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GEOLOGY AND MINERAL DEPOSITS OF LANDER COUNTY, NEVADA

(Prepared cooperatively by the United States Geological Survey)

PART I **GEOLOGY**

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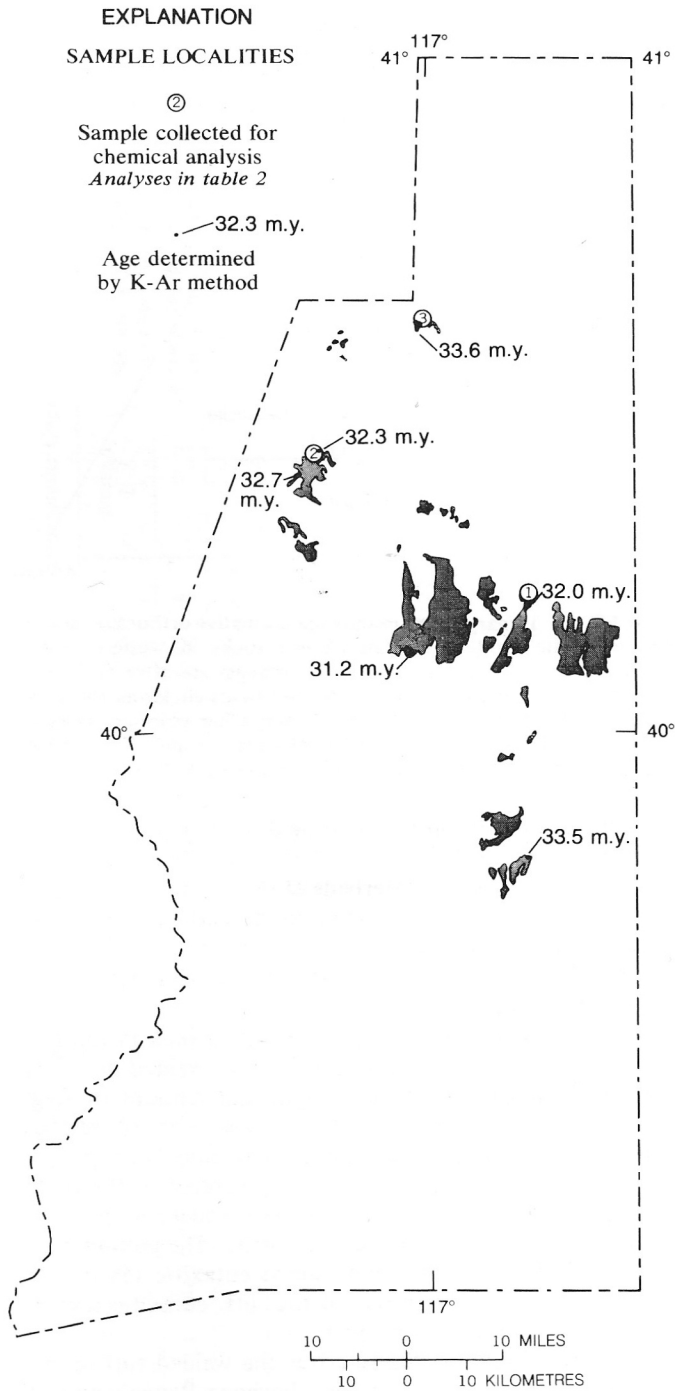


FIGURE 11. Map showing distribution of the Caetano Tuff in Lander County, location and age of samples dated by K-Ar method, and location of chemically analyzed samples.

consideration here because the anomalously high K_2O and low Na_2O percentages suggest that it is altered), show a higher percentage of SiO_2 than the three shown here and a significant difference in Al_2O_3 and alkalis. One of the samples (no. 2, table 6) is nearly identical to the three analyzed here.

Age. On the basis of 12 radiometric ages, 10 K-Ar and 2 fission track (listed in table 3, with a reference to their source), the Caetano Tuff is considered to be Oligocene.

The formation was originally dated as Oligocene(?) by Gilluly and Masursky (1965, p. 78) and subsequent dates (Wells and others, 1971, p. C132) confirm an Oligocene age.

Edwards Creek Tuff

The name Edwards Creek Tuff was proposed by McKee and Stewart (1971) for a group of five lithologically similar ash-flow cooling units which crop out in northeastern Churchill County and farther east in the west-central part of Lander County (fig. 13). The type section is on the west flank of the New Pass Range in Churchill County; its reference section is in Lander County at the eastern edge of Antelope Valley (McKee and Stewart, 1971). The five cooling units are combined as one formation because they seem to occur together, are lithologically similar, have the same K-Ar age, and are at most places underlain and overlain by other distinctive mappable units of welded tuff. This formation is the most widespread Tertiary unit in the New Pass Range; isolated outcrops are found as far east as the Shoshone Range. Originally this ash-flow sheet probably covered an area of some 400 square miles; now only distal remnants are found. The combined thickness of all the cooling units is more than 500 feet at the type section; at the reference section it is about 300 feet. In most places, the formation is only about 200 feet thick because one or more of the cooling units may be missing from the bottom or because erosion has removed upper units.

Petrology. All cooling units of the Edwards Creek Tuff are generally similar looking. Variation in amount of welding from place to place gives the rocks a different gross aspect, but this variation is as great within an individual unit as it is between different units. Densely welded portions are typically pink to pale red, moderately crystal-poor to moderately crystal-rich (5 to 25 percent phenocrysts) rock. The crystals are plagioclase and sanidine; some cooling units contain a trace of biotite. In most places the rock is dense and structureless and weathers in a distinctive nubby manner. At places, especially in the basal cooling unit, gas cavities up to 2 inches in diameter have formed, giving the rock a honeycomb structure.

Age. On the basis of two K-Ar dates on samples from two of the cooling units, the Edwards Creek Tuff is considered to be Oligocene or Miocene in age (McKee and Stewart, 1971, p. B13). These dates, both determined on sanidine mineral separates, are 26.9 ± 1.0 and 27.0 ± 1.0 m.y. The Oligocene-Miocene boundary is at 26 m.y. ago according to Harland and others (1964). Confirmation that the K-Ar age is probably correct is seen by the ages of the underlying and overlying cooling units, which have also been dated (by K-Ar methods) and which bracket the age of the Edwards Creek Tuff. These ages are 28.0 ± 1.0 and 26.3 ± 1.0 m.y., respectively.

Fish Creek Mountains Tuff

The name Fish Creek Mountains Tuff was applied by McKee (1970) to a crystal-rich ash-flow tuff that makes up almost the entire southern part of the Fish Creek Mountains (fig. 14). This formation covers about 200 square miles and is found only in, or very near, the Fish Creek

Table 2. Chemical analyses and norms of densely welded Caetano Tuff.

Map No. (fig. 11)	1	2	3
Field No.	6517-2J	10427-5	BM-1
Location	Carico Lake Valley	N. Fish Creek Mountains	E. edge of Battle Mountain
Chemical analyses			
SiO ₂	71.2	70.7	70.3
Al ₂ O ₃	14.6	14.2	14.4
Fe ₂ O ₃	1.7	1.4	1.1
FeO	.34	.56	.90
MgO	.32	.59	.64
CaO	1.7	1.8	1.5
Na ₂ O	3.3	4.2	3.8
K ₂ O	4.8	4.3	4.7
H ₂ O-	.22	.82	.22
H ₂ O+	1.4	.88	2.0
TiO ₂	.25	.34	.31
P ₂ O ₅	.06	.06	.05
MnO	.02	.04	.06
CO ₂	<.05	<.05	<.05
C.I.P.W. norms			
Q	29.71	25.57	26.03
OR	28.39	25.44	27.78
AB	27.95	35.58	32.16
AN	8.05	7.20	7.12
WO	---	.56	---
EN	.80	1.47	1.59
FS	---	---	.34
IL	.48	.65	.59
MT	.44	.95	1.56
AP	.14	.14	.12
C	1.03	---	.45

Mountains. A few isolated outcrops occur about 5 miles from the southern edge of these mountains in the northern Augusta Mountains and northern part of Antelope Valley. Because the ash flows are confined to the Fish Creek Mountains, their source is considered to be within the boundary of that range; its thickness and distribution patterns support this conclusion. Tectonic features suggestive of caldera structure that formed on eruption of the ash flow are present within this body of tuff.

The Fish Creek Mountains Tuff is a composite ash-flow sheet (terminology of Smith, 1960) consisting of at least two ash flows separated by a complete cooling break, and

many other ash flows separated by partial cooling breaks. All cooling breaks, partial or complete, can be traced for distances varying from a few hundred feet to several miles, but they ultimately disappear laterally and the units merge. The complete cooling break is between a lower unit characterized by the occurrence of abundant but variable lithic fragments and an upper unit characterized by absence of these fragments. Around the margins of the Fish Creek Mountains where the ash-flow sheet thins, a pronounced horizontal layering is developed. The layers of identical densely welded tuff are defined by horizontal joints or partings caused by partial cooling breaks. The welded tuff in this area is cut by vertical columnar joints that pass through all units and across the horizontal joints, suggesting that the entire ash-flow sheet cooled at the same time. Radiometric ages and remanent magnetization directions determined at different places within the ash flow support the conclusion that cooling was nearly simultaneous throughout the tuff body (McKee, 1970). In the south-central Fish Creek Mountains, where the welded tuff is thickest (3,000 feet or more), horizontal layering of the ash flow has not developed. Here it is a massive uniform rock, cut in places by columnar joints and characterized by large zones of alteration and what seem to be numerous faults. This core area of altered and structurally chaotic rock contrasts strongly with the layered marginal portions of the ash flow.

Petrology and chemistry. The Fish Creek Mountains Tuff is pink to light-gray, crystal-rich rock that is generally structureless and rarely shows eutaxitic features except in thin section or on wetted polished surfaces. Most of it is densely welded. It contains 30 to 50 percent phenocrysts of smoky quartz and sanidine in a groundmass of devitrified glass. Lithic fragments occur in places and one cooling unit is characterized by local accumulations of volcanic rock fragments which make up as much as 25 percent of the rock at its nonwelded base. This unit becomes progressively more welded upward; near the top, where most densely welded, it contains only a scattering of lithic fragments.

Chemical analyses show that the tuff is a rhyolite, about 74 percent SiO₂, 13 percent Al₂O₃, 1 percent total iron, 0.14 percent MgO, 0.75 percent CaO, and 8.5 percent total alkalis (McKee, 1970). The composition is very close to the average calc-alkali rhyolite of Nockolds (1954), compared in table 4 with an average of two chemical analyses taken from McKee (1970, table 3).

Age. The Fish Creek Mountains Tuff is considered to be early Miocene on the basis of radiometric ages (McKee, 1970). Three K-Ar and two fission-track dates determined on mineral separates from specimens collected at different places within the Fish Creek Mountains give an average age of 24.3±0.7 m.y., which is considered Miocene (Harland and others, 1964).

Bates Mountain Tuff

The Bates Mountain Tuff (Stewart and McKee, 1968a; McKee, 1968d) is the most widespread Tertiary formation in Lander County (fig. 15). Here this ash-flow sheet crops out in a belt extending northwestward from the Toquima

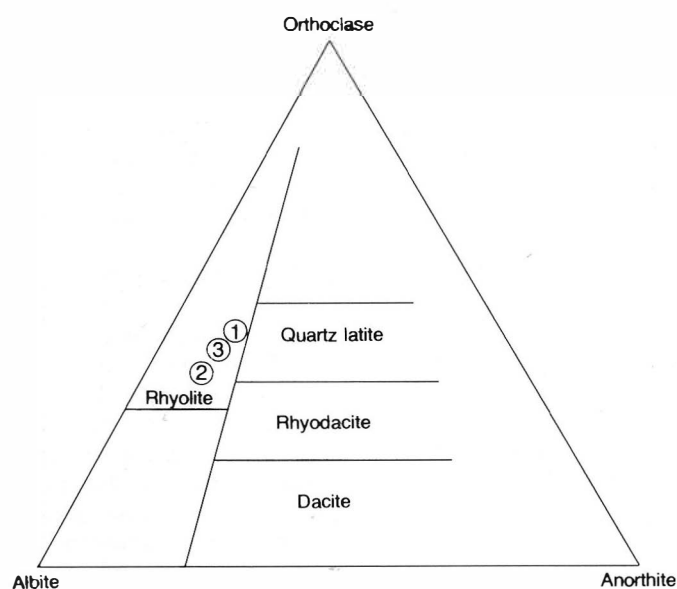


FIGURE 12. Ternary diagram showing normative orthoclase, albite, and anorthite content of three samples of Caetano Tuff. Classification follows O'Connor (1965). Sample numbers correspond to those on figure 11 and in table 2.

Range in the southeast corner of the county into the southern part of the Simpson Park Mountains, across the central part of the Toiyabe Range north of Austin, across the central part of the Shoshone Range northwest of Austin, and into the west-central part of the county where isolated outcrops are found in the northern part of the New Pass Range and Fish Creek Mountains. Outcrops of the formation cover about 250 square miles and at the time of deposition the ash-flow sheet probably covered an area of about 1,500 square miles in Lander County alone. The Bates Mountain Tuff has been recognized and mapped east and southeast of Lander County in the area near Eureka, southeastern Eureka County (Blake and others, 1968) and in northern Nye County (Sargent and McKee, 1969). The extent of the formation including the region outside Lander County is about 3,500 square miles. In most of this region the Bates Mountain Tuff is the youngest formation present.

In Lander County the Bates Mountain Tuff is usually represented by two or three cooling units, but in areas near the edge of the ash-flow sheet only one cooling unit may be present. In the Toiyabe Range the formation consists of four or five cooling units (Sargent and McKee, 1969), but it seems more probable that the upper one is a similar-looking but younger ash-flow sheet with different

TABLE 3. Radiometric ages of Caetano Tuff.

Location	Source of data	Mineral dated	Age	Avg. age
Cortez area, Eureka County	J. D. Obradovich, U. S. Geol. Survey, unpublished data	Biotite Sanidine	34.4±1.1 32.6±1.1	33.5
Northern Toiyabe Range	Armstrong, 1970	Biotite	30.6±0.6	30.6
Northern Toiyabe Range	Armstrong, 1970	RK(?)	31.2±1.0	31.2
Northern Toiyabe Range(?)	Gilluly and Masursky, 1965; G. H. Curtis, Univ. Calif., Berkeley, unpublished data	Biotite	31.5	31.5
East edge of Battle Mountain	McKee and Silberman, 1970	Biotite	33.6±1.3	33.6
Shoshone Range approximately 20 miles south of Mount Lewis	McKee and Silberman, 1970	Biotite Sanidine	31.3±1.3 31.0±1.0	31.2
Toiyabe Range approximately 25 miles south of Cortez	McKee and Silberman, 1970	Biotite	33.5±1.0	33.5
North end of Fish Creek Mountains	McKee and Silberman, 1970	Biotite Sanidine	33.4±1.4 31.3±1.3	32.3
Northwestern part of Fish Creek Mountains	E. H. McKee, unpublished data	Sanidine	32.7±1.1	32.7
North end of Fish Creek Mountains	Naeser and McKee, 1970	(Fission track)		33.3
North end of Carico Lake Valley	Naeser and McKee, 1970	(Fission track)	34.1 35.5 38.5	36.0
West edge, Carico Lake Valley	Naeser and McKee, 1970	Biotite		32.0
Average				32.6

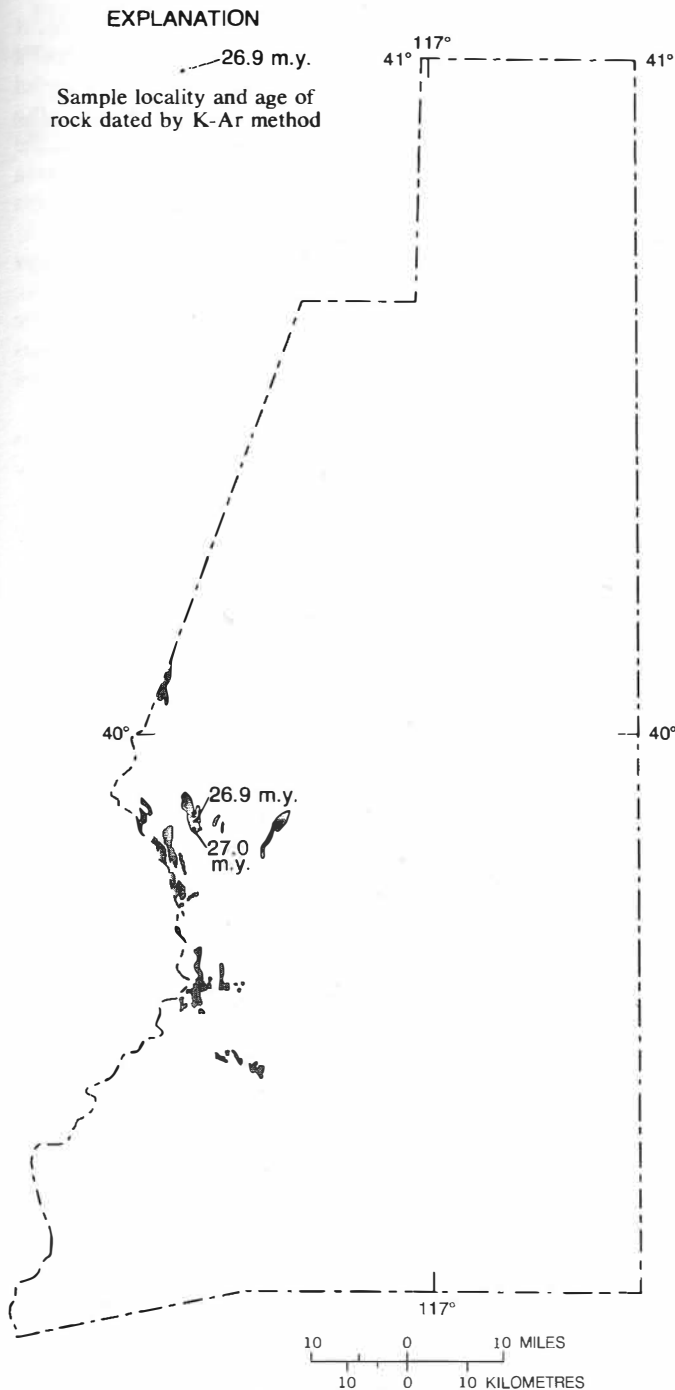


FIGURE 13. Map showing distribution of Edwards Creek Tuff in Lander County, and location and age of samples dated by K-Ar method.

distribution in central Nevada. All cooling units mapped as Bates Mountain Tuff are similar in general aspect as well as in lithology. Typically a cooling unit is 50 to 150 feet thick and consists of a nonwelded basal portion grading upward into a cliff of densely welded and devitrified tuff. In places a thin lenticular zone of black glass occurs at the bottom of the devitrified part, and in a few places a horizon of soft vapor-phase altered tuff forms the top of the cooling unit. Subtle differences such as variation in phenocrysts and

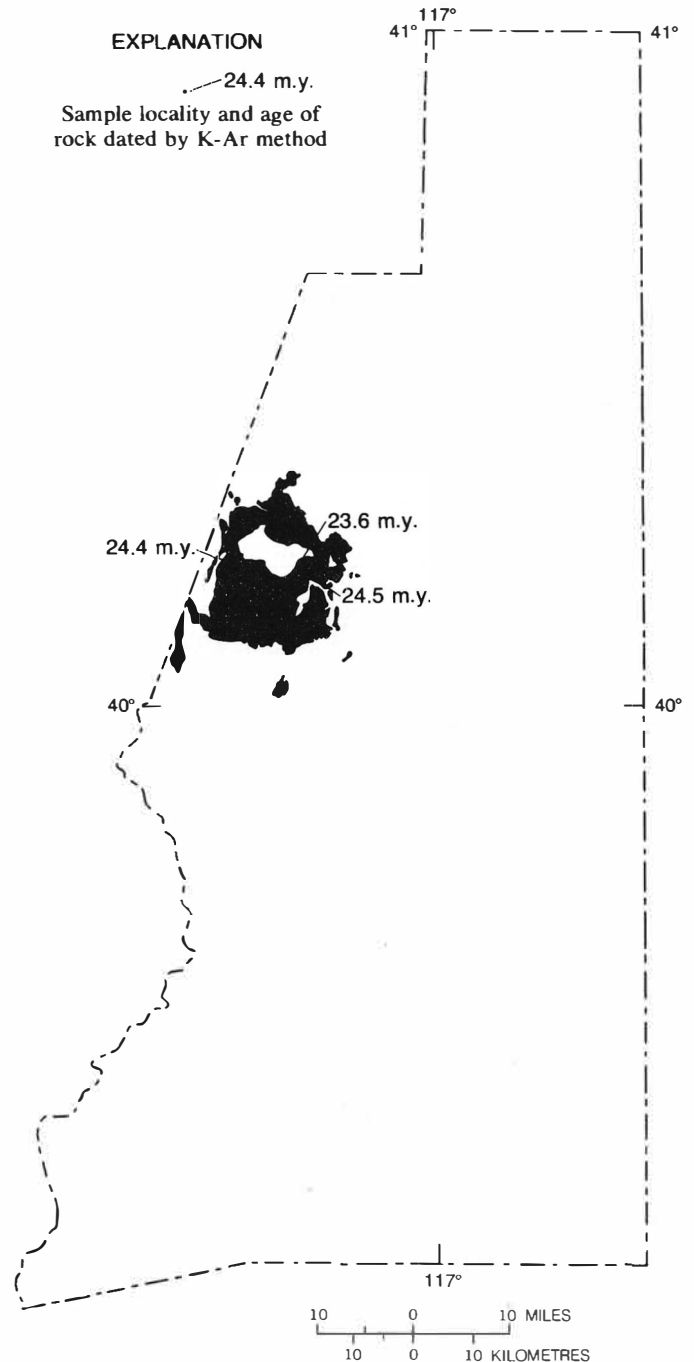


FIGURE 14. Map showing distribution of the Fish Creek Mountains Tuff in Lander County, and location and age of samples dated by K-Ar method.

textural features (gas cavities, platy or nubby weathering) can generally be used to distinguish the cooling units.

Petrology and chemistry. The Bates Mountain Tuff is in general characterized by crystal-poor ash flows that are grayish pink to buff where partially welded to nonwelded and pink to reddish brown where densely welded. The rock is crystal poor, containing less than 10 percent phenocrysts of sanidine and some quartz. A small amount of plagioclase is present in most of the rock and in some of the cooling

TABLE 4. Average of two analyses of Fish Creek Mountains Tuff. (Tuff compared with the average calc-alkali rhyolite and rhyolite obsidian of Nockolds (1954))

	Average of two analyses of Fish Creek Mountains Tuff (McKee, 1970)	Average calc-alkali rhyolite and rhyolite obsidian of Nockolds (1954)
SiO ₂	74.6	73.66
Al ₂ O ₃	12.9	13.45
Fe ₂ O ₃	.97	1.25
FeO	.22	.75
MgO	.13	.32
CaO	.73	1.13
Na ₂ O	3.8	2.99
K ₂ O	5.2	5.35
H ₂ O ⁺	.53	.78
H ₂ O ⁻	.56	--
TiO ₂	.16	.22

units a very small amount of biotite. A detailed petrographic description of the cooling units is given by Sargent and McKee (1969). One of the upper units is distinctive by the presence of ubiquitous gas cavities. This unit, informally called the "swiss cheese" unit, is the most widespread ash flow and the most easily recognized in Lander County and elsewhere.

Chemical analyses of fine samples of Bates Mountain Tuff from densely welded, devitrified parts of three cooling units show these ash flows to be rhyolite (table 5) and all plot within the rhyolite field in the classification of O'Connor (1965) based on normative Or, Ab, and An (fig. 16).

Age. The Bates Mountain Tuff is of Miocene age (McKee and Stewart, 1971, p. B15). Ten radiometric ages have been determined on samples of Bates Mountain Tuff, seven from Lander County and three from localities to the east. These ages, K-Ar, one fission track, have been determined on the upper and lower cooling units; they represent complete geographic coverage of the formation. The upper cooling unit in Lander County, found only in the Toquima Range, is significantly younger than the others; its distribution suggests that it is an unrelated ash-flow sheet. In this report it is called Bates Mountain Tuff, because of general lithologic similarity. The radiometric ages are listed in table 6. The youngest unit (see above) is about 22.1 m.y. old, the oldest about 24.4 m.y., and the intermediate units slightly younger than 24.4 m.y. The radiometric ages of all the units except the upper one overlap within the analytical precision of individual age determinations. The average age of all units, except the upper one, is 23.7 m.y., early Miocene on the time scale of Harland and others (1964).

New Pass Tuff

The New Pass Tuff is a distinctive, moderately widespread ash-flow unit in west-central Lander County (fig. 17) named for exposures at New Pass, a canyon at the south end of the New Pass Range through which U. S. Highway

50 passes (McKee and Stewart, 1971). In the type area, it is more than 400 feet thick; it thins to less than 100 feet a few miles east of New Pass. The formation serves as a useful marker horizon in the southern New Pass Range, the northern Desatoya Mountains, and near Mount Airy of the central Shoshone Mountains, where in each case it is a distinctive unit in a series of lenticular ash-flow sheets otherwise difficult to correlate.

Petrology. The New Pass Tuff is a crystal-rich ash-flow sheet that is densely welded through most of its thickness. Nonwelded to partially welded tuff occurs locally at the base of the unit and east of New Pass, some tuffaceous rocks on top of the formation may include its nonwelded top.

A representative sample of typical densely welded tuff is a pink to gray rock containing 35 to 50 percent smoky quartz and sanidine phenocrysts in about equal amounts, together with a little plagioclase. Eutaxitic texture can rarely be seen except occasionally in thin section. No chemical analysis of this rock is available, but a general similarity in phenocryst mineralogy to other crystal-rich welded ash-flow tuffs in central Nevada (i.e., Fish Creek Mountains Tuff, Windous Butte Formation) suggests that it is a rhyolite.

Age. A potassium-argon date of 22.0±0.9 m.y. on sanidine from a sample collected at the east end of New Pass (McKee and Stewart, 1971) suggests a Miocene age (Harland and others, 1964).

Crystal-poor Rhyolite Ash-flow Tuff, Central Desatoya Mountains

The central part of the Desatoya Mountains in Lander County (fig. 18) is underlain by a thick but lenticular ash-flow tuff or series of similar tuffs that are very difficult to distinguish in the field. Most of this rock is a homogeneous body of densely welded tuff; there are nonwelded to weakly welded zones and vitrophyre pods within the body. The unit covers about 70 square miles in the range in southwestern Lander County and an additional 10 to 20 square miles in adjacent Churchill County. This tabular body of tuff is at least 2,000 feet thick in the east-central part of the range north of State Highway 2, thinning abruptly in all directions within a distance of 10 miles or less. This tuff unit is not found to the east in the Shoshone Mountains, to the north in the northern part of the Desatoya Mountains and New Pass Range, nor to the south in the southern Desatoya Mountains and Paradise Range. The distribution and shape of this tuff body strongly suggest a source within the central part of the Desatoya Mountains.

Petrology. The densely welded tuff is pink to gray, crystal-poor rock that contains less than 10 percent phenocrysts of sanidine and plagioclase. Quartz is uncommon, but occurs in a few specimens. In places the rock has a very distinctive eutaxitic texture and large fragments of pumice partially or completely compressed give the rock a woody appearance. In other localities the unit is glassy and only partially devitrified; the outcrops are deep red to black and contrast with the pink and gray color typical of outcrops where the glass is devitrified.