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# FISSION-TRACK AGES OF AIR-FALL TUFFS IN MIOCENE SEDIMENTARY ROCKS OF THE ESPANOLA BASIN, SANTA FE COUNTY, NEW MEXICO

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## ABSTRACT

Zircon fission-track ages of two air-fall tuffs in the middle part of the Miocene Skull Ridge Member of Galusha and Blick (1971) of the Tesuque Formation of the Santa Fe Group range in age from 14.6 to 12.7 m.y. These ages place estimated limits of about 16 to 13 million years for the age range of the 220-m-thick member. The dated tuffs are stratigraphically near fossil-mammal quarries of the American Museum of Natural History and provide age control for the correlation of these fossils with those of the Lower Snake Creek quarries in the Sheep Creek Formation (sensu lato) in Nebraska and with fossil mammals in the upper one third of the Troublesome Formation in Middle Park, Colo.

Zircon fission-track ages of two air-fall tuffs of the overlying Pojoaque Member of Galusha and Blick (1971) of the Tesuque Formation are 11.4 and 9.4 m.y. and date the middle part of the 500-m-thick Pojoaque Member. These dated tuffs are stratigraphically near fossil-mammal assemblages in the member that correlate with fossil-mammal-assemblages in the Miocene Valentine Formation of the Ogallala Group (Galusha and Blick, 1971) in central Nebraska. A tuff stratigraphically near the Burge fossil-mammal quarry has a fission-track age about 10 million years.

## INTRODUCTION

An unusually large number of prominent, thick air-fall tuffs are interlayered in the continental Miocene and Pliocene sedimentary rocks of the Santa Fe Group in the Española Basin of north-central New Mexico. The names for the Miocene rocks of the Santa Fe Group used in this report are those advocated by Galusha and Blick (1971), although many of these names have not been, and are not herein, formally adopted by the U.S. Geological Survey. Miocene time as used in this report ranges from about 24 to 5 million years ago.

At least 37 superposed air-fall tuff beds, as thick as 2 m, occur in a nearly continuous stratigraphic succession in the Skull Ridge Member of the Tesuque Formation of the Santa Fe Group (Galusha and Blick, 1971, figs. 17 and 23), and these tuffs have the potential for establishing the isotopic age range of the upper Cenozoic rocks of the area. Large numbers of fossil land mammals have been collected in the last 100 years in the Española Basin, and many of the collections are stratigraphically related to the tuff bed succession (Galusha and Blick, 1971). Reliable isotopic ages of the tuffs would aid in establishing the age of fossil-mammal collections from elsewhere in the western United States. Moreover, isotopic ages of the tuff marker beds could set limits on the rates of evolution of the different land-mammal groups.

The paleomagnetic stratigraphy of the upper part of the Santa Fe Group rocks was studied by McFadden (1977), and a lower part of the Santa Fe is currently being studied by S. F. Barghoorn of Columbia University. Reliable isotopic ages are needed to calibrate the paleomagnetic-reversal sequence in the Española basin. Isotopic ages also are required to date the times of deformation of the Miocene rocks of the basin. For the above mentioned reasons, several of the thickest, purest-looking tuffs were collected for fission-track dating.

## FISSION-TRACK DATING

The fission-track method of dating volcanic ashes and tuffs has proven to be a generally much more accurate method than the potassium-argon method because of the problem of contamination of the ashes and tuffs with much older detrital minerals of the enclosing sediments incorporated into the tuffs during deposition. These older, spurious minerals (potassium-bearing minerals in particular) are difficult to remove from the mineralogically similar primary potassium-bearing minerals of the tuffs necessary for potassium-argon dating. These older potassium-bearing minerals supply a disproportionate amount of $^{40}Ar$ to the total $^{40}Ar$ extracted from the minerals in the laboratory. Accordingly, anomalously old ages result. In the early 1970's, Henry Faul and his co-workers at the University of Pennsylvania attempted to date, by the K-Ar method, certain of the upper Cenozoic tuffs in the Espanola basin and hoped to circumvent the contamination problem by using very careful collection techniques and by rejecting those tuffs that appeared contaminated with detrital sediments. However, the results of their work were disappointing in that unrealistically old ages were determined in most instances (H. Faul, oral commun., 1979). On the other hand, the fission-track method allows a geochronologist the opportunity to date only glass-mantled microphenocryts separated from ashes or tuffs, or to date only those microphenocryts that clearly belong to a pyrogenic population of primary microphenocrysts. For example, zircon crystals of Precambrian age incorporated in a tuff during deposition can be recognized by their extremely high fossil fission-track densities (coupled with normal uranium concentrations) and their metamict character, and therefore they would not be included in the fission-track count.

The samples used for the fission-track dating of the Santa Fe Group tuffs were collected by G. A. Izett in 1974 in company with Ted Galusha (deceased), at that time with the American Museum of Natural History. Nearly all of the individual tuffs of the Miocene and Pliocene sequence were collected with the hope that many of the beds could be dated. Galusha invited Izett to collect and date the tuffs inasmuch as he recognized the potential they have as stratigraphic markers and the potential they have as targets for isotopic age analyses. Unfortunately many of the tuffs proved not to be suitable for dating because not enough pyrogenic zircons could be obtained from many of the pervasively contaminated tuffs.

We dated two prominent marker tuffs of the Skull Ridge Member in its type area: the number 2 and number 4 white ash beds. These two thick tuffs were dated because they can be traced throughout much of the area and because they are stratigraphically related to important fossil-mammal quarries of the American Museum of Natural History. The number 2 white ash bed, which is about 1.5 m thick, lies about 40 m above the base of the Skull Ridge Member, and the number 4 white ash bed, which is about 1.5 m thick, lies about 145 m above the base of the member. The Skull Ridge Member, which overlies the Nambé Member (fig. 1), is about 220 m thick according to Galusha and Blick (1971).

Table 1--Fission-track ages of zircon microphenocrysts and glass shards separated from volcanic ash beds in the Tesuque Formation of Galusha and Blick (1971) in the Española Basin, Santa Fe County, New Mexico

[z, zircon; g, glass; F, neutron fluence; $P_s$, spontaneous track density; $P_i$, induced track density; ±, is 2 sigma numbers in parentheses are the numbers of tracks counted]

| Sample number | Description and location | Dated material | F neutrons/cm$^{-2}$ | $P_s$ tracks/cm$^{-2}$ x10$^{15}$ | $P_i$ tracks/cm$^{-2}$ x10$^{6}$ | Age x10$^{6}$ |
|---|---|---|---|---|---|---|
| 74G327 | Blue-gray volcanic ash in the Pojoaque Member of the Tesuque Formation of Galusha and Blick (1971, p. 62); SW1/4 SE1/4 sec. 36, T. 20 N., R. 8 E., Española 7 1/2-minute quadrangle, Santa Fe County, N. Mex. | z | 1.10 | 1.35 (153) | 9.47 (493) | 9.4±0.9 |
| | | g | 1.78 | 0.0149(157) | 0.253 (347) | 6.3±1.2 |
| 74G326 | Volcanic ash in the Pojoaque Member of the Tesuque Formation of Galusha and Blick (1971); about 60 m below blue-gray ash 74G327; this ash bed not shown on diagram by Galusha and Blick (1971, p. 62); SW1/4 SE1/4 sec. 36, T. 20 N., R. 8 E., Española 7 1/2-minute quadrangle, Santa Fe County, N. Mex. | z | 1.10 | 1.19 (132) | 6.88 (382) | 11.4±1.1 |
| | | g | 2.09 | 0.0212 (55) | 0.331 (228) | 8.0±2.4 |
| 74G314 | Volcanic ash in the Skull Ridge Member of the Tesuque Formation of Galusha and Blick (1971); number 4 white ash bed of Galusha and Blick (1971, p. 31); center sec. 14, T. 20 N., R. 9 E., Cundiyo 7 1/2-minute quadrangle, Santa Fe County, N. Mex. | z | 1.21 | 1.51 (251) | 7.76 (647) | 14.1±1.1 |
| | | z | .784 | 2.12 (491) | 7.81 (904) | 12.7±1.4 |
| 74G317 | Volcanic ash in the Skull Ridge Member of the Tesuque Formation of Galusha and Blick (1971); number 2 white ash bed of Galusha and Blick (1971); (1971, p. 31); center sec. 15, T. 20 N., R. 9 E., Cundiyo 7 1/2-minute quadrangle, Santa Fe County, N. Mex. | z | .780 | 2.50 (255) | 7.99 (40) | 14.6±1.2 |

Two other tuff beds in the overlying Pojoaque Member of the Tesuque Formation of Galusha and Blick (1971) were also dated: an unnamed ash bed not shown on the diagrams of Galusha and Blick (1971, fig. 23) and an overlying tuff called the blue-gray ash. These two tuffs are separated by about 60 m of orange-gray silty sandstone. The Pojoaque Member is about 500 m thick according to the diagrams presented by Galusha and Blick (1971). The two tuffs were collected in the Pojoaque Bluffs area, which is the area from which most of the fossil-vertebrate collections were made and studied by Cope (1877), and from which many collections of fossil vertebrates were made by Galusha.

## METHODS AND RESULTS

Zircon microphenocryts were separated from about 5 kilogram samples of the tuffs by conventional mineral-separation techniques, and the zircons were dated using fission-track dating methods described by Naeser (1969). The dosimeter used to measure the neutron flux at the time the samples were irradiated in the reactor was a National Bureau of Standards (NBS) standard glass no. 962 originally irradiated by B. S. Carpenter of the National Bureau of Standards in the NBS reactor along with copper and gold foils. The decay constant used to calculate the fission-track ages is $g_f = 1.703 \times 10^{-17}$ yr$^{-1}$. In addition, pure glass-shard fractions of the two gray ash beds (sample nos. 74G326 and 74G327) were dated by the fission-track method, and the results are given in table 1.

The fission-track ages of the glass shards are systematically younger than the zircon fission-track ages from the same tuffs. The tendency for fission-track glass ages to be younger than zircon ages from the same tuffs results from track fading or annealing at ambient temperatures in the glass shards over time (Naeser and others, 1980).

On the basis of fission-track ages reported here, the Skull Ridge Member probably ranges from about 16 to 13 million years, and the age of the middle part of the Pojoaque Member ranges from about 12 to 9 million years. According to Galusha and Blick (1971, p. 110) the fossil mammals of the Skull Ridge Member are Barstovian in terms of North American land mammal ages and most closely match fossil mammals of the Lower Snake Creek quarries excavated in the Sheep Creek Formation (sensu lato) in Nebraska. Fossil mammals collected from the upper third of the Troublesome Formation (Miocene) in Middle Park, Colo., are also about the same age as those in the Lower Snake Creek quarries (Izett, 1968, p. 45). The fossils in the Troublesome are stratigraphically near the level of a tuff fission-track dated at about 14 million years (Izett and Barclay, 1973). Fossil mammals of the Pojoaque Member most closely match fossil mammals of the Valentine Formation (Miocene) as used by Galusha and Blick (1971, p. 64) of the Valentine, Neb., area. In terms of North American land mammal ages, the rocks were assigned a Valentinian to Clarendonian age by Galusha and Blick (1971, p. 12 and 64). A tuff stratigraphically just above the Burge fossil quarry in the Ash Hollow Formation of the Ogallala Group in the Valentine, Neb., area was dated by the fission-track zircon method at about 10 million years (Izett, 1975). This age of 10 million years falls within the age range of the Pojoaque Member as determined by our fission-track ages.

Zircon fission-track ages (12.7±1.8 and 10.8±1.6), reported by Manley and Naeser (1977), for two air-fall tuffs in Miocene rocks in the northeast part of the Española Basin thought by Manley and Naeser to be

equivalent to the Tesuque Formation fall within the age range of the uppermost part of the Skull Ridge Member and the lower part of the Pojoaque Member as determined in this paper.

Fission-track zircon ages reported here for the tuffs in the Pojoaque Member (sample nos. 74G326 and 74G327 of table 1) previously were reported by Naeser and others (1980, table 5, p. 26-27, entries nos. 5 and 8). Unfortunately the age data and the descriptions were published incorrectly. In table 4 of Naeser and others (1980), entries no. 5 and 8 were switched; entry no. 5 should have read entry no. 8, and entry no. 8 should have read entry no. 5. Entry number 5 of table 5 was incorrectly given to be in sec. 31, T. 20 N., R. 9 E.; it should have been listed in the SE 1/4 sec. 36, T. 20 N., R. 8 E. In addition, entry no. 5 of table 5 should have been assigned sample no. 74G326 rather than 74G327, and entry no. 8 should have been assigned sample no. 74G327 rather than 74G326.

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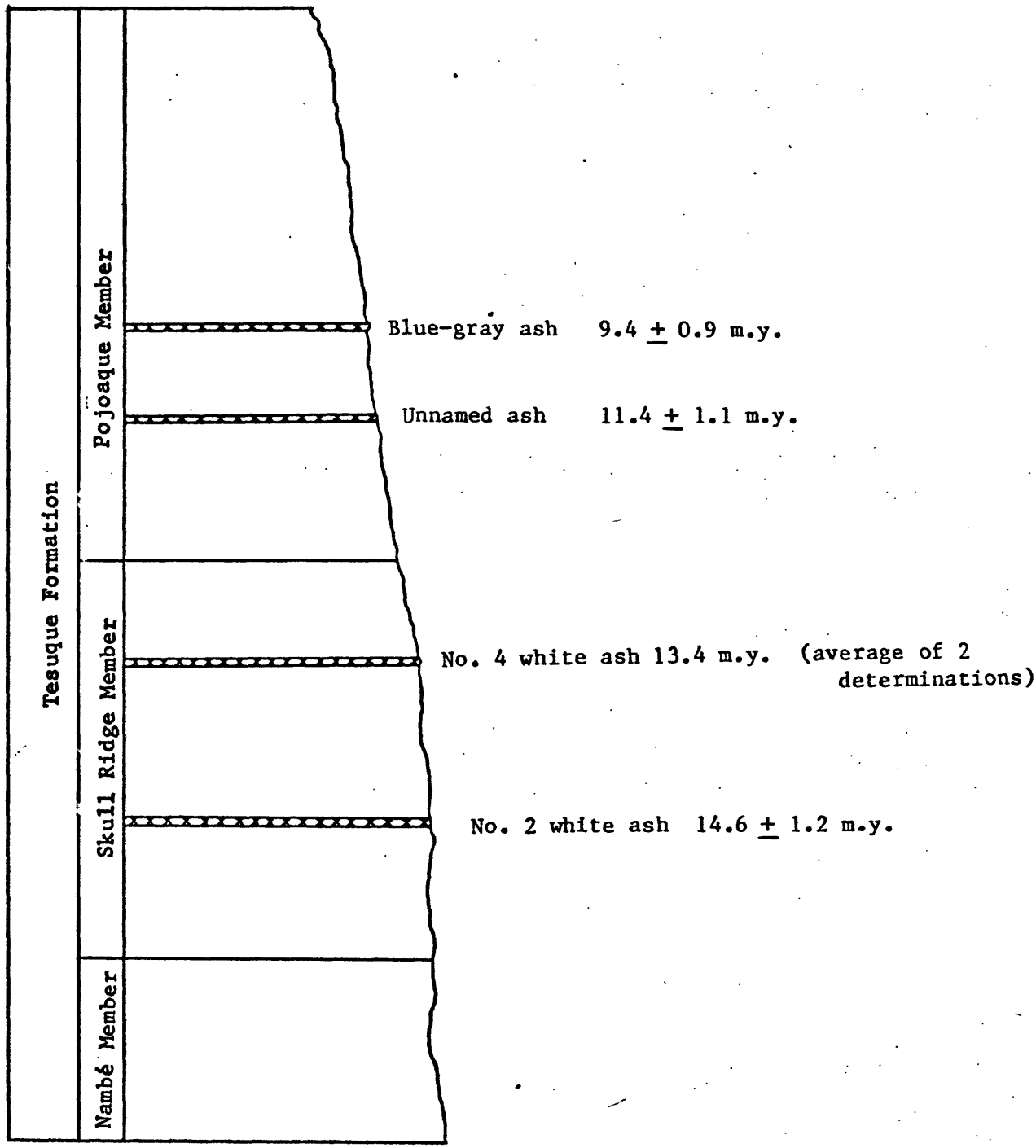


Figure 1.-- Generalized stratigraphic diagram showing the relationships among certain air-fall tuffs of the Skull Ridge and Pojoaque Members of the Tesuque Formation (Santa Fe Group) of Miocene age of Galusha and Blick (1971). Modified from the diagrams of Galusha and Blick (1971, figs. 17 and 23).