Geophysical Research Abstracts,
Vol. 11, EGU2009-4477, 2009
EGU General Assembly 2009

Southeast Atlantic upwelling intensity changes influencing late Miocene C4 plant expansion?

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The Late Miocene epoch (about 15 to 5 Myrs BP) is characterised by fundamental changes in Earth's climate system: turnovers in marine and terrestrial biota, sea-level variability, changes in surface- und deep-water circulations, and increase in upwelling intensities along the coasts [1,2]. During the transition period the Antarctic ice sheets expanded and were permanently established, while additionally ice volumes began to fluctuate [1]. Plants acting with the C_4 concentrating mechanism of CO_2 fixation for photosynthesis expanded nearly simultaneous at different places in the world, whereas the global CO_2 levels exhibit no corresponding change [1,3]. However, C_4 plants are also known to have a competitive advantage in habitats of higher temperature, light and fire intensities as well as of limited water supply, compared to the almost ubiquitous C_3 plants. This study tries to give insights to Miocene climatic conditions in Southwest Africa and how these conditions may be linked to the C_4 plant expansion.

We focused on data from a sediment core of the Ocean Drilling Program (Leg 175, ODP 1085A), which span about 10 Myrs of the late Miocene. The core is situated in the Cape basin at the south-western African continental margin in the upwelling zone of the Benguela coastal current. The current brings cold, nutrient-rich waters from South Atlantic and the Antarctic circumpolar current to the surface water along the coast of Southwest Africa. Miocene sea surface temperatures (SST) were reconstructed by two indices, tetraether index (TEX_{86}) and an alkenone based index ($U^{K'}_{37}$). Both trends exhibit a shift to cooler temperatures from around 27 to 18˚C, but are different in rate and timing. Especially by TEX_{86} reconstructed SSTs exhibit a similar trend as found for ice volume changes shown by the $\delta^{18}O$ curve [4]. These findings may reflect an intensification of the Benguela upwelling current during the late Miocene, probably in association with the formation of West Antarctic ice sheet. The increased upwelling enhances the marine primary production shown by a small overall shift in the total organic carbon (TOC) content ($<1\%$).

Terrestrial organic material is supplied to Cape basin by the Orange River and by airborne dust. The branched and isoprenoid tetraether (BIT) index correlates with the relative fluvial input of terrestrial organic material delivered to the ocean. The decline in BIT to almost negligible levels (<0.1) indicates a decrease in river runoff and continental humidity and/or an increase of upwelling, eliminating the river discharge contribution to the studied sediments. The C_4 plant contribution to the vegetation is ascertainable by stable carbon isotopic composition of sedimentary wax $n$alkanes ($\delta^{13}C_{WMA27-33}$). The shift to heavier values indicates an increased contribution of C_4 plants to the continental vegetation.

Upwelling supported cold SSTs are linked with continent to ocean heat transfer, which favours an increase in aridity on the adjacent continent. It is believed that these conditions enhance biomass burning driving the Miocene C_4 plant expansion on continents [5], probably driven by climatic changes due to the formation of polar ice sheet.

References

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