CARBON AND OXYGEN ISOTOPIC VALUES FOR A SHORT FACED BEAR INDIVIDUAL (*ARCTODUS SIMUS*) FROM CEDRAL, SAN LUIS POTOSÍ, MÉXICO

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Abstract

Dental enamel of a short-faced bear *Arctodus simus* from the Late Pleistocene archaeological-paleontological site of Cedral, San Luis Potosí, Mexico was analyzed for $\delta^{13}C$ and $\delta^{18}O$ biogeochemical markers. The results showed that this animal fed upon C_3 herbivores and lived in forested areas. However, it is not possible to infer if this individual fed on carrion or was an active carnivorous.

Samenvatting

In dit artikel worden de resultaten besproken van de $\delta^{13}C$ en $\delta^{18}O$ isotopenanalyse van een kortsnuitbeer *Arctodus simus* gevonden in Cedral, San Luis Potosí, Mexico. De resultaten tonen dat dit individu zich voedde met C3 herbivoren en in een beboste omgeving leefde. Echter, het is niet mogelijk om te onderscheiden of dit dier een volledig carnivoor of een omnivoor dieet had.

INTRODUCTION

In the Mexican Late Pleistocene, there was a quite diverse carnivore mammal fauna (Arroyo-Cabrales *et al*., 2010), including species pertaining to at least seven families: Canidae, Felidae, Herpestidae, Mustelidae, Mephitidae, Procyonidae, and Ursidae (Ferrusquia-Villafranca *et al*., 2010). The last family was represented by four known species: Short-faced bear, *Arctodos simus*; Pleistocene spectacled bear, *Tremarctos floridanus*; American black bear, *Ursus americanum*, and Grizzly bear, *Ursus arctos*. However, after the Pleistocene-Holocene transition, the first two species went into extinction (Arroyo-Cabrales *et al*., 2002).

Regarding the short-faced bear, skeletal remains are reported from several localities, including Cedral (San Luis Potosí), Chapala-Zacoalco (Jalisco), Arroyo Cedazo (Aguascalientes), Tequixquiac (State of México), Valsequillo (Puebla), and Puerta de las Lajas (Hidalgo) (Ferrusquía-Villafranca *et al*., 2010). Most of those reports have focused on the anatomical and taxonomical identifications, with no mention of any ecological data. On the other hand, there are several studies based on specimens from the USA trying to infer biological and ecological facts about these animals (Kurtén & Anderson, 1980; Matheus, 1995, 1997; Figuerido *et al*., 2010; Donohue *et al*., 2013).

Due to the lack of those studies, we present the first stable isotope analysis for an individual pertaining to *Arctodus simus* from Mexico for inferring its diet and possible habitat type (open or closed).

CARBON AND OXYGEN STABLE ISOTOPES

There are three photosynthetic pathways in plants, which are distinguished by differences in their $\delta^{13}C$ values. C_3 plants (-22‰ to -30‰) are the most abundant and include most dicotyledonous trees and shrubs, and a few temperate grasses. C_4 plants (-10 ‰ to -14 ‰) include monocotyledonous grasses, pterydophytes and few dicotyledonous trees and shrubs from tropical habitats. The CAM pathway is found in bromeliads, cacti, orchids and other succulent plants. The $\delta^{13}C$ values are between -10‰ and -30‰, and therefore are not easily separated from the other two pathways (Smith & Epstein, 1971; Vogel, 1978; Ehleringer *et al*., 1986; Cerling *et al*., 1997; Keeley & Rundel, 2003). These values are then passed onto herbivorous animals, with 14 % enrichment with respect to the plant's original values (Cerling & Harris, 1999; Sánchez, 2005). These final values can be assigned to the different feeding habits: C_3 species from -9‰ to -19‰; C4 species, -2‰ to +2 ‰; and mixed diet organisms from -2‰ to -9‰ (MacFadden & Cerling, 1996). In the case of carnivores, carbon isotopic values will depend upon the

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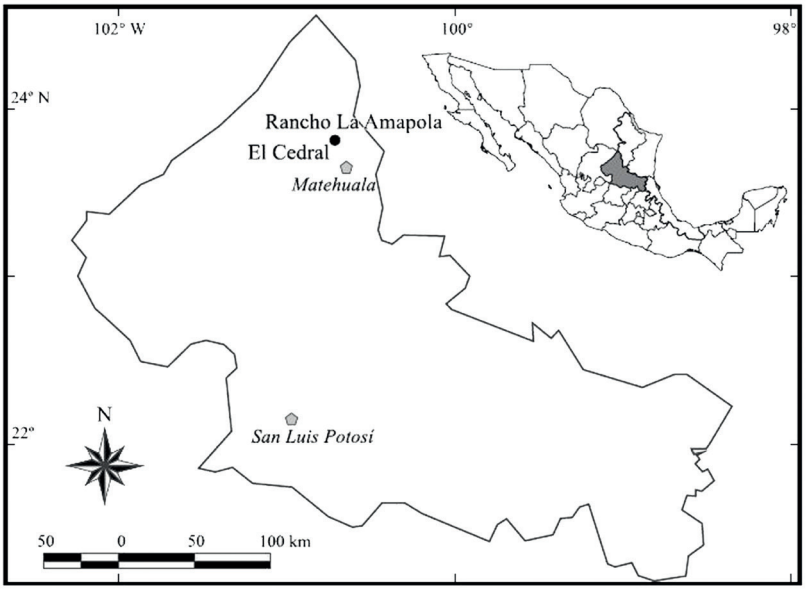

Figure 1: Geographic location of the Pleistocene fossiliferous locality at Cedral, San Luis Potosí, Mexico

Figuur 1: Geografische ligging van de Pleistocene fossielenvindplaats Cedral, San Luis Potosí, Mexico

eaten prey, as well as which part of the animal was eaten, like muscle, organs or bone (Coltrain *et al*., 2004; Kohn *et al*., 2005; Palmqvist *et al*., 2008; Feranec & DeSantis, 2014). As such, carnivore values will show an enrichment between 1.3‰ ± 0.2‰ in relation to the isotopic values of the herbivores they feed upon (Clementz *et al*., 2009). While oxygen is incorporated also into a mammal's bones through food, the main source is ingested water, and its $\delta^{18}O$ composition is mainly affected by environmental temperature (Dansgaard, 1964; Sánchez *et al*. 1994). Based on the previous statement, $\delta^{18}O$ values are mainly used for palaeoclimatic inferences (Ayliffe *et al*., 1992; Iacumin *et al*., 1996; Kohn, 1996; Grimes *et al*., 2008).

MATERIALS AND METHODS

Study area

The Cedral archaeological–palaeontological site is located in the state of San Luis Potosí, Mexico, at 23°49'N and 100°43'W, and 1700 m.s.l. (Figure 1). This site contains several ancient springs, which could have been used for drinking water by late Pleistocene carnivorous and herbivorous mammals, as well as smaller mammals and other vertebrates (Álvarez *et al*., 2012; Corona, 2012). Stratigraphically controlled excavations at the site enabled the identification of three fossiliferous levels, based on radiocarbon dates (modified from Mirambell & Lorenzo, 2012). These levels are: (1) between 30 000 and 25 000 years BP (before present); (2) between 17 000 and 11 000 years BP, and (3) between 10 000 and 8 000 years BP (Fig. 2). Unfortunately, the studied specimen is not associated with specific excavation data; however, the faunal assemblage (level 1) where it belongs to is composed of elements, which could be assigned to Rancholabrean NALMA age, and more specifically a late Pleistocene age.

Sample preparation

Sample preparation and analyses were performed in the Stable Isotopes Mass Spectrometry Lab at the Geology Institute, Mexicos National Autonomous University (UNAM). The preparation procedure follows the method proposed by Koch *et al*. (1997). First, 20 mg of enamel was ground and screened with a 125 µm mesh to obtain a fine and uniform dust. Then 10 ml of Hydrogen Peroxide Solution (H_2O_2 30 wt. % in H_2O) was added to remove the organic matter and was left for a period of two hours. Subsequently, the samples were centrifuged and the distilled water decanted. This procedure was executed three times. Once the washing was completed, 5 ml of a buffer solution made of $CaCH_3CO_2$–H_3COOH 1.0 M, pH = 4.75, was added and allowed to sit for nine hours. Afterwards, the buffer solution was discarded, and samples were washed three times again with distilled water. Finally, to eliminate any remaining water, ethanol was added, and the solution was left to rest for 12 hours in an oven at 90°C. Determination of sample isotopic abundance was executed in a Finnigan MAT 253 mass spectrometer with a dual inlet system, and Gas Bench auxiliary equipment with a GC Pal autosampler that has a temperature-controlled aluminum plate adjoined to the mass spectrometer (Révész & Landwehr, 2002). Results were reported as $\delta^{18}O_{VPDB}$ and $\delta^{13}C_{VPDB}$ and normalized using NBS-19, NBS-18 and LSVEC to the Vienna Pee Dee Belemnite (VPDB) scale in accordance with the corrections described by Coplen (1988), Werner & Brand (2001), and Coplen *et al*. (2006). For this technique, the standard deviation was 0.2‰ for oxygen, and 0.2‰ for carbon carbonates. Additionally, isotopic values recorded by Pérez-Crespo *et al*. (2014) for Cedral specimens pertaining to bison *Bison* sp., dire wolf *Canis dirus*, American mastodon *Mammut americanum*, Columbian mammoth *Mammuthus columbi*, American lion *Panthera atrox*, and Pleistocene tapir *Tapirus haysii*, were included in the analyses .

RESULTS

The $\delta^{13}C$ value for the *Arctodus* individual is -11.8‰, while $\delta^{18}O$ value is -5.1‰. These results indicated that this animal fed upon C_3 herbivores (browsers), and preferred habitation of closed areas, like forests. On the contrary, both dire wolf and American lion fed upon mixed feeders or grazers, and lived in open areas like savanna or grassland (Figure 3). The oxygen isotopic value for the study bear is similar to that shown by tapir, but different from the remaining species (Figure 3).

DISCUSSION

Carbon isotopic values for Cedral´s *Arctodus* individual showed that it used to feed upon C_3-eating herbivores, which inhabited in forested areas, like tapirs and American mastodons. Similarly, the bear $\delta^{18}O$ value indicated that it drank water from the same sources than tapirs. That is oppose to what Johnson *et al*. (2006) mentioned about short-faced bears in Mexico, since they considered that these bears were eating animals like horse, bison, and camel, living in savannas or grasslands. Previous isotopic analysis assayed by Mattheus (1997) and Fox-Dobbs *et al*. (2008) on Alaskan specimens showed that those individuals were eating herbivores that fed upon C_3, such as mammoths, horses, bisons, and cervids, and which inhabited grasslands, all of which is different from what we found for the Cedral specimen.

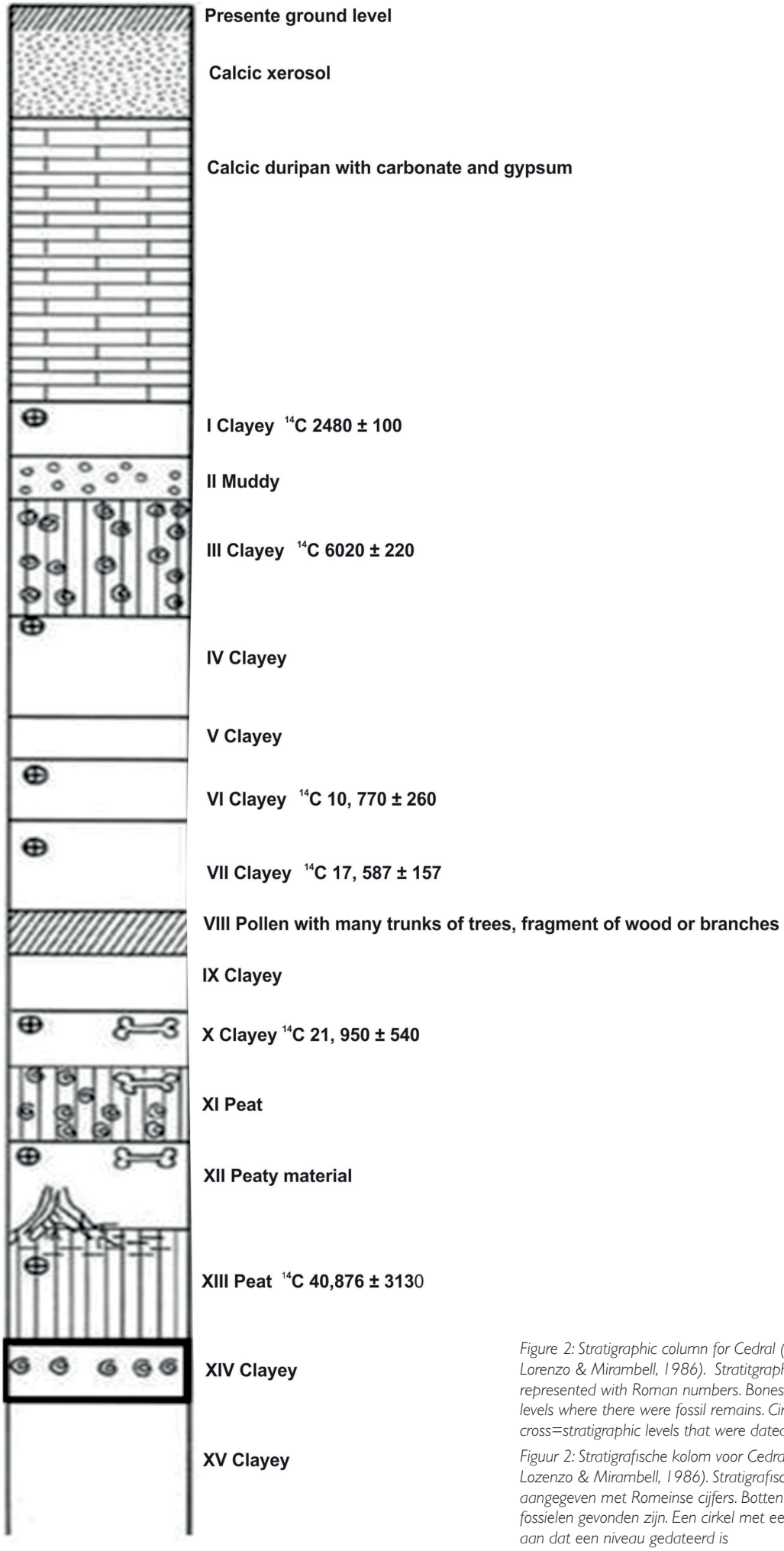

Figure 2: Stratigraphic column for Cedral (modified from Lorenzo & Mirambell, 1986). Stratitgraphic levels are represented with Roman numbers. Bones indicated levels where there were fossil remains. Circle with cross=stratigraphic levels that were dated

Figuur 2: Stratigrafische kolom voor Cedral (aangepast van Lozenzo & Mirambell, 1986). Stratigrafische niveaus zijn aangegeven met Romeinse cijfers. Botten geven aan date r fossielen gevonden zijn. Een cirkel met een kruis erin geeft aan dat een niveau gedateerd is

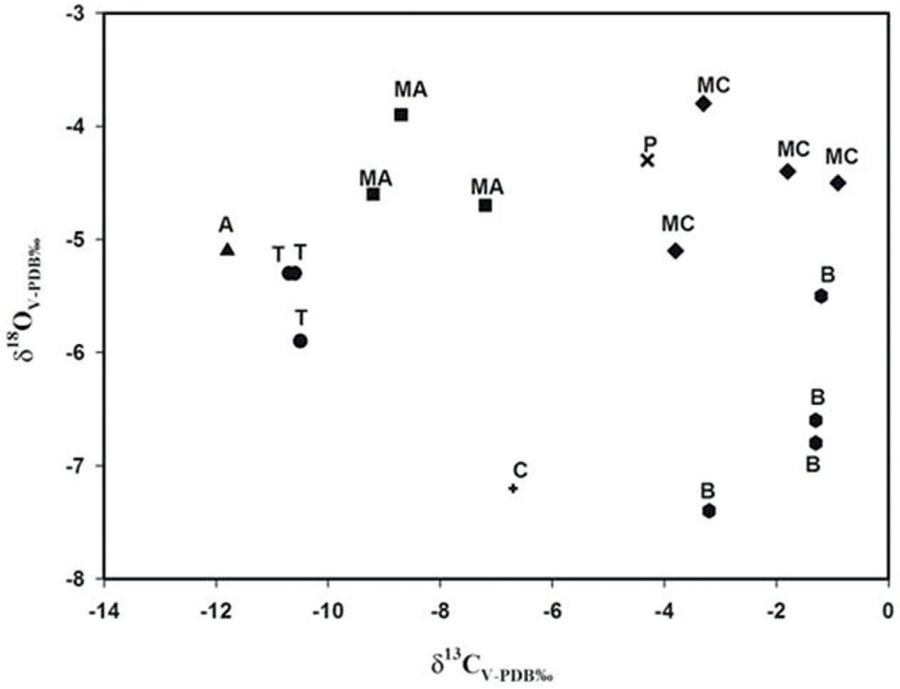

Figure 3: Carbon and oxygen isotopic values for Late Pleistocene mammal species individuals from Cedral (Mexico). Assayed species were: A: Arctodus simus, B: Bison sp., C: Canis dirus, MA: Mammut americanum, MC: Mammuthus columbi, P: Panthera atrox, and T: Tapirus haysii

Figuur 3: Koolstof- en zuurstofisotopenwaardes voor laatpleistocene zoogdiersoorden van Cedral (Mexico). Soorten: Arctodus simus, B: Bison sp., C: Canis dirus, MA: Mammut americanum, MC: Mammuthus columbi, P: Panthera atrox, en T: Tapirus haysii

On the other hand, Trayler (2012) found that specimens from McKittick and Asphalt Seep (California, USA) had a diet based on C_3 herbivores, like tapirs and deer, and lived in forested areas, similar to what was found for Cedral individual. Because of that, Trayler (2012) proposed that this animal may have been flexible on its diet and habitat, and not a carnivore specialist as inferred by Kurten & Anderson (1980) and Johnson *et al.* (2006), as it consumed herbivores that inhabited grasslands or savannas.

Food habits for *Arctodus simus* have been controversial since Kurten (1967) defined them as active hunters. Emslie & Czaplewski (1985) thought that this species was herbivorous, while Figuerido *et al.* (2010) and Donohue *et al*. (2013) thought it was omnivorous. However, carbon and nitrogen analyses assayed to specimens from Alaska have shown that the short-faced bear was mainly a meat-eater (Mattheus, 1995; Fox-Dobbs *et al*., 2008). Mattheus (1997), utilizing ecomorphological analyses, suggested that the short-faced bear was a scavenger, while Christiansen (1999), using the same technique, showed it to be an active hunter. Bocherens (2015) indicated that although meat was an important component of *Arctodus simus* diet, either as an active hunter or as a scavenger, it could have also fed on some plants, although on a lower amount. Since for this study, only $\delta^{13}C$ and $\delta^{18}O$ values from dental enamel were used, and not $\delta^{13}C$ and $\delta^{15}N$ bone collagen values, it is not possible to indicate if the Mexican specimen was a carnivore or an omnivore, warranting assays of more specimens along the country.

CONCLUSIONS

Cedrals short-faced bear used to eat herbivores which mainly fed upon C_3 plants; however, since only carbon and oxygen isotopic values from dental enamel were analysed, and not $\delta^{15}N$ values of collagen, it is not possible to infer if the individual was exclusively a carnivore or an omnivore.

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