1991

# Fission-Track Ages of Zircons from Lonergan Creek (Shoreline Fossil Locality, Ash Hollow Formation, Upper Miocene) in Western Nebraska

Michael B. Leite
*University of Wyoming*

1991. *Transactions of the Nebraska Academy of Sciences,* XVIII: 31–35

# FISSION-TRACK AGES OF ZIRCONS FROM LONERGAN CREEK (SHORELINE FOSSIL LOCALITY, ASH HOLLOW FORMATION, UPPER MIOCENE) IN WESTERN NEBRASKA*

**Michael B. Leite**

Department of Geology and Geophysics
The University of Wyoming
Laramie, Wyoming 82071-3006

*Earlier Nebraska workers assigned these deposits to the middle part of the Ash Hollow Formation, Ogallala Group, Pliocene—Editors.

A bed of vitric ash occurs 2 m above the primary fossiliferous unit at Lonergan Creek Locality in the Ash Hollow Formation on the north shore of Lake McConaughy, western Nebraska. Zircon crystals recovered from the ash were dated using the fission-track method. The grouping of youngest-age euhedral grains among the largely detrital suite is interpreted as the airfall population, with a fission-track age of 10.42 ± 2.5 Ma. Owing to uncertainties about the origin of this youngest group, the age should be interpreted as a "detrital" date and considered a maximum age for the ash. The Lonergan Creek Ash cannot be correlated with certainty to any other dated Great Plains ash. However, it is of similar age to an ash 37 m above the base of the type section of the Ash Hollow formation and also to the Davis Ash, lying above the Minnechaduza Fauna in Cherry County, Nebraska.

† † †

## INTRODUCTION

The Lonergan Creek fossil locality (upper Miocene, Late Clarendonian land-mammal age) is located near the town of Lemoyne on the north shore of Lake McConaughy in Keith County, Nebraska (Fig. 1). A bed of vitric ash is found at an elevation of 993.5 m above sea level, 2 m above the fossiliferous interval at Lonergan Creek (Fig. 2) and 14 m stratigraphically below the Early Hemphillian locality Lemoyne Quarry (Leite, 1986). This bed, herein called the Lonergan Creek Ash, is semi-indurated and light gray, with a distinctive luster of fine-grained volcanic glass. It is a lentil within fine-grained fluviatile sands, having a maximum thickness of 65 cm and width of 200 m between lateral pinchouts. Apparent fluvial reworking and bioturbation in the form of tubular sub-vertical structures, possible invertebrate burrows, have resulted in the introduction of fine sand into the ash.

Stratigraphy of the Ash Hollow Formation on the north shore of Lake McConaughy has been described in detail by Leite (1990). These beds contain concentrations of vertebrate fossils at two stratigraphic levels. Fossils of the lower, or "shoreline," localities collectively comprise the Shoreline Local Fauna, with its diagnostic late Clarendonian taxa *Eucastor*, *Epicyon haydeni*, and *Cormohipparion occidentale*, among others. The upper locality, Lemoyne Quarry, contains the Lemoyne Local Fauna (early Hemphillian), with *Dipoides*, *Epicyon* sp. cf. *E. validus*, *Neohipparion eurystyle*, *Megalonyx*, and others. Vertebrate fossils have been collected since the early 1970s from Lonergan Creek, one of the shoreline localities, by field parties from the University of Nebraska State Museum.

In constraining the absolute age of the Shoreline Local Fauna, a date for this ash is of use in correlating the Lake McConaughy local faunas with those from other North American localities. It is also useful in providing a criterion for correlation of the shoreline section with the Ash Hollow type section, about 25 km west of Lonergan Creek. Interpretation of the age of the primary population of zircons is complicated by a high proportion of detrital (reworked) grains. However, the youngest three zircons, considered most likely to be the population associated with formation of the ash, yield what must be considered a maximum fission-track date.

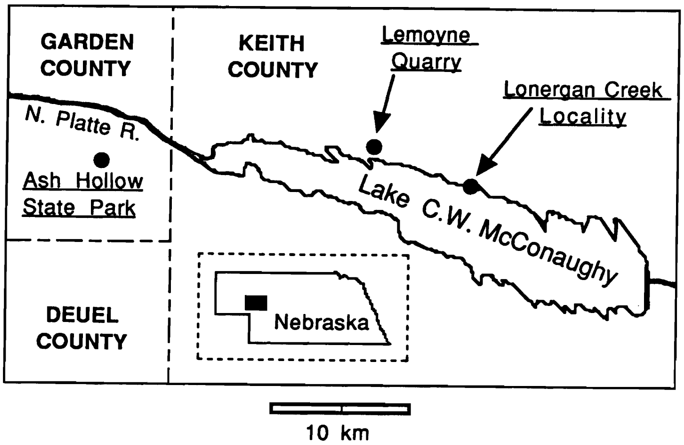


Figure 1. Location map showing Lonergan Creek fossil and ash locality in relation to other places mentioned in the text.

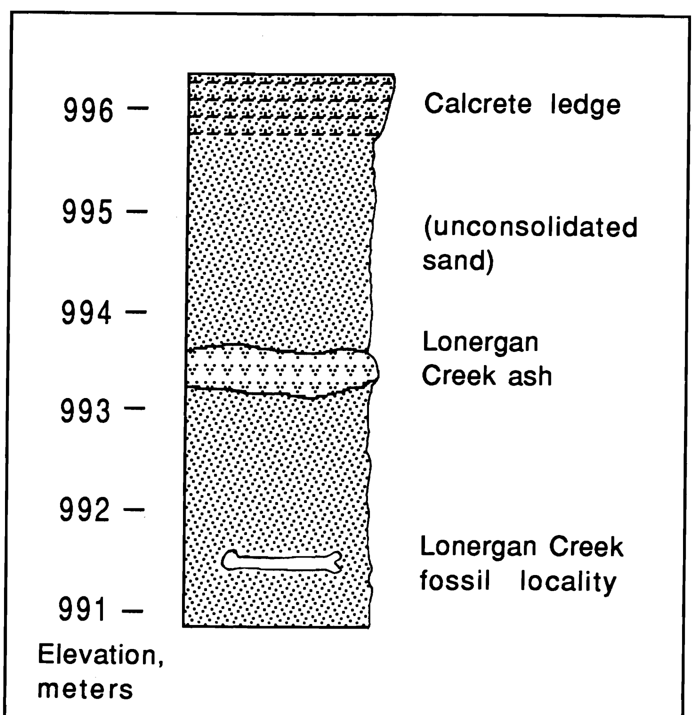


Figure 2. Stratigraphic section of the Lonergan Creek Locality, Keith County, Nebraska.

Further study of the entire suite of detrital zircons from this ash may be of use in determining provenance of sediments constituting this part of the Ash Hollow Formation.

## MATERIALS AND METHODS

Sample preparation followed methods described by Naeser (1976). Zircons recovered from the ash were mounted on teflon wafers, polished, and etched for 60 hours in a eutectic melt of 58% KOH and 42% NaOH (by weight) at 235°C. After the grains had been partially etched, it became evident that there was a range of different-age zircons present. In order to etch optimally the grains with the lowest fission-track density (likely the youngest grains), etching was carried out until no grains were underetched (Cerveny et al. 1988). This procedure presumably resulted in sacrifice to over-etching of most of the older grains and perhaps also some young grains with high uranium content.

The external detector method of dating was used (Naeser, 1976). Samples were irradiated to a total neutron fluence of 0.797 X $10^{15}$ neutrons/$cm^2$ in the TRIGA reactor at Oregon State University. Calibrated muscovite detectors in contact with glass standards SRM 962 of the National Bureau of Standards were used to calculate neutron fluence. A decay constant of 7.03 X $10^{-17}$/y was used (Roberts et al., 1968). Fossil and induced fission tracks were counted at a magnification of 1250 X; irradiation standards were counted at 600 X. To emphasize the youngest population of zircons, only crystals that exhibited euhedral faces and showed an absence of rounding, pitting, or other signs of reworking, were selected for counting. No glass-mantled zircons were noted. All dates are reported with ± two standard deviations.

## RESULTS

A total of 2,763 fission tracks from 21 zircon crystals were counted and individual ages were computed for each of those crystals. These data are presented in continuous frequency form in Figure 3. Despite selection of apparently younger grains for counting, a wide range of fission-track ages was obtained. This range is not consistent with the interpretation that these grains were derived from a single cooling event; several populations of grains considerably older than late Miocene appear to be present. The total sample fails the Chi-square test for goodness of fit to a population with a Poisson distribution (Chi-square value = 121, with 20 degrees of freedom).

Table I. Youngest fission-track grouping of zircons from the Lonergan Creek Ash.

| Grain No. | No. fossil tracks | No. induced tracks | Uranium PPM | Age (MA) | 2-sigma error (Ma) |
|---|---|---|---|---|---|
| 1 | 30 | 72 | 273 | 9.93 | 4.3 |
| 2 | 16 | 37 | 196 | 10.30 | 6.2 |
| 3 | 55 | 122 | 359 | 10.74 | 3.5 |
| TOTAL | 101 | 231 | 292 | 10.42 | 2.5 |

Neutron dose: $0.797 \times 10^{15}$ cm$^{-2}$
Tracks counted: 2763
Fossil track density: $1.60 \times 10^{6}$ cm$^{-2}$
Induced track density: $7.33 \times 10^{6}$ cm$^{-2}$

**Primary population**

Frequency plot of the data (Fig. 3) shows a major peak near 18 Ma, a minor peak at about 11 Ma, and a fairly long tail of older ages. Zircons with the same age as the ash, if they are present at all, must be represented by the youngest peak and low-end tail. This peak consists of three zircons with ages of 9.93 ± 4.3 Ma, 10.30 ± 6.2 Ma and 10.74 ± 3.5 Ma. Assuming that these three grains are associated with the same eruptive event, then their fission-track counts can be totaled, yielding a composite age of 10.42 ± 2.5 Ma (summarized in Table I). Inclusion of successively older-age zircons from the sample might decrease the error somewhat but at the risk of including zircons derived from older events and thus violating the assumption of association.

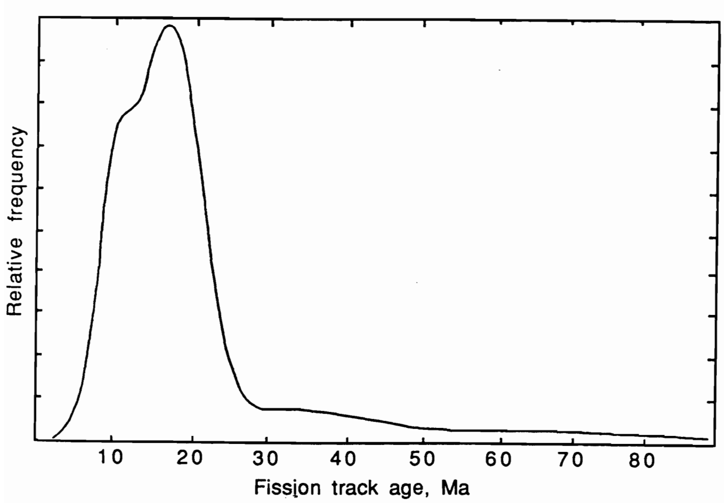


Figure 3. Frequency plot of all zircon fission track ages from the Lonergan Creek Ash. "Shoulder" on low side of the main peak is interpreted as age of airfall population.

**Secondary populations**

Plotting the single-grain age data in discrete form (Fig. 4) shows that the zircon component of the ash has a complex provenance history. A considerable number of these grains (17 of 21) have Miocene fission-track ages (i.e., those between 9.93 ± 4.3 and 21.40 ± 6.3 Ma).

Assuming that all of the zircons are of volcanic origin, all grains with mean fission-track ages between 12.5 and 26.2 Ma could have been reworked from ash beds or volcaniclastic sediments in the source area of Ash Hollow sediment in western Nebraska and Wyoming (Swinehart et al. 1985).

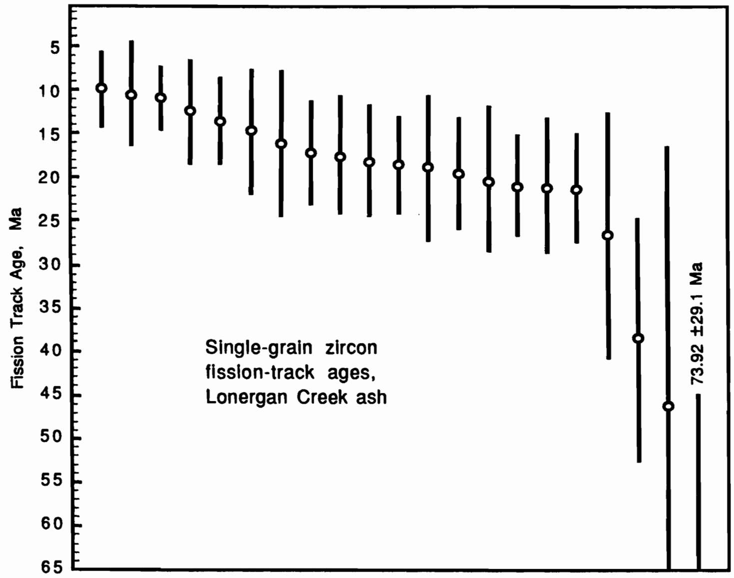


Figure 4. Discrete plot of single-crystal zircon fission-track ages, Lonergan Creek Ash. Error bars are ± 2 standard deviations. Age of the ash is derived from the three youngest grains (left). All others are interpreted as detrital "contamination."

While the absence of Precambrian-age zircons from the sample might at first seem significant, it should be remembered that the sample from which these ages was derived is far from unbiased. The dual biasing effects of long etch time and selection of euhedral grains for counting probably served effectively to eliminate any very old grains from consideration (P.F. Cerveny, personal communication, 1990).

## DISCUSSION

The conventional justification for dating a volcaniclastic rock is to determine the time of eruption and therefore the time of deposition, the difference between which is assumed to be geologically insignificant. In the case of the fission-track method, the critical date is that time when the crystals last cooled below their closure temperature (for zircon, about 200°C) (Cerveny et al., 1988). A chief assumption is that a pyroclastic rock rich in datable minerals will retain those mineral grains until deposited. Subsequent postdepositional reworking may, however, introduce contaminant minerals from other sources, effectively diluting the population of primary interest. In the case of the Lonergan Creek Ash, postdepositional contamination clearly took place, almost overwhelming the primary zircons. Thus it is possible that the youngest zircons in the sample are not primary. Therefore, the fission-track age derived from this analysis should be interpreted as a detrital age (Naeser et al., 1987) and considered a maximum age for the ash. The fission-track date of the Lonergan Creek Ash thus cannot be used to constrain very closely the age of the Lonergan Creek Local Fauna. Knowing only the maximum age of an overlying unit introduces an ambiguity that cannot be dealt with without knowing the depositional rate of the intervening sediments.

### Correlation

Fission-track ages have been reported previously from the Ash Hollow Formation in other localities by Izett (1975), Boellstorff (1976, 1978) and Naeser et al. (1980) and most are summarized by Tedford et al. (1987). Boellstorff (1978) reports three glass fission-track dates from the Ash Hollow Formation type section near the west end of Lake McConaughy. The oldest of these is an ash "120 ft. [37 m] above base of Ash Hollow Fm. at its type locality (SW 1/4 NE 1/4 NW 1/4 Sec. 23, T. 15 N., R. 42 W., Garden County, NE.)." This ash, reported by Tedford et al. (1987) as "ash 46," has a fission-track age of 8.0 ± 0.6 Ma (± 2 standard deviations). Although the fission-track age of the Lonergan Creek Ash overlaps that of ash 46, the error associated with the Lonergan Creek Ash is large enough so that correlation of these ashes is uncertain. Furthermore, these glass dates are not directly comparable to zircon dates. Work by Naeser et al. (1980) strongly suggests that fission-track dates on glass are consistently and significantly younger than dates from zircons with the same stratigraphic age. Thus it is possible that ash 46 and the ash at Lonergan Creek are indeed correlative and the difference in their apparent fission-track ages is due only to the different dating techniques (glass vs. zircon). Nevertheless, the data available do not permit simple correlation of the Lonergan Creek Ash with ash 46 or with any other ash in the Ash Hollow Formation type section.

The fission-track age of the Lonergan Creek Ash also falls within the 9.7 ± 1.2 Ma (zircon) age of the Davis Ash in the Ash Hollow Formation of Cherry County, Nebraska (Izett, 1975). Two other fission-track dates, both on glass, have been reported from this ash: 7.5 ± 2.2 Ma (Izett, 1975) and 10.2 ± 0.7 Ma (Boellstorff, personal communication, in Tedford et al., 1987). The Davis Ash (ash 45 of Tedford et al., 1987) lies just above the Minnechaduza Fauna, placing a minimum age of 9.7 ± 1.2 Ma on that fauna. A *maximum* age of 10.42 ± 2.5 Ma for the Lonergan Creek Ash is thus not in conflict with the relative ages of the mammalian faunas. The Shoreline Local Fauna is very close in age to the Minnechaduza, based on co-occurrence of some key species, namely *Epicyon haydeni*, *Teleoceras major*, *Cormohipparion occidentale*, and *Cranioceras unicornis* (Leite, 1990). More exact ash correlation will be possible only by comparing dates on definite primary populations of zircons and possibly chemical analyses of both ashes.

## CONCLUSIONS

The Lonergan Creek Ash is found 2 m above the fossiliferous unit at Lonergan Creek (one of the Shoreline fossil localities on the north shore of Lake McConaughy). The airfall component of zircons from this ash has been largely obscured by contamination from older zircons. Fission-track counts from the three youngest zircons in the ash yield an age of 10.42 ± 2.5 Ma. This should be regarded as a maximum age for the ash, however, owing to uncertainty that these grains are unreworked primary zircons. Correlation of the Lonergan Creek Ash with other dated Great Plains ashes must remain uncertain. However, equivalence with an ash 37 m above the base of the Ash Hollow Formation at its type section (Ash 46 of Tedford et al., 1987) cannot be ruled out. Another possible correlative is the

Davis Ash, which lies just above the Minnechaduza Fauna of Cherry County, Nebraska. Correlation with the Davis Ash would be in concordance with approximate correlation between the Shoreline Local Fauna and the Minnechaduza Fauna.

Detrital contamination of what appears to be a "pure" ash suggests a note of caution when dating other Great Plains ashes, which may have been deposited far from their volcanic sources.

## ACKNOWLEDGMENTS

My thanks go to P.F. Cerveny of the fission-track laboratory at the University of Wyoming, who carried out final sample preparation and counting and helped in interpretation of the results. I alone, however, am responsible for the conclusions. Dr. R.M. Hunt of the University of Nebraska introduced me to the fission-track technique and guided me through the sample-preparation procedure. Help in collecting the ash was provided by Dr. M.R. Voorhies and S.A. Spaulding. B.H. Breithaupt read an early draft of the manuscript and offered helpful suggestions for revision. Comments by two anonymous reviewers resulted in substantial improvements to the paper.

## LITERATURE CITED

Boellstorff, J. 1976. *The succession of Late Cenozoic volcanic ashes in the Great Plains: a progress report*. 24th annual meeting, Midwest Friends of the Pleistocene, Kansas Geological Survey Guidebook Series 1: 37–71.

_________. 1978. Chronology of some Late Cenozoic deposits from the central United States and the ice ages. *Transactions of the Nebraska Academy of Sciences* 6: 35–49.

Cerveny, P.F., N.D. Naeser, P.K. Zeitler, C.W. Naeser, and N.M Johnson. 1988. History of uplift and relief of the Himalaya during the past 18 million years: evidence from fission track ages of detrital zircons from sandstones of the Siwalik Group. *In*: K.L. Kleinspehn and C. Paola (eds.), *New perspectives in basin analysis*. New York, Springer-Verlag: 43–61.

Izett, G.L. 1975. Late Cenozoic sedimentation and deformation in northern Colorado and adjoining areas. In B.F. Curtis (ed.), *Cenozoic history of the southern Rocky Mountains*, Geological Society of America, Memoir 144: 179–209.

Leite, M.B. 1986. *Neogene stratigraphy and vertebrate paleontology of the north shore of Lake McConaughy, Keith County, Nebraska*. M.S. Thesis, University of Nebraska, vi + 165 pp.

________. 1990. Stratigraphy and mammalian paleontology of the Ash Hollow Formation on the north shore of Lake McConaughy, Keith County, Nebraska. *Contributions to Geology*, University of Wyoming 28: 1–29.

Naeser, C.W. 1976. Fission track dating: U.S. Geological Survey Open File Report 76-190: 65 pp.

_________, G.A. Izett and J.D. Obradovich. 1980. Fission track and K-Ar ages of natural glasses. U.S. Geological Survey Bulletin 1489: 1–31.

Naeser, N.D., P.K. Zeitler, C.W. Naeser, and P.F. Cerveny. 1987. Provenance studies by fission-track dating of zircon etching and counting procedures. *Nuclear Tracks and Radiation Measurement* 13: 121–126.

Roberts, J.H., R. Gold, and R.J. Armani. 1968. Spontaneous fission decay constant of $^{238}U$. *Physical Review* 174: 1482–1484.

Swinehart, J. B., V. L. Souders, H. M. DeGraw, and R. F. Diffendal, Jr. 1985. Cenozoic paleogeography of western Nebraska. *In*: R. M. Flores and S. S. Kaplan (eds.), *Cenozoic paleogeography of the West Central United States*. Society of Economic Paleontologists and Mineralogists, Rocky Mountain Section, Paleogeography Symposium 3: 209–229.

Tedford, R.H., T. Galusha, M.F. Skinner, B.E. Taylor, R.W. Fields, J.R. Macdonald, J.M. Rensberger, S.D. Webb, and D.P. Whistler. 1987. Faunal succession and biochronology of the Arikareean through Hemphillian interval (Late Oligocene through earliest Pliocene epochs) in North America. *In*: M.O. Woodburne (ed.), *Cenozoic mammals of North America*. Berkeley, University of California Press: 153–210.