Lakes

Large bodies of water in the middle of the desert are not only a natural spectacle, they also contain extremely precise environmental archives. Sediments extracted from these lakes document climate evolution and provide information on dust storms, savannah fires and volcanic eruptions.
A journey to north-east Chad

By Stefan Kröpelin

in the Sahara

Illustration: George

In a canoe on a salt lake. A drilling platform, consisting of two inflatables and some wooden planks, is anchored here. It has been transported across several thousand kilometres of Libyan and Egyptian, then Sudanese and Chadian desert to its present location.

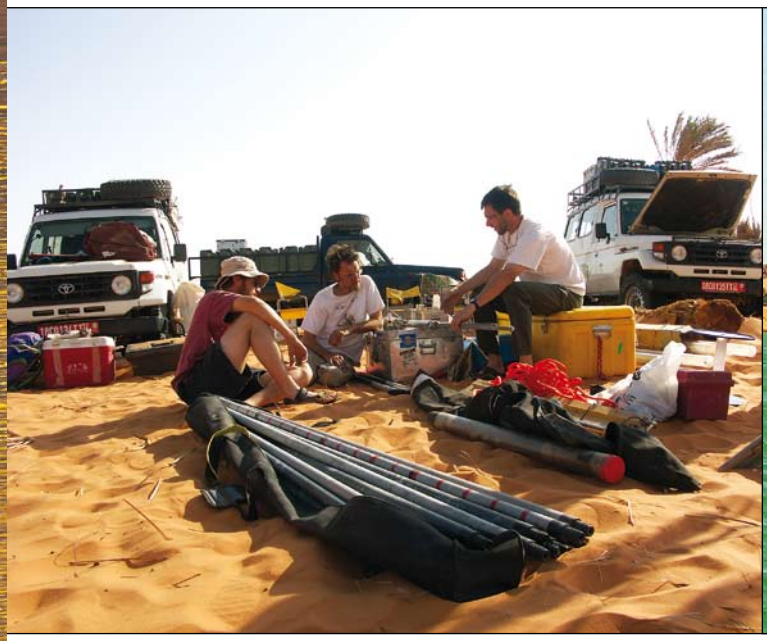
Now, in the afternoon, the constantly blowing trade winds have settled down slightly and the sun burns a little less glaringly from the sky. To be sure of reaching land again in an oncoming storm in one of the windiest regions of the Sahara, the platform is tied to a palm tree on the shore by a 400 metre long rope.

metre for metre, ensuring that the valuable core is not lost. Sediment cores up to 9 metres long, all exhibiting fine lamination in the millimetre range, are extracted using this method.

While previous investigations of lake deposits in the Egyptian and north-Sudanese deserts allowed the climate history of the last humid period in the Sahara to be reconstructed for the time between approximately 10,000 and 1,500 BCE, practically no data existed for the following period. However, indicators of environmental and climate change in the world's largest desert during the past 3,500 years are extremely valuable for

magazine in the hope of revealing the secret of the largest lakes in the Sahara. The aim was to investigate the palaeoclimatic potential of the Ounianga lakes and the surrounding areas.

The four square kilometre Lake Yoa at Ounianga Kebir lies in the centre of the Chadian Sahara. Rain almost never falls here, while annual evaporation reaches a world record of more than 6,000 millimetres – around 2,000 times the local precipitation. Evaporation losses, which approximate the water consumption of the city of Cologne with its population of one million, are compensated exclusively by the subsurface inflow of fossil ground-



Campsite in the Sahara: Researchers have arrived in Chad with expedition vehicles and coring equipment. Next to it: A drilling platform is anchored on the Yoa salt lake at Ounianga Kebir. The extracted cores (columns on the left and right margins) are a mirror of climatic history.

The water at the drilling point is 26 metres deep. The waves rock the boats, which are quickly covered with a white layer by the slopping salt water. A great deal of skill and manual dexterity is required to push the coring cylinder in the 35 metre long casing bit by bit deeper into the lakebed deposits and then to pull the heavy rods back up,

inferring recent dynamics in arid regions or for climate modelling in 'Global Change' programmes.

The remote north-eastern part of Chad remains to this day the least explored region of the Sahara, if not the whole of Africa because of its extremely harsh desert environment and notorious insecurity. The Ounianga lakes have therefore been neglected as a field for geoscientific research since their discovery by the French military geographer Jean Tilho early in the 20th century. It was not until January 1999 that a five week expedition was started in cooperation with Uwe George from GEO

water. Soundings in the extremely saline water indicated a maximum depth of 26 metres.

To identify the properties of the sub-bottom deposits, an initial sample was taken with a gravity coring cylinder suspended on a wire line. The 50 centimetre long sediment core exhibited millimetre-thin layers with a characteristic structure, clearly indicating winter and summer phases. Exceptionally constant conditions are required for the formation of such fine lamination, especially in an oasis in the extreme desert. This observation supported the as-

sumption that the bed of Lake Yoa conceals an environmental and climate archive, probably comprising the entire Holocene to the present day; that is, all the 12,000 years of the present post-glacial period.

The discovery of this exceptionally well preserved climate archive led to a new project in Chad within the Collaborative Research Centre 389 "Arid Climate, Adaptation and Cultural Innovation in Africa" (ACACIA). Following exhaustive preparation with the partner research authority in the Chadian capital N'Djamena and a three-month long transfer of the vehicles and drilling equipment from Germany to the east-central Sahara, the first systematic on-site studies began in December 2003. Using specially designed drilling equipment, it was possible to recover 4.5 metre long cores from the lake bed; they document the last 2600 years in detail.

The subsequent field campaign in the autumn of 2004 allowed deeper penetration into the increasingly compacted sediments by using a metal casing. Reaching the limit of the light-weight drilling method at a depth of 35 metres below lake level, cores up to 9 metres long were extracted, until a heavily compacted layer obstructed further penetration. The long sediment cores also displayed continuous fine lamination. Radiocarbon dating and counting of the single layers revealed that they record the past 6,000 years at a seasonal resolution. This new data base represents the most complete and precise Saharan climate archive available for the mid- and late Holocene.

The ongoing laboratory work, carried out in specialised, domestic and overseas laboratories, comprises sedimentological and geochemical investigations, high-resolution image analyses, dating and isotope studies, as well as detailed evaluations of the floral and faunal microfossil content. The 12,000 millimetre-thin layers allow not only uninterrupted insights into climate history and the evolution of aquatic and terrestrial ecosystems in the Sahara, they also provide information, precise to the year, on natural events such as large dust storms, savannah fires and volcanic eruptions, or on the first occurrence of certain crop plants such as the date palm. The data thus cover the mid- to late Holocene up to the time of modern nuclear tests and contemporary armed conflicts with a previously unattainable precision.

The findings also illuminate the climatic and ecological background of the prehistoric settlement history of the region. However, they primarily provide an answer to the question of whether or to which extent climate events and fluctuations derived from ocean and ice drilling cores can be applied to the continental African desert belt. In addition, they can help to evaluate computer-aided climate models and thus improve global climate forecasts.

The neighbouring Ounianga Serir basin (Arabic: serir = small), 40 kilometres east of Ounianga Kebir (Arabic: kebir = large), with its lakes is not only one of the most

Left: Lake Boku, fed by fossil groundwater, in the now sand-encroached basin of Ounianga Serir. The freshwater lake defies 4,000 years of extreme aridity. Next to it: Massive early Holocene lake deposits.

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beautiful sceneries in the Sahara, but one of the most interesting study areas. In an almost rainless region the very existence of these lakes is remarkable. Just as in the case of Lake Yoa, they only exist due to the permanent influx of fossil groundwater, which accumulated during the last wet period. Together with Ounianga Kebir the lakes represent the relics of the early Holocene 'Mega Chad', once one of the world's largest inland lake systems. Although all of the Sahara's water bodies are doomed as a result of ongoing desiccation, dropping groundwater tables and encroaching dunes, they will subsist for at least a few centuries if groundwater inflow continues.

Over the past millennia, the constantly blowing northeast trade winds have wafted long tongues of sand into the basin. They have divided the once contiguous freshwater lake into 15 smaller lakes that cover a total area of approximately 20 square kilometres. With the exception of the central salt lake (Teli), they are more or less, and in some cases entirely, covered by floating reed mats which considerably reduce evaporation.

The open central lake, in contrast, evaporates significantly more and therefore acts as a gigantic evaporation pump, causing the lowest lake level at this point. As a consequence of the gradient, water is constantly drawn in from the higher freshwater lakes through the permeable body of the dunes before it gets salty.

This mechanism explains the existence of freshwater lakes – a paradox under the climatic conditions of the Sahara, where salinisation generally occurs very quickly due to the high rate of evaporation. This makes the Ounianga Serir ecosystem so unique. Comparable freshwater ecosystems are not known in the Sahara or any other extreme desert.

Because of the heavy erosion by wind only very few remains from older lake deposits are preserved on the surface. They are exposed

Illustrations: Kröpelin

Gentle giant: The 5.5 square kilometre, saline Lake Teli at Ounianga Serir. The islands were once at least 50 metres below the water surface. Bottom left: The author with native dignitaries. Right: An overloaded lorry reaches the researchers' quarters following an odyssey through the Sahara.

up to 80 metres above today's lakebeds. Based on radiocarbon dating, the finely laminated diatomaceous muds and mollusc-bearing chalks are early Holocene, i.e. 7,000 to 10,000 years old. The individual sediment sequences shall later be correlated with the climate archive of Lake Yoa at Ounianga Kebir.

By precision surveying of the higher lake deposits with the aid of the differential global positioning system (DGPS), it was possible to determine past lake levels. 'Virtual flooding' of digital elevation models based on these measurements allow an accurate reconstruction of the much larger extent of the Ounianga Serir lake during the last humid period. In geo-archaeological cooperation, this procedure also helps in the search for prehistoric settlements which were generally set up near shorelines and would otherwise be practically impossible to locate in the vast, largely sand-covered terrain.

The palaeoclimatic data set acquired so far shall be expanded. It is planned to continue the coring in Ounianga Kebir using heavier drilling equipment in order to record and better understand the environmental and climate development of the Sahara during the entire Holocene and possibly even the late Pleistocene, i.e. the past 130,000 years.

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