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Timing of vegetation changes at the end of the Holocene Humid Period in desert areas at the northern edge of the Atlantic and Indian monsoon systems

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Abstract

This article aims at discussing the ecological response of the terrestrial and fresh water dependant environments to the installation of arid conditions at the end of the Holocene Humid Period in the Atlantic and Indian monsoon domains. It is mainly focused on dry environments from Chad, Oman and Pakistan where new, high-resolution pollen sequences have been provided. Pollen data show that local hydrological conditions have played a major role in the destruction or survival of tropical tree populations at the end of the Holocene Humid Period, as well as partly explaining the asynchronous pattern of recorded environmental changes in most tropical regions. In desert areas, the response of the fresh water dependant systems to the shift from humid to arid climate conditions appears to have followed a threshold-like pattern. In contrast, terrestrial ecosystems have gradually adapted to increased drought, as shown by the progressive decrease of tropical tree species at Yoa or the gradual expansion in dry plant types in Oman and Pakistan from 6000 cal yrs BP to the present. A remarkable synchroneity in environmental change is recorded at the northern edge of the Atlantic and Indian monsoon systems, with the extreme end of the Holocene Humid Period corresponding to the last occurrence of tropical trees in the desert and the last record of prolonged SW monsoon rainfall over north-western Asia around 4700–4500 cal yrs BP. ***To cite this article: A.-M. Lézine, C. R. Geoscience 341 (2009).***

Résumé

Chronologie des changements de la couverture végétale des zones désertiques à la limite nord de la zone d'influence des moussons atlantique et indienne au cours de la fin de la période Humide Holocène. Cet article a pour but de discuter la réponse des écosystèmes (terrestres et aquatiques) au passage des conditions humides à sèches à la fin de la période humide Holocène dans les domaines de la mousson atlantique et indienne. Il est principalement axé sur les environnements arides du Tchad, d'Oman et du Pakistan où de nouvelles données polliniques à haute résolution ont été obtenues. Les données polliniques montrent que les conditions hydrologiques locales ont joué un rôle majeur dans la destruction ou la survie des espèces d'arbres tropicales à la fin de la période Humide Holocène. Elles expliquent en partie l'asynchronisme des changements environnementaux dans la plupart des régions tropicales. Dans les zones désertiques, la réponse des écosystèmes aquatiques au basculement des conditions climatiques humides vers des conditions arides semble avoir été rapide, soumise à des effets de seuil. En revanche, les écosystèmes terrestres se sont peu à peu adaptés à une sécheresse croissante, comme en témoigne la disparition progressive des espèces d'arbres tropicaux à Yoa ou l'extension des écosystèmes arides en Oman et au Pakistan entre 6000 ans cal BP et aujourd'hui. Un remarquable

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synchronisme est enregistré dans l'évolution de l'environnement, à limite nord de la zone d'influence des moussons atlantique et indienne, à la fin de la période humide holocène, avec la dernière occurrence d'arbres tropicaux dans le désert et le dernier enregistrement prolongé des pluies de la mousson du Sud-Ouest en Asie occidentale à 4700–4500 ans cal BP. ***Pour citer cet article : A.-M. Lézine, C. R. Geoscience 341 (2009).***

Keywords: Atlantic monsoon; Indian monsoon; Pollen; Chad; Oman; Pakistan; End of the Holocene Humid Period

Mots clés : Mousson atlantique ; Mousson indienne ; Pollen ; Tchad ; Oman ; Pakistan ; Fin de la période Humide Holocène

1. Introduction

Environmental reconstructions of tropical deserts during the Mid- to Late Holocene have mainly focused on northern Africa. In this region, lake level and pollen data have been used for regional reconstruction of past vegetation or hydrological changes [11,13,20], as well as for paleoclimatic models connecting environmental changes with variations in the Earth's orbit, or investigating vegetation and ocean feedback in the climate system [3,16,17,33]. In contrast, little is known about western Asia, one of the most arid areas of the world with extensive desert areas (Rub al Khali in the Arabian Peninsula, Thar desert in Western India...), although recent studies on speleothems from Oman [10] or paleolakes from Yemen [25] and Oman [31] have yielded high resolution records showing variations of the Indian summer monsoon during the Holocene.

In such arid areas, the scarcity of continuous sedimentary archives due to desiccation and subsequent erosion of the sediment sequences complicate any investigation of the impact of monsoon variability on vegetation and possible feedback of land cover changes on regional climate. I present here a review of pollen data from tropical African and western Asian lowlands, including new results from sectors located at the northern edge of the Atlantic and Indian monsoon systems (Figs. 1 and 2) in order to document the shift from humid to arid environmental conditions in equatorial forest to the desert and the onset of the modern climate regime at the end of the ''Holocene Humid Period''.

2. In the Atlantic monsoon system, a local *versus* regional pollen signal

Considerable changes in vegetation have occurred in the West-African lowlands from the Guineo-Congolian forest zone to the Sahara at the end of the ''Holocene Humid Period''. Changes in the Atlantic Equatorial forest domain have been described in detail by Vincens et al. [44], while a more complete picture integrating pollen sites from the drier vegetation types of Sudanian to Saharan latitudes has been provided by Lézine [21] then analyzed in detail by Watrin et al. [46] (Fig. 2). They showed that forests between 4°S and 7°N were replaced by more open landscapes, wooded grasslands, grasslands or woodlands within a period lasting from 4500 to 1300 cal yrs BP. The local signature of this environmental change strongly varies from site to site according to local hydrological conditions. Some lakes, such as Sinnda, dried out [45], while other sites (e.g., Bosumtwi [42]) remained forested or only partially affected (e.g., Barombi Mbo [26]; Ngamakala [6], Songolo [7]; Nguène [29]), such as rain or swamp forests being replaced by more open formations with increasing importance of light dependent tree species.

In contrast with the Guineo-Congolian domain, Sudanian and Sahelian pollen sites from Benin and Nigeria show a remarkable agreement of environmental changes. In Benin, semi-evergreen rainforest trees which expanded at 8°N around Lake Sélé were replaced by an open savannah between 4500 and 3400 cal yrs BP [38] likely recording the installation of the modern ''Dry Dahomey Gap'', a dry corridor which interrupts the Guineo-Congolian forest domain between roughly 1° and 3°E along the northern coast of the Gulf of Guinea. During the same time interval, Guineo-Congolian gallery forests disappeared from central (Tilla [37]) and northern Nigeria (Bal, Kajemarun, Kaigama and Kuluwu [39]) to the benefit of widespread savannah formations. To the west, along the Atlantic Ocean, specific hydrological conditions linked to the proximity of the sea partly explain the persistence of noticeable forest communities more than 2000 years after the installation of dry climate conditions over the Sahel. Here, the sea which reached its modern level after 7000 cal yrs BP [1], and even raised above it around 6000 cal yrs BP and 3000 cal yrs BP during the so-called ''Nouakchottian'' [12] and ''Tafolian'' transgressions [9], led to the permanence of soil humidity near littoral areas with the fresh water-table lying near the surface at the bottom of interdunal depressions [22]. As a result, Guineo-Congolian gallery forests from the