Paleoenvironmental Reconstruction of Two Paleoindian Sites in North-Central New Mexico

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Introduction

Archaeologists use paleoenvironmental reconstructions to model the past and help understand the people who lived in a particular environment (Ballenger et al. 2011; Emery and Kennedy Thornton 2008; Mullen 2007; Stanford 2005). Stable isotopes found in faunal remains are a climate proxy, and are particularly useful to archaeologists since they are a typical, durable material culture class. Stable isotopic studies are ideal for archaeologists since the proxy record is directly associated with the archaeological record. This poster analyzes the isotopic ratios of $\delta^{13}C$ and $\delta^{18}O$ extracted from *Bison antiquus* teeth to develop a proxy environmental record for the early Paleoindian and late Paleoindian periods in north-central New Mexico. Analyzing $\delta^{18}O$ can help determine the climate while analyzing $\delta^{13}C$ can help sample the plants in the environment.

Fig. 1 *Bison antiquus* on display at the Field Museum, Chicago, IL

Hypotheses

Carbon

H_0: the C_3 and C_4 grasses ratio remained stable between the Younger Dryas and the Early Holocene

H_1: The ratio of C_4 grasses to C_3 grasses was higher in the Early Holocene than in the Younger Dryas

Oxygen

H_0: $\delta^{18}O$ will remain stable between the Younger Dryas and the Early Holocene

H_1: $\delta^{18}O$ will differ between the Younger Dryas and the Early Holocene.

Background

This poster focuses on bison teeth collected from two sites. The Boca Negra Wash site is in the Middle Rio Grande Basin and was occupied ca. 12,170 - 10,600 cal B.P. (Holliday et al. 2006; Huckell et al. 2011). The Water Canyon site is at the northeastern edge of the Magdalena Mountains and was occupied ca. 10,720 – 10,400 cal B.P. (Dello Russo et al. 2010; Holliday et al. 2019).

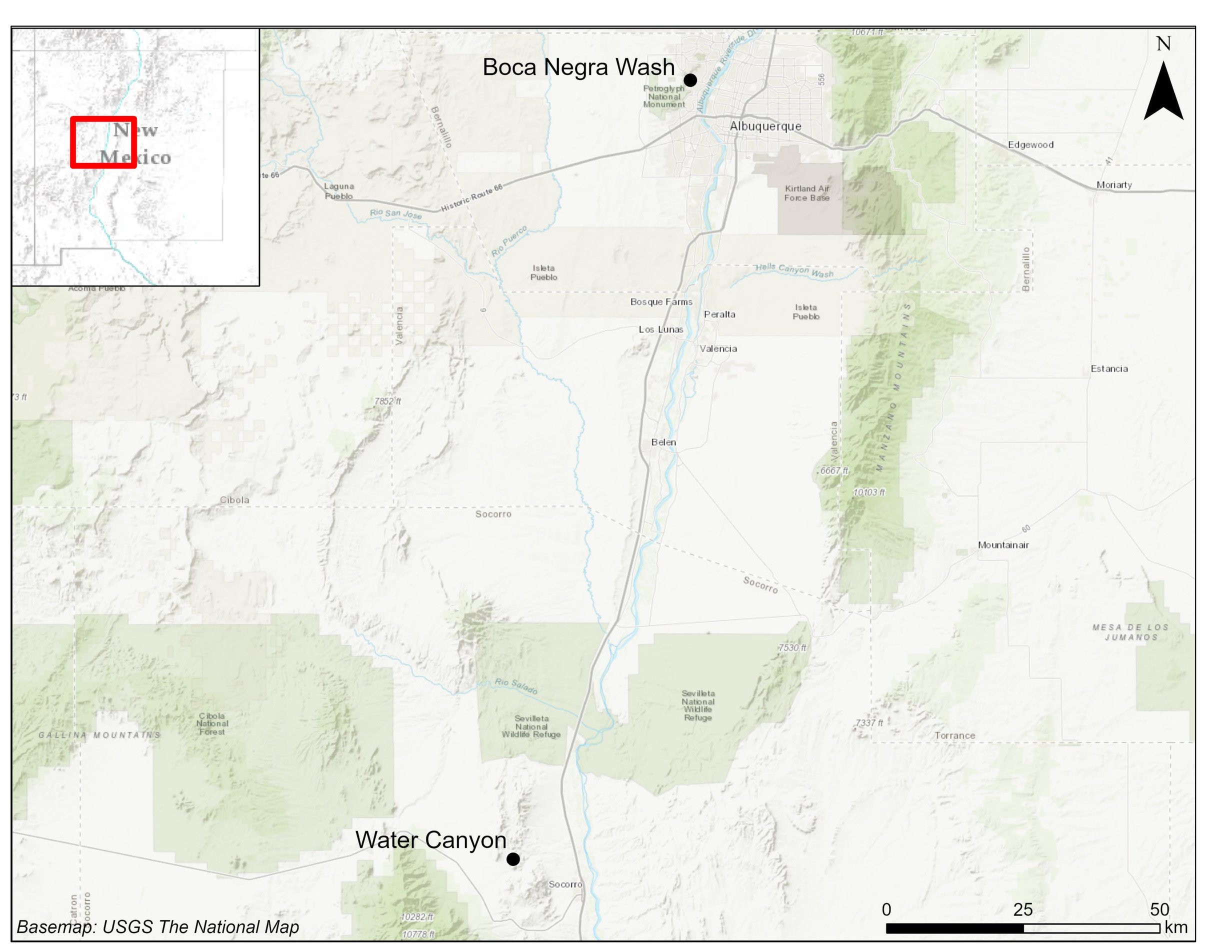


Fig. 2 Boca Negra Wash and Water Canyon in north-central NM

An isotope is a variant of an element that contains the same number of protons but a different number of neutrons (Sharp 2017). This poster analyzes the ratios of $\delta^{13}C$ and $\delta^{18}O$ as carbon can provide a proxy for habitat while oxygen can provide one for $\delta^{18}O$ climate. A summary and background is provided below:

Carbon

- Carbon exists in two naturally occurring stable forms in nature (^{12}C and ^{13}C)
- Plants have evolved different photosynthetic pathways for absorbing carbon from the atmosphere depending on the habitat: C_3, C_4, and CAM
- Bison do not feed on CAM (crassulacean acid metabolism) plants (e.g., succulents)
- Isotopes ^{12}C and ^{13}C are taken up at a different rate by C_3 and C_4 plants depending on the environment

Oxygen

- Oxygen exists in three naturally occurring stable isotopes (^{18}O, ^{17}O, and ^{16}O)
- ^{18}O to ^{16}O ratios can provide proxy evidence for an animal's environment
- There is no specific fractionation factor to determine an environment based on $\delta^{18}O$
- Environmental factors (precipitation, temperature, altitude, latitude) affect the value
- Lakes will have an average $\delta^{18}O$ across the seasons will $\delta^{18}O$ in rivers vary seasonally
- A higher ratio of ^{16}O to ^{18}O may indicate a wetter climate

Methods

I prepared the 17 samples using the protocol described in Ventresca Miller et al. (2018). I cleaned the teeth using a toothbrush, removed ~0.1 mm of enamel from each tooth across the lingual or buccal surface laterally with a small drill (Fig. 3a), and drilled the tooth above a weighing paper to catch the powdered sample. The drill bit was cleaned after each use to prevent contamination. Each sample was then poured into a micro-centrifuge tube for storage until needed. I pretreated each sample with acetic acid by adding the acid to the samples and placing each on an electric agitator. I then allowed the samples to sit for 10 minutes. I then placed the samples in a microcentrifuge for 2 minutes. Next, I removed the acid on top with a pipette and added 2 mL of ultrapure water. The sample was then placed in the microcentrifuge for 2 minutes (and I repeated this step three times). The samples were then permitted to dry. Next, the samples were washed with 3% hydrogen peroxide for 15 minutes and rinsed, followed by a wash of 0.1 M acetic acid for 15 minutes and rinsed. Finally, I weighed the samples in the Stable Isotope Laboratory, Department of Earth and Planetary Sciences (EPS), UNM, using the method described by Spötl and Vennemann (2003). Dr. Viorel Atudorei from UNM's Dept. of EPS performed the isotopic analysis (Fig. 3b).

Fig. 3a Bison tooth before and after drilling of surface

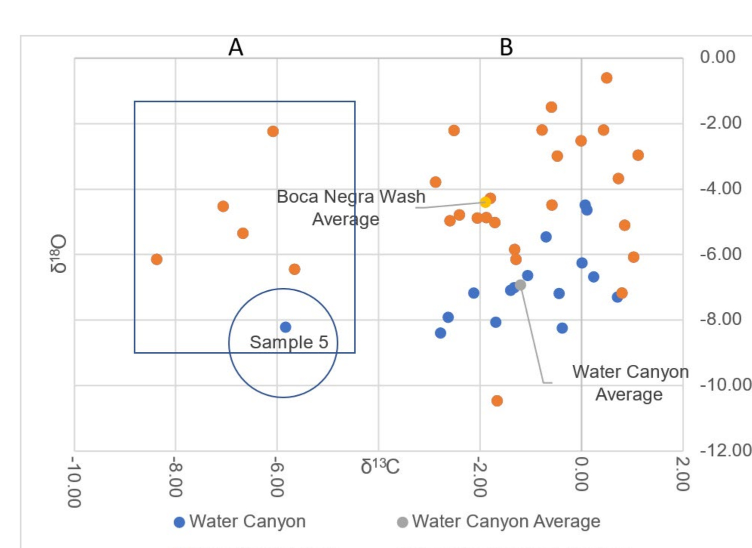
Dr. Atudorei from the Department of Earth and Planetary Sciences performed the mass spectrometer → He loaded the samples in a 12 mL borosilicate exetainer and flushed them with helium → The samples were reacted for 24 hours → The CO_2 was measured by the continuous flow Isotope Ratio Mass Spectrometry → Reproducibility was better than 0.15‰ for both the $\delta^{13}C$ and $\delta^{18}O$ based on repeat of lab standards → I present the isotopic ratios in the per mill (‰) notation

Fig. 3b Mass spectrometer procedure

Results

Sample Number	FS Number	Project	LA Number	weight (mg)	$\delta^{13}C$‰	$\delta^{18}O$‰
1	5029	41.901	134764	6.468	-0.44	-7.18
2	5121	WC field school	134764	6.212	-2.63	-7.91
3	5171	UNM field school	134764	6.561	-0.70	-5.47
4	5140	WC field school	134764	6.114	-1.07	-6.64
5	5080	41.901	134764	6.336	-5.83	-8.22
6	5140	WC field school	134764	6.242	-2.78	-8.40
7	5102	41.901	134764	6.428	-0.38	-8.24
8	5118	41.901	134764	6.994	-1.40	-7.09
9	5125	WC field school/41.901	134764	6.178	0.71	-7.29
10	5037	41.901	134764	6.45	0.01	-6.25
11	5055	WC field school	134764	6.499	0.11	-4.64
12	5013	41.901	134764	6.896	-1.69	-8.07
13	5145	WC field school	134764	6.075	-1.33	-7.00
14	5148	WC field school	134764	6.261	0.07	-4.49
15	5151	WC field school	134764	6.575	-1.46	-5.47
16	1198	WC 2012	134764	5.184	-2.13	-7.17
17	1276	WC 2012	134764	6.89	0.24	-6.67

Fig. 4 Results are presented in per-mill notation. Note that sample 15 was removed from further analysis due to possible contamination (Atudorei personal communication).



	Average		Range	
	$\delta^{13}C$	$\delta^{18}O$	$\delta^{13}C$	$\delta^{18}O$
Water Canyon	-1.20‰	-6.92‰	-5.83‰ – 0.71‰	-8.40‰ – -4.49‰
Boca Negra Wash	-1.89‰	-4.41‰	-8.38‰ – 1.12‰	-10.47‰ – -0.60‰

Fig. 5 Isotopic analysis results comparing bison from Water Canyon (blue) and Boca Negra Wash (orange)

Statistical Analysis

The statistics show that the $\delta^{13}C$ values for both sites are similar, while Water Canyon has more negative $\delta^{18}O$ values than Boca Negra Wash on average. The statistics also show that sample 5 from Water Canyon clusters with five samples from Boca Negra Wash. At Boca Negra Wash, only fragmentary enamel samples were analyzed due to preservation, so individual teeth could not be identified precisely. This same problem occurred at Water Canyon, with several samples too fragmentary to identify a specific tooth type. Gadbury et al. (2000), documented that the M1 teeth of ungulates had a "light" $\delta^{18}O$ compared to the M2 and M3 of the same animal, most likely due to the M1's utero enamel formation. I created Population A and B based on where they fell on the scatter plot and ran a Mann-Whitney *U*.

Carbon		Oxygen	
Mann-Whitney *U*	202	Mann-Whitney *U*	55.5
z	0.52455	z	4.0991
p	0.5999	p	< 0.01

Carbon	
Mann-Whitney *U*	0
z	3.4191
p	< 0.01

Fig. 6 Left: Mann-Whitney *U* results for Boca Negra Wash and Water Canyon, **Right:** Mann-Whitney *U* results for populations A and B from Boca Negra Wash (only)

C_3-browsers vs C_4-grazers according to Cerling et al. 2015

Water Canyon

- 53% C_4 grazers and 47% C_3/C_4 grazers

Boca Negra Wash

- 52% C_4 grazers and 48% C_3/C_4 grazers

Fig. 7 Left: Artistic depiction of Paleoindian bison hunting (Roy Andersen, displayed at Pecos National Historic Park), **Right:** results show whether the bison were C_4 or C_3/C_4 grazers based on Cerling et al. (2015)

Discussion

Carbon

H_0: the C_3 and C_4 grasses ratio remained stable between the Younger Dryas and the Early Holocene

~~H_1: The ratio of C_4 grasses to C_3 grasses was higher in the Early Holocene than in the Younger Dryas~~

Oxygen

~~H_0: $\delta^{18}O$ will remain stable between the Younger Dryas and the Early Holocene~~

H_1: $\delta^{18}O$ will differ between the Younger Dryas and the Early Holocene.

Conclusion

Carbon

- Statistically similar
- Water Canyon had 53% C_4-grazers and 47% mixed C_3/C_4 grazers
- Boca Negra Wash had 52% C_4-grazers and 48% mixed C_3/C_4-grazers
- **C_3 and C_4 grass habitat remained unchanged from the Younger Dryas into the early Holocene**

Oxygen

- Statistically different
- Water Canyon had "lighter" $\delta^{18}O$ compared to Boca Negra Wash
- **Bison had a different source of water during the Younger Dryas and Early Holocene**
- This may reflect a different hunting strategy between the two groups of Paleoindians (See: Judge 1973)

References

See references in linked paper

Acknowledgments

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