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C.D. Condit and M. Shafiqullah

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K-Ar AGES OF LATE CENOZOIC ROCKS OF THE WESTERN PART OF THE SPRINGERVILLE VOLCANIC FIELD, EAST-CENTRAL ARIZONA

CHRISTOPHER D. CONDIT *Department of Geology, University of New Mexico, Albuquerque, NM 87131*
M. SHAFIQULLAH *Department of Geosciences, University of Arizona, Tucson, AZ 85721*

As part of a joint mapping project between the University of New Mexico and the U.S. Geological Survey, 11 new whole-rock K-Ar ages, obtained in cooperation with the University of Arizona, are reported for the western 1000 km² of the Springerville volcanic field. With the exception of four ages, two published by Peirce and others (1979), no other isotopic ages were previously available for the western part of the 3000-km² Arizona segment of the Springerville volcanic field. Luedke and Smith (1978) quote a K-Ar age of 12.10 ± 0.06 m.y. (corrected to constants used in this report) obtained by McKee and McKee (1972) from an intracanyon flow-lobe of basalt sampled 25 km southwest of Show Low in Corduroy Creek. An aliquot of this sample was subsequently dated, using whole-rock K-Ar methods, at 1.76 ± 0.15 m.y. (Peirce and others, 1979). This flow-lobe has been correlated on the basis of mapping and paleomagnetic data with a unit (QTsf, sample UAKA 80-133) from the western part of the Springerville volcanic field (Condit, 1984). The age of this analysis supports the younger age of Peirce and others (1979).

The mapping that formed the basis for the sample selection of this report was compiled at a scale of 1:50,000 and is in review by the U.S. Geological Survey for an I-series lithologic map. This work resulted in the recognition of 162 volcanic units, including 121 flow-fields (terminology of Wadge, 1978), 27 composite flow-fields, and 14 isolated cinder cones; the units referred to in this report are those of Condit (1984). Terminology for rock types is that of Coombs and Wilkinson (1969). The convention for vent nomenclature, based on township and range coordinates, follows from the work of Wolfe and others (in preparation) in the San Francisco volcanic field in north-central Arizona, and can be found in Condit (1984).

Chemical compositions (table 1) were determined by XRF rapid-rock analysis by the U.S. Geological Survey, Lakewood, Colorado. For analytical details see Condit (1984). Note that representative chemical analyses for these flow- and composite flow-fields are from samples which were not colocated with age determination sample sites. The chemical data used in age determinations (e.g., %K) differs from that of the XRF analyses because age determination samples were groundmass feldspar concentrates (Damon and others, 1983), whereas XRF analyses were obtained from whole-rock samples. With two exceptions, magnetic polarity is included for each reported age (Castro and others, 1983; Condit, 1984). These data were obtained from core samples taken from sites colocated with age determination sample sites and analyzed using standard procedures described in McElhinney (1973) by L. L. Brown and J. Castro (written commun., 1983) at the University of Massachusetts at Amherst.

The isotopic ages of this study have been combined with basalt stratigraphy and paleomagnetic polarity determinations from 138 sites, which has allowed the relative and absolute age of most of the flow- and composite flow-fields to be interpreted within the geomagnetic polarity time scale of Mankinen and Dalrymple (1979). This information has been used to suggest that a large number of discrete magma batches is responsible for the petrogenesis of the western part of the Springerville volcanic field, and that no pattern of chemical evolution over time can be supported in this area. In addition, these age determinations have been used to calculate incision rates (from which uplift rates are inferred), horizontal retreat rates, and vertical denudation rates along the southern margin of the Colorado Plateau (Condit, 1984).

TABLE 1. Representative XRF analyses (in weight %) from dated flow- and composite flow-fields of the western part of the Springerville volcanic field, east-central Arizona.

Sample no.	55L	107L	215L	216L	226SM	237IP	238MC	254IP	260L
Unit[1]	Qsc_6	Qsg_2	QTsf	Qbb_4	Qme	Tbl	Qnd	Tbc	QTsf
Latitude	34:11:13	34:11:40	34:07:40	34:07:55	34:10:23	34:03:30	34:02:15	34:03:05	34:07:55
Longitude	109:57:50	109:55:20	109:52:45	109:52:58	109:52:10	109:56:20	109:51:20	109:56:48	109:55:05
SiO_2	47.87	47.70	48.50	46.10	49.60	52.30	49.60	46.70	47.70
TiO_2	2.49	2.38	1.93	1.56	1.89	2.15	2.06	2.19	1.96
Al_2O_3	16.97	16.40	15.60	11.80	16.00	17.20	16.50	16.09	16.30
$FeTO_3$[2]	12.25	11.90	12.70	13.10	11.20	10.10	12.20	12.20	12.30
MnO	0.19	0.17	0.17	0.17	0.17	0.18	0.18	0.19	0.18
MgO	6.96	7.86	7.97	17.60	7.97	2.43	6.83	5.92	6.46
CaO	8.96	9.99	10.30	7.99	8.99	5.64	8.49	8.34	11.00
Na_2O	3.85	3.19	2.82	2.16	3.46	4.40	3.55	3.53	2.76
K_2O	1.11	1.32	0.84	0.67	1.59	3.90	1.41	1.54	0.79
P_2O_5	0.44	0.47	0.23	0.26	0.52	1.48	0.48	1.12	0.29
LOI[3]	-NA-	<0.01	<0.01	<0.01	<0.01	0.60	0.01	1.59	0.35
Total	100.04	100.36	99.98	100.29	100.44	98.93	100.26	96.78	98.69

[1]Condit (1984).
[2]$FeTO_3$ = total iron as Fe_2O_3.
[3]LOI = lost on ignition (900°C).

The decay constants used in the age calculations are: $\lambda\beta = 4.963 \times 10^{-10}$ yr^{-1}; $\lambda\epsilon = 0.581 \times 10^{-10}$ yr^{-1}; $\lambda = 5.544 \times 10^{-10}$ yr^{-1}, and $^{40}K/K = 1.167 \times 10^{-4}$ atom/atom. Limits of precision reported are within 1σ standard deviation. UAKA refers to University of Arizona Isotope Geochemistry Laboratory sample number. XRF refers to field numbers in Condit (1984).

SAMPLE DESCRIPTIONS

1. *UAKA 82-184 (XRF 226SM* K-Ar
Olivine-pyroxene-plagioclase phyric hawaiite (Qme) (34°10'15"N,109°52'05"W; SE/4 S14,T9N,R22E; flow-field of vent 9418 [Turkey Mountain]; Sponseller Mountain 7.5' quad., Apache Co., AZ). *Analytical data:* K = 1.484%, 1.474%, 1.486%, 1.476%, 1.475%, 1.486%; $^{40}Ar^*$ = 1.313 × 10^{-12} mol/g, 1.293 × 10^{-12} mol/g, 1.128 × 10^{-12} mol/g, 1.254 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 79.0, 79.2, 81.6, 79.9. *Comments:* Magnetic polarity normal. Youngest dated flow-field in western part of Springerville volcanic field. Overlies Qmb_5, Qmb_6, Qmc_4 (Condit, 1984). *Collected by:* C. D. Condit.
(whole rock, groundmass) 0.486 ± 0.029 m.y.

2. *UAKA 82-96 (XRF 238MC)* K-Ar
Olivine phyric hawaiite (Qnd) (34°02'18"N, 109°51'34"W; no township/range [unsurveyed]; top flow-field of Gomez and Gooseberry Creeks; McNary 7.5' quad., Navajo Co., AZ). *Analytical data:* K = 0.7800%, 0.7715%, 0.7633%, 0.7769%, 0.7664%; $^{40}Ar^*$ = 2.106 × 10^{-12} mol/g, 1.906 × 10^{-12} mol/g, 1.896 × 10^{-12} mol/g, 1.969 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 66.6, 68.4, 67.8, 67.0. *Comments:* Magnetic polarity normal. May represent unrecognized subchron of the Matuyama reversed chron. Overlies Qng, QTnf, $QTnb_3$, QTnc (Condit, 1984). *Collected by:* C. D. Condit and B. A. Zinn.
(whole rock, groundmass) 1.47 ± 0.06 m.y.

3. *UAKA 80-131 (XRF 55L)* K-Ar
Microporphyritic olivine basalt (Qsc_5) (34°11'13"N, 109°57'45"W; SE/4 S12,T9N,R22E; flow-field of Timber Mesa and vent 9306 [Porter Mountain]; Lakeside 7.5'quad., Navajo Co., AZ). *Analytical data:* K = 0.859%, 0.850%; $^{40}Ar^*$ = 2.266 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 69.2. *Comments:* Magnetic polarity normal. Transitional between hawaiite and alkali olivine basalt. Underlies Qsa_1; overlies Qsc_4, Qsb_2, Qsb_1, Qsc_2, QTsf (Condit, 1984). *Collected by:* C. D. Condit, M. Shafiqullah, H. W. Peirce.
(whole rock, groundmass) 1.53 ± 0.21 m.y.

4. *UAKA 82-183 (XRF 216L)* K-Ar
Picrite, alkali olivine basalt (Qbb_4) (34°08'04"N, 109°53'00"W; NE/4 S34,T9N,R23E; flow-field of vent 9335; Lakeside 7.5' quad., Navajo Co., AZ). *Analytical data:* K = 0.7636%, 0.7626%, 0.7592%, 0.7618%, 0.7639%; $^{40}Ar^*$ = 2.245 × 10^{-12} mol/g, 2.178 × 10^{-12} mol/g, 2.061 × 10^{-12} mol/g, 2.201 × 10^{-12} mol/g, 2.197 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 81.8, 81.6, 81.9, 81.4, 81.5. *Comments:* Magnetic polarity normal. Overlies lower flow sheet of composite flow-field QTsf (Condit, 1984). Normal polarity suggests age can be further constrained to the Olduvai normal subchron, with an age of 1.67–1.74 m.y. *Collected by:* C. D. Condit.
(whole rock, groundmass) 1.65 ± 0.09 m.y.

5. *UAKA 80-132 (XRF 107L)* K-Ar
Olivine-feldspathic alkali olivine basalt (Qsg_2) (34°11'33"N,109°55'40"W; NE/4 S8,T9N,R23E; flow-field of vent 9305; Lakeside 7.5' quad., Navajo Co., AZ). *Analytical data:* K = 1.084%, 1.069%, 1.058%, 1.054%; $^{40}Ar^*$ = 3.27 × 10^{-12} mol/g, 3.15 × 10^{-12} mol/g, 3.21 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 72.2, 72.5, 72.4. *Comments:* Magnetostratigraphic correlations and other isotopic ages suggest age of about 1.60 m.y. Overlies Qsd (Condit, 1984). *Collected by:* C. D. Condit, M. Shafiqullah, H. W. Peirce.
(whole rock, groundmass) 1.74 ± 0.15 m.y.

6. *UAKA 80-133 (XRF 215L, XRF 260L)* K-Ar
Diktytaxitic olivine phyric alkali olivine basalt (QTsf) (34°04'15"N,109°55'10"W; no township/range [unsurveyed]; composite flow-field of Show Low Creek; Indian Pine 7.5' quad., Navajo Co., AZ). *Analytical data:* K = 0.885%, 0.875%, 0.885%, 0.882%; $^{40}Ar^*$ = 2.39 × 10^{-12} mol/g, 2.79 × 10^{-12} mol/g, 3.01 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 53.3, 51.0, 47.9. *Comments:* Magnetic polarity reversed. Composed of at least two flow sheets, each at least 2–10 m thick, locally separated by a soil zone; crops out over an area of 400 km² and has an inferred extent exceeding 700 km². Reversed magnetic polarity from 11 paleomagnetic sites, stratigraphic relations, and age shown in analysis 4 suggest ages of sheets are exclusive of the Olduvai normal subchron (1.67–1.87 m.y., Mankinen and Dalrymple, 1979). Plateau edge forming flow correlated by Condit (1984) with 4 samples collected 26 km southwest down Corduroy Creek; UAKA 75-52a (1.76 ± 0.15 m.y.), UAKA 74-136 (1.90 ± 0.06 m.y.) (Peirce and others, 1979); UAKA 73-80 (1.62 ± 0.08 m.y.), UAKA 73-137 (1.63 ± 0.08 m.y.) (M. Shafiqullah, unpublished data). Representative XRF samples: 215L (lower flow sheet), 260L (upper flow sheet). Composite unit underlies all flow- and composite flow-fields in contact with it, except $QTbc_1$, QTwg, QTwh, and Tbl (Condit, 1984). Overlies all sedimentary units in the area including Rim Gravels correlated by McKay (1972) to those of Price (1950) in Sycamore Canyon, 60 km southwest of Flagstaff, Arizona. *Collected by:* C. D. Condit, M. Shafiqullah, H. W. Peirce.
(whole rock, groundmass) 1.78 ± 0.22 m.y.

7. *UAKA 80-134* K-Ar
Olivine phyric basalt ($QTbc_2$) (34°05'10"N, 109°56'45"W; no township/range [unsurveyed]; flow-field of Bootleg Lake; Indian Pine 7.5' quad., Navajo Co., AZ). *Analytical data:* K = 1.319%, 1.316%, 1.371%, 1.376%; $^{40}Ar^*$ = 4.418 × 10^{-12} mol/g, 3.926 × 10^{-12} mol/g, 4.451 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 57.1, 61.2, 56.1, 66.1, 65.4, 64.4. *Comments:* Magnetic polarity normal. Flow lies at present base level of Corduroy Creek and is locally buried by alluvial fill. Underlies Qbc_1, Qbd_1 (Condit, 1984). *Collected by:* C. D. Condit, M. Shafiqullah, H. W. Peirce.
(whole rock, groundmass) 1.83 ± 0.21 m.y.

8. *UAKA 82-185* K-Ar
Same unit as sample description 6 (QTsf) (34°22'26"N,110°03'00"W; SW/4 S6,T11N,R22E; composite flow-field of Show Low Creek; Show Low

North 7.5' quad., Navajo Co., AZ). *Analytical data:* K = 0.5900%, 0.5896%, 0.5877%, 0.5788%; $^{40}Ar^*$ = 2.113 × 10^{-12} mol/g, 2.029 × 10^{-12} mol/g, 2.017 × 10^{-12} mol/g, 1.994 × 10^{-12} mol/g, 2.037 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 81.1, 81.6, 82.1, 81.7, 81.6. *Comments:* Magnetic polarity reversed. Oldest dated sample of unit. For additional information on composite flow-field QTsf, see sample description 6. *Collected by:* C. D. Condit.

(whole rock, groundmass) 2.00 ± 0.11 m.y.

9. *UAKA 82-95* K-Ar

Olivine phyric alkali olivine basalt (Tnc) (34°02'15" N, 109°51'32" W; no township/range [unsurveyed]; basal flow-field of Gomez and Gooseberry Creeks; McNary 7.5' quad., Apache Co., AZ). *Analytical data:* K = 0.9418%, 0.9426%, 0.9457%, 0.9437%, 0.9439%; $^{40}Ar^*$ = 3.320 × 10^{-12} mol/g, 3.344 × 10^{-12} mol/g, 3.287 × 10^{-12} mol/g, 3.496 × 10^{-12} mol/g, 3.309 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 86.8, 77.6, 77.6, 76.9, 77.4. *Comments:* Magnetic polarity normal. Flow-field at present base level of Gomez and Gooseberry Creeks. Oldest age determination of flows thought to be associated with the western part of Springerville volcanic field. Underlies Qnd, Qng, $QTnb_3$, QTnf; overlies Tnb, Tng (Condit, 1984). *Collected by:* C. D. Condit and B. A. Zinn.

(whole rock, groundmass) 2.05 ± 0.10 m.y.

10. *UAKA 80-135 (XRF 237IP)* K-Ar

Plagioclase porphyry, hawaiite (Tbl) (34°03'30" N, 109°56'20" W; no township/range [unsurveyed]; upper flow-field of Amos Mountain; Indian Pine quad., Navajo Co., AZ). *Analytical data:* K = 3.300%, 3.322%, 3.267%, 3.302%; $^{40}Ar^*$ = 49.56 × 10^{-12} mol/g, 49.64 × 10^{-12} mol/g, 49.89 × 10^{-12} mol/g, 49.57 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 10.4, 10.4, 10.4, 11.2. *Comments:* Correlated by Condit (1984) to Mount Baldy rocks; no documented vent within western part of Springerville volcanic field. Overlies Tbc (Condit, 1984). *Collected by:* C. D. Condit.

(whole rock, groundmass) 8.66 ± 0.19 m.y.

11. *UAKA 80-136 (XRF 254IP)* K-Ar

Olivine phyric hawaiite (Tbc) (34°02'58" N, 109°55'50" W; no township/range [unsurveyed]; upper flow-field of Amos Mountain; Indian Pine 7.5' quad., Navajo Co., AZ). *Analytical data:* K = 1.327%, 1.330%, 1.330%, 1.334%, 1.340%; $^{40}Ar^*$ = 21.17 × 10^{-12} mol/g, 20.65 × 10^{-12} mol/g, 20.55 × 10^{-12} mol/g, 20.74 × 10^{-12} mol/g; $^{40}Ar^*/\Sigma^{40}Ar$ = 38.5, 39.3, 39.5, 39.3. *Comments:* Magnetic polarity normal. Correlated by Condit (1984) to Mount Baldy rocks; no documented vent within western part of Springerville volcanic field. Underlies Tbl (Condit, 1984); overlies Rim Gravels correlated by McKay (1972) to those of Price (1950). *Collected by:* C. D. Condit.

(whole rock, groundmass) 8.97 ± 0.19 m.y.

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