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INFERRING DEPTH TO BASEMENT USING AIRBORNE MAGNETIC DATA AT WADI EL NAKHIL AREA, EASTERN DESERT, EGYPT

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Airborne magnetic dataset at Wadi El Nakhil area was processed to estimate the basement depth, and consequently the thickness of the sedimentary cover which may provide some insights into the groundwater potentiality at the study area. The corrected aeromagnetic data is represented by total magnetic intensity (TMI) was reduced to the magnetic pole (RTP). The radially averaged power spectrum technique (RAPS) and source parameter imaging technique (SPI) were used to estimate the depths to basement. The radial power spectrum technique showed that average depth of the isolated short wavelength anomalies is 9.23 m, and the depth of the long wavelength anomalies is 1587.21m whereas the SPI technique showed that the depth to basement ranges from 53m to 1500 m. In particular, the southeastern and northwestern parts of Wadi El Nakhil are characterized by a thick sedimentary cover of 385 and 1300m, respectively. These parts with thick sedimentary cover may represent areas or include horizons with high groundwater potentiality.

Key words: Wadi El Nakhil, aeromagnetic, depth to basement, radial average power spectrum, source parameter imaging, groundwater potentiality

1. INTRODUCTION

The magnetic method is one of the best geophysical techniques used for determining depth to magnetic source bodies (and possibly sediment thickness) and delineating subsurface structures (Reynolds, 1997). For resource exploration purposes one of the most useful inferences that may be derived from analyses of potential field (e.g., magnetic and gravity) data is the depth of crystalline basement beneath sedimentary cover. High-resolution aeromagnetic data are useful for the geologic and hydrologic mapping at a variety of scales, and also for environmental investigations (Kumar et al, 2006; Abu El Ata et al, 2013). The magnetic fields change when the physical properties like susceptibility and thickness of the subterranean rocks change.

Sedimentary rocks, in general have low magnetic properties compared with igneous and metamorphic rock that tend to have a much greater magnetic content (Reynolds, 1997). The magnetic data finds wide applications and is able to provide very valuable subsurface information (Reynolds, 1997; Hammza and Garba, 2010, Khalil et al, 2016).

Wadi El Nakhil basin lies between Latitudes 25° 58’ and 26° 16‘ N and Longitudes 34° 20' and 33° 55‘E (about 12 km west of Quseir area) (Fig. 1). Wadi El Nakhil is the largest and most conspicuous inland syncline in the central Eastern Desert of Egypt that extends WNW and NW generally about 54 km. It varies in width from 7 to 13 km and covers a total area of 348.8 km^2 approximately (Yousif and Sracek, 2016). Therefore, Wadi El Nakhil represents one of the most promising areas for land reclamation and future projects depending on groundwater for land irrigation and human use. The groundwater exploration of the study area is still very limited and only 4 active wells drilled at the site, in addition to one natural spring near the road in the front of Wadi El Nakhil. In wadi El-Nakheil, the Oligocene sandstone (El Nakhil Formation) is detected as a water bearing formation. The depth to groundwater ranges between 3.5 and 18m (Mohamed Gomaa et al, 2017).

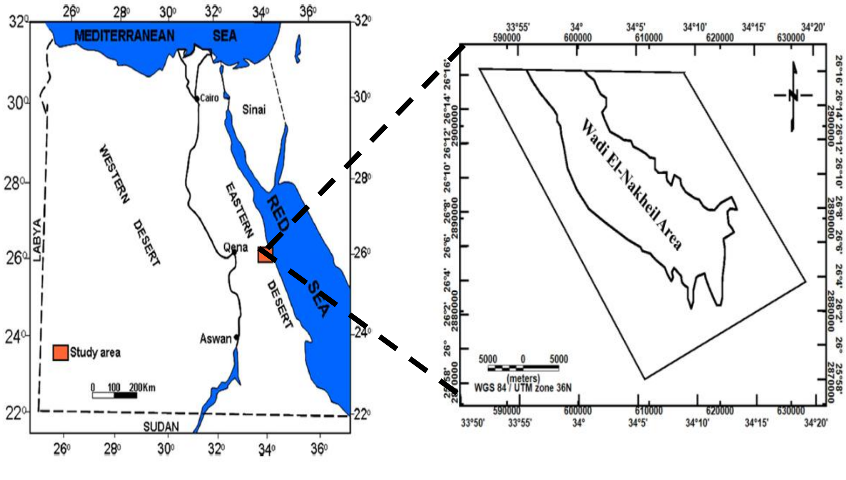

Figure 1: Location map of Wadi El Nakhil area.

The present study aims to estimate the basement depth, and consequently the thickness of the sedimentary cover which may provide some insights into the ground water potentiality at the study area. This was achieved through the following available geological and geophysical data:

- The aeromagnetic map of the studied area (scale 1:50.000, Sheet No. 61) prepared by Aero-Services Company, 1984 within a project called MPGAP (Minerals, Petroleum and Groundwater Assessment Program).
- The geological map of Egypt (scale 1:500.000) published by EGPC and Conoco (1987).

2. Geologic Setting of Wadi El Nakhil:

The regional rock units and the observed geologic structures predominant in the study area are shown in Figure 2. The main rock units in the study area (EGPC and Conoco, 1987; Said, 1990; EGSMA, 1992; Badawy, 2008; EMRA, 2009; Youssef et al., 2017) can be categorized from older to younger as follow: (A) Late Proterozoic rocks, comprise Muatiq Group (highly metamorphic schist, fine grained serecite, medium grained quartz of feldspathic and orthogneisses of alkali magma), Ophiolite Group (serpentine, metagabbro, undifferentiated metavolcanics, basic metavolcanics, intermediate to acid metavolcanics, metapyroclastics and metamorphosed shelf sediments), Hammamat clastics (non-metamorphosed conglomerate, greywackes, sandstone and siltstone), weakly deformed granitic rocks, alkaline undeformed granitic rocks, Dokhan volcanic (non-metamorphosed volcanics) and Post Hammamat units (effusive felsite, felsite porphyry and quartz porphyry, and overlain by a series of trachyte plugs and sheets). (B) Cretaceous rocks, comprise the following, from the older to younger; Taref Sandstone (a 130 m massive-thick-bedded, siliciclastic of Nubia Formation), Quseir Formation (varicolored shale, siltstone and flaggy sandstone) and Duwi (phosphate) Formation (three phosphate horizons ranging in thickness between 30 and 100 m, and separated by beds of marls, shale and Oyster limestone with flint). (C) Cenozoic rocks, from bottom to top, as follow; Dakhla Formation (a 100 m thick of marl and shale), Tarawan Formation (a 6 to 10 m thick of marl and marly limestones), Esna Formation (a 50 m thick of grey laminated shale), Thebes Formation (fossiliferous limestone), Nakhil Formation (very coarse brecciated beds and fine-grained lacustrine deposits), Ranga Formation (conglomerate is embedded in a red brown sandy matrix), Umm Mahara Formation (sandy limestone and gypsiferous fossiliferous limestone), Abu Dabbab Formation (evaporate (gypsum) deposits), Umm Gheig Formation (hard dolomite), Shagra Formation (sandstone, bioclastics and some siliciclastics) and Quaternary deposits.

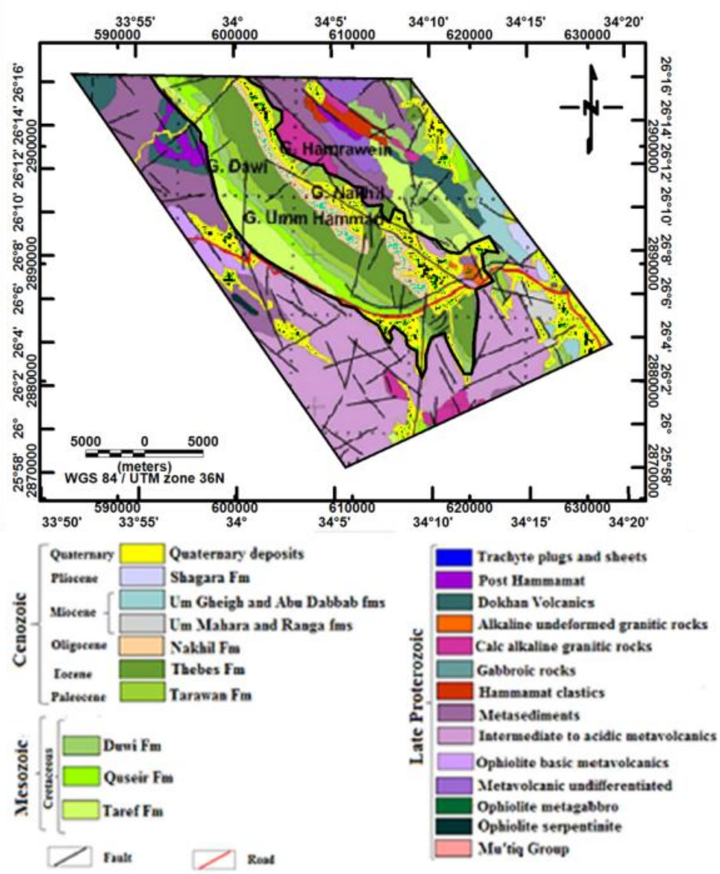

Figure 2: Simplified geologic map of Wadi El Nakhil area (After EGPC and Conoco, 1987)

The investigated area was subjected to different tectonic events, giving rise to some complex structures (Youssef et al. 2017). It is dissected by various types of faults with different trends. The two main two trends as reported by Said, 1990 are: NW-SE and NE-SW. The first direction is the most wide spreading one, that is adhered to the main direction of the Red Sea graben (known as the Red Sea or East African faulting), while the second direction corresponds with the Gulf of Aqaba direction (known as the Aualitic faults).

3. MATERIALS AND METHODS:

The Aeromagnetic data which constructed by Aero-Services Company, 1984 from a project called MPGAP (Minerals, Petroleum and Groundwater Assessment Program) aimed essentially at providing data that would assist in identifying and assessing the mineral, petroleum and groundwater resources of the region. Surveying flying was done at a mean terrain clearance of 120 m with aircraft average ground speed range of 222–314 km/h. The airborne magnetometer used during the survey was a Varian V-85 proton free-precession magnetometer, with a sensitivity of 0.1 nT. The aeromagnetic map has been digitized using the software of Didger (2001) to convert the analog aeromagnetic map into a digital format.

The digitized aeromagnetic map was imported into the Geosoft Oasis Montaj software version 6.2.4 (2007) environment and then aeromagnetic data were reduced to the pole. Generally, for good accuracy in interpretation of the magnetic anomaly map, it has to differentiate the hypothetical anomaly from the observed type on the total intensity magnetic map, where the causative body can be directed to the northern pole. An RTP (Reduction to the pole) of the total magnetic field application removes the asymmetric anomalies caused by the inclination and centering the anomalies directly above their broad deep seated sources. The total magnetic field intensity (TMI) map is reduced to the pole using the following parameters (declination = 4.18, inclination = 38.53, and IGRF total intensity value = 42162 nT) obtained from the aeromagnetic data sheet 61 for the study area.

The depth to the basement was determined by applying the radially averaged power spectrum analysis technique (RAPS) and source parameter imaging technique (SPI) to the RTP magnetic data using the Geosoft Oasis Montaj software version 6.2.4 (2007). The radially averaged power spectrum analysis technique will provide us with the average depth to the shallow and deep magnetic sources which depends on the transformation of the space domain data into frequency domain by using Fourier transform. This transformation gives us the ability to deal with each single anomaly as a wave. Review of the method is given elsewhere, by Bhattacharyya (1978). The energy decay curve includes linear segments, with distinguishable slopes, that are attributed to the contributions in the magnetic data from the residual (shallower sources), as well as the regional (deep sources). The depth of each source ensemble responsible for each segment is calculated by introducing the slope of this segment in the formula:

h (depth) = -slope/4π…………….(1)

The source parameter imaging (SPI) is a procedure for automatic calculation of source depths from gridded magnetic data (Thurston and Smith, 1997). The calculated depth solutions are saved in a database. These depth results are independent of the magnetic inclination and declination, so it is not necessary to use a pole-reduced input grid. This technique is used as quantitative method to obtain depth to basement by calculating the grid gradient amplitude in X and Y directions. The “x, y” derivatives are calculated by a 3x3 point convolution filter. The “z” derivative is calculated by one-step grid filtering operation to compute the first vertical derivative grid in the forward Fourier (frequency) domain transformation; SPI assumes a step-type source model. The SPI is powerful method for calculating the depth of magnetic sources, its accuracy has been shown to be +/- 20% in tests on real data sets with drill hole control. This accuracy is similar to that of Euler Deconvolution. However, the SPI has the advantage that it produces a more complete set of coherent solution points and is easier to use.

4. RESULTS AND DISCUSSION:

4.1. Total Magnetic Intensity (TMI) Map

Figure 3 shows the total intensity magnetic (TMI) map of Wadi El Nakhil area. The TMI map shows magnetic anomalies with magnitude values range from 42275 nT to maximum value 42475 nT. These anomalies can be grouped into high and low magnetic anomalies. The high magnetic anomalies of magnitude greater than

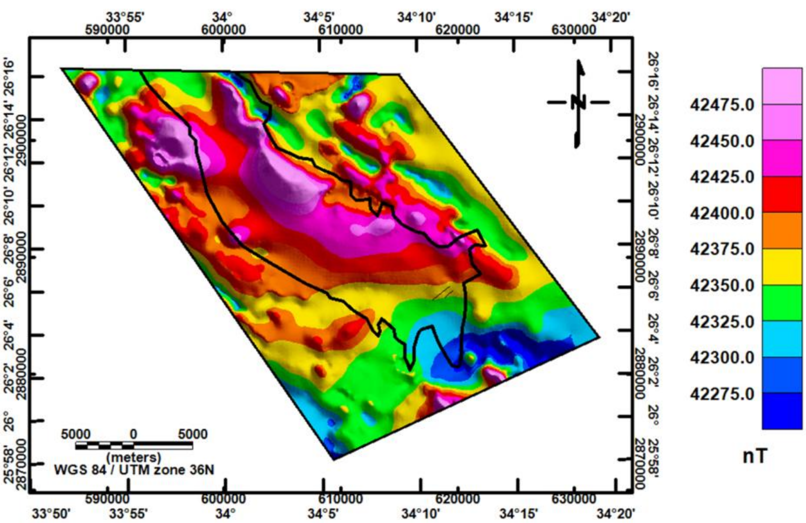

Figure 3: Total magnetic intensity (TMI) map of Wadi El Nakhil area.

42375 nT area predominant in the central, northwestern and western parts of the study area (Fig. 3). These high magnetic anomalies may indicate a shallower basement and thin sedimentary cover. Whereas, the low magnetic anomalies group comprises in the southeastern part of the study area and characterized TMI values less than 42325 nT (Fig. 3). These may indicate thick sedimentary cover or presence of low magnetic susceptibility basement complex. The eastern and southwestern parts of the study area are characterized by moderate magnetic values between 42325 nT and 42375 nT (Fig. 3).

4.2. Reduced to the Pole Magnetic (RTP) Map

The RTP map (Fig. 4) in combination with the TMI map (Fig. 3) shows that the reduction process shifts the magnetic anomalies northwards due to elimination of the inclination and declination of the anomalies. The position and shape of the obtained magnetic anomalies are then related to their subsurface source bodies in the area. The RTP map of the study area shows magnetic intensity values between 42250 nT and 42450 nT. The northern, northeastern, eastern and southern parts of the map is characterized by the presence of high amplitude magnetic anomalies (greater than 42350 nT) with elongated and semicircular shapes that may due to shallow bodies of high magnetic susceptibility features (Fig. 4). The southeastern and southwestern parts of the study area are characterized by low magnetic amplitudes (less than 42300 nT) whereas the central and western parts are characterized by moderate magnetic amplitudes between 42300 nT and 42350 nT (Fig. 4).

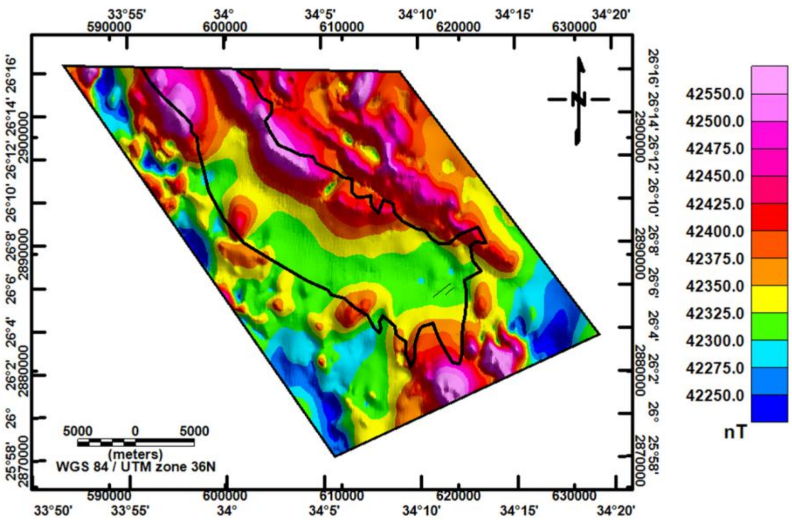

Figure 4: Reduced to the pole (RTP) magnetic map of Wadi El Nakhil area.

4.3. Depth to Basement

4.3.1. Radially Averaged Power Spectrum (RAPS) map

According to the radially averaged power spectrum (Fig. 5), it reveals that, there are two main average levels (interfaces) at depths 9.23 m and 1587.21 m below the measuring level. However, these results depend on the proper choice of the slope of the different segments of the power spectrum curve and could be over or under estimated.

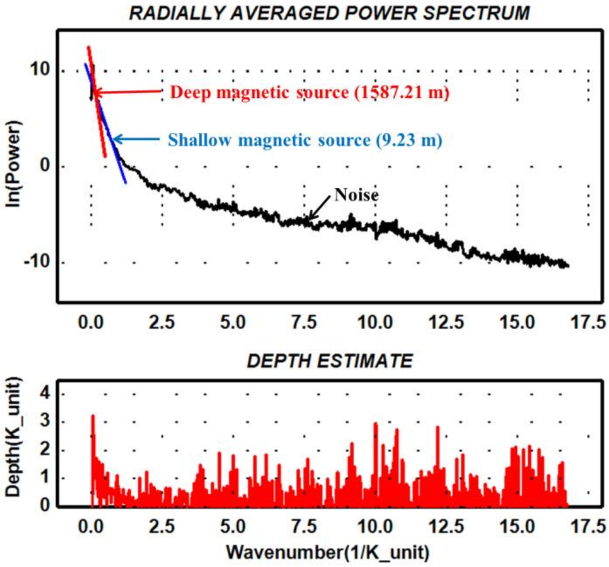

Figure 5: Radially averaged power spectrum of the RTP magnetic data of Wadi El Nakhil area.

4.4. Source Parameter Imaging (SPI)

Figure 6 shows the source depth map estimated by the source parameters imaging technique and presented as a shaded color relief map. The map shows that the basement depth values estimated by this technique range from 75 m to 650 m (Fig. 6). Within the boundary of Wadi Al Nakhil area, the results of the depth to basement can be catograized into three different groups. The first group labled as (L) is charcterized by shallow depth to besement or low sedimentary cover less than 175 m. This shallow source is characterized by narrow and elongated shape and mainly concentrated at the southeastern, southwetern and central parts of the study area (Fig. 6). The second group labled as (M) with moderate depth to basement or thickness of sedimentary cover ranges from 200 m to 300 m and mostly cover the central parts of the study area (Fig. 6). Areas with high depth to basement or thick sedimentary cover are labled with (H) with values range from 300 to 1350 m. These areas with thick sedimentary cover increases with size and thickness towards the northern part of the study area (Fig. 6). Acooriding to the categorazation of the depth to basement and consequently the thickness of sedimentary cover, it is apparent that areas with lable (H) may represent high groundwater potentialty.

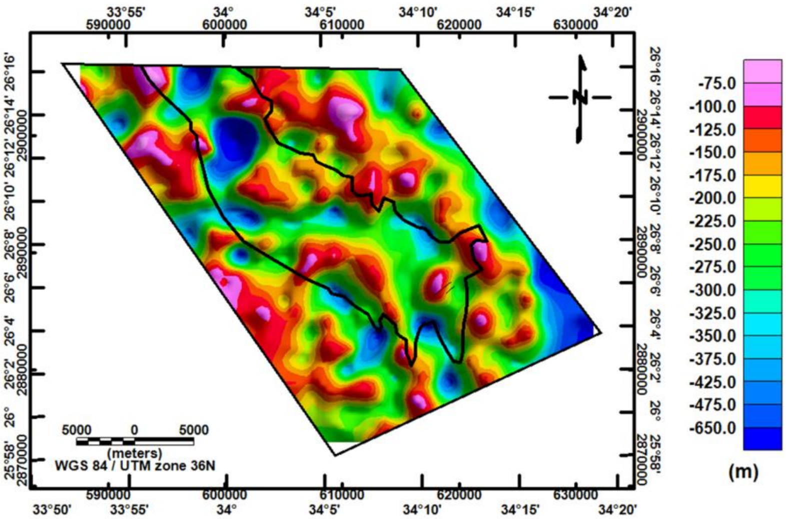

Figure 6: Basement depth from source parameter imaging (SPI) technique; (L), (M) and (H) represent areas with low, moderate and high depth to basement/thickness of sedimentary cover, respectively.

5. SUMMARY AND CONCLUSION:

The present study is concerned with the estimation of the depth to basement at Wadi El Nakhil and its surrounding area based on the interpretation of the available aeromagnetic data. Wadi El Nakhil represents one of the most promising areas that are located within the Golden triangle project for development in Egypt which extends from the Red Sea coast in the East to the Nile Valley in the west. The depth to basement obtained by the radial average power spectrum technique and source parameter imaging technique ranges from 9 m to 1587 m from ground surface. The northern parts of the study area displayed thick sedimentary cover which may represent areas of groundwater potentiality. Further analyses are needed to define the trending of the subsurface structure which could provide valuable information on the tectonic framework and the direction of groundwater movement at the study area.

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