Biomarkers for Terrestrial Plants and Climate

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Organic Carbon Production



>01 .02.03 .05 .1 .2 .3 .5 1 2 3 5 10 15 20 30 50 Ocean: Chlorophyll *a* Concentration (mg/m³) Maximum Land: Normalized Difference Land Vegetation Index

Organic Carbon Preservation

Soils: cold, wet, or both **Sediments:** productive, anoxic, or both



Keil and Mayer, 2014







Alkenone (open) (and GDGT, closed) Temperature Records Capture Long-term Trends



Zhang, Pagani, et al., 2014



Alkenones record phytoplankton ¹³C/¹²C values, which reflect pCO₂



Pagani, 2014

Paleoclimate Climate Sensitivity over long timescales and for different starting climate states

climate senitivity = $\frac{\Delta T}{\Delta PCO_2}$



'Charney' Sensitivity (~3 K/2xCO₂)

Water-vapor, cloud, lapse rate, snow and sea-ice

Rohling et al., 2012 PALEOSENS project Royer, 2016

Paleoclimate studies suggest a higher value, but tend to be marine data focused





Plant Biomarkers and Terrestrial Paleoclimate







Leaf Waxes

Geochemists' favorite biomarkers since the 1960's

Geoffrey Eglinton 1927-2016





Koch and Ensikat, 2008 Ficken et al. 2000

C₃ and C₄ Plants have distinct carbon isotope ratios



Carbon isotope ratio, ‰

Made in the Shade: isotopes reflect woody cover



Fraction woody cover

Cerling et al., 2011

Early human evolution linked to African climatology



Shultz and Maslin, 2013 Maslin et al., 2014

Olduvai Gorge

A. Bassisters

10

Olduvai Gorge, Tanzania





- Alkaline lake
- Volcanic highlands to the southeast
- Lake sediments reveal repeated dry-wet cycles
- Now lifted by tectonics, sediments exposed

Clay Magill









Leaf wax δ¹³C data: vegetation cycles tied to precession insolation cycles

Magill et al., 2013a

Rapid Swings in Vegetation, Lake Levels, and Lake Evaporation





Magill et al., 2013b

Fire Feedbacks Stabilize Grassland Ecology





PAH: Polycyclic Aromatic Hydrocarbons





Shelby Lyons



Christine Doman



Elizabeth Denis



l ime (Ma)

Ancient soil horizon covered by volcanic ash



Scavenger vs. hunter?

Debate is fueled by both cut marks and carnivore damage on fossil bones.





Biomarker Proxies....from Trash to Treasure

Climate sensitivity studies

Biomarkers for marine temperatures and PCO₂

Estimate sensitivity for long timescales, climate states

Terrestrial Biomarkers

Vegetation Dynamics and 3-D Structure

Aridity, Isotope hydrology

Fire Prevalence

Early human habitat variability





(

В

1 km

5

Archaeal GDGTs and TEX₈₆ Paleothermometry



Tierney, 2014 Schouten et al., 2002 Isotope Fractionation During Photosynthesis by Algae:

 $f_2 = \delta_2 / \delta_1$ (demand / supply)



C₃ plants regulate water, CO₂, and isotopes





b745310 [RM] © www.visualphotos.com



Aaron Diefendorf



Diefendorf et al., 2010

Leaf waxes are in marine sediments... everywhere





Alkane Distributions



Pagani, Freeman and Arthur, 2000

Freeman and Colarusso, 2001



Oldest alkenones?



Sediment age, million years

Brassell, 2014





Wavelength of light (nm)

Terrestrial Paleoclimate Proxies

 Vegetation type, structure



Hydrologic patterns



Alkane Abundance and Plant Phylogeny

Diefendorf et al., 2011; 2015

