# Application of the clumped isotope paleothermometer in soil carbonates to new estimates of Pleistocene glacial-interglacial temperature change in the Central Rocky Mountains

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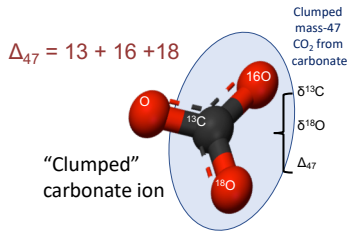
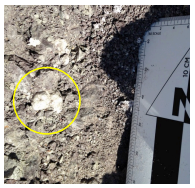
## 1. Introduction

- Learning about how past climates have responded to changes in carbon dioxide concentrations is important to understand how our current climate will respond to atmospheric changes.
- Extensive studies have tried to constrain the warming that occurred after the Last Glacial Maximum (LGM, ~20,000 years ago) and have estimated the temperature change from the LGM to today to be 5-10º C.
- In this study we:
  - Measure the clumped oxygen and carbon isotopes of soil carbonate samples collected in the Central Rocky Mountains from the LGM and today to develop a more precise estimate of the amount of warming since the LGM.
  - Investigate the time of year soil carbonates form, which is important for interpreting the soil temperature recorded by clumped isotopes.

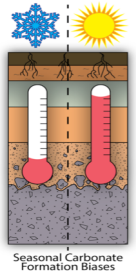
## 2. Carbonate clumped isotope thermometry

- **Measures ratio of "clumped" heavy isotopologues in carbonate minerals**
- Proportion of "clumped" molecules increases with decreasing temperature
- Calculate temperature of soil carbonate formation from clumping (Δ47) using an empirical calibration (Kelson et al., 2017)



Soil carbonate nodule

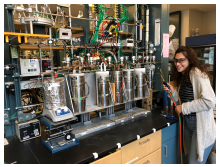



**We use the clumped isotope temperature to reconstruct climate.**

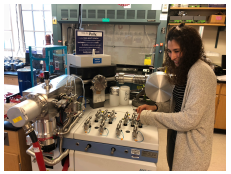
However, the temperatures recorded by the soil carbonates are **seasonally dependent**, because carbonate formation depends on seasonal rainfall/soil drying.

## 3. Analytical methods

- We measure clumping in $CO_2$ derived from carbonate
- Digested 10 soil carbonate samples (3 replicates each) in phosphoric acid to produce $CO_2$
- Purified $CO_2$ cryogenically using an automated vacuum line
- Analyzed purified $CO_2$ on a MAT 253 mass spectrometer



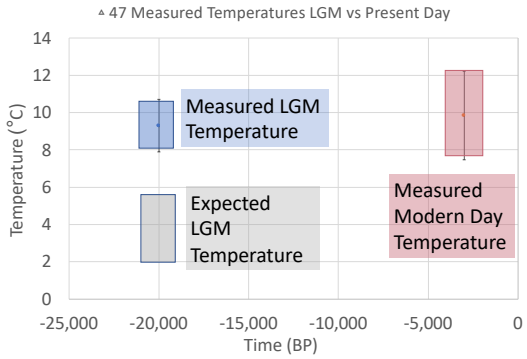
Prepping the samples in the prep-line



Mass Spectrometer

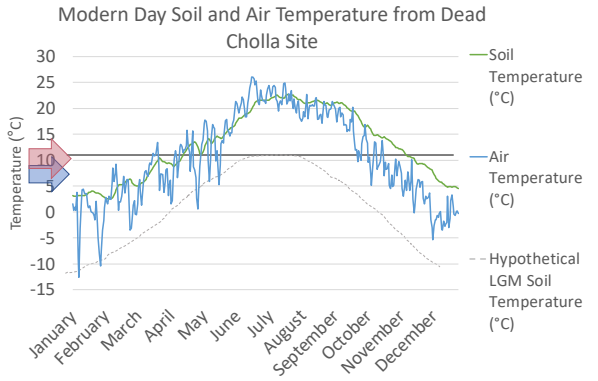
## 4. Clumped isotope temperature results

- **We expected clumped isotope temperature estimates from the LGM and today to differ by 5-10°C** (based on climate models, Braconnot et al., 2007) if the carbonates formed in the same season.
- **However, LGM and modern clumped temperatures are within error of each other** (LGM: 9 ± 1°C; modern: 10 ± 2 °C), indicating the samples formed in different seasons



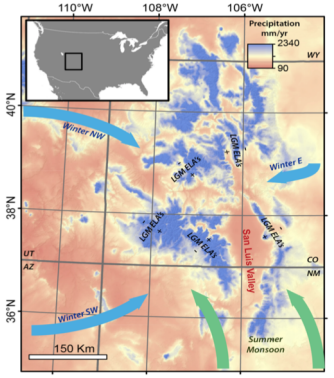

## 5. Discussion – Temperature interpretation

- Modern carbonate temperatures of 10° resemble fall or spring soil and air temperatures
- If LGM was 5-10°C cooler than modern → the 10 °C soil carbonate samples from the LGM formed in the summer




## 6. Implications for LGM Climate

- Because of the apparent change in the season of carbonate formation, we are unable to discern a meaningful temperature difference between the LGM and present day.
- However, the **change in carbonate seasonality implies that timing of seasonal precipitation was different in the LGM.** No summer monsoon in LGM?




**References**
Hudson, Adam. "Research Proposal-Mendenhall Opportunity #15-27." Proposal. 2017; Kelson JR, et al., (2017). Towards a university carbonate clumped isotope calibration: diverse synthesis and preparatory methods suggest a single temperature relationship. Geochimica et Cosmochimica Acta 197, 104-131. doi:10.1016/j.gca.2016.10.010.
Braconnot, P., et al., Results of PMIP2 coupled simulations of the Mid-Holocene and Last Glacial Maximum – Part 1: experiments and large-scale features, Clim. Past, 3, 261-277, https://doi.org/10.5194/cp-3-261-2007, 2007.