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Review of the Geothermal Resources in the Central Eastern Desert of Egypt: 2000-2024

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ABSTRACT

This review examines Egypt's geothermal resources from 2000 to 2024, with a focus on the Central Eastern Desert and Red Sea regions. Recent studies, particularly those by Gaber et al [1-3], have significantly enhanced our understanding of the geothermal potential in this area. These studies employed advanced geophysical techniques, including aeromagnetic surveys and 3D gravity and magnetic inversion modelling, to assess subsurface temperature distributions and geological structures. The integration of various geophysical data sets has revealed promising geothermal zones characterized by unique geological formations and tectonic activity. This synthesis of research highlights the importance of comprehensive geophysical assessments in identifying viable geothermal sites. The findings underscore Egypt's potential as a significant player in renewable energy through geothermal resources, advocating for further exploration and sustainable development. Future research directions are suggested, emphasizing advanced survey techniques, borehole data collection, and sustainability evaluations, crucial for effectively harnessing Egypt's geothermal capabilities.

1. Introduction

The unique geological setting of Egypt, particularly in the Central Eastern Desert and Red Sea region (Fig 1), influences its geothermal potential through active tectonic processes and diverse rock formations. Over the past two decades, numerous studies have sought to explore and quantify this potential, driven by the global shift towards renewable energy sources. This review focuses on key studies conducted from 2000 to 2024, examining methodologies, findings, and implications for future geothermal development.

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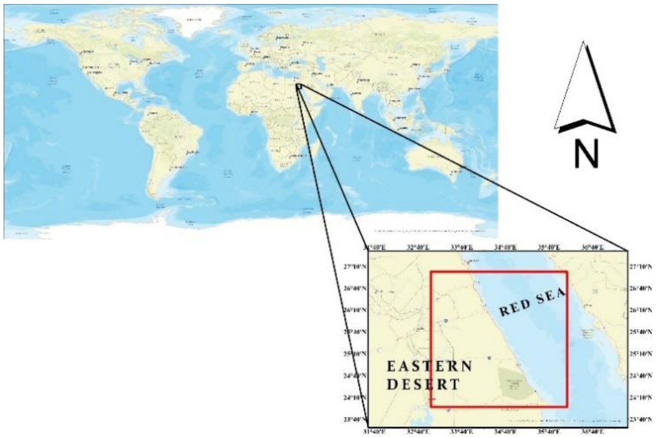

Fig. (1): Location map showing the Central Eastern Desert area.

The Central Eastern Desert and Red Sea region is marked by significant geological features, including the Red Sea Rift, which plays a crucial role in the geothermal landscape. The tectonic activity associated with this rift has formed various geothermal phenomena, making the area a focal point for renewable energy exploration. Lashin provided a comprehensive review of the geothermal resources in Egypt, highlighting the importance of the Red Sea Rift and its potential for geothermal energy production [4].

1.2 Objectives

This review aims to:

1. Summarize the key findings from the studies conducted by Gaber et al. [1-3].
2. Discuss the implications of these findings for geothermal energy exploration in Egypt.
3. Provide future research directions to enhance geothermal resource assessment and utilization.

2. Overview of Previous Work (2000-2024)

2.1 Historical Context of Geothermal Studies in Egypt

Geothermal research in Egypt dates to the early 2000s (Fig 2), with significant contributions was made by Morgan et al. [5] and Boulos [6] in assessing the geothermal potential of various regions. These foundational studies laid the groundwork for understanding the occurrence of geothermal resources, particularly with tectonic features such as the Red Sea Rift. Lashin emphasized that the geological complexity of Egypt, characterized by volcanic and tectonic activity, provides substantial geothermal potential [4].

2.2 Recent Advances in Geothermal Research

The period from 2000 to 2024 has seen a marked increase in the number of studies focusing on the geothermal potential of Egypt, driven by advances in geophysical techniques and a growing interest in renewable energy. Gaber et al. [1-3] have been at the forefront of this research, utilizing aeromagnetic data, gravity inversion modelling, and temperature modelling to assess geothermal resources comprehensively.

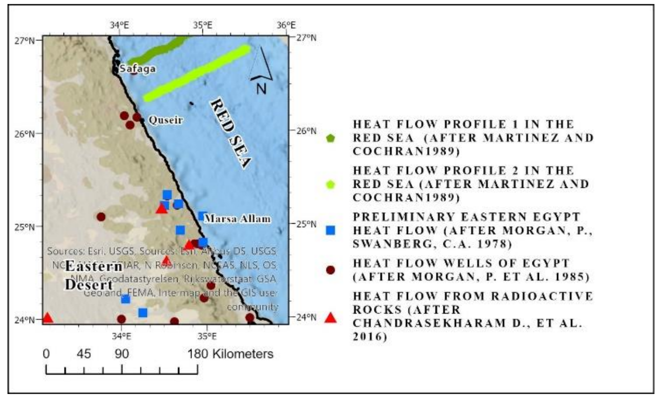

Fig. (2): Distribution of the previous work in the Central Eastern Desert.

2.2.1 Contributions from Previous Studies

Several key studies from 2000 to 2020 laid the groundwork for understanding Egypt's geothermal potential. The country's geothermal potential is primarily concentrated in regions such as the Gulf of Suez, Western Desert, and Eastern Desert, with notable sites like Ayun Musa, Ain El Sukhna, Helwan sulfur springs, and Hammam Faraun. Recent studies by Lashin [4] categorized Egypt's geothermal resources into low, medium, and high-heat content groups, highlighting the significance of locations like the Gulf of Suez and Red Sea rift depocenter regions. Early research by Morgan et al. [5] and Boulos [6] identified hot springs along the Gulf coastlines, linking their heat generation to fault systems in the region. Boulos [7] proposed plans for utilizing geothermal resources on an industrial scale. Chandrasekharam et al. [8] explored the geothermal potential of the Eastern Desert and Gulf of Suez, focusing on granitic rocks with high heat-generating capabilities. Recent studies in the Central Eastern Desert revealed significant geothermal potential for electricity generation and direct-use applications, contributing to Egypt's energy diversification efforts [9,10]. Limited studies in the central-eastern desert and other regions of Egypt conducted by researchers utilized various geophysical and geochemical techniques to assess geothermal resources. Abdel Zaher et al. [11] conducted geothermal exploration at Siwa Oasis in the Western Desert using airborne gravity and magnetic data, while Mohamed et al. [12] created a geothermal gradient map of the Northern Western Desert through aerogravity and BHT (Bottom Hole Temperature) data analysis. Studies by Abdel Zaher et al. [13,14] assessed geothermal resources in the Hammam Faraun hot spring and the Gulf of Suez, respectively, demonstrating diverse research efforts across Egypt. Additionally, analyses by Abdel Zaher et al. [15] and Mohamed et al. [16] utilized conceptual and numerical models to study geothermal fields in the Sinai Peninsula, reflecting a multidisciplinary approach to understanding geothermal potentials in various Egyptian regions.

3. Key Contributions of Gaber et al. (2024)

3.1 Investigating Geothermal Resources Using Aeromagnetic Data

Gaber et al. [1] employed aeromagnetic surveys to analyze geothermal resources in the Central Eastern Desert. Their findings underscore the importance of understanding subsurface magnetic properties, which can indicate potential geothermal zones (Fig 3). The study revealed that areas with lower magnetic susceptibility often correlate with higher temperatures, facilitating the identification of promising geothermal sites.

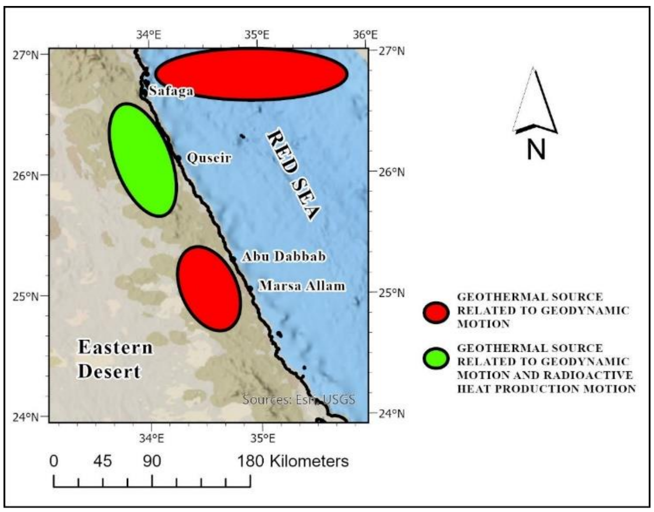

Fig. (3): Displays the regions identified for prospecting geothermal resources, as outlined in the extensive research conducted by Gaber et al. [1-3].

3.1.1 Methodology

The aeromagnetic data were collected using advanced surveying techniques, which provided high-resolution maps of the magnetic field intensity in the study area. The data were then analyzed to identify anomalies that could be indicative of geothermal activity.

3.1.2 Findings

The results indicated that specific regions within the Central Eastern Desert exhibit magnetic anomalies consistent with geothermal features, suggesting that these areas warrant further investigation for geothermal energy potential.

3.2 3D Gravity and Magnetic Inversion Modelling

In a complementary study, Gaber et al. [2] utilized 3D gravity and magnetic inversion modelling to deepen the understanding of subsurface structures and their relation to geothermal resources. This innovative approach allowed for a detailed analysis of density variations and magnetic properties.

3.2.1 Methodology

The study applied advanced inversion techniques using the Pygimli library in Python, which enabled the researchers to model subsurface density distributions based on gravity anomalies. The magnetic data were similarly analyzed to ascertain the magnetization characteristics beneath the surface.

3.2.2 Findings

The findings revealed distinct variations in density, with high-density zones correlating with potential geothermal resources. This study further emphasized the importance of integrating gravity and magnetic data in geothermal assessments.

3.3 Integrating Radiometric and Aeromagnetic Data

Gaber et al. [3] also integrated radiometric data with aeromagnetic information to provide a holistic assessment of geothermal potential. This study highlights the advantages of employing multiple geophysical methods to enhance the accuracy of geothermal assessments.

3.3.1 Methodology

The integration involved the analysis of radiometric data, which provided insights into the distribution of radioactive elements in the subsurface. By combining this data with aeromagnetic findings, the researchers were able to create a comprehensive geothermal potential map.

3.3.2 Findings

The results indicated several areas with promising geothermal characteristics, reinforcing the notion that the Central Eastern Desert is a viable candidate for geothermal energy exploration. Through hematological analysis and histological examination of rat spleen, the current work seeks to establish the anti-leukemic efficacy of Camellia sinensis extract (CSE) against benzene-induced leukemia in a rat model equivalent to Cyclophosphamide.

4. Geological Framework of the Central Eastern Desert and Red Sea Region

4.1 Tectonic Setting

The geological framework of the Central Eastern Desert and Red Sea region is characterized by its tectonic history,

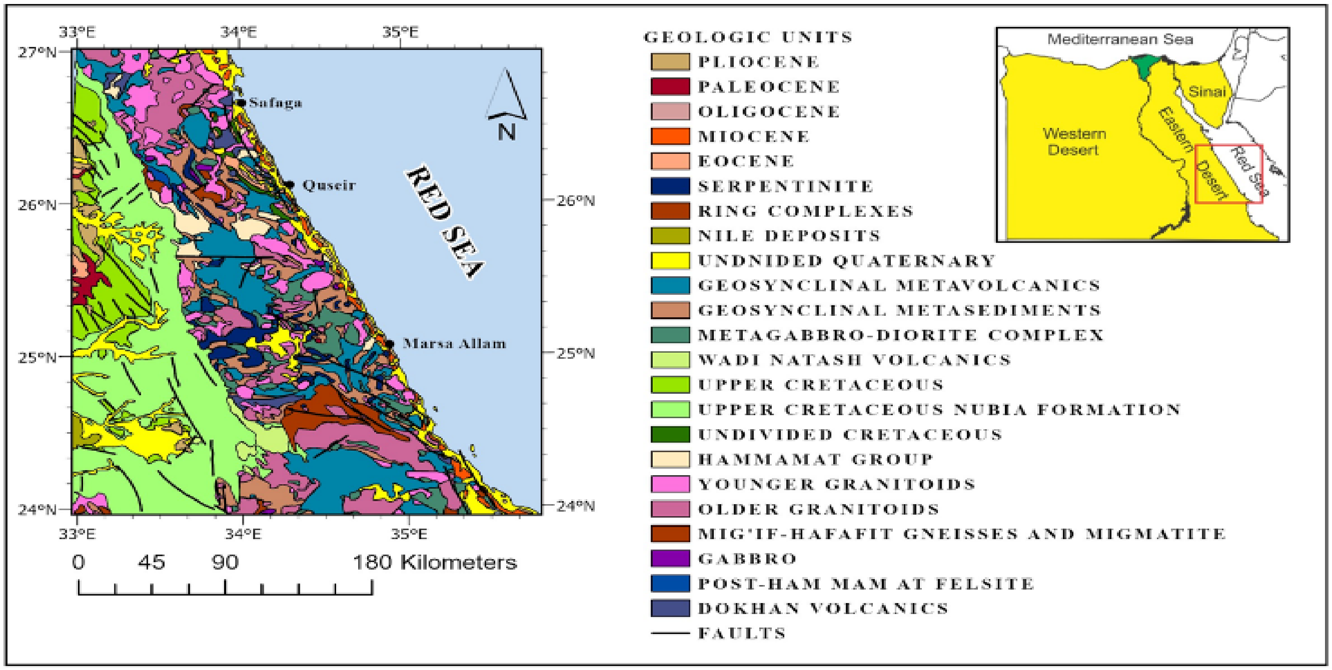

Fig. (4): The Geologic rock distribution map with the structure lineament of the Central Eastern Desert area (GSE, 1981) [17].

primarily influenced by the Red Sea Rift. This active tectonic setting has contributed to the formation of volcanic features and geothermal phenomena, making it an ideal location for geothermal exploration.

4.2 Geological Formations

The region is dominated by granitic rocks with high heat-generating potential (Fig 4), as well as other geological formations that contribute to its geothermal characteristics. Understanding the distribution and composition of these rocks is essential for assessing geothermal resources. Lashin noted that the presence of volcanic rocks and associated geothermal systems is critical in identifying potential geothermal reservoirs [4].

5. Geophysical Investigations

5.1 Aeromagnetic Data Analysis

The aeromagnetic data collected by Gaber et al. [1-3] provided valuable insights into subsurface features. The analysis revealed that areas with lower magnetic susceptibility often correspond to higher temperatures, facilitating the identification of geothermal prospects.

5.2 Gravity Inversion Modelling

The application of 3D gravity inversion modelling allowed for a detailed understanding of subsurface density distribution. Gaber et al. [2] found that high-density zones are often associated with geothermal anomalies, reinforcing the connection between subsurface density and geothermal potential.

6. Thermal Modelling

6.1 Importance of Temperature Models

The integration of thermal models with geophysical data is crucial for accurately assessing geothermal potential. Gaber et al. [2] utilized the WINTERC-G model as a temperature model for the world to develop a temperature distribution model for the study area, providing insights into the thermal structure and identifying areas with significant geothermal anomalies.

6.2 Temperature Profiles

The temperature profiles obtained from the modelling exercise indicated substantial geothermal resources, with temperature values ranging from 59 to 148 °C at various depths. These findings underscore the importance of thermal modelling in understanding subsurface processes.

7. Future Directions for Research

The findings from Gaber et al. [1,3] pave the way for future research in geothermal exploration in Egypt. Future studies should focus on:

1. Enhanced Geophysical Surveys: Employing advanced geophysical techniques, including electrical resistivity and seismic surveys, to complement existing data.

2. Borehole Data Collection: Conducting drilling programs to validate geophysical findings and obtain direct temperature and fluid samples from the subsurface.
3. Sustainability Assessments: Evaluating the sustainability of geothermal resources, considering the potential environmental impacts of geothermal energy extraction.

8. Conclusion

The studies conducted by Gaber et al. [1-3] significantly advance the understanding of geothermal resources in the Central Eastern Desert and Red Sea region. By integrating various geophysical methods, these works provide a robust framework for future exploration and utilization of geothermal energy in Egypt. As the global demand for renewable energy sources increases, Egypt's geothermal potential presents a promising avenue for sustainable energy development, warranting further exploration and investment.

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