Coupling $\delta^{18}O$ values of rodent tooth and mollusc shell carbonates: a new approach to reconstructing Pleistocene palaeotemperatures?

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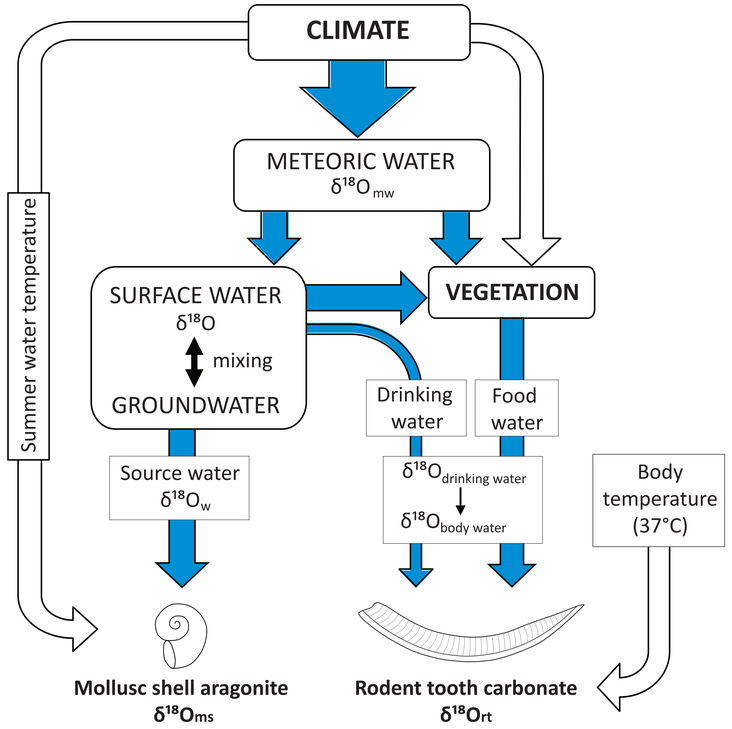
1 Introduction

- $\delta^{18}O$ of terrestrial carbonates provides valuable evidence of climate change
- Deriving quantitative temperature estimates is often problematic
- $\delta^{18}O$ of carbonate ($\delta^{18}O_c$) reflects:
  1) $\delta^{18}O$ of the meteoric water source ($\delta^{18}O_{mw}$)
  2) Temperature at mineralization (T)
- Unless $\delta^{18}O_{mw}$ can be reconstructed, temperature cannot be calculated
- **Coupling $\delta^{18}O$ values of rodent teeth and mollusc shell carbonates can potentially address this problem**
- **Approach has not yet been applied to reconstructing Pleistocene temperatures[1]**

2 Rationale

- $\delta^{18}O$ of mollusc shell = $\delta^{18}O$ of water and environmental temperature
- $\delta^{18}O$ of rodent tooth = $\delta^{18}O$ of water and constant body temperature

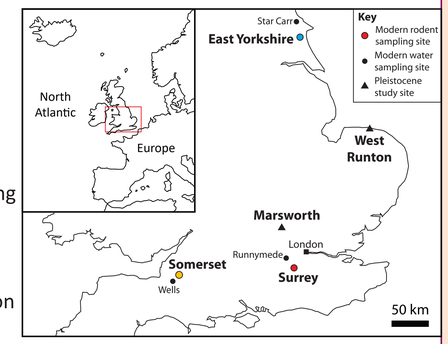


- $\delta^{18}O$ of rodent teeth can be used to infer $\delta^{18}O$ of meteoric water
- $\delta^{18}O$ of meteoric water can be combined with $\delta^{18}O$ of shell aragonite to calculate mean summer temperature
- Quantification and validation of the relationship between $\delta^{18}O$ of rodent teeth and $\delta^{18}O$ of meteoric water is required[2–4]

3 Methods & Study sites

Modern $\delta^{18}O_{rt}$ - $\delta^{18}O_{mw}$ relationship

- 3 UK study sites:
  1) Somerset, **2)** Surrey, **3)** Yorkshire
- 104 vole (*Microtus agrestis*) teeth analysed
- $\delta^{18}O$ of water obtained from new isotope analyses (Somerset) and existing published datasets (Surrey[5]; East Yorkshire[6])
- Average $\delta^{18}O_{rt}$ and $\delta^{18}O_{mw}$ used to generate modern fractionation equation

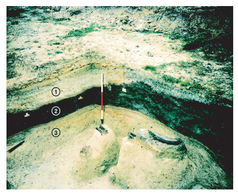


Pleistocene reconstructions

- Fossil vole teeth and shells analysed from 2 Middle Pleistocene interglacial sites:
  1) West Runton, Norfolk **2)** Marsworth, Buckinghamshire
- $\delta^{18}O$ of meteoric water calculated using modern $\delta^{18}O_{rt}$ - $\delta^{18}O_{mw}$ relationship
- $\delta^{18}O_{mw}$ combined with $\delta^{18}O$ of shells to estimate mean summer palaeotemperature[7]:

$$T\ (°C) = 21.36 - 4.83(\delta^{18}O_{aragonite} - \delta^{18}O_{water})$$

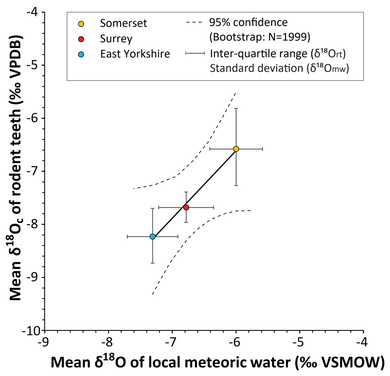
Section at West Runton
(Photo courtesy of Professor Jim Rose)



Section at Marsworth[10]

Top right: Mimomys savini *tooth*
Bottom right: Valvata picinalis *shell*

4 Modern fractionation relationship



- **Strong linear correlation between median $\delta^{18}O_{rt}$ and mean $\delta^{18}O_{mw}$**
- Slope of calibration line (1.31) is similar to published fractionation equations for the $\delta^{18}O$ of rodent tooth phosphate (1.14)[2,4]
- **Robust modern relationship enables past $\delta^{18}O_{mw}$ to be calculated**

$$\delta^{18}O_{rt} = 1.27(\pm0.10)\delta^{18}O_{mw} + 1.02(\pm0.67)$$
$$R^2 = 0.99$$

5 Pleistocene temperature reconstructions

West Runton

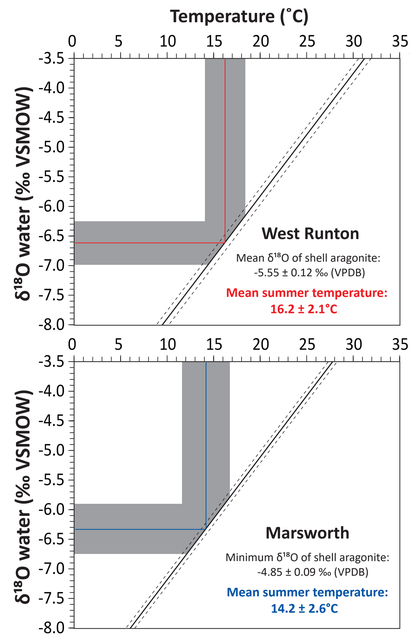
- Mean $\delta^{18}O$ of water vole (*Mimomys savini*) teeth (n=12) coupled with mean $\delta^{18}O$ of *Valvata piscinalis* shells (n=139)[8]
- Mean calculated temperature = **16.2 ± 2.1°C**
- Calculated temperature consistent with beetle-based mean summer temperature estimates for the site[9]:

MCR TMAX = **16-18°C**

Marsworth

- Analysed *Galba truncatula* shells indicate evaporation of meteoric water source: $\delta^{18}O$ and $\delta^{13}C$ values positively correlated (R^2=0.57)
- Mean $\delta^{18}O$ of vole (*Microtus* sp.) teeth (n=20) coupled with minimum $\delta^{18}O$ of shell
- Mean calculated temperature = **14.2 ± 2.6°C**
- Calculated temperature consistent, within uncertainties, with beetle-based summer temperature estimates[10]:

MCR TMAX = **15-17°C**



Reconstructed temperatures are statistically equivalent to published palaeotemperature estimates

6 Conclusions & Further work

- Strong linear relationship exists between the average $\delta^{18}O$ of rodent tooth carbonate and average $\delta^{18}O$ of local meteoric water
- Coupling the $\delta^{18}O$ values of rodent teeth and mollusc shells generates accurate mean summer palaeotemperature estimates
- This approach can potentially be applied to other Quaternary sites across Europe
- Analyses are being undertaken on additional modern rodent teeth from the UK to improve the robustness of the modern fractionation equation

Acknowledgements
This research was funded by the Natural Environment Research Council (UK).

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