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Groundwater salinization survey of the Upper Cretaceous-Miocene Complexe terminal aquifer in the Sabaa Biar area of southwestern Tunisia

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ABSTRACT

An integrated hydrogeological study involving the Schlumberger depth sounding method, geological data and wells data was conducted at the Sabaa Biar area of southern Tunisia to elucidate the problem of increasing groundwater salinity within The "Complexe Terminal". The "Complexe Terminal" aquifer near Sabaa Biar region is a bi-layered aquifer comprised of fractured limestones of the Cretaceous (Campanian–Maastrichtian) Berda Formation and sandstone of the Miocene Beglia Formation. The aquifer is affected by a main NW–trending fault, which is a chemical barrier that divides the study area into eastern and western blocks delivering freshwater and saline water, respectively. The salinization of groundwater within the limestone (Campanian–Maastrichtian Berda Formation) is linked mainly to the dissolution of outcropping Coniacian–Santonian gypsum along the core of the Jebel Sidi Bouhlel anticline to the east of the study area. Meteoric water dissolves salt from outcropping gypsum, flows through the fractures networks, and recharges the fractured limestone of the upper Berda Formation. The mobilization of salts stored in the salt-rich Quaternary sediment on hillslopes and inchannels contributes also to the salinization of groundwater within the sandstone (Miocene Beglia Formation) by lateral infiltration subsequent to water drainage during the wet season. The over exploitation of water from the Miocene sandstone causes an influx of saline-rich water from the underlying limestone of the Berda Formation into the sandstone of the Beglia Formation. Other sources of salinization of groundwater (such as ascension of hypersaline water from deep aquifer along faults, and the return flow of irrigation waters in the Djerid region) have been documented in this region, but are not discussed in this paper.

1. Introduction

The Complexe Terminal aquifer The Complexe Terminal aquifer supports a thriving data industry in southern Tunisia, but is threatened by problems of increasing salinization (e.g., Zammouri et al., 2007). This aquifer extends across much of southern Tunisia as well as adjacent regions of Algeria and Libya (Castany, 1982; Roberts and Mitchell, 1987; Swezey, 1999). The Complexe Terminal aquifer is in fact a multi-layer aquifer that includes Upper Cretaceous (Campanian–Maastrichtian) fractured limestone at the base of the aquifer interval and Miocene sandstone at the top of the aquifer interval (Castany, 1982; Hamza and Mamou, 1985; Swezey, 1999). In some areas, gypsum beds and abundant mineralization are present in the basal part of the aquifer, particularly in strata that are attributed to the "Senonian," which is an informal stratigraphic term that encompasses the Upper Cretaceous Stages of Coniacian through Maastrichtian. The threat of increasing salinization of the Complexe Terminal aquifer has resulted in several recent publications aimed at a greater understanding of the aquifer and its properties (e.g., Zouari et al., 1999, 2003, Edmunds et al., 2006, Guendouz et al., 2003a,b; Kamel et al., 2005, 2008 and 2014, Chkir and Zouari, 2007; Trabelsi et al., 2008; Abid et al., 2009;

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Kamel, 2011, 2013, Mhamdi et al., 2013; Tarki et al., 2012; Guellala et al., 2012; Kraiem et al., 2012, 2014, Tarki et al., 2012; Yangui et al., 2012; Abid et al., 2014; Hadj Ammar et al., 2014). This paper presents a detailed study of the Complexe Terminal aquifer in the Sabaa-Biar-Sedada region of southern Tunisia (Fig. 1). In this area, the Complexe Terminal aquifer contains water of generally higher salinity in the deeper "Senonian" (Coniacian through Maastrichtian) limestone and water of generally lower salinity (fresh water) in the more shallow Miocene sandstone. However, the salinity characteristics are not laterally uniform, and the reasons for these salinity variations are poorly understood. This study uses geoelectric data, well data, and lithostratigraphic data to characterize salinity variations within the aquifer. These data, in turn, provide constraints on determining (1) the origin of the salinization, and (2) why the salinity characteristics are not laterally uniform within the study area.

2. Geology and hydrogeology

The study area is located in southwestern Tunisia at about 15 km to the northeast of the city of Tozeur (Fig. 1). This study area extends 15 km east–west between the southern limb of a mountain named jebel Sidi Bouhlel and the lowlands of a continental sabkha named the Chott Jerid. Jebel Bouhelal forms the western end of a mountain range called the Chotts Range or Cherb Range.

A synthetic lithostratigraphic column of the study area has been established based on data from outcrops and available wells (Fig. 2). The lithostratigraphic units identified in outcrop at Jebel Sidi Bouhlel are Upper Cretaceous (Coniacian) to Quaternary in age (Mahjoub and Fakraoui, 1990; Hlaiem, 1999) (Figs. 2 and 3). The oldest strata consist of a ~360-m thick unit of alternating beds of clay and limestone, with some gypsiferous beds. This unit is mapped as the Upper Cretaceous (Coniacian–Santonian). These beds of marl and limestone are overlain by a~160-m thick unit of alternating beds of marl, limestone, sandy limestone, and sandstone that is mapped as the Upper Cretaceous (Campanian–Maastrichtian) Berda Formation which is capped by an unconformity. In some places outside of the study area, the uppermost unit of the Berda Formation is a fractured white limestone of Maastrichtian, but this limestone is missing in the study area. Instead, the unconformity that caps the Berda Formation is overlain by ~60-m thick unit of sandstone that is mapped as the Middle to Upper Miocene Beglia Formation (Solignac, 1931; Burollet, 1956; Swezey, 2003). This unconformity beneath the Beglia Formation is also present elsewhere in southern Tunisia (Burollet, 1956; Coque, 1962; Robinson and Wiman, 1976; Sassi, 1974, Ben Ferjani et al., 1990; Keller et al., 1998; Saïd et al., 2011), and it is probably a regional unconformity that extends across much of North Africa (Swezey, 2009). The Belgia Formation is overlain by a ~300-m thick unit of clay and gypsum that is mapped as the Upper Miocene to

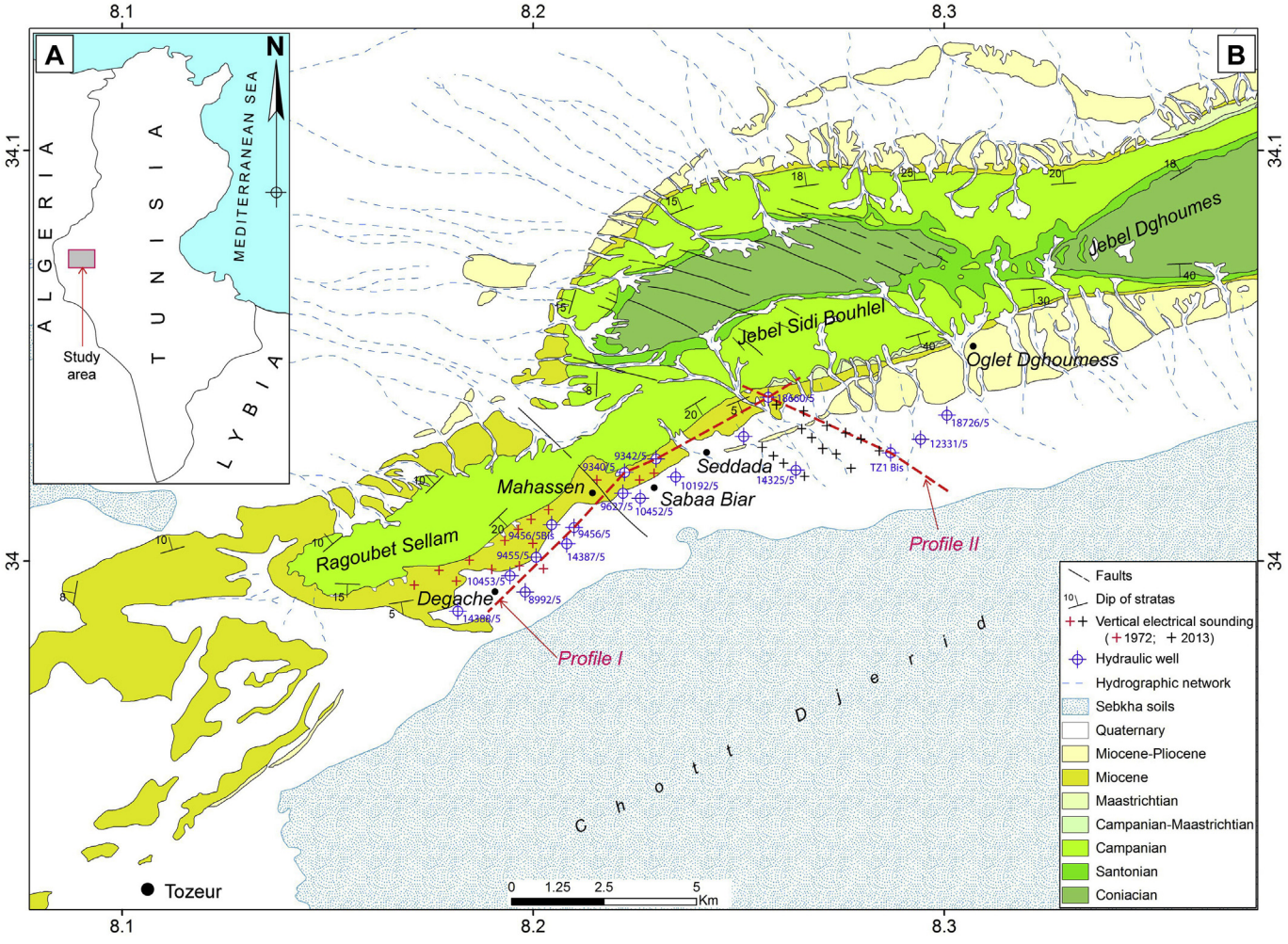

Fig. 1. A. Location of the study area. B. Geological map of the study area with location of vertical electrical sounding, hydraulic wells and geoelectrical profiles.