

Carbon Isotopic Values of Tooth Enamel of *Mammuthus columbi* from Tocuila, State of México, México

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The late-Pleistocene paleontological locality at Tocuila in central México (State of México, 19° 31' N, 98° 54' W, 2,240 masl), has been the target of many interdisciplinary studies. Research has focused on the history of the deposit, as well as ecological studies of the species found at the locality and the probability of human association (Morett et al., 1998). The Tocuila fauna is composed of remains of Columbian mammoth (*Mammuthus columbi*), bison (*Bison* sp.), camel (*Camelops hesternus*), horses (*Equus* sp.), a large felid, hare (*Lepus* sp.), and Mexican vole (*Microtus mexicanus*). These remains were found in a fluvial deposit mainly composed of volcanic ash. It is probably an ancient lahar and has an average AMS age of $11,188 \pm 76$ RCYBP (Arroyo-Cabrales et al. 2002). Above the lahar deposits, on top of an indurated carbonate layer, there

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are lake sediments containing remains of fish, aquatic birds, and turtles.

Mammoth remains are the most abundant in the deposit, with as many as five individuals. They may have been grazers, according to inferences from morphological features (McDonald and Pelikan 2006). However, previous studies using biogeochemical analyses of Columbian mammoth specimens from El Cedral and Laguna de las Cruces (San Luis Potosí, north-central México) showed that this species had a mixed C_3/C_4 diet (Pérez-Crespo 2007; Pérez-Crespo et al. 2009). Our study objective was to evaluate mammoth feeding behavior using samples from Tocuila. Enamel samples for the five individuals were assayed for $\delta^{13}C$ composition, following Pérez-Crespo et al. (2009). The values obtained for isotopic carbon are expressed relative to the VPDB standard; estimates of the percentage of C_4 plants eaten ($\%C_4$) are calculated following Koch et al. (2004). The $\delta^{13}C$ values were compared with those for specimens from San Luis Potosí (Pérez-Crespo 2007; Pérez-Crespo et al. 2009) using the Mann-Whitney test (Hammer and Harper 2006). Statistical analyses were performed with the program NCCS and PASS (Hintze 2004); probability level was $p < 0.05$. Specimens are housed in the Paleontological Collection, Archaeozoology Lab, National Institute of Anthropology and History; these specimens are uncatalogued, and the acronym TC was assigned (Table 1).

Table 1. Values of $\delta^{13}C$ obtained for enamel of *Mammuthus columbi* from Tocuila, México.

Sample	$\delta^{13}C_{VPDB}$ (‰)	C_4 (%)	Sample	$\delta^{13}C_{VPDB}$ (‰)	C_4 (%)
TC1	-3.9	57.1	TC4	-4.4	54
TC2	-3.5	59.8	TC5	-5.1	49.1
TC3	-1.3	74.3			

The values for C_4 (%) were obtained using the formula:

$$(100)\delta^{13}C_{\text{sample}} = (100-x)\delta^{13}C_{100\% C_3 \text{ enamel}} + (x)\delta^{13}C_{100\% C_4 \text{ enamel}}$$

The value for $\delta^{13}C_{100\% C_3 \text{ enamel}}$ is -12.5‰

The value for $\delta^{13}C_{100\% C_4 \text{ enamel}}$ is 2.5‰

These values are estimates for the late Pleistocene (after Koch et al. 2004; Koch 2007).

The results obtained show an average value of -3.67‰, with values ranging from -1.35‰ to -5.14‰. Comparisons between Tocuila and specimens from San Luis Potosí did not show any significant difference between mammoth groups (U: 17.5, d.f. 9, $p < 0.87$). On average, the Tocuila mammoth population had a mixed C_3/C_4 diet, with 58.9% C_4 plants. One individual was a dedicated grazer ($\%C_4$: 74.3%); four individuals were C_3/C_4 mixed feeders, including an individual that consumed more C_3 plants ($\%C_4$: 49.1%); and three individuals consumed more C_4 plants (Table 1). It is possible that those individuals had eaten aquatic plants, as well as leaves and bushes growing on the margins of the Texcoco Lake, which spread close to Tocuila during the late Pleistocene (Arroyo-Cabrales et al. 2002); such a behavior is known presently for African elephants. This feeding behavior is similar to that found in San Luis Potosí mammoths; this species in México was more of a generalist feeder than a specialist feeder.

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