Zircon fission-track age of 0.45 million years on ash in the type section of the Merced Formation, west-central California

C. E. Meyer[1], M. J. Woodward[1], A. M. Sarna-Wojcicki[1], and C. W. Naeser[2]

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1/ U.S. Geological Survey, Menlo Park, CA 94025

2/ U.S. Geological Survey, Denver, CO 80225

Abstract

A zircon fission-track age of 0.45 ± 0.08 million years (weighted average of 15 samples) has been determined on an ash interbedded with Pleistocene marine or littoral strata in the type section of the Merced Formation at two localities south of San Francisco. Separation of zircon crystals into several sample groups based on the presence or absence of glass coats, color, and surface texture has made it possible to identify the pyrogenic, detrital, and inferred accidental (xenocrystic) components in the zircon separates. The age obtained on pyrogenic zircons agrees closely with the youngest (0.45 ± 0.18 million years) of several K-Ar ages run previously on plagioclase and hornblende separates from the same localities. The older K-Ar ages (0.7 to 2.1 million years) on this ash are probably a result of detrital or accidental contamination, as determined by analyses on back-picked and untreated splits of the same feldspar separate.

Introduction

We present new data on zircon fission-track ages of the ash in the type section of the Merced Formation south of San Francisco. Previous age assignments for this ash have ranged from Pliocene (Lawson, 1914), to mid-Pleistocene (Hall, 1966), while previous K-Ar and fission-track ages have been scattered, ranging from 0.45 to 2.1 million years (G. B. Dalrymple and M. A. Lanphere, written commun., 1975; C. W. Naeser, written commun., 1975). The age of this ash is important to determine because the ash is a widespread time marker in central and northern California, and enables correlation of formations deposited in diverse environments: marine, littoral, estuarine, lacustrine, fluvial, periglacial, and volcanic (Sarna-Wojcicki and others, 1977). Furthermore, the ash affords important evidence for the age of fault movement and other types of crustal deformation at a number of critical localities (for example, the Humboldt Bay nuclear reactor facility in northwestern California).

Sampling localities and sampling methods

We collected about 50 kg of ash from each of two localities in the marine or near-shore non-marine littoral-estuarine beds of the Merced Formation south of San Francisco. Sample 1 (locality 1)[1/] was collected from an abandoned quarry located on the property of the Olympic club golf course, about 2 km east of Thorton Beach State Park, near the coast south of San Francisco. Sample 2 (locality 2)[2/] was collected from the coastal cliffs near the Daly City storm sewer outlets just north of Thornton Beach State Park. At locality 1, the ash bed is about 3 m thick, most-likely depositionally thickened, because it consists of alternating finer and coarser layers and laminae. The ash is silt to fine sand in size, and is interbedded with fine sand and silt beds uplifted and tilted 47° to the northeast. The samples for fission-track and K-Ar analyses were taken from an interval 15 to 60 cm stratigraphically above the base of the ash bed. This part of the bed looked more massive and

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1/ Sample location N37°42.3' W122°29.4'

2/ Sample location N37°42.8' W122°30.2'

less contaminated with detritus than the upper part. At locality 2, the ash is about 30 cm thick, cross-bedded, and fine to medium sand in size. The lower 20 cm is finer, purer, and more massive, although detrital contamination appears to be present throughout the ash bed, as indicated by presence of heavy minerals typical of metamorphic rocks of the Franciscan Formation. The upper 10 cm of the bed is coarser, more strongly cross-bedded, and contains a considerable amount of detrital sand. The sample for dating was taken from the lower 20 cm of the ash bed. The ash bed at this locality is interbedded with near-shore non-marine sands and gravels, uplifted and tilted 21° to the northeast.

Sample preparation and analytical methods

We disaggregated and sieved the ash samples, concentrated the heavier crystals by elutriation, and separated the heaviest using methylene iodide. Zircons were separated from other heavy minerals using a magnetic separator. The zircon separates from each sample were further separated into several groups by hand picking, using a binocular microscope. These groups consisted of the following categories, some of which were found in all samples analyzed:

1) light pink, with glass coats
2) deeper pink, with glass coats
3) surficially pitted, without glass coats
4) yellow, without glass coats
5) light pink, without glass coats or with frothy glass coats
6) deeper pink, without glass coats
7) purple, without glass coats

The separated zircon groups were mounted in teflon disks and etched using the KOH-NaOH eutectic method (Gleadow and others, 1976). All samples were etched in platinum crucibles in a gravity oven at $240^{\circ}C$. Etch times varied from less than 15 hours for some of the darker colored zircons (with high spontaneous track densities) to 18-24 hours for the lighter colored fractions (with low spontaneous track densities). During the etch procedure some or all of the zircons dropped out of the teflon mount; these zircons were recovered and mounted in lexan plastic. Separate ages were determined for both fractions in those cases where zircon loss occurred (table 1). The zircon mounts were irradiated in the U.S.G.S. reactor at Denver, Colorado. The irradiated sample detectors were etched and induced tracks were counted as described by Naeser (1976).

In calculating fission-track ages of individual samples, we have summed the total areas measured for all crystals in each sample group, including those crystals which had no fossil tracks. We excluded those zircon groups which contained crystals of much older ages (for example, the group of zircons that was surficially pitted, or the group of yellow zircons; table 2). The reason that we included crystals which had no fossil tracks in the age calculations is that there are about as many grains with one or two fossil tracks as there are with none, and crystals in these three categories (that is, crystals with no tracks, with one track, or with two tracks) are the most abundant, while crystals with three or more tracks are markedly less abundant (fig. 1). Some workers consider the presence of trackless zircon crystals in an etched sample to be the result of underetching, and consequently exclude these crystals from age calculations. This may be a valid practice for older zircon separates, or ones with high uranium concentrations. In the present case, however, the mode for the number of fossil tracks for all analyzed crystals is between 0 and 1 track (fig. 1). In view of the low concentration of uranium in these crystals (average of about 300 ppm) and the young geologic age of the ash inferred from other independent age and stratigraphic evidence (Hall, 1966; Sarna-Wojcicki, 1976), we conclude that trackless zircons in this instance are not underetched but are part of the statistically normal population of fossil tracks within the given population of zircon crystals in these separates. Another observation which supports the inclusion of crystals without tracks in age calculations is that separates containing smaller zircon crystals, such as those from locality 1 where the ash is generally finer, had a greater number of trackless zircons that separates from locality 2. All other factors being equal, the probability is greater that larger crystals will have more fossil tracks than smaller ones. Considering the entire population of crystals analyzed, the modes for finite and maximum ages calculated for individual crystals (fig. 2) are both in the interval 0.25 to 0.50 million years, suggesting that the true analytical age for this ash lies within this interval.

Fission-track ages

Table 1 summarizes fission-track age data for sampling localities 1 and 2. The average age for the ten separates analyzed from locality 1 is 0.48 ± 0.10 million years, while a weighed average age using the reciprocal of the sample standard deviations as a weighting factor is 0.44 ± 0.08 million years. If the reciprocal of the variance rather than that of the standard deviation is used as a weighing factor, the calculated age is even younger, 0.40 ± 0.07 million years. Samples from locality 1 are not obviously contaminated with older zircons, with the possible exception of sample KA-5d, which consists of pink crystals without glass coats, and has an age of 0.66 ± 0.11 million years. All other zircon separates from this locality are younger and had glass coats. Presence of glass coats is considered to be evidence of pyrogenic origin in tephra units, although this is not a foolproof criterion, since glass coated zircons can be incorporated from older tephra units during an explosive eruption, and fossil tracks from such crystals may remain unannealed or become only partially annealed. The age of sample group KA-5 (a through e) is calculated to be 0.42 ± 0.02 million years, if data from this group of 112 counted grains are treated as a single area with a fossil-track count of 306 and a uranium concentration of 296 ppm. This combined sample accounts for over half of the total grains counted for both localities 1 and 2 (112 out of 207) and about two thirds of the fossil tracks (306 out of 477), consequently it has a large influence in the combined age calculated for both localities (see below).

K-Ar ages on plagioclase separates from locality 1 (G. B. Dalrymple and M. A. Lanphere, written commun., 1975) are 0.45 ± 0.18 and 1.1 ±0.5 million years.[1/] Maximum ages of 0.7 and 2.2 million years were also determined on a plagioclase and a hornblende separate, respectively, for samples which contained less than one percent radiogenic argon.

The average fission-track age for the five samples analyzed from locality 2 (KA-6, a through d, table 1) is 0.47 ± 0.10, while the weighed averages

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1/ These ages, as well as other K-Ar ages in this report, have been multiplied by 1.0268 to convert to values based on new I.U.G.S. decay constants (Mankinen and Dalrymple, 1979).

using the reciprocal of the sample standard deviations and variances as weighing factors are both 0.47 ± 0.09. The sample from locality 2 contained four zircon separates (KA-6, e through h), which gave significantly older, and scattered, ages compared to the five other separates (KA-6, a through d) from this locality. The four older zircon separates are listed in table 2, together with ages calculated for individual crystals. Zircons from the latter four samples did not have glass coats, except for several crystals from separate KA-6g. Of the 21 crystals from these four older groups, grain 1 of KA-6e and grain 1 of KA-6g may have been pyrogenic crystals of the ash. The remaining grains are probably detrital, or possibly accidental (xenocrystic).

The deeper-pink zircons of separate KA-6a at locality 2 had a distinctly bimodal uranium concentration, with crystals in the group $KA\text{-}6a_1$ having an average of 200, and crystals in group $KA\text{-}6a_2$, an average of 500 ppm uranium. $KA\text{-}6a_2$ had a higher average age than $KA\text{-}6a_1$, although not significantly so at the one sigma level. Zircons from both separates had glass coats. The older, high-uranium crystals may be partially annealed xenocrysts incorporated from older volcanic and pyroclastic rocks which underlie the source area of this ash southeast of Mount Lassen in northeastern California (Sarna-Wojcicki, 1976). The average age for samples from locality 2, excluding sample $KA\text{-}6a_2$, is 0.44 ± 0.05 million years, while average weighed ages using the reciprocal of sample standard deviations and variances as weighing factors are 0.43 ± 0.10 and 0.43 ± 0.09 million years, respectively.

K-Ar ages on plagioclase separates from locality 2 (G. B. Dalrymple and M. A. Lanphere, written commun., 1975) are 0.7 ± 0.5 and 2.1 ± 0.3 million years. These ages were obtained on two splits of the same feldspar separate, the younger age having been determined on a split that had been back-picked for discolored, rounded, or unusual grains, while the other split had not. Results of these analyses, together with observations of detrital heavy minerals and old ages on several kinds of zircons from this locality, indicate that the older K-Ar ages result from detrital and possibly accidental contamination of the ash.

The combined average age for samples from localities 1 and 2 is 0.48 ± 0.10, while the weighed average ages using the reciprocal of the sample standard deviations and variances as weighing factors are 0.45 ± 0.08 and 0.42 ± 0.07, respectively.

We consider the age of 0.45 million years to be a good, representative working age for this unit. However, if some of the older ages given in table 1 are a result of the presence of unannealed xenocrysts, and not simply analytical scatter, then the true age of this unit may be younger.

References

Gleadow, A. J. W., Hurford, A. J., and Quaife, R. D., 1976, Fission track dating of zircon: improved etching techniques: Earth and Planetary Science Letters, v. 33, pp. 273-276.

Hall, N. T., 1966, Late Cenozoic stratigraphy between Mussell Rock and Fleishhacker Zoo, San Francisco Peninsula: California Division Mines and Geology Mineral Information Service, v. 19, no. 11, p. 522-525.

Lawson, A. C., 1914, Description of the San Francisco district: U.S. Geological Survey Atlas, Folio 193, 24 p.

Mankinen, E. A., and Dalrymple, G. B., 1979, Revised geomagnetic polarity time scale for the interval 0-5 m.y. B.P.: Journal of Geophysical Research, v. 84, no. B2, pp. 615-626.

Naeser, Charles W., 1976, Fission Track Dating: U.S. Geological Survey Open-File Report 76-190 (revised 1978).

Sarna-Wojcicki, A. M., 1976, Correlation of late Cenozoic tuffs in the central Coast Ranges of California by means of trace- and minor-element chemistry: U.S. Geological Survey Professional Paper 972, 30 p.

Sarna-Wojcicki, A. M., Hall, N. T., Bowman, H. R., Naeser, C. W., and Russell, P. C., 1977, Correlation and age of a widespread Pleistocene ash bed in northern California and western Nevada (abs): in Geological Society of America, National Meeting, Abstracts with Program, Nov. 1977, Seattle, Washington.

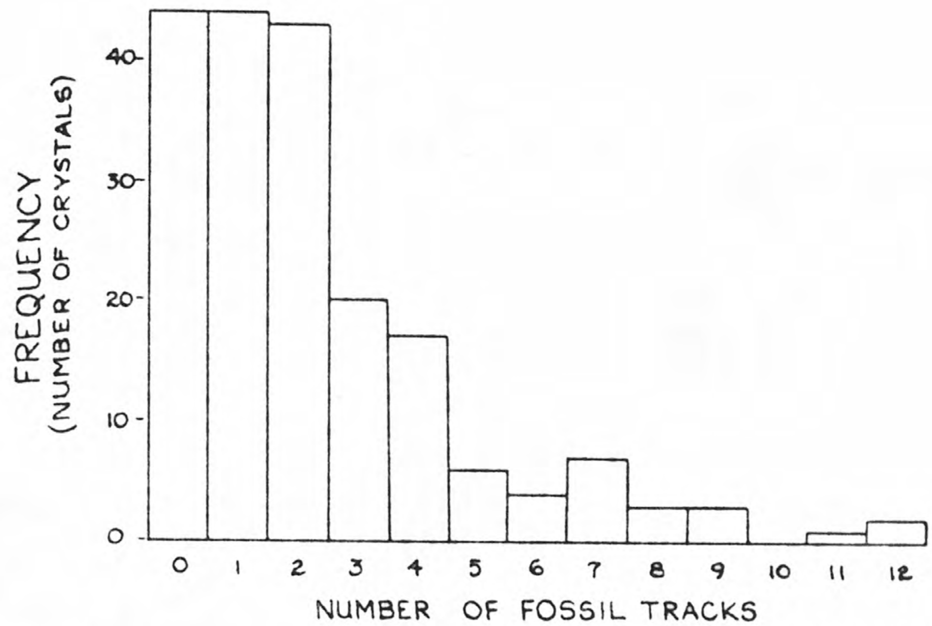

Figure 1. Frequency of zircon crystals analyzed for fission-track ages as a function of the number of fossil tracks.

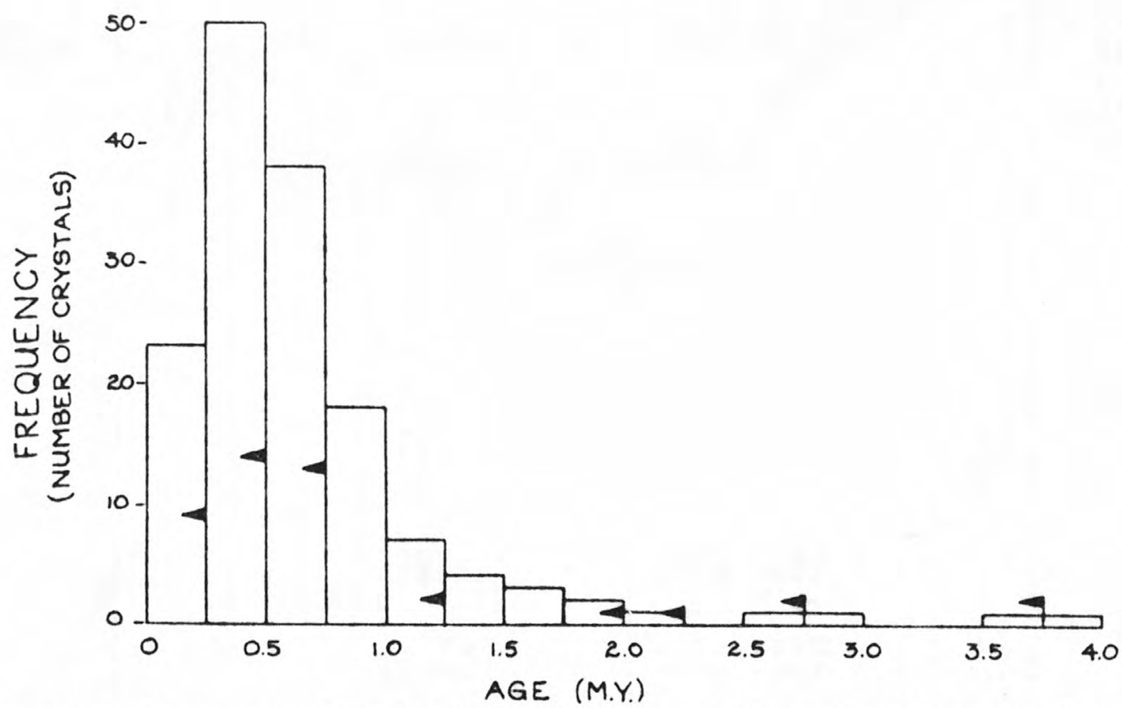

Figure 2. Frequency of individual zircon crystals analyzed for fission-track as a function of the age. Vertical bars represent the number of crystals with finite ages within each age interval. Black triangles represent maximum ("less than") ages for crystals which lacked fossil tracks.

Table 1. Summary of zircon fission-track ages of ash in the type section of the Merced Formation south of San Francisco. C. E. Meyer and M. J. Woodward, analysts, except where marked by asterisk, C. W. Naeser, analyst.

		Type of zircon separate		Sample No.	Age (x 10^6 yrs)	Anal. error (± 1σ)	U conc. (ppm)	No. of grains	Spontaneous tracks no.	Spontaneous tracks density (x10^4/cm^2)	Induced tracks no.	Induced tracks density (x10^6/cm^2)	Neutron dose (x10^{15}n/cm^2)
		unsegregated crystals		KA-1a	0.48	0.14	293	21	12	7.80	702	9.13	.95
		unsegregated crystals		KA-1b*	.56	.12	250	8	19	8.0	1017	8.61	1.00
Basal part of ash bed, locality 1	teflon mount	light pink w/glass coats		KA-5a	.29	.05	291	13	29	4.61	3343	10.6	1.11
	teflon mount	light pink w/glass coats		KA-5b	.45	.10	227	9	22	5.59	1601	8.13	1.09
	teflon mount	deeper pink w/glass coats		KA-5c	.33	.04	277	32	81	5.03	8085	10.0	1.10
	teflon mount	deeper pink w/o glass coats		KA-5d	.66	.11	367	10	38	13.4	1902	13.4	1.11
	lexan mount	light pink w/glass coats		KA-5e	.47	.06	273	24	61	7.09	4266	9.92	1.10
	lexan mount	deeper pink w/glass coats		KA-5f	.42	.08	505	7	29	11.7	2233	18.0	1.08
	lexan mount	deeper pink w/glass coats		KA-5g	.56	.14	297	7	16	9.19	973	11.2	1.14
	lexan mount	light pink w/glass coats		KA-5e	.58	.11	302	10	30	9.65	1743	11.2	1.13
Average age for locality 1			TOTAL		---	---	---	141					
			AVG.		0.48	0.10	308	14					
			± σ		0.10	---	78	---					
Weighted average age for locality 1			AGE		0.44								
			± σ		0.08								
Basal part of ash bed, locality 2	lexan mount	deeper pink w/glass coats		KA-6a_1	0.49	0.13	200	10	14	5.31	957	7.26	1.12
	lexan mount	deeper pink w/glass coats		KA-6a_2	.57	.08	500	12	57	16.1	3254	18.4	1.12
	lexan mount	light pink w/glass coats		KA-6b	.47	.10	290	12	22	7.44	1580	10.7	1.12
	lexan mount	light pink w/glass coats		KA-6c	.41	.07	206	24	32	4.64	2521	7.31	1.08
	lexan mount	unsegregated crystals		KA-6d*	.39	.10	260	8	13	6.0	987	9.07	.99
Average age for locality 2			TOTAL		---	---	---	66					
			AVR.		0.47	0.10	291	13					
			± σ		0.10	---	122	---					
Weighted average age for locality 2			AGE		0.47								
			± σ		0.09								
Weighted average age for localities 1 and 2, combined			AGE		0.45		TOTAL	207					
			± σ		0.08		AVR. (loc. 1 and 2)	14					

Table 2. Summary of single-grain fission track ages of crystals obtained from ash bed at locality 2, ash in type section of Merced Formation, south of San Francisco. Ages of these crystals were not included in calculations of the ash (table 1). C. E. Meyer and M. J. Woodward, analysts.

	Type of zircon separate	Sample No.	Grain No.	Age ($\times 10^6$ yrs)	Anal. error ($\pm 1\sigma$)	U conc. (ppm)	Spontaneous tracks no.	Spontaneous tracks density ($\times 10^6/cm^2$)	Induced tracks no.	Induced tracks density ($\times 10^6/cm^2$)	Neutron dose ($\times 10^{15}$ n/cm^2)
Basal part of ash bed, locality 2	Surficially pitted zircons without glass coats	KA-6e	1	0.39	0.28	346	2	.07	165	12.2	1.07
		"	2	10.5	1.5	136	64	.79	195	4.81	"
		"	3	54	10	167	84	4.97	50	5.92	"
		"	4	94	26	50	53	2.61	18	1.78	"
		"	5	119	27	67	90	4.44	24	2.37	"
	Yellow zircons without glass coats	KA-6f	1	47	12	69	37	1.82	26	2.56	1.11
		"	2	47	11	193	42	4.97	30	7.10	"
		"	3	133	34	102	77	7.59	19	3.75	"
	Pink zircons without glass coats; some with frothy glass coats	KA-6g	1	0.91	0.53	444	3	.22	110	16.3	1.11
		"	2	5.1	1.8	119	9	.33	59	4.36	"
		"	3	11	2	491	54	2.90	167	18.0	"
		"	4	14	2	93	73	.72	173	3.41	"
		"	5	67	8	160	230	5.92	114	5.87	"
		"	6	88	17	58	101	2.85	38	2.14	"
		"	7	110	15	74	237	4.52	71	2.71	"
		"	8	118	27	55	86	3.64	24	2.03	"
	Purple zircons without glass coats	KA-6h	1	33	7	322	49	5.80	50	11.8	1.12
		"	2	46	5	167	188	4.28	135	6.14	"
		"	3	57	9	133	100	4.23	58	4.90	"
		"	4	127	33	82	69	5.83	18	3.04	"
		"	5	154	40	52	84	4.52	18	1.94	"