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Isotope evidence of palaeorecharge and palaeoclimate in the deep confined aquifers of the Chad Basin, NE Nigeria

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Abstract

Groundwaters from the Quaternary and Continental Terminal Formations in the Nigeria sector of the Chad Sedimentary Basin (CSB) together with rain and surface waters have been chemically and isotopically analyzed in order to investigate sources and ages of waters, possible modern renewal and mixing of the deep groundwaters, and to infer palaeoclimate incidences. Most of the waters are slightly to moderately mineralized and are of Na-HCO_3 type induced mainly by Na-feldspar weathering and ion exchange reactions. The wide range of the $\delta^{18}O$ and $\delta^{2}H$ values and ^{3}H contents in the upper aquifer indicate replenishment with modern meteoric water. However, the deep system (middle and lower aquifers) with a narrow range of depleted stable isotope values and low ^{14}C activities indicates that these waters have a palaeometeoric origin. The period of infiltration was within the humid and cooler period (35 to 40 ka BP) prior to the Last Glacial Maximum. In addition, the isotope compositions of the deep system show no mixing with modern waters. These results are in agreement with other palaeorecord studies in the Sahel zone during this period.

Keywords: Chad Sedimentary Basin; Nigeria; Environmental isotopes; Palaeorecharge; Palaeoclimate

1. Introduction

Isotope geochemistry methods have been proven as valuable tools in investigating various problems in hydrology. They provide significant insights into origin of waters, recharge circumstances (time and location), water flow directions, residence times and provide information on climate (Kharaka and Carothers, 1986; Lambert, 1991; Clark and Fritz, 1997; Cook and Herczeg, 2000). They are particularly useful in complex geological systems where only scarce hydrologic data are available, and what is available is often unreliable for use as conventional approaches in understanding and ascertaining recharge sources for a viable long-term groundwater development. Stable isotopes of the water molecule ($\delta^{18}O$ and $\delta^{2}H$) have been widely and successfully used as inert tracers to indicate the residence time of groundwater, especially to distinguish between modern and palaeowaters and those which were recharged under colder conditions of the Late Pleistocene (Darling et al., 1997). Occurrence of ^{3}H in groundwater indicates the extent of migration of modern post-1950s recharge, but its use is limited by its short half life (12.3 years) (Edmunds and Smedley, 2000). Radiocarbon

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allows determination of water residence time over timescales to 30 ka, but since ^{14}C is involved in geochemical reactions a detailed understanding of the origins of inorganic C dissolved in groundwater is required to convert the measured activities to ages (Clark and Fritz, 1997).

The CSB groundwater in the NE of Nigeria is a multilayer aquifer system. Two of the aquifers are confined and present potential opportunities for study of palaeogroundwater evolution since the amounts of recharge under modern climate are expected to be small or negligible. The system is an important groundwater source for public and rural water supply; it has been extensively developed due to the existence of artesian conditions of the confined units where static water height may reach up to 21 m above ground level. As a consequence of the uncontrolled artesian flow, a significant decline in pressure as well as a cease in the natural artesian outflow in some boreholes and decrease in production yield (some boreholes are dried up) have already been observed over the past three decades in Maiduguri and villages in the NE part of the region (Edmunds et al., 1997, 1999; Maduabuchi et al., 2003). Satisfying the water needs in this region requires developing and managing the groundwater subsystem, especially as it is not known whether the older groundwater is being abstracted or if the modern recharge is being used.

This work presents the results of a collaborative project between the International Atomic Energy Agency (IAEA) and the Nigeria Federal Ministry of Water Resources (project code "Isotopes based investigations in the Chad Basin NIR/8/006-02"). This study, initiated in 2001, deals essentially with the investigation of the stable isotopes of ^{18}O, ^{2}H and ^{13}C, and radioactive isotopes of ^{14}C and ^{3}H, with lesser emphasis on chemical characteristics. The aim is to: (1) determine the chemical characteristics of the groundwaters; (2) investigate the origin and timing of recharge; (3) determine the relative residence times of the groundwater in the different layers; (4) evaluate possible modern recharge and mixing of groundwaters.

2. Site description

The study area is located in the western part of the CSB, which extends to Chad, Niger, Algeria, Libya, Sudan, Central Africa Republic and Cameroon. The

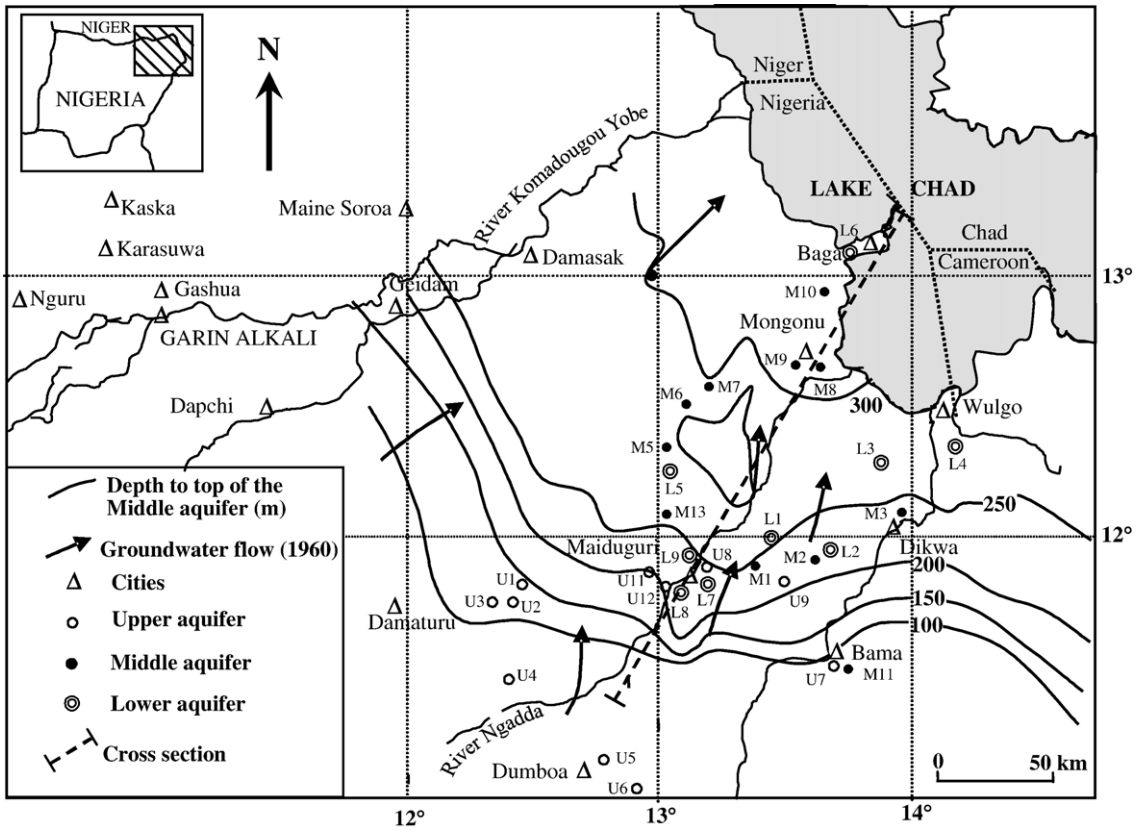

Fig. 1. Study area location and sampling network.