
Plant wax biomarkers reveal climatic and ecological context of high-altitude adaptations across the MSA-to-LSA transition in Lesotho, southern Africa

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Résumé

Archaeological and paleoecological studies seeking to determine human adaptations to high-altitude environments through the Late Quaternary often face a lack of proxy evidence obtained from archaeological sites. Plant wax biomarkers are an innovative proxy for reconstructing vegetation composition and structure, rainfall intensity, temperature, and other climatic and environmental dynamics directly associated with records of past human behaviour. Normal (*n*-) alkanes for example, serve as proxy measures for the continental vegetation that synthesized them, while the isotopic signature of environmental carbon ($\delta^{13}\text{C}$) and hydrogen (δD) incorporated during plant biosynthesis represent changes in water availability, vegetation communities, precipitation or aridity, evapotranspiration of leaf and soil moisture, and the relative abundance of C3 and C4 plants in response to climate changes. Compound specific measurements on *n*-alkanes also have the potential to circumvent the ambiguity inherent in bulk sediment isotope analysis.

The Ha Makotoko archaeological site of the Caledon River Valley, located at 1600 m a.s.l., in western Lesotho, offers an opportunity to investigate ecological change and high-altitude human adaptations, and the impact temperature shifts would have had on floral and faunal resources used by humans from the Late Pleistocene into the Holocene, from 56,000 years ago to present. In Lesotho, a well-defined altitudinal distribution of C3 and C4 plant taxa, and their plant wax biomarkers in archaeological sediments, provide a means of estimating past temperature shifts and the ensuing ecological reorganization: i.e., the dominance of

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C3 or C4 plants at specific altitudes. Here, we present a high-resolution isotopic analysis of molecular $\delta^{13}\text{C}$ and δD of *n*-alkanes from the site's sedimentary sequence to reveal ecological changes that coincided with the transition from the MSA (Post-Howiesons Poort) to the LSA (Oakhurst). Our isotope data show environmental fluctuations throughout the sequence, likely attributed to temperature changes and water availability, and the human response to these changes at high-altitude.

Mots-Clés: Plant wax biomarkers, reveal climatic, ecological context, high, altitude, adaptations, MSA, to, LSA transition, Lesotho, southern Africa