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Isochron/West, Bulletin of Isotopic Geochronology, v. 25, pp. 5

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LATE CENOZOIC VOLCANISM OF THE CENTRAL JEMEZ ZONE, ARIZONA–NEW MEXICO

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The Los Alamos Scientific Laboratory performed this study under the auspices of the U. S. Department of Energy.

Mayo (1958) defined a series of northeast and northwest trending lineaments in the southwestern United States that apparently influenced the localization of many ore districts within this region. One of these lineaments is the Jemez Zone which extends northeastward across Arizona and New Mexico. This lineament or zone is defined by a belt of late Cenozoic volcanic fields that includes, from southwest to northeast, the Pinacate region of Sonora, Mexico; the centers near Globe and in the vicinity of Show Low-St. Johns-Springerville in Arizona; and, in New Mexico, the Zuni Centers, the Bandera lava field, Mount Taylor, the Valles Caldera, the Taos and Cerros del Rio volcanic fields, and the centers near Raton-Clayton. With the exception of the Mount Taylor field (Baker and Ridley, 1970; Lipman and Moench, 1972) and the Valles Caldera (Smith, Bailey, and Ross, 1970) the volcanic rocks of these centers are predominantly mafic. At Mount Taylor and the Valles Caldera, intermediate and silicic volcanism occurred.

For several years we have been examining the petrology, geochemistry, and geochronology of the basaltic centers of the central Jemez Zone, i.e. the interval from Show Low, Arizona to Grants, New Mexico. We report here the results of chemical and Sr isotopic analysis and K-Ar dating of nine basaltic samples from this region (sample descritpions).

ACKNOWLEDGMENTS

This work was funded by the Division of Geothermal Energy, U.S. Department of Energy, the National Science Foundation, (Grant EAR-76-02590 to Paul E. Damon and DES72 01655 A01 to Douglas E. Brookins) and the states of Arizona and New Mexico.

Chemical analyses were provided by John Husler, University of New Mexico.

R. S. DellaValle, J. K. Register, and M. E. Register of the University of New Mexico provided laboratory assistance.

DISCUSSION

The results of our analyses will be discussed on the basis of their geographical location, progressing from the southwest to the northeast along the central Jemez Zone.

In the Springerville area, three basalt flows were analyzed. Two of these were sampled in a road cut along U.S. 60, 6.8 km east of Springerville. At this site, three flows can be distinguished; the lowermost flow (flow 1, AWL-40-74) is separated by approximately 10 m of fluvial sediments from flow 2 (AWL-41-74) and flow 3 lies directly on top of flow 2. There is no evidence of weathering or erosion of the top of flow 2 before eruption of flow 3 and we believe little time elapsed between eruptions. Although flows 1 and 2 are chemically indistinguishable (table 1), they differ in age by about 2 m.y. (2.94 m.y. versus 0.82 m.y.). Both flows are relatively high in SiO_2 and TiO_2 but low in Na_2O and K_2O. Initial $^{87}Sr/^{86}Sr$ ratios indicate that both flows 1 and 2 have been contaminated by crustal material; flow 1 to a significantly greater degree. Despite the varying degree of contamination, the bulk composition of the magma was not affected. Similar results were reported for the McCarty's flow by Carden and Laughlin (1974). Whatever the source of the magma that produced flows 1 and 2, it apparently remained relatively constant in terms of depth or degree of partial melting for approximately 2 m.y.

Concurrently with eruption of flow 1, alkalic basaltic magma (K-Ar age 3.06 m.y.) erupted to the west. The easternmost edge of this flow is exposed in low cliffs along the west side of the Little Colorado River, 3 km west of the town of Eagar, Arizona. This basalt (AWL-42-74) is significantly different in terms of its silica, titania, and alkali contents (table 1). The diversity in composition, but similarity in age between this flow and flow 1 suggests that either different depths of source regions were being tapped at the same time or that isolated magma sources existed with varying degrees of partial melting. In any case, a complex magmatic plumbing system is suggested for this area. The initial $^{87}Sr/^{86}Sr$ ratio of 0.7057 suggests some crustal contamination of the magma.

Moving to the northeast, the next sample (Di-4-74) came from a northwest striking dike, 27 km northeast of the town of Quemado, New Mexico. This dike is one of several that are readily discernible on LANDSAT photographs of this region. Compositionally the dike is a basaltic andesite with relatively high contents of silica, titania, and the alkali oxides. Its K-Ar age is 27.7 m.y., placing it within the mid-Tertiary period of igneous activity. This dike is apparently part of the volcanism occuring along the northwest striking Zuni lineament (Slawson and Austin, 1962), during mid-Tertiary times. Volcanism of similar age occurred along this northwest striking lineament from western Texas to Utah. Since it crosses the trend of the Jemez Zone and is of a totally different age, this dike is obviously not part of the Jemez Zone volcanism.

Further to the northeast, the next sample (FL-3-74) is from a large flow that covers about 600 km^2 north of Fence Lake. Its K-Ar age is 1.41 m.y. As shown in table 1, it is tholeiitic in composition with a low K_2O content. Compositionally it is similar to the McCarty's flow (Carden and Laughlin, 1974) which erupted about 700 A.D. from a vent 63 km to the northeast. North of Fence Lake, near the

Zuni Pueblo, a compositionally similar basalt (Br-2-74) yields an imprecise age of 0.70±0.55 m.y. Because of the errors associated with the dates on these two flows, FL-3-74 and BR-2-74 are indistinguishable in age. The similarities in composition suggest that they may have been derived from the same source. When the McCarty's flow is also considered, we again have evidence for chemically similar magmas erupting over an interval of more than 1 m.y.

Within the Bandera lava field three samples were dated; two were analyzed. The first of these is an alkali olivine basalt (B-1-74) that covers the land surface west of Bandera Crater (Laughlin and others, 1972). On geomorphological evidence, this flow is older than the numerous cinder cones of the Bandera lava field, and LANDSAT imagery indicates that it is one of the older flows of the area. Its K-Ar age of 0.199 m.y. thus establishes a maximum age for most of the other volcanism within the field. The second sample (ACE-8-75-12) from this area was collected from a northwest striking dike that is intrusive into the Precambrian core of the Zuni Mountains. It was mapped by Goddard (1966) as Tertiary in age, perhaps because of its parallelism to the mid-Tertiary dikes discussed above. The K-Ar age of this sample is 950.7 m.y.

This sample is relatively fine-grained and is slightly altered, suggesting that the 950 m.y. age is probably minimal. If this age is used to correct the measured $^{87}Sr/^{86}Sr$ ratio of 0.7230, an initial ratio of 0.711 is obtained. Since this value must be considered a maximum for the initial ratio, it is impossible to evaluate the effects of crustal contamination on this rock.

The Laguna flow near Grants, New Mexico was also dated, yielding an age of 1.57 m.y. Unpublished data of Laughlin indicate that it is comparatively similar to the Fence Lake, Black Rock, and McCarty's flow.

The initial $^{87}Sr/^{86}Sr$ ratios reported here for the basalts of the Central Jemez Zone are significantly higher than many other basalts from the Mogollon Datil volcanic field, 0.7034–0.7041 (Bikerman, 1976; Stinnett and Steuber, 1976), and the southern Basin and Range province (Damon, 1971). We suggest that the crustal contamination observed in these samples may be correlated with the heat flow high reported by Reiter and others (1975) for this same area. Because of severe thermal constraints on mixing of magma with cold material, crustal contamination is far more likely in regions of hot or even partially melted crust. Both the contamination and high heat flow of the Central Jemez Zone may reflect the introduction of basaltic magma into the crust over a relatively long period of time (3 m.y.).

The new dates reported here indicate that three periods of basaltic volcanism occurred within the area; one in the Precambrian and along northwest trending structures, one in the mid-Tertiary, and one in the late Cenozoic extending into historic times along the northeast trending Jemez Zone.

TABLE 1. Chemical and isotopic compositions of basaltic rocks from the Central Jemez Zone, New Mexico and Arizona

Sample no.	AWL-40-74 (%)	AWL-41-74 (%)	AWL-42-74 (%)	Di-4-74 (%)	FL-3-74 (%)	BR-2-74 (%)	B-1-74 (%)	ACE-8/75-12 (%)
SiO_2	52.04	52.18	44.74	53.50	50.22	48.25	46.76	47.87
TiO_2	1.59	1.59	2.08	2.26	1.34	1.36	2.05	2.21
Al_2O_3	15.40	15.02	15.25	14.00	15.25	15.40	15.25	14.91
Fe_2O_3	1.70	2.57	3.02	3.54	1.62	1.77	4.40	5.07
FeO	9.00	7.90	8.50	6.96	10.01	10.42	7.18	8.86
MgO	6.82	6.68	8.84	3.20	8.40	9.84	9.38	5.74
CaO	8.62	8.80	12.19	6.14	9.30	8.99	9.20	7.17
MnO	0.152	0.150	0.171	0.179	0.168	0.172	0.166	0.194
SrO	0.030	0.032	0.059	0.045	0.024	0.029	0.066	0.034
Na_2O	3.16	3.32	2.89	3.73	2.64	2.71	3.09	2.91
K_2O	0.89	0.94	1.07	2.07	0.42	0.50	1.34	1.97
H_2O	0.11	0.04	0.13	0.57	0.12	0.02	0.01	0.05
H_2O^+	0.35	0.35	0.15	1.25	0.37	0.01	0.24	1.81
CO_2	0.24	0.14	0.28	0.55	0.13	0.33	0.40	0.45
P_2O_5	0.19	0.20	0.34	1.60	0.16	0.166	0.489	0.31
	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)	(ppm)
Rb	19.5 (15.8)*	16.9 (16.0)	19.6	84.7 (66.6)	9.7 (5.5)	(5.2)	(10.0)	103.2
Sr	296.5 (298.1)	290.8 (281.2)	604.1	458.7 (452.2)	243 (239.7)	(243.7)	(672.0)	330.9
$^{87}Sr/^{86}Sr$	0.7116	0.7069	0.7057	0.7144	0.7063	0.7087	0.7032	0.7230

*Rb and Sr concentrations in parentheses were measured at the University of Arizona. All other measurements were made at the University of New Mexico.

CONSTANTS USED:

$\lambda_\beta = 4.963 \times 10^{-10} yr^{-1}$
$\lambda_\epsilon = 0.581 \times 10^{-10} yr^{-1}$
$\lambda = 5.544 \times 10^{-10} yr^{-1}$
$^{40}K/K = 1.167 \times 10^{-4}$ atom/atom

SAMPLE DESCRIPTIONS

1. *AWL-40-74* K-Ar
Olivine tholeiite (Lowermost flow in roadcut along U.S. 60, 6.8 km E of Springerville; 34°08'29"N, 109°12' 35"W; Apache Co., AZ). Also forms cliffs along E side of Little Colorado River. *Analytical data:* K = 0.690%, radiogenic ^{40}Ar = 3.37, 3.45, 3.73 x 10^{-12} m/g, atmospheric ^{40}Ar = 82.9, 82.1, 80.6%.
(whole rock) 2.94±0.14 m.y.

2. *AWL-41-74* K-Ar
Olivine tholeiite (34°08'29"N, 109°12'35"W; Apache Co., AZ. Same location as AWL-40-74). Second flow in sequence. Separated by channel fill gravels from underlying flow. *Analytical data:* K = 0.717%, radiogenic ^{40}Ar = 1.01, 1.04 x 10^{-12} m/g, atmospheric ^{40}Ar = 76.6, 76.2%.
(whole rock) 0.824±0.040 m.y.

3. *AWL-42-74* K-Ar
Alkali basalt (34°06'39"N, 109°18'56"W; Apache Co., AZ). Flow forms low cliffs on W side of Little Colorado River at margin of flood plain. *Analytical data:* K = 0.768%, radiogenic ^{40}Ar = 4.16, 4.00 x 10^{-12} m/g, atmospheric ^{40}Ar = 51.9, 53.0%.
(whole rock) 3.061±0.080 m.y.

4. *Di-4-74* K-Ar
Basaltic andesite (34°31'51"N, 108°21'55"W; Catron Co., NM). Olivine and pyroxene bearing dike, which strikes N60°W. Dike can be traced for about 48 km on ERTS photographs. *Analytical data:* K = 1.74%, radiogenic ^{40}Ar = 4.16, 4.00 x 10^{-12} m/g, atmospheric ^{40}Ar = 51.9, 53.0%.
(whole rock with pyroxene phenocrysts removed) 27.67±0.59 m.y.

5. *FL-3-74* K-Ar
Olivine tholeiite (34°44'55"N, 108°21'55"W; Valencia Co., NM). Very large flow covering approximately 600 km^2. Sample collected from tongue of flow crossed by NM Highway 32-36. *Analytical data:* K = 0.378%, radiogenic ^{40}Ar = 0.87, 0.98 x 10^{-12} m/g, atmospheric ^{40}Ar = 94.0, 93.3%.
(whole rock) 1.41±0.29 m.y.

6. *BR-2-74* K-Ar
Olivine tholeiite (35°05'12"N, 108°44'18"W; McKinley Co., NM). Flow erupted E of collection site at Black Rock and flowed W down valley of Zuni River. *Analytical data:* K = 0.397%, radiogenic ^{40}Ar = 0.938, 0.410, 0.066, 0.062, 0.500, 0.921 x 10^{-12} m/g, atmospheric ^{40}Ar = 98.8, 99.5, 99.9, 99.0, 98.2%.
(whole rock) 0.70±0.55 m.y.

7. *B-1-74* K-Ar
Alkali basalt (35°00'36"N, 108°05'47"W; Valencia Co., NM). This flow is one of the oldest flows in the Bandera lava field. It overlies Permian San Andreas limestone. Covers large portion of the valley floor W of Bandera Crater. *Analytical data:* K = 1.096%, radiogenic ^{40}Ar = 0.339, 0.362, 0.433 x 10^{-12} m/g, atmospheric ^{40}Ar = 91.6, 94.2, 93.1%.
(whole rock) 0.199±0.042 m.y.

8. *AWL-2-77* K-Ar
Tholeiitic basalt (35°07'31"N, 107°47'33"W; Valencia Co., NM). Laguna flow from San Jose River valley, 3 miles E of Grants, NM. This flow lies beneath the McCarty's basalt flow. *Analytical data:* K = 0.645%, radiogenic ^{40}Ar = 1.79, 1.78, 1.72 x 10^{-12} m/g, atmospheric ^{40}Ar = 94.6, 93.7, 96.8%.
(whole rock) 1.57±0.26 m.y.

9. *ACE-8-75-12* K-Ar
Diabase (34°59'27"N, 108°01'27"W; Valencia Co., NM). NW striking dikes in Precambrian core of Zuni Mountains. Mapped by Goddard (1966) as Tertiary in age. *Analytical data:* K = 1.93%, radiogenic ^{40}Ar = 4166.8, 4167.2 x 10^{-12} m/g, atmospheric ^{40}Ar = 4166.8.
(whole rock) 950.7±19.7 m.y.

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