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Atlas of Cultural and Environmental Change in Arid Africa

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High-resolution climate archives in the Sahara (Ounianga, Chad)

Persistent lack of climate records from the Sahara for the period since its final desiccation about 3,500 years ago (Kuper & Kröpelin 2006) because of the deficiency of aquatic deposits has hampered analysis of climate and environmental change of northern Africa. In an attempt to fill this gap, a five-week reconnaissance survey of northeast Chad was undertaken in early 1999 to explore the palaeoclimatic potential of the largest Saharan lakes at Ounianga which have been neglected since their discovery in the early 20th century because of their remoteness and notorious insecurity.

The entirely groundwater-supported Lake Yoa of Ounianga Kebir occupies a late Pleistocene deflation basin at 19°03′ N / 20°31′ E in the hyperarid Chadian Sahara. Rainfall there is erratic and annual evaporation exceeds 600 cm. The lake water is hypersaline and features important growth of algae. Sounding cross sections revealed a rather flat-floored bottom at depths of 24-27 m (Fig. 4). To find out the nature of the subbottom deposits, a test core was taken in the lake centre by aid of a gravity corer. It revealed finely laminated sediments with varve-like characteristics that obviously consisted not only of annual, but of seasonal layers. The formation of such strata requires extraordinary conditions, even more so in the Saharan desert. Moreover, the deposits appeared to extend much further down than the 1 m core taken. The overall evidence suggested that the subbottom sediments of Lake Yoa did not only retain a complete record of the last millennia to the present day, but of the entire Holocene.

Fig. 1 Preparation of the drill equipment.

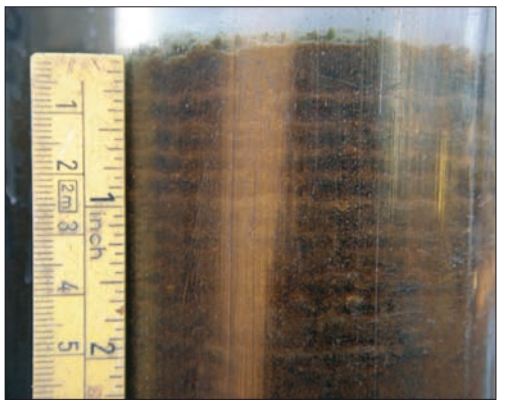

Fig. 2 Lamination of the top layers.

The proof of a continuous high-quality climate archive with very high temporal resolution in the central Sahara gave reason to propose a new subproject within ACACIA that was granted in 2002 and which facilitated more detailed studies. After extensive preparations, and the transfer of vehicles and drilling equipment from Germany through the deserts of Libya, Egypt and Sudan which required about three months, more substantial coring was carried out in December 2003 in cooperation with Dirk Verschuren of the University of Gent. With a metal cylinder coring device up to 4.5 m of continuous cores were extracted from the lake floor that covered the last 2,600 years.

A third five-week drilling campaign in autumn 2004 allowed for deeper penetration into the increasingly compacted sediments by applying a 35 m long casing (Fig. 1,5). By approaching the limits of this method, up to 9 m long cores could be extracted at a water depth of 27 m before hitting a more resistant layer (Fig. 3,6). The long core yielded a continuously laminated record at subannual resolution for the past 6,200 years. Figure 2 shows its surface and the lamination of the top strata which represent the winter and summer layers deposited in the years 1990-2004. This record represents the Sahara's (if not north Africa's) most complete very high-resolution climate and environmental archive for the middle and late Holocene so far.

Full multiproxy analysis of the samples will take years. Ongoing investigations include sedimentological, geochemical, chronological, high-resolution imaging and stable isotope analyses and various examinations of the microfossil content. The combined data will provide a consistent long-term record of climate and environmental variations. Depending on the scale of analyses of the > 12,000 millimetre-thin layers, statements will be possible, for example, on the first occurrence of specific plants such as the date palm, or events such as heavy dust storms, savannah fires or volcanic eruptions for every single year or even season of the past six millennia up to the nuclear tests and war activities in the last decades. The already existing data for the middle and late Holocene specify the climatic and ecological conditions of the late prehistoric occupation in the region and beyond. They also contribute to the validation and calibration of numeric global climate models. By using heavier drilling equipment, it is intended to complete the existing data set for the entire Holocene.

Fig. 3 Pulled cores on drill platform.

Fig. 4 Lake Yoa of Ounianga Kebir is the largest of the very few permanent waters in the hyperarid Sahara. Today, it is only maintained by a subsurface inflow of fossil groundwater that was recharged during the early Holocene humid period and that compensates for the extreme (> 6 m/year) evaporation which equals the water consumption of the city of Cologne. The hypersaline lake has a maximum depth of 27 m and covers 4 km² with a circumference of 35 km. Evaporation and quasi-permanent trade winds cool the water temperature down to 17°C. Peninsula-like tongues of dune sands migrate into the lake at a rate of about 1 m per year.

Fig. 5 Anchoring of the drill platform above the deepest (27 m) spot in the centre of Lake Yoa. Inset shows lowering of the coring rod in 35 m long casing.

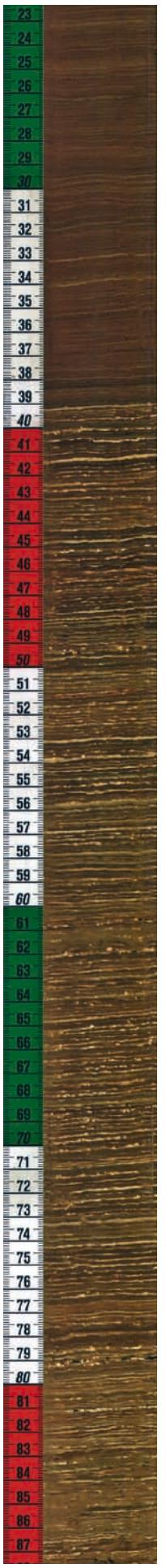

Fig. 6 A part of the upper section of the 750 cm long core which covers 6,200 years at subannual resolution. The displayed varve-like layers represent 700 years of seasonal sedimentation, i.e. 12 % of the total record available so far. The base layer dates from the year 525. The transition from light (high carbonate) to dark (low carbonate) stratification in the year 980 indicates a crucial change in the lake metabolism and the onset of hypersaline conditions. The top of the section was deposited in 1225.