Description and ?-Ar ages of volcanic units of the Caliente vol canic field, Lincoln County, Nevada, and Washington County

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DESCRIPTION AND K-AR AGES OF VOLCANIC UNITS OF THE CALIENTE VOLCANIC FIELD, LINCOLN COUNTY, NEVADA, AND WASHINGTON COUNTY, UTAH[1]

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The Caliente volcanic field is composed of calc-alkalic ash-flow tuffs and lavas of middle Miocene age erupted from a vent complex centered at approximately lat. 37°35′N., long. 114°15′W., in eastern Lincoln County, Nevada (fig. 1). The field was studied in reconnaissance in the fall of 1965 and the spring of 1966 as part of geologic studies done in connection with investigations of seismic effects of underground nuclear explosion at the U. S. Atomic Energy Commission's Nevada Test Site.

Rocks of the Caliente Volcanic Field

Hiko Tuff

The Hiko Tuff was named by Dolgoff (1963) for exposures near the settlement of Hiko, Lincoln County, Nevada. Cook (1965) assigned the Hiko Tuff member status as part of his Page Ranch Formation and designated its type section as in sec. 3, T. 5 S., R. 62 E., about 6 miles south of U. S. Highway 96 on the east side of the Hiko (South Pahroc) Range, where the Hiko Tuff overlies an unnamed, poorly welded sequence of ash-flow tuff which in turn overlies units of his Condor Canyon Formation. Within the South Pahroc Range (Alamo Range) and elsewhere in the Pahranagat Valley, the Hiko Tuff is overlain by the Kane Wash Tuff. The Hiko Tuff is readily mappable in the Pahranagat Valley, in the Meadow Valley and Delamar Mountains, and in adjacent areas. We consider this ash-flow sheet to warrant formational rank and adopt the name Hiko Tuff for the unit, and on the basis of available K-Ar age determinations (Table 1) assign a middle Miocene age to the formation.

The Hiko Tuff is composed of relatively crystal-rich rhyodacite containing phenocrysts of plagioclase, quartz, alkali feldspar, biotite, hornblende, zircon, apatite, and sphene. Exposures in the Delamar Range west and southwest of Caliente, Nevada, contain many more lithic fragments than do rocks farther west, southwest, and south. Noble and others (1968) interpreted this lateral facies change as indicating that the source of the Hiko Tuff is in the eastern part of the Caliente depression. (The term "Caliente depression" is here used in a nongenetic sense for a roughly circular area of generally low and somewhat subdued topography approximately 20 miles in diameter centered at approximately lat. 37°35′N., long. 114°17′W.). E. B. Ekren, of the U. S. Geological Survey (oral commun., 1972), who recently remapped the region including the Caliente volcanic field, considers the extremely thick section of Hiko Tuff located directly southwest of the town of Caliente, Nevada, to represent a collapse caldera or cauldron subsidence block marking the vent area of the Hiko Tuff. This interpretation is consistent with our observations.

Racer Canyon Tuff

The name Racer Canyon Tuff was first used by Blank (1959) for exposures in the vicinity of Racer Canyon, Washington County, Utah. Cook (1960) adopted the name for a member in his Cove Mountain Formation and later (1965) tentatively correlated the Racer Canyon Tuff with the Hiko Tuff. The Racer Canyon Tuff of Cook, although

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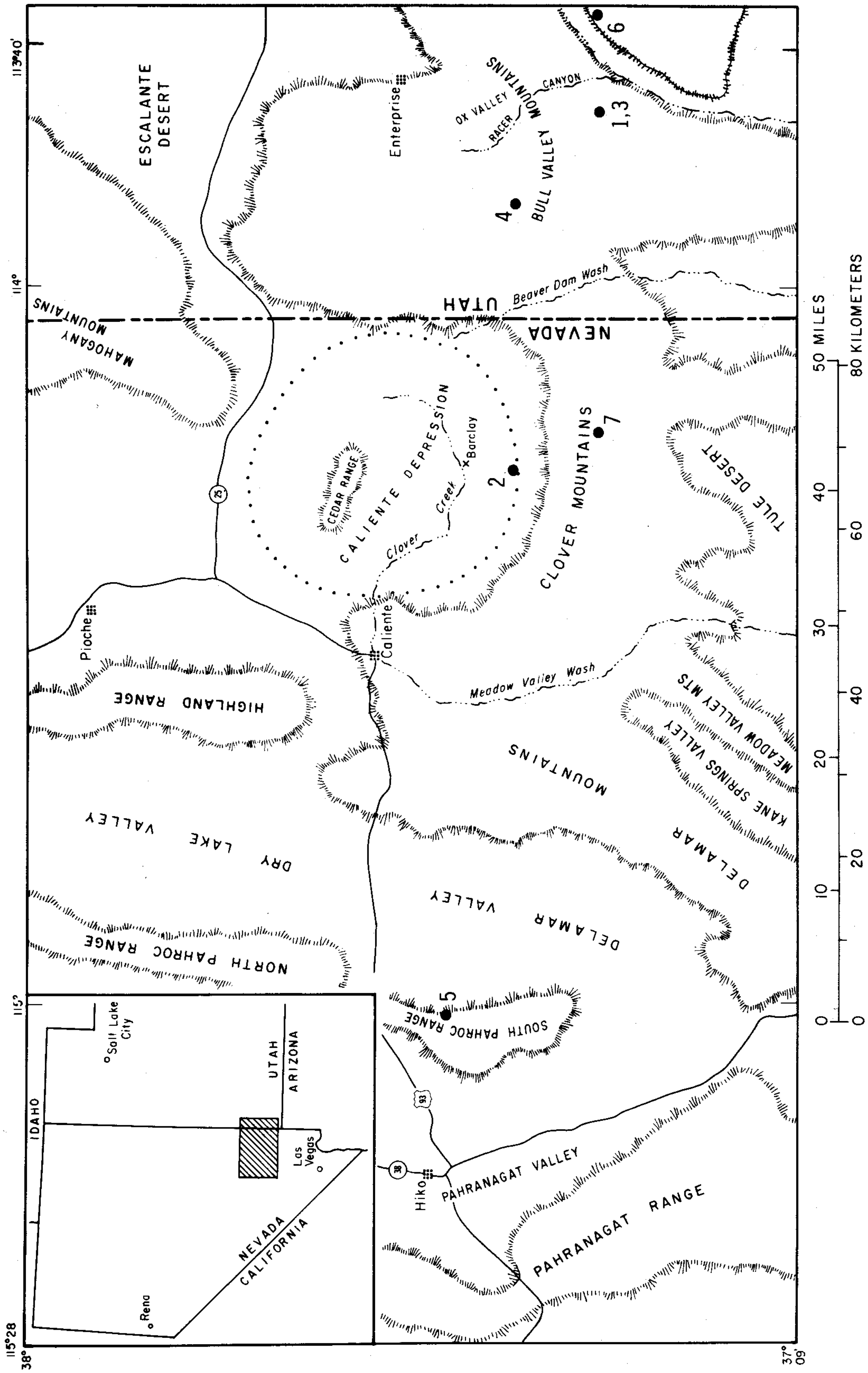

Figure 1. Map showing location of dated rock samples. The numbers are keyed to the sample descriptions.

similar in general appearance to the Hiko Tuff, lacks hornblende and sphene, which are present in appreciable amounts in the Hiko Tuff. We conclude that the units are not correlative but rather are two distinct ash-flow sheets of about the same (about 19 m.y.) age.

Cook (1960) shows the general distribution of the Racer Canyon Tuff in southwestern Utah. Thick sections of this unit also are present northeast and south of the Caliente depression in Lincoln County, Nevada, and rocks exposed to the south in a north-south-trending fault block at lat. 35°46'N., long. 114°13'W., contain appreciably more lithic fragments than rocks at the type section in Utah. As with the Hiko Tuff, we take this as evidence that the Racer Canyon had its source within or very near to the Caliente depression.

Harmony Hills Tuff

The Harmony Hills Tuff Member was first described by Mackin (1960) as a widely distributed crystal-rich ash-flow sheet which underlies both the Hiko Tuff and the Racer Canyon Tuff Member of Cook (1960). Cook (1965) assigned the unit member status in his Quichapa Formation. The age of this formation was considered to be Oligocene or Miocene by Averitt (1967). On the basis of K-Ar ages (Table 1) we consider its age to be Miocene (20-21 m.y.). As the Caliente depression is located approximately at the center of the known distribution of the unit (Cook, 1965), we think it likely that the Harmony Hills Tuff was erupted from a vent or vents located within the Caliente depression early in the history of the Caliente volcanic field.

Table 1 – *Summary of radiometric dates for rocks related to the Caliente volcanic field*

Unit name	Reference	Age (m.y.)
Ox Valley Tuff of Cook	This report	12.3±0.3
do.	do.	15.1±0.4
Hiko Tuff	This report	19.6±0.5
do.	Armstrong, 1970	17.6±0.6
do.	do.	17.7±1.0
do.	do.	17.9±0.4
Racer Canyon Tuff of Cook	This report	18.2±0.5
do.	do.	20.3±0.5
Harmony Hills Tuff Member of Quichapa Fm. of Cook	This report	19.9±0.5
do.	Armstrong, 1970	19.6±0.4
do.	do.	20.4±0.4
do.	do.	20.9±1.0
do.	do.	21.3±0.4
do.	do.	23.8±0.5
Unnamed ash-flow sheet	This report	25.5±0.6

Ox Valley Tuff

The name Ox Valley Tuff was first used by Blank (1959) for exposures in the vicinity of Ox Valley, Washington County, Utah. The name was first published by Cook in 1960. We have recognized this petrographically distinctive unit within the Caliente depression several miles south of Barclay, where it overlies ash-flow tuffs of the Caliente volcanic field with apparent conformity. K-Ar age determinations (Table 1) indicate a late Miocene (about 14 m.y.) age for the unit. As noted by Noble (1968), the Ox Valley Tuff is not, as suggested by Cook (1965), correlative with the late Miocene Kane Wash Tuff, which was erupted from vents many miles southwest of the Caliente depression.

Unaltered gray lavas lithologically very similar to the Ox Valley Tuff of Cook overlie the formation in the southwestern part of the Caliente depression and in the vicinity of Beaver Dam Wash along the Utah-Nevada border. The distribution of the Ox Valley Tuff of Cook and the lithologic similarity of the lavas suggest that the units were erupted from vents near the southeastern margin of the depression. It is not clear whether the Ox Valley Tuff of Cook and the petrologically similar lavas are part of the volcanic episode in the Caliente volcanic field that produced the Racer Canyon Tuff of Cook and the Harmony Hills Tuff or represent a later, unrelated episode of volcanism.

Other Rocks of the Caliente Volcanic Field

At least five ash-flow sheets lithologically similar to the Hiko Tuff and Racer Canyon Tuff of Cook (1960) are exposed along Clover Creek between Caliente and Barclay, Nevada, and beneath the Ox Valley Tuff of Cook (1960), south of Barclay. One of these units is probably the Hiko Tuff. Other unnamed rhyodacitic ore quartz latitic ash-flow sheets are exposed along Nevada Highway 25 west of the Utah-Nevada border.

A very thick ash-flow sheet of rhyodacitic or rhyolitic composition (Table 2, specimen 3) is widespread in the mountains directly south and southeast of the Caliente depression. Although it is located near the Caliente depression, it appears to be considerably older (about 5 m.y.) than rocks considered to have been erupted from vents in the Caliente volcanic field and its relation to this eruptive center is not clear.

Lavas of intermediate to silicic composition are locally exposed in the vicinity of Caliente and within the Caliente depression, as for example, north of Barclay and in the Cedar Range. Other lavas undoubtedly are hidden beneath Pliocene playa deposits and Quaternary alluvium and colluvium which cover much of the depression. Many of the exposed lavas are silicified or otherwise altered.

Potassium-argon Age Determinations

Biotite and sanidine separates were made from seven samples of unaltered welded tuff considered to be representative of three ash-flow sheets erupted from the Caliente volcanic center and one of the ash flows that originated outside the area but spread across it. Of these samples, four were collected and dated in 1966 (see Noble and others, 1968), three in 1968. Analysis was done at the U. S. Geological Survey isotope geology laboratory in Menlo Park, California. K-Ar dates subsequently reported by Armstrong (1970) that are pertinent to the Caliente volcanic field and that corroborate certain of the ages reported here are listed in the summary of all ages (Table 1). Analytical data and location of the seven samples determined here are listed in the sample description section.

K analyses were made by flame photometer using lithium metaborate fusion, the lithium serving as an internal standard; analytical uncertainty was about 0.5%. Ar analyses were done by standard isotope dilution techniques on a Nier-type 6-inch 60°-sector mass spectrometer operated in the static mode; analytical uncertainty of the Ar analyses was about 1.7% for samples containing more than 30% radiogenic Ar. All uncertainties are given at one standard deviation. Constants used in the age calculations are: $\lambda_\epsilon = 0.585 \times 10^{-10} yr^{-1}$; $\lambda_\beta = 4.72 \times 10^{-10} yr^{-1}$; K^{40}/K total = 1.22×10^{-4} gm/gm.

We note unaccountably large discrepancies between the determinations obtained in 1966 and 1968 on specimens of the Ox Valley Tuff of Cook (2.8 m.y.), and the Racer Canyon Tuff of Cook (2.1 m.y.), and between the value obtained by us for the Hiko Tuff and the average of the three determinations reported by Armstrong (1.9 m.y.). We have no way of choosing between the ages and conclude that appropriately weighted averages of the determinations provide the best estimates of the ages of the rock units.

Table 2 – *Percent in weight of major constituents and trace elements in specimens of the Hiko Tuff and of an unnamed ash-flow sheet*

Major Constituent	Sample No. 1	Sample No. 3	Trace Element	Sample No. 1	Sample No. 2	Sample No. 3
SiO_2	67.8	71.6	B	0.002	0.002	0
Al_2O_3	15.9	14.8	Ba	0.13	0.13	0.05
Fe_2O_3	2.3	2.5	Be	<0.0002	0.0002	0.0003
FeO	0.73	0.13	Ce	--	--	0.01
MgO	0.80	0.44	Co	0.0003	0.0003	0
CaO	2.8	1.0	Cr	0.0005	0.0008	0.0002
Na_2O	4.2	3.7	Cu	0.0012	0.0031	0.001
K_2O	3.8	4.3	Ga	0.0018	0.0020	0.003
H_2O^-	0.44	0.45	La	0.006	<0.005	0.007
H_2O^+	0.54	0.25	Mo	0.0002	<0.0002	0
TiO_2	0.49	0.36	Nb	0.002	0.002	0.003
P_2O_5	0.23	0.09	Ni	0.0007	0.0008	0
MnO	0.06	0.05	Pb	0.004	0.004	0.002
CO_2	<0.05	<0.05	Sc	0.0006	0.0006	0.0005
			Sn	<0.0005	<0.0005	0
Sum	100	100	Sr	0.064	0.074	0.007
			V	0.0041	0.0038	0.0015
			Y	0.0020	0.0017	0.007
			Yb	0.0002	0.0002	0.0007
			Zr	0.018	0.014	0.02

Sample data:

No. 1 Hiko Tuff, field no. PA-2: unaltered, densely welded, devitrified specimen from the South Pahroc Range, Lincoln County, Nev. Major elements by rapid methods, P. Elmore, H. Smith, L. Artis, and S. Botts, analysts. Minor elements by quantitative optical emission spectrographic methods, J. Haffty, analyst.

No. 2 Hiko Tuff, field no. EP-4: unaltered, densely welded, devitrified specimen from the southern end of the East Pahranagat Range, Lincoln County, Nev. Minor elements by quantitative optical emission spectrographic methods, J. Haffty, analyst.

No. 3 Unnamed ash-flow unit, field no. C-111-C: densely welded, granophyrically crystallized ash-flow tuff, lat. 37°22'N.; long. 114°13'W. Major elements by rapid methods, P. Elmore, H. Smith, L. Artis, J. Glenn, S. Botts, C. Chloe, and D. Taylor, analysts. Minor elements by semiquantitative (six-step) optical emission spectrographic methods, H. Neiman, analyst.

Chemistry and Petrology

The tuffs and lavas of the Caliente volcanic field are mainly rhyodacites and dacites but appear to include smaller amounts of rhyolite, andesite, and quartz latite. Very limited chemical data and petrographic features such as the general abundance of hornblende and the scarcity of pyroxene show that the rocks are of definite calc-alkalic character. They appear to be somewhat less potassic than the typical Oligocene calc-alkalic lavas and tuffs of the central and east-central Great Basin.

The rhyodacitic Hiko Tuff is relatively undifferentiated containing rather high concentrations of Mg, Ca, Ba, Sr, P, Co, Cr, Ni, Sc, and V (Table 2). Available major-element (Cook, 1965) and petrographic data suggest similar compositions for the Racer Canyon Tuff of Cook and other ash-flow units of the Caliente volcanic field. (L. F. Rader has determined a P_2O_5 content of 0.12 weight percent for the Racer Canyon and values of 0.21 and 0.15 for ash-flow tuffs within the Caliente depression.) The high concentration of plagioclase and hornblende phenocrysts and the low quartz content of the Harmony Hills Tuff of Cook suggests that this unit is somewhat less silicic and richer in Ca, Mg, etc. than the Hiko and Racer Canyon.

Initial Sr^{87}/Sr^{86} ratios of from 0.7066 to 0.7072 (values $\pm$ 0.0005 at 2 sigma and normalized to a value of 0.7080 for the E and A standard) have been obtained on feldspar phenocrysts separated from the Harmony Hills Tuff, Hiko Tuff, Racer Canyon Tuff of Cook, and Ox Valley Tuff of Cook (Hedge and others, 1973). These determinations, which are identical within the limits of analytical error, suggest that the parent magmas were derived from a common source material probably located well within the mantle (Hedge and Noble, 1971).

Volcano-tectonic Relations

We interpret the Caliente volcanic field as a small-scale analogue of a volcanic field, such as the San Juan volcanic field in southwestern Colorado (Lipman and others, 1970), in which chemically similar tuffs and lavas were erupted from a number of distinct, but nearby and perhaps partially overlapping vent areas. K-Ar age determinations indicate that the field was active from approximately 21 to 17 m.y. ago and possibly later if the Ox Valley Tuff of Cook and related lavas are considered to belong to the same episode of volcanism.

The Caliente depression is not a large collapse caldera. Rather, the presence of ash-flow tuffs of the late Miocene ($\sim$13.5 m.y.) Kane Wash Tuff (Noble, 1968; Armstrong, 1970) both within the western part of the depression and on ridges directly southwest of the depression—an elevation difference of 2,500 feet—shows that most, if not all, of the topographic relief was produced by genetically unrelated high-angle faulting during the latest Miocene and (or) Pliocene.

The Caliente volcanic field lies at or near the southeastern end of an arcuate belt of middle Miocene calc-alkalic volcanism, possibly subduction-related, extending from the western Cascades through the west-central Great Basin (Virginia City—Hawthorne and Tonopah areas—northern Nellis Bombing and Gunnery Range) to southwesternmost Utah (Noble, 1972). The Rencher Formation described by Cook (1957) and Blank (1959) and other related intrusions of intermediate composition may be a further eastward extension of this belt.

SAMPLE DESCRIPTIONS

1. USGS(M)8I-142 K-Ar (sanidine) 12.3±0.3 m.y.

Ox Valley Tuff (Cook, 1960). Rhyolite ash-flow tuff (37°22'N, 113°45'W; Washington Co., UT). Analytical data: K_2O = 6.16% (2 analyses); $\overset{*}{Ar}{}^{40} = 1.12 \times 10^{-1}$ mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 91.9%. Collected by: H. R. Blank, Jr. & E. H. McKee, 1968. Comment: age is significantly younger than the second sample of Ox Valley Tuff dated (see no. 2).

2. USGS(M)6I-122 K-Ar (sanidine) 15.1±0.4 m.y.

Ox Valley Tuff (Cook, 1960). Rhyolite ash-flow tuff (37°28'N, 114°16'W; Lincoln Co., NV). Analytical data: K_2O = 6.52% (2 analyses); $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 72.2%. Collected by: E. H. McKee & D. C. Noble, 1966. Comment: age is significantly older than the first sample of Ox Valley Tuff dated (see no. 1).

3. USGS(M)8I-143 K-Ar (biotite) 18.2±0.5 m.y.

Racer Canyon Tuff Member (Cook, 1960). Rhyolite to quartz-latite ash-flow tuff (37°22'N, 113°45'W; Washington Co., UT). Analytical data: K_2O = 8.76% (2 analyses); $\overset{*}{Ar}{}^{40}$ = 2.37×10^{-10} mole/gm; $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 72.5%. Collected by: J. R. Blank, Jr. & E. H. McKee, 1968. Comment: age is significantly younger than the second sample of Racer Canyon Tuff (see no. 4).

4. USGS(M)6I-124 K-Ar (biotite) 20.3±0.5 m.y.

Racer Canyon Tuff Member (Cook, 1960). Rhyolite to quartz-latite ash-flow tuff (37°28'N, 113°50'W; Washington Co., UT). Analytical data: K_2O = 8.63% (2 analyses), $\overset{*}{Ar}{}^{40}$ = 2.60×10^{-10} mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 78.2%. Collected by: D. C. Noble, 1965). Comment: age is significantly older than the other sample of Racer Canyon Tuff dated (see no. 3).

5. USGS(M)6I-123 K-Ar (sanidine) 19.6±0.5 m.y.

Hiko Tuff. Quartz-latite ash-flow tuff (37°32'N, 115°02'W; Lincoln Co., NV). Analytical data: K_2O = 10.81% (2 analyses), $\overset{*}{Ar}{}^{40}$ = 3.14×10^{-10} mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 91.2%. Collected by: D. C. Noble, 1965.

6. USGS(M)8I-150 K-Ar (biotite) 19.9±0.5 m.y.

Harmony Hills Tuff of Quichapa Formation (Cook, 1965). Quartz-latite ash-flow tuff (37°22'N, 113°38'W; Washington Co., UT). Analytical data: K_2O = 6.04%, $\overset{*}{Ar}{}^{40}$ = 1.78×10^{-10} mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 43.8%. Collected by: H. R. Blank, Jr. & E. H. McKee, 1968.

7. USGS(M)6I-125 K-Ar (sanidine) 25.5±0.6 m.y.

Unnamed quartz-latite ash-flow tuff (37°22'N, 114°13'W; Lincoln Co., NV). Analytical data: K_2O = 4.75% (2 analyses), $\overset{*}{Ar}{}^{40}$ = 1.80×10^{-10} mole/gm, $\overset{*}{Ar}{}^{40}/\Sigma Ar^{40}$ = 82.4%. Collected by: E. H. McKee & D. C. Noble, 1966.

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