Black Carbon Isotopes From the Eastern Tethys Across the Paleocene-Eocene Thermal Maximum

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Introduction

- The Paleocene-Eocene Thermal Maximum (PETM, *ca.* 56Ma) was characterized by a rapid increase in global temperatures and carbon cycle perturbation.
- Wildfires were common during the PETM, which may have contributed to the total amount of emitted carbon into the atmosphere.
- One byproduct of these wildfires is black carbon (BC), which is incomplete burned organic matter.
- We focus on the black carbon and its carbon isotopes preserved at the newly discovered Kuzigongsu section in the Tarim Basin of the eastern Tethys.
- Our objective is to reconstruct terrestrial paleoenvironment using the occurrence and isotopes of BC, which can further determine how vegetation and regional precipitation responded to the PETM.

Figure 1: Modern-day location of the Kuzigonsu site

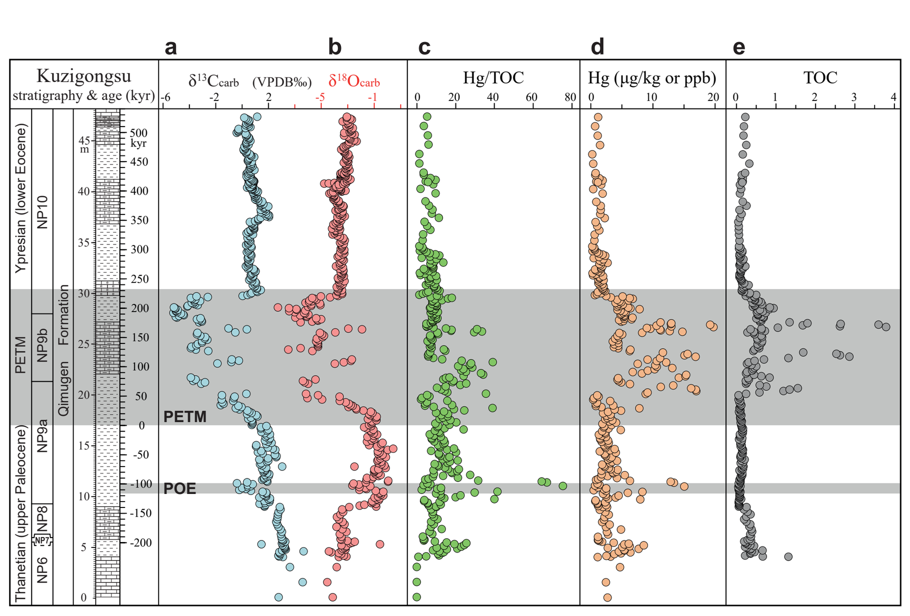
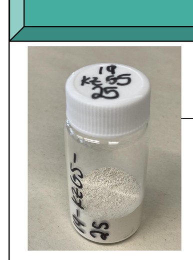


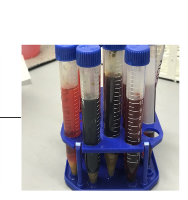
Figure 2: The PETM starts at 19.9 m and ends at 30.5 m. Note the shift in geochemistry during the PETM (Jiang et al., in prep).

Methods

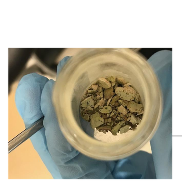


Weigh ≈ 2.0 grams of sample

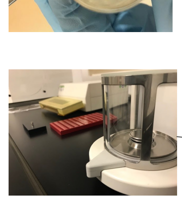
Remove carbonates & silicates through acid digestion
1.6M HCL, 20 hours, 60°C
2.6M HCl+ 22M HF, 20 hours, 60°C
3.6M HCl, 20 hours, 60°C



Remove organic carbon through chemical oxidation for 12 days, 55°C (potassium dichromate/sulfuric acid, 0.5 M $K_2Cr_2O_7$/ 2M H_2SO_4)



Dry the samples in oven for 48 hours at 60°C




Weigh 14.0-14.5 mg for analysis using an elemental analyzer isotope ratio mass spectrometer (EA-IRMS)

Mean annual precipitation (MAP) equations (Chen et al., 2020):

$$\Delta_{leaf} = \frac{(\delta^{13}C_{atm} - \delta^{13}C_{leaf})}{1+\delta^{13}C_{leaf}/1000}$$

$$\Delta_{leaf} = 5.37(\pm 0.30) \times \log_{10}(MAP) + 5.06(\pm 1.00)$$

Results

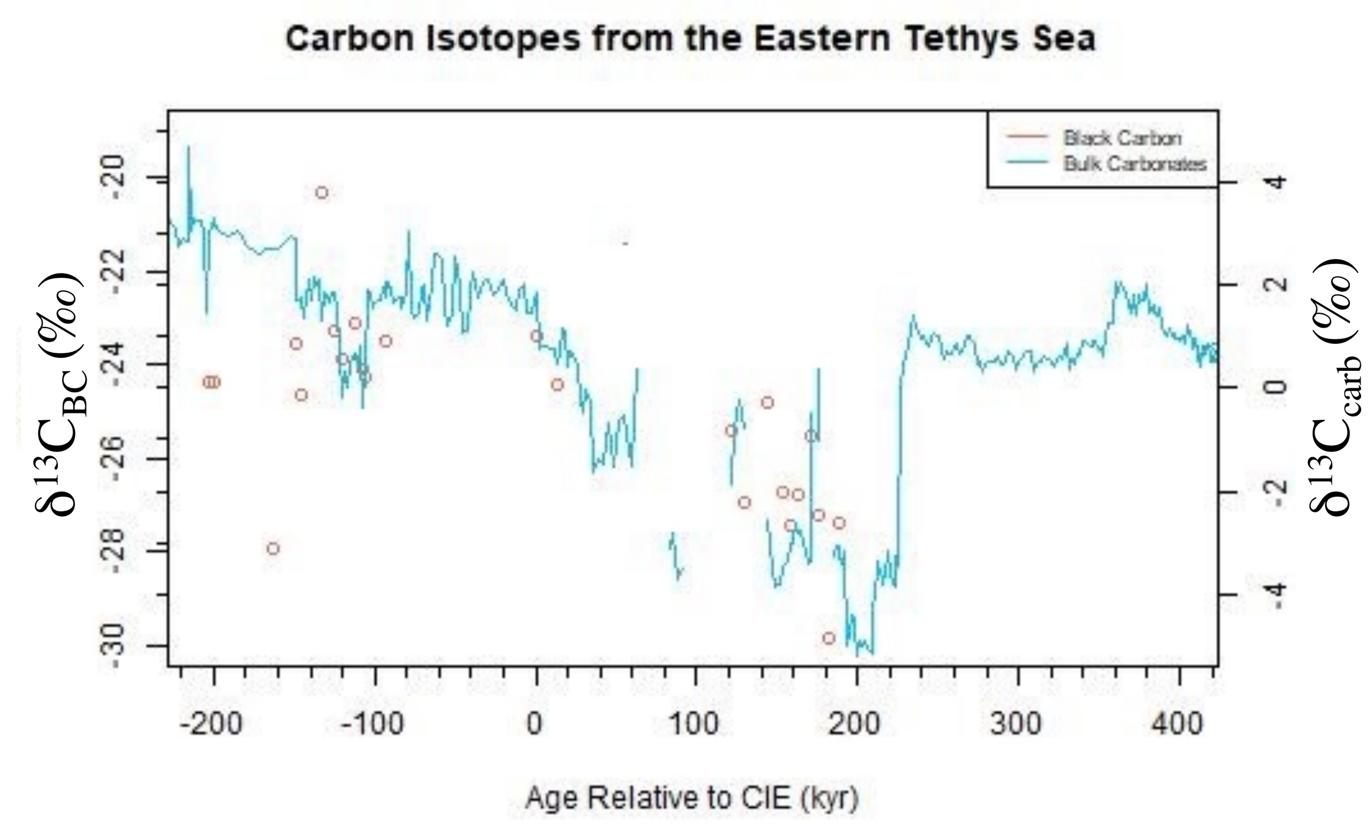


Figure 3: The blue line represents bulk carbonates from the Kuzigongsu section. The red circles represent $\delta^{13}C_{BC}$. The x-axis represents time. Zero represents the start of the PETM, negative values represent time before the PETM, and positive values portray time after the PETM.

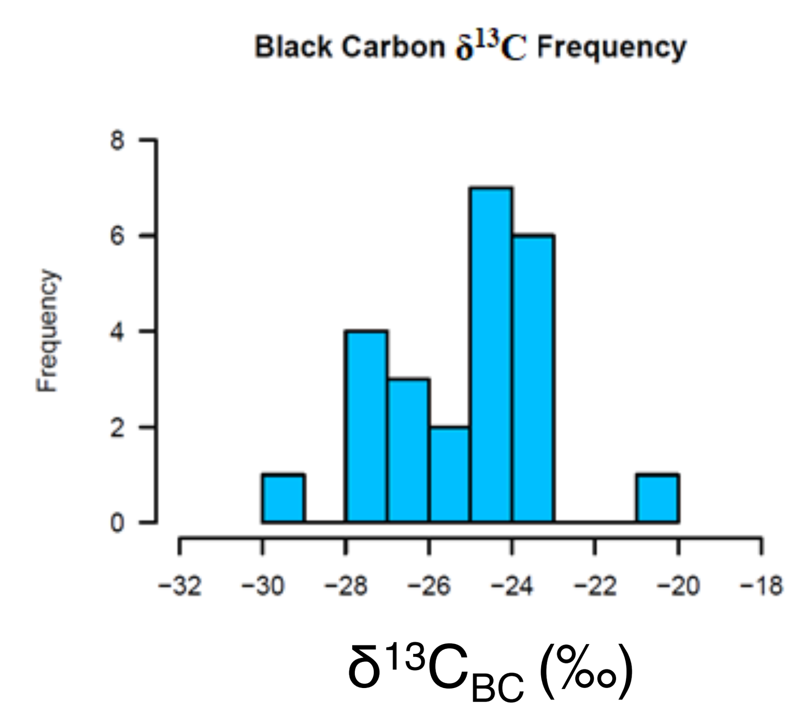


Figure 4: A frequency plot of the $\delta^{13}C_{BC}$ results. The data shows -23 ‰ and -24 ‰ are the most commonly observed values, which falls within the range of gymnosperms.

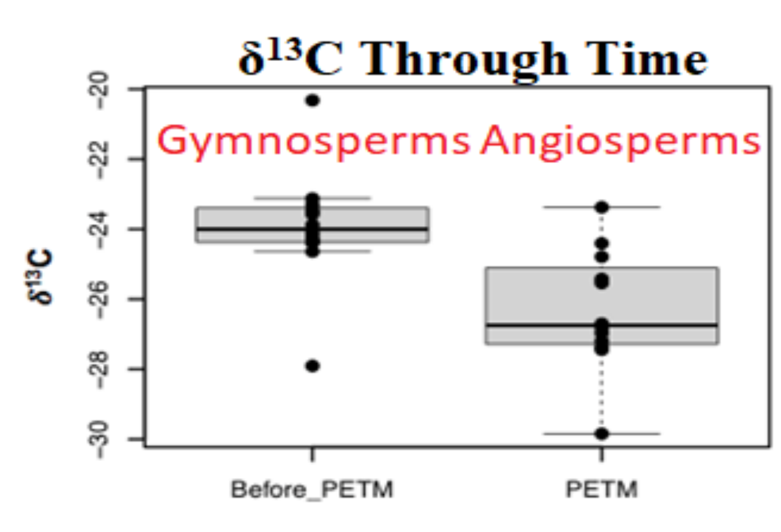


Figure 5: The $\delta^{13}C_{BC}$ distribution. Average values are -24 ‰ for gymnosperms and -27 ‰ for angiosperms, respectively. Black carbon results suggest this could be a transition from gymnosperms to angiosperms.

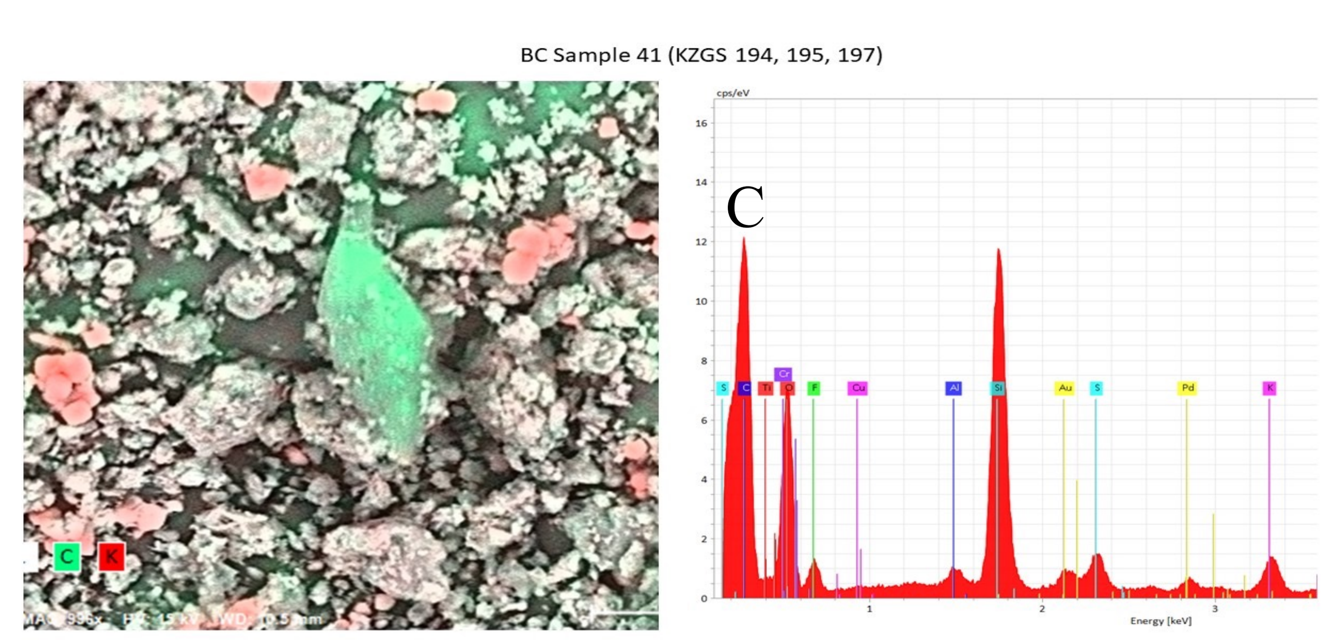


Figure 6: Scanning electron microscope (SEM) image of black carbon, with the green color denoting elemental carbon abundance. The graph to the right is an energy dispersive x-ray spectroscopy (EDS) spectrum of the elements found in the image to the left.

Discussion

- Prior to the PETM, the climate in the eastern Tethys was semi-arid, which likely led to frequent wildfires.
- Using the equations shown in Methods, we find the MAP increased from ~1,100 mm (before the PETM) to ~2,300 mm (during the PETM), which may have caused a larger decrease in $\delta^{13}C_{BC}$ values compared to the $\delta^{13}C_{carb}$ values. Vegetation shift from gymnosperms to angiosperms may also have played a role.
- During wet seasons, angiosperm biomass likely increased, potentially becoming fuel for wildfires in the dry season (Chen et al., 2020).
- Increased humidity may decrease the wildfire frequency, but higher pCO_2 and warmer conditions can create lighting-induced wildfires.
- BC could have then been transported to the eastern Tethys through runoff following wet season.

Conclusions and Future Work

Conclusions

- The eastern Tethys was a semi-arid environment that could have been prone to wildfires in the late Paleocene.
- The PETM changed the hydrologic cycle, delivering more precipitation to the region, potentially causing a vegetation shift.
- Our work can be applied to investigate BC in other paleo applications and infer how modern-day vegetation could respond to shifts in climate.

Future Work

- We plan to finish collecting the rest of the isotope data and are currently looking for more BC using SEM.

Acknowledgements

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References

Chen, Z., Dong, X., Wang, X., Tang, Z., Yang, S., Zhu, M., & Ding, Z. (2020). Spatial change of precipitation in response to the Paleocene-Eocene Thermal Maximum warming in China. Global and Planetary Change, 194, 103313. doi:https://doi.org/10.1016/j.gloplacha.2020.103313

Denis, E. H., Pedentchouk, N., Schouten, S., Pagani, M., & Freeman, K. H. (2017). Fire and ecosystem change in the Arctic across the Paleocene–Eocene Thermal Maximum. Earth and Planetary Science Letters, 467, 149-156. doi:https://doi.org/10.1016/j.epsl.2017.03.021

Moore, E. A., & Kurtz, A. C. (2008). Black carbon in Paleocene–Eocene boundary sediments: A test of biomass combustion as the PETM trigger. Palaeogeography, Palaeoclimatology, Palaeoecology, 267(1), 147-152. doi:https://doi.org/10.1016/j.palaeo.2008.06.010