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Universidad Nacional Autónoma de México, Instituto de Geología; y Sociedad Geológica Mexicana, México, D.F.

FISSION-TRACK AND SINGLE-CRYSTAL $^{40}Ar/^{39}Ar$ LASER-FUSION AGES FROM VOLCANIC ASH LAYERS IN FOSSIL-BEARING PLIOCENE SEDIMENTS IN CENTRAL MEXICO

Bart J. Kowallis[1], Carl C. Swisher III[2], Óscar Carranza-Castañeda[3], Wade E. Miller[1], and David G. Tingey[1]

ABSTRACT

Pliocene sediments, containing a wide variety of vertebrate fossils, crop out in the states of Hidalgo, Guanajuato, and Jalisco in central Mexico. These sediments contain numerous glassy ash beds and ashy sediment. Samples collected from localities with the widest diversity of late Tertiary mammal fossils throughout this region have been dated by zircon fission-track and single-crystal sanidine $^{40}Ar/^{39}Ar$ laser-fusion techniques. Most of the samples dated contain more than one population of grains, but a few appear to be uncontaminated. Blancan age sediments have yielded fission-track zircon ages ranging from 3.9 ± 0.3 Ma to 4.6 ± 0.3 Ma (1σ std. error) and single-crystal sanidine $^{40}Ar/^{39}Ar$ laser-fusion ages ranging from 3.36 ± 0.02 Ma to 4.74 ± 0.07 Ma. At present, only three Hemphillian samples have been dated; GTO-2C from Guanajuato gave a zircon fission-track age of 4.8 ± 0.2 Ma, GTO-43 gave a zircon fission-track age of 4.4 ± 0.3 Ma, and JAL-20 gave a sanidine $^{40}Ar/^{39}Ar$ laser-fusion age of 4.89 ± 0.16 Ma. Because of the larger uncertainties in the fission-track ages, the 4.4 Ma age is not statistically different from the other two ages at ± 2σ. The more precise laser-fusion ages place the Hemphillian-Blancan boundary between 4.74 and 4.89 Ma.

Older grains found and dated in the samples from Guanajuato by both fission-track and $^{40}Ar/^{39}Ar$ laser-fusion methods fall into several groups. The youngest group is 5–9 Ma, an intermediate group lies between 22–27 Ma, and the oldest group is between 30–31 Ma. A few other scattered single grain ages range up to about 110 Ma. These age groups are consistent with periods of silicic volcanism in the Guanajuato region.

Key words: Pliocene, fission-track ages, $^{40}Ar/^{39}Ar$ single-crystal laser-fusion ages, central Mexico.

RESUMEN

En el centro de México, en los estados de Hidalgo, Guanajuato y Jalisco, existen sedimentos pliocénicos que contienen una gran diversidad de vertebrados fósiles. Interestratificados con estos sedimentos, están presentes estratos de ceniza volcánica con abundantes cristales de vidrio y sedimentos con ceniza volcánica.

Las muestras de ceniza, que se recolectaron en diversas localidades que contienen esta gran diversidad de mamíferos del Terciario tardío, han sido fechadas con los métodos de *fission-track* en zircones y $^{40}Ar/^{39}Ar$ por fusión con láser en cristales de sanidino. Los ejemplares fechados, en su mayoría, contienen más de una clase de cristales; sólo unos cuantos no están contaminados. Los sedimentos del Blancano han dado edades por *fission-track* del orden de 3.9 ± 0.3 Ma hasta 4.6 Ma ± 0.3 y por $^{40}Ar/^{39}Ar$ mediante fusión con láser en el intervalo de 3.36 ± 0.02 Ma a 4.74 ± 0.07 Ma. Hasta ahora, sólo tres ejemplares del Henfiliano han sido fechados: en la localidad GTO-2C de Guanajuato, el análisis por *fission-track* en zircones dio una edad de 4.8 ± 0.2 Ma; en la GTO-43, también por *fission-track*, se obtuvo un resultado de 4.4 Ma ± 0.3 Ma; y en la JAL-20, por medio de $^{40}Ar/^{39}Ar$ mediante fusión con láser en un cristal de sanidino, se obtuvo una edad de 4.89 ± 0.16 Ma. Debido a lo incierto de las edades por *fission-track*, la edad de 4.4 Ma no es estadísticamente diferente de las otras dos edades de ± 2σ. Las edades por fusión con láser, de mayor exactitud, sitúan los límites de las edades Henfiliano-Blancano entre 4.74 y 4.89 Ma.

En los ejemplares de Guanajuato, que fueron fechados por los dos métodos, *fission-track* y $^{40}Ar/^{39}Ar$ por fusión con láser, se obtuvo edades diferentes: el grupo más joven fue de 5–9 Ma, un grupo intermedio fue de 22–27 Ma y el más antiguo fue de 22–27 Ma. Unos cuantos granos dan edades de 110 Ma. Las edades proporcionadas por estos grupos de cristales son concordantes con los períodos de vulcanismo silícico en la región de Guanajuato.

Palabras clave: Plioceno, edades *fission-track*, edades $^{40}Ar/^{39}Ar$ por fusión con láser en cristal único, México central.

INTRODUCTION

Vertebrate fossils from Hemphillian-Blancan sediments (Miocene-Pliocene) of central Mexico have been known and collected since at least the 1860's (Carranza-Castañeda *et al.*, 1982; Miller and Carranza-Castañeda, 1984). The sediments in which these fossils are found also contain several layers of vitric volcanic ash, as well as sandstones and siltstones rich in volcanic detritus. Zircons extracted from two sample localities were dated by Kowallis and collaborators (1986) and showed that the ashy beds were often contaminated with older detrital grains. Any attempts to date the sediments, therefore, need to

[1]*Department of Geology, Brigham Young University, Provo, UT 84602, USA.*
[2]*Berkeley Geochronology Center, 2455 Ridge Road, Berkeley, CA 94709, USA.*
[3]*Instituto de Geología, Universidad Nacional Autónoma de México, Ciudad Universitaria, Delegación Coyoacán, 04510 D.F., México.*

employ single crystal techniques so that older contaminant grains can be separated from younger age populations that might be more representative of the depositional age. This paper reports on our recent attempts to date the Pliocene sediments in central Mexico using zircon fission-track and sanidine single-crystal laser-fusion $^{40}Ar/^{39}Ar$ dating techniques. The ages will help to better constrain the timing of vertebrate migrations through central Mexico, aid in determining the sources of the Pliocene sediment, and also better define the age of the Hemphillian-Blancan vertebrate stage boundary.

GEOLOGIC SETTING AND METHODS

Central Mexico is cut by a 20–150-km-broad, 1,000-km-long belt of volcanism called the Mexican Volcanic Belt (MVB) (Nixon, 1982; Verma, 1987). This area is also the southernmost part of the Basin and Range province, and the volcanic belt cuts across the earlier structural fabric of the region developed during Basin and Range extension (Henry, 1989; Henry and Aranda-Gómez, 1992).

The Pliocene ashes and ashy sediments that were sampled for dating come from beds deposited in small, local, fault-bounded grabens related to Basin and Range extension (Figure 1). The beds are thought to be fluvial and lacustrine in origin (Arellano, 1951; Carranza-Castañeda *et al.*, 1994), and are usually green-gray to tan in color with lighter gray to whitish ash horizons. Samples were collected for dating from areas in three states (Figure 1); namely, Jalisco (JAL), Guanajuato (GTO), and Hidalgo (HGO). Most of the samples come from the State of Guanajuato north of San Miguel de Allende (Figure 2); specific localities are GTO-2 Rancho El Ocote (from two sub-localities, GTO-2C and GTO-2D), GTO-5 Miller Place, GTO-11 Garbani, GTO-12 La Pantera, and GTO-43 Rinconada. The Hemphillian-Blancan sediments (Rancho Viejo Beds) in this region are part of the fill in a north-south trending Tertiary graben (Figure 3). The oldest rocks exposed in the graben walls are tilted Cretaceous carbonates of the San Miguel de Allende Beds, which are overlain unconformably by Oligocene-Miocene volcanic rocks (Carranza-Castañeda *et al.*, 1994).

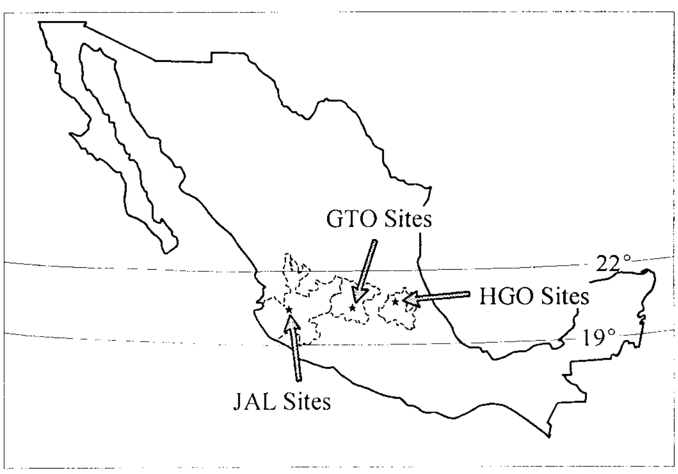

Figure 1. Index map showing states and sample sites discussed in this paper.

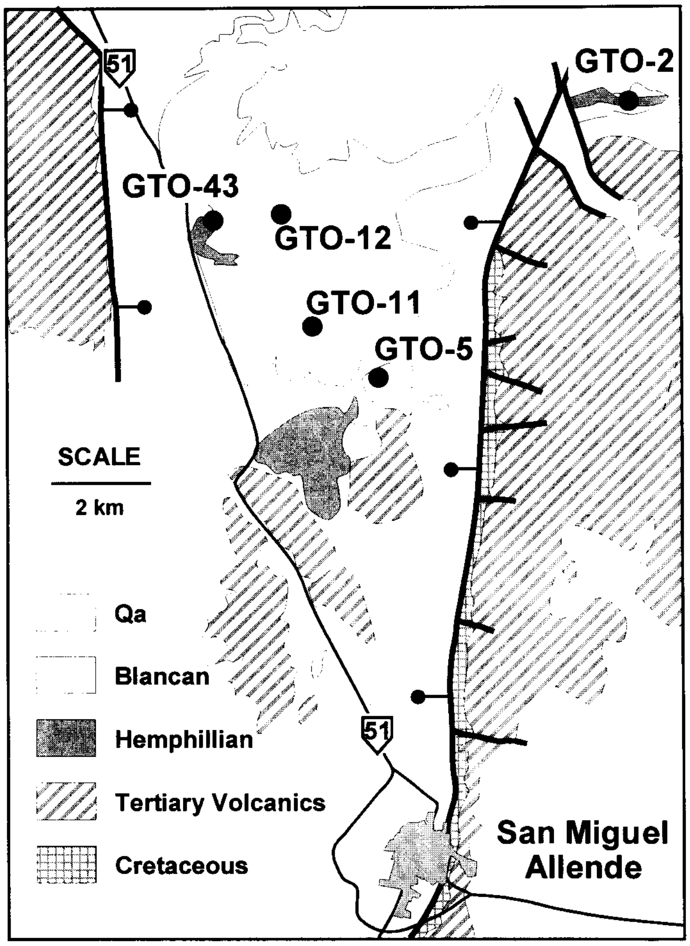

Figure 2. Generalized geologic map of the San Miguel de Allende area showing sample sites. Modified from Carranza-Castañeda and collaborators (1994).

One sample each has also been dated from similar beds in similar tectonic settings (sediment filling N-S trending grabens) from the states of Hidalgo (HGO-12 Santa María Amajac) and Jalisco (JAL-20 La Hacienda in the Tecolotlán area). Approximately 10–15 kg of ash or ashy sediment were collected at each locality. This material was washed to remove fine materials and clays and then processed through standard heavy liquid and magnetic separation techniques to obtain clean sanidine and zircon separates. Zircons were dated using the external detector fission-track method (see Kowallis *et al.*, 1986; Wagner and Van den Haute, 1992) at Brigham Young University and sanidines were dated by the single-crystal, $^{40}Ar/^{39}Ar$ laser-probe technique (see Deino and Potts, 1990; Kowallis *et al.*, 1995) at the Berkeley Geochronology Laboratory.

DATING RESULTS

Tables 1 and 2 list the fission-track and $^{40}Ar/^{39}Ar$ ages, respectively, for the youngest age populations in each sample that was dated. Also listed are the mammalian stages from

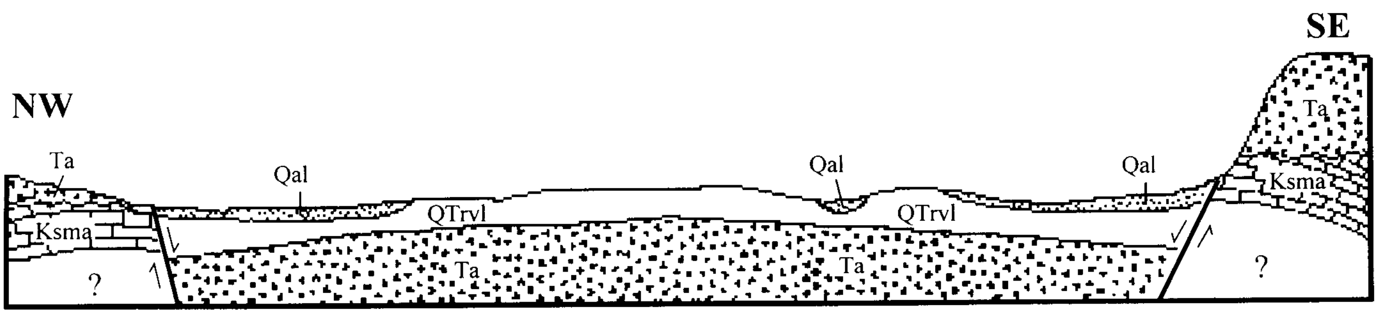

Figure 3. Generalized cross section of the San Miguel de Allende graben. Ksma, Cretaceous San Miguel de Allende Beds; Ta, Oligocene-Miocene intermediate volcanics; QTrvl, Miocene-Pleistocene Rancho Viejo Beds; Qa, Holocene alluvium. Modified from Carranza-Castañeda and collaborators (1994).

which the samples came. Most of the samples are contaminated with older grains; a common occurrence with ash beds that are deposited in terrestrial environments where sedimentary processes can rework the ash and incorporate older grains into the layers (Kowallis *et al.*, 1986; Kowallis *et al.*, 1993). Figure 4 shows an example of the age probability distribution curves (Hurford *et al.*, 1984; Kowallis *et al.*, 1986) used in determining the ages listed in Tables 1 and 2. The age distributions shown in Figure 4 for fission-track and $^{40}Ar/^{39}Ar$ ages come from GTO-2D from the Rancho El Ocote site. This sample was a sandstone rich in volcanic detritus. Abundant fossil material, representing the greatest diversity of Late Tertiary (Hemphillian) taxa found anywhere in the San Miguel de Allende region, occurs at the Rancho El Ocote locality. The sub-localities where the most significant fossil material was collected were GTO-2C and GTO-2D, which also contained volcanic ash and ashy sediment that was collected for dating. A comparison of both fission-track and $^{40}Ar/^{39}Ar$ dating methods shows that both give essentially the same age for the youngest age peak, and show a scattering of older ages (Figure 4).

Table 1. Fission-track ages

Sample #	Stage	Age ± 1σ error
GTO-2C	Hemphillian	4.8 ± 0.2 Ma
GTO-43	Hemphillian	4.4 ± 0.3 Ma
GTO-2D	Blancan	4.6 ± 0.3 Ma
GTO-11	Blancan	4.1 ± 0.5 Ma
GTO-12B	Blancan	3.9 ± 0.3 Ma
HGO-12C	Blancan	4.2 ± 0.3 Ma

The ages listed in Tables 1 and 2 bracket the Hemphillian-Blancan boundary. The $^{40}Ar/^{39}Ar$ laser-fusion ages are more precise than the fission track ages and are used here to propose limits on the boundary. The oldest Blancan age of 4.74 ± 0.14 Ma provides a minimum boundary age, and the only $^{40}Ar/^{39}Ar$ laser-fusion Hemphillian age of 4.89 ± 0.16 Ma provides a maximum boundary age. The fission-track ages are all in agreement with a boundary between these limits. Even GTO-43, which gives a zircon fission-track age of 4.4 ± 0.3 Ma (1σ) for a Hemphillian ash, is not problematic when the error limits are taken into consideration. At the 2σ level (95% confidence level) the true age for GTO-43 could be anywhere between 3.8 and 5.0 Ma, certainly compatible with the $^{40}Ar/^{39}Ar$ ages. Lundelius

Table 2. $^{40}Ar/^{39}Ar$ ages.

Sample #	Stage	Age ± 1σ error
JAL-20	Hemphillian	4.89 ± 0.16 Ma
GTO-2D	Blancan	4.74 ± 0.14 Ma
GTO-5A	Blancan	3.36 ± 0.04 Ma
HGO-12C	Blancan	4.59 ± 0.01 Ma

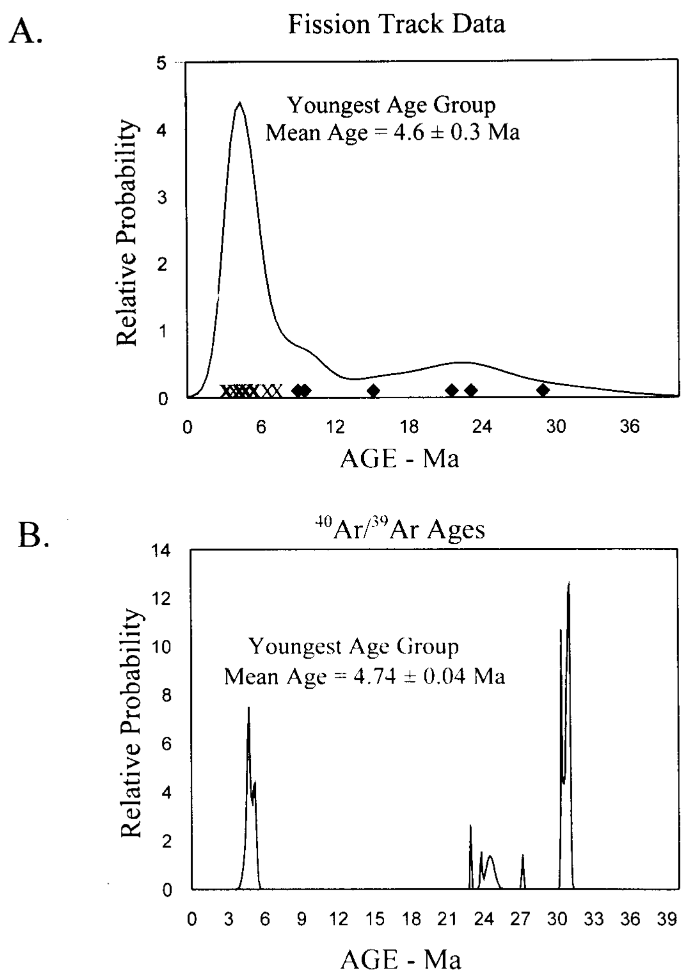

Figure 4. Relative probability for (a) fission-track, and (b) $^{40}Ar/^{39}Ar$ ages from sample GTO-2D from the Rancho El Ocote site in Guanajuato. X's and ♦'s in (a) are individual grain ages. The X's were used to calculate the youngest age peak.

and collaborators (1987) placed the boundary in the Gilbert Chron between 4.0 and 4.4 Ma, while Repenning (1987), although agreeing that the boundary falls within the Gilbert Chron, placed the boundary at 4.8 Ma. Our data, presented here, support the proposal of Repenning (1987) for a boundary at about 4.8 Ma.

The older grain ages found in all of the samples fall into three main groups: 5–9 Ma, 22–27 Ma, and 30–31 Ma. These age groups correspond well with the ages of older volcanic rocks in the Mexican Volcanic Belt (Moore *et al.*, 1994) and with older volcanic rocks near the sampling sites (Carranza-Castañeda *et al.*, 1994).

CONCLUSIONS

Although more radiometric ages are still needed from the Pliocene sediments in central Mexico to completely define their age range, the ages reported here are important in helping to define the ages of the faunal assemblages found in these sediments and to provide limits on the age of the Hemphillian-Blancan boundary. Based upon the high-precision $^{40}Ar/^{39}Ar$ laser-fusion ages reported here, the age of this boundary is between 4.74 and 4.89 Ma. The fission-track ages are not as precise, but are not significantly different from the $^{40}Ar/^{39}Ar$ laser-fusion ages.

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