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K-Ar and fission-track zircon ages of Cerro Toledo rhyolite tephra units in the Jemez Mountains, north-central NM

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K-Ar and fission-track zircon ages of Cerro Toledo Rhyolite tephra units in the Jemez Mountains, northcentral New Mexico

By

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

Abstract. Pumice units of the Cerro Toledo Rhyolite of early Pleistocene age in Pueblo Canyon in the eastern part of the Jemez Mountains of northcentral New Mexico lie stratigraphically between the Otowi (lower) and Tshirege (upper) Members of the Bandelier Tuff. The K-Ar ages of sanidine, plagioclase, and hornblende from a lower unit of air-fall pumice of the Cerro Toledo are 1.46±0.03 m.y., 1.50±0.03 m.y., and 1.58±0.11 m.y., respectively, based on the newly recommended decay constants for ^{40}K. A K-Ar isochron age for the three minerals is 1.47±0.04 m.y. The K-Ar age of sanidine from the uppermost pumice unit of the Cerro Toledo is 1.23±0.02 m.y. These K-Ar ages are compatible with K-Ar ages of the lower and upper members of the Bandelier Tuff determined by G. B. Dalrymple in 1968. Zircon fission-track ages of the lower unit of the Cerro Toledo are 1.39±0.11 m.y. and 1.46±0.12 m.y.

At a few localities in the southern High Plains (fig. 1), such as at the Borchers Ranch locality (Hibbard, 1941) in Meade County, Kans., deposits of volcanic ash occur (9 m stratigraphically above the type B Pearlette ash) that have mineralogic and chemical affinities with tephra units of the Cerro Toledo Rhyolite of early Pleistocene age in the Jemez Mountains, northcentral New Mexico. Elsewhere in New Mexico and Texas (fig. 1); volcanic ash beds have been identified that correlate with two large pyroclastic units in the Jemez Mountains (Guaje and Tsankawi Pumice Beds of the Bandelier Tuff) (Izett and others, 1972; G. A. Izett, unpub. data); but until the present, downwind equivalents of the Cerro Toledo Rhyolite have not been recognized. If in the future these deposits of volcanic ash can be correlated with certainty with their suspected source-area tephra units (Cerro Toledo Rhyolite), then they will have the potential of increasing the stratigraphic resolving power of the established sequence of ash beds and increasing the stratigraphic usefulness of associated fossil land mammals. The usefulness of these potential marker volcanic ash beds may be further enhanced if reliable K-Ar ages can be assigned to their source-area equivalents. It is the purpose of this report to present K-Ar ages of the Cerro Toledo Rhyolite tephra units, which previously have not been dated but whose stratigraphic position between the Otowi and Tshirege Members of the Bandelier Tuff is well established.

The samples chosen for K-Ar age dating were collected from the eastern Jemez Mountains (fig. 3) in northcentral New Mexico in company with R. L. Smith of the U.S. Geological Survey. Large samples (77G55 and 77G56) were taken from two air-fall pumice units (fig. 2) of these Cerro Toledo Rhyolite of early Pleistocene age in Pueblo Canyon east of Los Alamos, N. M. Smith, Bailey, and Ross (1970) did not show the deposits of Cerro Toledo Rhyolite at the sample locality in Pueblo Canyon, owing to their small areal extent (R. L. Smith, oral commun., 1977). According to Smith (oral commun., 1977) and Smith, Bailey, and Ross (1970), the pumice units sampled are pyroclastics associated with the emplacement of rhyolite domes. These domes were emplaced following the eruption of the lower Bandelier Tuff (Otowi Member) of early Pleistocene age and subsequent collapse that formed the Toledo caldera.

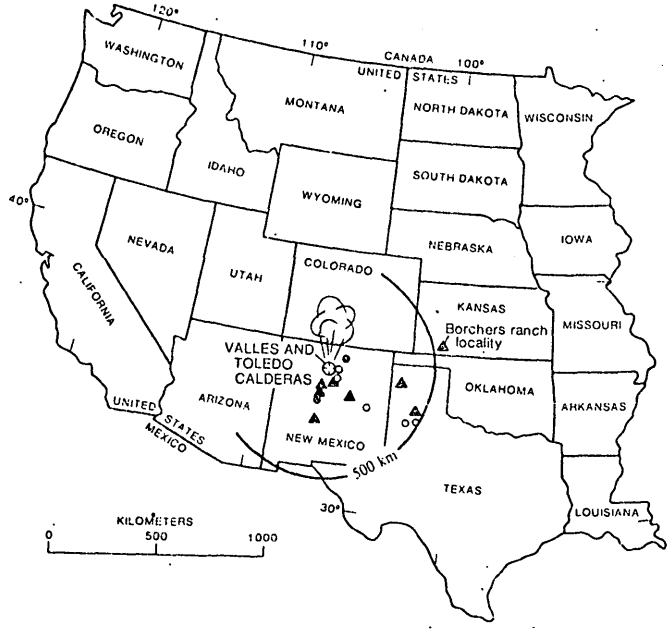

Figure 1.--Map showing the distribution of lower Pleistocene volcanic-ash beds derived from pyroclastic eruptions from the Toledo and Valles calderas in the Jemez Mountains area, New Mexico. Volcanic ash bed localities: Guaje ash, open circle; Cerro Toledo ash, triangle; Tsankawi ash, filled circle. Correlation of volcanic-ash beds here provisionally assigned to the Cerro Toledo and Tsankawi ashes with their suspected source-area tephra is tentative until more mineralogic and chemical data are available.

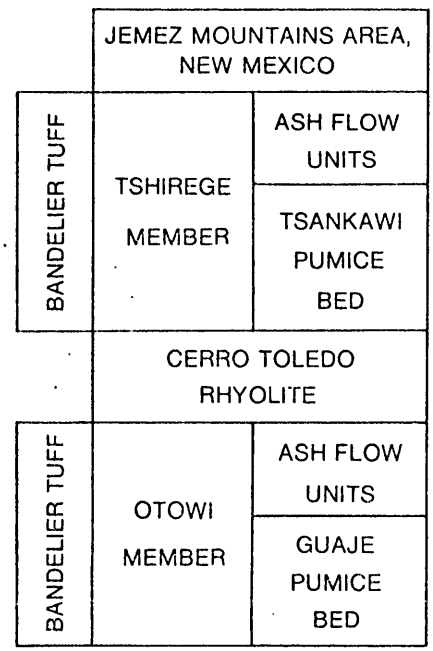

Figure 3.--Diagram showing the nomenclature of lower Pleistocene pyroclastic units of the Jemez Mountains area, northcentral N. M. Modified from Smith, Bailey, and Ross (1970).

Figure 2.--View in Pueblo Canyon, NW 1/4, NW 1/4 sec. 13, T. 6 E., R. 19 N., Guaje Mountain 7 1/2-minute quadrangle, Los Alamos County, N. M., showing the stratigraphic succession where samples 77G55 and 77G56 were collected for K-Ar age determinations of the Cerro Toledo Rhyolite of early Pleistocene age. Topmost part (covered) of the lower Bandelier (Otowi Member) is in lower part of photograph; it is overlain by a succession of air-fall pumice units of the Cerro Toledo Rhyolite and the Tshirege Member of the Bandelier Tuff.

At the sample locality, the two pumice units form the uppermost units of several discrete air-fall pumice beds interlayered with tuffaceous sediments that lie in stratigraphic succession above the Guaje Pumice Bed and overlying ash flows of the Otowi Member and below the Tsankawi Pumice Bed and overlying ash flows of the Tshirege Member. Figure 3 shows the nomenclature for lower Pleistocene pyroclastic units of the Jemez Mountains, N. M. K-Ar sanidine ages of samples of the Bandelier Tuff were determined by G. B. Dalrymple and reported in a paper by Doell and others (1968, p. 238). Dalrymple's K-Ar sanidine ages are given in table 1, as well as those ages recalculated using the new decay constants recently recommended by the IUGS Subcommission on Geochronology (Steiger and Jäger, 1977).

Methodology

Mineral separations were made on the two samples from two of the air-fall pumice units of the Cerro Toledo Rhyolite by G. T. Cebula, M. Sawlan, and J. W. Groen, U.S. Geological Survey. About 28 kg of sample 77G55 was used to obtain 39 g of calcic albite, 10 g of sanidine, 5 g of hornblende, and 0.04 g of zircon. About 2 kg of sample was used to obtain about 10 g of sanidine from sample 77G56. The separation procedure for sample 77G55 consisted of screening the raw sample with a 4-mesh sieve and collecting only those 4-mesh pumice lumps that floated in water. Only the water-float pumice lumps were used for the mineral separation to insure that accidental lithic fragments would not contribute material to the mineral separations. The pumice lumps were ultrasonically scrubbed, dried at about 50°C, and crushed and pulverized so that the sample would pass through a 50-mesh sieve. About 2 kg of sample was lost during sample preparation. Plagioclase was recovered using a bromoform and acetone mixture cut to appropriate specific gravity from the less than 50-mesh and greater than 150-mesh size range, whereas the hornblende, sanidine, and zircon were recovered from the less than 50-mesh size range owing to their small grain size and scarcity. The quality of the mineral separates was improved by using a Frantz isodynamic separator set at appropriate current, forward, and side tilt. Sanidine was recovered from sample 77G56 using the same procedures as for 77G55. Because many of the mineral grains had glass welded to their edges, the mineral grains were etched with hydrofluoric acid to remove the glass, using the following etch times:

77G56	sanidine-----2 minutes in 24 percent HF
77G55	sanidine-----3 minutes in 24 percent HF
77G55	plagioclase--3 minutes in 24 percent HF
77G55	hornblende---6 minutes in 24 percent HF

Table 1.--K-Ar ages of the Otowi and Tshirege Members of the Bandelier Tuff of northcentral New Mexico reported in Doell and others (1968) and recalculated ages using the recently recommended IUGS decay constants for ^{40}K (Steiger and Jäger, 1977)

			Age x 10^6 years	
			Data from Doell and others (1968)[1]	Decay constants from Steiger and Jäger (1977)[2]
Bandelier Tuff	Tshirege Member	Ash flows	1.02±0.04 1.06±0.03	1.05±0.04 1.09±0.03
		Tsankawi Pumice Bed	1.09±0.03	1.12±0.03
	Otowi Member	Ash flows	1.48±0.09 1.44±0.04	1.52±0.09 1.48±0.04
		Guaje Pumice Bed	1.37±0.04	1.40±0.04

[1] $^{40}K/K_{total}=1.19\times10^{-4}$; $\lambda_\varepsilon=0.585\times10^{-10}yr^{-1}$; $\lambda_\beta=4.72\times10^{-10}yr^{-1}$.

[2] $^{40}K/K_{total}=1.167\times10^{-4}$; $\lambda_\varepsilon+\lambda_{\varepsilon'}=0.581\times10^{-10}yr^{-1}$; $\lambda_\beta=4.962\times10^{-10}yr^{-1}$.

Following the hydrofluoric acid etch, the minerals were ultrasonically scrubbed for about 5 minutes and sieved as follows:

sanidine (77G56)--------	-50 and +140 mesh
sanidine (77G55)--------	-50 and +150 mesh
plagioclase (77G55)-----	-50 and +140 mesh
hornblende (77G55)------	-50 mesh

After the samples were sized, they were split, using a Jones-type microsplitter, into fractions for argon and potassium analysis.

Argon was collected and argon isotopic ratios determined by G. A. Izett under the supervision of J. D. Obradovich and H. H. Mehnert from melted splits of the samples. The argon extraction line used is similar to the one shown diagrammatically by Evernden and Curtis (1965, p. 344). The samples and extraction line were baked overnight at about 300°C, and the samples were slowly heated by an RF induction furnace to about 1600°C and held there for 25 minutes until the samples appeared to be fused.

Argon isotope ratios of the gas samples were determined using a modified Nier-type mass spectrometer with a 15-cm radius of curvature and a single-stage 60° sector magnet. The mass spectrometer was operated in the static mode.

The potassium content of splits of the minerals used for argon analysis was determined by three methods--isotope dilution, flame photometry, and electron microprobe (table 2), although only the potassium contents as determined by isotope dilution were used to calculate the ages. Isotope dilution analysis of the samples was done by J. D. Obradovich and K. Futa on all samples. Flame photometry was done by G. A. Izett and Wayne Mountjoy to compare the results with those done by isotope dilution.

The potassium content of the samples was determined by G. A. Izett using an Applied Research Laboratories EMX model electron microprobe to compare the results by this method with the isotope dilution results. Splits of the samples were mounted in epoxy in holes drilled in an aluminum wafer. The potassium content was determined by analyzing the specimens using $15^{KV}_{\wedge}$ (kilovolts) operating voltage and 15 nA (nannoamps) sample current measured on benitoite. A fixed count of beam current was used with a counting period of about 15 seconds. The analytical procedure consisted of first analyzing 10 grains of each of four standard feldspar samples. A Fortran computer program linked to the electron microprobe calculated (1) a mean value of the number of counts and its associated standard deviation for potassium in standard feldspars and (2) determined a least-squares curve relating number of counts to weight percent potassium. Ten grains of each of the samples of unknown potassium content were analyzed, and their mean counts were compared by the computer with the curve relating counts to weight percent of standard feldspars. The potassium contents determined in

Table 2.--K-Ar ages of minerals from pumice units of the Cerro Toledo Rhyolite, Jemez Mountains, New Mexico

Sample No. and mineral	Lab No.	K_2O (percent)	Sample weight (grams)	Moles radiogenic ^{40}Ar	Percent radiogenic ^{40}Ar	Age $\times 10^6$ years[4]
77G56 (sanidine)	DKA-3502	[1]7.21 [2]7.33 [3]7.22	3.9867	5.11×10^{-11}	56.8	1.23±0.02
77G55 (sanidine)	DKA-3500	[1]8.36 [2]8.62	1.0727	1.89×10^{-11}	24.5	1.46±0.03
77G55 (plagioclase)	DKA-3499	[1]1.98 [2]2.01 [3]1.98	12.5853	5.36×10^{-11}	28.3	1.50±0.03
77G55 (hornblende)	DKA-3497	[1] .56 [2] .56	4.2865	5.50×10^{-12}	6.1	1.58±0.11

[1] Potassium determined by J. D. Obradovich and K. Futa by the isotope dilution technique.
[2] Potassium determined by G. A. Izett using the electron microprobe.
[3] Potassium determined by G. A. Izett and W. Mountjoy by flame photometry techniques.
[4] Decay constants: $\lambda_\beta = 4.962\times10^{-10}$ yr^{-1}; $\lambda_\varepsilon+\lambda_c = 0.581\times10^{-10}$ yr^{-1}. ^{40}K abundance: $^{40}K=1.167\times10^{-4}$ atom/atom K. Precision of age determinations given at the 1-sigma level. K-Ar ages calculated using the potassium content as determined by isotope dilution.

this way for the different runs were averaged to give the potassium content of each sample, and the results are in fairly good agreement with the results by isotope dilution.

Discussion

The K-Ar age determinations (table 2) made on pumice units of the Cerro Toledo Rhyolite of Pleistocene age are compatible within their analytical uncertainty with K-Ar ages of underlying and overlying units of the Bandelier Tuff determined by G. B. Dalrymple (in Doell and others, 1968; and table 1). The results suggest that the lower pumice unit of the Cerro Toledo herein dated 1.47±0.04 m.y. (77G55) is very close in age with the Otowi Member of the Bandelier Tuff as determined by G. B. Dalrymple (1.45 m.y.; average of 3 determinations (weighted mean)) and cannot be separated from it based on the K-Ar ages at hand. The uppermost pumice unit of the Cerro Toledo Rhyolite (77G56) has a K-Ar age (1.23±0.02 m.y.) significantly younger than the K-Ar age of the underlying pumice unit (77G55) of the Cerro Toledo (1.47±0.04 m.y.), and significantly older than K-Ar ages of the overlying Tshirege Member of the Bandelier Tuff as dated by G. B. Dalrymple (about 1.09 m.y.; average of 3 determinations (weighted mean)).

The K-Ar ages of sanidine (1.46±0.03 m.y.), plagioclase (1.50±0.03 m.y.), and hornblende (1.58±0.11 m.y.) of sample 77G55, are in agreement within their analytical uncertainty at the 2-σ level. Because of the small amount of hornblende recovered from mineral separations of the phenocryst-poor rhyolite (77G55), and because of the low potassium content of the hornblende, the K-Ar age of the hornblende has a fairly high uncertainty. A K-Ar isochron plot of the analytical data for the three minerals from sample 77G55 is shown in figure 4, and the age calculated from the data is 1.47±0.04 m.y. The analytical precision estimate for this isochron age was calculated using a modified York linear regression. The minerals contain no analytically significant amount of inherited argon, inasmuch as the $^{40}Ar/^{36}Ar$ intercept is about 297.

Two fission-track age determinations (table 3) were made by C. W. Naeser on zircon separated from sample 77G55 of the Cerro Toledo. The calculated ages are 1.39±0.11 m.y. and 1.46±0.12 m.y. (2σ), and these ages are concordant with the K-Ar ages within their analytical uncertainty. The fission-track age of 1.46 m.y. is perhaps the better of the two, inasmuch as it was made following re-irradiation of the original sample, which had too high an induced-track density for optimum counting conditions.

Table 3.--Zircon fission-track age determination of an airfall pumice unit of the Cerro Toledo Rhyolite (77G55) from the Jemez Mountains, N. Mex.

[$\lambda_f = 7.03 \times 10^{-17} yr^{-1}$. Number of tracks counted shown in parentheses; t, track; ρ_s, spontaneous track density; ρ_i, induced track density; ϕ, neutron flux; age $\pm 2\sigma$]

Lab No.	Sample No.	Mineral	ρ_s $\times 10^6$ t/cm^2	ρ_i $\times 10^6$ t/cm^2	ϕ $\times 10^{15}$ n/cm^2	Age $\times 10^6$ yr	U (ppm)
DF 1646	77G55	zircon	0.423 (45)	19.14 (1019)	1.05	1.39±0.11	520
DF 1646A	77G55	--do--	.374 (71)	7.55 (717)	.493	1.46±0.12	440

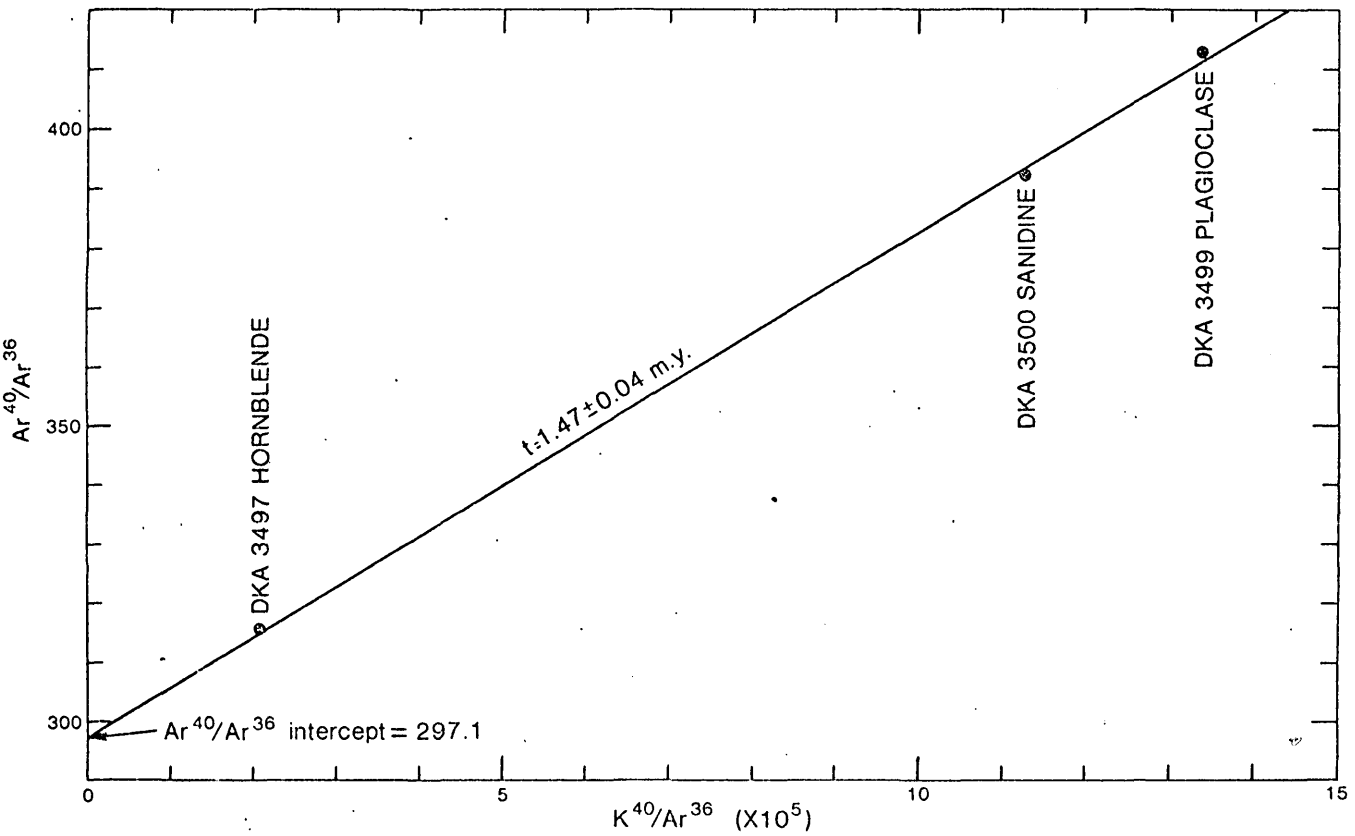

Figure 4.--K-Ar isochron plot for three minerals from sample 77G55 of a pumice unit in Cerro Toledo Rhyolite in the eastern Jemez Mountains, N. M.

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