Geothermics 75 (2018) 220–234

Contents lists available at ScienceDirect

Geothermics

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

Crustal thermal structure of the Farafra oasis, Egypt, based on airborne potential field data

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ARTICLE INFO

Keywords:
Geothermal potential
Aeromagnetic
Aerogravity
Landsat 8 ETM+
Curie point depth
Earthquake events

ABSTRACT

The Farafra oasis is one of the most interesting and promising areas for geothermal energy development in Egypt. The objective of the present study is to evaluate the geothermal potential in the Farafra oasis and its suitability for geothermal development in the Western Desert using different tools such as remote sensing, seismic events, and aeromagnetic and aerogravity data. Remote sensing (Landsat 8 ETM+) was utilized to estimate the land surface temperature (LST) in the Farafra oasis. The resultant map of LSTs indicates that the surface temperature of the Farafra area ranges from 10 °C to 30 °C and that the mean surface temperature of the whole area is approximately 26 °C. Most earthquake events are located to the east and northeast of the Farafra oasis (toward the Bahariya Oasis). However, the highest magnitude event (4.62) is located near the eastern border of the Farafra oasis. One event with a magnitude of 3.08 is located to the south and within the Farafra outline. The distributions of low-magnitude earthquake events can provide information about the locations of active faults, which indicate possible fracture permeability. The interpretation of aeromagnetic data indicates that the Curie point depth (CPD) ranges from 16 km to 26 km with an average of 22 km. The CPDs increase toward the center and north of the Farafra oasis and decrease westward. The interpretation of aerogravity data shows maximum anomalies above four main localities: Ain-Dalla, Bir-Sitta, northeast of Bir-Sitta and at the southern margin of the Farafra oasis, which indicates the existence of vertical or near-vertical contacts (faults) in these areas and provides a good correlation with structural lines on the geological map. Linear features striking NE-SW are pronounced on the tilt gradient map.

1. Introduction

Since 2014, Egypt has tried to create and utilize more sustainable power sources to address growing energy challenges with the objective of delivering 20 percent of Egypt's energy demand from renewable resources (Aman, 2015). In January 2015, Egypt announced its goal of creating approximately 4300 megawatts of power from solar and wind energy within three years (Reuters, 2015). Thus, it is essential and necessary to utilize geothermal resources for generating power and supplying Egypt's energy demands in a clean and effective way. Ordinarily, geothermal activity in Egypt is recognized in different areas in terms of small hot springs exposed at the surface or thermal deep wells. Harvesting the undiscovered geothermal resources could address local needs for energy and empower Egypt to export electricity.

Many geothermal studies have been carried out in the eastern parts of Egypt, especially the Gulf of Suez and Red Sea regions (e.g., Morgan and Swanberg, 1979; Morgan et al., 1983; Boulos, 1990; El-Qady, 2006, Abdelzaher et al., 2011; Abdel Zaher et al., 2011, 2012; Atef et al., 2016); however, few studies have been conducted in the Western Desert of Egypt. Mohamed et al. (2015) created a temperature gradient map of the northern Western Desert of Egypt by connecting bottom-hole temperature (BHT) logs of deep oil wells with gravity data using the Artificial Neural Network (ANN) system. The output map illustrates that the temperature gradient ranges from 20 to 40 °C/km with an average of approximately 30 °C/km. Abdel Zaher et al. (2018) utilized airborne gravity data in Siwa oasis to outline the surface of the Precambrian rocks and their connection with the thermal characteristics obtained from processing aeromagnetic data by applying a power spectrum technique. Generally, the western part of Egypt (Western Desert) is distinguished by low regional temperature gradients and heat flow (Swenberg et al., 1983; Lashin, 2013; Mohamed et al., 2015); however, there are numerous hot springs and thermal wells with profound artesian aquifers, which indicate low-temperature geothermal resources.

Farafra oasis has been mentioned as an interesting and promising geothermal resource for geothermal development in a protocol between the New and Renewable Energy Authority (Nrea) and the Ganoub El

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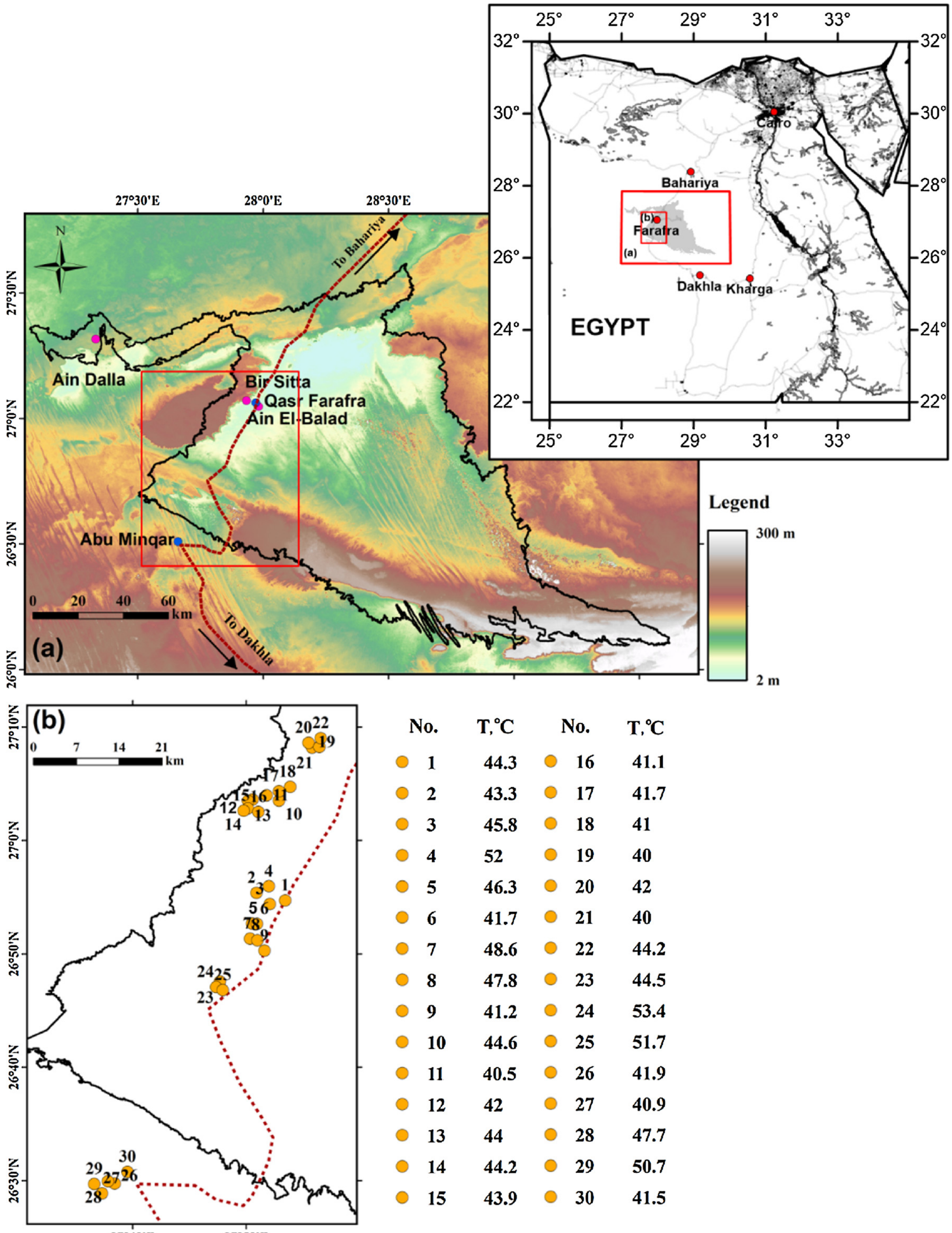
https://doi.org/10.1016/j.geothermics.2018.05.006
Received 1 March 2018; Received in revised form 15 May 2018; Accepted 30 May 2018



No.	T,°C	No.	T,°C
1	44.3	16	41.1
2	43.3	17	41.7
3	45.8	18	41
4	52	19	40
5	46.3	20	42
6	41.7	21	40
7	48.6	22	44.2
8	47.8	23	44.5
9	41.2	24	53.4
10	44.6	25	51.7
11	40.5	26	41.9
12	42	27	40.9
13	44	28	47.7
14	44.2	29	50.7
15	43.9	30	41.5

Fig. 1. (a) Location and topographic map (DEM from a satellite dataset) of the Farafra Oasis. The map shows the outlines of the Farafra Oasis, with a surface area greater than 800 km^2, and the locations of Ain Dalla and Bir Sitta. (b) Locations of thermal wells and their temperatures in °C, measured in December 2017.

Wadi Petroleum Company (Ganope). It is located in the heart of the Western Desert of Egypt (Fig. 1), approximately 500 km southwest of Cairo, 300 km west of the River Nile at Asyut and midway between the Bahariya and Dakhla oases (140 km southwest of the Bahariya Oasis). It is part of an arid area that is characterized by the lack of rainfall throughout the whole year, and groundwater is the main source of water for people in this remote area. Springs are the easiest and cheapest water supply for drinking and irrigation. The hot springs in the Farafra oasis (Fig. 1) include Ain El-Balad (28 °C) and Ain Dalla (35 °C) (Idris, 2001). However, according to Waring's definition (Swenberg et al., 1983) of the hot spring as any spring with an average temperature of +8.3 °C more than the mean ground temperature (26–30 °C), such reported hot springs cannot strictly be classified as thermal. Nevertheless, there are numerous thermal water from deep wells in Farfara oasis, many of which are artesian. The temperature of these thermal wells was measured and listed in Fig. 1 and ranges 40–50 °C.