Linking oxygen stable isotopes with archaeological results

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Stable isotopes: Applications in the archaeological context

- Climatic and environmental conditions
- Human habits and behaviour
  - Food resources
  - Animal domestication
  - Migration…
- Isotope ratios traditionally used:

  $^{15}N/^{14}N$, $^{13}C/^{12}C$, $^{18}O/^{16}O$, $^{2}H/^{1}H$

Oxygen isotopes

- Average natural abundance:

  ^{16}O: 99.76%

  ^{17}O: 0.04%

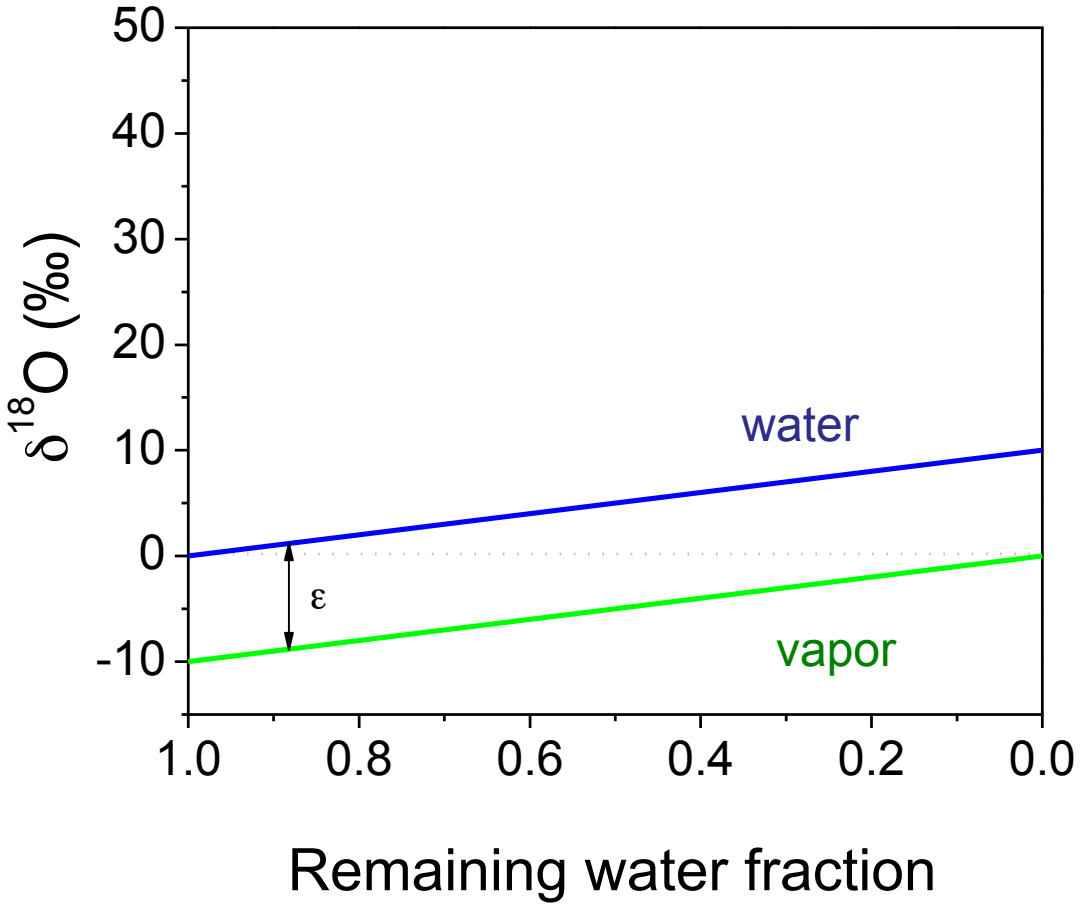
  ^{18}O: 0.20%

- $^{18}O/^{16}O$ is analysed versus a standard (VSMOW) and given in per mil:

$$\delta^{18}O = [(^{18}O/^{16}O)_{sample} / (^{18}O/^{16}O)_{standard} - 1] * 1000$$

Isotope fractionation (ε)

e.g. evaporating water in a closed system



ε depends on temperature

➔ use of $\delta^{18}O$ as palaeothermometer

$\delta^{18}O$ in the hydrological cycle

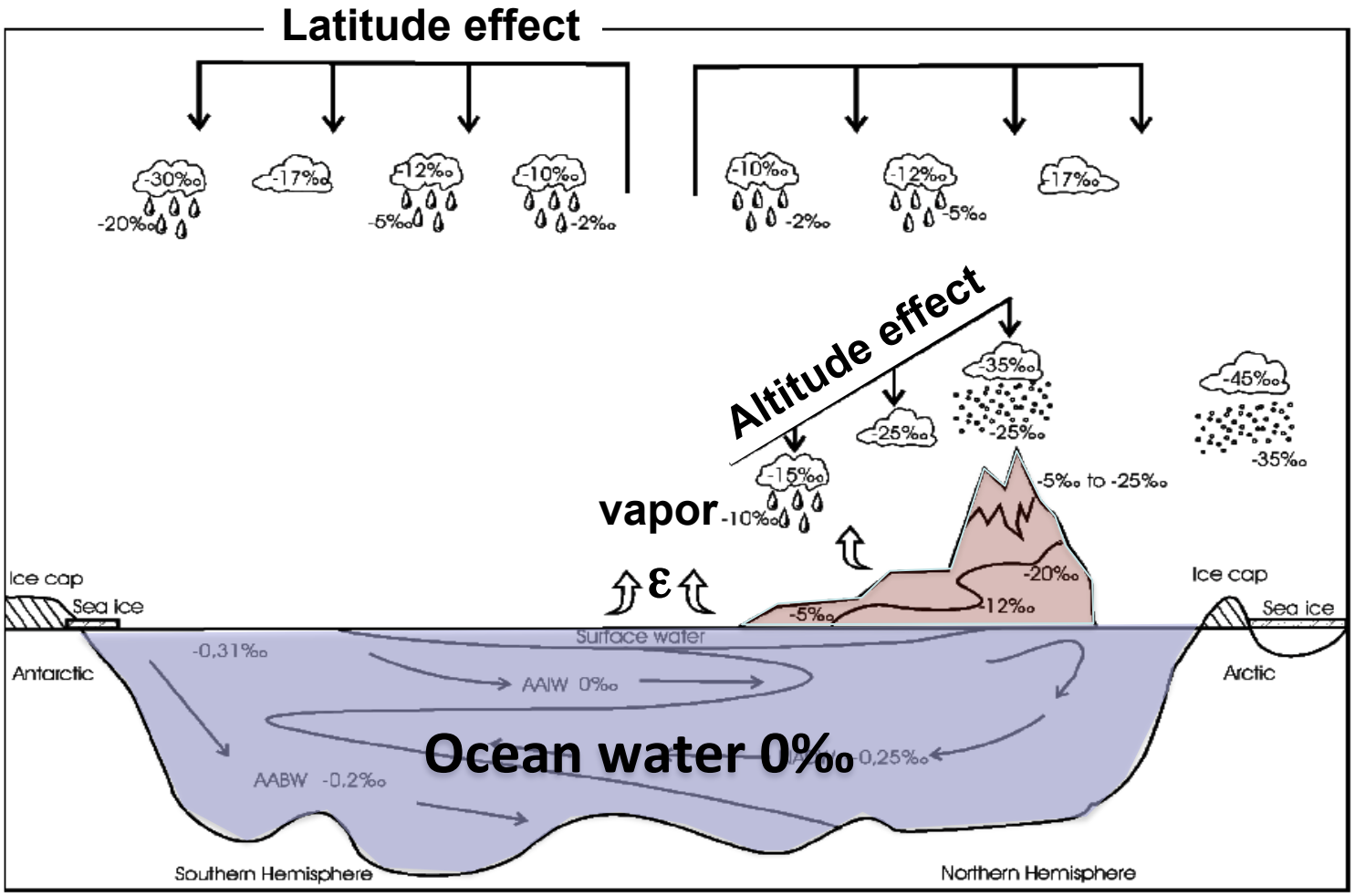


Fig. 1. Sketch of the global $\delta^{18}O$ cycle. In our simulations, only the oceanic part has been considered so far.

Modified from Paul et al., 1999

From archive to reconstruction

Archives

soils, sediments, wood, bones...

Isolation of oxygen-containing compound

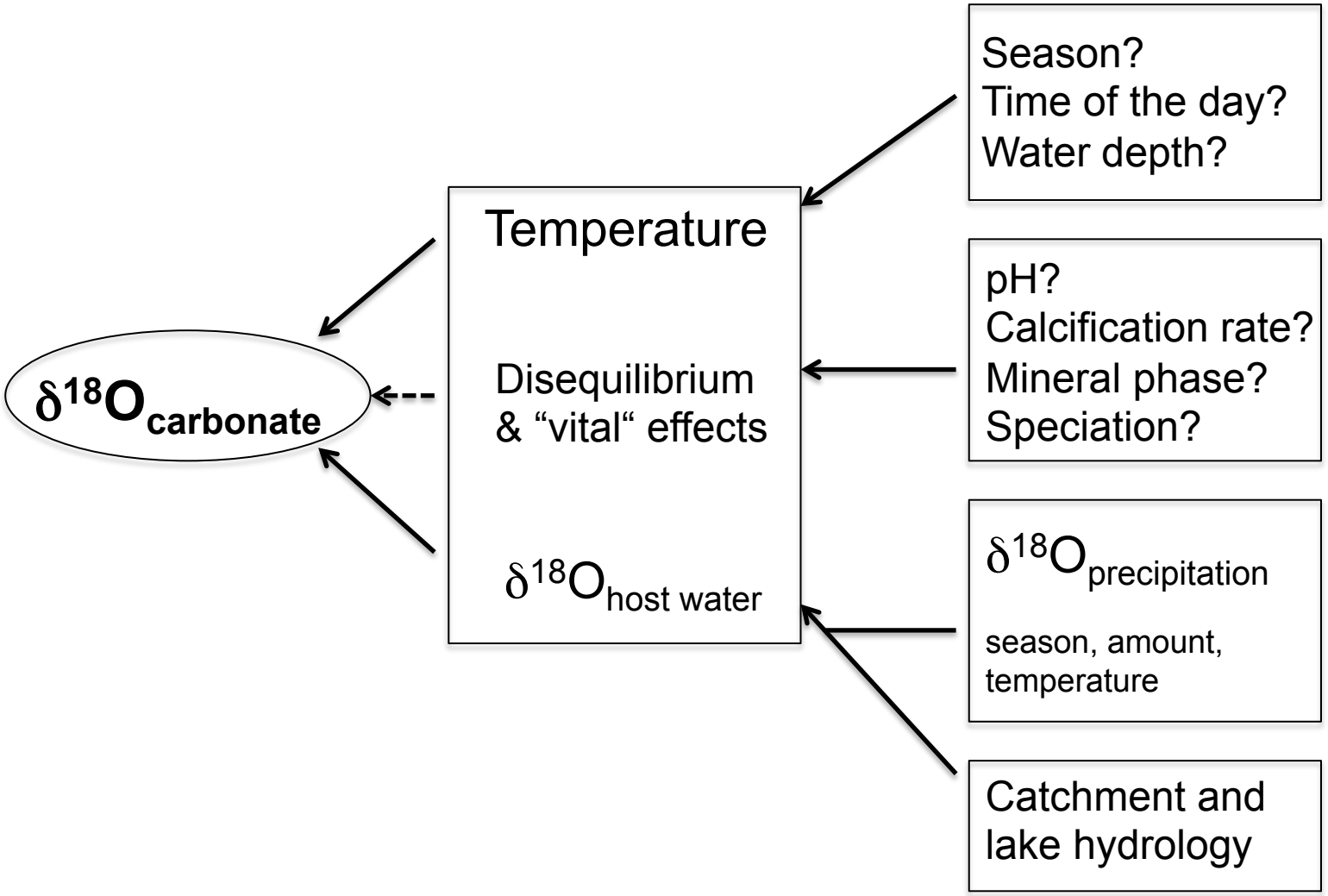
cellulose, chitin, carbonate, phosphate,...

Analysis & age control

➔ Interpretation

$^{18}O/^{16}O$

Example $\delta^{18}O$ of lacustrine carbonates: Influencing factors



Modified from Leng & Marshall (2004)

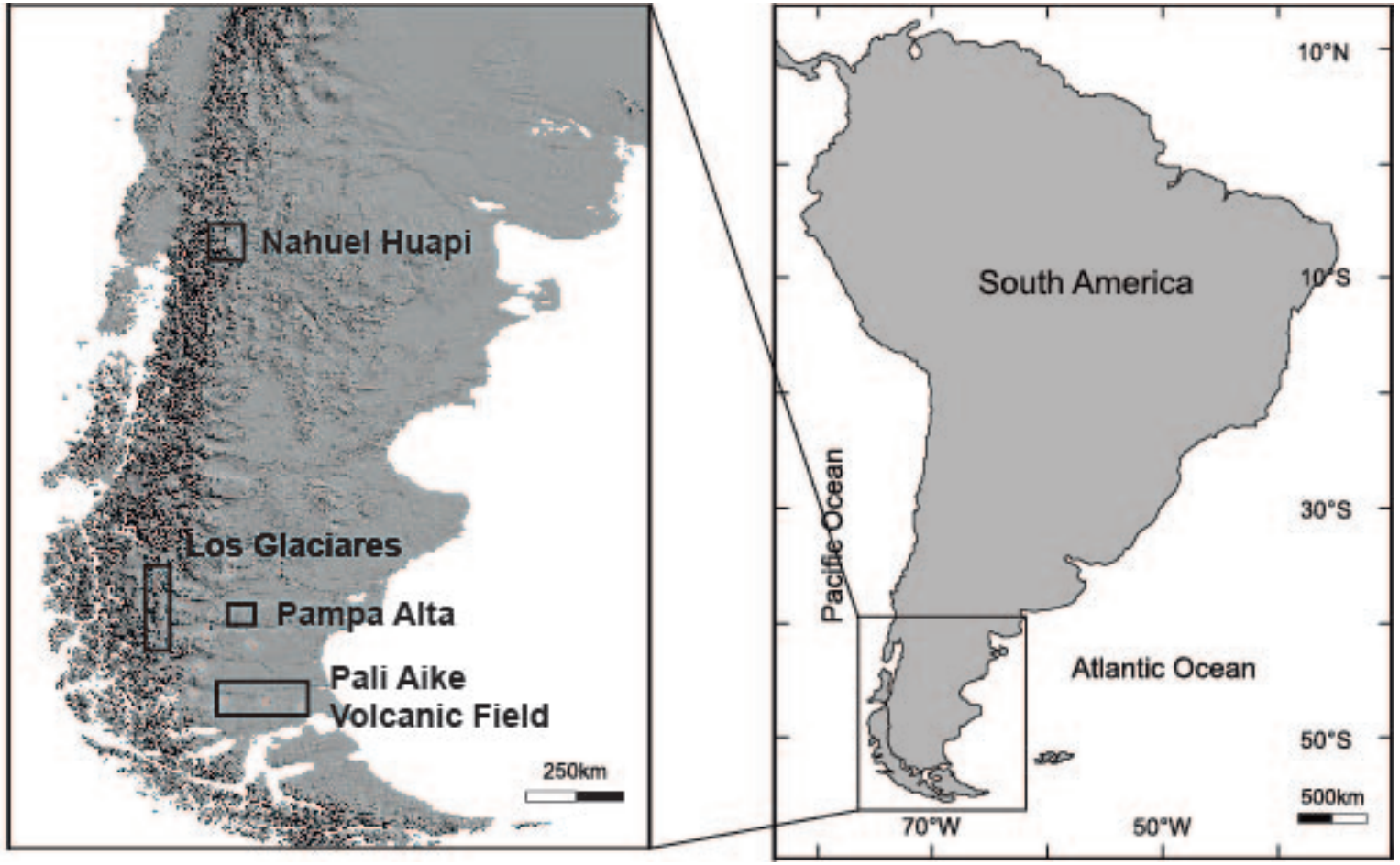
Case study 1

Proxy calibration

Lakes in Patagonia

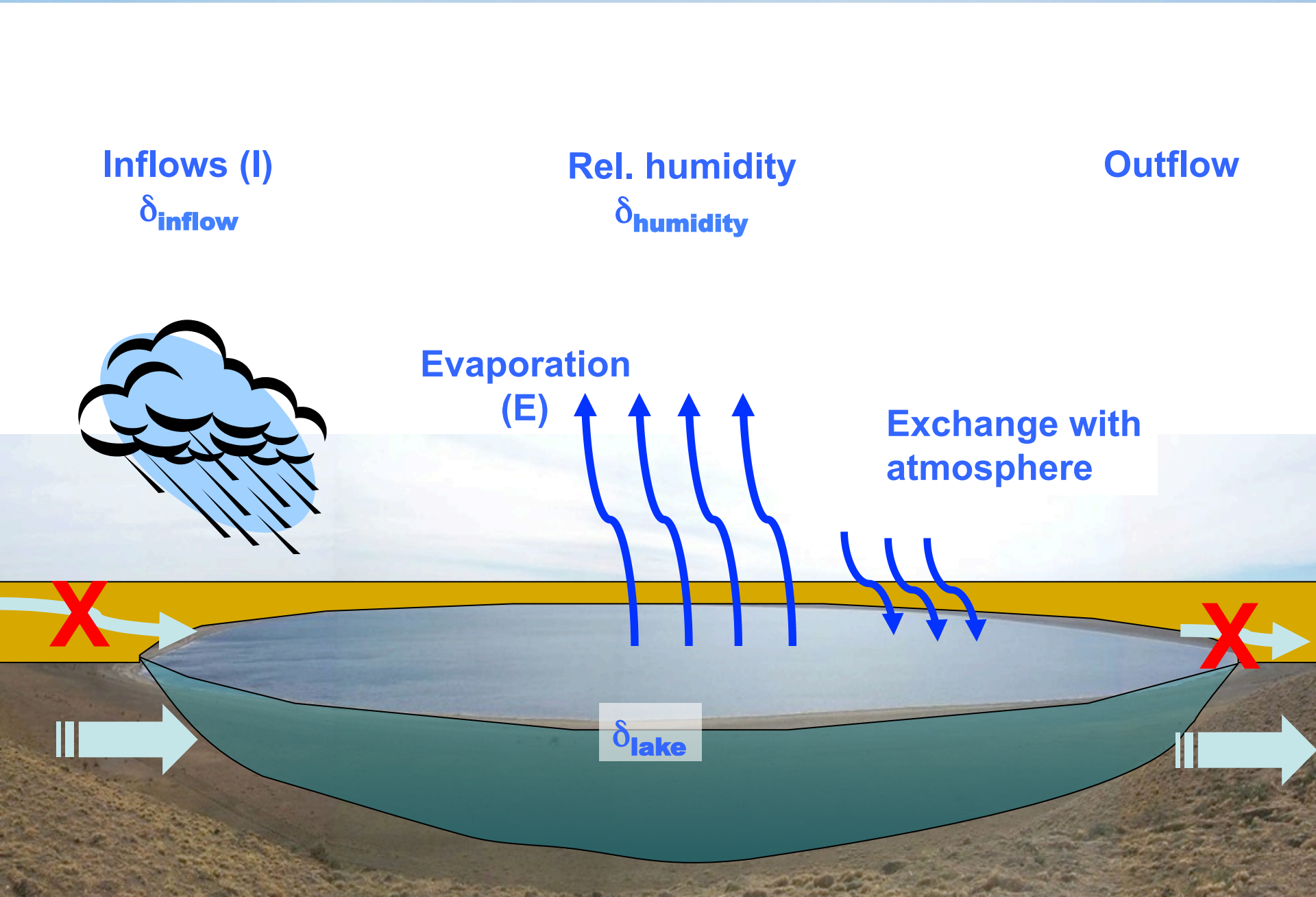
Research area 41-52°S

- 44 sites (ponds, creeks, lakes)
- Calibration study: water samples, surface sediments and living organisms



Mayr et al., in review

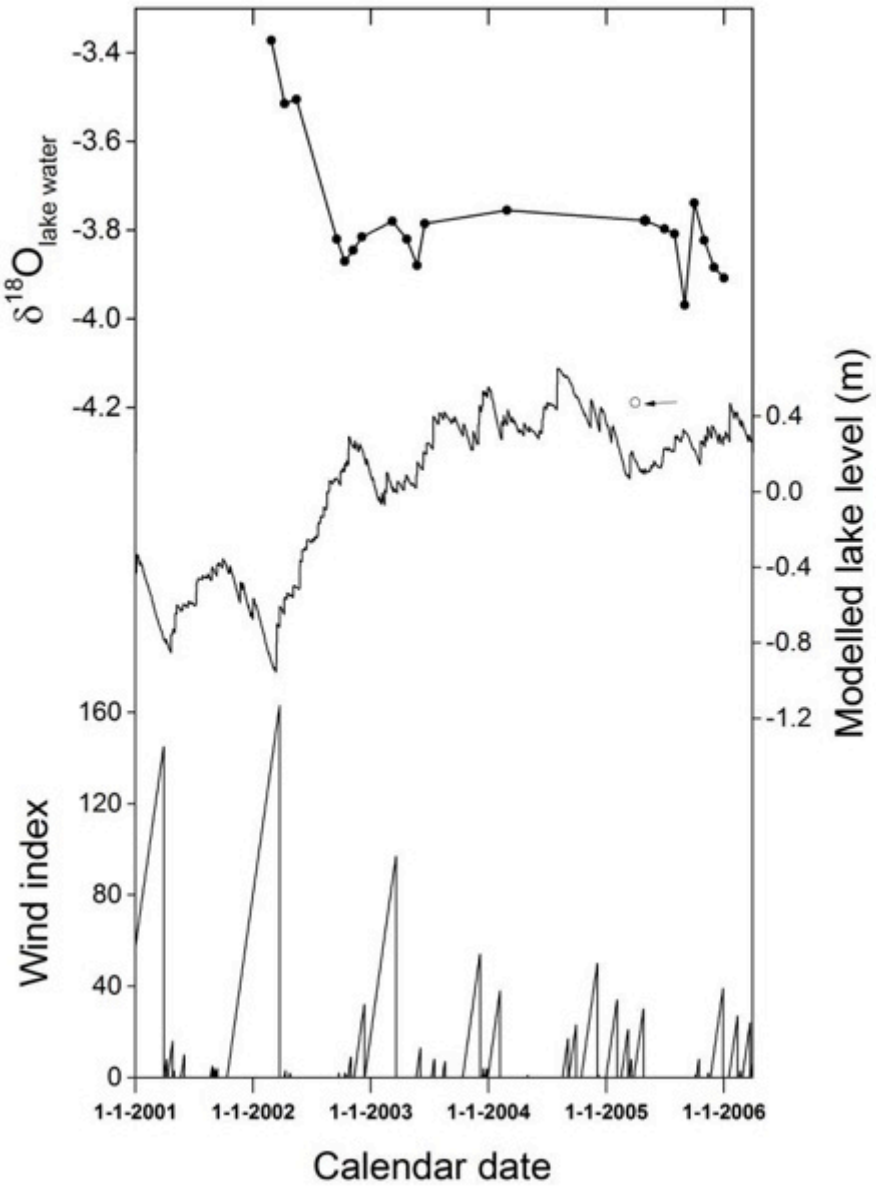
$\delta^{18}O$ and lake water balance



Monitoring: Lake water $\delta^{18}O$ and climate

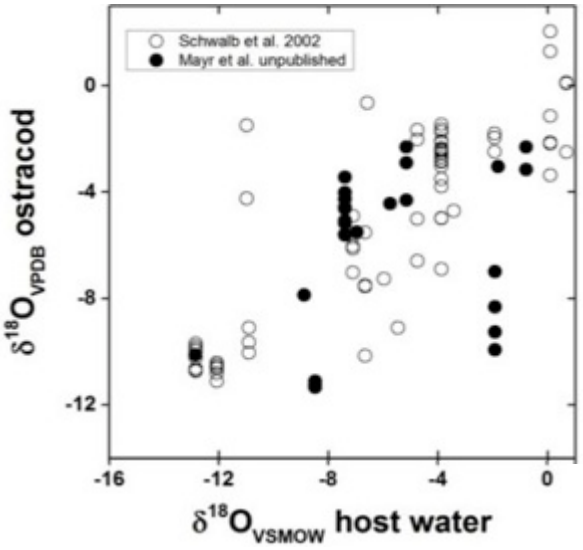
Laguna Potrok Aike

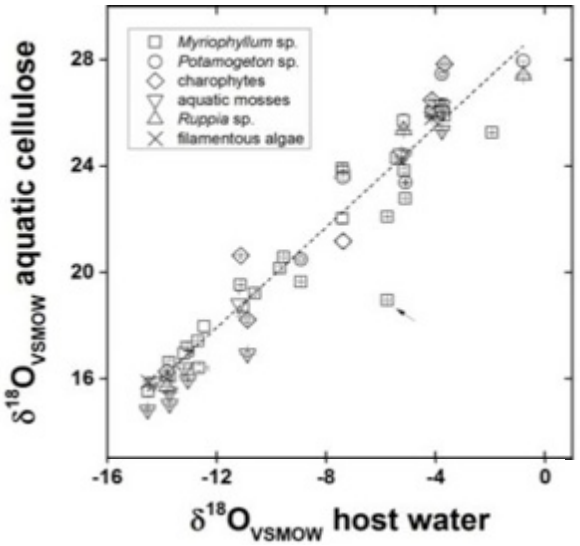
- $\delta^{18}O$ values of lake water as Proxy for water balance changes
- Water balance is controlled by climatic parameters like wind intensity

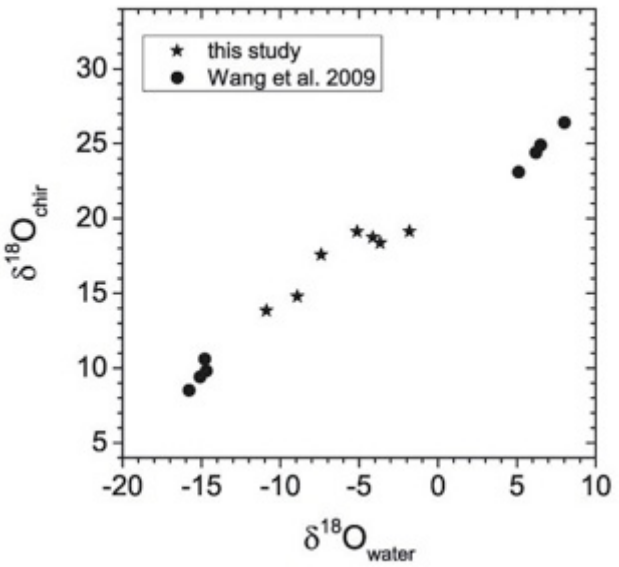


Ohlendorf et al., 2013 & Mayr et al., unpublished

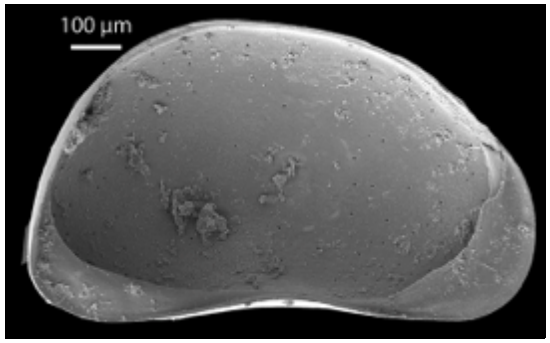
$\delta^{18}O$ proxies as recorders of host water isotope composition

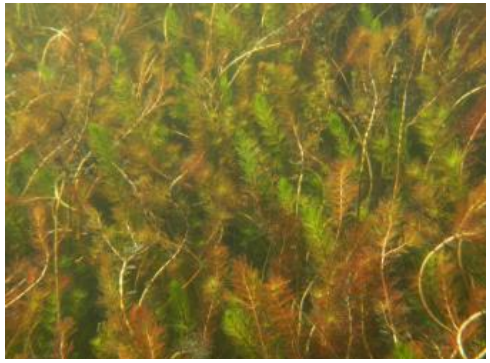






Mayr et al., in review, 2014





carbonate:
ostracods

cellulose:
aquatic macrophytes

chitin:
chironomids

Case study 2

Proxy calibration

Humans and Prehistoric Environment

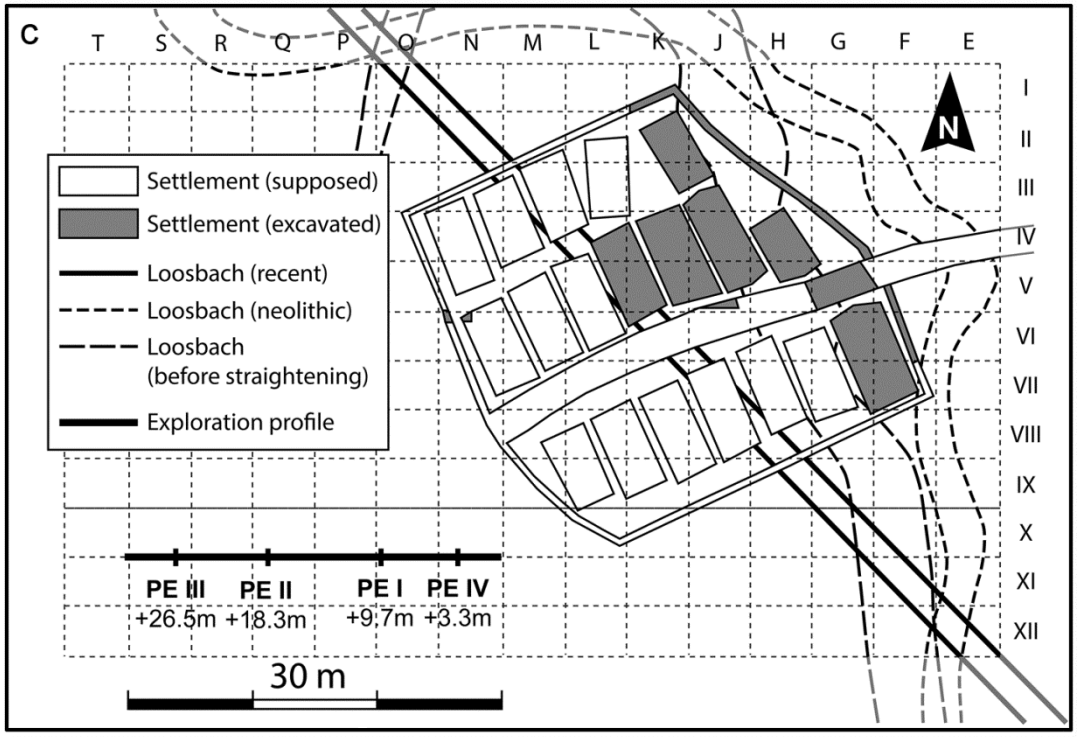
Lakes in Patagonia

Neolithic settlement Pestenacker

Environmental change since the Neolithic

Wetland dwelling Pestenacker next to Landsberg/S-Germany

Altheim Group (3800-3300 BC)
World Heritage Site



Mayr, Matzke-Karasz, Manthe et al. (2014) *J. Archaeol. Sci.*

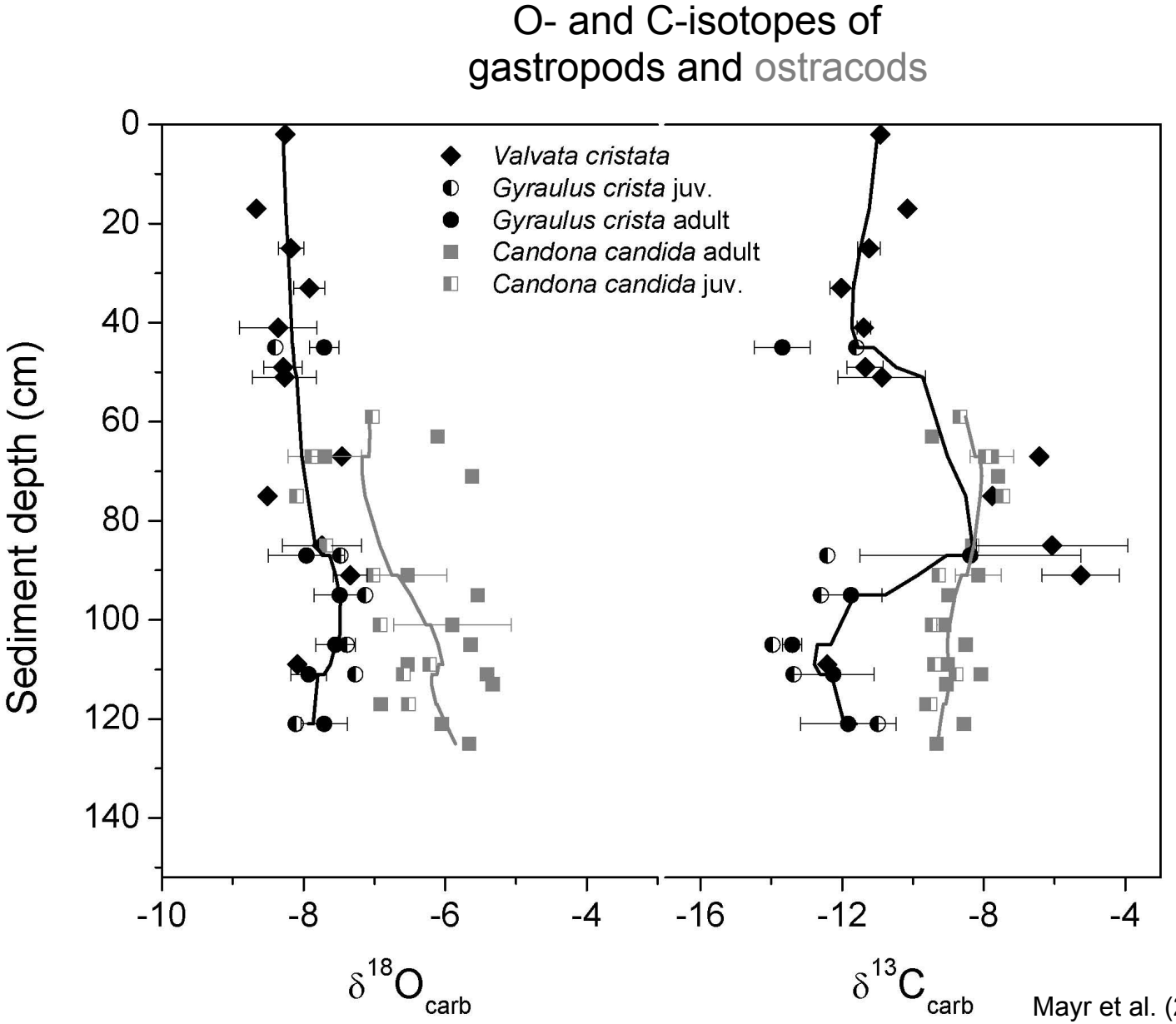
Research questions

- Environment during settlement
- Post-settlement landscape development

Multi-proxy approach

- ostracod-, gastropod assemblages as eco-indicators
- Isotope geochemistry (organic matter, gastropods, ostracods)

Isotope records of biogenic carbonate



Mayr et al. (2014)

Palaeoecology

I fen

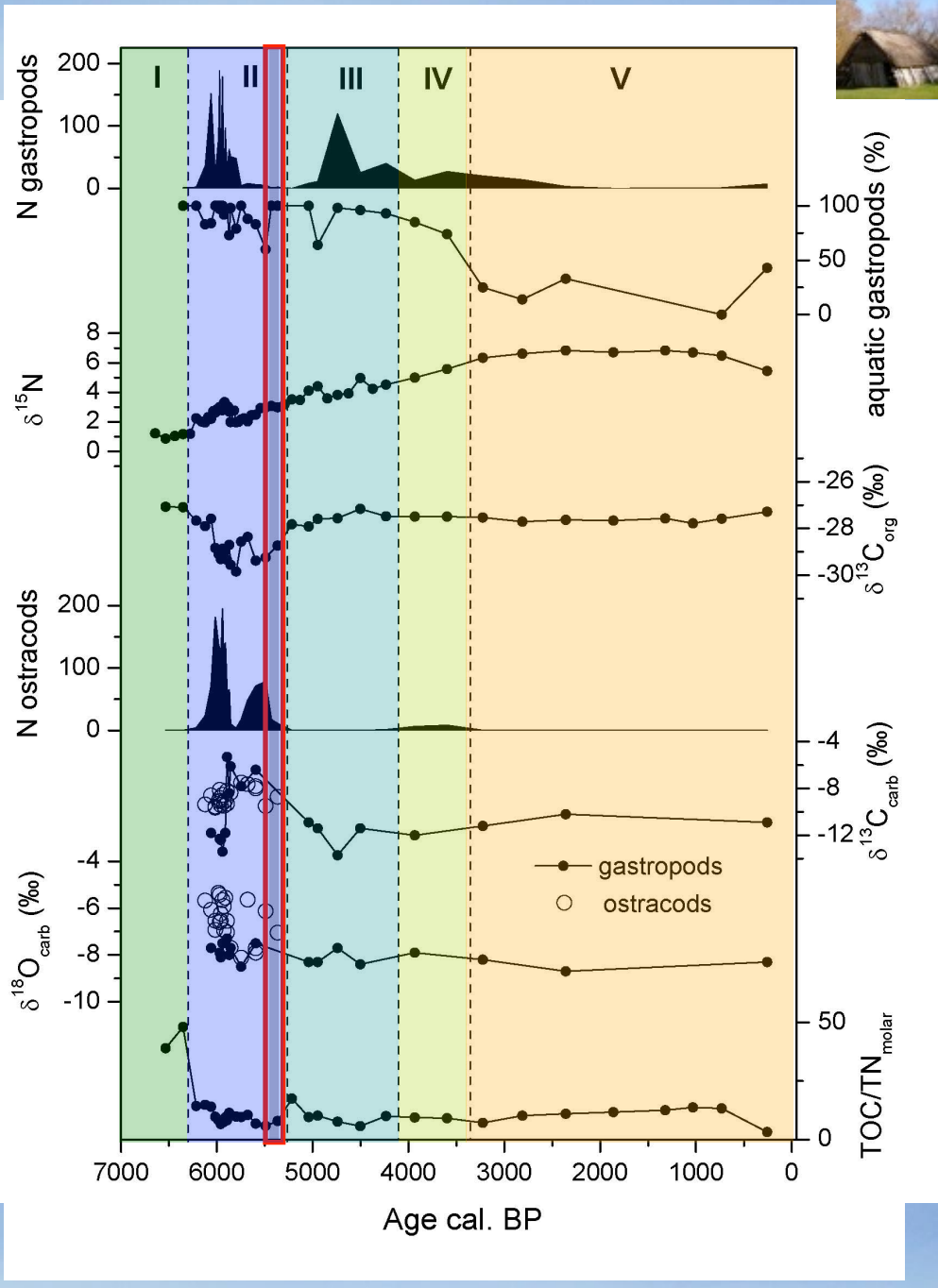
II open water bodies

III shallower water bodies

IV proceeding aggradation

V soil formation

Neolithic settlement



Mayr et al. (2014)

Case study 3

Proxy calibration

Lakes in Patagonia

Humans and Prehistoric Environment

Neolithic settlement Pestenacker

Transalpine mobility

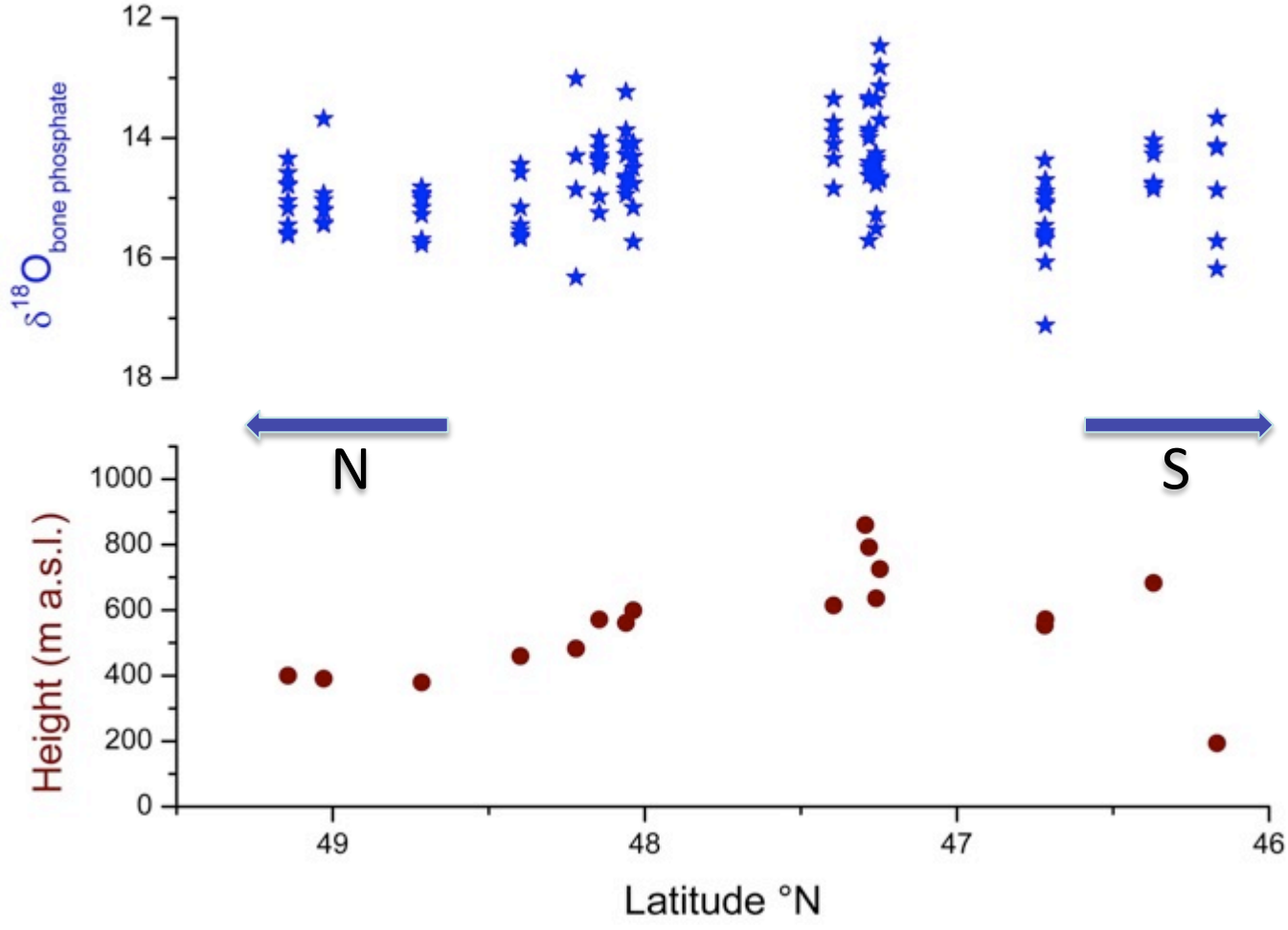
First results

Presently available dataset

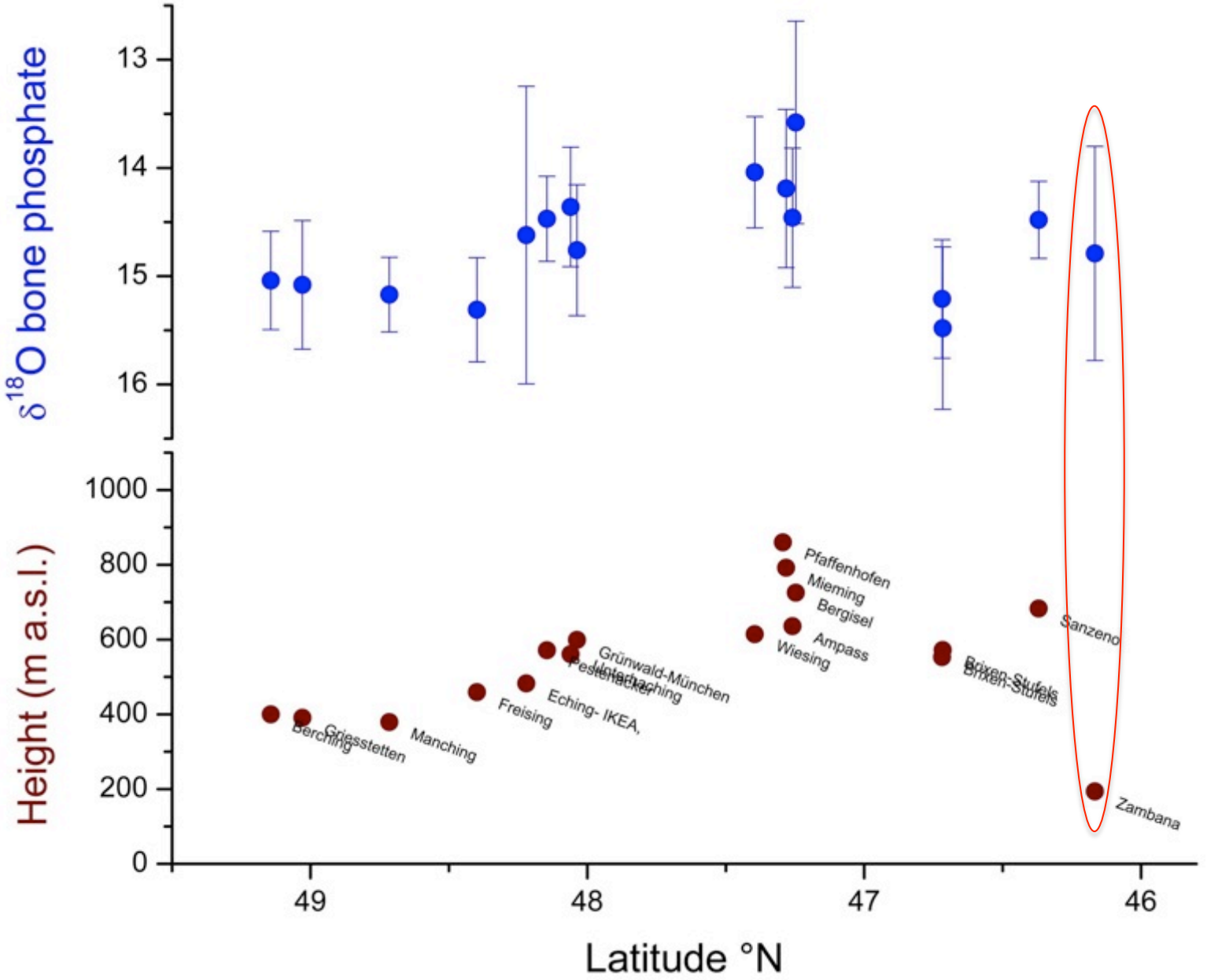
- $\delta^{18}O$ values of bone phosphates from deer (*Cervus elaphus*), pig (*Sus domesticus*), and cattle (*Bos taurus*)
- 0-4 individuals per species and archaeological site
- Time frame: from the Neolithic to the Roman period
- 16 sites from Northern Bavaria (Berching) to Northern Italy (Zambana), altitudinal range from 193 to 792 m a.s.l.

Project Transalpine Mobility

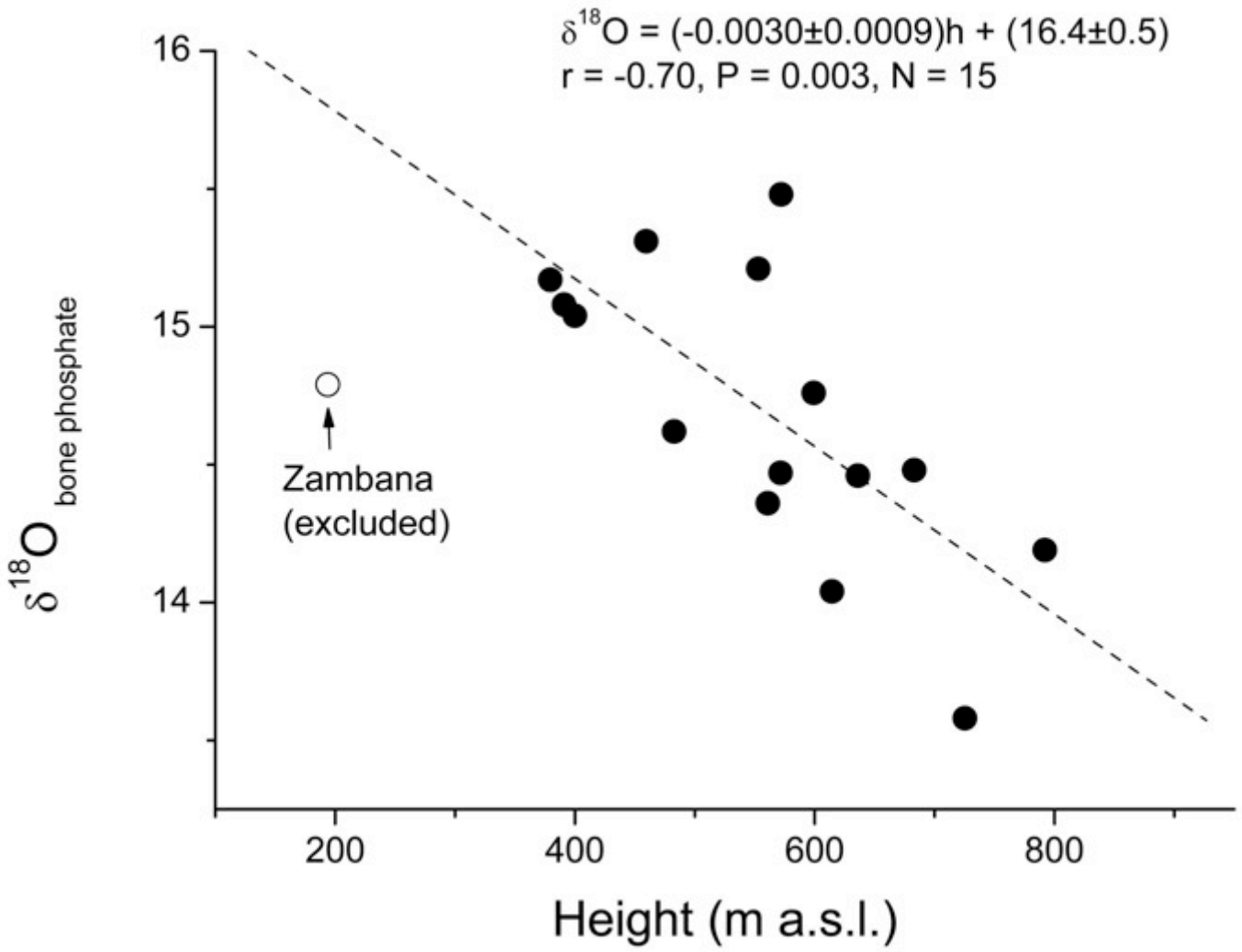
$\delta^{18}O$ of animal bone phosphate



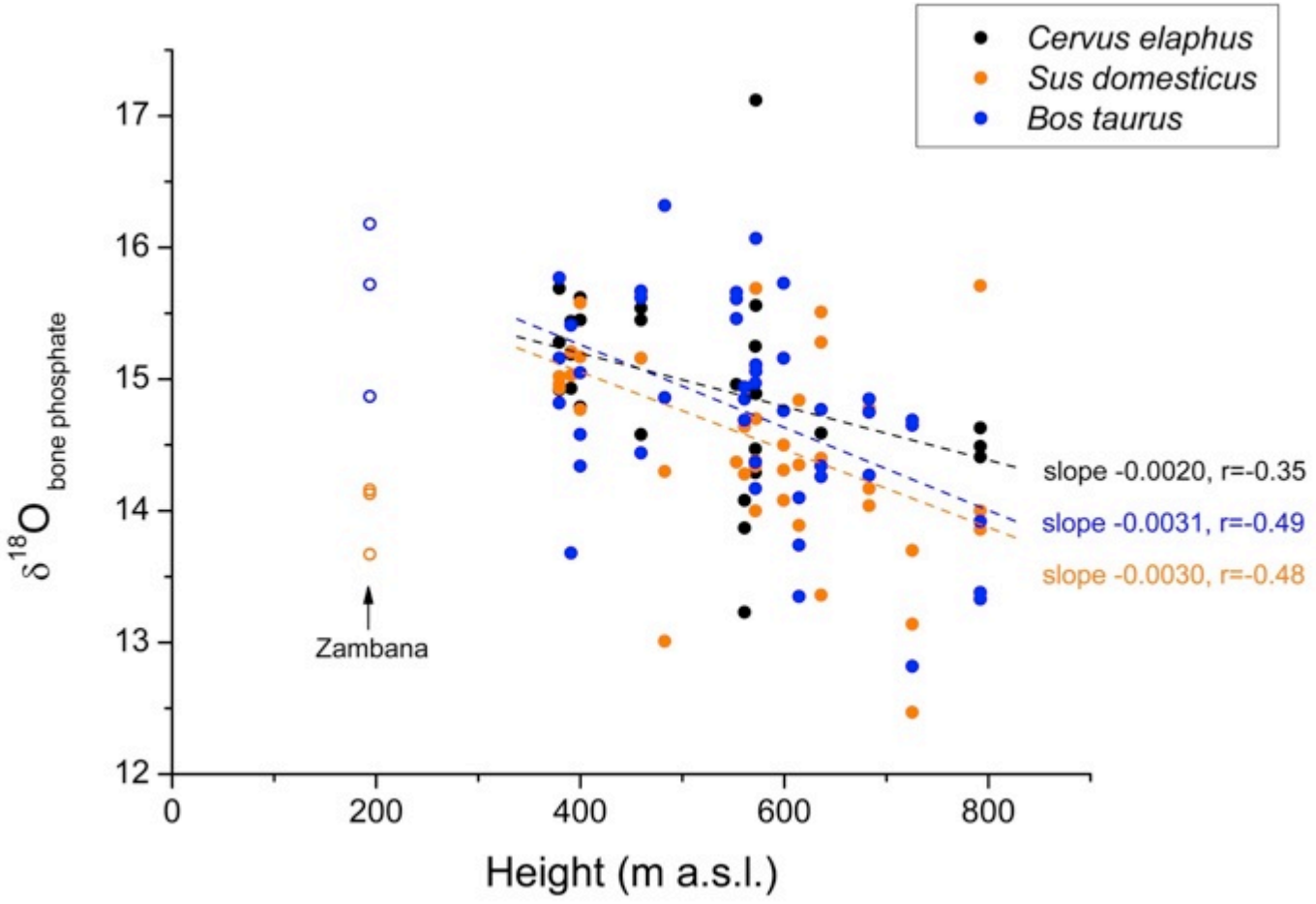
Mean $\delta^{18}O$ values of each site compared to altitude



$\delta^{18}O$ vs. altitude: mean of all species per site



$\delta^{18}O$ phosphate vs. altitude: species effects?



Species-specific isotopic fractionation

Fractionation between blood water and bone phosphate is constant,

but variable between $\delta^{18}O_{blood}$ and $\delta^{18}O_{water}$ for different taxa:

Deer: $\delta^{18}O_{phosphate} = 1.13\ \delta^{18}O_{water} + 25.55$

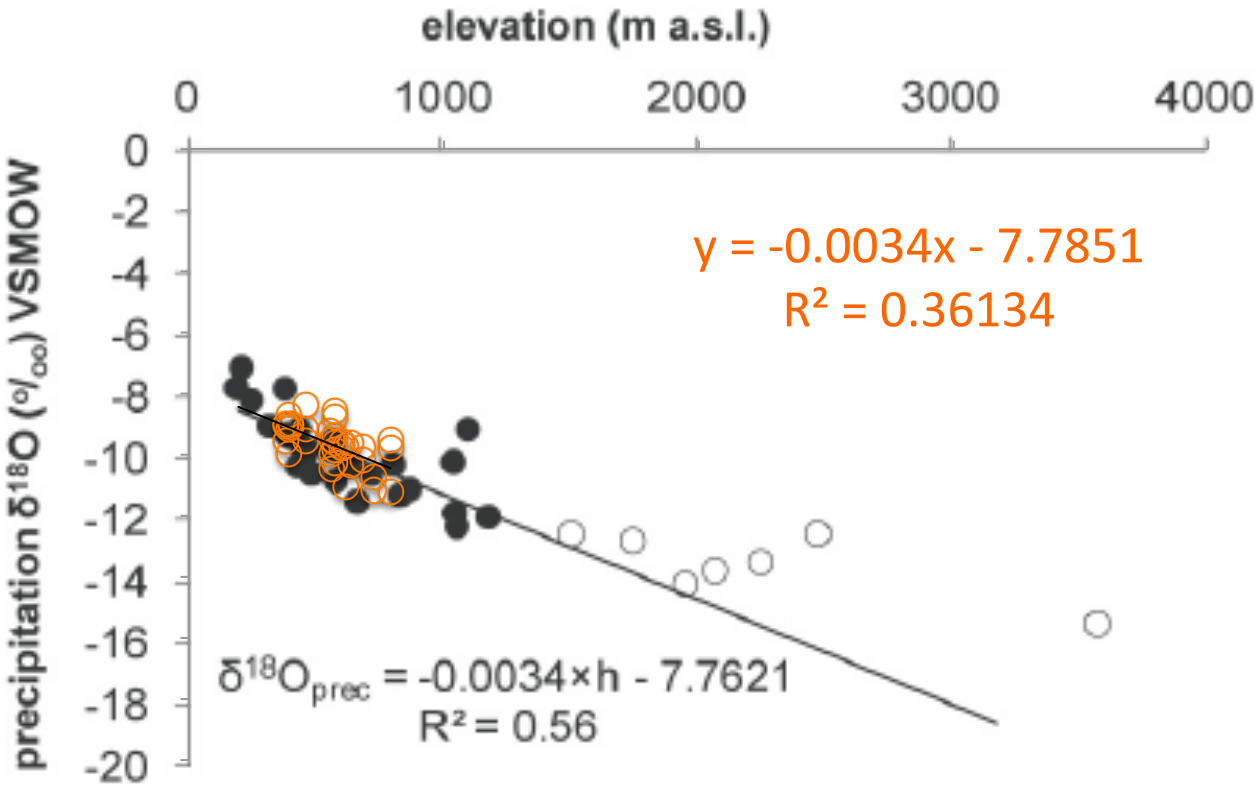
Pig: $\delta^{18}O_{phosphate} = 0.86\ \delta^{18}O_{water} + 22.71$

Cattle: $\delta^{18}O_{phosphate} = 1.01\ \delta^{18}O_{water} + 24.90$

(Longinelli 1984, D'Angela & Longinelli 1995)

Reconstruction of $\delta^{18}O_{water}$ (Zambana excluded)

Comparison with $\delta^{18}O$ of Alpine precipitation (Kern et al., 2014)



Kern et al., 2014

Summary of preliminary results

- Relationship between altitude and $\delta^{18}O_{\text{bone phosphate}}$
- Reconstructed $\delta^{18}O$ values of water fit with modern altitudinal isotope gradient of precipitation
- Exception: Zambana. Animals consumed there bred at a different site or use of different water source (river water)?

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