Fundamental Research on the Fractionation of Carbon Isotopes during Photosynthesis …
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Fundamental Research on the Fractionation of Carbon Isotopes during Photosynthesis: New Interpretations of Terrestrial Organic Carbon within Geologic Substrates Final Report (8/15/14 to 8/14/16)

A Collaborative Proposal:

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The Funded Proposal Described three years of work to quantify how our recognition (quantified during the previous funding period) of pCO_2-dependent changes in plant carbon isotope fractionation affects any interpretation of the rock record. Our overarching goal for the renewal of this work is to produce a unified quantitative approach to the interpretation of carbon isotopes in the terrestrial organic record of the Phanerozoic specific to, and indicative of, the pCO_2 level of the time (Table 1).

Table 1. The five projects proposed, including their objectives and the approaches to be used. The laboratory with primary responsibility for the short-term objectives of the project (i.e., worksite) are designated. However, we note that both P.I.s will be involved with all data analysis, presentation of results, and authorship.

Objective	*Approach*
Project 1 (Jahren Lab): Confirm the hyperbolic relationship between $\Delta\delta^{13}C$* and pCO_2 under subambient values of pCO_2	Experimental growth of *Arabidopsis* across pCO_2 = 200 – 350 ppm compared to an ambient control ($\delta^{13}C$ analysis of leaf tissues and *n*-alkanes)
Project 2 (Schubert Lab): Calculate the potential effect of changing pCO_2 on published terrestrial CIEs	Compare and reconcile the CIE reported for terrestrial *vs.* marine realms by incorporating the isotopic effect of known changes in pCO_2 into the terrestrial signal
Project 3 (Jahren Lab): Quantify the effect of water stress on the $\Delta\delta^{13}C$ of plant tissue grown under elevated pCO_2	Experimental growth of water-stressed *Arabidopsis* across pCO_2 = 700 – 2255 ppm compared to an ambient control ($\delta^{13}C$ analysis of leaf tissues and *n*-alkanes; mRNA microarray and secondary metabolite profiling)
Project 4 (Jahren Lab): Quantify the relationship between $\Delta\delta^{13}C$ in C_4 plant tissues pCO_2 under subambient to elevated values of pCO_2	Experimental growth of C_4 Poaceae species across the entire range of pCO_2 = 200 – 2255 ppm compared to ambient controls ($\delta^{13}C$ analysis of leaf tissues and *n*-alkanes)
Project 5 (Jahren Lab): Develop the $\delta^{13}C$ of fern tissues as a proxy for pCO_2 through the last 400 Ma	Experimental growth of *Pneumatopteris* and *Angiopteris* across pCO_2 = 200 – 2255 ppm compared to an ambient control ($\delta^{13}C$ analysis of leaf tissues, *n*-alkanes and isolated spores)

* $\Delta\delta^{13}C = \delta^{13}C_{CO2} - \delta^{13}C_{plant\ tissue}$

Towards these goals, the following work was performed during the grant period can be summarized as the following:

Results of the Completed Funding Period (2013 – 2016)

The goal for the current grant period (2013 – 2016) was to quantify the effect of changing atmospheric carbon dioxide concentration (pCO_2) on published terrestrial carbon isotope excursion events. This work supported four scientists across multiple career stages, and resulted in 5 published papers. This work resulted in a new geochemical proxy for reconstructing paleo-pCO_2 based upon the carbon isotopic composition ($\delta^{13}C$) of C_3 plant content within terrestrial organic matter and earned the Best University Research Award at the annual DOE/BES Symposium in Gaithersburg, MD. The proxy was validated through excellent agreement with ice core data and then applied to early Paleogene terrestrial organic matter. These analyses together with our new, statistics-based uncertainty analysis of the proxy has set the stage for further research on how the newly quantified pCO_2 effect can be used to interpret changes in terrestrial carbon isotope fractionation in terms of recent pCO_2 rise and climate change using annually resolved tree-ring records. Such an analysis can be used to disentangle the confounding effects of pCO_2 rise and climate change on any long-term, terrestrial carbon isotope record.

Personnel Supported*:

1. A. Hope Jahren, P.I. University of Hawaii: 0.25 months per year
2. Brian A. Schubert, P.I. University of Louisiana: 1 month per year
3. William M. Hagopian, Technician, University of Hawaii: 1 month per year
4. Joshua N. Bostic, Junior Technician, University of Hawaii: 12 months per year

* Salaried personnel only (excludes 4 per-hour undergraduate research assistants)

DOE Supported Publications: Five publications have been generated using work funded by this project during the period of report. An asterisk (*) is used to indicate co-authors that have been salary-supported by DOE funding during the course of the work and/or analysis. Links to PDF are provided.

1. B.A. Schubert* and A.H. Jahren*. 2015. Global increase in plant carbon isotope fractionation following the last glacial maximum caused by increase in atmospheric pCO_2. *Geology*, 43(5): 435-438, DOI: 10.1130/G36467.1. (link to PDF)
2. W.M. Hagopian*, B.A. Schubert* and A.H. Jahren*. 2015. Large-scale plant growth chamber design for elevated pCO_2 and $\delta^{13}C$ studies. *Rapid Communications in Mass Spectrometry,* 29(5): 440-446. (link to PDF)
3. N.C. Arens, A.H. Jahren* and D.C. Kendrick. 2014. Carbon isotope stratigraphy and correlation of plant megafossil localities in the Hell Creek Formation of eastern Montana, USA. *Geological Society of America Special Papers,* 503: 149-171. (link to PDF)

4. B.A. Schubert* and A.H. Jahren*. 2013. Reconciliation of marine and terrestrial carbon isotope excursions based on changing atmospheric CO_2 levels. *Nature Communications,* 4:1653, DOI: 10.1038/ncomms2659. (link to PDF)
5. A.H. Jahren*, B.A. Schubert*, L. Marynowski and J.P. Wilson. 2013. The carbon isotope organic geochemistry of Early Ordovician rocks from the Annascaul Formation, County Kerry. *Irish Journal of Earth Sciences*, 31: 1-12; doi: 10.3318/IJES.2013.31. (link to PDF).