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Tectonic, climatic and hydrothermal control on sedimentation and water chemistry of northern Lake Malawi (Nyasa), Tanzania

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Abstract

This paper presents a multi-disciplinary characterisation of processes that influence sedimentation and lake water chemistry in the northern part of the Lake Malawi (or Lake Nyasa), East Africa. This characterisation is based on geophysical (heat-flow), tectonic, hydrological, hydrochemical (major elements, stable isotopes) and sedimentological (seismic profiles, core mineralogy) studies of data acquired from 1990 to 1994 during the CASIMIR project (Comparative Analysis of Sedimentary Infill Mechanisms in Rifts).

Sub-surface activity is expressed through seismic and volcanic activity, as well as elevated heat-flow values, both beneath the lake and the surrounding area; hydrothermal activity is observed in the watershed however it was not clearly identified in the sub-lacustrine environment. Relatively high heat-flow values (80–90 mW/m^2) and the chemical composition of hydrothermal fluids in hot springs suggest the presence of a magmatic body at depth.

The influence of Quaternary tectonic activity on sedimentary dynamics and infilling is observed not only on land but also in the lake through high-resolution seismic profiles. The main feature is a general tilting of the Kyela Plain as shown by a shift in the river course. The Quaternary stacking pattern of seven sedimentary sequences identified on a grid of high-resolution seismic reflection profiles represents a complete long-term lake-level cycle, from a lake lowstand at about 320 m below the present level to the present-day lake highstand. The North-Kiwira and Songwe River delta systems, composed of a number of stacked lobes, were developed in response to the interplay between gradual lake-level rise, tectonic movement and sediment input. The river dynamics is also recorded in a short core by a mineralogical evolution probably due to a decrease of detrital inputs from the Songwe River in response to hydroclimatic changes. Such changes are very important as this northern part of the watershed is considered as a recharge zone for the entire lake. Sedimentological patterns (from shallow depth to about 240 m water depth) and hydrochemistry are both influenced by watershed characteristics (pedology, geology, vegetation, hydrology, climate, etc.) but also by lacustrine biological processes: diatom productivity in epilimnetic water and degradation or preservation in deeper waters.

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Physico-chemistry and isotopic data of epi- and metalimnetic waters document the importance of the various water sources but also of evaporation and mixing processes linked to the thermo-haline stratification. Even if hydrothermal discharges have not been observed in the lake, they contribute to the lake chemistry at least through riverine inputs (Kiwira River).

Keywords: East African Rift; Lake Malawi (Nyasa); Quaternary; Tectonics; Seismic profiles; Heat flow; Sediments; Water chemistry; Climate

1. Introduction

Lake Malawi or Nyasa (Fig. 1) is the second largest lake of the East African Rift by volume and the fifth largest in the world. As this water body contains 7% of the world's free surface fresh water, its study is extremely important for the proper management of freshwater resources. The creation and evolution of Lake Malawi, like others in the rift, was and still is closely linked with regional geological activity.

The purpose of the present paper is to evaluate the influence of endogenous and exogenous processes on the recent evolution of the Livingstone (or Karonga) Basin (northern basin of the lake) by combining different geological and limnological approaches. These included studies of active tectonic movements on land and those expressed by the lake bottom topography, high-resolution reflection seismic profiling to explore the sedimentary infill and the structural deformations affecting it, heat flow measurements, water chemistry and sediment mineralogy. These different approaches were performed within the framework of the CASIMIR project (Comparative Analysis of Sedimentary Infill Mechanisms In Rifts).

2. Materials and methods

All data presented here were collected during different field expeditions organised between 1990 and 1994 within the framework of the CASIMIR project. All lake operations were performed aboard the *Nyanja* vessel.

The tectonic context of the area was characterised using published geological informations (maps, catalogues and papers), fieldwork and the interpretation of Landsat TM images.

Thirteen seismic profiles (Fig. 1) were acquired in October 1992 using a Centipede-sparker-seismic source (frequency range: 150–1500 Hz, when operated at 300 J) and a single channel streamer (De Batist et al., 1996).

A total of 32 heat-flow measurements were performed in the northern part of the lake during the 1991, 1992 and 1993 fieldwork campaigns (Table 1) using a non-autonomous cable thermoprobe which measures the in situ temperature and thermal conductivity of the bottom sediments (Golubev and Klerkx, 1993).

Water and sediment samples for geochemical analysis were collected in the Livingstone Basin in October 1993 (Fig. 1). Three water columns (water depths from 200 to

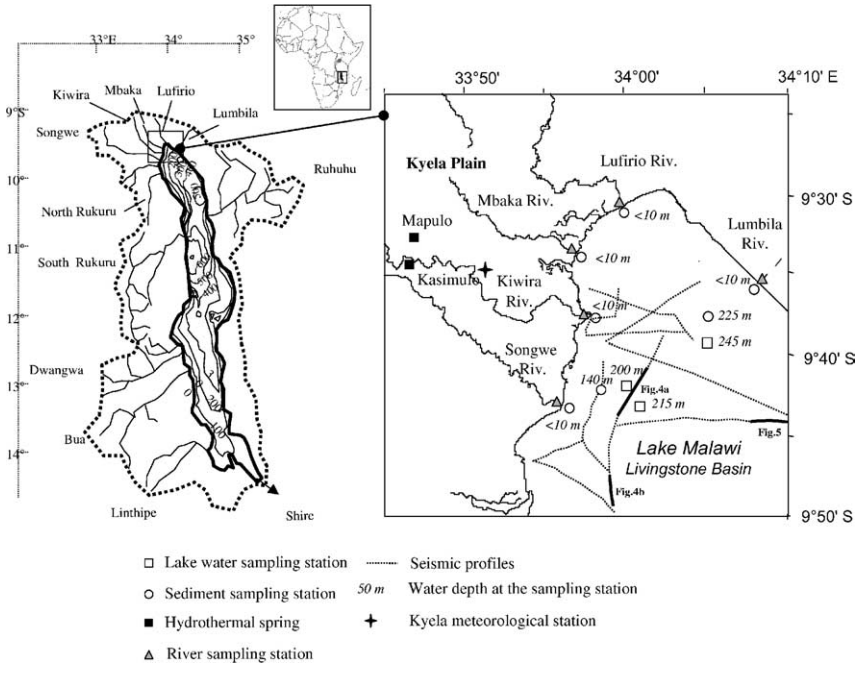

Fig. 1. Schematic bathymetric (from Johnson and Davis, 1989) and hydrographic map of Lake Malawi and locations of sediment/water sampling stations and seismic profiles in the Livingstone basin and its catchment. Inset box shows location of Lake Malawi in Africa.