Journal of African Earth Sciences 138 (2018) 289–308

Contents lists available at ScienceDirect

Journal of African Earth Sciences

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

Geophysical methods integration for deep aquifer reservoir characterization and modeling (Sidi Bouzid basin, central Tunisia)

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ARTICLE INFO

Article history:
Received 14 March 2017
Received in revised form
16 November 2017
Accepted 20 November 2017
Available online 23 November 2017

Keywords:
Central Tunisia
Aquifer geometry
Gravity data filters
Gravity forward modeling
Depth to basement modeling
Geophysical mapping

ABSTRACT

Groundwater resources of the Sidi Bouzid basin (central Tunisia) are hydrogeologically and economically important. This importance is restrained by the complex and poorly understood subsurface geometry of the main basin, the overexploitation of its near-surface aquifers and the lack of deep hydrogeological wells in the study area. To overcome these issues a multidisciplinary study was conducted integrating geological, geophysical, and hydrogeological methods. As the regional structural tendency of the study area is predominated by Atlassic NE-SW trends, gravity anomalies could be defectively interpreted. Thus, different gravity treatments and filters were processed. A residual gravity response of Sidi Bouzid basin was rationally isolated, the main structural features were then outlined and depths of rooted sources were detected. The obtained results are in a good conformity revealing a newly detected sub-horizontal geophysical lineament that seems to be a high zone which may act as a hydrogeological barrier within the investigated basin.

Forward gravity modeling supported by 2D seismic reflection data over geological and geophysical methods integration, highlighted the Sidi Bouzid basin subsurface extent. It also defined its thick Tertiary complex substratum and the unknown total thickness and arrangement of its subsurface series. The used approaches provided a depth to basement modeling of the siliciclastic Tertiary complex estimating its depth and disclosing its subsurface configuration and its internal preferential water flow directions. A geophysical basement topography mapping enhancing the subsurface overview was also yielded.

1. Introduction

The Sidi Bouzid region is in the eastern side of the central Tunisian Atlas (Fig. 1) characterized by an arid to semi-arid climate. The Sidi Bouzid basin is one of the most important and largest hydrogeological basins in central Tunisia (Smida, 2008; Yangui et al., 2011; Azaiez et al., 2011). However, near surface water resources in this area are overexploited due to the increase in human demands (Smida, 2008; Yangui et al., 2011; Azaiez et al., 2011; Khazri and Gabtni, 2015). This area houses many sedimentary detrital and carbonated water reservoir levels including the Sidi Bouzid basin groundwater. The latter was the subject of several studies investigating its shallow and deep aquifer systems, its hydro-geophysical and geochemical properties, its vulnerability to pollution and its recharge mode and mineralization (Yangui et al., 2011; Aydi et al., 2013; Jellalia et al., 2015). Yet, investigations of its hydrogeological basin subsurface geometry, structural framework and main aquifers extent and deepening are still lacking.

The basin's siliciclastic Tertiary complex is of a big interest. Its sedimentary series are known for their significant thickness variation and their vertical and lateral heterogeneity. The geometry and structural features of this Tertiary package remain unrecognized. Its substratum is also undefined since it could not be reached by the neighboring hydrogeological wells (Smida, 2008; Zouaghi, 2008; Azaiez, 2011; Azaiez et al., 2011; Yangui et al., 2011; Aydi et al., 2013). A good understanding of the Tertiary complex framework within Sidi Bouzid basin and a reassessment of deep water resources highly require a multidisciplinary study integrating geological, geophysical and hydrogeological approaches. Such integration based on gravity analysis, seismic reflection interpretation and gravity modeling is of a good interest in the geometry characterization of aquifer reservoir. In fact, the combination of these geophysical exploration methods helps to depict the target aquifer geometry with a good reliability and a cost effective manner (Lachaal et al., 2012; Gabtni et al., 2012; Alam and Ahmad, 2014;

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https://doi.org/10.1016/j.jafrearsci.2017.11.024
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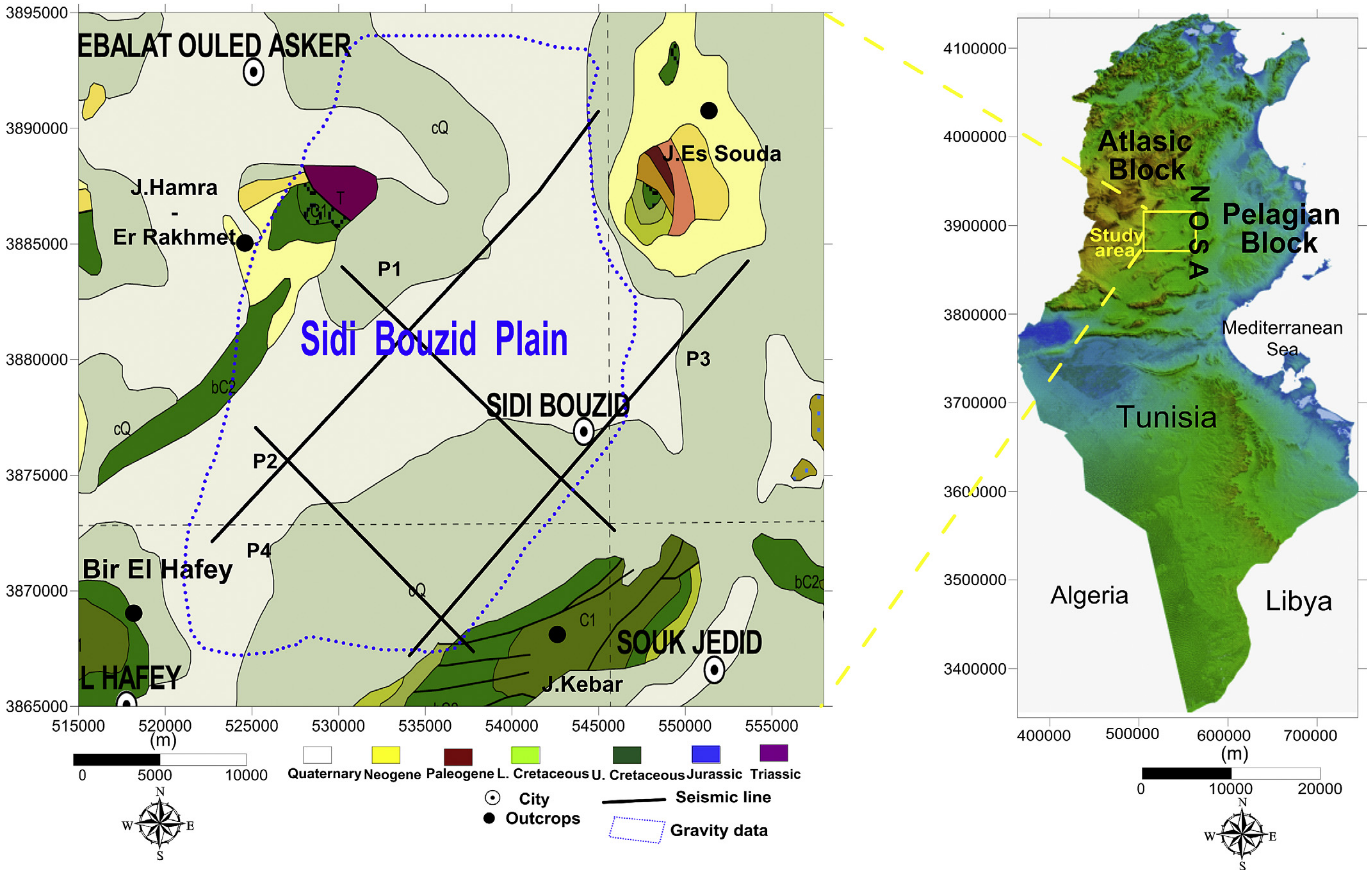

Fig. 1. Study area location map and the used geophysical data (after Ben Haj Ali et al., 1985).

Jellalia et al., 2015; Khazri and Gabtni, 2015; Djebbi and Gabtni, 2018). The gravity method contributes to the exploration of sedimentary basins groundwater resources and the characterization of complex aquifer geometry in the subsurface. Thus, the resulting measured density differences or anomalies in the earth's gravitational field could define the underlying geologic structures, highlight important structural features and detect subsurface geophysical lineaments. Applying this method is then crucial to solve some of the hydrogeological problems by locating potential zones for exploitation (Mariita, 2007; Gabtni et al., 2012; Khazri and Gabtni, 2015; Djebbi and Gabtni, 2018). The main characteristic of the seismic reflection method is its ability to map structures up to several kilometers in the subsurface and to highlight the subsurface layers arrangement and the structural framework for a better understanding of the geological and hydrogeological setting (Hunter and Hobson, 1977; Martin et al., 2013). In geophysics, gravity forward modeling is a procedure calculating a response from a given earth model. It's based on an iterative manipulation leading to a resulting model, providing an answer to a case study question and giving the closest subsurface geometry definition. In this paper, the gravity modeling process is used to valid reflection seismic interpretations. It's a technique revealing subsurface geological formations properties, highlighting their geometry and determining the aquifer reservoirs depths with an acceptable precision (Bullard and Cooper, 1948; Mundim et al., 1998; Oldenburg and Jones, 2007). At this level, integration of seismic and gravity methods is then fundamental in producing gravity forward models of semi-deep and deep aquifers.

The aim of this paper is to investigate the Sidi Bouzid basin geometry and structural features to reveal its subsurface layers arrangement, estimate the depth of its Tertiary siliciclastic complex and define its substratum. This study is also an attempt to understand the important relation between the detected geophysical lineaments and the basin's hydrogeological aspect and to carry out a close to reality image in the subsurface of the main basin in its geophysical and hydrogeophysical framework.

The present work is divided into four sections. The first is devoted to several gravity treatments and filters defining the Sidi Bouzid basin geometry and determining its important structural features. The second section presents interpreted seismic reflection sections providing an idea about the distribution of the subsurface stratigraphic units and a 3D visualization of the basin's siliciclastic Tertiary complex isochronous mapping. In the third section, a gravity forward modeling is computed to define the Sidi Bouzid basin layers arrangement and to propose a depth to basement modeling of its thick Tertiary complex. A gravity mapping of the main sedimentary basin is also accomplished. Finally, section four concludes with a summary.

2. Geological and hydrogeological setting

Central Tunisia including the Sidi Bouzid basin, belongs to the Atlassic chain exposing a geodynamic and paleogeographic context controlled by Eustatic, Tectonics, and Halokinetic factors (Boukadi, 1994; Bédir, 1995; Zouaghi, 2008; Azaiez, 2011). Such factors were recorded in the area's sedimentary series. The central Tunisian Atlas is limited to the North by the Tunisian dorsal, to the South by the Southern Atlas and to the East by the North-South axis (NOSA)