A stable carbon isotopic record of climatic change from a tropical mountain ecosystem in Colombia

A. Boom — Hugo de Vries-laboratory, Dept of Palynology and Paleo/Actuo-ecology, University of Amsterdam, Kruislaan 318, 1098 SM Amsterdam, Netherlands Centre for Geo-ecological Research (ICG)
Netherlands Institute for Sea Research, (NIOZ), Dept of Marine Biogeochemistry and Toxicology, P.O. Box 59, 1790 AB Den Burg, The Netherlands
FOM Institute for Atomic and Molecular Physics, Kruislaan 407, 1098 SJ Amsterdam, the Netherlands

S. Schouten
J. S. Sinninghe Damsté
J. W. de Leeuw — Netherlands Institute for Sea Research, (NIOZ), Dept of Marine Biogeochemistry and Toxicology, P.O. Box 59, 1790 AB Den Burg, The Netherlands

J. J. Boon — FOM Institute for Atomic and Molecular Physics, Kruislaan 407, 1098 SJ Amsterdam, the Netherlands

H. Hooghiemstra — Hugo de Vries-laboratory, Dept of Palynology and Paleo/Actuo-ecology, University of Amsterdam, Kruislaan 318, 1098 SM Amsterdam, Netherlands Centre for Geo-ecological Research (ICG)

The altitudinal position of the highplain of Bogotá at 2550 m elevation renders its unique archive in the lake sediments sensitive to past climatic change. At present the upper forest line lies at 3200 meters, but during glacial time, it descended to around 2000–1800 m Above the forest line lies the paramo, a vegetation belt dominated by grasses and shrubs. Palynological studies of a 568-m long core, taken in the centre of this large drained lake, resulted in a pollen record showing changes in climate and vegetation during the last 3.2 million years.

Here we present organic geochemical data from this core Funza II that give new insights into the regional climatic history. Bulk analyses of the total organic carbon (TOC) and irmGC-MS analyses of the lipids, show significant isotopic excursions. The excursions of the *n*-alkanes, derived from leaf-wax lipids follow similar trends with $\delta^{13}C$ values ranging from −30 to −12‰ (e.g. Fig. 1). These isotopic excursions of terrestrial signals can be interpreted as shifts in terrestrial plant composition from C_3 to C_4 dominated ecosystems. C_4-Ecosystems mainly include grasses that are highly adapted to aridity or severely CO_2-stressed environments, while C_3 ecosystems usually consist of trees and other grasses that are less adapted to environmental stress. At present, C_4 ecosystems are mainly found in tropical savannahs or water stressed environments. The grass paramo that is found above the forest line of today is completely dominated by C_3 grasses. This implies that previous reconstructions of the vegetation within glacial times need to be revised. The paramo as we know it today, did not, descended to lower altitudes. More likely is that the C_4 savannah now occurring at altitudes below that of the Andean forest, triggered by the glacial low pCO_2 situation, actually started to colonise higher altitudes and out competed the C_3 grasses of the paramo.

The aquatic ecosystem also responded to climatic changes by changing fractionation effects towards ^{13}C. Octahydrobotryococcene and mono cyclic botryococcenes, biomarkers for *Botryococcus braunii* algae have extremely heavy $\delta^{13}C$ values up to +5‰. Such high values can only be explained when bicarbonate is assimilated without any significant fractionation by the algae. Possibly, at some stages dissolved CO_2 was not available to the algae while bicarbonate still was. Isotopically heavy mono cyclic botryococcenes have also been found. The timing of these events fall in glacial intervals, an explanation for this phenomena would be that the lake had started to dry out and experienced increasing alkaline conditions possibly due decreased rainfalls during glacial times. This combined with the low

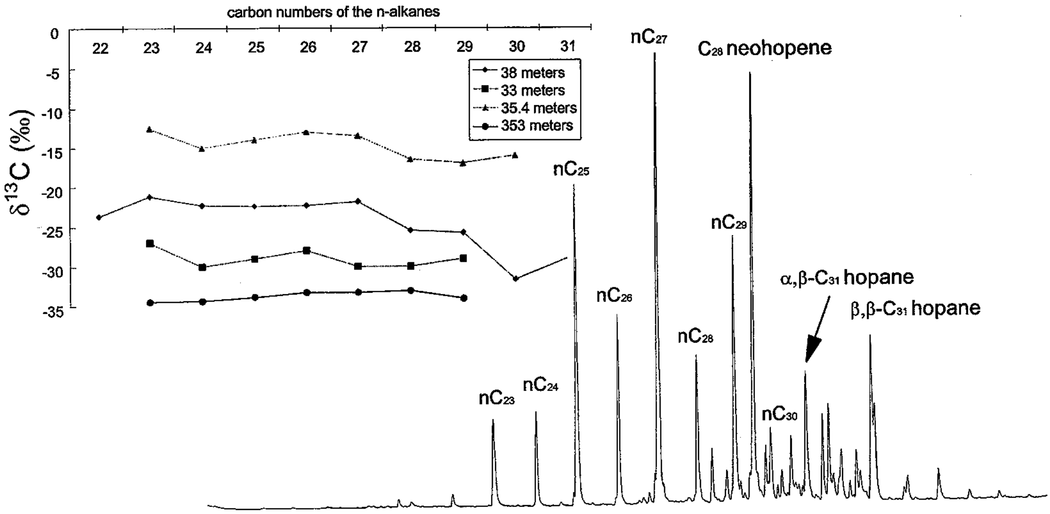

FIG. 1. Chromatogram from the apolar fraction of the 38 m depth sample, with predominant *n*-alkanes. The inset shows their $\delta^{13}C$ values (diamonds) and those of *n*-alkanes present in other samples. Samples of 35.4 and 353 meters depth represent end members, where terrestrial alkanes are mainly derived from C4 and C3 plants, respectively.

atmospheric pCO_2, would make dissolved CO_2 virtually unavailable for the algae. The terrestrial ecosystem would respond to this increasing aridity by favouring even more C_4 grasses on the land. The shallow parts of the lake could at some stages be colonised by C_4 sedges.

Thus the stable carbon isotope record of this tropical mountain ecosystem shows changes that can be related to climatic change and suggests an increased aridity during glaciations and reflects decreases in atmospheric pCO_2. It also shows that C_4 grasses are able to compete with C_3 grasses at lower temperatures while under low pCO_2. It may be possible to make estimations of the palaeotemperature when evaluating the $\delta^{13}C$ values of the *n*-alkanes. These temperature estimations will result in less drastic glacial cooling of this tropical area than previously thought and will correlate better with palaeo-oceanographical derived temperatures.