A NEW APPROACH TO INVESTIGATING PAST VEGETATION REGIMES USING HIGH RESOLUTION LIPID BIOMARKER RECORDS PRESERVED IN STALAGMITES

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Lipid biomarker records in stalagmites are a valuable new tool for palaeoenvironmental research: biomarkers are established proxies for environmental change, while stalagmites provide long, easily datable profiles, protected from post-depositional degradation and disturbance. Combining the two allows high resolution records of terrestrial environmental change to be obtained back to a minimum of 100,000 years BP. Here we present the first high resolution lipid records recovered from stalagmites, and demonstrate that they clearly reflect changes in the overlying vegetation.

PDS-5 is a stalagmite collected from Punta Degli Stretti, a cave on the Tuscan coast that is currently overlain by woodland vegetation. The sample contains a distinct band of heavily laminated calcite that, based upon calcite structure and trace element analyses, represents a major disturbance in the overlying environment. The lipid profile of this band differs distinctly from the rest of the stalagmite. In particular, there is a significant relative increase in vegetational biomarker input (as represented by the CPI2 and ratios of HMW/LMW *n*-fatty acids), and a substantial change in the C_{27}/C_{31} *n*-alkane ratio, and the C_{24}/C_{26} and C_{24}/C_{28} *n*-alkanol ratios. The C_{27}/C_{31} ratio has been proposed as a marker for arboreal vs. herbaceous plants (Marseille et al., 1999), and all three show a switch in chain length dominance from those compounds more associated with woodland vegetation (C_{27} *n*-alkane, C_{24} *n*-alkanol) to those more commonly dominant in grasslands or agricultural land (C_{31} *n*-alkane, C_{26} and C_{28} *n*-alkanols (ibid.; Bull et al., 2000)). We therefore propose that this band represents a decline in the overlying woodland and a period of vegetational clearance.

The hypothesis that these lipid signals are a coherent set of signatures relating to specific environmental changes is strongly supported by samples from the Mechara karst in south-east Ethiopia. These stalagmites were deposited continuously over the past 100 years, a time period which saw considerable changes in the local vegetation regime as the native scrub was cleared to make way for agricultural crops. This change is clearly seen in the lipid signals preserved, with the clearances in the early 20th century being closely mirrored by significant variations in the C_{27}/C_{31} *n*-alkane ratio (changing in favour of C_{31} as agricultural activity increased), and supported by variations in the C_{24}/C_{28} *n*-alkanols, and in the increased input of vegetational material as reflected by relative abundances of HMW *n*-fatty acids. Significantly, while the lipid signal shows a close relationship to the known vegetational history of the area, it records events that are not apparent in established stalagmite proxies such as stable carbon isotopes, demonstrating the value of this new technique.

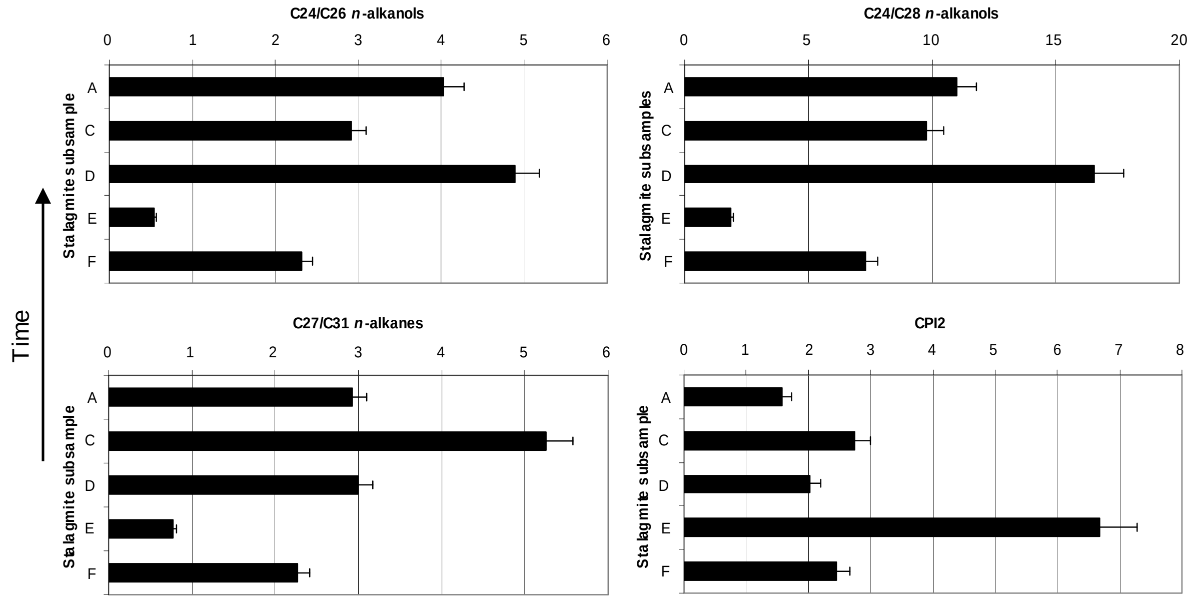

Figure 1. Changes in n-alkane and n-alkanol compositions through PDS-5. Note the significantly decreased ratios and increased CPI2 in band E.

REFERENCES

Bull, I.D., van Bergen, P.F., Nott, C.J., Poulton, P.R., Evershed, R.P. 2000. Organic geochemical studies of soils from the Rothamsted classical experiments – V. The fate of lipids in different long-term experiments. Organic Geochemistry 31, 389-408.

Marseille, F., Disnar, J.R., Guillet, B., Noack, Y. 1999. *n*-Alkanes and free fatty acids in humus and A1 horizons of soils under beech, spruce and grass in the Massif-Central (Mont-Lozère), France. European Journal of Soil Science 50, 433-441.

O81

VEGETATION CHANGES AND WET/ARID PHASES IN THE SOUTHEASTERN AFRICAN TROPICS DURING THE PAST 23,000 YEARS

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Changes in the hydrological cycle have a far greater impact on human welfare in tropical Africa than does the relatively small range of temperature variability. Therefore, understanding the timing of past arid and wet phases in low-latitude regions is critical to understanding human and faunal migrations as well as the role and response of the tropics in global climate change. Here, we examine the record of plant leaf wax (*n*-alkane) carbon isotopes and lignin phenols from a well-dated Lake Malawi sediment core in order to examine vegetation changes in southeastern Africa since the Last Glacial Maximum (LGM). Tropical vegetation is a sensitive indicator of aridity and its distribution is mainly controlled by precipitation, which, in tropical East Africa, is influenced by the position and seasonal migration of the Intertropical Convergence Zone (ITCZ). Plants utilizing the C_4 photosynthetic pathway are characterized by higher water use efficiency than C_3 plants, and are common today in tropical savannahs, temperate grasslands, and in semi-arid regions. As aridity is recognized as the dominant control on the large-scale distribution of C_3 versus C_4 vegetation in tropical Africa (Schefuβ et al., 2003), changes in aridity can be examined by determining the past distribution of C_3 versus C_4 vegetation.

Results of this study show that cinnamyl to vanillyl (C/V) ratios of lignin phenols, used to distinguish between inputs of non-woody vs. woody vegetation (Goñi and Hedges, 1992), correlate closely with *n*-alkane $\delta^{13}C$ values in Lake Malawi. Higher C/V ratios are noted when *n*-alkane $\delta^{13}C$ values are heavier, thus indicating increased inputs of non-woody C_4 grass tissues. Peak wet phases in southeastern Africa occurred at 13.6 and 4.9 cal ka, while arid phases are noted during the LGM (23-18 cal ka), the Younger Dryas (12.9-11.9 cal ka), in the early Holocene (10-7.7 cal ka) and during the Little Ice Age (1700-1880 AD).

When compared ice core methane records from Antarctica and Greenland (Brook et al., 2000), indicative of global tropical wetness, we find wet/arid phases in the southeastern

African tropics closely paralleling high latitude ice core methane records from the Last Glacial Maximim (LGM) until ~11 cal ka (Figure 1). At the start of the Holocene this in-phase relationship abruptly deteriorates and a generally anti-phase relationship prevails, with dry conditions at Lake Malawi correlating with wet conditions in equatorial and northern Africa. The abrupt switching of the dominant mechanisms controlling aridity is likely related to a change in the mean latitudinal position of the ITCZ during the last glacial, as southward displacements occur during northern hemisphere cold periods (Broccoli et al., 2006). Following northern hemisphere ice sheet retreat, the influence of precessional variability in summer insolation on moisture availability in the southern tropics became relatively more important, and anti-phased with the northern African tropics.

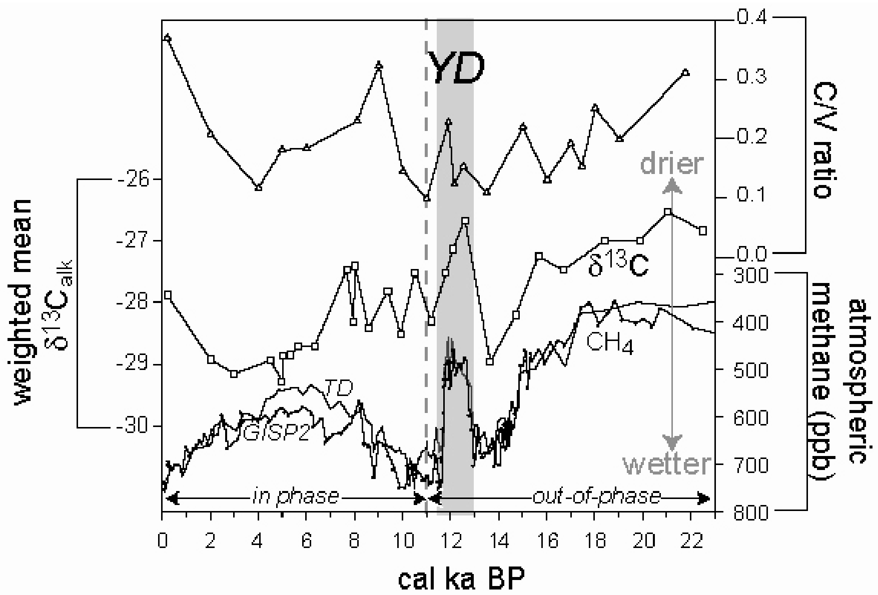

Figure 1. Lake Malawi *n*-alkane $\delta^{13}C$ (the weighted mean of the C_{27}-C_{31} *n*-alkanes) and lignin phenol C/V ratios compared to the Greenland (GISP2) and Antarctica (Taylor Dome) atmospheric methane records (CH_4 data from Brook et al., 2000). The Younger Dryas (YD) cold period is indicated by the grey shading.

REFERENCES

Broccoli, A.J., Dahl, K.A, and Stouffer, R.J., (2006) Response of the ITCZ to Northern Hemisphere cooling. *Geophysical Research Letters*, 33, L01702.

Brook, E.J, Harder, S., Severinghouse, S., Steig, E.J., and Sucher, C.M., (2000) On the origin and timing of rapid changes in atmospheric methane during the last glacial period. *Global Biogeochemical Cycles*, 14, 559-572.

Goñi, M.A., and Hedges, J.I., (1992) Lignin dimers: structures, distribution, and potential geochemical applications. *Geochimica et Cosmochimica Acta*, 56, 4025–4043.

Schefuβ, E., Schouten, S., Jansen, J.H.F., Sinninghe Damsté, J.S., (2003) African vegetation controlled by tropical sea surface temperatures in the mid-Pleistocene period. *Nature*, 422, 418-421.

CONTINENTAL CLIMATE CHANGE IN TROPICAL AFRICA SINCE THE LAST GLACIAL: ORGANIC PROXY RECORDS FROM THE MT. KILIMANJARO AREA

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Climate-proxy records from across Africa and Asia underscore the fact that tropical climates have been anything but stable during the late Quaternary, but the regional synchrony and extra-tropical links of late-Glacial and Holocene moisture-balance variations remain uncertain because of the lack of complete, highly-resolved continental archives with good age control from the Equator. Also contentious is to what extent reconstructed lake-level fluctuations, and oxygen-isotope signatures in tropical archives such as glacier ice and fossil diatoms, mostly reflect variations in rainfall and drought, or also of temperature and its effect on evaporation. The EuroCLIMATE project CHALLACEA aims to answer some of these questions by reconstructing -with excellent time resolution and age control- a continuous 25-kyr history of temperature and moisture-balance variation in equatorial East Africa from the sediment record of Lake Challa, a 4.2 km^2, 92 m deep crater lake on the lower East slope (altitude ca. 880 m) of Mt. Kilimanjaro. This freshwater lake has a permanently stratified water column and its water budget is controlled by subsurface in- and outflow. Three parallel piston-core profiles of 20 to 22 m length consist of banded to finely laminated sediments intercalated with some homogenous sections, from which a 21.65 m long continuous composite profile was constructed which was dated using 34 AMS ^{14}C measurements.

We applied the TEX_{86} proxy for lake surface-water temperature based on fossilized crenarchaeotal membrane lipids[1]. A centennial record for lake temperature of the past 25 kyr was obtained: TEX_{86} values ranged from 0.48 during the Last Glacial Maximum (LGM) to 0.78 at the end of the Holocene, with a distinct warming phase between 19 and 8 kyr ago (Fig. 1). With the TEX_{86} calibration for large lakes[2], this translates into a warming from ca. 14 ºC at the LGM to 31 ºC in the Holocene. Core-top sediments give TEX_{86} temperatures of 28-30 ºC, slightly above the peak (stratified-season) lake surface temperature of 27.5 ºC. The low temperatures at the LGM are somewhat surprising, but are possibly related to the greater regional influence of the Kilimanjaro ice cap, which at the LGM reached down to ca. 3500 m altitude on the south-east slope. Terrestrial organic matter input had a distinct effect on the TEX_{86} values as archaeal lipids from soils interfered with lipids produced in the lake. This is evident from the Branched and Isoprenoid Tetraether (BIT) index[3], which is high when the amount of soil-derived branched tetraethers is high (Fig. 1). High BIT indices (>0.60) occur particularly during the 14-8.5 kyr interval except for the Younger Dryas episode when BIT values fall back to those during the last Glacial. This probably indicates a period of extensive input of soil-derived organic matter into the lake associated with greater sub-surface inflow during wetter conditions. The high-resolution record of $\delta^{13}C_{org}$ indicates a rapid shift towards more ^{13}C-depleted values between 16 and 15 kyr (Fig. 1). Compound-specific isotopes of the C_{31} *n*-alkane suggest that this sudden shift is probably related to a rapid change in vegetation cover from dominance of C_4-grasses towards a greater component of C_3 plants as a response to more humid conditions. We are currently performing δD measurements on the *n*-alkanes to reconstruct changes in humidity.

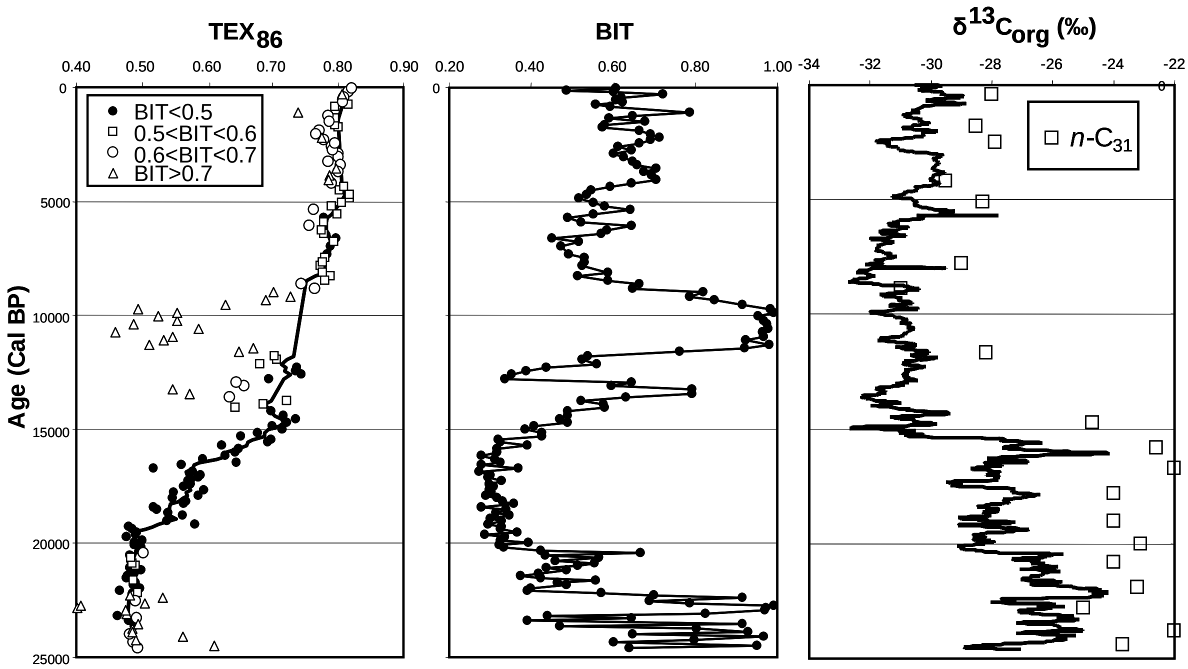

Figure 1. Sedimentary record of TEX_{86}, BIT and $\delta^{13}C_{org}$ of Lake Challa. The solid line in the TEX_{86} plot represents the 5-point moving average for data points with BIT<0.6. $\delta^{13}C$ values of the n-C_{31} alkane are plotted in the $\delta^{13}C_{org}$ plot. The solid line represents the 5-point moving average of $\delta^{13}C_{org}$.

REFERENCES

1. Schouten S.et al. (2002) Earth Planet. Sci. Lett. 204, 265-274.
2. Powers L. A. et al. (2005) Geophys. Res. Lett. 32, L08706-10.1029/2004GL022014.
3. Weijers J.W.H. et al. (2006) Org. Geochem. 37, 1680-1693.