Supplementary material to

A terrestrial record of atmospheric CO_2 across the Middle Eocene Climatic Optimum

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SUPPLEMENTARY TEXT & FIGURES

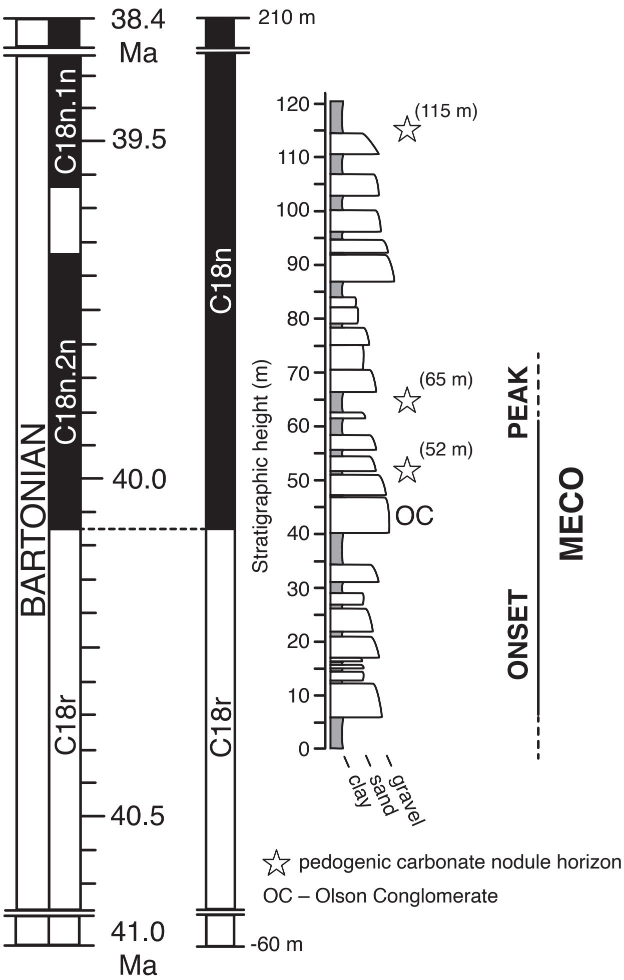

Fig. S1 Stratigraphy of the Olson section. Stratigraphic log showing lithology, magnetostratigraphic framework, age model, and stratigraphic positions of analyzed pedogenic carbonate nodule horizons. The onset and peak of the Middle Eocene Climatic Optimum (MECO) are indicated based on organic carbon isotope data from Sharma et al. (2024).

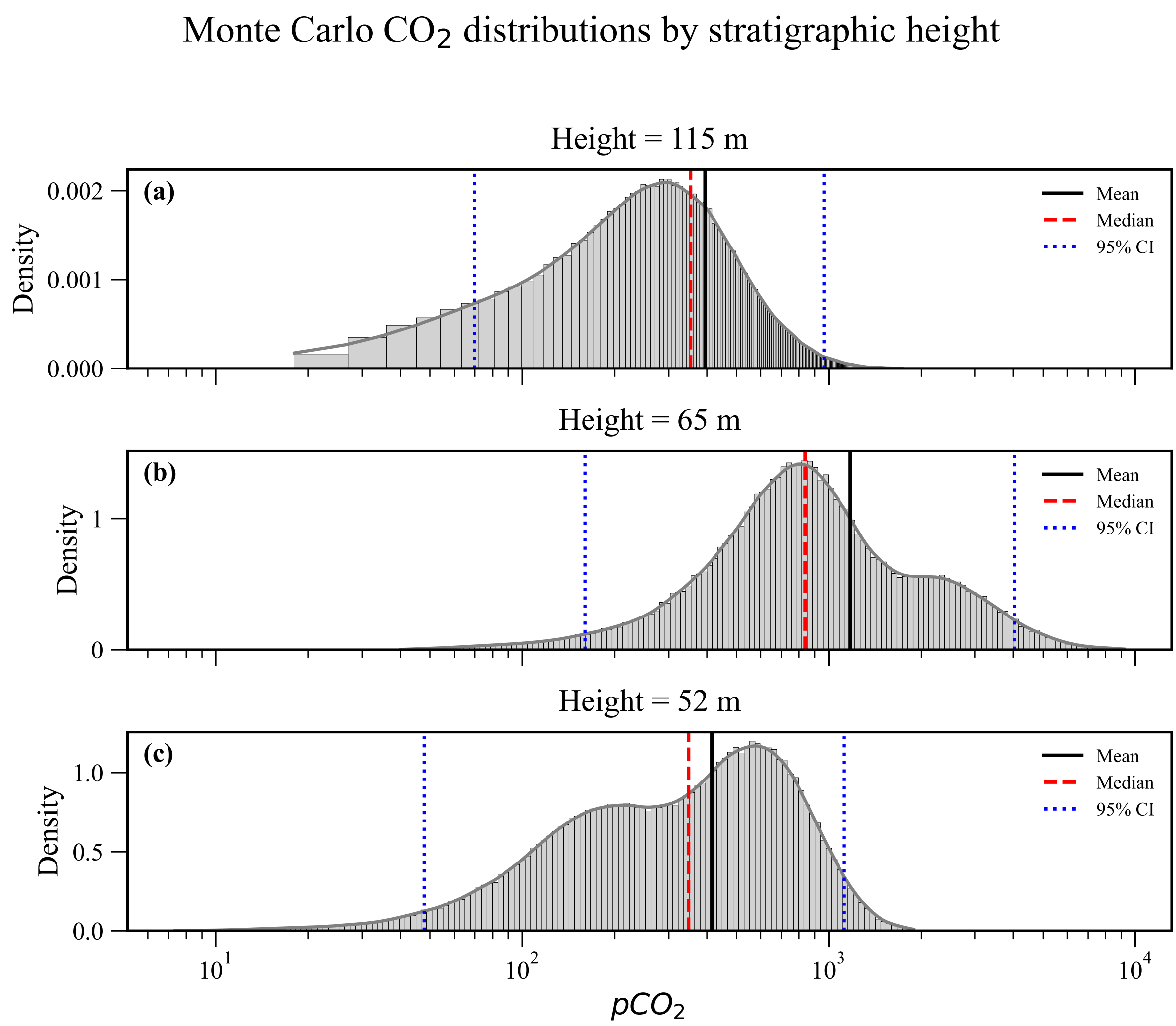

Fig. S2 Monte Carlo distributions of reconstructed atmospheric CO_2 by stratigraphic height in the Olson section. Probability density functions derived from Monte Carlo CO_2 simulations are shown for paleosol carbonate horizons at (a) 115 m, (b) 65 m, and (c) 52 m stratigraphic height. Histograms represent the full ensemble of simulated CO_2 values for each horizon, displayed on a logarithmic CO_2 axis. Vertical black solid lines indicate the mean CO_2 estimate, red dashed lines indicate the median, and blue dotted lines denote the 95% confidence interval of the simulated distributions.

Together, these distributions illustrate both the central tendency and uncertainty structure of CO_2 reconstructions at each stratigraphic level.

For comparison, atmospheric CO_2 was also reconstructed using the formulation of Cotton and Sheldon (2012), which estimates soil-respired CO_2 concentrations (S(z)) from mean annual precipitation (MAP) through an empirical relationship. Application of this approach to the Olson section results in CO_2 estimates that are markedly higher than those derived from the paleosol carbonate CO_2 paleobarometer and exceed reasonable bounds imposed by independent middle Eocene CO_2 records. The obtained values are therefore considered inconsistent with the present study. Moreover, this approach does not perform reliably for weakly developed soils such as Entisols. For paleosol-based CO_2 reconstructions, accurate identification and characterization of soil type are therefore critical.

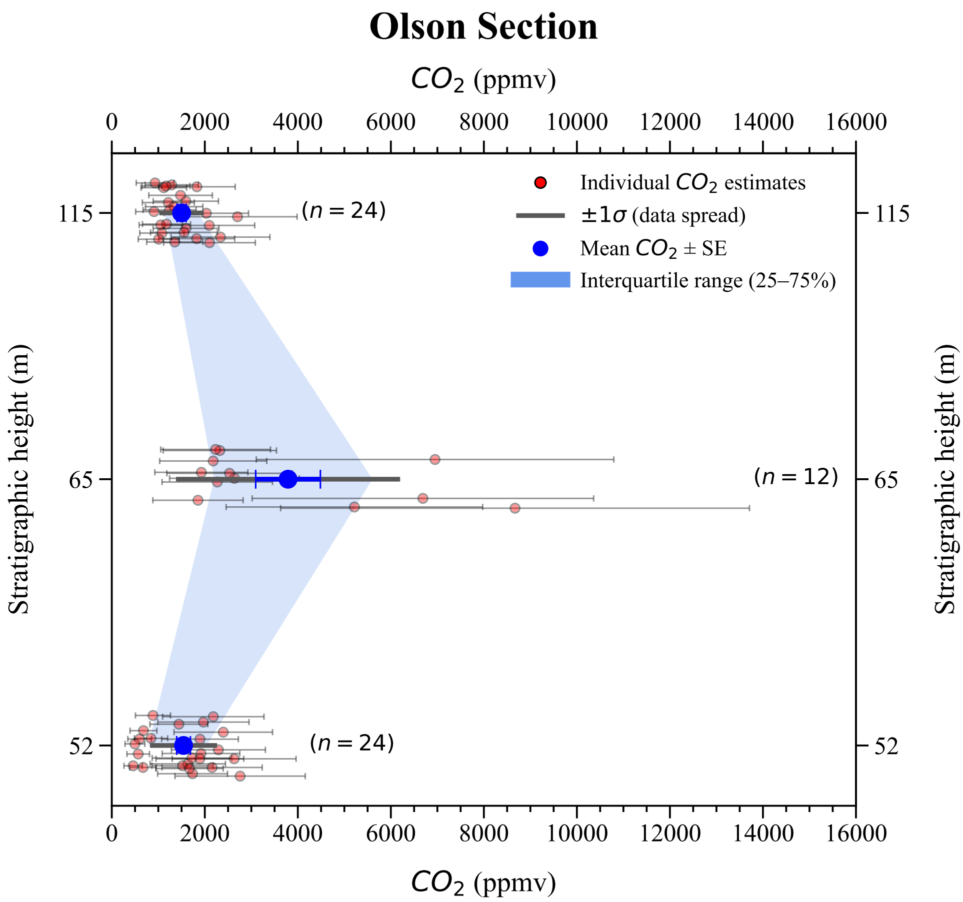

Fig. S3 Atmospheric CO_2 estimates from the Olson section calculated using the Cotton and Sheldon (2012) approach. Atmospheric CO_2 reconstructions derived using the pedogenic carbonate paleobarometer in which soil-respired CO_2 concentrations (S(z)) are estimated from mean annual precipitation (MAP) following the empirical calibration of Cotton and Sheldon (2012). Individual red circles represent CO_2 estimates for each paleosol carbonate sample, with horizontal error bars indicating propagated 1σ uncertainties. Dark horizontal bars denote ±1σ variability (data spread) at each stratigraphic horizon, while blue circles show mean CO_2 values with horizontal bars indicating the standard error of the mean (SE). The shaded blue envelope represents the interquartile range (25–75%) of CO_2 estimates at each stratigraphic level. Numbers in parentheses indicate the number of individual estimates (*n*) per horizon. This approach yields substantially elevated CO_2 values, particularly at the 65 m horizon, and is interpreted to be inconsistent with the weakly developed paleosols examined here.

REFERENCES

1. Sharma, N. et al. Middle Eocene Climatic Optimum (MECO) and its imprint in the continental Escanilla Formation, Spain. Clim. Past 20, 935–949 (2024).
2. Cotton, J. M. & Sheldon, N. D. New constraints on using paleosols to reconstruct atmospheric pCO2. GSA Bull. 124, 1411–1423 (2012).