Abstract 268-22

Hot summers on land in the early Eocene subtropics

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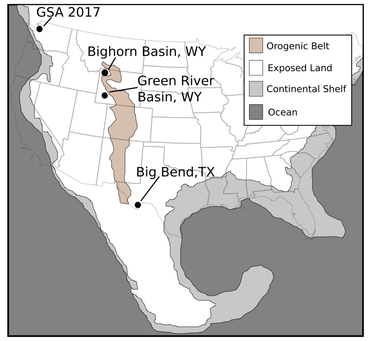
GSA Meeting
October 2017

Introduction

- The early Eocene (~56-50 Ma) is the peak of protracted warmth of the Cenozoic. Proxy reconstructions of climate on land during this time period are crucial to test our understanding of climate dynamics in greenhouse regimes.
- Currently, the tropical and subtropical temperatures predicted by models seem unreasonably hot given the evidence for life at these latitudes (Peppe et al., 2013). These high subtropical temperatures are necessary to match proxy estimates of latitudinal temperature gradient.
- We seek to test model predictions for high summer temperatures at low latitudes.
- Clumped isotope thermometry is a compelling proxy for summertime temperatures, especially given recent improvements in clumped isotope methodology and improvements in our understanding of carbonate growth seasonality.
- We went to the Tornillo basin in Big Bend, TX to create a stable isotope record using carbonate nodules from paleosols.



The paleosols in the Tornillo basin in Big Bend, TX are at ~30 °N. Big Bend can be compared to other Eocene studied basins in Wyoming.

Methods and Materials

- We collected ancient, preserved soil matrix and soil carbonates from the Hannold Hill and Canoe Formations (~54 to 52 Ma) in Big Bend National Park, Texas.
- We assessed carbonate material for diagenesis with a cathodoluminescent microscope.
- We measured **$\delta^{13}C_{carb}$, $\delta^{18}O_{carb}$, and clumped isotopes (Δ_{47})** of soil carbonate nodules at UW Isolab. Clumped isotope temperatures are calculated with the Kelson et al. (2017) Δ_{47}-temperature calibration. **$\delta^{18}O_{water}$** is calculated using the $T(\Delta_{47})$ and the calcite-water fractionation from Kim and O'Neil (1997).
- We compare our data to various HADCM3L model runs.

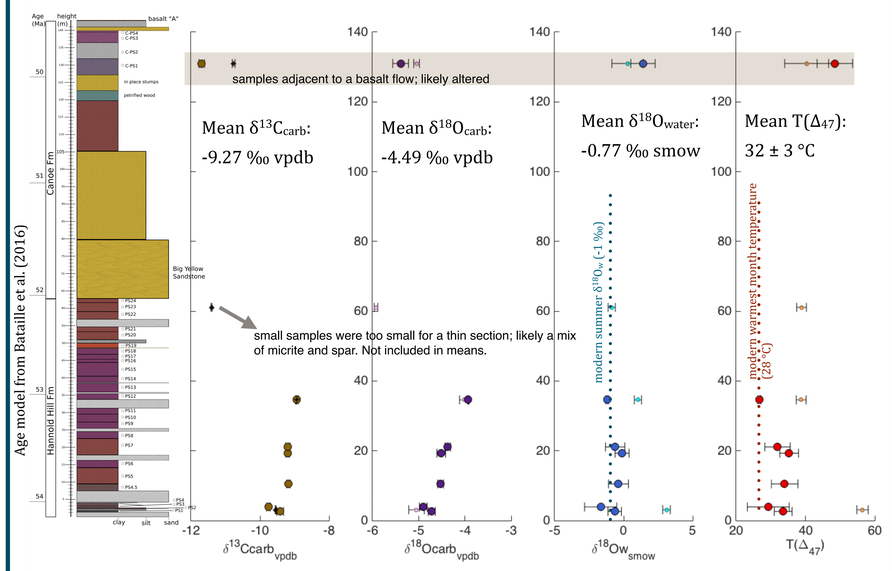
Soil carbonate nodule

Models used in comparison	greenhouse gas forcing (x preindustrial CO2, land surface scheme	Reference
tdddms (preferred)	x4 CO2, dynamic vegetation	Loptson et al. (2014)
tddmg	x4 CO2, fixed shrubland	Loptson et al. (2014)
tbpif	x4 CO2	Lunt et al. (2010)
tbpig	x6 CO2	Lunt et al. (2010)
tdlud	x4 CO2, varied paleogeography	Lunt et al. (2016), Inglis et al. (2017)

Table 1: HADCM3L model runs used in comparison with clumped isotope data

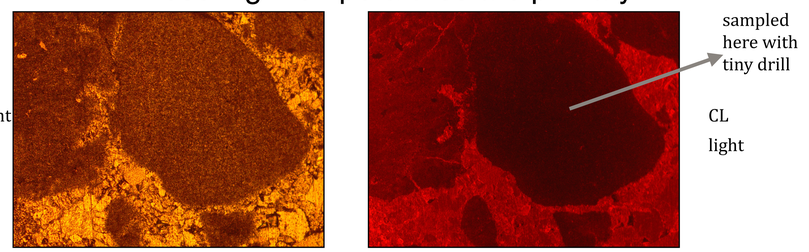
GRFP Grant No. DGE-1256082

Stratigraphy and chemostratigraphy: consistent isotopic compositions in primary carbonate



- The Hannold Hill and Canoe Formations consist of fluvial channel deposits, like cross-bedded sandstone (Big Yellow), and soils formed in over-bank deposits that occasionally yield carbonate nodules.
- Carbonate nodules collected near a basalt layer appear altered. Similarly, nodules that were too small to make a thin section of appear to be a mix of altered and primary carbonate.
- The isotopic values do not change significantly through the section; we can average the primary values to produce an estimate for early Eocene.
- $\delta^{18}O_{water}$ is similar to the $\delta^{18}O$ of modern summer precipitation. $T(\Delta_{47})$ is hotter than modern warmest month temperatures.

These high temperatures are primary



Example of a thin section of a carbonate nodule (Paleosol 7-Bk1)

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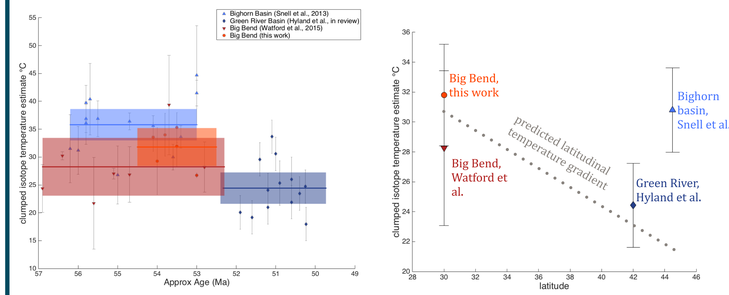
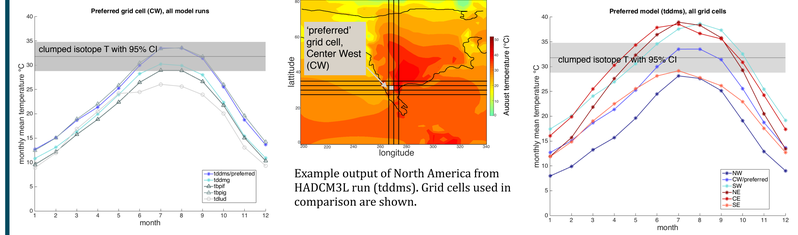
Comparison to other early Eocene clumped isotope records from North America



- Previous work from Big Bend agrees with our estimates (Watford et al., 2015, MS thesis).
- Our mean temperature estimate is warmer than the estimate from Green River Basin (Hyland et al., in review), which is consistent with the continental latitudinal temperature gradient predicted in Huber and Caballero (2011).
- The temperature estimate from Bighorn Basin is warmer than that from Green River, and within error of our estimate from Big Bend. This may reflect local, excessive warming in the Bighorn basin, cryptic diagenesis, or improved Δ_{47} methods.

Eocene global climate model (HadCM3L) agrees with clumped isotope T



Example output of North America from HADCM3L run (tddms). Grid cells used in comparison are shown.

- We compare our clumped isotope temperature estimate to HadCM3L (Table 1 in Methods)
- Because of uncertainty in the position of the Eocene coastline, we compare our clumped isotope temperature to several grid cells within each model.
- Our clumped isotope temperature generally agrees with summer temperatures predicted by the models. In some cases, our clumped isotope temperatures agree with fall temperatures.
- To achieve agreement with our summer temperature estimate, models use more CO_2 than estimated by proxies (e.g., Anagnostou, et al., 2016)
- The range of temperature predicted by the model is larger when comparing different grid cells in the same model vs. comparing model runs in a single cell. Therefore when comparing model results to proxy data, accurate paleogeography is important.

Conclusions

- We present clumped isotope temperatures from Big Bend that are summer temperatures.
- Our temperature estimate is warmer than the estimate from Green River Basin. This is consistent with a latitudinal temperature gradient. The temperature estimate from Bighorn Basin is warmer than our estimate from Big Bend (> 10° further south). This may reflect local conditions, and highlights the need for multiple localities for proxy reconstructions.
- Our temperature estimate agrees with summer temperatures predicted by HadCM3L, especially when comparing to the model that uses x4 CO_2 with dynamic vegetation at the most paleogeographically likely grid cell.
- We confirm that summers in the Eocene subtropics were quite warm; future work may reconcile our hot temperatures with observations of forest ecosystems at these latitudes.