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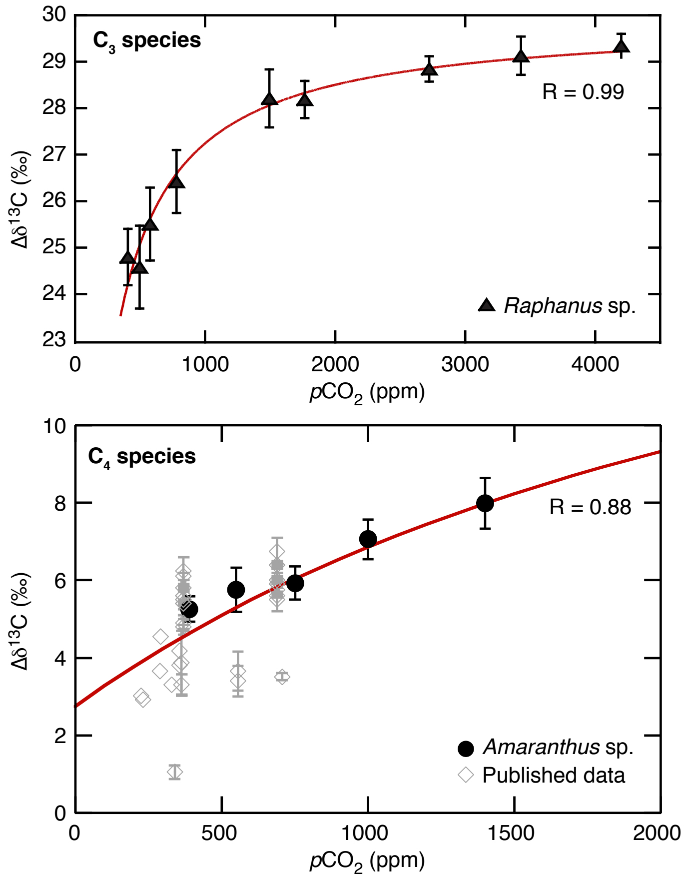
How should we interpret the carbon isotope composition of terrestrial rocks? Insight from controlled plant-growth experiments

A. Hope Jahren[1] and Brian A. Schubert[2]

[1]University of Hawaii, SOEST, Honolulu, HI 96822, USA
[2]University of Louisiana at Lafayette, School of Geosciences, Lafayette, LA 70504, USA

Changes in the carbon isotope composition ($\delta^{13}C$) of terrestrial substrates have been widely observed throughout the geologic record and often coincide with critical transitions such as the Permian-Triassic, the Cretaceous-Tertiary and the Paleocene-Eocene, to name a few. Upon quantification, such changes have been variously interpreted, usually invoking any one of the myriad ways in which the environment exerts control over plant biology. Many environmental parameters have been demonstrated to influence the $\delta^{13}C$ value of plant tissue, using both empirical fieldwork and controlled laboratory experiments. Changes in soil moisture availability and associated water-use efficiency give rise to per-mil scale changes in carbon isotope composition of leaves. Species-to-species variability in $\delta^{13}C$ value is often cited, as differing proportions of plant lipids (especially) may lead to per-mil scale differences between major groups (e.g., angiosperms vs. gymnosperms). This has led several researchers to suggest that perturbations in the carbon isotope record within terrestrial sediments may be interpreted as a change in environmental water availability, or a change in biome distributions, respectively. Atmospheric carbon dioxide is the primary carbon source for photosynthesis and pCO_2 level has been shown to influence multiple aspects of plant functioning, leading workers to hypothesize as early as 1960 that there could be a direct influence of pCO_2 upon the net carbon isotope fractionation between plants and the atmosphere ($\Delta\delta^{13}C$). However, prior to our controlled growth experiments, the magnitude of this response was uncertain. We report here upon multiple growth experiments involving both C_3 and C_4 plants that have quantified the relationship between pCO_2 and $\Delta\delta^{13}C$ across the levels of atmospheric pCO_2 hypothesized for the entire Phanerozoic using previous proxies. Our work has revealed an increase in $\Delta\delta^{13}C$ value within increasing pCO_2 (see Figure), which is quite different for C_3 and C_4 plants reflecting the different role of respiration between the two photosynthetic types. Upon the strength of these relationships, we suggest that changes in the $\delta^{13}C$ of terrestrial organic matter during periods of known carbon cycle disruption are best interpreted as resulting from changes in atmospheric pCO_2. We discuss our ongoing work to further quantify this relationship and describe its mechanism, such that it may be useful as a new terrestrial proxy for ancient pCO_2 levels.



The effect of pCO$_2$ level on carbon isotope fractionation ($\Delta\delta^{13}$C) in C$_3$ (top) and C$_4$ (bottom) land plants. Both plant types show an increase in $\Delta\delta^{13}$C with increasing pCO$_2$, but the shape of the relationship differs. Solid symbols indicate our data.