New K-Ar ages of lavas fromt he Colorado Plateau-Basin and Range transition zone, east-central Arizona

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NEW K-Ar AGES OF LAVAS FROM THE COLORADO PLATEAU-BASIN AND RANGE TRANSITION ZONE, EAST-CENTRAL ARIZONA

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The Rio Grande Rift region of the southwestern United States contains numerous complex tectono/magmatic associations making it an excellent laboratory to study relationships between volcanism and tectonism. During the past 10 Ma, the primary locus of volcanism in this region has been within the structurally and geophysically defined transition zone between the Colorado Plateau and Basin and Range provinces. A detailed understanding of the origin and evolution of magmatism within this transition zone is therefore essential to an overall understanding of the volcano/tectonic evolution of the entire region.

The 3000 km² Springerville volcanic field (SVF) of east-central Arizona is one of the major centers of volcanism located within the Colorado Plateau-Basin and Range transition zone. Previous work on the SVF including detailed mapping (Condit and others, in review), K-Ar dating (Laughlin and others, 1979, 1980; Condit, 1984, Aubele and others, 1986), paleomagnetic observations (Castro and others, 1988), and major element data (Condit, 1984; Cooper, 1986) indicated a progression from initial voluminous tholeiitic volcanism (2.0-1.75 Ma) to less voluminous alkalic volcanism (1.75-1.0 Ma), with the youngest products (1.5-0.5 Ma) consisting of evolved alkalic compositions such as hawaiites and mugearites (Condit and others, 1989). Ongoing investigations of mafic magmatism in the SVF are building on the exceptional base of information available and focus on the chemical and isotopic characteristics of the erupted magmas and the relationships between magma genesis and tectonic processes within this transition zone (Cooper and Hart, in review).

RESULTS

Eleven new K-Ar ages are reported here for lavas from the Springerville volcanic field. The K-Ar data are given below and correspond to the sample locations in figure 1. Chemical analyses and CIPW normative compositions of the samples are listed in table 1. Two of the new ages (map locations 8 and 9) expand the known period of volcanism in the field with the oldest dated flow occurring in the extreme northern portion of the field at 6.59 ± 0.12 Ma (map location 9). Morphology of the flow indicates a vent location north of the previously defined Springerville field proper. This information rules out its origin from the Mt. Baldy volcanic complex to the south as has been suggested for several other older flows (2.94-6.03 Ma; Laughlin and others, 1980) in the southeastern portion of the field (fig. 1, stars). Sample 717MR from map location 7 is an olivine tholeiite which erupted from one of the

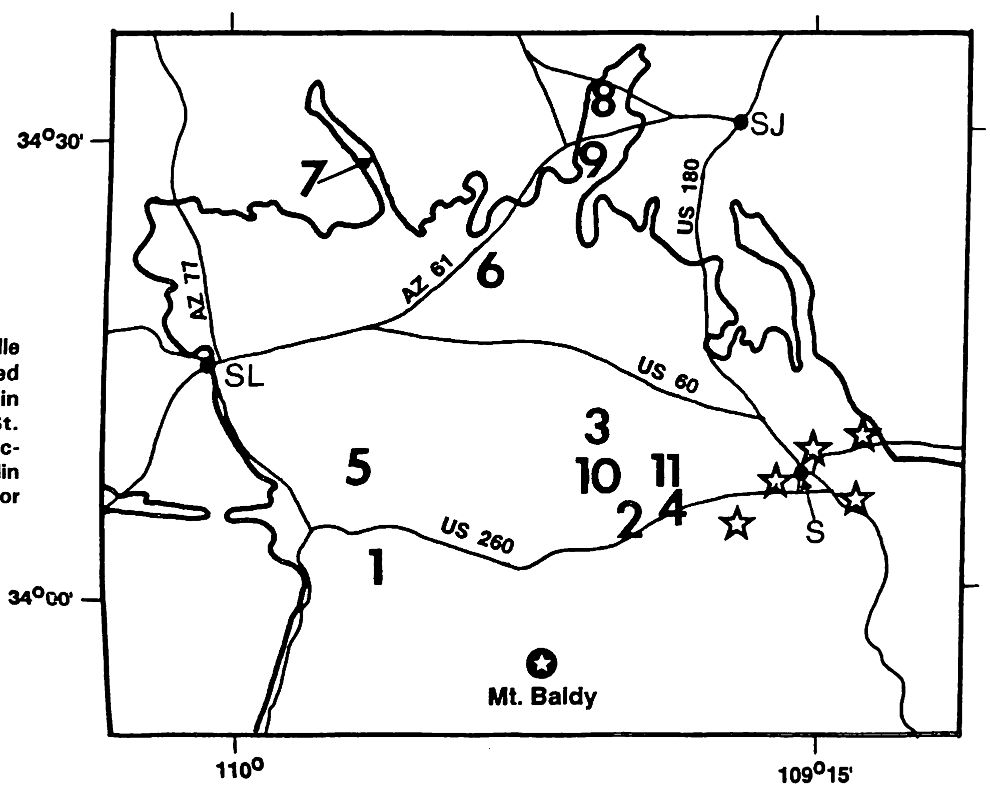

FIGURE 1. Location map of the Springerville volcanic field. Sample locations are numbered and correspond to the chemical data given in table 1. Springerville, Show Low, and St. Johns are designated by S, SL, and SJ respectively. Stars are samples dated by Laughlin and others, 1979 and 1980 (see text for discussion).

northern most vents in the field and is one of the only tholeiitic units which can be correlated to a vent. It is much younger (1.56 Ma) and less hypersthene normative (tholeiitic) than samples 771 and 801C (5.31 and 6.59 Ma respectively). Alkali olivine basalts and hawaiites from map locations 1-6, 10, and 11 range in age from 0.30 to 1.3 Ma.

The eleven samples analyzed in this study were combined with twenty-eight samples from the Springerville region to produce the histogram in figure 2. This summary illustrates that a major pulse of mafic magmatism occurred between approximately 0.3 and 2.0 Ma which is in agreement with previous interpretations of Springerville magmatism. Chemically, the majority of these lavas are basanites, alkali olivine basalts, and evolved alkalic compositions (hawaiite-benmoreite) with the exception of a few transitional to tholeiitic lavas (sample 717MR). It is clear from this histogram that mafic magmatism continued after the cessation of Mt. Baldy volcanism approximately 8 Ma ago. Most of the 8 to 2.5 Ma lavas are transitional to tholeiitic basalts thus strengthening the previous interpretation of initial tholeiitic magmatism followed by eruption of increasingly alkalic magmas. This is in direct contrast to other portions of the transition zone such as the Lucero field where mafic volcanism progressed from initially alkalic to bimodal alkalic and tholeiitic compositions (Baldridge and others, 1987). Additional mapping and dating is necessary before it can be determined if volcanism was continuous or if lulls in magmatism occurred during the 8.0 to 2.5 Ma period. The lack of identifiable vents for the northern most (map locations 8 and 9) tholeiitic lavas may indicate a period of fissure type eruptions between approximately 8 and 3 Ma perhaps associated with the initiation of extensional tectonics in this portion of the transition zone.

All samples were collected by J. L. Cooper and C. D. Condit unless otherwise indicated. Ar measurements were performed at Case Western Reserve University. Unit designations and vent nomenclature are those of Condit (1984). The decay constants used in the age calculations are as follows: $\lambda_\epsilon = 5.81 \times 10^{-11}$ yr^{-1}; $\lambda = 5.543 \times 10^{-11}$ yr^{-1}; and $^{40}K/K = 1.167 \times 10^{-4}$ atom/atom.

ACKNOWLEDGEMENTS

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SAMPLE DESCRIPTIONS

K-Ar

1. *705MC*
Alkali olivine basalt (Qhe) (34°2′53″N, 109°46′25″W; composite flow of vent 8435; McNary 7.5′ quad., Apache Co., AZ). Fine-grained, holocrystalline matrix of plagioclase, oxide, and mafic microlites; porphyritic olivine (to 2.5 mm), augite, and plagioclase; glomeroporphyritic plagioclase; microphenocrysts of Ti-augite. *Analytical data:* sample weight = 5.0460 gm; K = 1.282%, 1.246%; $^{40}Ar^*$ = 0.90 x 10^{-12} mol/g; $^{40}Ar^*$ = 4.13%.
(whole rock) 0.50 ± 0.03 Ma

K-Ar

2. *706GP*
Alkali olivine basalt (Qph_2) (S-C, S30,T8N,R27E; massive bomb in cinder pit of vent 8730; Green's Peak 7.5′ quad., Apache Co., AZ). V. fine-grained matrix of plagioclase, oxide, and mafic microlites (pyroxene and olivine); phenocrysts of olivine (altered to hematite) and plagioclase. *Analytical data:* sample weight = 5.1905 gm; K = 1.096%, 1.124%; $^{40}Ar^*$ = 2.04 x 10^{-12} mol/g; $^{40}Ar^*$ = 3.30%.
(whole rock) 1.27 ± 0.07 Ma

TABLE 1. Major element and CIPW normative analyses.

Map no.	1	2	3	4	5	6	7	8	9	10	11
Sample	705MC	706GP	709WK	712GP	716SM	719V	717MR	771	801C	708WK	713SN
Type	AB	AB	AB	AB	AB	TR	TH	TH	TH	HAW	HAW
SiO_2	46.04	45.09	45.49	47.88	45.49	46.39	48.16	50.17	51.27	49.21	48.03
TiO_2	1.95	2.41	1.93	1.71	2.11	1.77	1.58	1.54	1.67	2.02	1.87
Al_2O_3	14.71	17.64	15.22	15.72	13.67	15.82	16.12	14.94	15.21	18.37	16.71
Fe_2O_3	11.33	13.20	11.76	11.20	12.55	11.42	12.36	12.63	11.72	11.06	11.29
MnO	0.16	0.21	0.18	0.17	0.18	0.17	0.17	0.16	0.15	0.17	0.16
MgO	11.12	5.37	10.36	8.20	12.49	7.77	8.31	8.18	7.26	4.79	7.05
CaO	9.07	9.74	10.08	9.96	9.62	10.51	9.77	8.44	8.76	7.35	8.47
Na_2O	2.93	3.60	3.19	3.18	2.61	2.72	2.83	3.00	3.07	4.23	4.02
K_2O	1.15	1.13	1.05	0.97	0.93	0.88	0.56	0.60	0.86	1.74	1.36
P_2O_5	0.46	0.83	0.65	0.43	0.34	0.44	0.30	0.24	0.22	0.79	0.52
LOI	−0.28	−0.38	0.32	0.39	0.18	0.29	0.01	−0.02	0.04	0.03	0.38
TOTAL	98.65	98.84	100.23	99.81	100.17	98.18	100.16	99.90	100.22	99.75	99.85
AN	55.2	58.0	60.5	51.3	58.9	56.3	55.3	50.1	49.2	43.9	47.4
or	6.8	6.7	6.2	5.7	5.5	5.2	3.3	3.6	5.1	10.3	8.0
ab	19.1	20.7	15.7	24.5	15.9	22.0	24.0	25.4	26.0	33.2	26.1
an	23.6	28.6	24.1	25.8	22.8	28.4	29.6	25.5	25.2	26.0	23.5
ne	3.1	5.3	6.1	1.3	3.3	0.6				1.4	4.3
di	14.8	11.8	17.5	17.0	18.3	17.1	13.8	12.1	13.8	4.4	12.3
hy							6.7	19.0	20.1		
ol	23.6	16.2	21.9	17.8	26.1	17.2	15.8	7.6	3.2	15.7	17.3
il	3.7	4.6	3.7	3.3	4.0	3.4	3.0	2.9	3.3	3.9	3.6
ap	1.1	1.9	1.5	1.0	0.8	1.0	0.7	0.6	0.5	1.8	1.2
MG#	65.8	44.4	63.3	58.9	66.1	57.2	56.9	55.9	54.8	45.9	55.0

Major element analyses by DCP; all values in weight %; Fe_2O_3 = total Fe as Fe_2O_3.
LOI = % loss on ignition; CIPW norms calculated with Fe_2O_3 = 1.5.

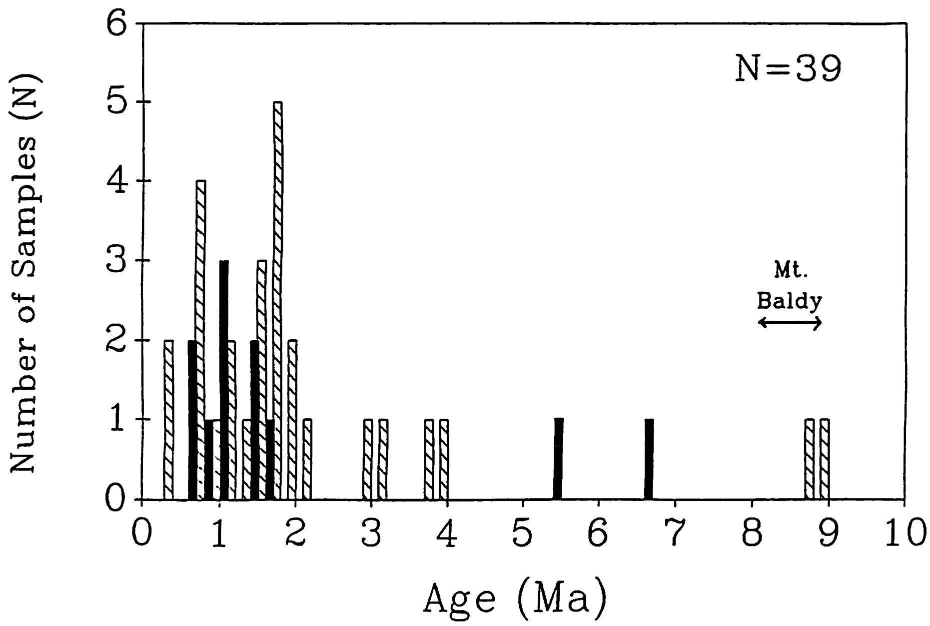

FIGURE 2. Histogram of K-Ar ages for lavas from the Springerville region. Solid black bars indicate samples from this study. Diagonal slashed bars represent data from Laughlin and others, 1979 and 1980, Aubele and others, 1986, and Condit and Shafiqullah, 1985.

3. *709WK* K-Ar
Alkali olivine basalt (Qgb_1) (SW¼,NW¼, S15,T9N,R26E; flow of vent 9621 (Whiting Knoll); Whiting Knoll 7.5' quad., Apache Co., AZ). V. fine-grained, holocrystalline matrix of plagioclase, Ti-augite, olivine, and oxide; porphyritic and glomeroporphyritic olivine (up to 2.5 mm). *Analytical data:* sample weight = 5.3550 gm; K = 1.053%, 1.073%; $^{40}Ar^*$ = 1.39 x 10^{-12} mol/g; $^{40}Ar^*$ = 9.98%.
(whole rock) 0.91 ± 0.02 Ma

4. *712GP* K-Ar
Alkali olivine basalt (Qpc_8) (SW¼, S28,T8N,R27E; flow of vent 8732A (Pole Knoll); Green's Peak 7.5' quad., Apache Co., AZ). Fine-grained, holocrystalline, intergranular, pilotaxitic matrix of plagioclase, Ti-augite, olivine, and oxide; porphyritic olivine and augite; glomeroporphyritic olivine + augite and augite + augite. Augite phenocrysts are twinned. *Analytical data:* sample weight = 5.0185 gm; K = 1.025%, 1.029%; $^{40}Ar^*$ = 1.92 x 10^{-12} mol/g; $^{40}Ar^*$ = 9.19%.
(whole rock) 1.30 ± 0.04 Ma

5. *716SM* K-Ar
Alkali olivine basalt (Qmb6) (N-C,S20,T9N,R24E; flow of vent 9416 or 9417; Sponsellar Mtn. 7.5' quad., Navajo Co., AZ). Fine-grained, holocrystalline matrix of plagioclase, intergranular augite, olivine, and oxide; porphyritic and glomeroporphyritic olivine; microphenocrysts of olivine. *Analytical data:* sample weight = 5.2580 gm; K = 0.987%, 1.002%; $^{40}Ar^*$ = 1.45 x 10^{-12} mol/g; $^{40}Ar^*$ = 16.8%.
(whole rock) 1.01 ± 0.02 Ma

6. *719V* K-Ar
Transitional basalt (Qvc_4) (W-C, S11,T11N,R25E; flow of Little Ortega Lake; Vernon 7.5' quad., Apache Co., AZ). Medium-grained, holocrystalline, diktytaxitic matrix of subophitic augite and plagioclase; phenocrysts of olivine (partially altered to iddingsite); few scattered grains of resorbed plagioclase. Analytical data: Sample weight = 5.5252 gm; K = 0.937%, 0.924%; $^{40}Ar^*$ = 1.34 x 10^{-12} mol/g; $^{40}Ar^*$ = 14.5%.
(whole rock) 1.00 ± 0.02 Ma

7. *717MR* K-Ar
Tholeiitic basalt (Owg_3) (S-C, S29,T12N,R24E; Point of the Mtn. flow from vent 1414 (Sides Knoll); Mesa Redonda 7.5' quad., Apache Co., Az). Fine- to medium-grained holocrystalline, diktytaxitic matrix of sub-ophitic augite and plagioclase; porphyritic olivine (partially altered to iddingsite) and resorbed plagioclase. *Analytical data:* sample weight = 5.0435 gm; K = 0.573%, 0.568%; $^{40}Ar^*$ = 1.28 x 10^{-12} mol/g; $^{40}Ar^*$ = 15.16%.
(whole rock) 1.56 ± 0.03 Ma

8. *771* K-Ar
Tholeiitic basalt (unmapped) (34°43'39" N, 109°34'39" W; roadcut along Rt. 180, 5.3 miles N of intersection with Rt. 61, flow of Volcanic Mtn.; Stinking Springs 7.5' quad., Apache Co., AZ). Fine- to medium-grained, holocrystalline, diktytaxitic matrix of sub-ophitic augite and plagioclase; anhedral olivine phenocrysts; a few large resorbed plagioclase grains. Analytical data: Sample weight = 5.9080 gm; K = 0.598%, 0.612%; $^{40}Ar^*$ = 4.67 x 10^{-12} mol/g; $^{40}Ar^*$ = 25.1%. *Collected by:* J. L. Cooper and W. K. Hart.
(whole rock) 5.31 ± 0.11 Ma

9. 801C K-Ar
Tholeiitic basalt (Qoc_1) (34°22'40" N, 109°33'19" W; natural outcrop near top at flow edge; flow of unknown vent; Concho 7.5' quad., Apache Co., AZ). Coarse-grained, holocrystalline, diktytaxitic, nearly equigranular, ophitic to sub-ophitic augite and subcalcic augite; intergranular olivine (partially altered to iddingsite). *Analytical data:* sample weight = 4.9320 gm, 5.3675 gm; K = 0.873%, 0.884%; $^{40}Ar^*$ = 8.26 x 10^{-12} mol/g, 8.43 x 10^{-12} mol/g; $^{40}Ar^*$ = 17.6%, 17.7%. *Collected by:* C. D. Condit.
(whole rock) 6.52 ± 0.12 Ma
(whole rock) 6.66 ± 0.12 Ma

10. *708WK* K-Ar
(Qgh₇) (W-C, S27,T9N,R26E; flow of vent 8611A (Green's Peak); Whiting Knoll 7.5′ quad., Apache Co., AZ). Fine-grained, holocrystalline, pilotaxitic matrix of plagioclase, oxide and intergranular olivine; microphenocrysts of olivine and plagioclase. *Analytical data:* sample weight = 5.0690 gm; K = 1.631%, 1.640%; $^{40}Ar^*$ = 1.80 x 10^{-12} mol/g; $^{40}Ar^*$ = 24.3%.

(whole rock) 0.76 ± 0.02 Ma

11. *713SN* K-Ar
Hawaiite (Qkc_4) (NE¼, S35,T9N,R27E; flow of vent 8702; Springerville NW 7.5′ quad., Apache Co., AZ). Fine-grained, holocrystalline matrix of plagioclase, intergranular augite, olivine, and oxide; porphyritic olivine and augite; glomeroporphyritic olivine + augite; microphenocrysts of plagioclase and olivine. *Analytical data:* sample weight = 5.2630 gm; K = 1.294%, 1.320%; $^{40}Ar^*$ = 1.15 x 10^{-12} mol/g; $^{40}Ar^*$ = 16.3%.

(whole rock) 0.61 ± 0.01 Ma

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Geologic time chart references

The 1983 revision of this geologic time chart was prepared by the Geologic Names Committee for U.S. Geological Survey use. It supersedes the 1980 chart. Numerical ages of chronostratigraphic boundaries are subject to many uncertainties besides the analytical precision of the dating. The placement of boundary stratotypes and the achievement of international agreements on these ages is a slow process subject to much revision and review. Recent studies and revisions of the geologic time scale of especial interest are reported in *A geologic time scale,* by W. B. Harland, A. V. Cox, P. G. Llewellyn, C. A. G. Pickton, A. G. Smith, and R. Walters, 1982: Cambridge University Press, 132 p.; *The decade of North American geology 1983 geologic time scale,* by A. R. Palmer, 1983: Geology, v. 11, p. 503–504; and *The chronology of the geological record,* N. J. Snelling (ed.), 1985: Blackwell Scientific Publishers, The Geological Society, Memoir No. 10, 343 p.

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