STABLE ISOTOPIC COMPOSITION OF EAST AFRICAN LAKE WATERS

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Abstract

The investigation of stable isotopic composition of East African lake waters was conducted by scientists from the Department of Geology, University of Nairobi as part of the International Decade for the East African Lakes (IDEAL) project and in close collaboration with the scientists from Large Lakes Observatory of the University of Minnesota and the Isotope Hydrology Laboratory of the IAEA in Vienna. The Research Contract was part of the IAEA Co-ordinated Research Programme on Isotope Techniques in Lake Dynamics Investigations, and was sponsored by the Agency.

Water and grab sediment samples were obtained from East African Lakes during the month of January and February, 1994 and July/August 1995. Water samples were analysed for oxygen and deuterium isotopic composition at the IAEA Laboratories in Vienna, Austria. In this final paper we report the results of the study of oxygen and deuterium isotopic composition from the East African lake waters.

Introduction

Since 1990, we have observed that most if not all lakes in East Africa had a rapid decrease in lake level. Rocky shorelines in Lake Baringo for example indicate a decrease of at least 1 metre during this period. Lakes Elmenteita and Nakuru have almost run dry. Whether the current trend in lake levels in East Africa is a local response to current drought conditions in sub-Saharan Africa or to global warming is subject to speculation. This situation provided a unique opportunity to monitor and study the changes in the isotopic composition of the lake waters as well as the chemical and ecological responses of small lakes to these changes.

Objective

The primary objective of this project is to study temporal changes in the chemical and isotopic composition of lake waters induced by climate change in the tropics, and the ecosystem response to these changes. The other objective was to establish a lake water sampling programme in East Africa covering different climatic setting, altitude, mean annual temperature, rainfall and chemistry (Table 1, Fig. 1) in order to investigate seasonal variability in isotopic composition of precipitation in the region.

Methods

Lakes that were sampled (Fig. 1) were selected to cover a wide latitudinal as well as altitudinal, range (Table 1). This selection was done with the aim of trying to establish an evaporation/precipitation gradient as well as a temperature gradient. In each lake, between one and three grab sediment samples were obtained using an Ekman dredge. Surface water samples were obtained coincidentally with the grab samples. The waters were filtered with a .45m filter paper and three 250 ml portions were saved to be later analysed for major anions, cations and isotopes. Field titrations were also performed to determine alkalinities. Measurement of water temperature pH, conductivity and total dissolved solids (TDS) were also carried out.

Water samples were analysed for oxygen and deuterium isotopic composition at the International Atomic Energy Agency Laboratory in Vienna, Austria. Sediment samples were analysed at the University of Minnesota, and at the University of Nairobi.

Results

The deuterium and ^{18}O content of lake waters in East Africa is presented in Table 2. The result is reported in conventional delta notation (δ) as parts per thousand deviation of the isotope ratios $^{2}H/^{1}H$ or $^{18}O/^{16}O$ relative to the standard V-SMOW (Vienna Standard Mean Ocean Water). The deuterium excess, defined as $\delta = \delta^{2}H - 8\delta^{18}O$, describes the location of individual data points on the plot with respect to the so-called Global Meteoric Water Line (GMWL) defined by the equation $\delta^{2}H - 8\delta^{18}O + 10$. Using this equation the $\delta^{18}O$ and δD values of lake waters in East Africa was plotted in Figure 2. The range of $\delta^{18}O$ values of the lake waters is from -3‰ to 12‰ while δD varies from about -16‰

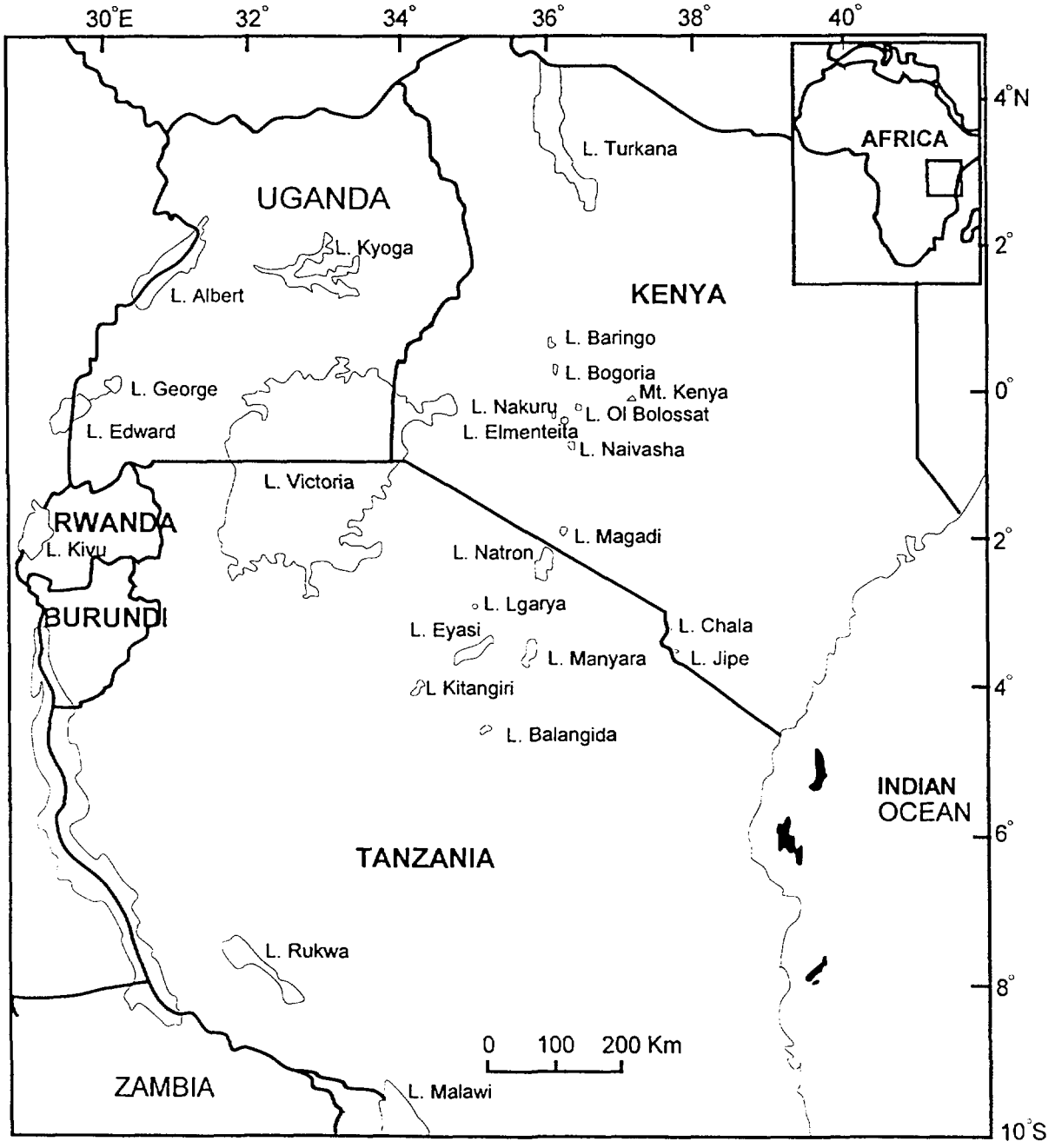

Fig.1 Location map for the East African Lakes of this study

Table 1. Description of East African lakes sampled in this study

Lake	Altitude	Latitude	Longitude	Lake Area (Km^2)	Zm (m)	Z(Mean) (m)	Vegetation
Turkana (16GC)	375	2°50'N	36°28'E	7500	110	31	Semi arid, shrubs
Jipe	701	3°35'S	37°45'E	30	-	~3	Savanna
*Chala	838	3°19'S	37°41'E	5	~100	-	Open forest
*Katwe+	895	0°08'S	29°52'E	2.45	2.45	0.33	-
Edward+	913	0°25'S	29°30'E	2800	120	-	Open forest
Kitagata+	925	0°03'S	29°58'E	-	-	-	-
Baringo	975	0°38'N	36°05'E	160	4	-	Savanna
*Nyamusigire+	975	0°17'S	30°02'E	4.4	4.9	-	Forest
*Kamweru+	1160	0°15'S	30°07'E	0.3	33.5	22.7	Forest
*Nkugute+	1220	0°19'S	30°06'E	1.05	58	20	Farms, forest patches
Manyara	1235	3°35'S	35°50'E	400	-	-	Savanna
*Nyabikere+	1265	0°30'N	30°20'E	-	40	-	Farms, forest patches
Nyinbulita+	1327	0°31'N	30°19'E	-	65	-	Farms, forest patches
*Katanda+	1340	0°29'N	30°16'E	0.4	146	-	Forest
*Saka+	1520	0°42'N	30°14'E	0.01	8.5	2.7	Open forest, grasses
Babati	1540	4°15'S	35°44'E	5	-	-	Farms, ~50% forest
Singidai	1540	4°47'S	34°45'E	10	~4	-	Savanna
Kindai	1540	4°51'S	35°44'E	3	-	-	Savanna
*Duluti	1600	3°23'S	36°47'E	1	-	-	Forest
Nkunga	1840	0°07'N	37°36'E	~1	-	-	Forest
Small Momela	1850	3°14'S	36°54'E	~0.5	-	-	Open forest
Naivasha	1880	0°46'S	36°21'E	175	~5	-	~90% farms, grasses
Ol Bolossat	2320	0°09'S	36°26'E	40	~2	-	~90% farms, grasses
*Rutundu	3079	0°19'S	37°28'E	1	~10	-	Alpine

to -70‰ (Table 2). The plotted $\delta^{18}O$ and δD values relative to SMOW of meteoric waters is shown in Figure 2.

Discussions

The lakes sampled in this research contract range in altitude from 360 m to 3,000 m (Table 1, Fig. 1). The altitudinal distribution of these lakes provide two major climatic gradients; a precipitation/evaporation gradient and a temperature gradient. These climatic gradients should be reflected in the isotopic and chemical composition of the lake waters in East Africa. The results obtained in this work clearly indicate that lake waters from East Africa behave differently, perhaps due to excessive evaporation that characterises this region.

The isotopic composition of precipitation in the East African region reflects the regional circulation pattern (Rozanski, 1995). The region experiences recurrent events of extremely low deuterium and $\delta^{18}O$ isotope composition of precipitation, often persisting for more than one month, which most probably are associated with unusually strong convective activity within the air column, associated with passage of the intertropical convergence zone (ITCZ). In general, isotopically depleted waters are associated with the rainy seasons (Table 2).

Table 2 Values of Isotope (δD, $\delta^{18}O$) in East African lakes in this study.

Location	Sample Code	delta (O-18)	delta (H-2)
L. Manyara	A1/1	-2.44	-8.9
L. Manyara	A1/2	-2.42	-10.9
L. Momela	A2/1	3.92	23.7
L. Momela	A2/2	2.69	24.4
L. Singindai	A3/1	7.32	47.6
L. Singindai	A3/2	7.19	45.6
L. Babati	A4/1	4.16	25.4
L. Babati	A4/2	4.37	25.9
L. Kindai	A5/1	6.01	37.2
L. Kindai	A5/2	6.00	36.2
L. Duluti	A6/1	3.42	18.7
L. Duluti	A6/2	3.58	19.2
LT95-1WS	A7/1	5.70	36.4
LT95-1WS	A7/2	5.70	40.9
LT95-2WS	A8/1	5.41	38.8
LT95-2WS	A8/2	5.69	39.9
LT95-3WS	A9/1	5.73	39.9
LT95-3WS	A9/2	5.72	41.0
TURK R.-5WS	A10/1	-0.60	3.5
TURK R.-5WS	A10/2	-0.68	2.7
LT95-5WS	A11/1	6.01	41.3
LT95-5WS	A11/2	6.05	41.2
Omo R.-6WS	A12/1	-0.81	3.0
Omo R.-6WS	A12/2	-0.89	-1.9

Location	delta (O-18)	delta (H-2)	d-excess
L. Edward, 0 m	4.04	29.7	-2.6
L. Kifuruka, 0 m	5.80	32.1	-14.3
L. Saka, 0 m	1.87	17.3	2.4
L. Katanda 0 m	6.65	39.2	-14.0
L. Kamweru 0 m	3.25	22.3	-3.7
L. Nkugute, 0 m	3.40	25.0	-2.2
L. Nyinabuiita, 0 m	5.45	35.0	-8.6
L. Nyabikere, 0 m	0.83	13.9	7.3
L. Kitagata, 0 m	6.16	34.8	-14.5
L. Nyambusiri, 0 m	6.84	39.4	-15.3
L. Nyantonde, 0 m	4.64	28.1	-9.0
L. Nyantonde, 10 m	4.59	32.3	-4.4
L. Nyantonde, 20 m	4.52	27.8	-8.3
L. Nyantonde, 30 m	3.15	23.4	-1.8
L. Nyantonde, 60 m	3.28	23.7	-2.5
L. Nyantonde 150 m	3.68	21.8	-7.6

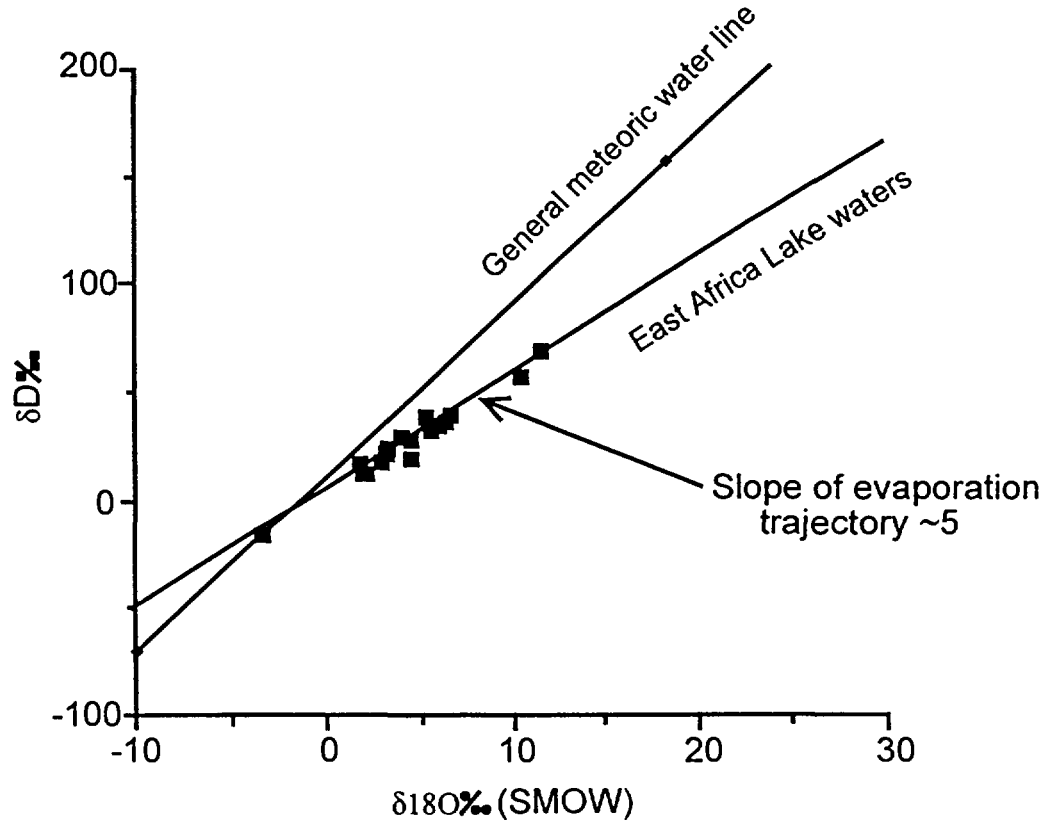

Fig.2 Plot of δ18O and δD values relative to SMOW of meteoric waters of this study.

In lakes with seasonally dry climate, the oxygen isotopic composition of a lake's water is mainly the result of evaporative evolution and residence time of the water body (Beadle, 1974; Gat, 1981; Gonfiantini, 1986). This does not seem to be the case in East Africa. The isotopic composition of the lake waters studied in this contract seems to be an interplay between basin size, altitude and hydrology. However, further research is required in order to have a better understanding of the physical and chemical factors that cause the observed variability in the isotopic composition of lake waters in this region.

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