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Combined application of vertical electrical sounding and 2D electrical resistivity imaging for geothermal groundwater characterization: Hammam Sayala hot spring case study (NW Tunisia)

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ABSTRACT

The following work is an attempt to enhance and optimize the potential exploitation of the Hammam Sayala thermal spring (NW Tunisia). This hot spring is located at 10 km of South-western Béja city, with higher temperature values around 42 °C and a low discharge value of about 1 l s^{-1}. The geological and structural settings of the study area are complex and associated with faults and Triassic intruded salt and evaporate.

An integrated geophysical approach using Electrical Resistivity Tomography (ERT), Induced Polarization (IP) and Vertical Electrical Sounding (VES) techniques can provide a high-resolution subsurface image of the principal geothermal plume and associated pathways. These data were used to determine and understand the mechanisms responsible of the rise of hot water flowing out onto the surface.

Our results add new information of the hydrothermal system's context in Hammam Sayala area, which can help to create a therapeutic center opening new perspectives in the Béja region and to encourage regional thermal tourism development.

1. Introduction

Hot springs and hydrothermal systems seeps through the bedrock underlying are the most common thermo-mineral features in Tunisia. Some of which grow at temperatures upper than 50 °C. It was very important to valorize the hot springs of the Béja city. Previous studies demonstrated that the chemical composition and the location of these thermal manifestations are greatly influenced by regional geology (Ben Dhia and Meddeb, 1990; Meddeb, 1993; Sadki, 1998).

After opening the sector of regional thermal tourism to private investors, the following work is an attempt to valorize the potential exploitation of the Hammam Sayala thermal spring (NW Tunisia). The Hammam Sayala region is located in north western Tunisia, at 10 km of Southwestern Béja city (Fig. 1). The Hammam Sayala hot spring is the case of water emerging that is pumped using a deep well of 3 m depth having a flow rate of 1 l s^{-1}.

Geoelectrical method has been important in the field of applied geophysics for about a century, extensively in groundwater mapping and aquifers and shallow aquifers for investigations. The geoelectrical method (VES, ERT and IP) is based on the calculated the direct current flow injected into the ground by the A and B electrodes, and the electric potential difference measured between the two measurement electrodes M and N. In order to provide insights of the subsurface heterogeneity, near surface geophysical method such as Vertical Electrical Sounding (VES), Electrical Resistivity Tomography (ERT) and induced polarization (IP) are becoming increasingly applied. The coupled of the VES survey, the ERT and IP geophysical prospecting has been used in this study.

In this study, geoelectrical survey involving the VES, ERT resistivity imaging and IP was carried out using Schlumberger array for VES and Wenner-α array configuration for ERT and IP. The survey purpose was to delineate and identify the lithology of the aquifer characteristics in the study area along VES1 to VES 6, EP1 to EP5 and IP1, IP2 (Fig. 2a and b).

In this paper, combination of VES, ERT and IP data provided information about ascertain the origin and subsurface geometrical configuration of the hot spring of Hammam Sayala. After a summary of geological and structural knowledge the adapted field

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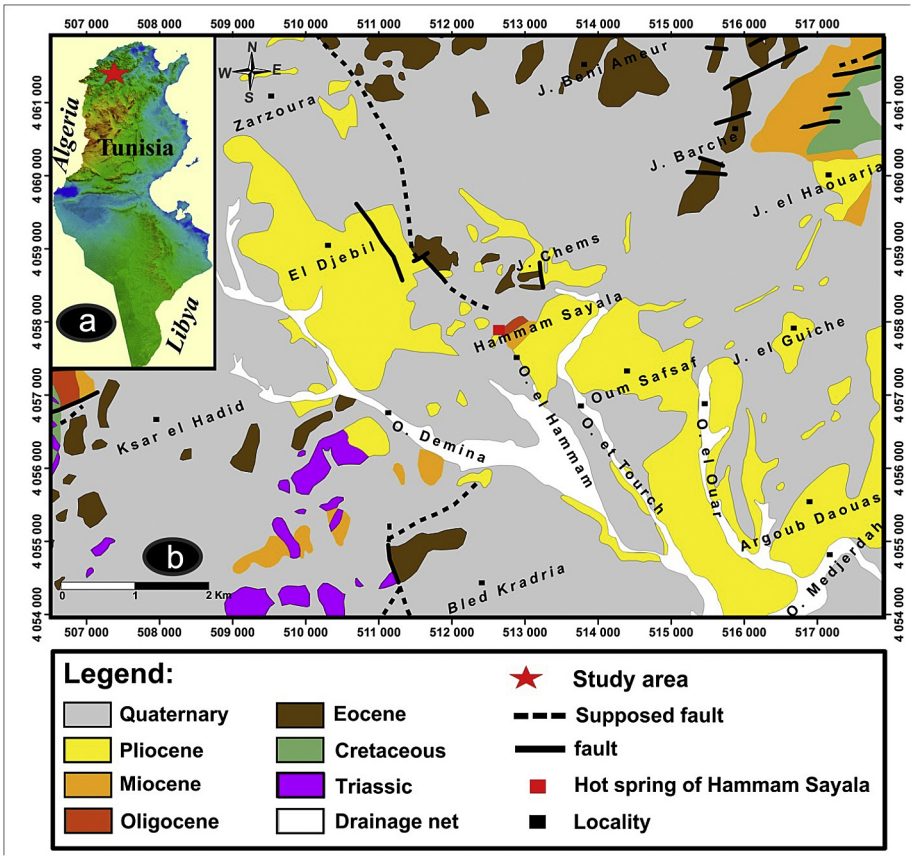

Fig. 1. a) Geographical location of study area; **b)** General geological map of the Hammam Sayala study area.

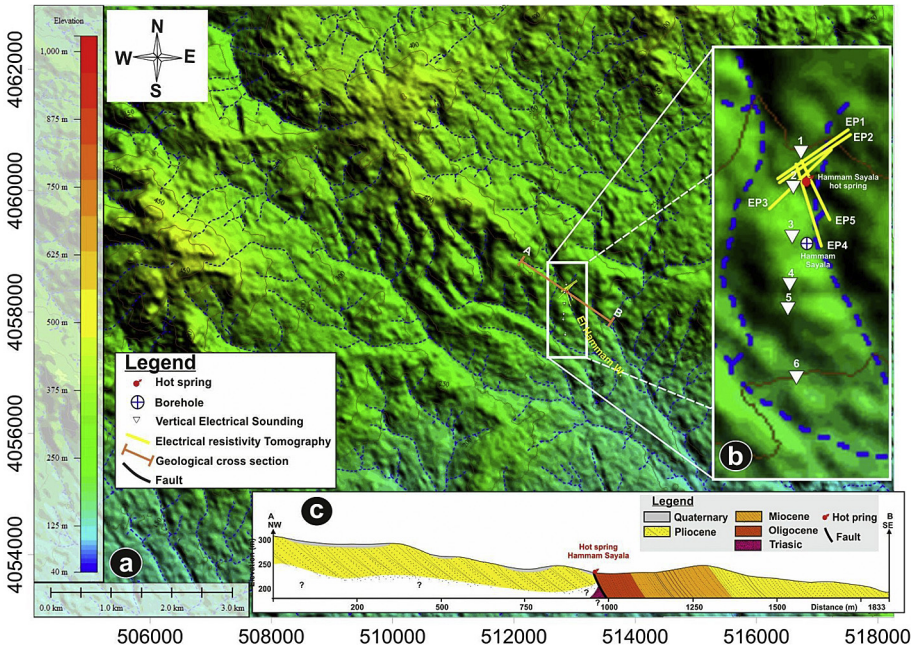

Fig. 2. a-b) Location of the Hammam Sayala spring and geo-electric data on elevation map. Panoramic view of the study area, **c)** NW-SE geological cross section.

methodology and the results of each method are presented. The geophysical approach was carried out to define geological structures, depths and geometry of the shallow aquifer containing hot water (Richards et al., 2010; Sudha et al., 2011; De Filippis et al., 2013; Chang et al. 2014).