Goldschmidt 2000
September 3rd–8th, 2000
Oxford, UK.

Journal of Conference Abstracts
Volume 5(2), 886

The mid-Pleistocene Climate Transition: Insight from Organic Geochemical Records from the Tropical Atlantic

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The mid-Pleistocene climate transition (MPT, 950-650 ka BP) led to the development of the Late Pleistocene ice ages with large swings in ice-volume, occurring every 100 ka. Before 950 ka BP, ice-volume was dominated by the obliquity cycle (41 ka) with lower amplitude changes. The mean ice-volume increased from 950 to 890 ka BP, the 100 ka cycle (eccentricity), however, did not become significant before 725 ka BP and was fully established only around 650 ka BP (Mudelsee & Schulz, 1997). A global vegetation change associated with the MPT has been suggested (Raymo et al., 1997). However, cause and effects of the transition are not yet understood. ODP Site 1077, drilled below the low-salinity-plume of the Congo River, recovered the entire Pleistocene. The ocean area off the Congo constitutes an ideal setting to monitor palaeo-environmental changes associated with the MPT in the tropical Atlantic and equatorial Africa. The sedimentary organic matter is derived from marine production and riverine input of terrestrial plant matter from the catchment area of the Congo River (> 3.5 * 10^6 km^2). We investigated the time interval from 1.2 Ma to 600 ka BP, with bulk and molecular organic geochemical techniques. The aim is to explore the effects of the MPT on marine production and terrestrial vegetation. Alkenone derived sea surface temperatures (SST) show high frequency variations, forced by the precessional cycle (23 ka). A first significant cooling occurred already in marine isotope stage (MIS) 30, about one eccentricity cycle before onset of the MPT. Low SST, comparable to the last glacial maximum, are recorded for MIS 24. During MIS 22, precessional variability of SST is suppressed, possibly caused by increased aridity. Total organic carbon contents (TOC) vary between 0.8 and 3.3%, with elevated values during times of lowered SST. Higher TOC may thus have been derived from enhanced marine productivity due to coastal upwelling of cold, nutrient-rich waters. Stable carbon isotopic compositions of TOC ($\delta^{13}C_{TOC}$) generally follow the TOC values, being elevated in cold periods. $\delta^{13}C_{TOC}$ values range between -23.3 and -16.6‰ vs. VPDB, with heaviest values occurring during MIS 22. Enhanced accumulation of marine organic matter may be responsible for the isotopic maxima in cold periods. Additionally, terrestrial vegetation changes from C_3 plants to C_4 plants could have contributed to the variations. Accumulation of long-chain alkenones is connected with coastal upwelling events, haptophyte blooms occurring during precessional monsoon minima with lowered river discharge (Schneider et al., 1997). Highest concentrations are reached when monsoon minima co-occur with minima in eccentricity, when trade winds are more meridional. The cooling event at MIS 30, however, is not accompanied by elevated alkenone accumulation, pointing to a suppressed coastal upwelling by higher river discharge. Loliolide is a degradation product of fucoxanthin, the main carotenoid in diatoms (Klok et al., 1984). In the present river plume, diatoms bloom mainly during increased silicate supply with higher freshwater discharge. Therefore, elevated concentrations of loliolide should only occur during monsoon maxima. However, from MIS 30 to MIS 26 loliolide concentrations show generally elevated values, suggesting unusually high humidity during that time. The long-chain n-alkanes are derived from leaf-waxes of terrestrial plants. Their stable carbon isotopic composition depends on the type of photosynthetic carbon fixation and can reveal vegetation changes. $\delta^{13}C$ values of the C_{29} n-alkane range between -35.7 and -27.8‰ vs. VPDB. Minor variations relate to precessional cycles, but a strong increase can be detected during MIS 24 and 22, indicating a significant expansion of C_4 photosynthesis. The heavy $\delta^{13}C_{TOC}$ values during MIS 24 and 22 can therefore, at least for some part, be ascribed to a terrestrial vegetation change. C_4 plants show a more efficient use of water and CO_2 than C_3 plants. The increase in C_4 photosynthesis during the onset of the MPT can thus be explained by higher aridity in tropical Africa and/or decreased atmospheric CO_2 levels. Preceding the onset of the MPT, a sequence of events could be detected: A first significant cooling occurred during MIS 30, followed by an unusually humid period. From MIS 24 on, glacial aridity increased, probably associated by a decrease of pCO_2 during the build-up of extra ice. Terrestrial vegetation in tropical Africa changed, but returned to previous conditions after MIS 22.

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