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When the desert was green: Grassland expansion during the early Holocene in northwestern Arabia

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ABSTRACT

An early-to-mid Holocene lake in the north of the oasis of Tayma, northwestern Saudi Arabia, proved to be an excellent palynological archive. A shallow, probably brackish water body formed at about 9200 cal BP, with the dominance of goosefoot throughout the sequence indicating the persistence of desert vegetation. However, distinct vegetation changes are recorded during the early Holocene. Grasslands spread soon after 9000 cal BP and reached their maximal expansion ca 8600–8000 cal BP. At about 8000 cal BP these grasslands retreated abruptly and were replaced by more drought-resistant dwarf-shrublands, similar to the present-day ecosystems. The recorded early Holocene grassland expansion furnishes for the first time evidence of an additional and more favourable grazing resource, and thereby improved conditions for herders/hunters, during the Early Holocene in northwestern Arabia, which retreated abruptly due to aridification at about 8000 cal BP.

1. Introduction

Green landscapes were postulated by archaeologists for (northern) Arabia during the early Holocene, enabling the expansion of a Neolithic mobile herding economy (Drechsler, 2009; Crassard et al., 2013). Until now, the assumptions of greener landscapes in north Arabia are mainly based on supra-regional palaeoenvironmental archives including speleothems, lake level fluctuations, and the occurrence of lacustrine sediments. $\delta^{18}O$ values of speleothems in southern Arabia record the northward shift of the monsoon during 10,500–9500 BP, providing more humid conditions until at least 7800 BP, when the monsoonal system began to migrate southward again (e.g. Fleitmann et al., 2007, 2009).

In the eastern Mediterranean, dominated by mid-latitude climate systems, $\delta^{18}O$ records of speleothems show maximum wetness during early-to-mid Holocene (e.g. Bar-Matthews et al., 1999; Verheyden et al., 2008; Develle et al., 2010). Lake level fluctuations of the Dead Sea document an early Holocene wet phase (e.g. Migowski et al., 2006).

Palaeolakes in northwestern Arabia provide further evidence for increased moisture during that time. Shallow lakes in interdune depressions of the Nafud date to about 9500–5800 cal BP (Whitney et al., 1983; Schulz and Whitney, 1986). In the Jubbah region, lake formation started between 12,200 and 10,000 cal BP (Crassard et al., 2013; Hilbert et al., 2014) while a ^{14}C dated palaeosol/swamp near Jubbah yielded an age of about 7500 cal BP (Garrard et al., 1981).

A recently palaeolake north of Tayma in northwestern Arabia corroborates these findings (see Fig. 1). Previous sedimentological, mineralogical, palaeontological (Engel et al., 2012; Ginau et al., 2012), and hydrological (Wellbrock et al., 2011) investigations have the following palaeoclimatic implications: About 10,000–9000/8500 cal BP a palaeoshoreline together with the basal sediments in the depression indicate the highest lake level. Micropalaeontological proxies point to increasing salinity due to aridisation during this wettest period. Long term aridification started about 8500 cal BP, interrupted by at least one probably mid-Holocene short period of increased humidity. Annual precipitation rates were modelled for the Holocene lake period. Annual precipitation amounted to 150 ± 25 mm, an increase of about 300% compared to the present annual average of 45 mm.

How the increased moisture during early-to-mid Holocene impacted the vegetation is unknown, because continuous

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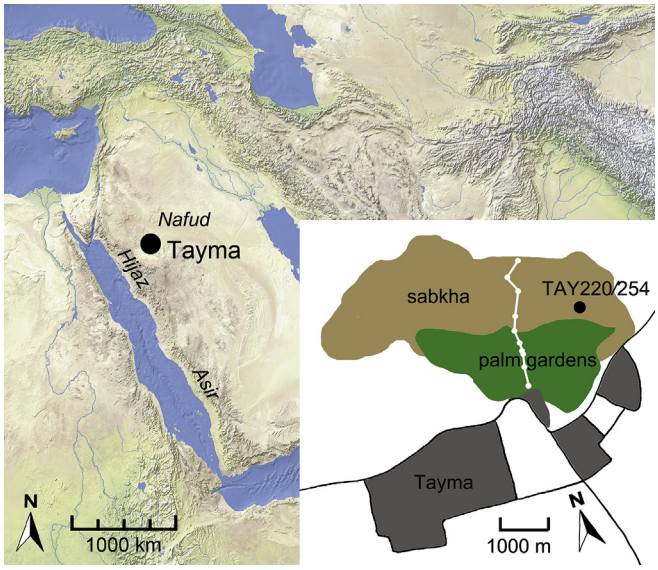

Fig. 1. Location of the study region Tayma and the palaeolake near Tayma, the coring site Tay 220 and Tay 254 and – in white – the coring transect through the sabkha of Engel et al., 2012.

palynological records are missing for northern Arabia. Changing precipitation amounts may not necessarily effectuate vegetation changes due to the resilience of ecosystems. However, if a threshold value is crossed, ecosystems are reorganised, including changes in vegetation (e.g. Campos et al., 2013).

For human populations in prehistory, vegetation and water availability are the key commodities for subsistence. Changing vegetation implies changing pastures, while the abundance and composition of vegetation/pastures impact the size of wild animal populations, which may retreat or migrate when natural vegetation cover retreats or changes. A decrease of natural vegetation cover thus affects the subsistence of hunter-gatherers. Herders may be affected similarly. During the hot season, goats and sheep need water and food everyday or every other day (Smith 1978, cited by Drechsler, 2009, p 88–89). Denser vegetation cover and/or the presence of favoured foraging resources such as grasslands thus are environmental conditions that facilitate a herding economy. Sparse vegetation cover and/or the spread of less palatable plants may impede a herding economy.

To date, ten pollen spectra from four different interdune depressions in the Nafud and adjacent areas were investigated for northwestern Arabia. They record (slightly) denser vegetation cover during early-to-mid Holocene but the same vegetation formation as today (Schulz and Whitney, 1986). Increased early-to-mid Holocene humidity in northwestern Arabia would not have affected terrestrial ecosystems distinctly.

The sediments of the palaeolake near Tayma proved to be an excellent palynological archive with good pollen preservation. Palynological investigations were conducted to get detailed and more precisely dated information on the early Holocene vegetation history of this region.

2. Study site

The oasis of Tayma is situated in northwest Saudi Arabia (27°38′ N, 38°33′ E, ~830 asl). In the west, the Hijaz Mountains run from north to south, and in the east the western fringes of the sand desert Nafud border on the Tayma region (see Fig. 1). Ongoing archaeological excavations have yielded evidence of human occupation since the 7th millennium BP at the oasis Tayma (Hausleiter, 2011).

The region is part of the hyper arid interior of Saudi Arabia. Long-term climate data are available from Tabuk and Al-Ula (north and south of Tayma, respectively). Mean annual rainfall at Tabuk and Al-Ula is 29.3 mm and 61 mm, respectively, with rainfall mostly during November–April, with extreme inter-annual fluctuations of rainfall amounts (Tabuk 2.8–55.1 mm, Al-Ula 2.0–188.9 mm). The mean annual temperatures are 21.4 °C for Tabuk and 24.6 °C for Al-Ula. Frosts are rare and of short duration (Alex, 1985; Almazroui et al., 2012). Thus, the low amount of plant-available water is the main restriction for plant life in the region.

Desert vegetation dominates the Tayma region. Typical for the vast rock (hammada) and gravel deserts (reg) is vegetation dominated by various *Fagonia* species. It is replaced on the extended sandy desert plains by “rimth” shrubland with *Haloxylon salicornicum* (Chenopodiaceae), mixed with the “arfaj” shrubland, dominated by *Rhanterium epapposum* (Asteraceae). These two desert shrubland types are most common in northern Saudi Arabia. On sand dunes, the “adhir” shrubland with *Artemisia jordanica* and *Calligonum* (mainly *C. comosum*) is widespread. A chorotype analysis of the plant communities documents the strong Saharo-Arabian character of the vegetation in the Tayma region (Kürschner and Neef, 2011; Pandalayil, 2011).

3. Material and methods

3.1. Fieldwork and stratigraphy

Closed, overlapping cores of 1 m length were drilled in the eastern part of the sabkha, an ancient lake (see Fig. 1). The overlapping cores Tay 220 and Tay 254 were in direct vicinity (about 25 cm apart), and thus correlation of the cores is possible by stratigraphy. The 1 m long cores have a diameter of 6 cm. Vibracoring was performed with H. Brückner and M. Engel (Universität Köln). Further technical details concerning the drilling equipment are provided in Engel et al. (2012). At 6 m below the surface, bedrock was reached.

The early Holocene sediments discussed in this article are lake sediments. The good pollen preservation supports the assumption of a perennial lake. In Table 1, the main sedimentological characteristics are summarized.

Table 1
Simplified stratigraphy of the basal, early Holocene part of the sequence.

cm below surface	
420–330	Grey-brownish silty marl with clay layers and gypsum crystals (1 mm–1.5 cm)
550–425	Marl, continuously fine laminated, organic-rich
565–550	Silty marl with interrupted lamination
603–565	Grey, silty marl with gypsum concretions up to 4 cm

3.2. Radiometric dating and age depth model

A radiometric chronology based on pollen concentrations was produced for the following reasons: 1. The coring material contains no seeds of terrestrial plants. 2. Dating extracted pollen directly ages the material on which the vegetation development is reconstructed. 3. Molluscs and shell fragments occur, but their dating may be influenced by (sub)fossil carbon (hard water effect).

A combination of different protocols was applied to extract pollen for dating, including the treatment of the samples with