Ancient Middle Stone Age climates at SM-1 in NW Ethiopia as revealed by stable isotopic scelerochronology

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2017 Annual Meeting
Paleoanthropology Society
Vancouver

Abstract

The Shinfa River, a tributary of the Blue Nile located in NW Ethiopia, is the site of an archaeological and paleoecological research project investigating Middle Stone Age human adaptations. The river system is home to many riverine mollusk species. Today, the region is subject to brief but intense summer rains and an extended dry season. This extreme seasonality produces fluctuations in the river's water level, ranging from bank-full flows in the wet season to no flow during the dry season with isolated waterholes subjected to high evaporative rates. Because water level and temperature are guiding factors in mollusk shell formation, we hypothesize that evidence of wet and dry seasons is recorded in the $\delta^{18}O$ levels of mollusk shells. Mollusk shells can provide a useful tool for reconstructing ancient climates because the shells grow in layers. The SM-1 MSA site, located along the Shinfa River, has yielded many fragments of ancient mollusk shells. We present isotope records of both $\delta^{18}O$ and $\delta^{13}C$ extracted from modern and ancient Shinfa mollusks. By sampling the layers incrementally, we can observe how temperature and water level fluctuated over time. The $\delta^{18}O$ of the modern mollusk ranges from 7.2 to -1.7 ‰ vs. VSMOW. The very large range between the wet and dry seasons illustrates the extreme seasonality found in this region, and the pattern of fluctuations is cyclical. The SM-1 MSA mollusk shells date from 30->80,000 ka, and perhaps older, and serial-sampled $\delta^{18}O$ values range from 4.7 to –1.1 ‰ vs. VSMOW. This smaller range indicates that at least some of the ancient SM-1 timeframe presented seasonality conditions somewhat less extreme than seen today, which potentially provided a more hospitable landscape for the people living in the region at the time.

Introduction

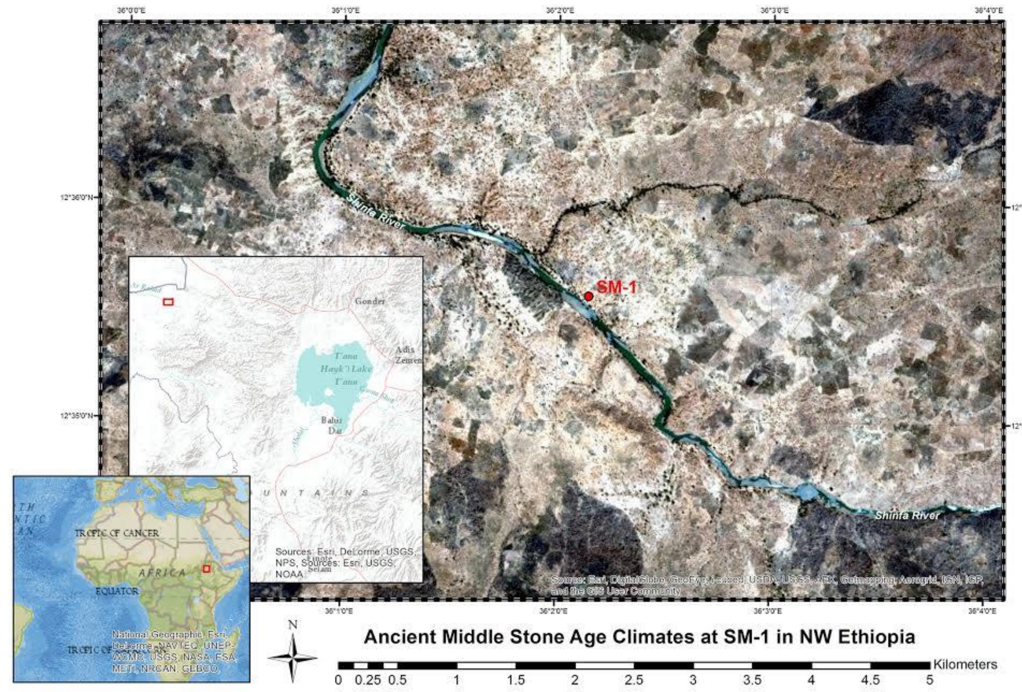


Figure 1: Map of Shinfa River and SM-1 site location.

Figure 2

Figure 3

Figures 2, 3: Photographs of the Shinfa River taken from approximately the same location in a down-stream view during the wet and dry seasons in 2007. The river is bank full during the wet season. The yellow circle shows the crown of the same large tree.

Shinfa River Water Samples

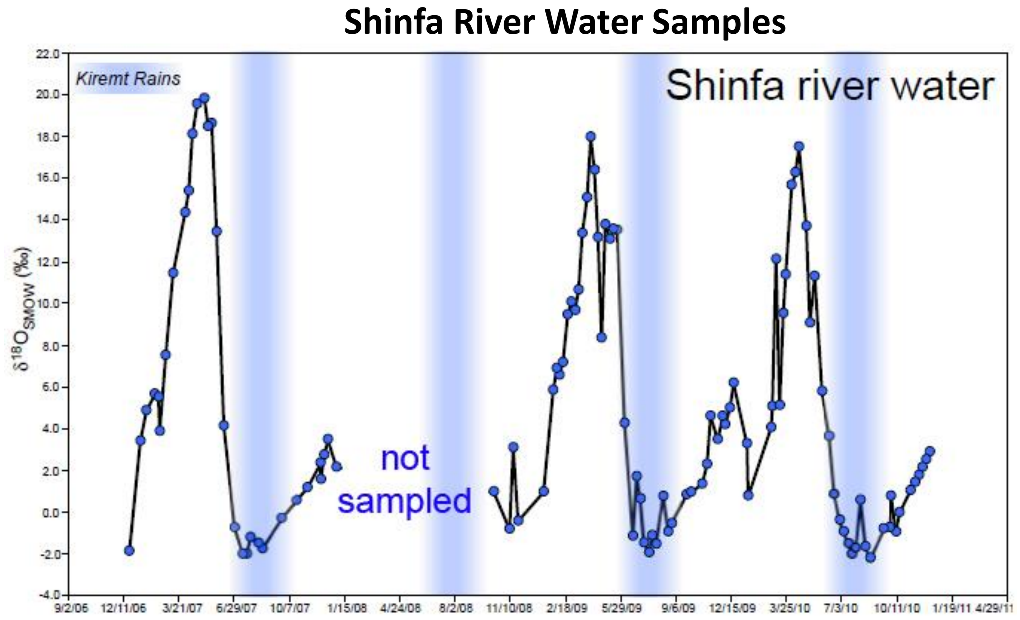


Figure 4: Water $\delta^{18}O$ values of Shinfa. The cyclicity of the $\delta^{18}O$ levels corresponds directly with observed wet and dry seasons of the area, with the increase in $\delta^{18}O$ values driven by evaporation during the dry season, and the decrease in values initiated with the Kiremt rains. We hypothesize that the $\delta^{18}O$ levels in modern mollusks will reflect this same pattern.

Figure 5: Thin section of an ancient shell, sample SM1 W14-16-390.

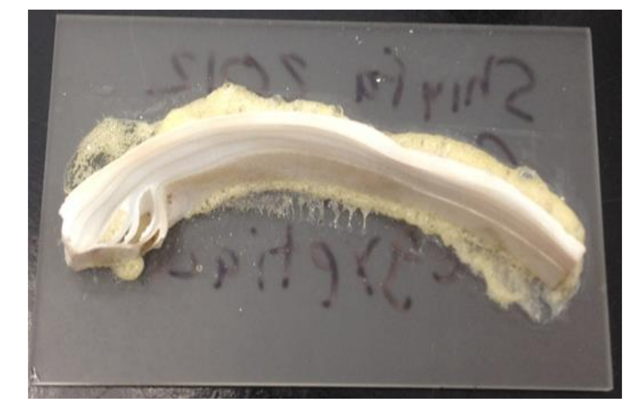


Figure 6: Thin section of a modern *Coelatura aegyptiaca* shell, collected from the Shinfa River in 2012.

Methodology

Mineralogy/Diagenesis

- X-Ray diffraction on a Rigaku Ultima III was used to identify mineral composition of each shell, testing for diagenesis from original aragonite to calcite.

Sampling/Isotope Analysis

- Shells were drilled manually by growth increment.
- Each growth layer sample was reacted under vacuum with 1 mL of pure orthophosphoric acid. Samples reacted for 24 hours at 25˚C.
- CO_2 resulting from the reaction was extracted off-line, and carbon and oxygen isotope ratios were measured on a Finnigan-MAT 252 or 253 isotope ratio mass spectrometer.

Modern River Water Collection

- Water was collected on a weekly basis by a Shinfa local, who also took a photo of the river during each collection

Results

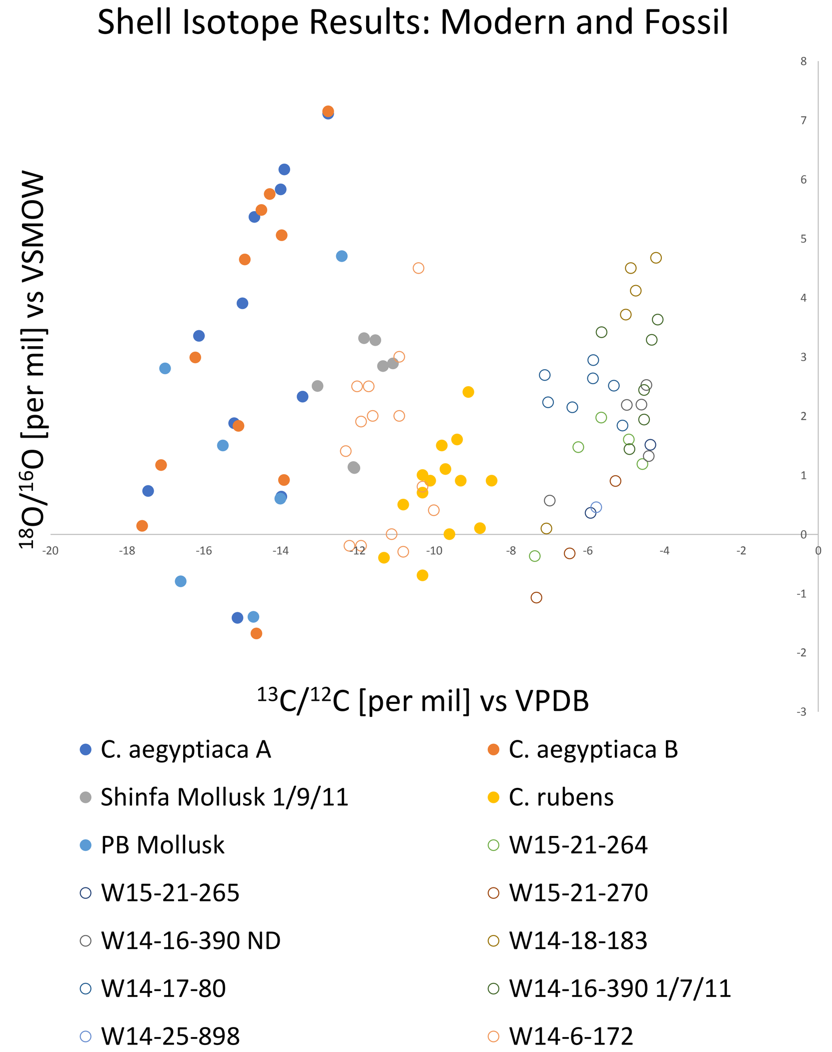


Figure 7: Carbon and oxygen isotope levels of all sampled aragonite shells

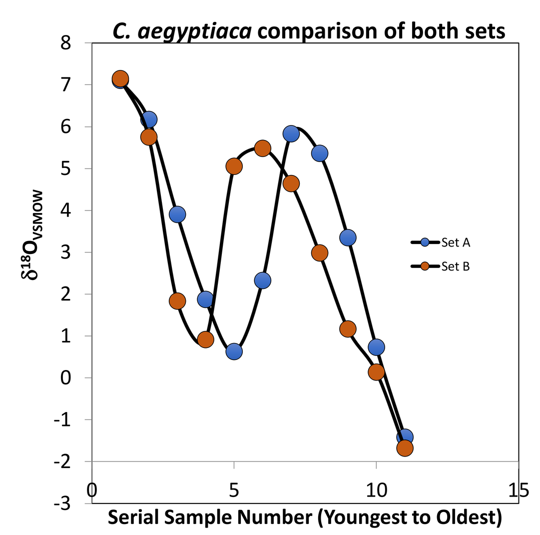


Figure 8: $\delta^{18}O$ of one modern shell that was sampled twice laterally, confirming that sampling methods are accurate and replicable

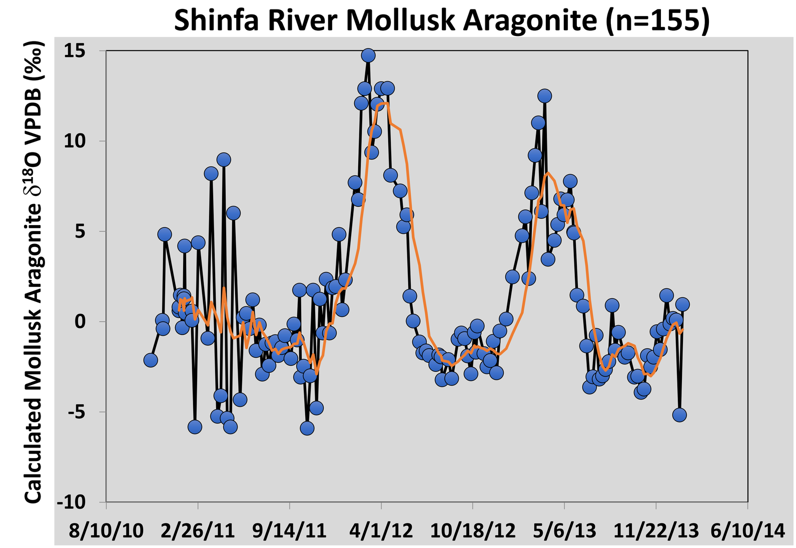


Figure 9: Predicted modern aragonite mollusk $\delta^{18}O$ values calculated from $\delta^{18}O$ and temperature of modern Shinfa River water. Accurately reflected in sampled modern shells.

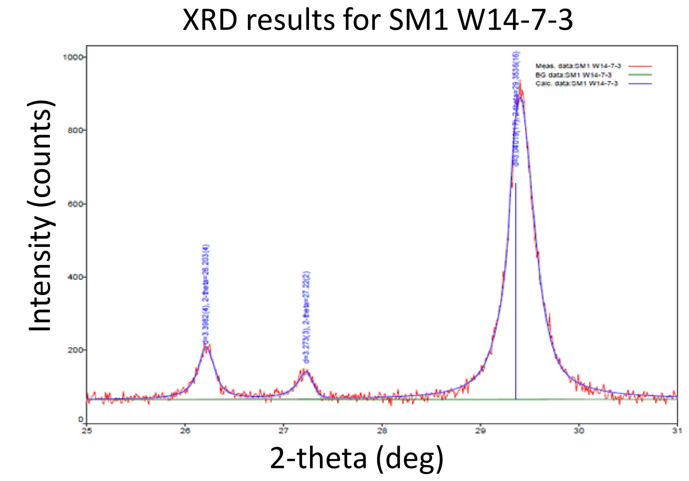


Figure 10: XRD results for an ancient shell that displays extreme diagenesis, as indicated by the high calcite peak at 29.3536.

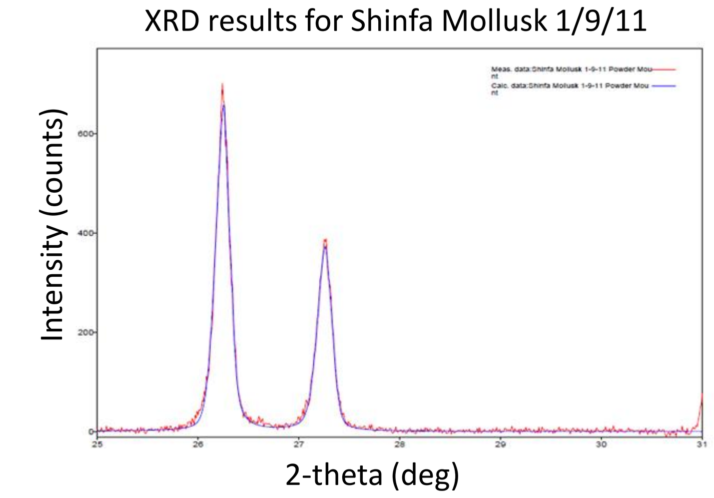


Figure 11: XRD results of a modern shell indicating that the make up is pure aragonite

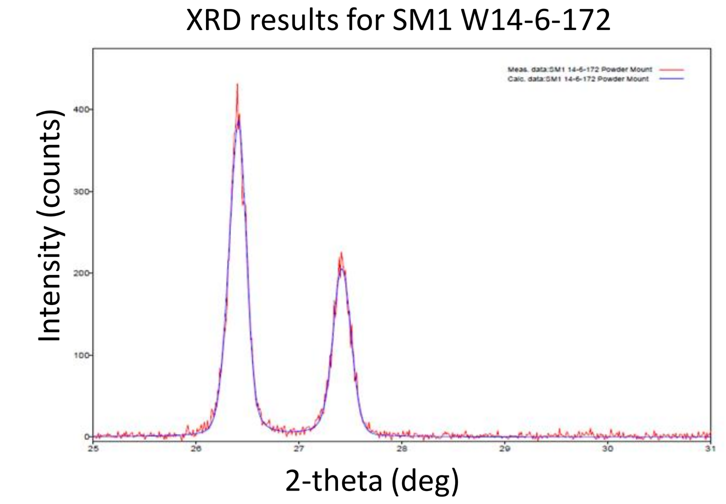


Figure 12: XRD results of an ancient shell whose make up is pure aragonite, making it an ideal fossil shell to analyze (see Fig. 15, results)

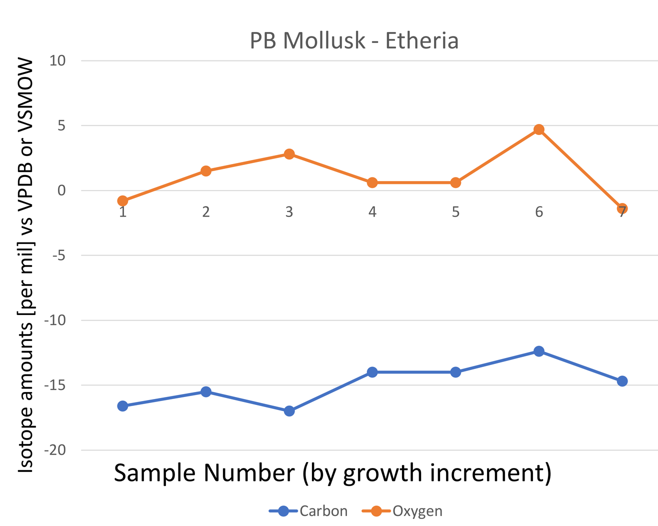


Figure 13: Modern shell results for both carbon and oxygen

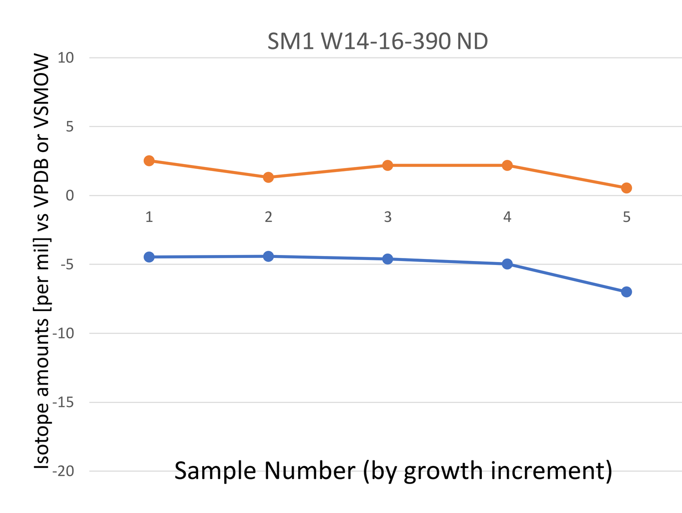
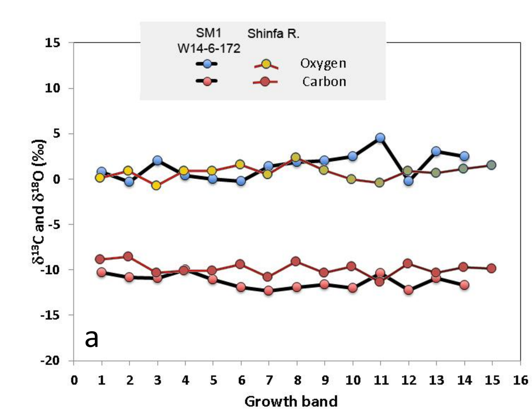


Figure 14: Ancient shell results for both carbon and oxygen



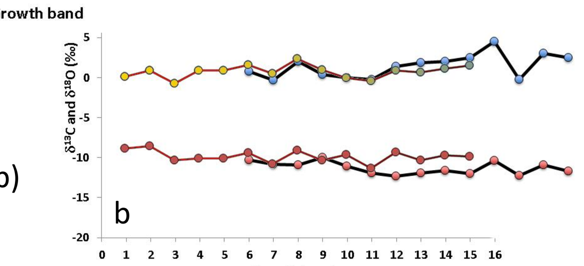


Figure 15: (a) Ancient shell compared with modern, with (b) values reset to visual best-fit

Discussion and Conclusion

Modern mollusks from the Shinfa River display a consistent cyclical pattern of $\delta^{18}O$ values in their shell layers, with a moderate range between minimum and maximum values. This pattern appears to reflect seasonal variation in available $\delta^{18}O$ in the river water, a consequence of extreme seasonal rainfall in the region that produces a strong evaporative cycle as flows cease and the river is reduced to a series of ever-smaller pools. Modern taxa demonstrate a range of values that are likely species-specific and reflect differences in their metabolism, and we intend to test this issue in future studies. Fossil taxa display a similar cyclical pattern. In order to test for differences or similarities between the modern and ancient climates, the comparison must be between identical taxa. On balance, it appears that the ancient climate was within the range of the modern climate and likely experienced marked seasonality. If there was an extreme dry season, MSA humans would have had better access to aquatic food sources when the river was reduced to a series of disconnected small pools.

Acknowledgements

Thanks to the Ethiopian ARCCH for permission to conduct this research; and for funding support from NSF REU Grant 1460986, Rutgers Aresty Research Center for Undergraduates, and the Bigel Endowment Award for Undergraduate Research in Anthropology for funding this research. Additional thanks to Craig Feibel, Timothy Scott Myers, Leslie Reeder-Myers, and Lauren Michel for help in the labs and advising, and our friends who live near SM-1 for assisting with field logistics and water collection.

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