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Geochemical processes in Kandi Basin, Benin, West Africa: A combined hydrochemistry and stable isotopes approach

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ABSTRACT

Detailed hydrochemical and stable isotopic data of surface and groundwater were used to understand the geochemical processes occurring in the Kandi basin in Benin. Hydrochemical investigations show that waters in this basin are of low mineralization, with values of Total Dissolved Solids (TDS) generally less than 1200 mg/L. Water types in the basin are HCO_3–Mg, HCO_3–Na, Cl–Na, HCO_3–Ca, Cl–Ca and most fall in mixture water type (i.e. HCO_3–Mixe and Cl–NO_3–Mixe). The mineralization is governed essentially by the dissolution of dolomite, calcite, aragonite, and magnesite, but not cation exchange reactions. The stable isotope approach underlined the interchange phenomenon between aquifers in the basin, direct recharge of aquifers by surface waters in some areas, and recharge of aquifers by modern precipitation, which influence the groundwater geochemistry in the basin. Anthropic origin of nitrates is underlined by stable isotopes.

1. Introduction

On a global scale, one third of the population depends on groundwater for drinking, in urban as well as rural areas (BGR, 2008). Groundwater also plays a pivotal role in agriculture, as it is increasingly extracted for irrigation purposes. The growing population and recent climate change are putting water resources under pressure all over the world, calling for new approaches for water planning and management if escalating conflicts are to be avoided and environmental degradation is to be reversed (Ragab and Prudhomme, 2002). In arid and semi-arid areas, the dependency on groundwater for water supply is even higher, between 60 and 100% (GTZ, 2007), as those regions are generally subject to low and irregular precipitation.

The Kandi basin, which is part of the transboundary Iullemeden sedimentary basin (shared between Niger, Nigeria and Benin), belongs to the semiarid zone where people mostly depend on groundwater as their main source of water supply. Strategic importance of groundwater in Africa has grown, in particular its significance for community water supply. However, this is threatened by poor understanding and mismanagement of groundwater supply sources. A better knowledge of groundwater resources in this shared basin is fundamental to ensure the integrated and shared management of groundwater resources.

The use of environmental isotopes techniques in hydrogeology provides useful information which cannot be obtained by other means (Abid, 2010). Isotope geochemistry techniques have been proven as valuable tools in investigating many problems in hydrology and evaluating hydrogeological and hydrochemical controlling mechanisms in aquifer systems (Clark and Fritz, 1997). Isotope techniques give insights on the origin and movement of groundwater and they can offer an evaluation of physical processes affecting water masses, such as evaporation and mixing (Geyh, 2000). They provide valuable insights to recharge processes and are necessary for developing sustainable water resource management plans within the context of climate variability (Scanlon et al., 2006). These techniques have been applied in several regional and

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local investigations to understand the origin of water, the flow paths, the residence time and the geochemical processes within aquifers (Edmunds and Smedley, 2000).

This study focuses on Kandi basin and aims at using a combined hydrochemical and isotopic approach to provide valuable knowledge on groundwater mineralization and geochemical processes.

2. Site description

2.1. Location, climate and hydrology

The study area is the transboundary Iullemeden basin in Benin which is a shared sedimentary basin between Benin, Nigeria, and Niger. This basin is known as Sotoko basin in Nigeria, Iullemeden basin, in Niger and Kandi basin in Benin. This study concerns Benin's part (Kandi basin) located in a semi-arid zone between 10°12′ and 12°08′N; 2°45′ and 3°46′ E, where the altitude varies between 160 m (around Karimama township) and 410 m (around Kalalé township). High altitude values are recorded in the southern basin and altitudes decrease gradually toward the northern basin. The Kandi basin is limited in the north by the Niger river, in the south by the basement rocks, in the west by the Kandi regional fault and in the east by the republic of Nigeria (Figs. 1 and 2). It covers an area of about 8700 km^2 which represents 7% of Benin's territory. The basin is flanked in the west and south by basement rocks (Fig. 2).

The climate is characterized by a rainy season from May to October (Le Barbé et al., 1993). The mean annual rainfall recorded at Kandi meteorological station (from 1990 to 2009) is 973 mm with a mean temperature of 34.6 °C. The annual mean potential evapotranspiration is 1668 mm which exceeds the annual rainfall (Achidi et al., 2012).

The Niger River is the largest in Kandi basin (as its northern limit). It has two tributaries in the basin, Alibori and Sota, characterized by permanent flow. Sota River has its source in the southern Kandi basin, at an elevation of more than 400 m a.s.l. (above sea level), on a hill around Kalalé township. It flows throughout and

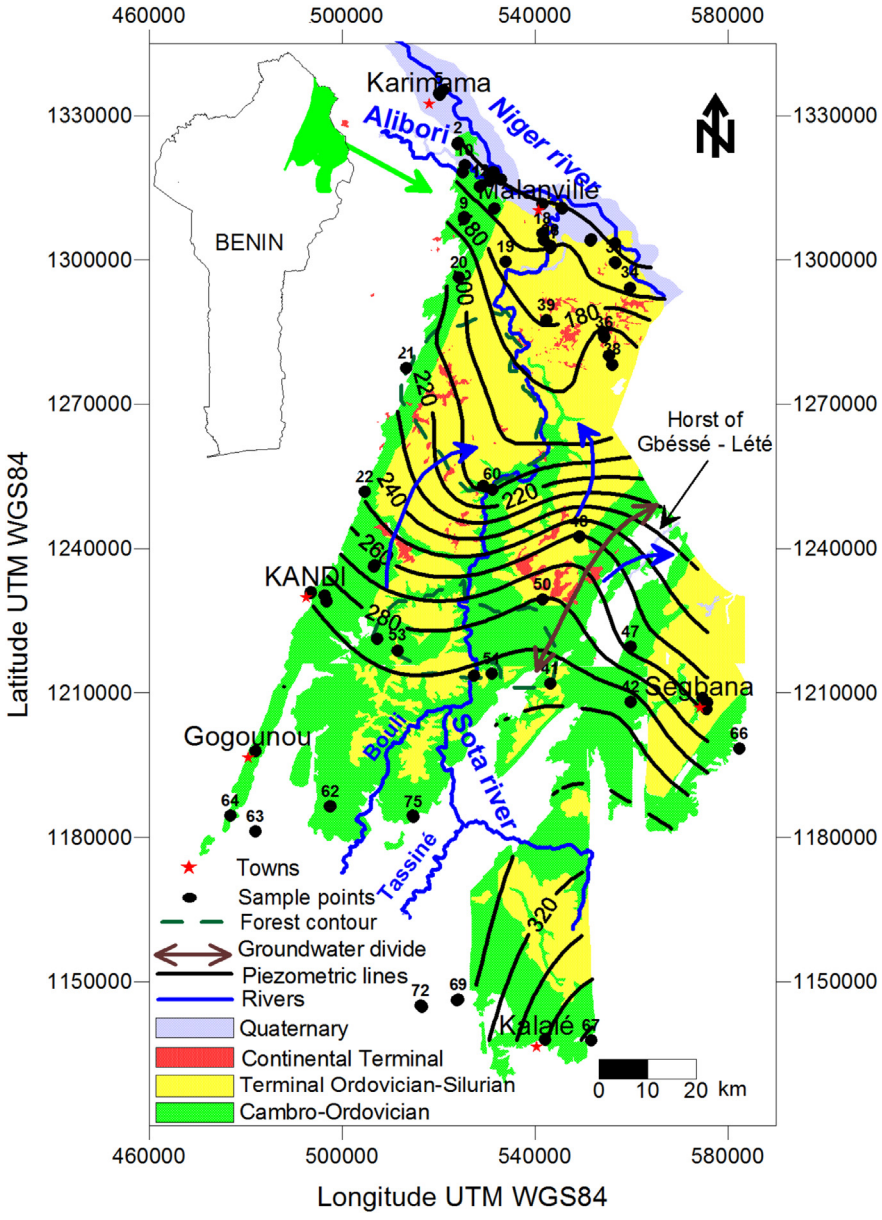

Fig. 1. Localisation and piezometric map of the shallow water table (March 2013) of the study area showing sampling points.