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Carbon Isotope Evidence for Changes in Cenozoic Mid-Latitude Primary Productivity and Water Use Efficiency

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The carbon isotope composition of pedogenic carbonates ($\delta^{13}C_{carb}$) from paleosols has been extensively used as a proxy to estimate atmospheric pCO$_2$ over the Phanerozoic. Given that atmospheric CO$_2$ has a higher δ^{13}C than soil-respired CO$_2$, higher $\delta^{13}C_{carb}$ should reflect higher atmospheric pCO$_2$. However, a number of other factors—including the concentration of plant-respired CO$_2$ and the isotopic composition of both atmospheric and plant-respired carbon—influence $\delta^{13}C_{carb}$. For example, paleosol $\delta^{13}C_{carb}$ records from the mid-latitudes in central Asia and western North America increase despite decreasing pCO$_2$ during the late Cenozoic, which suggests that other factors play an important role in determining the isotopic composition of pedogenic carbonates. We suggest that these records are primarily recording changes in primary productivity due to changing water use efficiency rather than changes in atmospheric pCO$_2$ and therefore propose a novel use of paleosol carbonate records to understand paleo-ecosystem dynamics.

Here, we use a large database of Cenozoic paleosol $\delta^{13}C_{carb}$ to estimate broad changes in soil respiration and primary productivity in both Asia and western North America. Overall, $\delta^{13}C_{carb}$ in most localities either increases or remains constant, despite large declines in atmospheric pCO$_2$. However, throughout the entire Cenozoic, there is substantial spatial variability in $\delta^{13}C_{carb}$. The long-term increase and/or constancy of $\delta^{13}C_{carb}$ indicates a decrease in plant productivity as atmospheric pCO$_2$ declined, likely reflecting the influence of a reduction in plant CO$_2$ fertilization. The sustained spatial variability reflects the effect of tectonics in altering regional climate and, hence, plant productivity. We estimate changes in water use efficiency by combining independent estimates of paleo-precipitation to estimate how this critical ecosystem parameter changes with variable atmospheric pCO$_2$. These results point to a new method to extract critical paleo-ecosystem characteristics and understand the coupling between climate, hydrology, and terrestrial primary productivity.