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# Fission-track geochronology of the Arkansas alkaline province

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CONTENTS



Illustrations



Tables

## ABSTRACT

The Arkansas alkaline province consists of a series of small alkaline complexes and apparently associated dikes which define a northeast- (from Little Rock) to southwest- (Murfreesboro) trending outcrop belt. The complexes to the north of the Mississippi embayment consist of a variety of mafic to felsic alkaline rocks and, in addition at Magnet Cove and Potash Sulphur Springs, carbonate phases. The dikes show the same range of rock types as the complexes. To the south of the Mississippi embayment are found a series of syenite stocks. Apatite and sphene fission-track ages were determined for the various complexes and dikes of the province.

The fission-track ages determined in this study are in good agreement with previously determined K-Ar biotite ages and U-Pb zircon ages. The dates define two periods of igneous activity, one centered around 88 Ma (million years ago), which encompasses the syenite stocks, and the other period centered around 100 Ma, which encompasses all the other alkaline complexes and dikes. There is no apparent age trend along the outcrop belt, but the limit of the Mississippi embayment is a convenient dividing line between the older igneous activity to the north and the younger activity to the south. With the exception of Magnet Cove, the fission-track ages indicate a short magmatic history for all of the complexes. At Magnet Cove the carbonates were apparently emplaced about 5 million years after the silicate rocks of the complex. Petrogenetic models for Magnet Cove should consider the potential decoupling of the silicate magmatism from the carbonatitic magmatism. The age data indicate a simultaneity of igneous activity throughout the province with the exception of the syenite stocks. While the syenites may be derived from similar sources as the other rocks, they were emplaced during a separate magmatic event.

## INTRODUCTION

The Arkansas alkaline province consists of a series of small plutons and apparently associated dikes which define a northeast-southwest-trending outcrop belt. This belt runs from Murfreesboro at the southwest end to the vicinity of Little Rock at the northeast end (fig. 1). A variety of lithologies are represented. These include carbonatite (Morrilton-Perryville) and lamprophyric to felsic dikes (Benton dike swarm and V-intrusive), carbonate and associated alkaline rocks (Magnet Cove and Potash Sulphur Springs), syenite stocks (Granite Mountain and Saline County, the protolith of the Arkansas bauxite deposits), and lamproite (Prairie Creek). Previously determined radiometric dates for the igneous rocks give a Cretaceous age and the dates suggest that the rocks are younger in a northeasterly direction (Mullen and Murphy, 1985).

The purpose of the present study was to investigate the ages of the various plutons and dikes of the Arkansas alkaline province using fission-track geochronology with the goal of obtaining a more detailed geochronologic history for this province. Specific questions concern the validity of the apparent age trend and whether or not there was an extended period of igneous activity at any of the intrusive centers. Opinions and conclusions expressed here do not necessarily represent those of the U.S. Geological Survey.

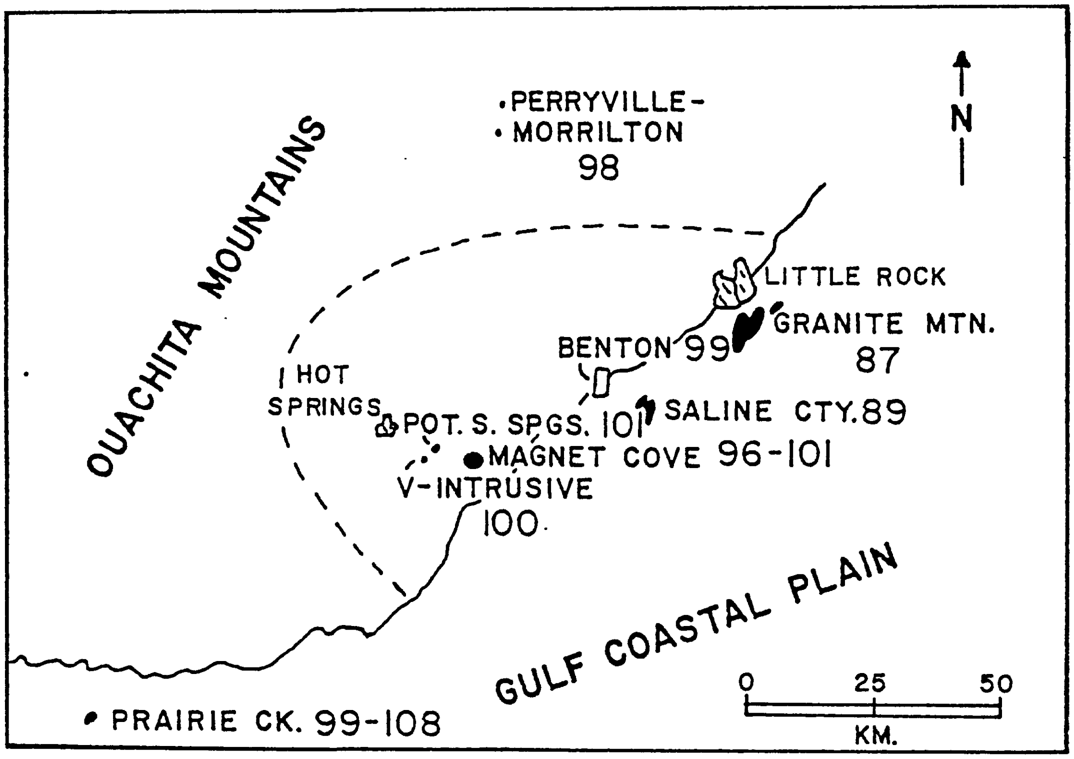


Figure 1. - Locations of the various intrusive and dike complexes of the Arkansas alkaline province. Numbers indicate mean ages (in Ma) for the various complexes as determined from this study. The ages for the Prairie Creek complex are from Zartman and others (1967). The dashed line represents the limit of the lamprophyre dikes. Map modified from Mullen and Murphy (1985).

## METHODOLOGY

Fission-track ages were determined using both apatite and sphene. Since these two minerals have different geologic resetting temperatures (100 °C for apatite and 240 °C for sphene) they potentially contain information regarding the thermal history of a pluton or region. The minerals were separated from the rocks using standard magnetic and heavy-liquid separation techniques. Apatite ages were determined using the population method while sphene ages were determined using external mica detectors. The procedures utilized were those described by Naeser (1976). The fluence was determined using mica detectors on NBS fission-track glass standard 962. The results of the age determinations are reported in table 1.

The question of the precision and accuracy of a fission-track age, and the best statistical method for estimating the error in a fission-track age, has been debated for some time. In general, errors in population-method ages are determined using Gaussian statistics, whereas errors in external-detector-method ages are determined using Poisson statistics. Errors calculated using these methods are generally quite large, often on the order of 10 percent at the 2-sigma level. Since it was necessary in this study to detect relatively small variations in age, a variety of approaches were used to try and minimize the error in the age determinations.

In the case of the population method, separate populations of grains, were counted on different days. Depending on the track density, 50-100 grains were counted for both fossil and induced tracks. On a subsequent day an equal number of grains were counted from different portions of the grain mounts. In table 1 the ages and errors reported under the column "Age" are those based on a single grain population with the error calculated using Gaussian statistics. If more than one population of grains was counted the results are reported under the column "Mean Age," and the error is the standard deviation of the ages reported under the column "Age" plus the error associated with the fluence determination. As is to be expected, the error of the mean is generally significantly smaller than that reported for an individual determination.

In the case of the sphene ages, multiple determinations of the ages were generally not done, and the errors reported are based on Poisson statistics. It is felt that these errors are generally overstated. In one case, sample 86-20, sphene ages were determined for two different sets of grains on successive days and the error in this case is relatively small.

Finally, in the case of three samples the ages were determined in duplicate using two different irradiations so that both variations in determining the fluence and variations in track counting could be assessed. All three duplicates were done using apatite and these duplicates are indicated by the "(1)" or "(2)" following the sample designations in table 1. These samples represent truly independent estimates of the error in the age determinations and at the 2-sigma level these errors are 1.7 percent (AK-5B), 3.7 percent (MC3), and 0.7 percent (AK-10).

It would seem that it is possible to significantly reduce the error associated with a fission-track age by doing multiple determinations of the age. The best approach would be to determine the ages in duplicate using two different irradiations. The time required to produce a fission-track age is of course greatly increased when doing ages in duplicate, and the individual investigator must decide whether the increased precision is worth the additional effort.

## GEOLOGY AND GEOCHRONOLOGY

Refer to figure 1 for the locations of individual plutons and dike clusters. All of the fission-track ages discussed in this section are reported in table 1.

### Granite Mountain and Saline County syenites

Gravity and drill-hole data (Gordon and others, 1958) indicate that syenite underlies a substantial region south and southwest of Little Rock. The two principal exposures of syenite are in a series of quarries at Granite Mountain on the southern edge of Little Rock and in Saline County near Bauxite. A number of investigators have studied these rocks (Bath, 1983; Beardsley, 1983; Jackson, 1978; Marks, 1977; and Simmen, 1955) and three major lithologies have been identified: nepheline syenite, pulaskite, and quartz syenite. At Granite Mountain Morris and Eby (1986) describe several stages of syenite emplacement. An early Stage I "blue syenite" is characterized by the presence of magnesium-rich olivine. This unit occurs as isolated "blocks" in the more extensive Stage II "gray syenites" which show evidence of potassic-metasomatism. The Stage III red-pink syenites occur as well-developed dikes which crosscut the earlier rocks. Samples from all three stages at Granite Mountain plus a nepheline syenite sample from Saline County were selected for age determinations.

Zartman and others (1967) have previously reported K-Ar biotite ages of 89 and 93 Ma and a Rb/Sr age of 88 Ma for nepheline syenites from the Little Rock area. Note that all ages have been calculated on the basis of the new decay constants recommended by Steiger and Jaeger (1977). Apatite fission-track ages for the Stage I syenites at Granite Mountain are 89.4 and 96.1 Ma. The Stage II syenites yield an apatite age of 89.2 Ma and sphene ages of 85.7, 87,0, and 86.6 Ma. The Stage III syenites yield apatite ages of 87.8 and 85.5 Ma and sphene ages of 86.7 and 85.1 Ma. The mean sphene age for the Stage II syenites is 86.4±1.3 Ma and for the Stage III syenites the mean apatite age is 86.7±3.3 Ma and the mean sphene age is 85.9±2.3 Ma. In the case of the Stage II and Stage III syenites the ages are indistinguishable and the virtually identical ages for both sphene and apatite indicate that there was a short cooling history. All of these ages are close to those previously reported by Zartman and others (1967) although they tend to be slightly younger. The sphene age (89.7 Ma) for the Saline County nepheline syenite is virtually identical to the age previously reported by Zartman and others (1967).

The somewhat older age determined for the Stage I syenites warrants further discussion. The apatites in these rocks are significantly different from those found elsewhere in the Granite Mountain pluton. The apatites are crowded with minute, oriented, opaque inclusions and the track density is extremely low. The abundant opaque inclusions make track counting difficult and the low track density produces relatively poor statistics. Four separate age determinations were carried out for sample Mu8X in an effort to improve the statistics. Two separate populations of 100 grains each were counted resulting in the first two ages reported. The grain mounts were then repolished to expose a new surface and re-etched. Two additional populations of 100 grains each were counted resulting in the third and fourth ages reported. The resulting mean age of 96.1±11.7 Ma is the oldest reported for the Granite Mountain pluton, but due to the large error its statistical significance is questionable. The other age determined for the Stage I syenites (sample 85-211) is consistent with all the other ages reported for

Table 1. Analytical data for fission-track determinations

| Sample | Lithology | Mineral dated | Spontaneous tracks Density ($10^5/cm^2$) | Spontaneous tracks Total counted | Induced tracks Density ($10^5/cm^2$) | Induced tracks Total counted | Thermal neutron dose ($10^5/cm^2$) | Age (Ma±2σ) | Mean age (Ma±2σ) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | Granite Mountain | | | | |
| MuB | Pulaskite | Apatite | 1.37 | 59 | 1.44 | 69 | 1.58 | 89.2±16.5 | |
| | | Sphene | 6.63 | 159 | 7.17 | 86 | 1.56 | 85.7±11.5 | |
| MuC | Coarse syenite | Sphene | 3.33 | 56 | 3.57 | 30 | 1.57 | 87.0±19.7 | |
| Mu8X | Ol syenite | Apatite | 0.58 | 1.40 | 0.53 | 128 | 1.58 | 102.6±13.7 | |
| | | | 0.59 | 142 | 0.57 | 137 | 1.58 | 97.1±11.8 | |
| | | | 0.63 | 150 | 0.66 | 158 | 1.58 | 89.6±11.5 | |
| | | | 0.68 | 1.63 | 0.67 | 160 | 1.58 | 95.2±11.7 | 96.1±11.7 |
| KL-86-11 | Pink syenite | Apatite | 2.31 | 222 | 2.72 | 261 | 1.74 | 87.8± 9.0 | |
| | | Sphene | 3.75 | 99 | 4.55 | 60 | 1.77 | 86.7±14.2 | |
| 85-211 | Ol syenite | Apatite | 0.49 | 117 | 0.56 | 135 | 1.74 | 90.4±13.2 | |
| | | | 0.53 | 126 | 0.62 | 1.48 | 1.74 | 88.4±11.1 | 89.4± 3.8 |
| 86-12 | Pink syenite | Apatite | 3.53 | 178 | 4.27 | 215 | 1.74 | 85.5±11.5 | |
| | | Sphene | 2.71 | 52 | 3.33 | 32 | 1.76 | 85.1±19.1 | |
| 86-20 | Pegmatite | Sphene | 3.75 | 126 | 4.46 | 75 | 1.75 | 87.4±12.7 | |
| | | | 4.33 | 104 | 5.25 | 63 | 1.75 | 85.8±13.7 | 86.6± 3.3 |
| | | | | | Saline County | | | | |
| Mu1 | Neph. syenite | Apatite | 8.44 | 81 | 9.17 | 88 | 1.58 | 86.4±25.0 | |
| | | Sphene | 42.2 | 1,113 | 43.4 | 573 | 1.55 | 89.7± 4.6 | |
| | | | | | Morrilton-Perryville carbonatites | | | | |
| 85-59 | Carb. breccia | Apatite | 5.21 | 625 | 5.58 | 669 | 1.75 | 97.0± 9.1 | |
| | | | 4.74 | 569 | 4.99 | 599 | 1.75 | 98.7± 9.2 | 97.9± 3.4 |
| 85-65 | Carbonatite | Apatite | 2.64 | 317 | 2.72 | 326 | 1.74 | 100.2±12.8 | |
| | | | 2.90 | 348 | 3.12 | 374 | 1.74 | 96.0±12.2 | 98.1± 6.9 |
| | | | | | Benton dikes | | | | |
| AK-16 | Camptonite | Apatite | 2.25 | 324 | 2.29 | 330 | 1.73 | 100.9±12.7 | |
| | | | 1.93 | 268 | 2.05 | 295 | 1.73 | 96.7±14.3 | 98.8± 6.9 |
| AK-18 | Sannaite | Sphene | 5.67 | 68 | 10.67 | 64 | 3.17 | 100.0±17.3 | |
| | | | | | Potash Sulphur Springs | | | | |
| AK-5A | Carbonatite | Apatite | 0.75 | 181 | 0.69 | 165 | 1.56 | 100.6±13.1 | |
| | | | 0.72 | 172 | 0.64 | 153 | 1.56 | 104.1±12.8 | 102.4± 5.9 |
| AK-5B(1) | Ijolite | Apatite | 2.91 | 349 | 2.88 | 346 | 1.73 | 103.7±10.7 | |
| | | | 2.89 | 347 | 3.06 | 368 | 1.73 | 97.0±11.3 | 100.4±10.5 |
| Ak-5B(2) | Ijolite | Apatite | 3.65 | 438 | 3.35 | 402 | 1.56 | 100.9±11.7 | |
| | | | 3.22 | 386 | 3.06 | 367 | 1.56 | 97.5±12.0 | 99.2± 5.8 |
| | | | | | V-intrusive | | | | |
| AK-6 | Microijolite | Apatite | 3.40 | 408 | 3.42 | 411 | 1.73 | 102.1± 9.6 | |
| AK-7 | Neph. syenite | Sphene | 3.39 | 57 | 6.31 | 53 | 3.19 | 101.7±19.5 | |
| AK-8 | Mlagnite | Apatite | 3.76 | 542 | 3.97 | 571 | 1.73 | 97.3± 8.6 | |
| | | | 4.03 | 580 | 4.18 | 602 | 1.73 | 99.0± 9.0 | 98.2± 3.4 |
| | | Sphene | 1.75 | 42 | 3.33 | 40 | 3.18 | 99.2±21.9 | |

Table 1. Analytical data for fission-track age determinations--Continued

| Sample | Lithology | Mineral dated | Spontaneous tracks Density ($10^5/cm^2$) | Spontaneous tracks Total counted | Induced tracks Density ($10^5/cm^2$) | Induced tracks Total counted | Thermal neutron dose ($10^5/cm^2$) | Age (Ma±2σ) | Mean age (Ma±2σ) |
|---|---|---|---|---|---|---|---|---|---|
| | | | | Magnet Cove | | | | | |
| MC1 | Phonolite | Apatite | 0.95 | 91 | 0.99 | 95 | 1.73 | 98.5±17.9 | |
| | | Sphene | 7.26 | 122 | 13.69 | 115 | 3.22 | 101.3±13.2 | |
| MC2 | Jacupirangite | Apatite | 8.50 | 1,020 | 9.19 | 1,103 | 1.73 | 95.0±12.5 | |
| | | | 8.34 | 1,001 | 8.81 | 1,057 | 1.73 | 97.2±12.3 | 96.1± 4.1 |
| MC3(1) | Carbonatite | Apatite | 11.78 | 1,414 | 12.58 | 1,510 | 1.75 | 97.3± 8.4 | |
| MC3(2) | Carbonatite | Apatite | 9.47 | 1,136 | 10.26 | 1,231 | 1.73 | 94.8± 8.7 | |
| MC4 | P-leuc. syenite | Sphene | 4.58 | 44 | 8.54 | 41 | 3.20 | 102.0±22.1 | |
| MC5 | Gt-pyx. syenite | Apatite | 6.53 | 627 | 6.19 | 594 | 1.56 | 97.7± 8.2 | |
| MC6 | Ijolite | Apatite | 0.47 | 112 | 0.43 | 105 | 1.56 | 101.2±18.2 | |
| | | | 0.46 | 110 | 0.46 | 111 | 1.56 | 92.6±15.4 | 96.9±13.2 |
| | | Sphene | 1.42 | 34 | 2.67 | 32 | 3.20 | 100.9±24.8 | |
| AK-9 | Neph. syenite | Apatite | 1.68 | 202 | 1.63 | 195 | 1.56 | 95.5±13.9 | |
| AK-10(1) | Ijolite | Apatite | 2.88 | 415 | 2.91 | 419 | 1.73 | 101.6±11.3 | |
| | | | 2.75 | 396 | 2.89 | 416 | 1.73 | 97.7±10.6 | 99.7± 6.5 |
| AK-10(2) | Ijolite | Apatite | 2.51 | 301 | 2.38 | 285 | 1.56 | 97.7±11.9 | |
| | | | 2.61 | 314 | 2.40 | 288 | 1.56 | 100.7±11.9 | 99.2± 5.2 |
| AK-11 | Carbonatite | Apatite | 5.31 | 637 | 4.88 | 585 | 1.56 | 100.7±13.2 | |
| | | | 4.21 | 505 | 4.29 | 515 | 1.56 | 90.9±14.9 | 95.8±14.9 |
| AK-12 | Ijolite | Apatite | 1.54 | 222 | 1.44 | 207 | 1.56 | 99.0±12.1 | |
| | | | 1.68 | 241 | 1.55 | 224 | 1.56 | 100.4±11.5 | 99.7± 3.0 |
| AK-15B | Phonolite | Sphene | 28.2 | 406 | 52.6 | 379 | 3.18 | 101.2± 7.2 | |

Granite Mountain. Since apatite ages are reset at geologic temperatures of around 100 $^{o}$C it is somewhat surprising that an older age would be retained for sample Mu8X. However, if this age is valid it does have significance in that it indicates an earlier period of magmatic activity for the Granite Mountain pluton (which would be consistent with ages reported elsewhere in the province) and it would suggest that a low-temperature process (potassic-metasomatism?) may have played a role in the formation of the Stage II syenites.

Potash Sulphur Springs complex

The Potash Sulphur Springs complex consists of a core of feldspathoidal syenite and a partial outer annulus of pulaskite and leucopulaskite. These earlier units were subsequently intruded by a variety of lamprophyres and the igneous activity culminated with the intrusion of a central body of carbonatite and ijolite (Howard, 1974). Zartman and Howard (1985) determined U-Th-Pb ages for zircon crystals from the feldspathoidal syenite. They concluded that the best age for this unit was 100 Ma. Samples for fission-track dating were selected from a drill core which intersected the carbonatite and ijolite units. In this sequence the ijolites are embayed by carbonatite so that the apatite ages for this lithology have undoubtedly been reset by the intrusion of the carbonatite. For the carbonatite an apatite age of 102.4 Ma was obtained, whereas for the ijolite a mean apatite age of 99.8 Ma was obtained. These ages are, within analytical error, in agreement with the U-Th-Pb age reported for the feldspathoidal syenite, and thus indicate the contemporaneity of the igneous activity at Potash Sulphur Springs.

V-intrusive complex

The V-intrusive complex crops out on the west shore of Lake Catherine and is located about 10 km southwest of Magnet Cove. The complex consists of a number of crosscutting dikes which have a somewhat "V-shaped" appearance in map view. The lithologies range from malignite and melteigite to a variety of nepheline and sodalite syenites. Owens (1964) suggested that the sequence of intrusion (from oldest to youngest) was as follows: malignite, melteigite, microijolite, tinguaite porphyry, sannaite, melanite-nepheline syenite, pyroxene-nepheline syenite, nepheline syenite, phonolite, pulaskite, alkali-syenite aplite, fluorite, pyrite, and silica veins.

Apatite and sphene ages were determined for a malignite, a microijolite, and a nepheline syenite. The malignite gave the youngest age, the microijolite the oldest, and the nepheline syenite an intermediate age. This sequence is not the the same as that established by Owens (1964), but within error all of the ages are the same and no radiometric age sequence can be identified for this complex. The mean apatite age of the intrusive is 100.2±5.6 Ma and the mean sphene age is 100.5±3.6 Ma, which suggests, as expected, a very short cooling history.

Magnet Cove complex

The Magnet Cove carbonatite complex can conveniently be subdivided into an outer ring, a U-shaped middle ring, and a core (fig. 2). The outer ring consists of nepheline syenite, garnet pseudoleucite syenite, jacupirangite, and pyroxenite. The middle ring consists of trachyte and phonolite, whereas the core consists of low-alkali carbonatite and ijolite. Erickson and Blade

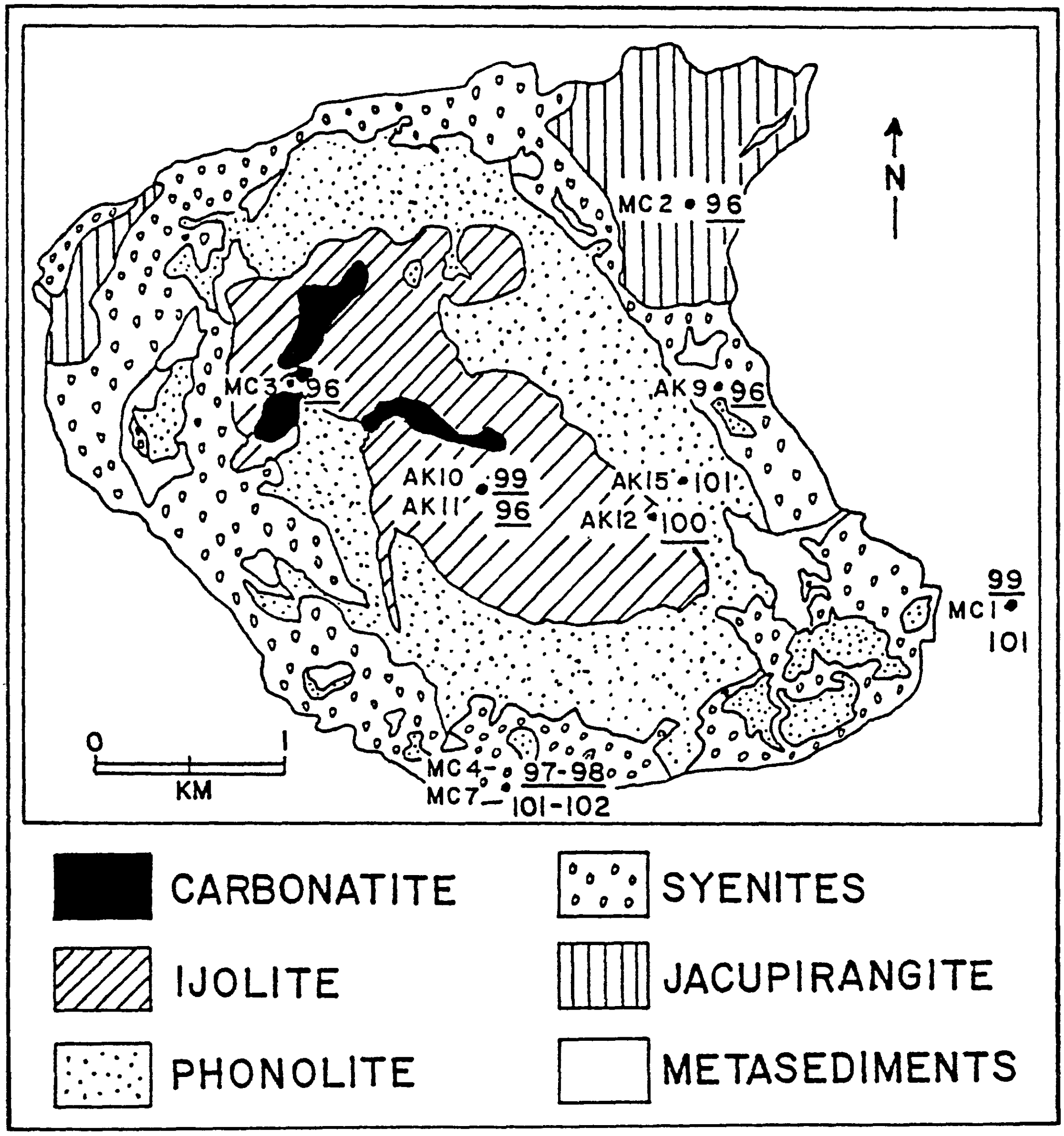


Figure 2. - Generalized geologic map of the Magnet Cove complex (modified from Erickson and Blade, 1963) showing the locations of samples dated in this study. The numbers are the ages in Ma for each sample site. Underlined numbers are apatite ages, other numbers are sphene ages.

(1963) envisaged the sequence of intrusion to be (from oldest to youngest): phonolite and trachyte, jacupirangite, outer-ring syenites, ijolite, carbonatite. Erickson and Blade (1963) believed that all of the lithologies could be derived by fractionation of a single magma. Zartman and others (1967) obtained K-Ar biotite ages of 97 Ma for a melteigite and 99 Ma for a garnet ijolite. They also determined a Rb-Sr age of 101 Ma for the garnet ijolite. Naeser and Faul (1969) obtained an apatite fission-track age of 97 Ma for the carbonatite and a sphene fission-track age of 102 Ma for the nepheline syenite.

A suite of samples was selected for geochronology which represented all of the major lithologies of the complex (fig. 2). Sphene ages were deteremined for the ijolite, psuedoleucite syenite, and phonolite. An additional sphene age was determined for a small phonolite intrusion, boulders of which are found at the Magnet Cove school; this phonolite is clearly associated with the complex. The mean sphene age for the complex is 101.4±1.0 Ma. Apatite ages for two carbonatite samples give a mean age of 95.9±0.4 Ma. Apatite ages determined for all of the other intrusive units fall between 95.9 Ma and 101.4 Ma. Significantly, where apatite and sphene ages were determined for the same sample, the apatite ages are always younger. The data strongly suggest that there were two periods of intrusion at Magnet Cove. The first period of intrusion involved the emplacement of all of the silicate units while the later period involved the emplacement of the carbonatite. Given that apatite resetting temperatures are much lower than those of sphene, this later intrusive event partly reset the apatite ages (explaining the dispersion of these ages) while not affecting the sphene ages. It should be noted that at the nearby Potash Sulphur Springs complex the carbonatite and silicate magmas are apparently contemporaneous, so that the question arises as to why the Magnet Cove magmas were not also contemporaneous. It would be useful to obtain ages by another geochronologic technique to verify the age gap found at Magnet Cove. The fission-track ages determined for Magnet Cove in this study are in excellent agreement with previously determined ages.

## Morrilton-Perryville carbonatites

Thin carbonatite dikes are found in the vicinity of Morrilton and Perryville. Although the magmatic phase of the dikes has an apparent mantle origin, the variety of xenoliths found in the dikes may be derived from the lower crust (Mullen and Murphy, 1985). McCormick and Heathcote (1979) have distinguished two generations of carbonatite in the Morrilton dike, but these two generations may be closely related in time. The two apatite ages determined for these dikes are virtually identical and yield a mean age of emplacement of 98.0±0.3 Ma.

## Benton Dikes

Lamprophyric dikes are widely distributed throughout central Arkansas, but a particularly high concentration of dikes is found within a 10-mile radius north of Benton. The most common dikes are monchiquites, ouachitites, and minettes, but camptonites, sannaites, and syenites also occur. These dikes have not been previously dated so a number of samples were collected for geochronology. Only two dikes yielded minerals suitable for age determinations. A camptonite gives an apatite age of 98.8 Ma while a sannaite gives a sphene age of 100.0 Ma. These ages are in excellent agreement with those for the alkaline complexes of the Arkansas province (with the exception of the Granite Mountain and Saline County syenites), and demonstrate that these dikes are contemporaneous with the plutons of the province.

## DISCUSSION AND CONCLUSIONS

The fission-track geochronology suggests that there are two distinct periods of magmatism in the Arkansas alkaline province. The older period is centered around an age of 100 Ma and encompasses the Potash Sulphur Springs, V-intrusive, and Magnet Cove complexes and the Morrilton-Perryville and Benton dikes. The younger period of magmatism is centered around an age of 88 Ma and encompasses the syenite stocks of the province. Such a distribution in ages requires that any petrogenetic models developed for this province include consideration of the unrelated nature of these two periods of igneous activity, and that a single magmatic source and melting event is not an adequate representation of the igneous activity.

The periods of magmatism are also distinguishable petrographically in that the older period contains the carbonatites and other strongly alkaline mafic igneous rocks, whereas the younger period is only represented by larger, less alkaline, and less silica-undersaturated syenite stocks. A comprehensive geochemical and isotopic study of the province has not been conducted, so it is not possible to correlate the age dispersion with any differences in chemical or isotopic characteristics. Since syenites are found in a number of the alkaline complexes, and a comparative study of these lithologies with those of the syenite stocks would be desirable.

The age progression suggested by the previously existing radiometric dates is not substantiated by this study (fig. 1). In fact, with the exception of the Prairie Creek lamproite, the limit of the Mississippi embayment marks a convenient dividing line with the older period of igneous activity found to the north and the younger period to the south. The reported age of the Prairie Creek lamproite (Zartman, 1977) is older than the ages for the rest of the province, and it is largely on the basis of this older age that a southwest to northeast age progression could be constructed. Zartman (1977) reports two phlogopite ages for this complex, 99±2 Ma and 108±3 Ma. Gilbert and Foland (1986) have recently suggested that even in small intrusive centers, excess argon can lead to "old" crystallization ages. Since the younger phlogopite age is in excellent agreement with ages determined elsewhere in the province, it is tempting to speculate that the older phlogopite age may be due to excess argon. A number of samples were collected from the Prairie Creek complex for fission-track dating, but it was not possible to separate suitable material from any of these samples. The question of the true age of the Prairie Creek complex is therefore unresolved.

For all of the intrusive centers, with the exception of Magnet Cove, it is not possible to distinguish geochronologically separate magmatic events. At Magnet Cove the data indicate that there is a statistically significant hiatus between the emplacement of the silicate rocks and the carbonatite. Such a break requires that separate magma sources and history be considered for the silicates rocks and the carbonatite. A similar geochronologic decoupling between carbonatite and associated silicate rocks has been reported for the Oka complex, Quebec (Gold and others, 1986), and Sarambi, Paraguay (Eby and Mariano, 1986). While these examples are exceptions to the general rule of simultaneity of emplacement, they do demonstrate that there are cases in which the supposed close association of silicate and carbonatite magmas does not hold.

The following conclusions can be drawn from this study:

1. Where comparisons are possible, fission-track and previously determined K-Ar ages are in excellent agreement, which supports the contention that the fission-track ages accurately represent the geochronologic history of the Arkansas alkaline province.

2. Two major periods of igneous activity can be distinguished, one centered around 100 Ma and the other around 88 Ma.

3. There is no regular age progression along the strike of the Arkansas alkaline province.

4. With the exception of Magnet Cove, all of the intrusive centers had short magmatic histories.

5. At Magnet Cove the igneous activity associated with the formation of the the alkaline silicate rocks was a distinct and separate event from that associated with the formation of the carbonatites.

## ACKNOWLEDGMENTS

Dr. Ellen M. Morris served as field guide and assisted the author in sample collection. Dr. Morris also provided the suite of samples dated at Granite Mountain, the Saline County sample, and the two Morrilton-Perryville carbonatite samples. Her help in this study was invaluable and is greatly appreciated.

## REFERENCES

Bath, T., 1983, Igneous lamination and layering in the nepheline syenite quarry, Sec. 36, T1S, R14W, Saline County, Arkansas: Fayetteville, University of Arkansas, Unpublished M.S. thesis, 111 p.

Beardsley, R., 1983, Modal analysis of the Granite Mountain pulaskite, Pulaski County, Arkansas: Fayetteville, University of Arkansas, Unpublished M.S. thesis, 60 p.

Eby, G.N., and Mariano, A.N., 1986, Geology and geochronology of carbonatites peripheral to the Parana Basin, Brazil-Paraguay: Geological Association of Canada, Mineralogical Association of Canada, Canadian Geophysical Union, Joint Annual Meeting, Program with Abstracts 11, 66.

Erickson, R.L., and Blade, L.V., 1963, Geochemistry and petrology of the alkalic igneous complex at Magnet Cove: U.S. Geological Survey Professional Paper 425, 94 p.

Gilbert, L.A., and Foland, K.A., 1986, The Mont Saint Hilaire plutonic complex--Occurrence of excess 40Ar and short intrusion history: Canadian Journal of Earth Sciences 23, 948-958.

Gold, D.P., Eby, G.N., Bell, K., and Vallee, M., 1986, Carbonatites, diatremes, and ultra-alkaline rocks in the Oka area, Quebec: Geological Association of Canada, Mineralogical Association of Canada, Canadian Geophysical Unit, Joint Annual Meeting, Ottawa 1986, Field Trip 21, Guidebook, 51 p.

Gordon, Mackenzie, Jr., Tracey, J.I., Jr., and Ellis, M.W., 1958, Geology of the Arkansas bauxite region: U.S. Geological Survey Professional Paper 299, 103 p.

Howard, J.M., 1974, Transition element geochemistry of the Potash Sulphur Springs intrusive complex, Garland County, Arkansas: Fayetteville, University of Arkansas, Unpublished M.S. thesis, 118 p.

Jackson, K.C., 1978, Arkansas syenites--Fenitized crustal material?: Geological Society of America Abstracts with Programs 10, 7-8.

Marks, J.H., 1977, Petrographic and geochemical study of a selected nepheline syenite in Bauxite, Arkansas: Fayetteville, University of Arkansas, Unpublished M.S. thesis, 104 p.

McCormick, G., and Heathcote, R., 1979, Mineralogy of the Morrilton alvikite dike, Conway County, Arkansas: Geological Society of America Abstracts with Programs 11, 163.

Morris, E.M., and Eby, G.N., 1986, Petrologic and age relation in Granite Mountain syenite: Geological Society of America Abstracts with Programs 18, 256.

Mullen, E.D., and Murphy, S.G., 1985, Petrology of the Arkansas alkalic province--A summary of previous and new investigations, in Morris, R.C., and Mullen, E.D., eds., Alkalic rocks and carboniferous sandstones, Ouachita Mountains--New perspectives: Guidebook Geological Society of America Regional Meeting, Fayetteville, Ark., 34-62.

Naeser, C.W., 1976, Fission-track dating: U.S. Geological Survey Open-File Report 76-190, 58 p.

Naeser, C. W., and Faul, Henry, 1969, Fission-track annealing in apatite and sphene: Journal of Geophysical Research 74, 705-710.

Owens, D.R., 1964, Bedrock geology of the "V" intrusive, Garland County, Arkansas: Fayetteville, University of Arkansas, Unpublished M.S. thesis, 96 p.

Simmen, L.E., 1955, Petrography of the "blue" syenite of Granite Mountain, Pulaski County, Arkansas: Fayetteville, University of Arkansas, Unpublished M.S. thesis, 37 p.

Steiger, R.H., and Jaeger, E., 1977, subcommission on geochronology--Convention on the Use of decay constants in geo- and cosmochronology: Earth and Planetary Science Letters 36, 359-362.

Zartman, R.E., 1977, Geochronology of some alkalic rock provinces in eastern and central United States, in Donath, F.A., Stehili, F.G., and Wetherill, G.W., eds., Annual Review of Earth and Planetary Sciences 5, 257-286.

Zartman, R.E., Brock, M.R., Heyl, A.V., and Thomas, H.H., 1967, K-Ar and Rb-Sr ages of some alkalic intrusive rocks from central and eastern United States: American Journal of Science 265, 848-870.

Zartman, R.E., and Howard, J.M., 1985, U-Th-Pb ages of large zircon crystals from the Potash Sulfur Springs igneous complex, Garland County, Arkansas: Geological Society of America Abstracts with Programs 17, 198-199.