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Identifying Dietary and Migratory Patterns of Illinois *Mammuthus primigenius* Populations Using Stable Isotope Analysis of Carbon, Oxygen, and Strontium

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Abstract

The extinct woolly mammoth (*Mammuthus primigenius*) ranged from Alaska to the Northeastern Seaboard throughout the Late Pleistocene (100-10 Ka). Although it is recognized that woolly mammoths coincided with and lived in a region heavily influenced by glacial ice sheets, little is known about their behavior with respect to activities like migration and dietary preferences in this environment. This study classifies and provides insight into the diet and mobility of Midwestern mammoths by analyzing stable isotopes of carbon, oxygen, and strontium preserved in the tooth enamel of these extinct elephantids. A woolly mammoth tooth from Moline, IL, was bulk-sampled and micromilled to extract the aforementioned isotopes from the base of the enamel. Dated to 16,410 ±110 BP (20,085-19,530 calBP), measured $\delta^{13}C$ (-12.6‰ to -11.1‰, VPDB) values indicate that the terminal LGM (Last Glacial Maximum) landscape of western Illinois was dominated by C3 vegetation, which is typical of a cooler climate. This cooler climate during the LGM should also be reflected by low $\delta^{18}O$ values. However, resulting $\delta^{18}O$ values (-10.8‰ to -8.1‰, VPDB) are less negative than should be expected. The ratios of $^{87}Sr/^{86}Sr$ isotopes retained in the tooth enamel were mapped using GIS onto a regional isoscape to determine the mobility of one mammoth across its lifetime. The mobility patterns were compared to seasonal and annual dietary shifts to better understand any underlying causes for migrations. Preliminary analyses of the $^{87}Sr/^{86}Sr$ values (0.7907 – 0.7156) suggest that there were regional population movements around the northern Mississippi River Valley. The data reveals the climate and landscape during the terminal Pleistocene in western Illinois and how woolly mammoths responded to it.

Methods

Bulk Sampling

- 2mm Dremel bit was used to serially sample enamel perpendicular to the growth axis down the length of a plate at 6-7 mm intervals.
- Powderized enamel was chemically treated to remove impurities

Micromill Sampling

- Controlled by a Newark NSC-G 3-axis motion controller using GalilTools on a PC
- 0.5mm Dremel bit was used to sample enamel at depth increments of 100µm until the dentin was reached. The tooth was sampled perpendicularly to the growth axis at 1mm intervals

Isotope Analysis

- $\delta^{13}C$ and $\delta^{18}O$ values were acquired at the Iowa State University Stable Isotope Lab on a ThermoFinnigan MAT Delta Plus XL mass spectrometer in continuous flow mode connected to a Gas Bench with a CombiPAL autosampler
- $^{87}Sr/^{86}Sr$ values were acquired at the University of Kansas Isotope Geochemistry Laboratory measured on a Thermal Ionization Mass Spectrometer (TIMS), an automated VG sector, and a 6-collector system with a 10-sample turret

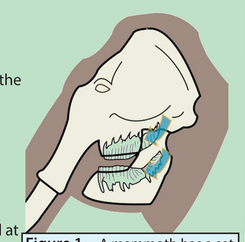

Figure 1. A mammoth has a set of six teeth in each quadrant of its mouth. Each successive tooth erupts horizontally after the former has worn away completely.

Figure 2. Specimen V-405; unerupted *M. primigenius* tooth from Moline, IL. Bulk sample location and scheme shown with vertical line and dashes; micromill location shown with ellipse

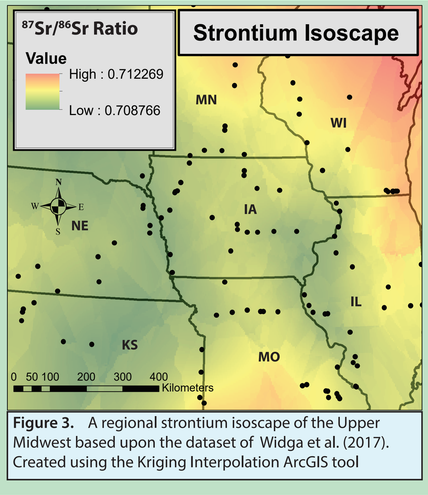

Figure 3. A regional strontium isoscape of the Upper Midwest based upon the dataset of Widga et al. (2017). Created using the Kriging Interpolation ArcGIS tool

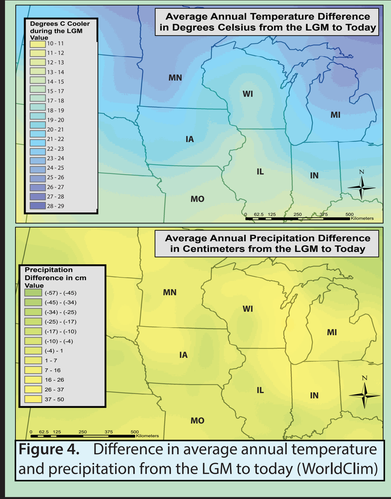

Figure 4. Difference in average annual temperature and precipitation from the LGM to today (WorldClim)

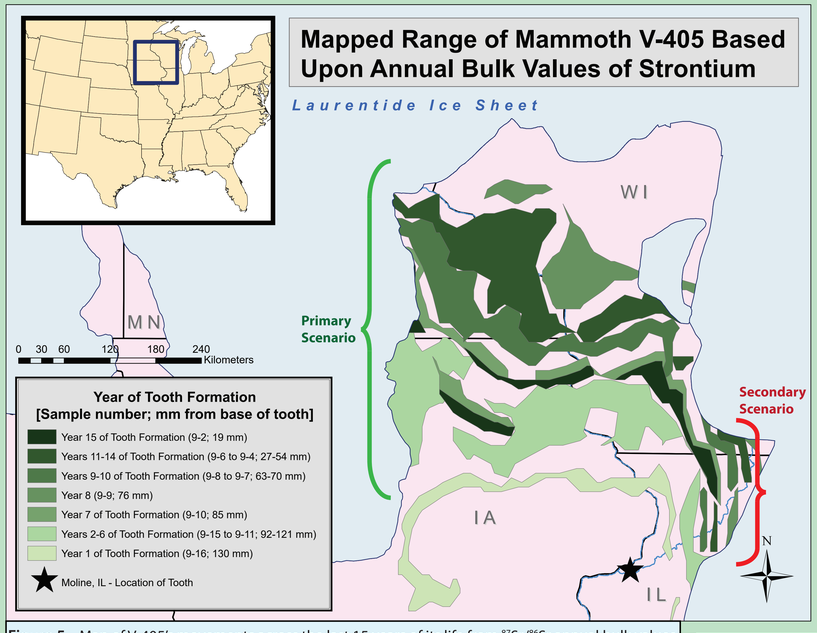

Figure 5. Map of V-405's movements across the last 15 years of its life from $^{87}Sr/^{86}Sr$ annual bulk values

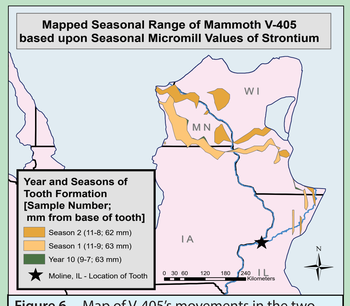

Figure 6. Map of V-405's movements in the two seasons following year 10 of the tooth's formation. Note season 1 overlays year 10.

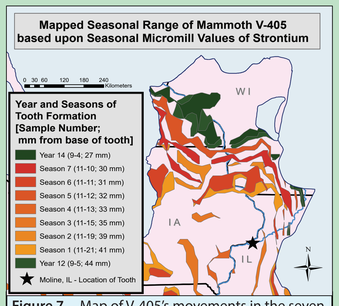

Figure 7. Map of V-405's movements in the seven seasons in between years 12 and 14 of the tooth's formation.

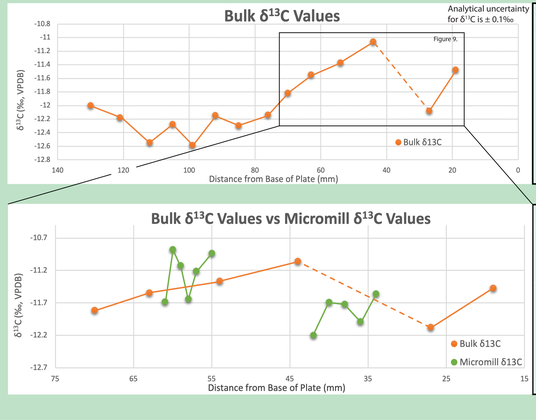

Figure 8. Annual bulk values of $\delta^{13}C$ across the growth axis of the tooth. The values indicate a strong C3 diet. The dashed line refers to a two-year gap in the absence of a bulk sample at 36 mm.

Figure 9. Seasonal micromill $\delta^{13}C$ values graphed alongside annual bulk values. The values show seasonal fluctuations and an averaging out of the annual bulk values

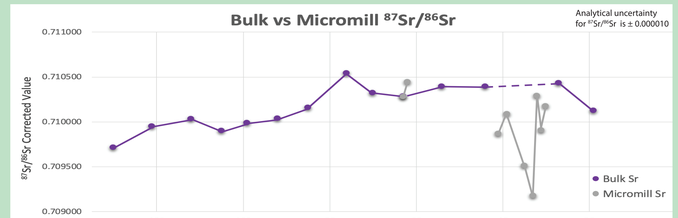

Figure 10. Graph of both annual bulk and seasonal micromill $^{87}Sr/^{86}Sr$ values across the growth axis of the tooth

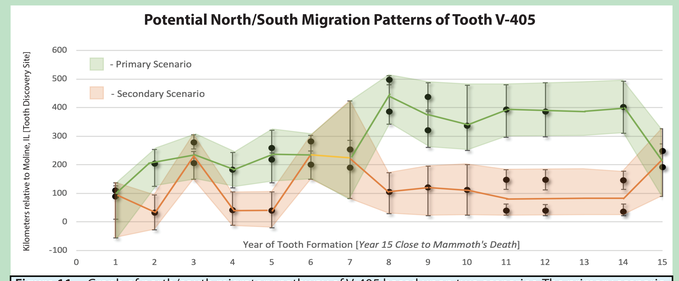

Figure 11. Graph of north/south migratory pathway of V-405 based upon two scenarios. The primary scenario assumes V-405 lived in the northern pocket between the two ice lobes. The secondary and more unlikely scenario assumes V-405 lived close to the ice sheets in the small south-eastern slivers of Figure 5.

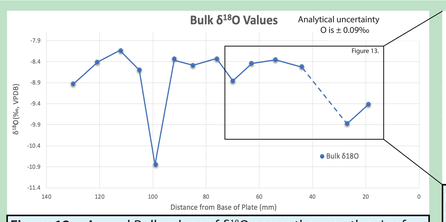

Figure 12. Annual Bulk values of $\delta^{18}O$ across the growth axis of the tooth. Values are less negative than expected.

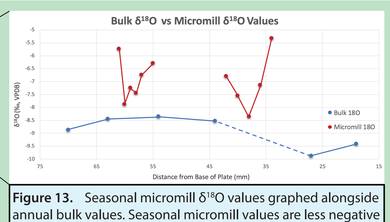

Figure 13. Seasonal micromill $\delta^{18}O$ values graphed alongside annual bulk values. Seasonal micromill values are less negative than expected and fail to average out annual bulk values

Conclusions

- V-405 most likely engaged in nomadic movements and not annual migrations
- V-405 ate a primarily C3 diet
- V-405 most likely lived north of Moline, IL between the glacial ice lobes
- V-405 seasonal micromill $^{87}Sr/^{86}Sr$ values give insight into seasonal movements within an annual bulk average
- V-405 seasonal micromill $\delta^{13}C$ values reflect seasonal variations and approximate the averages of the annual bulk $\delta^{13}C$ values
- Why are $\delta^{18}O$ values less negative than expected values?
- Seasonal micromill $\delta^{18}O$ values did not reflect expected values or the annual bulk $\delta^{18}O$ values. Was the Laurentide ice sheet not as depleted as modern glaciers? Or does enamel microstructure not reflect deeply negative values?

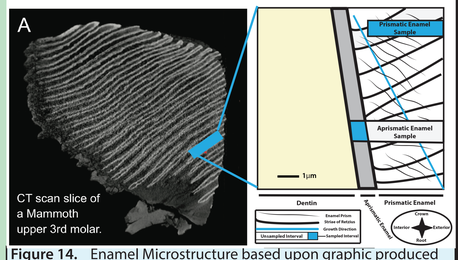

Figure 14. Enamel Microstructure based upon graphic produced by Don Esker (Widga et al. 2017) (Esker, 2018)

Acknowledgements

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