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Curie point depth and heat flow from spectral analysis of aeromagnetic data over the northern part of Western Desert, Egypt

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ABSTRACT

The present work aims to estimate the Curie point depth and the surface heat flow for the northern part of the Western Desert using aeromagnetic data. Applying spectral analysis to aeromagnetic anomalies has provided equitable promising geological results, useful for further geothermal or petroleum exploration. The total intensity aeromagnetic map was first reduced to the north magnetic pole to correct the shape and position of different magnetic anomalies over their causative bodies. Secondly, the short wavelengths were removed to enhance the deeper long wavelengths related to the deep sources. Spectral analysis indicates that the area is underlined by an average Curie point depth of about 27 km. This implies an average thermal heat flow (53 mW/m^2) lower than the average global heat flow. The investigated area was divided into eighteen blocks, where the average depths to centroid and top of the magnetic source were estimated for each block. The results of this work show a general depth increase of the magnetic boundaries from 24.5 km in the southern area to 33 km at the northern part. The calculated surface heat flow decreases from about 56 to 42 mW/m^2 in the same direction. Consequently, this area is characterized by its low geothermal gradient and surface heat flow. This low geothermal gradient indicates that the upper mantle contributes to the magnetic features at the northern offshore parts. This work also recommends by deep drilling for petroleum exploration and production within the Egyptian Mediterranean Sea exploration strip.

1. Introduction

The Western Desert is the second important oil province of Egypt after the Gulf of Suez province. Because of this importance, it is interested to study its geothermal gradient for further geothermal and petroleum exploration. Hosney (2000) studied two-heat flow provinces (west and east the River Nile) based on density and compressional wave velocity. He noticed that the west of Nile, at the northern part of Egypt, is characterized by low heat flow (46 mW/m^2) while the eastern part of Egypt is tectonically active province with high heat flow up to 80–130 mWm^2 including the Gulf of Suez and the northern Red Sea rift system. Mohamed et al. (2015) studied the geothermal gradient on the northern part of the Western Desert (between latitudes 27 to 32°N and longitudes 25 to 31°E) based on bottom-hole temperature (BHT) that was recorded from 149 deep oil wells (2000–4500 m). He concluded low geothermal gradient of about 30 °C/km. There is no research dealt with the study of thermal gradient based on magnetic data in the Western Desert. The idea of using magnetic anomalies to estimate the geothermal gradient is based mainly on calculating the depth to the bottom of the magnetic source that caused these magnetic anomalies. This depth is equal to the Curie point depth (CPD) at which the substance loses its magnetic polarization.

Many authors used the analysis of the magnetic data to estimate CPD in different localities all over the world. Among of them Smith et al. (1974), Bhattacharyya and Leu (1975), Byerly and Stolt (1977), Connard et al., 1983, Okubo et al. (1985), Blakely (1988), Tsokas et al. (1998), Tanaka et al. (1999), Maden et al. (2009), Trifonova et al. (2009), Kasidi and Nur (2012), Maden (2012), Hsieh et al. (2014), Gao et al. (2015), Abraham et al. (2015). This method is rapid and yields satisfied results. Usually, it can be applied as a reconnaissance technique for geothermal exploration targets because of the abundance of magnetic data.

This study aims to through more light on the geothermal gradient and the surface heat flow of the northern onshore part of the Western Desert and the southern offshore strip of Eastern Mediterranean Sea. To achieve these goals, the spectral analysis technique was applied to magnetic data of studied area.

2. The study area

The study area lies in the northern part of the Western Desert, Egypt. It comprises both on- and offshore parts. It extends from latitudes 30° 00′ to 32° 00′N and longitudes 25° 00′ (along Egyptian-Libyan borders) to 30° 00′E (Fig. 1). The surface area of the studied region covers about 104,500 km^2. According to El Shazly and Abdel Hady (1976), the outcrops of the study area are composed of rocks and loose sediments

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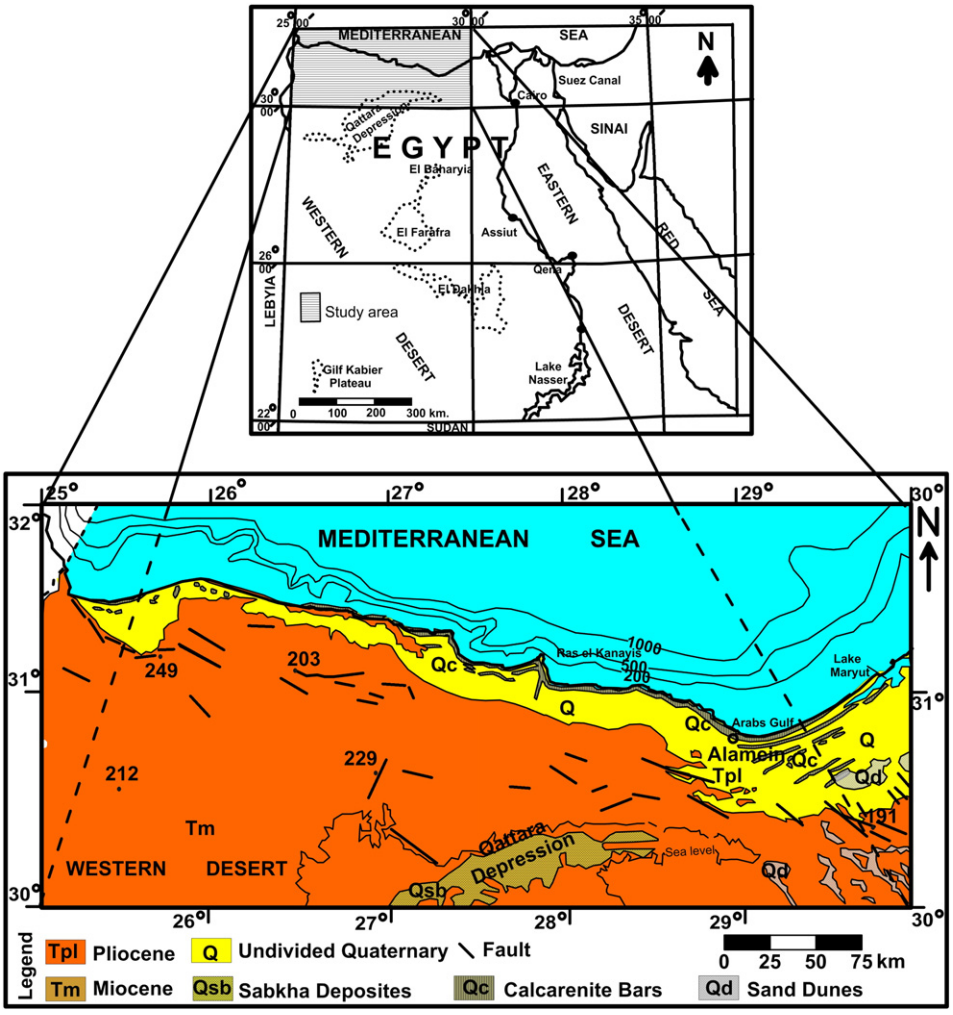

Fig. 1. Location map of the investigated area shows its geologic features (after Egyptian Geological Survey and Mining Authority, 1981).

belonging to Miocene and Quaternary ages (Fig. 1). The subsurface stratigraphic sequence ranges from Cambro-Ordovician to Recent, resting non-conformably over the crystalline basement rocks (EL Shaarawy et al., 1994). Barakat (1982) subdivided the sedimentary section of the north Western Desert into the lower clastic division (Cambrian to Early Mesozoic), the middle calcareous division (Cenomanian to top Eocene), and the upper clastic division (Oligocene to Recent). He also concluded that the detected structural elements in this area are in the form of folds, faults and subsurface ridges separating different sedimentary basins. Hantar (1990) concluded that north Western Desert is

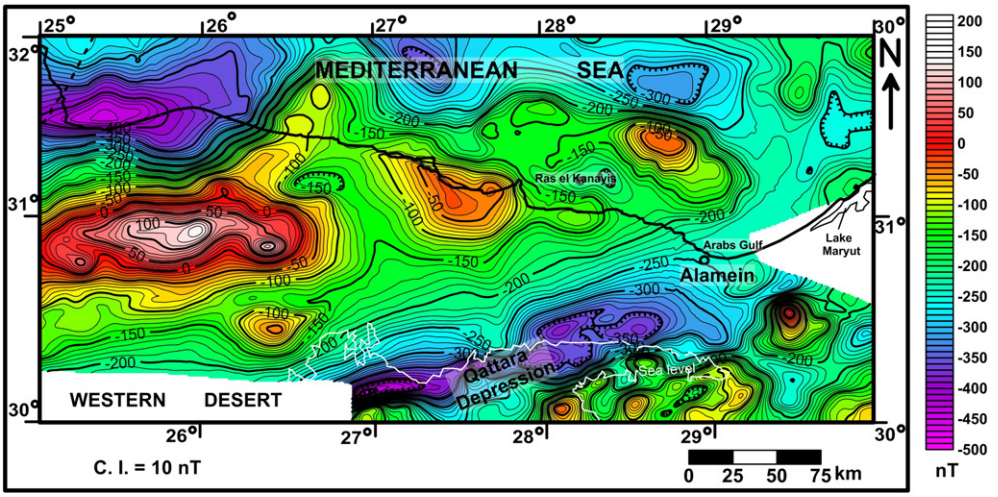

Fig. 2. Total intensity aeromagnetic map of the study area.