GEOMORPHOLOGICAL RECONSTRUCTION OF PALAEO-LAKE ASHENGI, NORTHERN ETHIOPIA

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Zusammenfassung

Holozäne Seespiegelhochstände des Lake Ashengi sind geomorphologisch durch fossile Strandlinien und –wälle, Kliffe und Strandterrassen in verschiedenen Höhenlagen über dem heutigen Seespiegel dokumentiert. In Gullys und Bacheinschnitten sind zudem Seeablagerungen aufgeschlossen, die sich lateral mit Schichtflut- und Deltasedimenten- sowie kolluvialen Abschwemmmassen verzahnen. Lithologische Veränderungen und Erosionsdiskordanzen in den Seeablagerungen weisen auf abrupte Seespiegelschwankungen hin, die vermutlich durch den Wechsel humider und arider Klimaperioden im Einzugsgebiet des Sees verursacht wurden. Die geomorphologischen und sedimentologischen Befunde lassen erhebliche Änderungen der Paläoumwelt des Sees im Holozän vermuten.

Abstract

Indicators for high lake levels of Lake Ashengi during the Holocene include fossil shorelines, cliffs, beach ridges and beach terraces at different altitudes above the present lake level. Lake sediments are exposed in gully and stream sections, and are laterally interfingering with sheet flood, delta and colluvial deposits.
Unconformities within the lake sediments point to abrupt lake level fluctuations, and might be related to humid and arid climate periods and changes in the water balance in the lake catchment area. The geomorphological and sedimentological data indicate distinct changes of the palaeoenvironment of Lake Ashengi during the Holocene.

1 Introduction

During the Holocene, lake levels in the Main Ethiopian and in the Afar Rift fluctuated considerably (overview in Umer et al. in press). The reconstruction of lake levels and environmental conditions in the Ethiopian Rift region is based on geomorphic, sedimentologic and palaeontologic evidences, such as palaeoshorelines, fossil lake deposits, stromatolites, diatoms, pollen and on radiocarbon dating (e.g. Grove et al. 1975, Gasse & Street 1978, Lamb 2001, Chalié & Gasse 2002, Benvenuti et al. 2002).

Levels of Holocene lakes are controlled by a combination of climatic, geologic and anthropogenic influences. For levels of closed-basin lakes, the fluctuations are mainly controlled by climatic conditions, which are the result of changing balances between precipitation and evaporation. The levels of palaeolakes in closed-basin settings are therefore regarded as one of the best sources of palaeoclimate data in Northeast Africa (Umer et al. in press).
In the Main Ethiopian and Afar Rift, lake levels were generally low during the Last Glacial Maximum; the re-establishment of wet conditions started at ~12500 ^{14}C yrs. BP (Gillespie et al. 1983). High lake levels dominated from about 9500 to 4500 ^{14}C yrs. BP, with short arid intervals causing lake level regression at around 7800-7200 ^{14}C yrs. BP and ~5900 ^{14}C yrs. BP (Gasse 1977, 1990, 2000 ; Gasse et al. 1980; Gillespie et al. 1983).
A major shift to dry conditions and low lake levels occurred at about 5000-4500 ^{14}C yrs. BP. Low lake levels dominated during the late Holocene, interrupted by a short-term highstand at ~2000-1500 ^{14}C yrs. BP (Gasse 1990, Gillespie et al. 1983).
In the Ethiopian Rift region, lake levels are frequently influenced by tectonic movements and volcanic activity, too (e.g. Gasse 1990, Le Turdu et al. 1999, Benvenuti et al. 2002).

These influences are probably irrelevant in the case of Lake Ashengi, which is situated in a relatively stable tectonic position, and is lacking nearby volcanism. In contrast to the Rift lakes, the response of the lakes of the Ethiopian highland, such as Lake Ashengi, to Holocene climate change is hardly known.

In our study of Lake Ashengi, we try to (a) reconstruct the extent and timing of Holocene lake level changes of Lake Ashengi, (b) to decipher the corresponding environmental conditions in the lake basin and (c) to correlate these developments with synchronous changes in the Rift lakes. This article concentrates on the geomorphological evidences for significant Holocene lake level changes of Lake Ashengi.

2 Study site

Lake Ashengi ($12^0 30'$N, $39^0 30'$E) is located in the Ethiopian highlands, at an altitude of ~2450 m a.s.l. (Fig. 1). The lake has a surface area of approximately 14 km^2, and a catchment area of about 82 km^2. It is a relatively shallow, unstratified lake, with a maximum depth of 23 m. The lake is fed by direct precipitation and small seasonal streams. Several small springs and seeps discharge directly into the lake along its southern steep-sided shoreline, suggesting a significant groundwater contribution to the lake water balance.
The lake basin is topographically closed and has no surface outlet. Nevertheless, the lake seems to loose water by sub-bottom leakage towards the Raya Valley in the East.

Lake Ashengi is located in the southern part of the basin, which is surrounded by mountain ridges, reaching on its north-western side a height of about 3700 m a.s.l., and on its eastern and south-eastern side up to 2800 m a.s.l.. A comparable basin is located just a few kilometres south of Lake Ashengi, but it does not contain a lake at present. Lacustrine sediments are exposed in the centre of this basin, which suggests that an analogous lake existed in the basin during more humid periods in the Holocene.

Geologically, Lake Ashengi is situated in a graben structure near to the eastern border of the north-western Ethiopian Plateau, which is predominantly built up of up to 2 km thick Oligocene (around 30 Ma) volcanics (Hofmann et al. 1997, Ukstins et al. 2002), consisting mostly of basalts and minor rhyolithes (Mohr and Zanettin, 1988).

Towards the Danakil and the Afar Depression, the north-western Ethiopian Plateau is bounded by an discontinuous system of graben structures. These marginal grabens were initiated during the early phase of Afar rifting (Chorowicz et al. 1999, Tesfaye et al. 2003). In the west, they are accompanied by smaller graben structures. Lake Ashengi was formed in one of these minor grabens. Normal faults are abundant in the western and north-western part of the lake basin.
Considering the asymmetric morphology of the basin, with the highest mountain ridges on the western side, it is most probably a half-graben structure, with the main boundary fault zone in the west.

Fossil lake sediments are exposed at several locations in the lake basin. Their distribution suggests, that the lake level was formerly at least 25 m higher than at present. The age of the investigated lake sediments has not yet been determined. But in all probability it is Holocene, because the base of a core from Lake Ashengi was dated 11.920 ^{14}C years BP (H. F. Lamb, pers. comm.).

The climate of the region is characterised by two rainy seasons, a long one in summer, from July to September, and a one in spring, from March to April. On average, the rainfall totals ~800 mm yr^{-1}, and the mean monthly temperature varies between 14^0 C in winter and 18^0 C in summer (Ethiopian Meteorologic Service, pers. comm.). Slopes are covered by shrubs and scattered trees and are used for pasture. The grass-covered, swampy lowland north of the lake is partly used for cattle-breeding, whereas the drier areas around the lake are utilised for cultivating cereal crops.

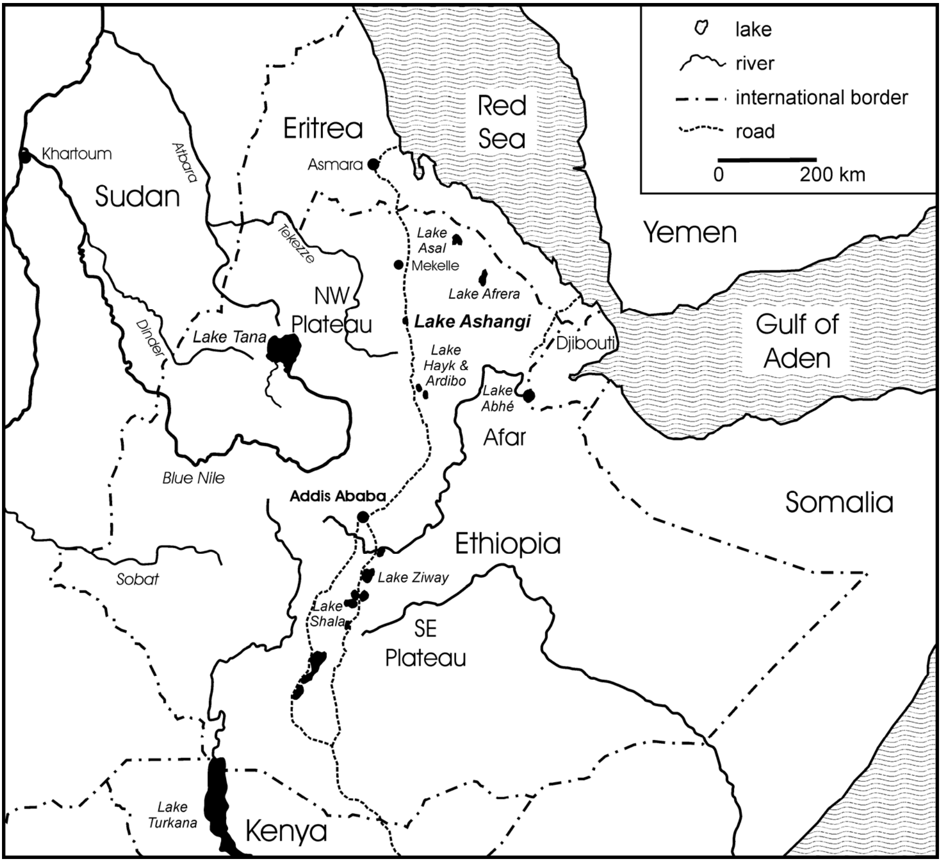

Figure 1 Location map of Ethiopia.

3 Methods

Field work is focussed on the documentation of palaeoshorelines and stromatolites, as well as on the recording of sedimentological sections in gully exposures at various locations in the lake basin. Their positions were located by using a GPS receiver. Field work was complemented by the interpretation of aerial photographs.

4 Results and Discussion

The geomorphology of the lake basin is largely controlled by its tectonic setting. On its north-western and western side, the basin is bordered by steep fault scarps. Sedimentation along the foot of the fault scarps is dominated by gravity processes, producing angular blocks and boulders. Outlets can be found in the escarpment, in the foot-zone of which alluvial fans have developed. The feeder channels of the alluvial fans are incised into the fan surfaces. This indicates that the fans are not aggrading at present, but are actively dissected.

In contrast to its steep borders, the floor of the basin is relatively flat. The northern part of the lake basin is partly covered by wetland, forming marshy wet meadows and swamps (Fig. 2).
The wetland is fed by seasonal streams, and possibly by groundwater inflow stemming from nearby alluvial fan deposits. The flat morphology of these areas suggests that they represent a fossil lake floor, which is now exposed due to lake level regression. Seasonal wetland is forming after the rainy seasons along the south-eastern shore of the lake.Low-relief areas along the margin of the lake are dissected by gullies, which give good exposure to alluvial and littoral sediments. The comparison of aerial photos from 1965, 1980 and 1986 with field evidence in 2003 and 2004 indicates an increase in abundance and size of the gullies. Increased gullying in the Ethiopian highland is enhanced by human activities, such as land use, building of settlements and roads, digging of small canals for irrigation etc. (Nyssen et al. 2004). Small deltas have been formed where streams and gullies enter into the lake (Fig. 2).

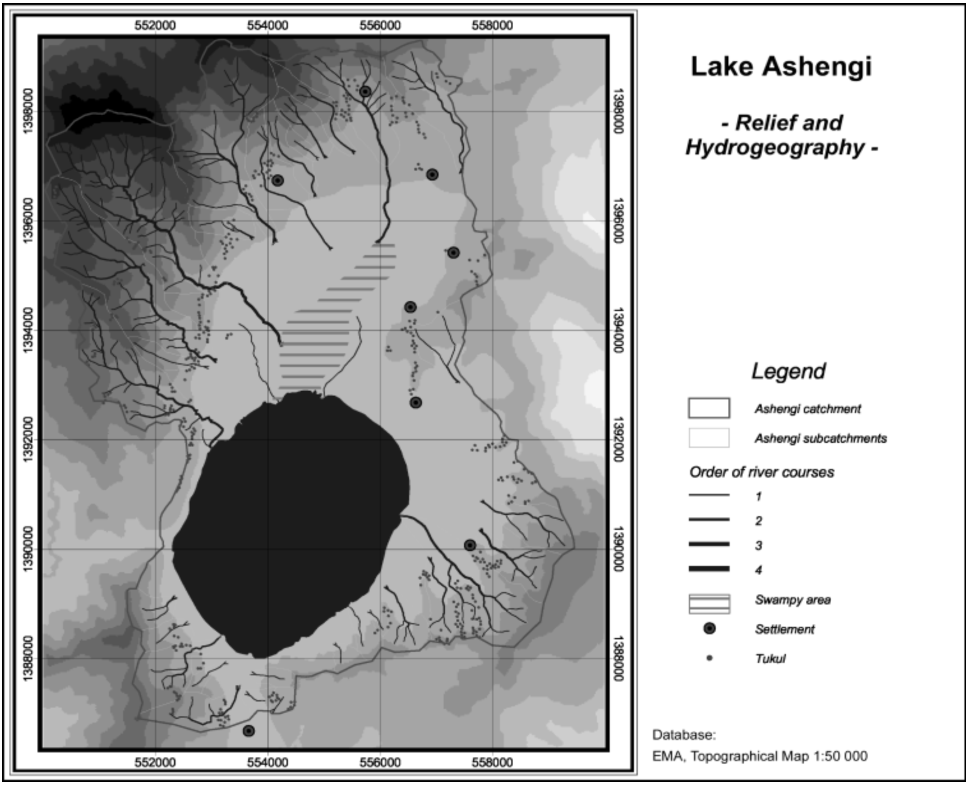

Figure 2 Relief and hydrogeography of Lake Ashengi basin.

Stromatolites

Calcite crusts are existing in numerous locations along the steep rocky shores of the lake (Fig. 3). The crusts are highly variable in shape, but most of them constitute thin veneers, only a few centimetres to some decimetres thick, that mimic the morphology of the underlying substrate such as boulders or tree stems. Others form columnar or domal build-ups, up to 1,5 m tall. Domes and columns show rounded, gently convex shaped and intensely ornamented upper surfaces. They often appear in clusters, but also as isolated build-ups. The crusts occur at different elevations, from the shoreline to about 25-30 m above the present lake level. Due to their overall shape, ornamentation and columnar structure, they are interpreted as lacustrine stromatolites.

Palaeostrandlines

Along the low-relief margins of the lake, slope breaks occur at different elevations above the present lake level. In several places, they are accompanied by small-scale ridges and depressions. Some of the slope breaks are also visible on aerial photographs, as bright lineaments striking more or less parallel to the present shoreline. They are interpreted to represent palaeostrandlines or cliffs, that were formed by wave erosion of unconsolidated sediment; occasionally, they are escorted by small-scale beach ridges. Several generations of such palaeostrandlines can be differentiated (Fig. 3).

Elongate mounts striking parallel to the present shoreline and a few decimetres high, occur within the innermost strandline. These are most probably beach ridges, that were formed during the latest high-stands of the lake. A cavity on the steep rocky western shore of Lake Ashengi, located ~25 m above the present lake level and covered partly by a calcite crust could represent a fossil cliff. Terraces in the northern part of the lake basin were formed as wave-cut terraces carved on unconsolidated sediments and on volcanic bedrock. During maximum highstands, overflow on the western and south-western side of the lake basin, where only low ridges separate the basin from neighbouring valleys, is most likely.

Fossil lake deposits

Fossil lake sediments are exposed in gully and stream sections at different elevation above the present lake level. They consist predominantly of lithofacies types characteristic of shallow littoral environments, mostly calcareous mud and calcareous diatomite. These lithofacies types contain abundant gastropods, diatoms and ostracods. The shallow littoral sediments interfinger with lithofacies types, which are interpreted as swampy wetland and with alluvial-colluvial sediments.

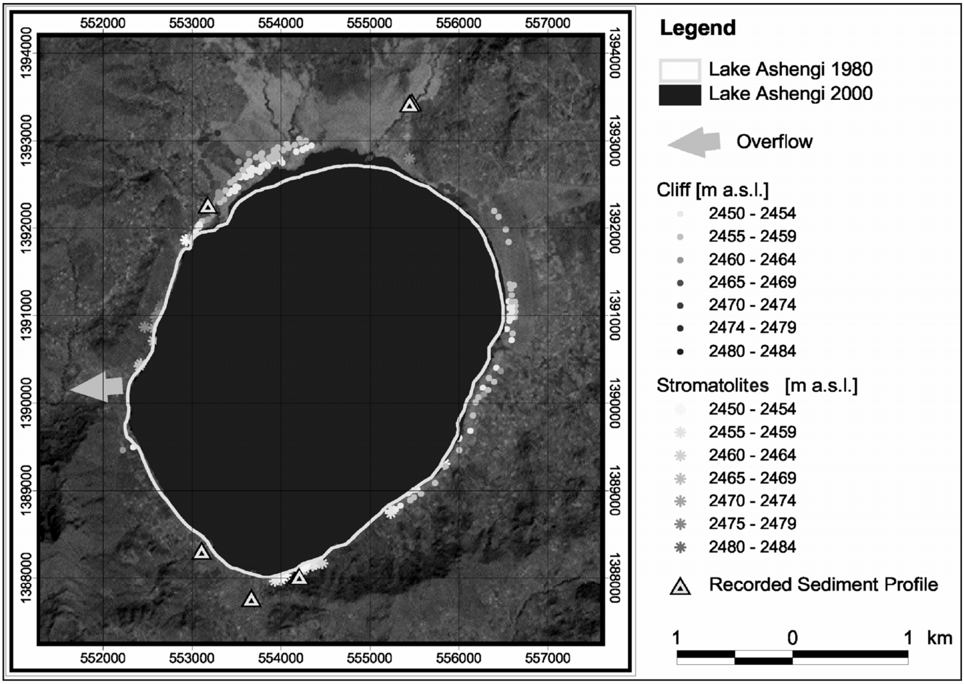

Figure 3 Map of lake level indicators in Lake Ashengi basin.

During field work, we have identified palaeoshorelines and fossil lake deposits at different elevations above the present lake level of Lake Ashengi. This implies periods of notably different climatic and hydrological conditions in the past. Without absolute age dating, the timing of these periods is speculative. Lake highstands might have occurred during the early Holocene, when most of the Ethiopian Rift lakes experienced elevated lake levels. Alternatively, they could be related to the short-term highstand around 2000-1500 ^{14}C yrs. BP reported by Gillespie et al. (1983) and Gasse (1990). Even during the last decades, the lake level fluctuated significantly. Locals report that during the 1930's and 1960's, the lake level was up to ~10 m above the present level. In the 1980's, the lake experienced a lowstand. In the last years, the lake level seems to have risen again, as indicated by the presence of drowned trees near to the western shoreline of the lake.

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