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Exploration and assessment of the geothermal resources in the Hammam Faraun hot spring, Sinai Peninsula, Egypt

Mohamed Abdel Zaher [a,*], Hakim Saibi [b], Jun Nishijima [c], Yasuhiro Fujimitsu [c], Hany Mesbah [a], Sachio Ehara [c]

[a] National Research Institute of Astronomy and Geophysics, Helwan, Cairo 11421, Egypt
[b] Laboratory of Exploration Geophysics, Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan
[c] Laboratory of Geothermics, Department of Earth Resources Engineering, Faculty of Engineering, Kyushu University, 744 Motooka, Nishi-ku, Fukuoka 819-0395, Japan

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ABSTRACT

The tectonic position of Egypt in the northeastern corner of the African continent suggests that it may possess significant geothermal resources, especially along its eastern margin. The most promising areas for geothermal development in the northwest Red Sea-Gulf of Suez rift system are located where the eastern shore of the Gulf of Suez is characterized by superficial thermal manifestations, including a cluster of hot springs with varied temperatures. Magnetotelluric and gravity-reconnaissance surveys were carried out over the geothermal region of Hammam Faraun to determine the subsurface electric resistivity and the densities that are related to rock units. These surveys were conducted along profiles. One-dimensional (1D) and two-dimensional (2D) inversion model techniques were applied on the MT data, integrating the 2D inversion of gravity data. The objectives of these surveys were to determine and parameterize the subsurface source of the Hammam Faraun hot spring and to determine the origin of this spring. Based on this data, a conceptual model and numerical simulation were made of the geothermal area of Hammam Faraun. The numerical simulation succeeded in determining the characteristics of the heat sources beneath the Hammam Faraun hot spring and showed that the hot spring originates from a high heat flow and deep ground water circulation in the subsurface reservoir that are controlled by faults. These studies were followed by an assessment of the geothermal potential for electric generation from the Hammam Faraun hot spring. The value of the estimated potential is 28.34 MW, as the reservoir is assumed to be only 500 m thick. This value would be enough for the desalination of water for both human and agricultural consumption.

1. Introduction

Egypt, in the northeastern corner of the African plate, is bound to the east by what has been interpreted as a median spreading center in the Red Sea and Gulf of Suez (Mckenzie et al., 1970). Therefore, this area is an important candidate for geothermal development. Additionally, the most promising areas for geothermal development in the northwestern Red Sea-Gulf of Suez rift system are located where the eastern shore of the Gulf of Suez is characterized by superficial thermal manifestations, including a cluster of hot springs with various temperatures. The previously obtained data indicate that a temperature of 120 °C or higher exists in the reservoir located adjacent to the Gulf of Suez and the Red Sea coastal zone (Morgan et al., 1983). The most important area for geothermal manifestation is located in the Hammam Faraun hot spring (see Fig. 1), which is the hottest spring in Egypt (Morgan et al., 1983).

In this study, MT and gravity-reconnaissance surveys were carried out over the geothermal region of Hammam Faraun to determine the subsurface densities and electric resistivity related to rock units. These surveys were conducted along two profiles (shown in Fig. 1). One-dimensional (1D) and two-dimensional (2D) inversion model techniques were applied to the MT data, integrating the 2D inversion of the gravity data. The resistivity method provides information about rock properties and the subsurface structure. This information can be used to determine the geometry of a hydrothermal reservoir, its depth and the location of the heat source. To complement the resistivity method of choice (MT), gravity surveys were conducted along the MT survey lines to interpret the subsurface and to aid in locating the prospective heat source, and thereby to elicit the origin of the Hammam Faraun hot spring.

Integrating the MT and gravity data reduces the ambiguity of either dataset, produces a more robust interpretation and provides a comprehensive picture of the geothermal system's characteristics,

* Corresponding author. Tel.: +20 2 25560645; fax: +20 2 25548020.
E-mail address: moh_zaher@yahoo.com (M. Abdel Zaher).

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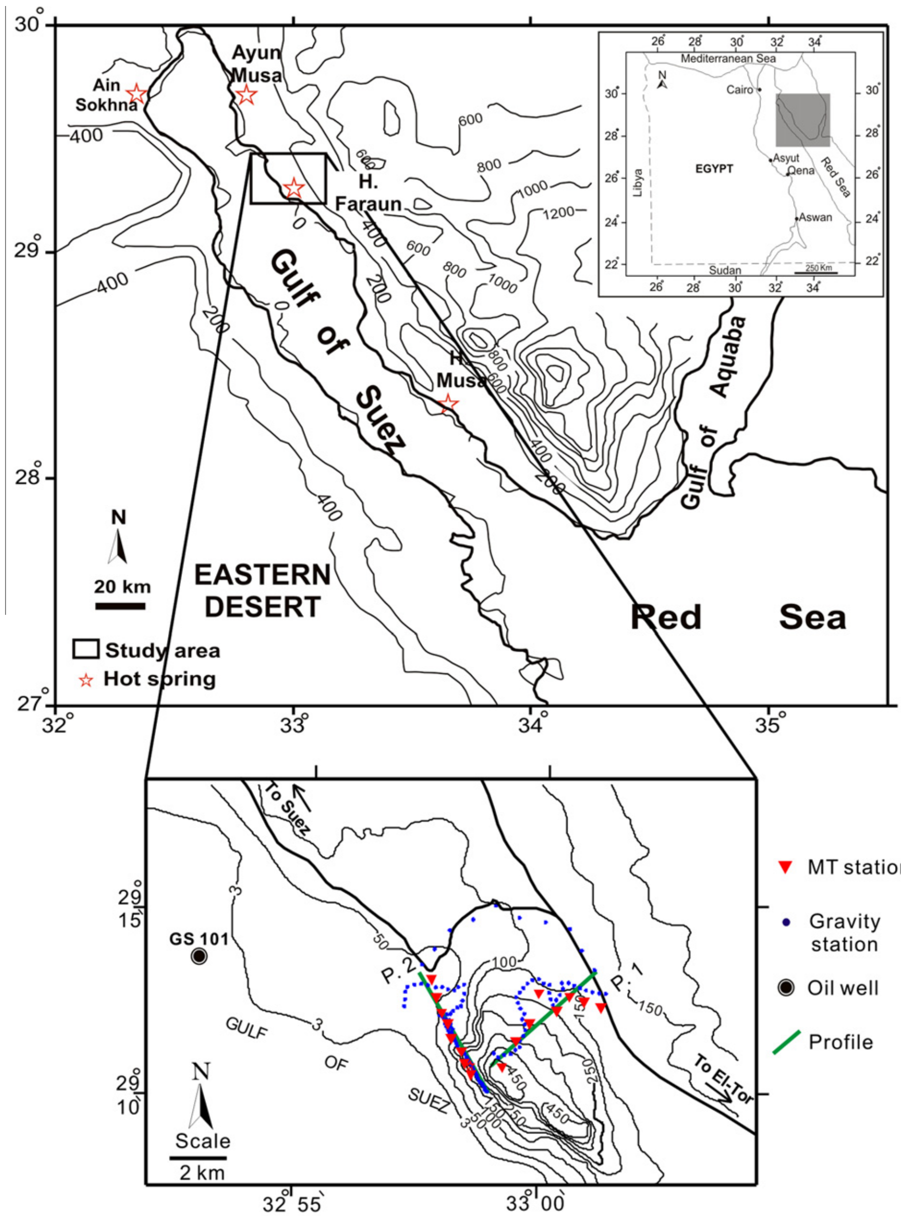

Fig. 1. Topography of the Gulf of Suez region from the GTOPO30 dataset (Gesch et al., 1999). This figure shows the location of the hot springs on the eastern and western margins of the Gulf. Locations of the measured gravity and MT sites are plotted on a topographic map of the study area.

helping to create an assessment of the geothermal potential for electric generation from the Hammam Faraun hot spring.

Previous studies have been conducted on the geological and geophysical explorations for geothermal investigations (Demirel et al., 2004; Heise et al., 2007; Mogi and Nakama, 1993; Saibi et al., 2006, 2008). MT surveys were carried out on the southern margin of the Mount Amiata geothermal region (Tuscany, Italy) by Volpi et al. (2003), with the aim of defining the shallow and deep electric structures related to the local geothermal reservoirs and system heat recharge. Schill et al. (2010) carried out a 2D magnetotelluric and 3D inversion of existing gravity data based on a 3D geological model in the area of the geothermal power plant of Soultzsous–Forêts in northeastern France. Naganjaneyulu and Santosh (2011) analyzed MT data along the N–S trending Kalugumalai–Tiruchengode profile in the Madurai Block in southern India to evaluate the crustal architecture and its implications on the tectonic development of Madurai Block. Sari and Salk (2006) estimated the thickness of the sedimentary cover on the Menderes Massif in western Turkey as deduced from 2D and 3D analyses of the gravity data. Abdel Zaher et al. (2011) evaluated potential geothermal resources in the Gulf of Suez region using both bottom-hole temperature data and geophysical data.

2. Geological and geochemical background

The Gulf of Suez is a failed intercontinental rift that forms the NW–SE continuation of the Red Sea rift system. This rift is mainly controlled structurally by extensional normal faults that strike northwest and form a complex array of tilted half-grabens and asymmetric horsts (Pivnik et al., 2003). The Hammam Faraun tilted block is one of the main fault blocks in the central dip province of the Suez rift, and it is bound on the east and west by major normal fault zones (Fig. 1). These major border fault zones are in excess of 25 km long, dip steeply to the west and have displacements between 2 and 5 km long (Moustafa and Abdeen, 1992; Sharp