K-Ar ages of late Cenozoic volcanic rocks from the northern Death Valley region, California

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K-Ar AGES OF LATE CENOZOIC VOLCANIC ROCKS FROM THE NORTHERN DEATH VALLEY REGION, CALIFORNIA

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K-Ar age determinations of late Tertiary basaltic rocks give control on the timing of basin-and-range faulting in the northern Death Valley region. The geochronology of these rocks was determined from samples collected in an area extending from the Inyo Mountains to northern Death Valley, including localities in the Saline Range, the Dry Mountains, the Last Chance Range, and the Grapevine Mountains (fig. 1). The distribution and ages of basaltic rocks in these areas give information about rates of uplift, erosion, and normal and strike-slip faulting during late Cenozoic time. These rocks can be divided into two sequences separated by the Death Valley–Furnace Creek fault zone. The older sequence of basaltic rocks lies east of the fault zone and is Miocene. The younger sequence west of the fault is Pliocene.

Volcanic rocks studied west of the Death Valley–Furnace Creek fault zone underlie most of the Saline Range and small parts of adjacent ranges. Most of these rocks are flows identified in the field as olivine-basalt; they were classified as trachyandesite by Ross (1970). Silicic to intermediate volcanic rocks are interlayered with the mafic volcanic rocks in the Saline Range and Last Chance Range. These rocks include lava flows, ash-flow tuffs, and air-fall tuffs that are much less abundant than the mafic rocks. Numerous cinder cones mark eruptive sites of the mafic lavas within the lava fields, and a few plugs are sources of the silicic and intermediate rocks.

Basalt and trachyandesite in the Saline Range and adjacent ridge-capping lava flows in adjacent ranges are interpreted as having been connected in a volcanic field at least 50 km across. These lava flows are similar in age and composition. They have been offset along numerous north-northwest trending normal faults, some of which may have been active during eruptions, localizing extrusions in the volcanic field. Remnant lava flows in the Dry Mountains are now perched some 1400 m above the floor of Saline Valley (fig. 1). In the Last Chance Range, flows 5 km apart are offset vertically as much as 800 m. The separation of the volcanic field by Saline Valley, Eureka Valley, and the valley west of the Dry Mountains clearly shows that the present basin-and-range topography is younger than the lava flows.

Basaltic rocks east of the Death Valley–Furnace Creek fault zone cap hills along the California-Nevada border at the northern end of the Grapevine Mountains. These rocks were found to be fine-grained basalt with phenocrysts of olivine and plagioclase and are locally vesicular. These lavas have been cut by north to northwest trending normal faults.

The Death Valley–Furnace Creek fault zone separates the area along the California-Nevada border from that part of the study area to the west (fig. 1). This major fault zone has offset rocks on either side of Death Valley during the late Cenozoic. Right-lateral movement that offset Pliocene sedimentary rocks north of Death Valley along the Death Valley–Furnace Creek fault zone has been documented by McKee (1968).

Volcanic rocks in the Death Valley region outside the study area have a history of block faulting similar to that of the basalts described here. Fleck (1970) showed that volcanic rocks were offset vertically during development of the southern part of Death Valley. His results indicate that most of the basin-and-range faulting there occurred in the last 6 m.y. Bacon and others (1982) showed that late Cenozoic volcanism and block faulting were approximately contemporaneous in the Coso Range, 55 km south of the Saline Range. They reported that volcanism in the Coso Range area began around 6 m.y. ago and that most of the basin-and-range faulting took place in the last 4 m.y. The youngest volcanic rocks there are about 40,000 years old, and fault scarps in alluvium are suggestive of Holocene movement.

DISCUSSION

Eleven age determinations are presented graphically in figure 2; three are from Ross (1970). The volcanic rocks in the study area can be divided into two groups based on age and composition. The groups are separated by the Death Valley–Furnace Creek fault zone. Basalt east of the fault has been dated as 7.5 ± 0.3 and 7.4 ± 0.4 m.y. old. Samples of volcanic rocks collected west of the fault and dated in this study range in age from 4.6 ± 0.5 to 2.5 ± 0.3 m.y. old. Two samples of trachyandesite from this area have ages of 6.4 ± 3.2 and 6.8 ± 3.9 m.y. (Ross, 1970). Because of the large analytical uncertainty in these dates, Ross placed more confidence in dates from samples that gave smaller analytical uncertainty and concluded that the trachyandesite in the Saline Range has an age of about 3.6–2.9 m.y. Our data indicate these rocks are as old as 4.6 ± 0.5 m.y. Moreover, our data indicate that late Cenozoic volcanic rocks that were brought together along the Death Valley–Furnace Creek fault zone differ in age as well as composition.

Volcanic rocks from the eastern front of the Inyo Mountains to the Last Chance Range were cut by basin-and-range faults during and after eruption of 2.5 ± 0.3-m.y.-old lava flows. Here, basin-and-range faults and eruptive centers are abundant. Absence of flows younger than 4 m.y. at higher elevations suggests that block faulting may have occurred between eruption of the oldest and youngest flows, isolating the 4 m.y. ± flows at higher elevations while volcanism continued at lower elevations. This would suggest that volcanism and early basin-and-range faulting were approximately contemporaneous in the Saline Range and surrounding areas during the Pliocene between about 4.6–2.5 m.y. ago. However, development of the present mountains and valleys after eruption of the youngest lava flows shows that most of the basin-and-range faulting in this region is younger than 2.5 m.y. Fault scarps in Quaternary alluvial fans in Saline Valley, Eureka Valley, and along the west side of the Dry Mountains show that the faulting has continued into the Holocene.

ANALYTICAL PROCEDURES

Supporting analytical data and sample locations are given in the sample descriptions section. Sample preparation and argon analyses were carried out in the U.S.

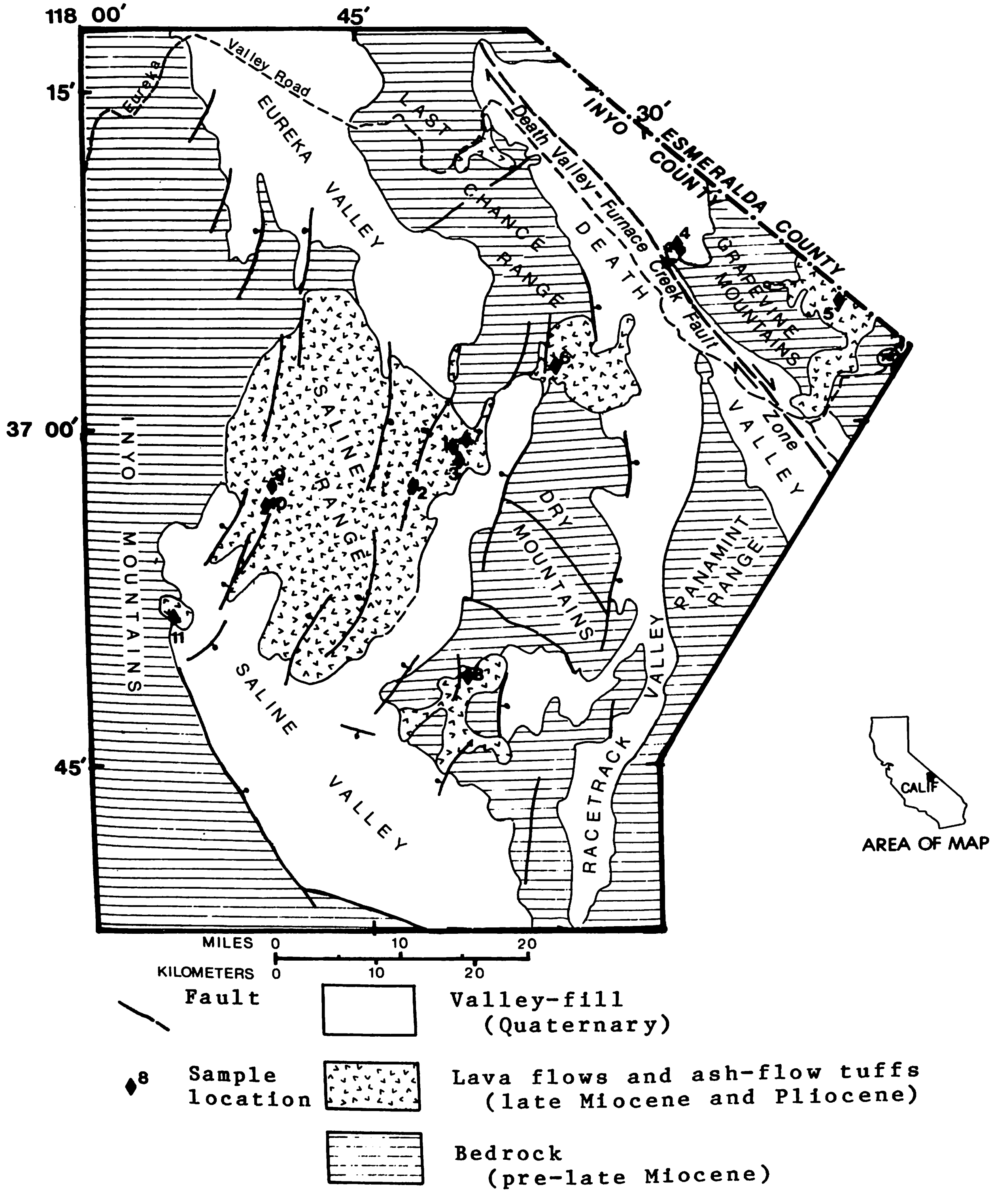

FIGURE 1. Map of study area, including locations and ages of K-Ar dated samples.

TABLE 1. K-Ar age determinations from the northern Death Valley region.[1]

Sample loc. (fig. 1)	Sample no.	Material dated/Rock type	Apparent age (m.y.)
1	ES102	Biotite/latite ash-flow tuff	3.4 ± 0.2
2	ES179	Whole rock/trachyandesite	2.5 ± 0.3
3	ES219	Whole rock/trachyandesite	3.7 ± 0.7
4	ES442	Whole rock/basalt	7.4 ± 0.4
5	ES443	Whole rock/basalt	7.5 ± 0.3
6	ES449	Whole rock/olivine basalt	4.2 ± 0.3
7	ES458	Whole rock/trachybasalt	4.6 ± 0.5
8	ES459	Whole rock/trachybasalt	4.0 ± 0.3
9	[2]7	K-feldspar/trachyandesite	3.6 ± 0.1
10	[2]F158	Whole rock/trachyandesite	2.9 ± .5
11	[2]14	Whole rock/trachyandesite	3.1 ± 1.2

[1]The ± value is the estimated cumulative analytical uncertainty at 1 standard deviation.
[2]Samples from Ross (1970). Ages have been recalculated using new decay and abundance constants recommended by the 1976 IUGS Subcommission on Geochronology.

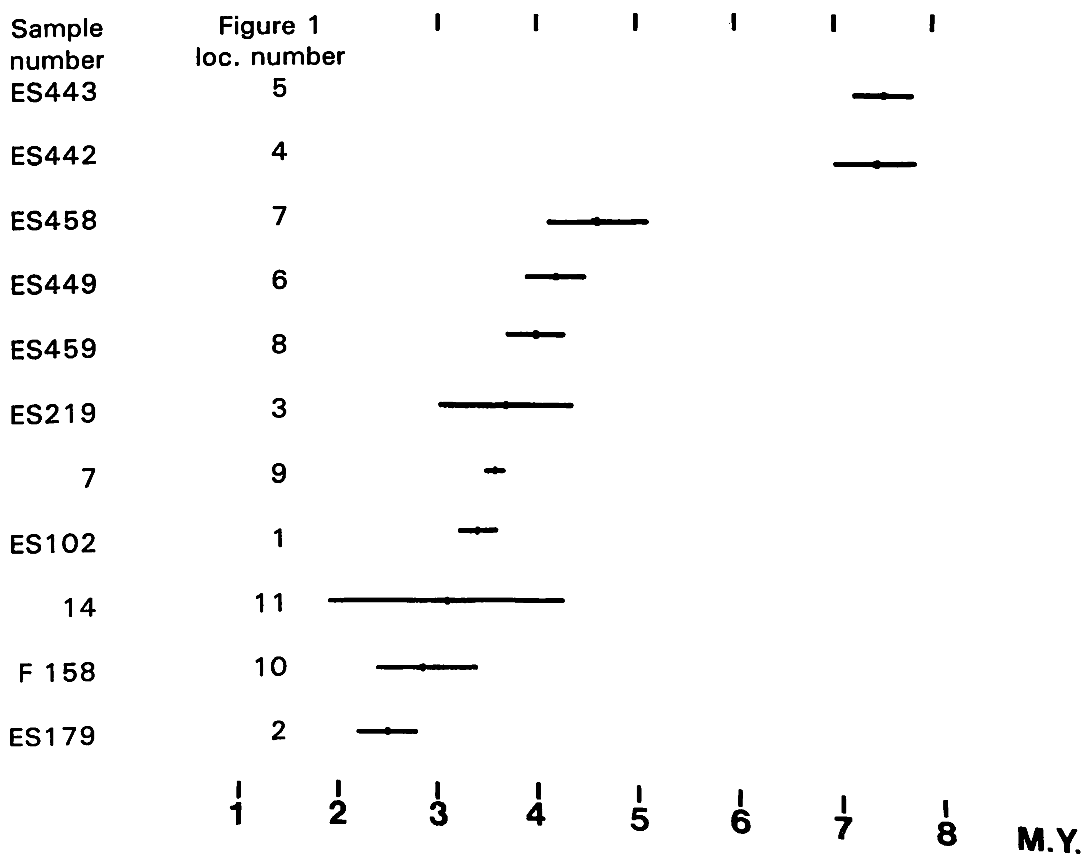

FIGURE 2. K-Ar ages of biotite, K-feldspar, and whole-rock basalt and andesite from the northern Death Valley region. Horizontal bars represent analytical uncertainty in each determination.

Geological Survey laboratories in Menlo Park. K_2O analyses were performed by a lithium metaborate flux fusion-flame photometry method using the lithium as an internal standard (Ingamells, 1970). Argon analyses were made according to standard isotope-dilution procedures (Dalrymple and Lanphere, 1969) using a 60° sector, 15.2 cm radius, Neir-type mass spectrometer and a 23 cm radius, 90° sector multi-collector mass spectrometer (Stacey and others, 1981). The precision of the data is the estimated analytical uncertainty at one standard deviation and is based on experience with replicate analyses in the Menlo Park laboratories. The decay constants for ^{40}K are $\lambda_\epsilon + \lambda'_\epsilon = 0.581 \times 10^{-10}\ yr^{-1}$, $\lambda_\beta = 4.962 \times 10^{-10}\ yr^{-1}$, and the atomic abundance of ^{40}K is 1.167×10^{-4} mole/mole.

SUMMARY

K-Ar ages from late Cenozoic volcanic rocks in the northern Death Valley region indicate that volcanism took place in the late Miocene and Pliocene. The oldest volcanic rocks studied in the area are olivine basalt east of the Death Valley–Furnace Creek fault zone. These lava flows were emplaced about 7.5 m.y. ago. Right-lateral movement along the Death Valley–Furnace Creek fault zone has moved these late Miocene flows to a position adjacent to younger (mostly Pliocene) volcanic rocks west of the fault. Volcanic rocks west of the Death Valley–Furnace Creek fault zone are mostly basalt to trachyandesite, with smaller amounts of silicic to intermediate types. The volcanic field comprised of these rocks was probably at least 50 km across; remnants are found on the eastern flank of the Inyo Mountains to the west and in the Last Chance Range to the east. Rocks of this volcanic field were erupted between about 4.6 and 2.5 m.y. ago.

Volcanic rocks in the Inyo Mountains, Saline Range, and Last Chance Range were erupted approximately contemporaneously with basin-and-range faulting. Early Pliocene flows are now perched in upfaulted locations in the Last Chance Range and the Dry Mountains. Late Pliocene flows in the Saline Range are now topographically lower than the older, perched flows. The greater part of basin-and-range faulting in the northern Death Valley Region has occurred since eruption of the late Pliocene volcanic rocks and has continued into the Holocene. The late Cenozoic volcanic and tectonic history is similar to that of the southern Death Valley region and the Coso Range.

SAMPLE DESCRIPTIONS

1. *ES102* K-Ar

Latite (36°59'5"N,117°40'20"W; Dry Mountain 15' quad, Inyo Co., CA). Medium-gray and pale brownish banded, porphyro-aphanitic ash-flow tuff containing phenocrysts of plagioclase, clinopyroxene, biotite, small crystals of euhedral and minor amounts of sphene. Groundmass consists of partially devitrified glass containing irregularly shaped vesicles lined with secondary calcite. *Analytical data:* K_2O = 7.99%; $^{40}Ar^{rad} = 3.92916 \times 10^{-11}$ moles/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 32.1%. *Collected by:* G. S. Elliott, 1981.

(biotite)3.4 ± 0.2 m.y.

2. *ES179* K-Ar

Trachyandesite (36°57'25"N,117°42'20"W; Dry Mountain 15' quad, Inyo Co., CA). Lava flow containing phenocrysts of andesine, clinopyroxene, and olivine. Groundmass is hypocrystalline, containing fine-grained potassium feldspar, plagioclase laths, and microlites of olivine, magnetite, and an opaque mineral. *Analytical data:* K_2O = 2.047%; $^{40}Ar^{rad} = 7.45379 \times 10^{-12}$ mole/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 7.7%. *Collected by:* G. S. Elliott, 1981.

(whole rock)2.5 ± 0.3 m.y.

3. *ES219* K-Ar

Trachyandesite (36°58'30"N,117°40'5"W; Dry Mountain 15' quad, Inyo Co., CA). Dark gray, fine-grained lava; phenocrysts are olivine and minor andesine. Groundmass is composed of calcic plagioclase laths, potassium feldspar, predominantly euhedral magnetite(?) and other opaque minerals, olivine and secondary interstitial calcite; matrix has trachytic texture. *Analytical data:* K_2O = 1.164%; $^{40}Ar^{rad} = 6.19067 \times 10^{-12}$ mole/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 5.6%. *Collected by:* G. S. Elliott, 1981.

(whole rock)3.7 ± 0.7 m.y.

4. *ES442* K-Ar

Basalt (37°7'35"N,117°28'30"W; Ubehebe Crater 15' quad, Inyo Co., CA). Medium-gray, fine-grained, vesicular lava composed of subhedral to anhedral olivine and minor euhedral labradorite phenocrysts in a matrix of plagioclase, clinopyroxene, olivine, and anhedral opaque crystals. Vesicles are rimmed with an isotropic mineral and minor secondary calcite. *Analytical data:* K_2O = 0.78%; $^{40}Ar^{rad} = 8.29345 \times 10^{-12}$ mole/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 4.4%. *Collected by:* G. S. Elliott, 1982.

(whole rock)7.4 ± 0.4 m.y.

5. *ES443* K-Ar

Basalt (37°5'45"N,117°20'30"W; Ubehebe Crater 15' quad, Inyo Co., CA). Medium-gray, fine-grained aphanitic flow rock containing a minor amount of olivine phenocrysts. Groundmass consists of zoned plagioclase, anhedral opaque crystals, olivine, and augite; contains interstitial calcite and phenocryst-sized vesicles. The texture is somewhat trachytic. *Analytical data:* K_2O = 2.146%; $^{40}Ar^{rad} = 2.3254 \times 10^{-11}$ moles/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 8.3%. *Collected by:* G. S. Elliott, 1982.

(whole rock)7.5 ± 0.3 m.y.

6. *ES449* K-Ar

Quartz-bearing olivine basalt (37°2'45"N, 117°34'45"; Last Chance 15' quad, Inyo Co., CA). Dark-gray porphyritic aphanite containing phenocrysts of olivine and crystals of embayed quartz surrounded by a reaction rim of fine-grained clinopyroxene. The quartz shows undulatory extinction. Groundmass is dark brown to black devitrified glass containing some crystallites of plagioclase, olivine and opaque crystals. There is some subtle trachytic texture around phenocrysts. *Analytical data:* K_2O = 2.164%; $^{40}Ar^{rad} = 1.32147 \times 10^{-11}$ moles/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 7.4%. *Collected by:* G. S. Elliott, 1982.

(whole rock)4.2 ± 0.3 m.y.

7. *ES458* K-Ar

Trachybasalt (36°59'40"W,117°39'50"W; Dry Mountain 15' quad, Inyo Co., CA). Medium-gray, fine-grained, vesicular lava flow consisting of abundant olivine phenocrysts and some finer grained plagioclase crystals in a groundmass of plagioclase, predominantly euhedral magnetite(?) and other anhedral opaque crystals, and altered olivine. *Analytical data:* K_2O = 1.375%; $^{40}Ar^{rad}$ = 9.22878 × 10^{-12} moles/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 6.6%. *Collected by:* G. S. Elliott, 1982.

(whole rock)4.6 ± 0.5 m.y.

8. *ES459* K-Ar

Trachybasalt (36°48'40"N,117°39'30"W; Dry Mountain 15' quad, Inyo Co., CA). Dark-gray lava flow containing phenocrysts of olivine and green clinopyroxene. Groundmass includes crystallites of plagioclase, clinopyroxene, altered olivine, predominantly euhedral magnetite(?) and other opaque crystals. Groundmass plagioclase shows trachytic textures around phenocrysts. *Analytical data:* K_2O = 1.075%; $^{40}Ar^{rad}$ = 6.1786 × 10^{-12} mole/gm; $^{40}Ar^{rad}/^{40}Ar^{tot}$ = 14.1%. *Collected by:* G. S. Elliott, 1982.

(whole rock)4.0 ± 0.3 m.y.

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