STABLE ISOTOPE RECORD OF PALEOECOLOGICAL CHANGE IN THE LATE NEOGENE OF NEBRASKA FROM ENAMEL IN LARGE MAMMALS



Zachary A. Kita (zkita@huskers.unl.edu) and Ross Secord (rsecord2@unl.edu)
Department of Earth and Atmospheric Sciences, University of Nebraska-Lincoln, 214 Bessey Hall, Lincoln, NE 68588



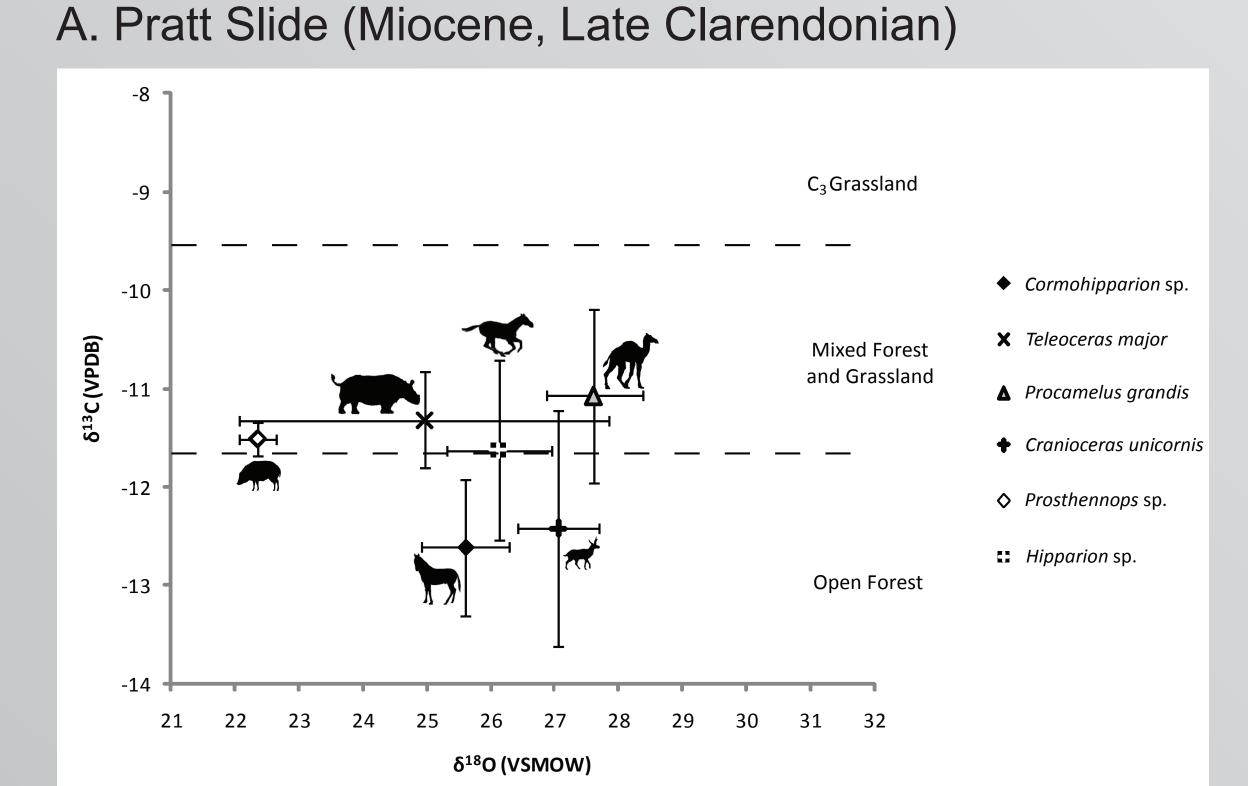
1: Abstract

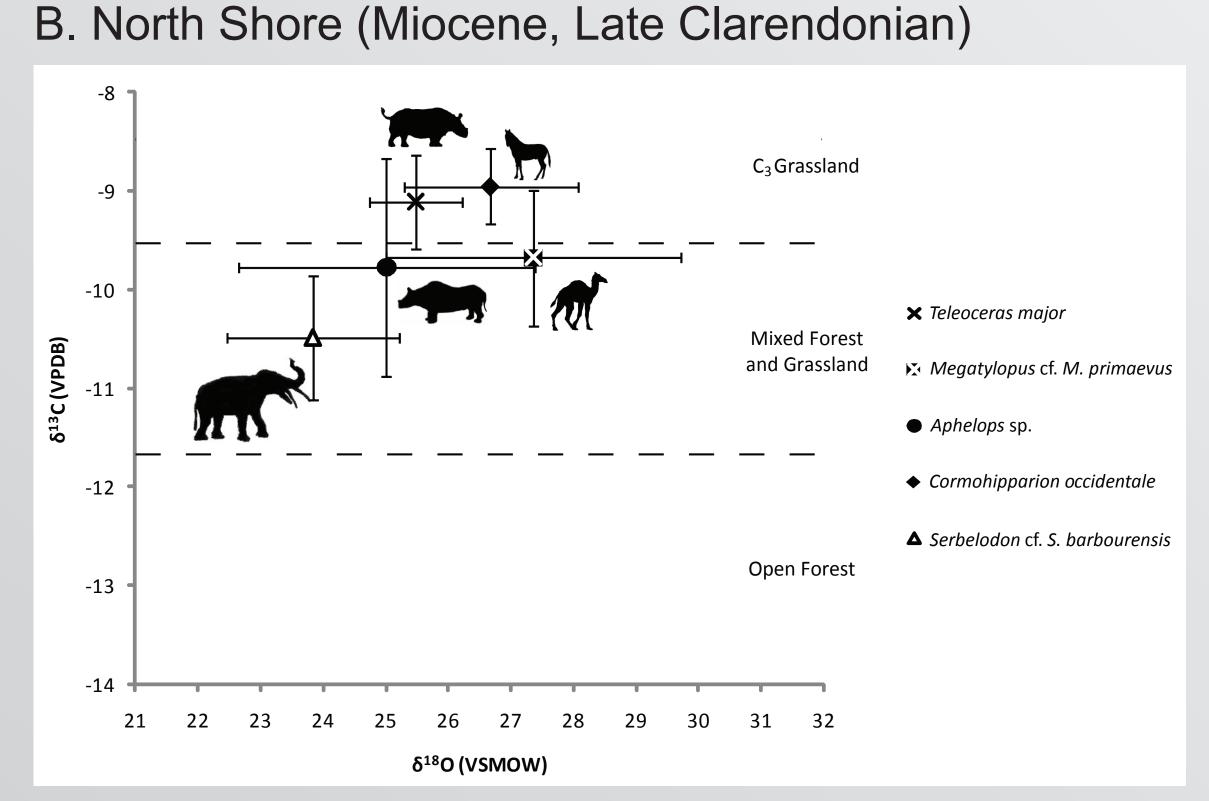
The expansion of C₄ grasslands occurred between 6 to 8 million years ago in the North American Great Plains, as indicated by a marked shift to higher stable carbon isotope values (δ^{13} C) in fossil mammals and soil carbonates. Prior to this expansion, Great Plains floras were predominantly composed of C₃ vegetation. In response, there was a forced shift in diet by large mammals. To explore this problem we present a compilation of bulk stable carbon and oxygen (δ^{18} O) isotope values from a variety of large mammals from six localities in Nebraska, ranging in age from late Miocene (Clarendonian) to late Pliocene (Blancan). As expected, late Miocene taxa had δ¹³C values indicating that they exclusively exploited C₃ vegetation with habitats ranging from open forests in northern Nebraska to C₃ grasslands in southwestern Nebraska. A shift to higher δ¹³C values occurs in Pliocene camels, horses, and gomphotheres indicates that they were consuming some C₄ vegetation. In contrast, a Blancan peccary (*Platygonus* sp.) still consumed only C₃ vegetation indicating that C₃ niches were still present. Through this Miocene-Pliocene transition there is an overall shift to lower δ¹⁸O values in tooth enamel which is consistent with the long-term decrease in mean annual temperature observed in the marine record. Our results indicate marked change in climate and vegetation in the Great Plains from the late Miocene to the

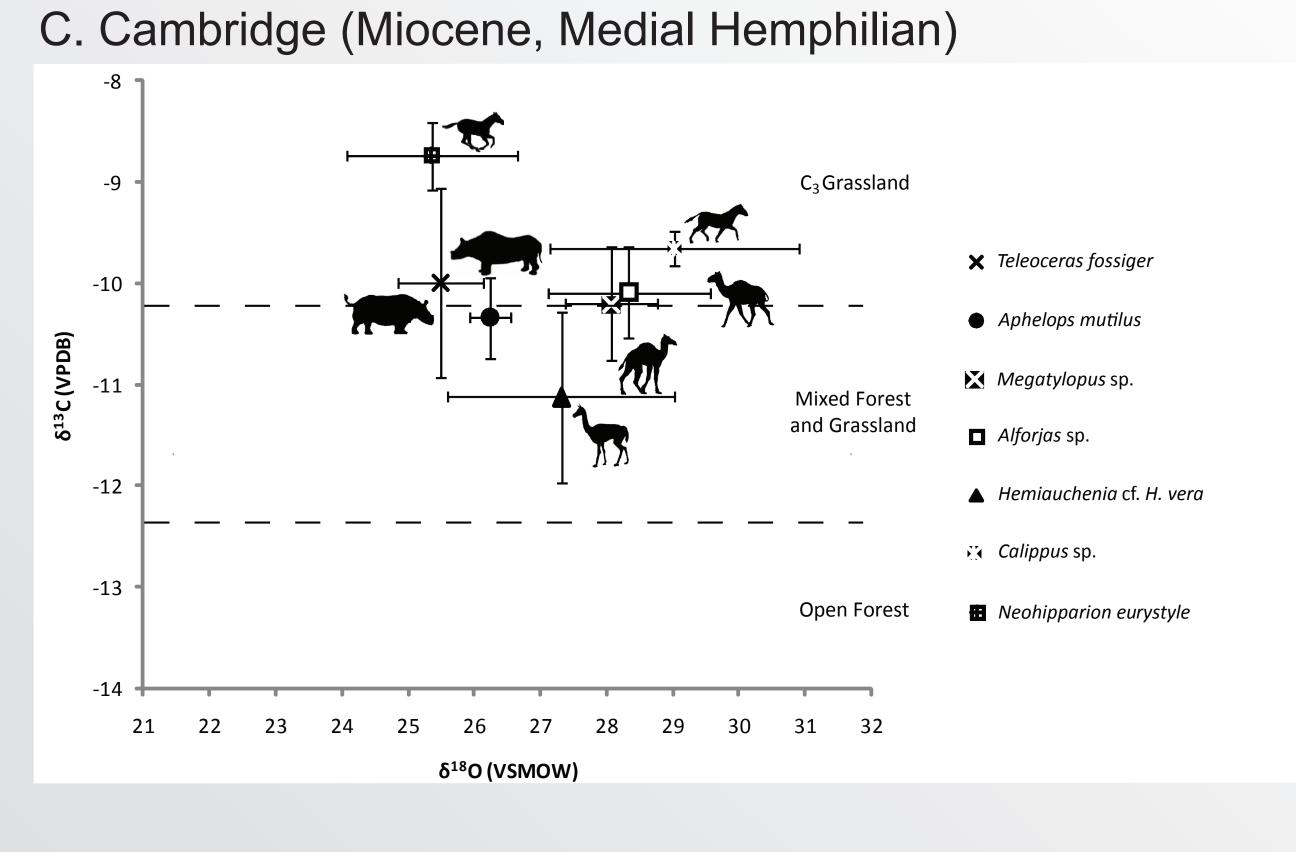
2. Fossil Localities North American Land-Mammal Ages Irvingtonian Pliocene Neogene North American Land-Mammal Ages Irvingtonian Big Springs Broadwater Lisco Cambridge Pratt Slide North Shore

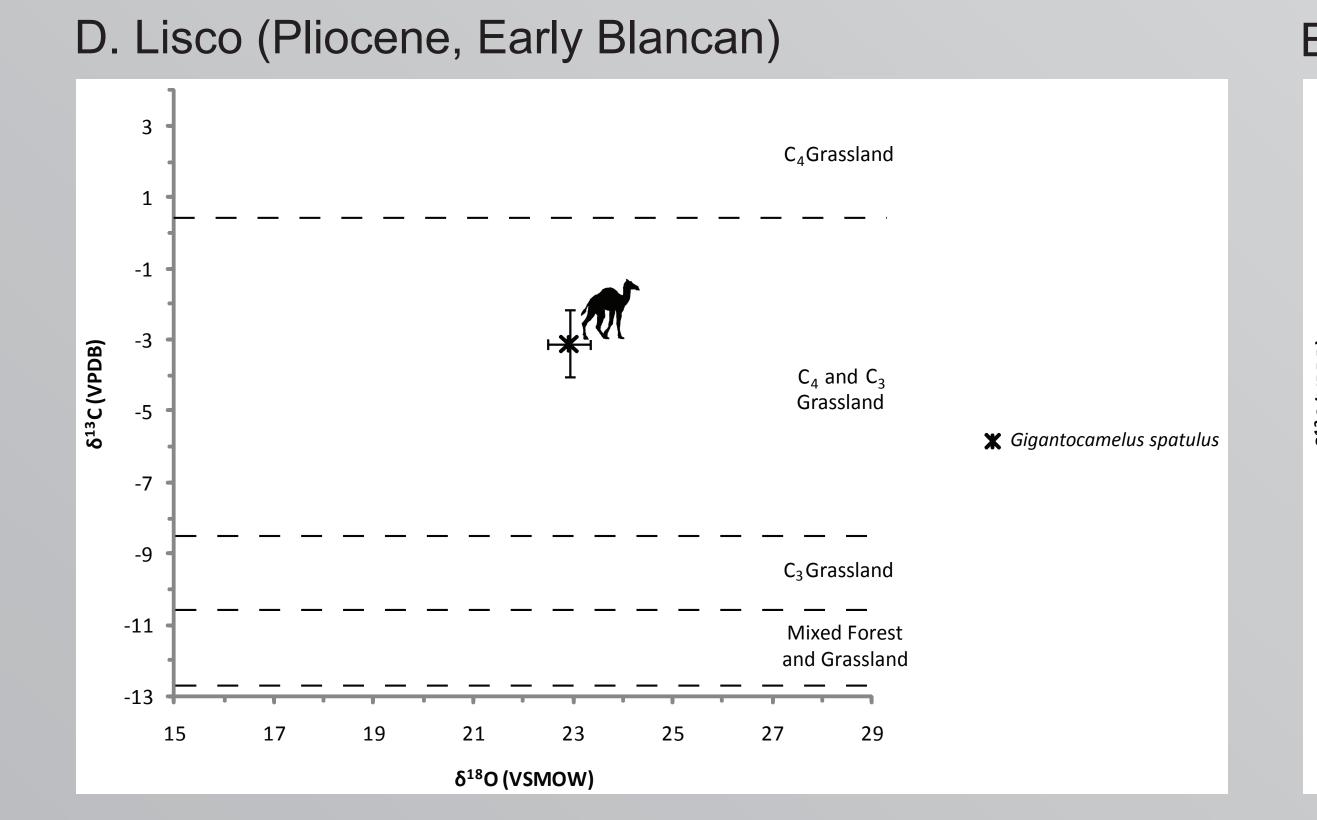
Generalized diagram showing the geochronologic sequence of Nebraska fossil localities, timing of North American land-mammal ages, and geographic distribution of fossil localities sampled in this study. Compiled using data from Voorhies (1990) and Passey et al. (2002).

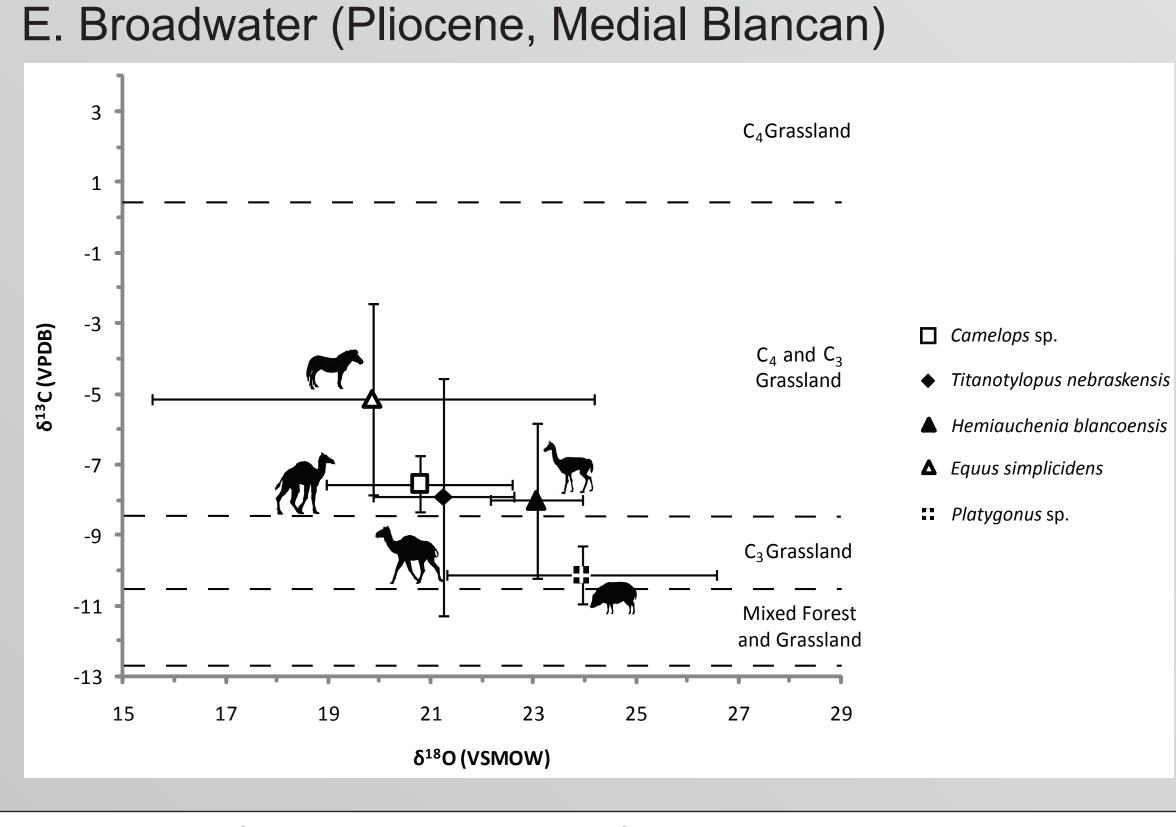
5. Results Within Localities

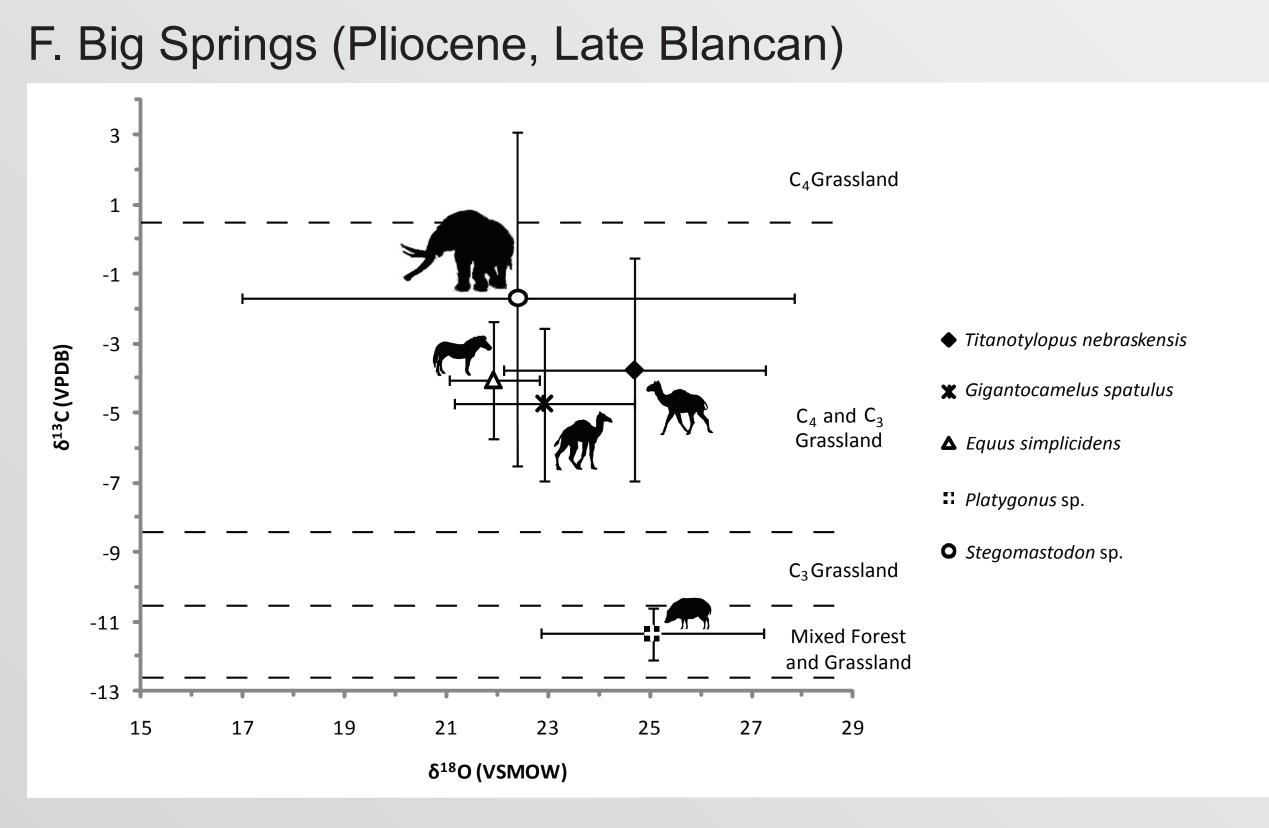










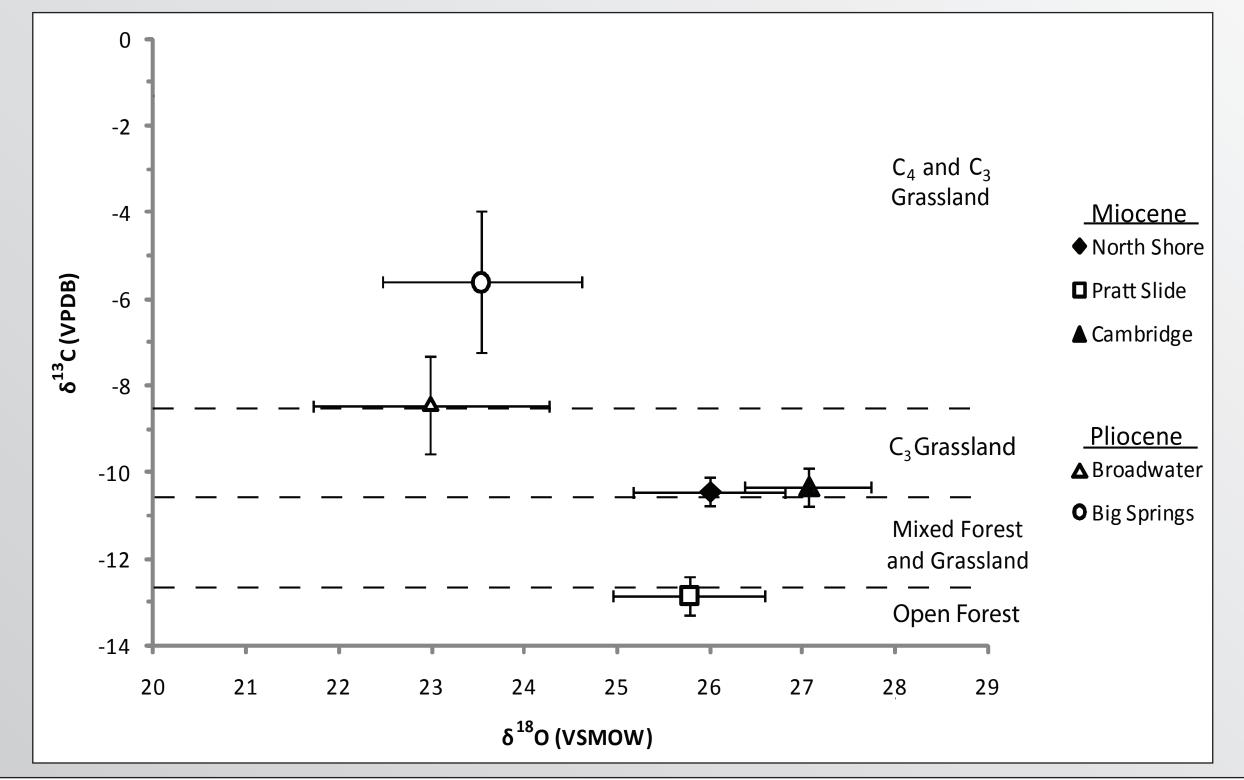


Stable carbon and oxygen isotope values from mammalian taxa at fossil localities throughout Nebraska with interpreted diets from Part 4 corrected for diet-enamel enrichment of 14‰ and atmospheric δ¹³C values for each locality. Symbols represent the mean value; error bars represent 95% confidence (±1.96 SE). A, B, and C are from the Miocene. D, E, and F are from the Pliocene.

3. Methods

- Tooth enamel of 105 specimens from six localities in Nebraska was sampled for bulk analysis. Preference was given to sampling the third molar and premolars since these teeth are among the last ones to develop, mineralize, and erupt in mammals (Hillson, 2005). When necessary, these were supplemented by the sampling of second and first molars.
- The general method for stable isotope sampling of tooth enamel followed Koch et al. (1997). 3-4 mg of pristine enamel powder was drilled off the tooth along a non-occlusal surface parallel to the growth axis using a diamond bit and a variable speed dental drill.
- The powder was collected and treated with 2-3% reagent grade NaOCl for 24 hours to remove organics. The samples were rinsed five times with distilled water and dried. Nonstructural carbonates were removed by soaking in 1 M buffered acetic acid for 24 hours. This was followed by rinsing 5 times and drying at 60°C overnight.
- Samples were reacted with phosphoric acid at 77.1° ± 1°C in a Finnigan MAT Kiel automated carbonate reaction device at the University of Michigan Stable Isotope Laboratory. δ¹³C and δ¹⁸O values of the resulting CO₂ were measured on a Finnigan MAT 253 triple collector isotope-ratio-monitoring mass spectrometer. Isotopic ratios were normalized using international standards.
- Intra-lab enamel standards (LOX, from modern elephant enamel; MES-1, from fossil mammoth enamel from New Mexico) were used to monitor variance among batches. Mean values and variance were: $\delta^{18}O = 32.07 \pm .04\%$ and $\delta^{13}C = -5.66 \pm .01\%$ (Standard error, n = 29) for LOX and $\delta^{18}O = 23.30 \pm .07\%$ and $\delta^{13}C = -9.67 \pm .01\%$ (Standard error, n = 19) for MES-1

6. Results Among Localities



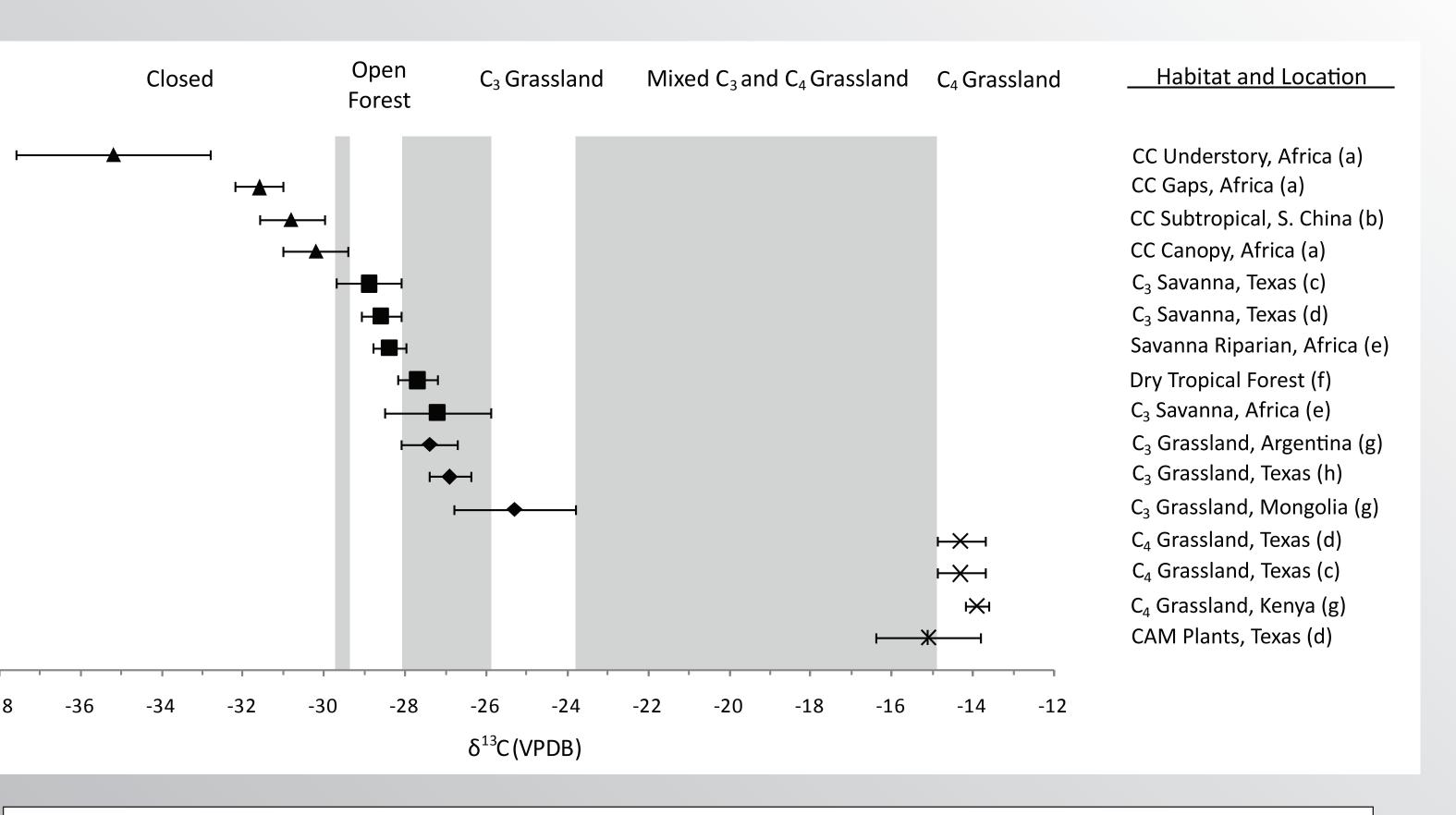
Mean stable carbon and oxygen isotope values from all the localities in Nebraska. Error bars represent 95% confidence (±1.96 SE)

7. Conclusions

- The spread of C₄ grasslands in the Blancan is recorded by many taxa that have switched their diet from C₃ grasses and evolved adaptations for grazing. Late Miocene camels were mixed feeders while taxa within this group switched to C₄ grazing in the Pliocene. The Miocene gomphothere, *Serbelodon*, was probably a C₃ mixed feeder, while *Stegomastodon* was a C₄ grazer in the Pliocene.
- Late Miocene faunas were exclusively exploiting C₃ vegetation. Horses have the highest δ¹⁸O values in the Cambridge and North Shore faunas, suggesting a preference for open habitats and C₃ grazing. Camels and rhinos exploited a range of niches, from mixed feeding to possibly grazing. The horse *Cormohipparion* appears to have been able to exploit both open forest and grassland environments.
- C₃ vegetation was still prevalent enough in the Blancan to support some C₃ feeders. The peccary *Platygonus* sp. has the lowest mean δ¹³C values of both Blancan faunas, indicating that it was feeding exclusively on C₃ vegetation and probably occupying a riparian habitat. It may serve as good indicator of maximum vegetation density in local microhabitats.
- Pratt Slide locality appears to have been a more forested environment compared to the Cambridge and North Shore localities in the Miocene.
- Rhinos have consistently low δ¹⁸O values in the late Miocene faunas, suggesting water dependence, while camels have higher values suggesting that they relied more on food for water. The peccary *Prosthennops* sp., in Pratt Slide, has very low ¹⁸O values with extremely low variance, strongly suggesting a preference for aquatic vegetation.
 Oxygen isotope values are significantly lower in the Blancan, which is consistent with major global cooling from the

Oxygen isotope values are significantly lower in the Blancan, which is consistent with major global cooling from the late Miocene to the late Pliocene, as indicated by marine proxies (e.g., Zachos et al., 2001).

4. Predicted Cutoffs for Various Habitats



Modeled constraints on carbon isotope values for vegetation in various habitats normalized to 42° N latitude in North America based on δ^{13} C values from modern floras. Gray areas indicate overlap in δ^{13} C values for habitats. Error bars show 95% confidence of mean (± 1.96 SE). CC = closed canopy. Data sources: a, Cerling et al. (2004); b, Ehleringer et al. (1987); c, Boutton et al. (1998); d, Jessup et al. (2003); e, Codron et al. (2005); f, Mooney et al. (1989); g, Cerling and Harris (1999); h, Brown and Smith (1975)

8: Acknowledgments

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