units farther north. The most widespread unit at Mount Airy—the New Pass Tuff—can be mapped in the southern New Pass Range and in the northern part of the Desatoya Mountains. Across most of the southern third of the region this welded tuff is the youngest rock, although there are several units on top of it in the vicinity of New Pass and in the southern part of the New Pass Range. Most of the welded tuffs beneath the New Pass Tuff in the northern Desatoyas do not seem to correlate with rocks in the same stratigraphic position elsewhere (central part of the Shoshone Mountains and New Pass Range). One unit near the base of the Desatoya section may be the tuff of McCoy mine, but this correlation is uncertain.

Tuffaceous sedimentary rocks at different localities and at different places in the stratigraphic column generally look alike. Some of these strata are approximately the same age but are separated stratigraphically by one or more ash-flow tuffs. Other units are of widely different ages. In deciphering the stratigraphy the welded tuffs serve as isochronal planes and can be relied on for correlation, but the sedimentary units may be of different ages and consequently are less reliable for correlation.

POTASSIUM-ARGON DATES

ANALYTICAL TECHNIQUES

Analyses were made on sanidine or biotite mineral separates from hand specimens considered representative of a particular unit. For two samples, 9 and 17 (table 1), the mineral pair sanidine and biotite were taken from the same specimen. Ash-flow units characterized by an abundance of lithic fragments were not dated, and any minor lithic fragments visible in the samples were removed in the field or after initial crushing. From most rocks 1–2 grams of pure or nearly pure mineral was obtained; this was split three times, giving five representative samples. The final splits were used for two potassium analyses, one of the second splits for argon analysis, and the remaining sample was saved for repeat analyses if necessary. However, no repeat analysis seemed necessary because all the dates obtained were compatible with the stratigraphic framework seen in the field. The two mineral pairs also agreed within the limits of the analytical precision.

The argon analyses were carried out using standard isotope-dilution techniques on a Nier-type, 6-inch-radius, 60°-sector mass spectrometer. The potassium analyses were done by flame photometer using a lithium internal standard.

The decay constants used for K^{40} are $\lambda e = 0.585 \times 10^{-10}$ yr^{-1} and $\lambda_\beta = 4.72 \times 10^{-10}$ yr^{-1}, and the atomic abundance of K^{40} is 1.19×10^{-4}. Errors shown as ± values have been assigned on the basis of experience with duplicate analysis and uncertainties in the individual runs. They 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 concentration of the flame photometer standards. Errors range from 3 to 4 percent of the calculated ages.

DATES AND STRATIGRAPHY

The relative age of a number of the welded tuffs was established by their stratigraphic position and, if possible, K-Ar ages were determined for major cooling units in the sequence. Usually units in stratigraphic contact in the series are the same age within the limits of the analytical uncertainty, but end members (top and bottom units) in a series can be separated on the basis of their age. (See pl. 2, bottom stratigraphic section.) In several areas, if lithologic correlations are correct, some of the units are separated by a hiatus of long-enough duration to be indicated by the K-Ar data. (See section on "Older tuffs and sedimentary rocks.")

The bar diagram shown in plate 2 emphasizes the overlap in apparent age between successive units. It also shows the general agreement between the individual age determinations (center point on each bar) and the stratigraphic position of successive units. As would be expected, lower units give older average ages than overlying units. Nowhere did a stratigraphically younger tuff give an older age than the unit below it (the plus and minus factor being considered), and at mose places the series of ages corresponds to the sequence of tuffs. However, for post-New Pass and New Pass Tuff (samples 10 and 11, pl. 2 and table 1) and welded tuff overlying the Bates Mountain Tuff and Bates Mountain Tuff (samples 1 and 2, pl. 2; and table 1), the ages obtained without regard to the plus or minus value were the reverse of that expected; but as plate 2 shows, the dates overlap when account is taken of the plus or minus factor. Repeat analyses would probably only confirm that these units are the same age within the analytical uncertainty although the average age, without consideration of the analytical uncertainty, might be reversed.

REFERENCES

Armstrong, R. L., Ekren, E. B., McKee, E. H., and Noble, D. C., 1969, Space-time relations of Cenozoic silicic volcanism in the Great Basin of western United States: Am. Jour. Sci., v. 267, p. 478–490.

Blake, M. C., Jr., McKee, E. H., Marvin, R. F., and Nolan, T. B., 1968, Stratigraphy and geochronology of Tertiary volcanic rocks, Eureka, Nevada [abs.]: Geol. Soc. America, Inc., Cordilleran Sec.—Seismol, Soc. America —Paleont. Soc., Pacific Coast Sec., 64th ann. mtg., Tucson, Ariz., 1968, Program, p. 38.

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

Harland, W. B., Smith, A. G., and Wilcock, Bruce, eds., 1964, The Phanerozoic time-scale—A symposium dedicated to Professor Arthur Holmes: Geol. Soc. London Quart. Jour., supp., v. 120s, 458 p.

McKee, E. H., 1968a, The Bates Mountain Tuff of central Nevada [abs.]: Geol. Soc. America, Inc., Cordilleran Sec.—Seismol. Soc. America—Paleont. Soc., Pacific Coast Sec., 64th ann. mtg., Tucson, Ariz., 1968, Program, p. 81.

——— 1968b, Geologic map of the Spencer Hot Springs quadrangle, Lander County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ-770, scale 1:62,500.

Stewart, J. H., and McKee, E. H., 1968a, Geologic map of the Mount Callaghan quadrangle, Lander County, Nevada: U.S. Geol. Survey Geol. Quad. Map GQ–730, scale 1:62,500.

——— 1968b, Geologic map of west-central part of Lander County, Nevada: U.S. Geol. Survey open-file map, May 6, 1968, 1:62,500.

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