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Geothermal energy resources in Egypt: update and perspectives

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ABSTRACT

Egypt is attempting to diversify its energy supplies by obtaining new energy resources at competitive prices to maintain long-term growth. Egypt's need for clean and renewable alternative energy is expanding due to its limited water and fossil fuel sources, in addition to growing environmental concerns. Presently untapped geothermal resources, together with other renewable energy sources, might help to fulfill Egypt's domestic energy needs.

In this study, we examine Egypt's existing geothermal potential and resources, in addition to current geothermal energy applications and prospective advancements. Furthermore, geophysical data in the form of aeromagnetic data and temperature logs from oil/gas wells were used to update geothermal gradients and heat flow maps of Egypt. Broadly, Egypt has significant geothermal potential along the Red Sea, Gulf of Suez, and Gulf of Aqaba coastlines that might be utilized to generate electricity. In addition, hot springs and thermal wells of the Western Desert may be used directly.

1. INTRODUCTION

Egypt's tectonic situation in the extreme northeastern corner of the African continent implies that it may have significant geothermal resources, especially near its eastern border (Fig. 1). This is due to the country's proximity to the Red Sea spreading center and its two branches (Gulf of Suez and Gulf of Aqaba) that form the northern continuation of the East African Rift (Bosworth et al., 2019).

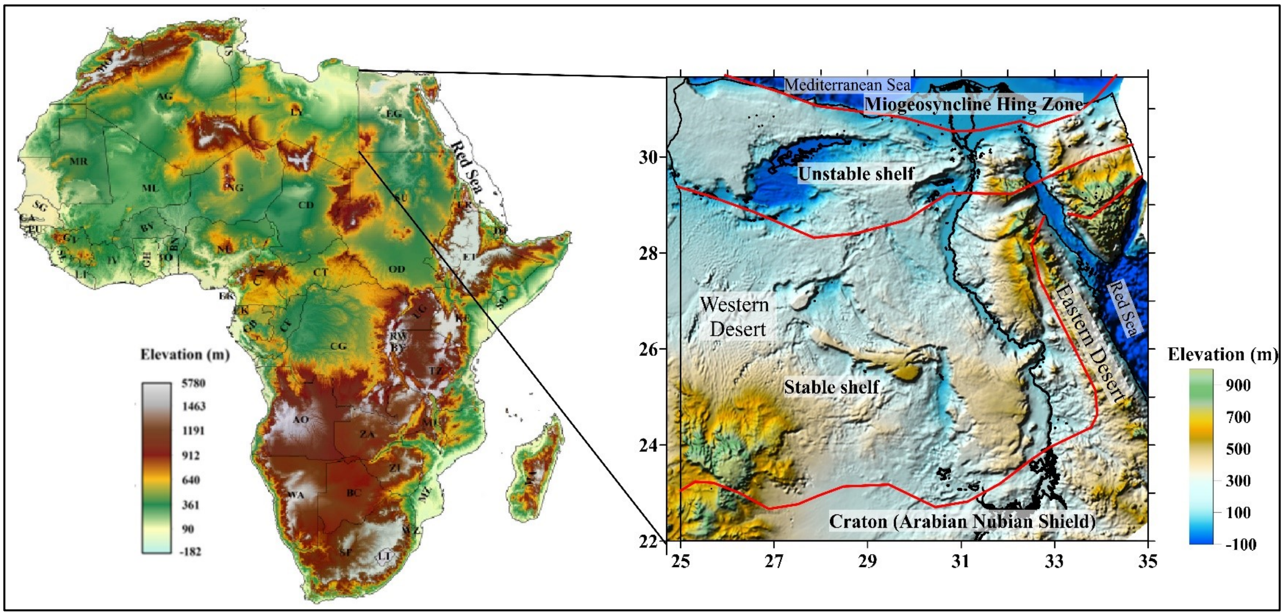

Figure 1: Elevation images of Africa and Egypt (Digital Elevation Model from a satellite dataset available from the U.S. Geological Survey). The red lines refer to the structural aspects of the Nubian Arabic Shield margin in Egypt (after Said, 1962)

Based on the map of the African continent's geothermal potential made by Elbarbart et al., 2022, Egypt appears to have a massive geothermal resource distribution, particularly along its eastern border. The areas closest to the Red Sea and the Gulf of Suez offer the greatest potential for geothermal development. Our current analysis of Egypt's geothermal potential is based on a wide variety of surface and subsurface datasets that have been gathered across Egypt.

The general tectonic framework of Egypt can be described as consisting of three units that have controlled the sedimentological history and the structural makeup of the country. These three units are the Arabian-Nubian massif, the stable shelf, and the unstable shelf. Each of these units has played a role in determining the structural makeup of Egypt (Youssef, 2003). The Arabian–Nubian Massif is surrounded by the stable shelf, which extends across a significant area of Egypt, indicating that the tectonic conditions to the south of the massif have remained relatively stable over time. This area is covered by sedimentary bedrock that dates back to the Cretaceous period and directly underlies the stable shelf (Said, 1962).

2. GEOTHERMAL SURFACE MANIFESTATIONS IN EGYPT

Geologically, Egypt's geothermal resources can be divided into two major systems: one that is tectonically controlled and situated in the Red Sea rift and the Gulf of Suez, where many hot springs can be found, and one that is not tectonically controlled. Other resources are governed by the sedimentological system of Egypt's Western Desert, which also contains numerous hot springs. The hot springs in Egypt with the highest temperatures primarily found around the coastlines of the Gulf of Suez, such as Ain Sokhna on the west and Ayun Musa, Ain Hammam Faraun, and Hammam Musa on the east (see Fig. 2). The Gulf of Suez rift is interpreted as responsible for the formation of these tectonic or non-volcanic springs (Boulos, 1990). The Helwan sulfur spring, situated 25 km south of Cairo, is another probable thermal spring, with temperatures ranging from 23 to 32°C. In addition, the Western Desert's hot water comes from deep wells, many of which are artesian (Abdel Zaher et al., 2018).

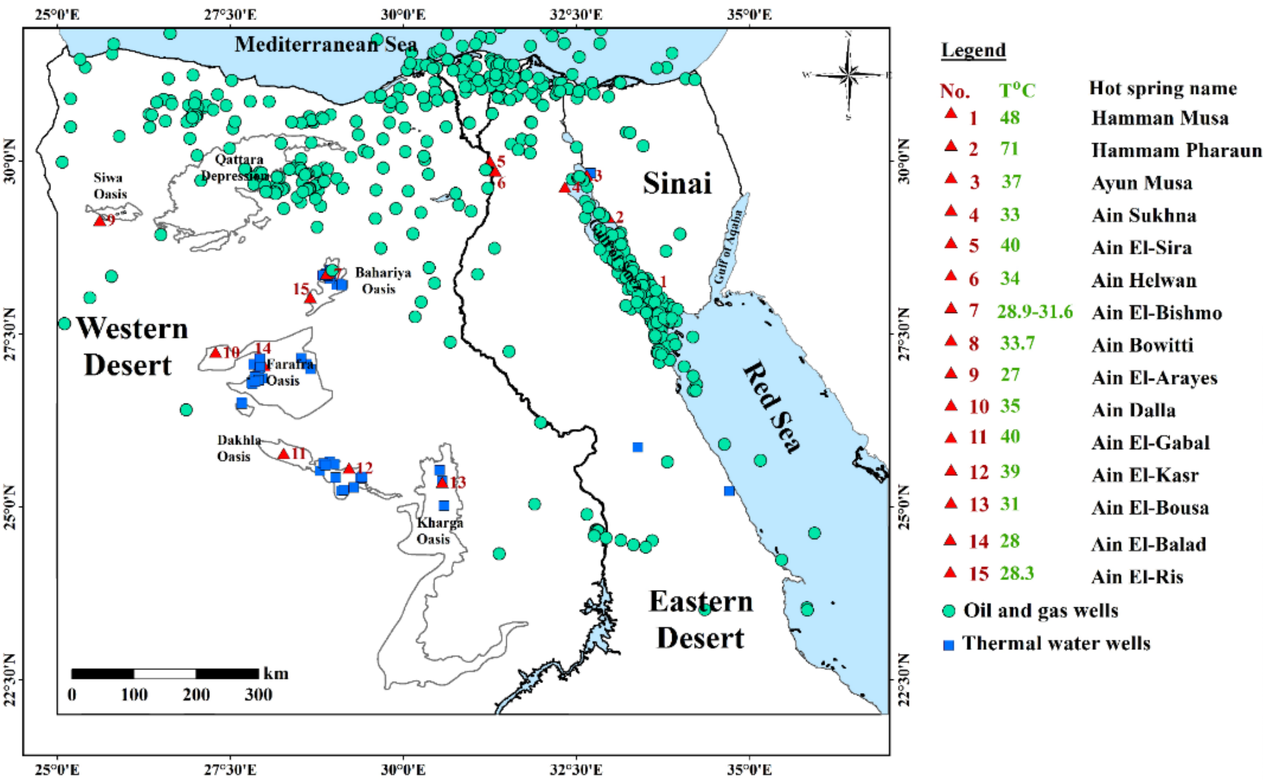

Figure 2: Map of Egypt illustrating the locations of hot springs and thermal wells, in addition to the location of oil and gas wells in which the bottom-hole temperature (BHT) was recorded (modified after Abdel Zaher et al., 2018).

3. LAND SURFACE TEMPERATURE

The Sea and Land Surface Temperature Radiometer (SLSTR) is a low Earth-orbiting dual-view scanning temperature radiometer (800–830 km altitude). Two instruments are presently in orbit on the Sentinel-3A and Sentinel-3B satellites, which form an operational component of the Copernicus program. The operational SLSTR land surface temperature (LST) algorithm is influenced by the biome, day/night, proportion of vegetation, and viewing zenith angle. Due to the typically greater thermal variability of land surfaces, an accuracy of 1.8 K and a precision of 1.2 K were calculated for daylight data (Pérez-Planells et al., 2021). In our study, we applied the SLSTR Level-2 LST product, which provides land surface temperatures based on a 1-km measurement grid. These data will be utilized subsequently in the surface heat production calculation. The LST data were gathered in November 2021 (see Fig. 3).

4. GEOTHERMAL REGIME OF EGYPT

Regional heat flow studies may aid in the basic evaluation of likely areas of geothermal potential. Geothermal energy may be used for generating electricity, space heating, local industry, and agriculture in areas with high heat flow and suitable hydrological media that can convey heat to near-surface depths or even to the land surface. Abdel Zaher et al. (2018) assessed Egypt's heat flow map and temperature gradients using data from 596 deep wells with bottom-hole temperature (BHT) measurements.

Egypt's heat flow values range from 27 to roughly 180 mW/m^2, with an average value of around 78 mW/m^2 (Fig. 4). The results indicate that the regions around the shores of the Red Sea and the Gulf of Suez in Egypt have the highest potential for the development of geothermal energy resources. There is also significant geothermal activity potential in the Harghada-El-Gouna area, which is located to the south of the Gulf of Suez. This may be tied to the Sinai triple junction, which links Africa, Arabia, and Sinai.

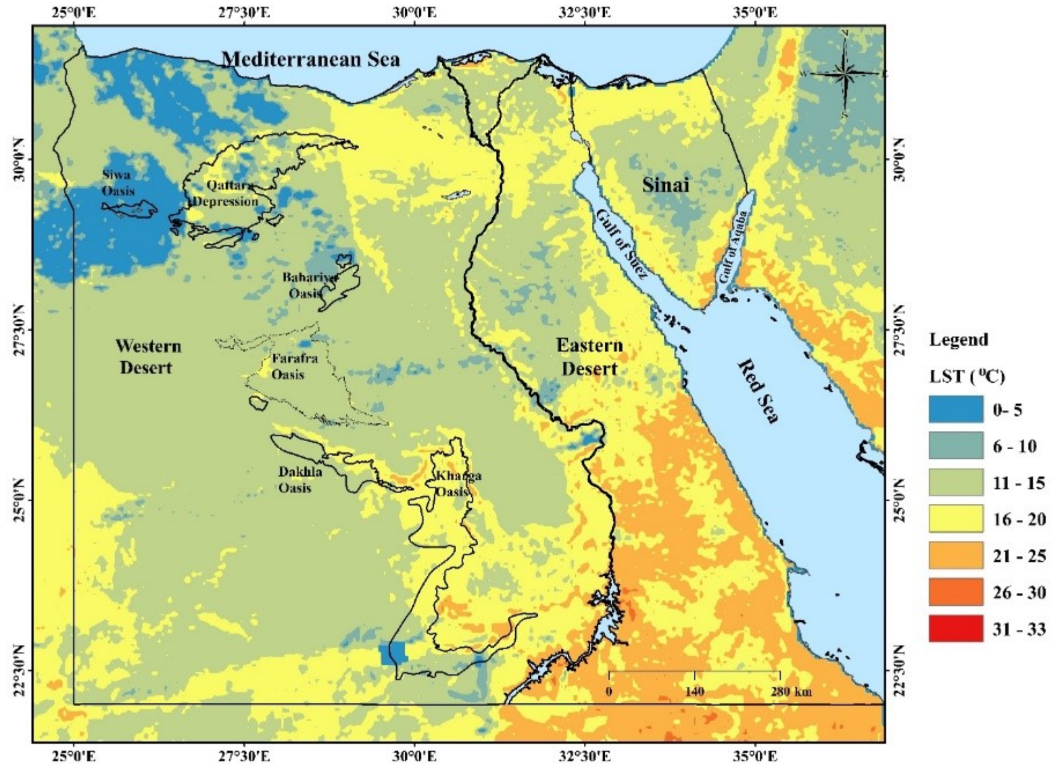

Figure 3: A map of Egypt's land surface temperature (LST), indicating that LST values increase toward the east and reach a maximum of 33 °C.

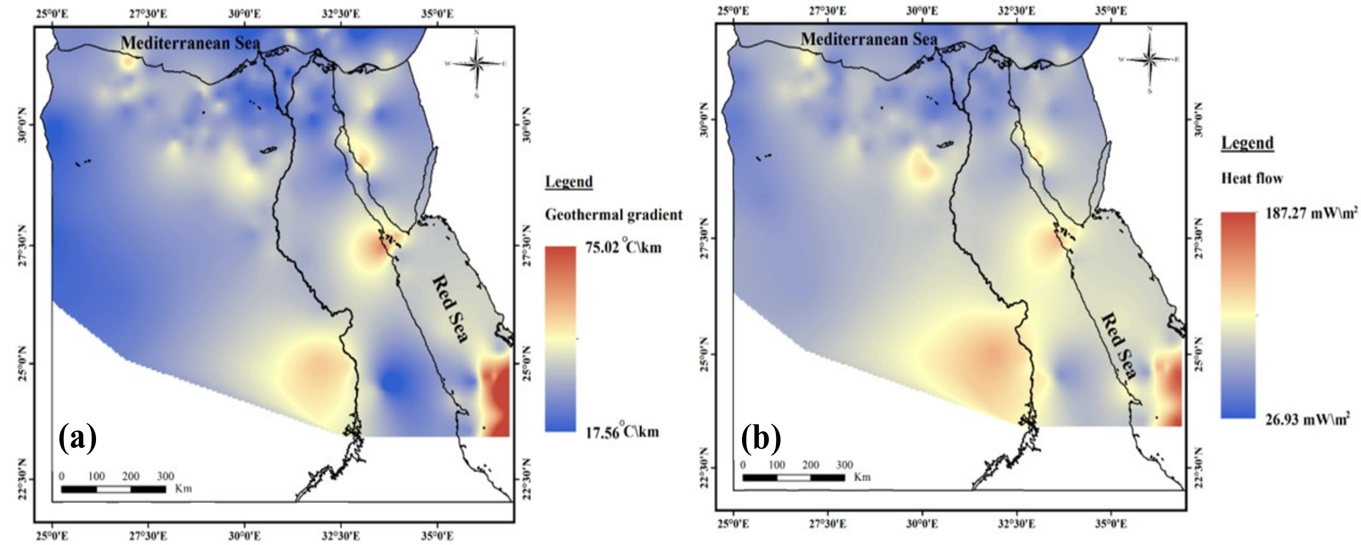

Figure 4: (a) Geothermal gradients map of Egypt; (b) heat flow map of Egypt. Both maps are based on corrected BHT of 596 deep onshore and offshore wells, provided by the Egyptian General Petroleum Corporation.

5. GEOCHEMICAL STUDIES

More than 60 thermal water samples were collected from hot springs and thermal wells. Figure 5 depicts the water sampling sites. Polyethylene bottles were used to collect and store the samples. The aliquots used for trace metal analysis were passed through a filter with a pore size of 0.45 micrometers and were then preserved by acidification with nitric acid. The Desert Research Center (DRC) and the National Water Research Center (NWRC), both located in Egypt, were responsible for performing all of the relevant chemical analyses at their laboratory.

We are continuing to work on analyzing the gathered samples, and we are hopeful that we will be able to share the findings during the conference.

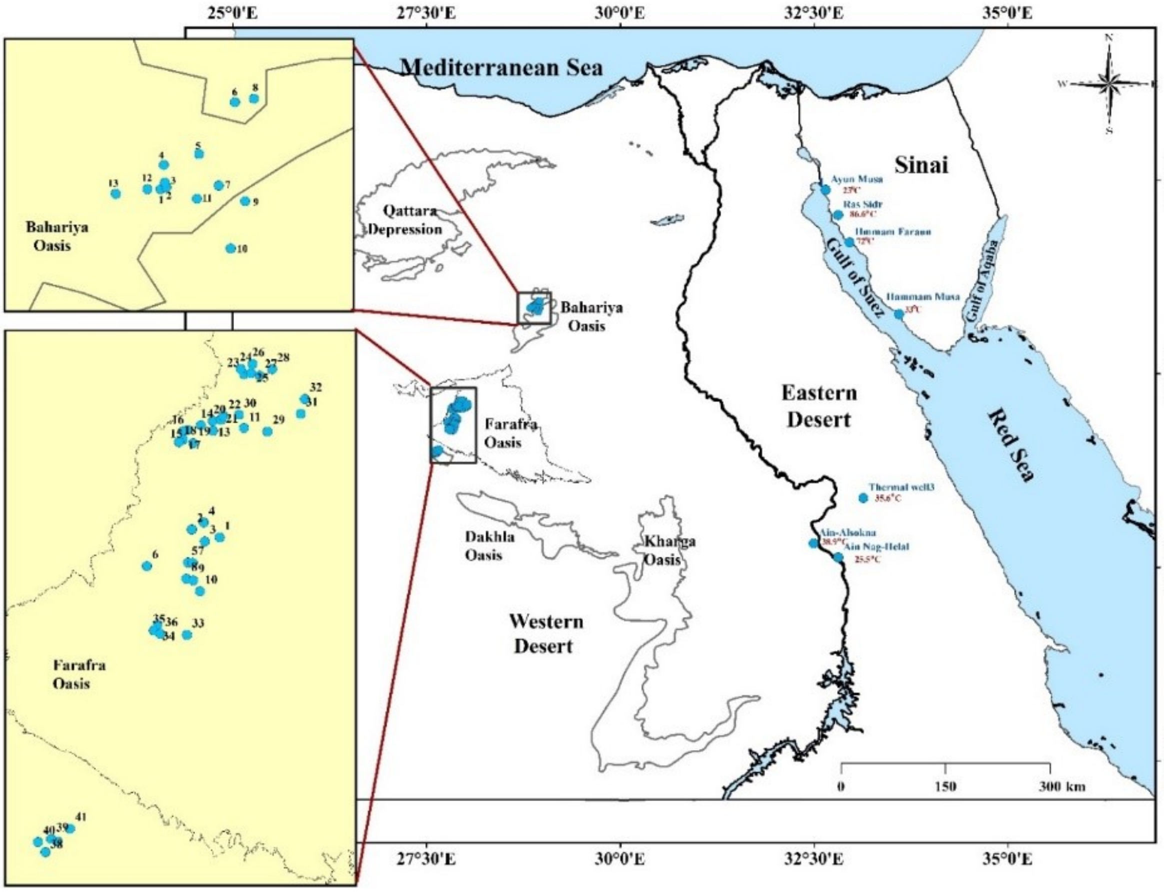

Figure 5: Map showing the locations of groundwater samples collected from the most geothermally prospective sites in Egypt, including hot springs and thermal wells.

6. CURRENT GEOTHERMAL USE AND POTENTIAL GROWTH

At present, there are no geothermal power plants in Egypt; nevertheless, numerous direct use applications have been established. Thermal water was directly used for thousands of years in ancient Egypt, with many ancient Egyptians utilizing warm waters from hot springs for medicinal and household purposes (Gianfaldoni et al., 2017), with various papyruses uncovered in Egypt's Western Desert that document such uses. Recently, several direct, low-grade geothermal applications have been established. The most common geothermal applications include district heating, fish farming, agricultural applications, and greenhouses. Some pools have already been created along the eastern shore of the Gulf of Suez, the majority of which are used for recreational and therapeutic purposes. Geothermal water derived from hot springs provides the primary water source for these pools (Kaiser and Ahmed, 2013). Low-enthalpy resources in the Gulf of Suez, on the other hand, could be potentially exploited to create electricity using ordinary binary-cycle technology (Abdel Zaher et al., 2012). The resulting power generation would be adequate to desalinate water for both human and agricultural purposes, which in turn could yield significant benefits for long-term growth in the Sinai Peninsula.

7. CONCLUSIONS

Egypt's search for clean, renewable, alternative energy sources, as well as the prospect of collecting geothermal resources, may allow Egypt to fulfill its domestic electrical needs while also exporting electricity. In general, Egypt has significant geothermal potential around the Red Sea, Gulf of Suez, and Gulf of Aqaba coastlines that may be exploited to generate electricity. In addition, hot springs and thermal well resources in the Western Desert can be utilized directly.

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