New K-Ar ages from tuffs in the etchegoin formation, San Joaquin basin, Nevada

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NEW K-Ar AGES FROM TUFFS IN THE ETCHEGOIN FORMATION, SAN JOAQUIN BASIN, CALIFORNIA

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Volcanic tuff beds are interbedded with sedimentary rocks of the upper Miocene and Pliocene Etchegoin Formation in the west-central San Joaquin basin of California (figs. 1, 2). Three regionally extensive tuff units, informally termed the "Gate", "Deadman", and "Den Hartog" tuffs, were mapped (Loomis, 1990b, Plate 1) in the Jacalitos Creek-Zapato Chino Creek area, near the towns of Coalinga and Avenal (fig. 2). Potassium-argon dates were obtained from these three tuff beds and the results are presented in this report.

LITHOLOGY AND PETROLOGY

The Gate, Deadman, and Den Hartog tuffs are light- to dark-gray, fine-grained, crystal vitric tuffs that range from 5 to 10 ft (1.5 to 3 m) thick. The tuff beds can be traced at the surface for approximately 6 mi (10 km). These units occur as massively bedded, relatively pure tuff, as laminated to thin-bedded tuff with planar to wavy laminations and ripple laminations of clay, and as tuff interbedded with shale. Rare bivalved mollusks and burrows also occur within some tuff units. The presence of ripple laminations, marine invertebrate macrofossils, and biogenic structures in the tuff units indicate reworking in marginal-marine to shallow-marine environments (Loomis, 1990a, 1990b).

The glass content of the tuffs ranges from 80–95%, and the glass occurs as lath-like, curvilinear, and triangular bubble-wall shards. Microprobe analyses of the Den Hartog tuff (table 1) indicate that it is rhyolitic in composition. Silt-size crystals within the tuffs include anhedral to euhedral quartz, plagioclase, hornblende, biotite, and Fe-Ti oxides. Some of these crystals could represent detrital grains that were incorporated into the tuff as it was reworked. Petrographic and lithologic characteristics of the Gate, Deadman, and Den Hartog tuffs are described in more detail in the sample descriptions below.

ANALYTICAL METHODS

Glass concentrates were prepared using conventional heavy liquid and magnetic separation techniques, sieved to −100/+270 mesh, and treated with dilute HF and HNO_3.

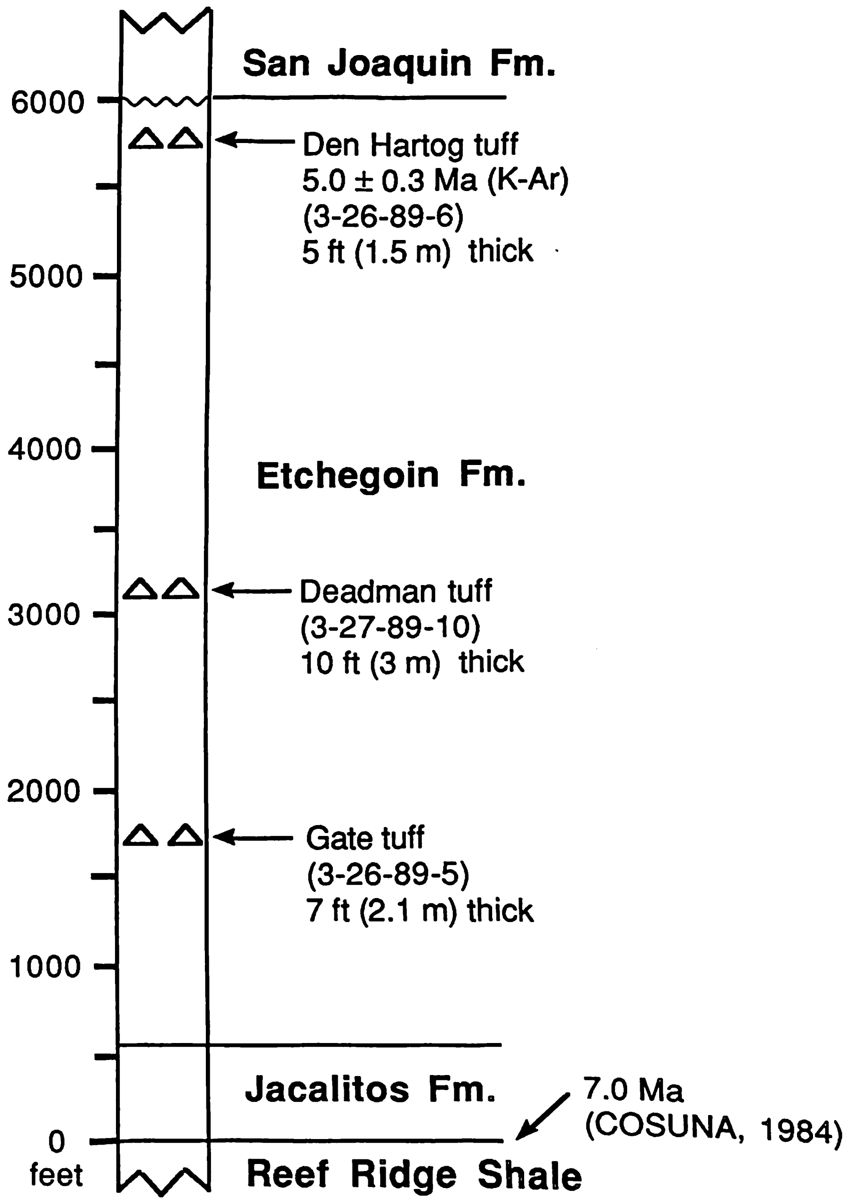

FIGURE 1. Stratigraphic section measured near Zapato Chino Creek, west-central San Joaquin basin. The K-Ar age of 5.0 ± 0.3 Ma for the Den Hartog tuff is inferred to be representative of the true age of this volcanic unit. Location of measured section is shown in figure 2.

TABLE 1. Results of microprobe analyses of the Den Hartog glass shards (sample 3-26-89-6)[1].

Element	Analysis #1 Weight %	Analysis #2 Weight %	Analysis #3 Weight %
K_2O	4.33	4.59	4.25
SiO_2	71.83	72.10	72.14
Na_2O	1.96	2.74	1.96
FeO	0.77	0.69	1.14
CaO	0.71	0.77	0.80
MgO	0.00	0.00	0.00
Al_2O_3	11.62	11.90	11.72
MnO	0.00	0.00	0.02
Cl	0.20	0.14	0.21
F	0.00	0.00	0.00
TiO_2	0.12	0.08	0.03
Total	91.55	93.02	92.55

[1]Microprobe analyses were done by J. Lowenstern at the Center for Materials Research at Stanford University on a JEOL 733 Superprobe with Kevex Sesame Automation. Microprobe analyses were run on individual glass shards at a beam current of 15 nA and a potential of 15 KeV; a defocused beam (30 μm diameter) was used to minimize volatilization and migration of Na and K.

Potassium and argon analyses of the glass concentrate were made by Geochron Laboratories, Cambridge, Massachusetts. Decay constants used in the calculations were: $\lambda_\beta = 4.962 \times 10^{-10}$/year, $\lambda_\epsilon = 0.581 \times 10^{-10}$/year; $^{40}K/K = 1.193 \times 10^{-4}$ g/g.

RESULTS

The well-preserved condition of the Den Hartog tuff reinforces the reliability of the K-Ar age of 5.0 ± 0.3 Ma. The glass shards have not devitrified, thus indicating little or no diagenetic alteration. In addition, the potassium content of the Den Hartog tuff is relatively high (K = 3.65%, determined from microprobe analysis, table 1; K = 3.857%, determined from potassium analyses, see sample descriptions), indicating that potassium was not leached from the tuff.

The Gate and Deadman tuffs have undergone devitrification and are characterized by low potassium contents (K = 0.632% and K = 0.505%, respectively; see sample descriptions), thus impugning the reliability of the ages. In addition, these ages are not stratigraphically consistent: the Gate tuff, which is the stratigraphically lowest of the three tuffs (fig. 1), yielded an age of 4.2 ± 0.5 Ma, whereas the Deadman tuff, occurring higher in the section (fig. 1), yielded an age of 8.1 ± 0.9 Ma.

An age of 7.0 Ma has been assigned to the base of the Jacalitos Formation (COSUNA, 1984), which underlies the Deadman tuff of the Etchegoin Formation (fig. 1). If the 7.0 Ma age is correct, then the 8.1 ± 0.9 Ma K-Ar age for the Deadman tuff in the middle Etchegoin Formation (fig. 1) is too old. In addition, $^{87}Sr/^{86}Sr$ ages (Loomis, 1990b; Loomis, this issue) for the Etchegoin Formation range from 4.0 ± 1.5 Ma to 7.5 ± 1.0 Ma, further suggesting that the age of the Deadman tuff derived from potassium-argon analysis is spurious.

DISCUSSION

Assigning an age to the Etchegoin Formation is difficult because it contains a macrofauna that is not narrowly constrained biostratigraphically and because, in the study area,

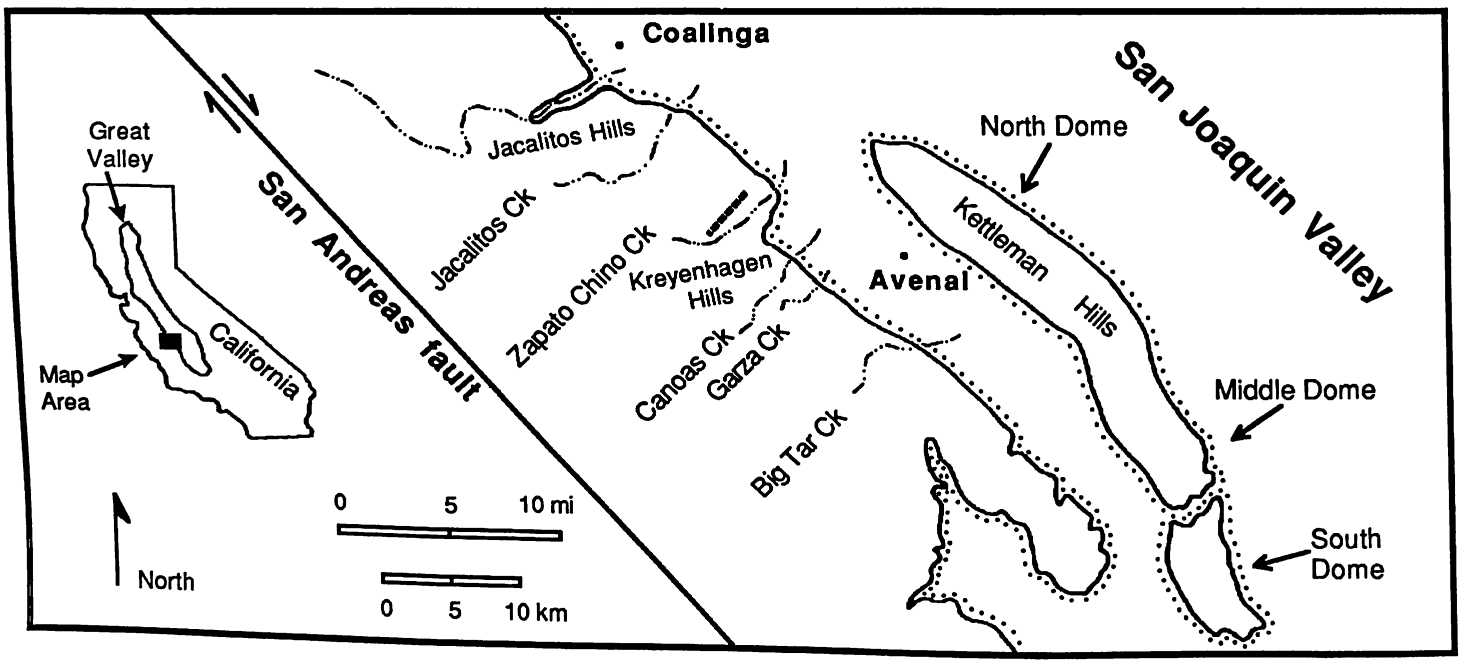

FIGURE 2. Index map showing key geographic and geologic features in the study area. Dashed line represents location of measured outcrop stratigraphic section near Zapato Chino Creek. The San Joaquin Valley forms the southern half of the Great Valley of California.

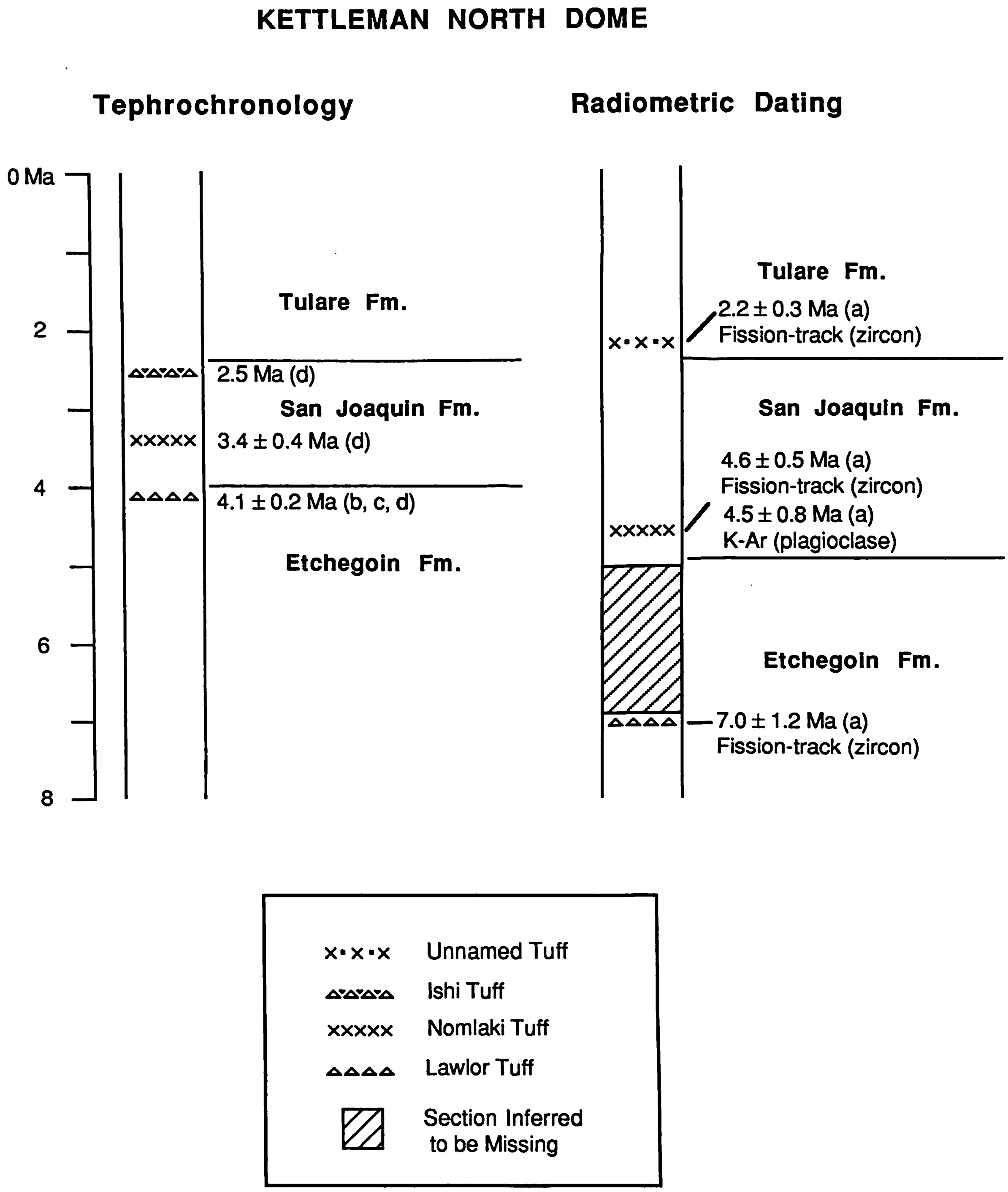

FIGURE 3. Schematic stratigraphic columns on Kettleman North Dome, showing tuff beds and the inferred age ranges of the formations. Ages of tuff units are based on geochemical tephra correlations and radiometric dating methods. Tuff units in the Kettleman Hills have been correlated by means of geochemical tephrochronology with the radiometrically dated Ishi, Nomlaki, and Lawlor Tuffs of northern California. Fission-track and potassium-argon dating of these same tuff units in the Kettleman Hills have yielded different ages. References for age data are: (a) Obradovich and others (1978); (b) Sarna-Wojcicki (1976); (c) Sarna-Wojcicki and others (1979); (d) Sarna-Wojcicki and others (1991).

it lacks an age-diagnostic microfauna. However, the K-Ar age of the Den Hartog tuff, in addition to ages derived from other dating techniques, can be used to help constrain the age of the Etchegoin Formation. Ages of tuffs occurring in the Etchegoin, San Joaquin, and Tulare formations on Kettleman North Dome, ~8 mi (~13 km) east of the study area (fig. 2), have been derived by fission-track dating, potassium-argon analysis, and from geochemical tephrochronology data (fig. 3).

A tuff bed in unit "Te_2" (Woodring and others, 1940) in the upper part of the Etchegoin Formation yielded a fission-track (zircon) age of 7.0 ± 1.2 Ma (Obradovich and others, 1978) (fig. 3). A tuff in the middle part of the San Joaquin Formation yielded a fission-track (zircon) age of 4.6 ± 0.5 Ma, and a potassium-argon (plagioclase) age of 4.5 ± 0.8 Ma (Obradovich and others, 1978) (fig. 3). Fission-track dating of zircons occurring within an ash at the base of the Tulare Formation yielded an age of 2.2 ± 0.3 Ma (Obradovich and others, 1978) (fig. 3).

Ages for the tuffs in the Etchegoin and San Joaquin formations have also been determined by means of geochemical tephrochronology (i.e., the identification and correlation of individual tephra layers on the basis of the major-, minor-, and trace-element chemical composition of the volcanic glass, as determined from electron-microprobe analyses, x-ray fluorescence, and instrumental neutron activation analyses; Sarna-Wojcicki and others, 1991). The tuff unit in the upper Etchegoin Formation (Te_2) was correlated with the Lawlor Tuff, which yielded a K-Ar age of 4.1 ± 0.2 Ma (Sarna-Wojcicki, 1976; Sarna-Wojcicki and others, 1979, 1991), and the tuff in the middle part of the San Joaquin Formation was correlated with the Nomlaki Tuff, which yielded a K-Ar age of 3.4 ± 0.4 Ma (Evernden and others, 1964; Sarna-Wojcicki and others, 1991) (fig. 3). In addition, a tuff in the uppermost San Joaquin Formation was correlated with the Ishi Tuff, which has an age of 2.5 Ma (Sarna-Wojcicki and others, 1991) (fig. 3).

The results derived from geochemical tephrochronology methods differ from those derived from fission-track and potassium-argon analyses. For example, the 7.0 ± 1.2 Ma age derived for the Te_2 tuff bed in the upper Etchegoin Formation (fig. 3) is thought to be too old by Sarna-Wojcicki and others (1991) owing to contamination of the zircon separate with detrital zircons derived from older volcanic formations. Despite discrepancies between results from various dating techniques, all of the above age data are consistent with the K-Ar age of 5.0 ± 0.3 Ma derived from the Den Hartog tuff in the upper Etchegoin Formation (fig. 1). However, the dates from the Te_2 tuff and the San Joaquin Formation suggest that the K-Ar age of 4.2 ± 0.5 Ma for the Gate tuff occurring in the lower Etchegoin Formation and below the Den Hartog tuff (fig. 1) is too young.

In summary, the age of 5.0 ± 0.3 Ma derived from K-Ar analysis of the Den Hartog tuff, in addition to tephrochronologic and radiometric age data from tuffs in the Kettleman Hills, suggest that the Etchegoin Formation in the west-central San Joaquin basin is older than ~4.0 Ma and younger than ~7.0 Ma.

ACKNOWLEDGMENTS

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SAMPLE DESCRIPTIONS

1. *3-26-89-5* K-Ar

"Gate tuff" (NE¼ NW¼ S29,T22S,R16E; The Dark Hole 7.5′ quad., Fresno Co., CA; on northwest end of NW-SE-oriented hill, ~300 ft (~91 m) south of dirt road; elevation 1,240 ft or 378 m). Light- to dark-gray, fine-grained crystal vitric tuff; devitrification common—glass shards appear as pseudomorphs replaced by smectite and zeolites; glass shards (~0.01–0.02 mm) have bubble-wall shapes; contains crystals (~0.01–0.03 mm) of quartz, biotite, hornblende, and plagioclase; 90% glass, 10% crystals; bed is massive (i.e., no bedding visible) with sharp basal and upper contacts; 7 ft (2.1 m) thick. *Analytical data:* K = 0.638%, 0.625% (average K = 0.632%); ^{40}K = 0.753 ppm; $^{40}Ar^*$ = 1.77 × 10^{-4} ppm ($^{40}Ar^*/\Sigma^{40}Ar$ = 4.3%), 1.88 × 10^{4} ppm ($^{40}Ar^*/\Sigma^{40}Ar$ = 3.1%) (average $^{40}Ar^*$ = 1.82 × 10^{-4} ppm); $^{40}Ar^*/^{40}K$ = 2.42 × 10^{-4}. *Comments:* Low potassium content probably reflects diagenetic alteration of glass shards; age is too young and is not consistent with stratigraphy.

(glass concentrate) 4.2 ± 0.5 Ma

2. *3-26-89-6* K-Ar

"Den Hartog tuff" (SW¼ NE¼ S18,T22S,R16E; Kreyenhagen Hills 7.5′ quad., Fresno Co., CA; on south-facing slope, at southeast end of NW-SE-oriented ridge, northwest side of Zapato Chino Canyon; elevation 1,150 ft or 350 m). Buff-white to light-gray, fine-grained crystal vitric tuff with silt laminae; bubble-wall glass shards (~0.01–0.02 mm) are well preserved; contains angular to subangular crystals (~0.005–0.03 mm) of quartz, biotite, hornblende, plagioclase, and opaque minerals; 85% glass, 10% clay laminae, 5% crystals; tuff unit is thin bedded to laminated; lower contact is sharp and planar to slightly undulatory, upper contact is bioturbated; 5 ft (1.5 m) thick. *Analytical data:* K = 3.839%, 3.874% (average K = 3.857%); ^{40}K = 4.601 ppm; $^{40}Ar^*$ = 1.326 × 10^{-3} ($^{40}Ar^*/\Sigma^{40}Ar$ = 11.1%), 1.477 × 10^{-3} ($^{40}Ar^*/\Sigma^{40}Ar$ = 9.4%), 1.212 × 10^{-3} ($^{40}Ar^*/\Sigma^{40}Ar$ = 24.6%) (average $^{40}Ar^*$ = 1.338 × 10^{-3} ppm); $^{40}Ar^*/^{40}K$ = 2.91 X 10^{-4}. *Comments:* Glass shards in tuff are well preserved and are isotropic in thin section; potassium content derived from K-Ar analysis is consistent with potassium content determined from microprobe analyses (see table 1); this age is considered to be reliable.

(glass concentrate) 5.0 ± 0.3 Ma

3. *3-27-89-10* K-Ar

"Deadman tuff" (NW¼ NE¼ S8,T22S,R15E, Kreyenhagen Hills 7.5′ quad., Fresno Co., CA; on southeast-facing slope, west side of Deadman Canyon; elevation 1,100 ft). Light- to dark-gray, fine-grained crystal vitric tuff; devitrification is pervasive, original bubble-wall glass shards (~0.01–0.02 mm) have been replaced by smectite; contains crystals (~0.005–0.03 mm) of quartz, plagioclase, hornblende, biotite, opaque minerals, and rare sphene; 80% glass, 20% crystals; tuff unit is thinly to thickly laminated with silt laminae, interbedded with shale beds 2–3 in (5–8 cm) thick; rare bivalved mollusk (*Platyodon colobus* Woodring) *in situ* in shale interbed; basal contact is sharp and planar, upper contact is intermixed with overlying fossiliferous sandstone; 10 ft (3 m) thick. *Analytical data:* K = 0.504%, 0.506% (average K = 0.505%); ^{40}K = 0.602 ppm; $^{40}Ar^*$ = 2.74 × 10^{-4} ppm ($^{40}Ar^*/\Sigma^{40}Ar$ = 2.9%), 2.91 × 10^{-4} ppm ($^{40}Ar^*/\Sigma^{40}Ar$ = 3.8%) (average $^{40}Ar^*$ = 2.83 × 10^{-4} ppm); $^{40}Ar^*/^{40}K$ = 4.69 × 10^{-4}. *Comments:* Low potassium content reflects diagenetic alteration of glass shards; age is too old based on stratigraphic position and fission-track, potassium-argon, and strontium-isotope data (see discussion).

(glass concentrate) 8.1 ± 0.9 Ma

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