

Introduction

Animal husbandry first developed in the Fertile Crescent during the Pre-Pottery Neolithic B (10th to 9th millennia BCE)^{1,2}. Despite this proximity, widespread evidence for Neolithic lifeways appears in the Southern Caucasus only by the early 6th millennium BCE, likely introduced by migrating agropastoral groups. Examining how these communities adapted to new environmental conditions is key to understanding the ecological flexibility of Neolithic people. This study analyzes sequential stable carbon ($\delta^{13}\text{C}$) and oxygen ($\delta^{18}\text{O}$) isotope values from sheep (*Ovis aries*) enamel from Shulaveris Gora, a Late Neolithic settlement in southern Georgia (ca. 5985–5685 cal BCE), to reconstruct herd management practices. Building on previous isotope work at nearby Gadachrili Gora³, which indicated year-round lowland pasturing with limited seasonal movement, we investigate whether similar herding strategies were practiced at Shulaveris Gora and what these results reveal about the adaptive capacity and resilience of early farming communities in the Southern Caucasus.

Location



Fig 1. Map of the Southern Caucasus showing Late Neolithic and Early Chalcolithic sites. The inset (top left) situates the study area within the broader regional context, with the white dashed line indicating the extent of the larger map.

Methods

Stable oxygen and carbon isotope values in herbivore enamel reflect the composition of ingested water and the plants consumed, respectively. Four sheep lower third molars (M3) from Shulaveris Gora were selected for sequential enamel sampling following established dental identification criteria. Between 12 and 16 samples were drilled perpendicular to the growth axis using a 1 mm burr at approximately 2 mm spacing. Analyses were conducted at the Ján Veizer Stable Isotope Laboratory, University of Ottawa. Spearman's rank correlation was used to assess relationships between $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values within individual sequences. To compare enamel $\delta^{18}\text{O}$ values with modern meteoric water, data were converted to $\delta^{18}\text{O}_{\text{drinkingwater}}$ (V-SMOW) using three published equations^{4,5,6}.

Results

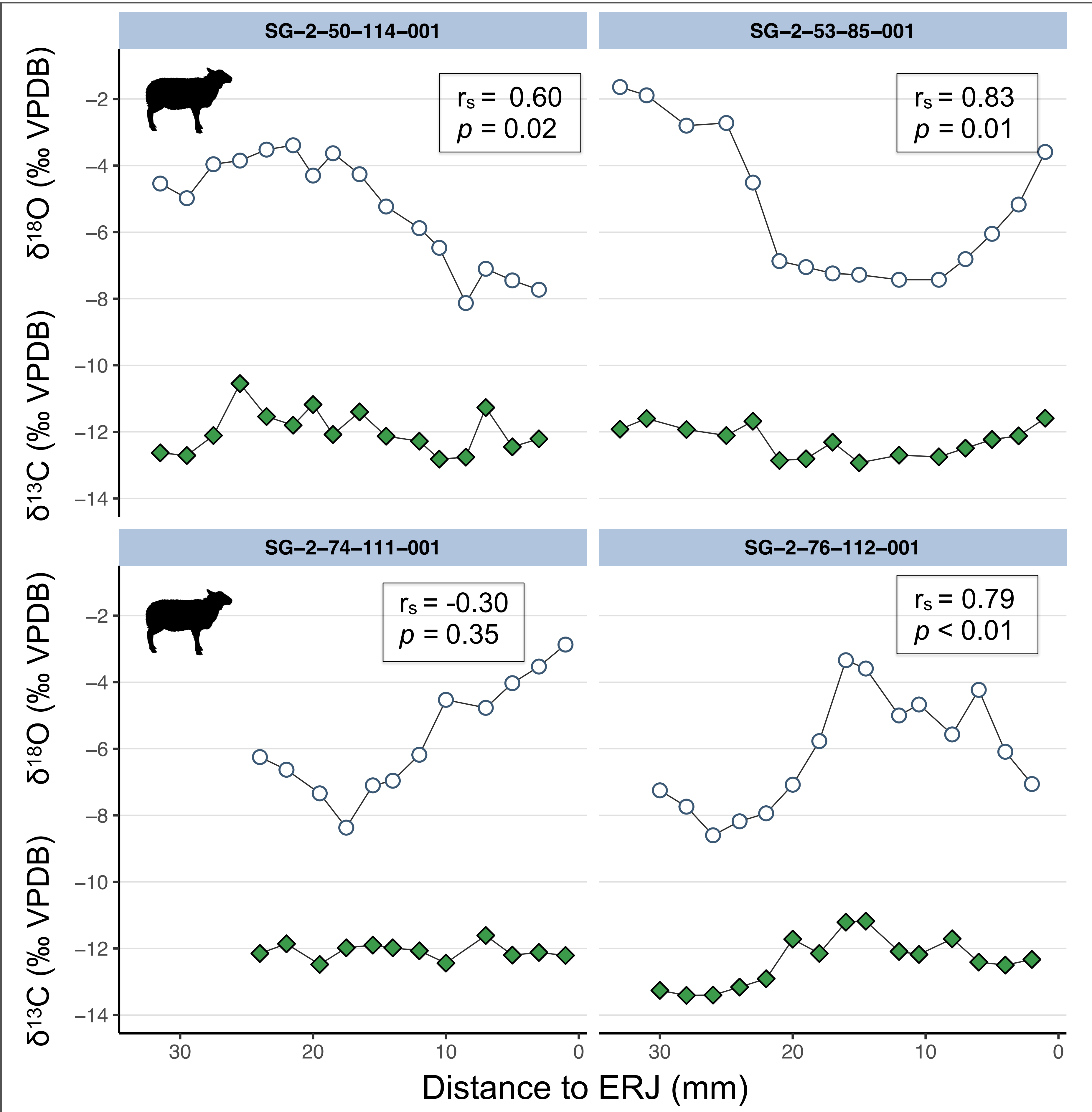


Fig 2. Serial stable isotope profiles of sheep M3s from Shulaveris Gora. Y-axes show variation in oxygen (white circles) and carbon (green diamonds) isotope values; the X-axis shows sample position along the tooth growth axis (distance to enamel root junction). Spearman's rank correlation coefficients (r_s) and associated p -values are shown for each individual. Majority of sequences show positive correlations, suggesting year-round residence of animals in lowland areas near the site.

Table 1. Descriptive statistics for individual sheep. SD indicates standard deviation from the mean. Amp. indicates the amplitude of variation in $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values.

Specimen	$\delta^{13}\text{C}_{\text{enamel}}$ (‰ VPDB)					$\delta^{18}\text{O}_{\text{enamel}}$ (‰ VPDB)				
	Mean	SD	Max	Min	Amp.	Mean	SD	Max	Min	Amp.
SG-2-50-114-001	-12.0	0.7	-10.6	-12.8	2.3	-5.3	1.6	-3.4	-8.1	4.7
SG-2-53-85-001	-12.3	0.5	-11.6	-12.9	1.3	-5.2	2.2	-1.6	-7.4	5.8
SG-2-74-111-001	-12.1	0.2	-11.6	-12.5	0.9	-5.7	1.7	-2.9	-8.4	5.5
SG-2-76-112-001	-12.4	0.7	-11.2	-13.4	2.2	-6.1	1.7	-3.3	-8.6	5.3

Results

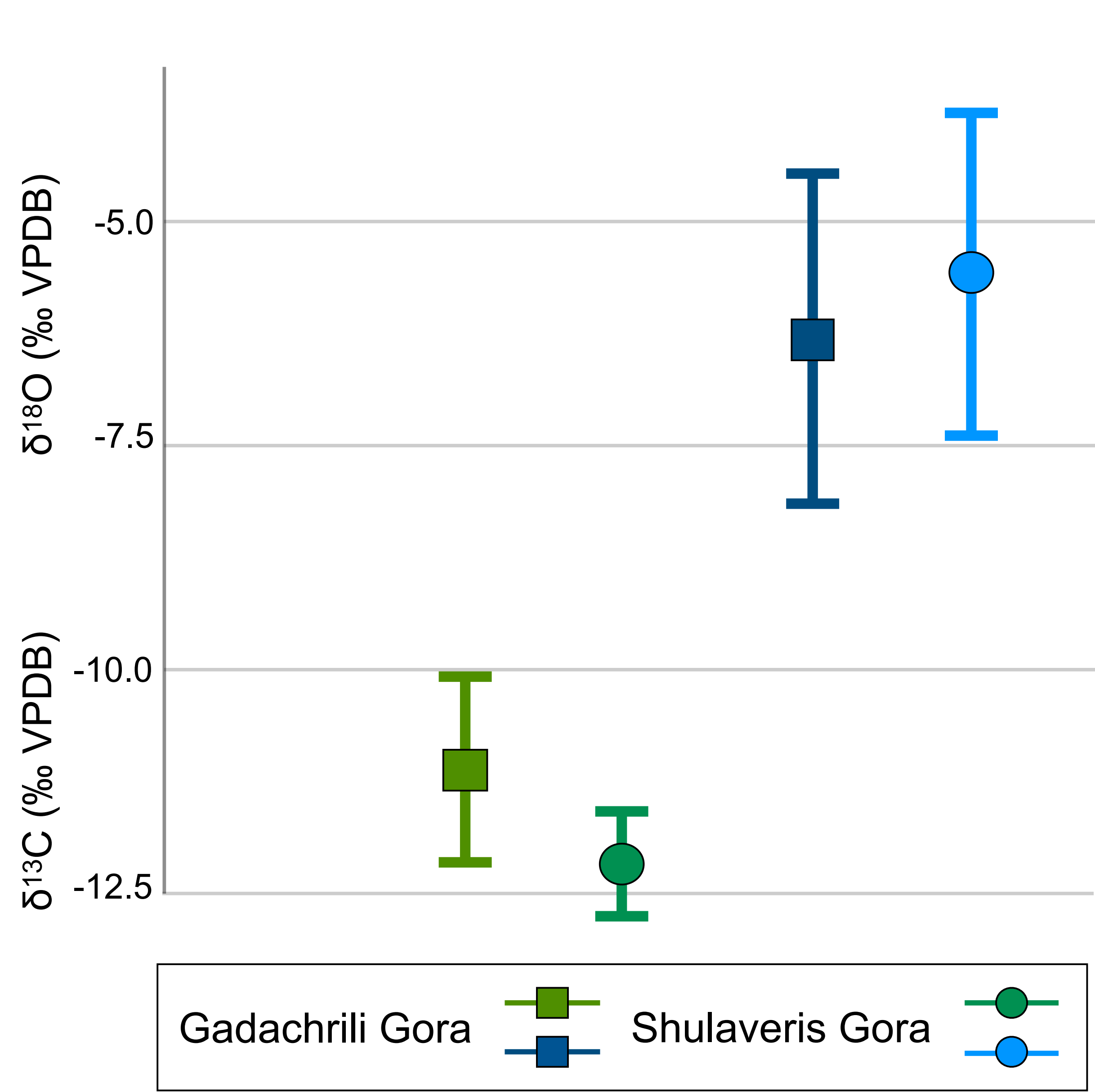


Fig 3. Mean tooth enamel $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ values (± 1 SD) for sheep from Shulaveris Gora (ca. 5985–5685 cal BCE) and neighbouring Gadachrili Gora³ (ca. 5986–5048 cal BCE). Overlapping $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values suggest similar drinking water sources, plant types consumed, and environmental conditions at both sites.

Discussion & Continuing Research

- Sequential $\delta^{18}\text{O}$ and $\delta^{13}\text{C}$ data indicate sheep grazed in a consistently humid, mixed C_3 landscape with both open and lightly canopied zones
- Positive correlations in most specimens suggest year-round residence in lowland areas near the site
- Sinusoidal $\delta^{18}\text{O}$ patterns with a mean amplitude of $\sim 5.3\text{‰}$ reflect moderate seasonal variation in temperature and evapotranspiration
- The mean $\delta^{18}\text{O}_{\text{drinkingwater}}$ value (-7.5‰) and modest intra-individual variation (3.6‰) are comparable to river water from the Kura system, suggesting consumption of plants grown in stable, well-watered soils
- Overlapping $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ values between Shulaveris Gora and Gadachrili Gora³ sheep indicate similar environmental conditions and herd management strategies
- Future research will include additional domestic and wild fauna from Shulaveris Gora and Gadachrili Gora to refine reconstructions of Neolithic animal management and environmental adaptation in the Southern Caucasus

References

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