Extreme summer warming of the East Asian interior during the Paleocene Eocene thermal maximum

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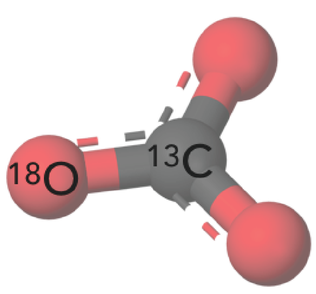
ABSTRACT

The Paleocene-Eocene thermal maximum is a large climate perturbation during the early Cenozoic, which yields important information to better constrain greenhouse forcing and climate sensitivity. Temperature reconstructions based on proxy data indicate a global warming within a range of 4 to 5 degrees C for this hyperthermal event. However, this estimate is largely derived from marine proxy data. To date, there is only limited data available from terrestrial archives. Here we present stable carbon and oxygen isotope as well as clumped isotope data derived from carbonate soil nodules from terrestrial deposits in China. The carbon isotope profile of the studied section shows clear evidence for the carbon isotope excursion (CIE) that is associated with the PETM. Alongside the shift in carbon isotopes, we find a large (>10 degree C) shift in the clumped isotope based terrestrial temperatures. This magnitude is similar to the temperature shift that is found in clumped isotope based temperatures from the interior of North America across the PETM, suggesting that the warming in the mid-latitudes is comparable, across the Northern Hemisphere. Considering the formation process, soil carbonate based temperatures presumably represent summer temperatures. The comparison with the marine proxy data suggests further that the warming was either amplified in the terrestrial realm, or that the seasonality increased, with a more extreme summer warming.

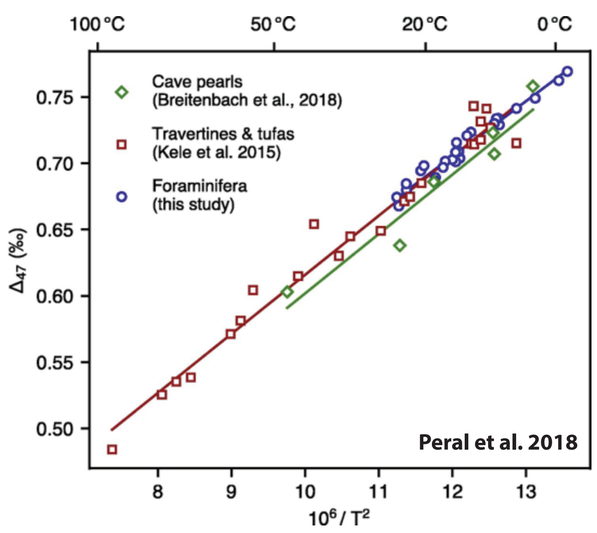
Clumped isotope thermometry



Underlying thermodynamic principle:

The ordering of isotopes within a crystal structure (or preferential clumping of heavy isotopes at low temperature) is counter-balanced by the effects of entropy: this implies that as temperature increases, clumping must decrease and eventually reach a purely stochastic distribution at high temperature (i.e. > 1000˚C).

Results are usually expressed as Δ47 (said as "cap 47"), which is the deviation of the ratio of isotopologues of CO2 with a molecular weight of 47 to those with a weight of 44 from the ratio expected if they were randomly distributed.

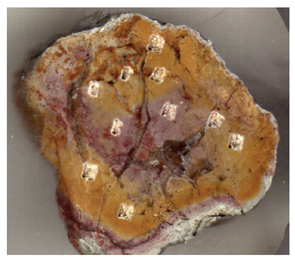


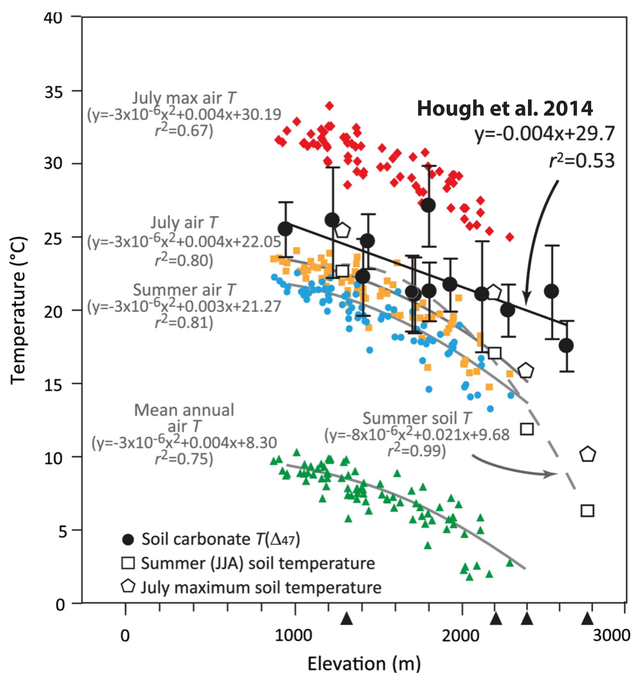
- ***based on theory***
- ***large temperature range***
- ***applicable on different materials***

Soil Carbonate Nodules

Soil carbonates typically form as the soil dries after seasonal rainfall, and therefore record seasonal aspects of climate rather than mean annual conditions.

A calibration study in North America showed soil carbonate values to be 16 °C higher than mean annual air temperature and 3–5 °C higher than mean summer air temperature, suggesting that soil carbonates are formed in summer and that their formation temperatures are influenced by soil heating by solar radiation. Thestudy also shows that soil carbonate values are equal to or higher than maximum soil temperature, suggesting soil carbonates may also be biased to warmest periods or extreme warm/dry events during the summertime.

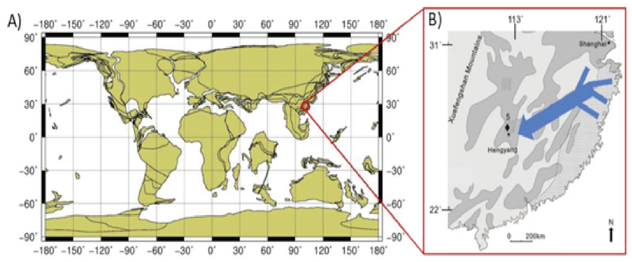


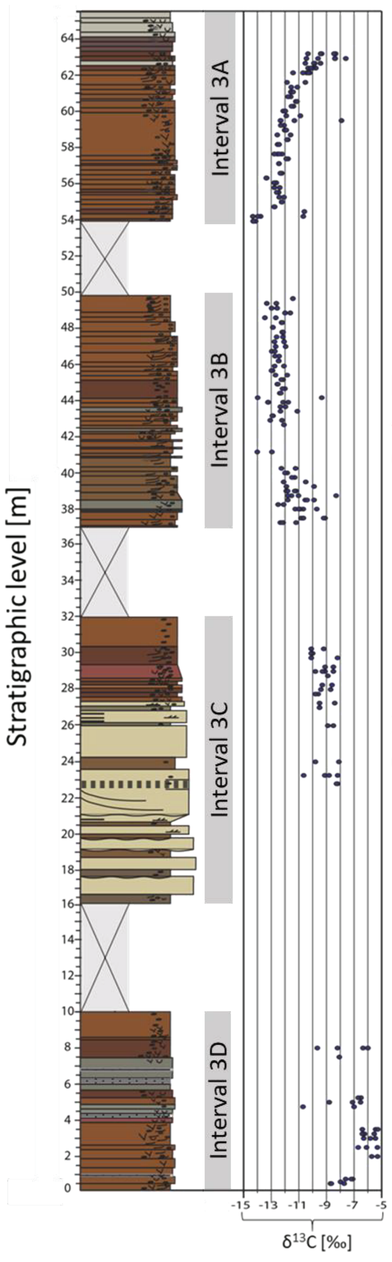


PETM - Terrestrial temperature reconstruction East Asia

Hengyang Section

The Hengyang basin is situated in the south China craton at the border between the Cathaysian block and the Yangtze block . The basin is approximately 5200 km2 and lies in the Hunan Province near the city of Hengyang in south-central China.





Δ_{47} Temps

PETM
42.3°C ± 4.1
(n=21)

Pre-PETM
23.7°C ± 4.8
(n=31)

Pre-PETM
29.9°C ± 4.2
(n=14)

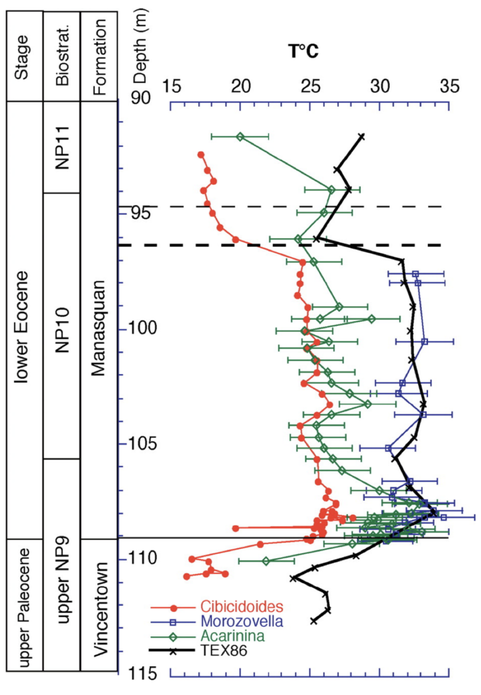
- ***Temperature shows a clear increase with***
- ***terrestrial temperature change appears to be ampliefied compared to the marine realm***
- ***extreme summer warming, also consistent with observations from North America / Bighorn Basin***

PETM - Ocean surface temperature reconstructions

Ocean surface temperatures rapidly warmed by ~5°C during the Paleocene-Eocene Thermal Maximum (PETM), ~56 million years ago.

This warming coincided with a global negative stable carbon isotope excursion (CIE) recorded in terrestrial and marine sedimentary components in conjunction with deep ocean carbonate dissolution, reflecting the injection of ^{13}C-depleted carbon into the ocean-atmosphere system.

Some reconstructions indicate that mid- and high-latitude temperatures exceeded modern tropical temperatures (24° to 29°C) during the PETM.



Zachos et al. 2008

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