Latitudinal shifts of forest and savanna in N. W. Africa during the Brunhes chron: further marine palynological results from site M 16415 (9°N 19°W)

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Abstract. Palynological data of the marine core M 16415-2 show latitudinal shifts of the northern fringe of the tropical rain forest in north-west Africa during the last 700 ka. Savanna and dry open forest expanded southwards and tropical rain forest expanded northwards during dry and humid periods, respectively. Until 220 ka B.P., the tropical rain forest probably kept its zonal character in West Africa during glacials and interglacials. It is only during the last two glacial periods that the rain forest possibly fragmented into refugia. Throughout the Brunhes chron, pollen and spore transport was mainly by trade winds.

Key words: Marine palynology - Tropical rain forest - North-west Africa - Brunhes chron

Introduction

For over 15 years, deep-sea sediments from the Atlantic Ocean off the N.W. African coast have been studied palynologically. As a result, data are available from core stations between 33° and 8°N and surface sediment samples ranging from 35°N to 3°S (Agwu and Beug 1982; Hooghiemstra 1986; Hooghiemstra et al. 1986, 1992; Dupont et al. 1989; Dupont and Agwu 1991). Hooghiemstra and Agwu (1988) published the results from 0.5-2.4 m of core M 16415-2 at 9°N covering about 70 to 140 ka BP. This study, in combination with time-slice and transect studies (Hooghiemstra et al. 1986, 1987; Hooghiemstra 1988, 1989), demonstrated the importance of the trade-wind transport in determining the pollen content in sediments at site M 16415-2 and the possibility of deducing shifts in the vegetational zones on the adjacent continent from the marine palynological data. Although poor in pollen, the material was considered promising enough to extend the palynological analysis to the rest of the core, which is over 10 m long and spans the Brunhes chron.

The interpretation of the palynological results is based on the representation of palynomorphs in modern marine sediments (Hooghiemstra and Agwu 1986; Hooghiemstra et al. 1986; Dupont and Agwu 1991) in combination with time-slice studies for the Holocene optimum at 9 ka B.P. and the glacial maximum at 18 ka B.P. (Hooghiemstra et al. 1987; Hooghiemstra 1988). The time-scale of the core (Table 1) is based on the studies by Pflaumann (1986) on the oxygen-isotope stratigraphy and adjusted by Winn et al. (1991). The paper attempts to reconstruct the latitudinal distribution of the savanna and dry open forest and the tropical forest for the last 700 ka.

Table 1. Age-depth relationship used in constructing the linear time-scale

<table>
<thead>
<tr>
<th>Base of isotope stage</th>
<th>SPECMAP age (ka B.P.)</th>
<th>Depth at Site M 16415 (cm)</th>
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<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>24</td>
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<tr>
<td>2</td>
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<td>4</td>
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<td>5</td>
<td>130</td>
<td>176</td>
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<td>6</td>
<td>189</td>
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<td>9</td>
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<td>10</td>
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<td>15</td>
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<td>877</td>
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<tr>
<td>16</td>
<td>659</td>
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<td>970</td>
</tr>
<tr>
<td>18</td>
<td>726</td>
<td>1020</td>
</tr>
</tbody>
</table>

The time-scales above and below the hiatus are after Winn et al. (1991) and Pflaumann (1986), respectively. The Brunhes-Matuyama boundary was recorded in site M 16415 at 1035 cm (Pflaumann 1986).

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Materials and methods

Meteor Site M 16415 is located at 9°34'N, 19°05'W, at the eastern side of the Kane Gap in 3851 m of water. Sediments in this area show alternating layers of brown to brownish-grey nanofossil ooze, calcareous ooze with diatoms and radiolaria, and black-grey to olive clay-ooze. M 16415-2 is a 13-m-long gravity piston core covering the Brunhes chron (Sarnthein et al. 1983; Pflaumann 1986). The position of the oxygen isotope stage boundaries in M 16415-2 were determined by Pflaumann (1986) and Winn et al. (1991). These stage boundaries were set on the SPECMAP time-scale (Imbrie et al. 1984; Martinson et al. 1987). An alternative calibration of time-scale below isotope stage 16 (older than 620 ka BP) as proposed by Shackleton et al. (1990) would stretch the lower part of the diagram by 50 ka. The chronology that may attach to the lowermost part of the profile does not, however, affect the conclusions reached here.

Core M 16415-2 has been sampled at irregular sample intervals varying from 3 to 10 cm, with the aim of achieving a time resolution of ca. 5000 years or higher especially in the upper part. Samples of ca. 25 cm³ have been prepared with HCL, HF, acetylsis and ultrasonic separation (10 µm). To calculate concentration values, sample volume was measured using water displacement and tablets with the exotic, Lycopodium, were added. Samples were completely analysed, resulting in widely ranging total counts. Percentages are only calculated if the total exceeded 50 pollen and spores. Samples from the upper 7.5 m were analysed by C.O.C. Agwu, those from 7.5-10.5 m by L.M. Dupont. Dupont also analysed the samples at 239-250, 366-394, 591-593, 618-634, and 730-740 cm. H. Hooghiemstra analysed the samples between 28 and 59 cm. A list of identified palynomorphs is given in Appendix I and concentration values of selected taxa/groups of taxa are given in Appendix 2.

Data are expressed as percentages of the total pollen sum, as concentrations per cm³ (Appendix 2), and as total influx of pollen and spores on a log scale. Spectral analysis was carried out using CROSPEC developed by SPECMAP (cf. Jenkins and Watts 1968; Imbrie et al. 1984). Cross-spectral analysis has been carried out on 132 spectra between 72 and 727 ka B.P. that have been linearly interpolated at 5 ka. From the influx curve of the fern spores and the pollen influx curves of Elaeis and Crossopteryx, mean and linear trend were removed. Frequencies were scanned from 0.001 to 0.06 with a step of 0.001 using a bandwidth of 0.004 (60 lags). The level for the confidence interval was 80%.

Outlines of interpretation

Eolian and fluvial transport regimes permit the areas of marine pollen deposition to be correlated with the pollen source areas on the continent (Hooghiemstra et al. 1986; Dupont and Agwu 1991). However, the deep-sea offshore position of site M 16415 (Fig. 1) limits fluvial transport of palynomorphs to this site, leaving wind as the main transport mechanism of pollen and spores. As 9°N is well south of the trajectory of the African Easterly Jet, palynomorphs from the continent reach the site mainly by means of trade-wind transport (cf. Hooghiemstra and Agwu 1988; Hooghiemstra 1989). Due to the formation of aggregates (faecal pellets and marine snow; Fowler and Knauer 1986), pollen grains settle within a few weeks through the water column, and their atmospheric distribution over the ocean is reflected in the marine sediments (cf. Melia 1984).

While grasses and most temperate trees depend on wind pollination and thus produce large amounts of well-dispersed pollen grains, almost all trees of the tropical forests are entomophilous and produce low amounts of pollen grains that are often sticky. These features do not favour dispersal by wind. Trees of the tropical forest are, therefore, severely under-represented in marine sediments and only partly suitable as tracers of the latitudinal distribution of the tropical forest. Although, at present, the northern fringe of the tropical forest reaches about 10°N, the sum of Sudanian or of Guinean pollen grains hardly exceeds 5% in modern marine sediments from these latitudes. Better tracers of the tropical rain forest are fern spores, their representation in modern marine sediments rising steeply from 30% to 50% between 10° and 9°N, reflecting the northern distri-