Journal of African Earth Sciences 83 (2013) 10–24

Contents lists available at SciVerse ScienceDirect

Journal of African Earth Sciences

journal homepage: www.elsevier.com/locate/jafrearsci

Hydro-geochemical and isotopic composition of groundwater, with emphasis on sources of salinity, in the aquifer system in Northwestern Tunisia

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ARTICLE INFO

Article history:
Received 6 June 2012
Received in revised form 3 February 2013
Accepted 8 February 2013
Available online 27 February 2013

Keywords:
Groundwater
Hydrogeochemistry
Isotopic data
Salinity
El Kef region
Tunisia

ABSTRACT

The hydro-geochemical and isotopic data of groundwater of the aquifer of the El Kef area, North-Western Tunisia, were examined to determine the main factors controlling the groundwater chemistry and salinity as well as its hydro-geochemical evolution. This study area has a complex geological structure which is mainly controlled by halokinesis movements and inherited structures. Groundwater occurs in different water bearing formations belonging to Upper Cretaceous, Paleogene (Eocene) and Mio-Plio-Quaternary (MPQ). Different geochemical interpretation methods were used to identify the geochemical characteristics. Groundwater of the MPQ aquifer has the highest salinity values (0.3–7.0 g l^{-1}) in the study area due to the impact of agricultural activities. Piper diagram showed that Cl^- and SO_4^{2-} are the dominant anions, where as Na^+ is the most dominant cation, where it is sometimes replaced by Ca^{2+} and/or Mg^{2+} in the hydro-chemical facies of the groundwater. Dissolution of carbonate and sulfate minerals in the aquifer matrices and recharge areas as well as cation exchange are shown to modify the concentration of ions in groundwater. The groundwaters are depleted in ^2H and ^{18}O and displayed an isotopic signature close to that of meteoric water with *d*-excess values indicating present-day precipitation over the region and reflect the contribution of vapor masses from Mediterranean and Atlantic origins. The isotopic features suggest that most of the groundwater at the study area result from mixing between recent recharge and an older component recharged under climatic conditions cooler than at present.

1. Introduction

Groundwater in many arid basins, particularly in developing countries, is the only available water resource. During the last decades groundwater exploitation in the El Kef region (Northwestern Tunisia) has increased dramatically, mainly due to an increase in irrigated agriculture, tourism and industry. To meet the needs of drinking water for future generations, sustainable watershed management is essential for drinking water supply especially in semi-arid areas, and requires a more detailed knowledge about recharge processes. In arid and semi-arid zones, high salinity typifies most groundwater. A perennial problem for agriculture in these areas is the scarcity of water due to low and irregular rainfall. In the last century, expansion of the global population has increased the pressure on water resources. In northern Tunisia, most groundwater is taken from deep aquifers via more than 800 boreholes and from dams (DGRE, 2010). Most aquifers show signs of advanced overexploitation, revealed by hydrothermal springs drying, declining piezometric levels and deterioration of groundwater quality (Hamed, 2004). Before 14 January 2011 – the date of the Tunisian revolution or the Arabian spring revolution, the total annual abstraction of groundwater (agricultural and potable water supply, including the tourist and the industrial sectors) in the study area is about 22.5×10^6 m^3 (DGRE, 2010). Probably this consumption was increased by random access after this revolution.

Geochemical indicators constitute effective tools for solving various problems in hydrology, in particular in the arid and semi-arid regions (Clark and Fritz, 1997; Cook and Herczeg, 2000; Etcheverry, 2002). In such environments, groundwater is a precious resource subject to intensive exploitation for agricultural, urban and industrial uses. Multi-tracer investigations are commonly used to estimate hydrodynamic parameters such as groundwater flow, mixing patterns between different groundwater sources, and recharge rate, and such information is needed to improve water-resources management. However, in arid areas, estimation of groundwater

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http://dx.doi.org/10.1016/j.jafrearsci.2013.02.004

recharge remains complicated due to spatial variability of rainfall and a low amount of recharge (Le Gal La Salle et al., 2001).

The present work is focused on the NW aquifer system which constitutes the main water resource in North of Tunisia (Fig. 1). Hydro-geological, hydro-chemical and isotopic information from the groundwater system is integrated and used to determine the main factors and mechanisms controlling the chemistry of groundwater in the investigated area. Geochemical data are particularly useful for evaluating groundwater evolution and recharge in the arid regions of North Africa where groundwater resources are generally non-renewable. Despite the water development schemes, caused by urban and agricultural expansions, an acute environmental problem of groundwater salinization appeared in these area. The main issues that will be addressed in this report include: (i) hydrological and geological factors controlling water chemistry; (ii) processes affecting salinization of groundwater; (iii) location of recharge and discharge zones, and (iv) identification of the interconnection between the aquifer systems.

2. Physiography and climate of the study area

Topographically, El Kef area is characterized by flat plains with mountainous features with an average altitude of around 540 m above sea level. The study area, which extends over about 1000 km^2, belongs to the NE–SW troughs domain of Tunisia that is located in northwestern Tunisia and at the southward the Tellian Nappes and makes the eastern extend of the Algerian Atlas (Fig. 1). It is boarded to the north by the Alpines "Nappes" zone, to the east by the Diapirs zone, to the south by the Tunisian Atlas and to the west by the Algeria territory (Fig. 1). The semi-arid climate characterizing the study area is largely controlled by the influence of two major air masses trajectories: the cool North Atlantic air masses; which circulate from the west over northern Africa, and the warm Mediterranean air masses that circulate from the north (Celle, 2000; Celle et al., 2001; Hamed, 2011, 2012). The long-term mean annual rainfall ranges between 400 and 600 mm (Hamed, 2004; Hamed and Ben Dhia, 2010). About 80% of this precipitation occurs between September and March, followed by dry spring and summer months. The potential evapo-transpiration is about ≈1350 mm year^{-1}. The mean annual temperature is about 17 °C with maximum temperatures up to 38 °C in summer (August month) and a minimum in December month (−4 °C) (Hamed, 2004). Regionally, the surface drainage is toward the north and the west reflecting regional topographic gradients. It is constituted by several ephemeral Wadis (Etine, Ermal, Saboun, Cheria, Lahmar, Tessa, Amir, El Malah, etc.), which collect surface runoff from the surrounding highlands (Tunisian and Algerian) toward the exorheic

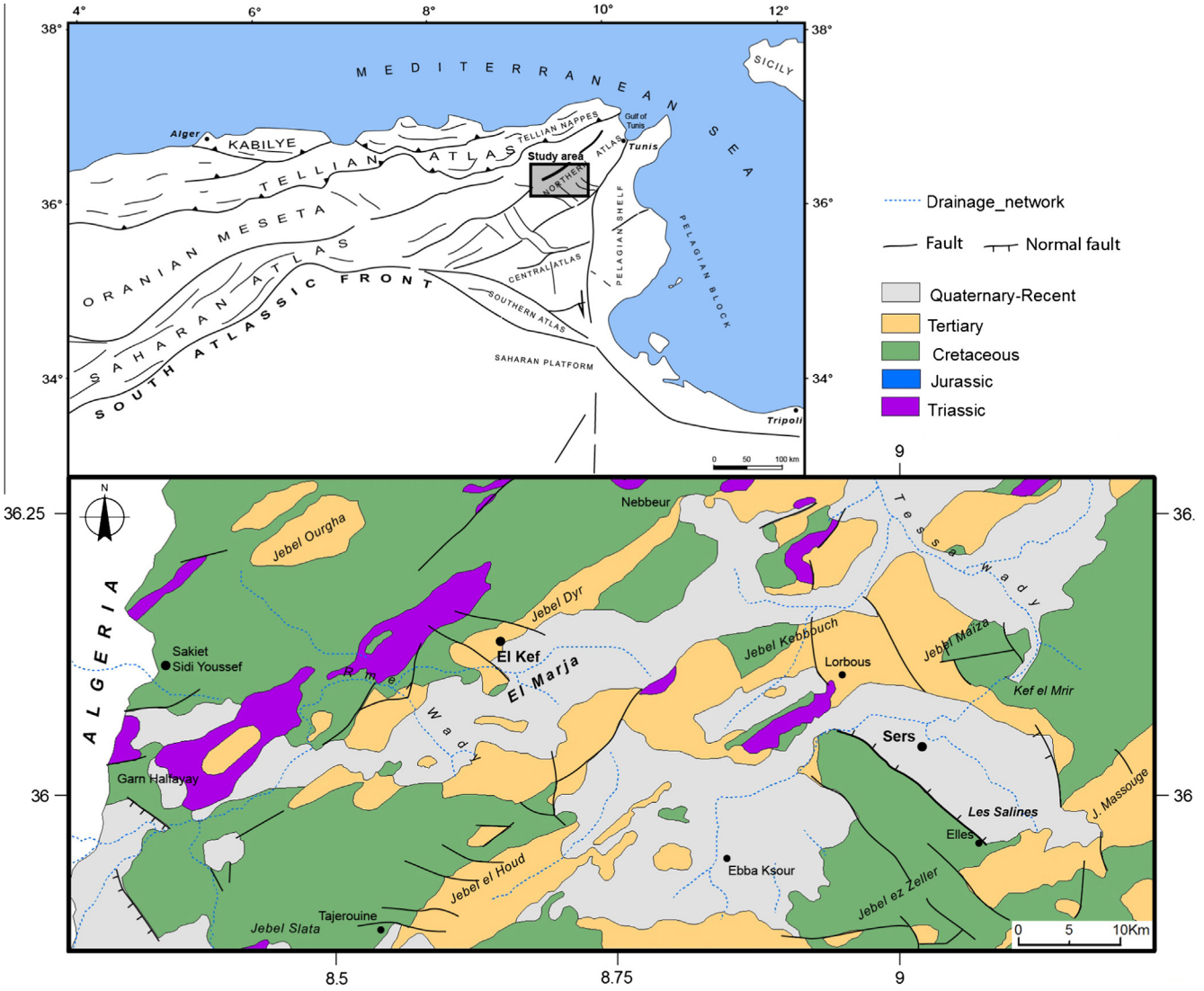

Fig. 1. Geologic and hydrology map of the study area (Northwestern Tunisia).