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DELINEATING SUBSURFACE GEOMETRY AND STRUCTURAL FRAMEWORK OF WADI EL-ASSIUTI BASIN USING AIRBORNE MAGNETIC DATA MODELLING, EASTERN DESERT, EGYPT

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ترسيم الهندسة تحت السطحية والإطار التركيبى لحوض وادي الأسيوطي باستخدام نمذجة البيانات المغناطيسية الجوية، الصحراء الشرقية، مصر

الخلاصـــة: يعتبر وادي الأسيوطي واحدا من الأحواض الأكثر أهمية بالصحراء الشرقية فى مصر. فهو يحتل مساحة كبيرة شرق نهر النيل، وعلى مقربة من مدينة أسيوط. ويمكن اعتباره امتدادا طبيعيا وأساسيا للتنمية المستمرة وعمليات الاستصلاح الزراعي. ومن هذا المنطلق، تأتى ضرورة ترسيم العوامل التي تؤثر في الشكل الهندسي والإطار التركيبى للمنطقة باستخدام واحدة من أدوات التنقيب الجيوفيزيائي الشهيرة لكى تصبح الأولوية الأولى لصانعي القرار. يتناول هذا البحث دراسة ومعالجة وتفسيرنتائج بيانات المسح الغناطيسي الجوي الذي تم تنفيذه بمنطقة الدراسة. وقد أظهرت نتائج التفسير النوعي وكذلك الكمي لبيانات المسح المغناطيسي الجوي الحصول على مزيد من المعلومات حول البنية التركيبية لصخور القاعدة وعمق سطحها. وقد حددت النتائج أن سطح صخور القاعدة يقع بين ٩٣٠ متر إلى ٢٥٦٠ متر تحت مستوى سطح البحر ويصل متوسط سمك الحوض الرسوبي إلى حوالي ٢١٨٦ م. كما كشف النتائج عن ان التراكيب تحت السطحية بالمنطقة تتخذ اتجاهات شمال شرق – جنوب غرب، وشمال غرب – جنوب شرق، وشرق – غرب، كما ان سمك الحوض الرسوبى يزداد باتجاه الشمال الشرقى لمنطقة الدراسة.

ABSTRACT: *Wadi El-Assiuti is considered as one of the most substantial basins in the Eastern Desert (ED) of Egypt. It occupies a large area at the eastern bank of the River Nile, close to Assiut city. It can be considered as the natural and fundamental extension for the ongoing development and agricultural reclamation processes at this part of the Eastern Desert of Egypt. From this point, the necessity to delineate the factors affecting the perspective shape and structural framework of the area using one of the famous geophysical prospecting tools becomes a first priority for decision makers. The present study deals with the aeromagnetic survey that was executed over the study area as a part of the Eastern Desert of Egypt. Qualitative as well as quantitative interpretation of the aeromagnetic data were carried out to obtain more information about the crystalline basement structure and the depth to its surface.*

Results define that the surface of basement rocks occur between 930 m to 2560 m below sea level and the average thickness of the sedimentary cover reaches to about 2186 m. The regional structure lineaments revealed from the derived magnetic maps have directions nearly NE-SW, NW-SE and E-W directions.

INTRODUCTION

The study area is located between latitudes 26° 44' N and 28° 00' N, and longitudes 30° 50' E and 32° 44' E and cover about 21368 Km^2, (Fig. 1). Wadi El-Assiuti starts in the form of tributaries, the most important of them is the area that starts in the south from W. Qena and goes northwards, then extends westwards to meet the Nile valley in the form of a delta, whose base is parallel to the River Nile. W. El-Assiuti represents one of the largest Wadis in Central Egypt, with a notable dry drainage basin, whose main channel reaches about 186 km in length (Dawoud & Ewea, 2011). It includes potential soils, where classifications indicated the appropriateness of the Wadi for agricultural expansion, if irrigation water is presented (Elewa, 2008; El-Desouqi et al. 1998).

The study area was subjected to many previous geological, hydrological and geophysical studies. Some of these studies targeted a small part of the Wadi at its entrance and others were at detached localities around it (Korany et al., 2013; Elewa & Samei, 2007; Elewa & Fathy, 2005; Bakheit, 1993, 1989 & 1983; Bayoumi & El-Gamili, 1966).

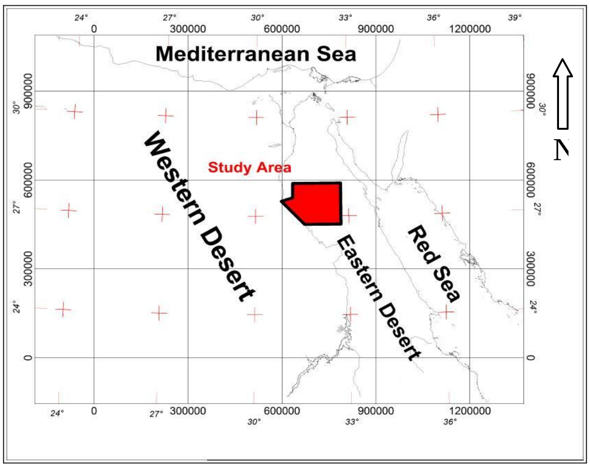

Fig. (1): Location map of the study area, ED, Egypt.

Previous studies on W. El-Assiuti showed the existence of two possible resources of renewable shallow aquifer (Dawoud et al., 2006; Yan et al., 2004; MWRI, 2001; RIGW, 2000; Ashmawy and Nassim, 1998). One of these aquifers lies within Quaternary alluvium (Dawoud, 1997; Warner et al., 1991; Attia, 1989). The other aquifer is located within deep groundwater coming from the Nubian aquifer that is discharged through deep major faults feeding the Quaternary alluvium aquifer (Yan et al., 2004).

The main purpose of this study is to delineate the main subsurface structural elements of the study area, estimate the depth to the basement rocks, and consequently the thickness of the sedimentary basin using the aeromagnetic survey. The study is based on the acquired aeromagnetic data prepared by the Nuclear Materials Authority (NMA) of Egypt on Oct, 2012. Such information is of a particular importance in previously-unexplored areas, such as the continental shelves (including the study area), newly opened for prospecting and also employed to map topographic features on the basement surface that might influence the structure of the overlying sediments.

Therefore, defining the depth to the surface of the basement is generally equal to determining the thickness of the sedimentary section.

Geological Setting

The study area is placed within the stable shelf of Egypt, which is situated between the Arabian Nubia massif in Southern Egypt and the unstable shelf to the north (Yousef, 2003). The sedimentary successions in W. El-Assiut region overlie unconformably the Pre-Cambrian basement, with a total thickness of 2279 m at W. Habib well that was drilled by Apache Oil Company in Oct., 2000 (Fig. 2). Folds and faults are the most important structural features in the study area. According to Osman (1980), the Eocene limestone plateau at the area, northwest of Assiut, is affected by several joint systems and fractures, trending in N35°W, N-S, N45°E and E-W directions. Faults have an important role in the water recharge mechanisms to groundwater aquifers in the Assiut area, especially the Eocene aquifer at the Western Desert fringes and the Pleistocene aquifer of Wadi El-Assiuti at the Eastern Desert fringes.

Wadi El-Assiuti is mainly covered by Tertiary and Quaternary sediments, concealing Lower Eocene limestone bed rock. It is bounded by the Eocene limestone scraps from the north and south, while it is bounded by Mesozoic sediments at the east and by the Nile flood plain from the west. Now, it drains southwestward into the present Nile River (Fig.2).

The Lower Eocene limestone exposed on the escarpment faces bounding the entrance of the Wadi can be arranged from base to top as: Thebes, Durnka, Manfalout and Ibrahimi formations (Mansour and Philobbos, 1983).

According to Bakheit (1989), the structural elements observed in the limestone plateau surrounding the entrance of W. El-Assiuti include faults and folds. The faults have different trends; N140°, N50°-70° and N-S. Folds are represented by a very dense system of narrow and long folds having the dominant direction N115°.

Survey Design and Data Acquisition:

The magnetic survey was carried out by NMA, started on Oct. 2012, using a twin-engine Beechcraft King aeroplane B200SE, equipped with a multi - sensor airborne geophysical survey system. The magnetic survey was conducted over traverse lines directed (71.39˚- 251.39˚) and tie lines directed (161.39˚-341.39˚), with a flight line spacing of 1000 m, (Fig. 3). A Novatell DL-V3 Global Positioning System (GPS) was used on-board the aircraft to provide positioning control during the survey. The system determines the absolute position of the aircraft in three dimensions, resulting in a position sampling accuracy of better than 3.0 m.

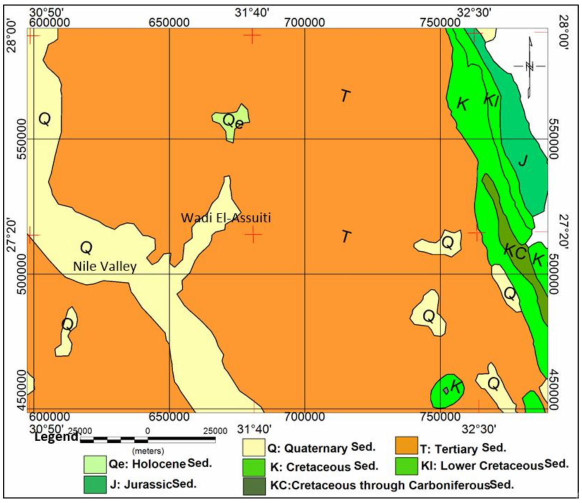

Fig. (2): Geologic map of the study area, (USGS, 1997).

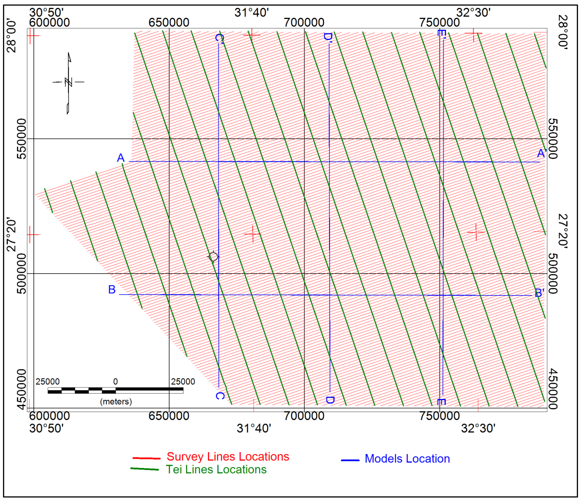

Fig. (3): Locations of magnetic survey lines (Red) and modelling profiles (Blue), of the study area, ED, Egypt.

The positioning data were recorded at 0.5 second intervals. A Scintrex MMS-4 Airborne Cesium Magnetometer system was used during the survey. The system utilizes a split-beam, optically-pumped Cesium vapor magnetic sensor, which is sampled at 0.1 seconds and has an in-flight sensitivity of 0.001 nT. The data acquisition system used in this study was Scintrex Airborne Geophysical Information System (AGIS), while a dual antenna radar altimeter 405B system was used to record the terrain clearance, with an accuracy of about ±0.3 m, and measured the aircraft elevation above the sea level, with an accuracy of about ±5 m.

A digitally-recording Smart Mag Cesium magnetometer of the model SM-4, having a resolution 0.01 nT was used as a base station for monitoring and recording the geomagnetic diurnal and other time-varying fields. This magnetometer was calibrated and operated continuously throughout the survey production inside the survey area (Assiut). To ensure high-quality magnetic data, the time of both the ground and airborne magnetometers were synchronized to ±1 second or better, using GPS real-time signals. The digital data, from this monitor, was used in correcting the acquired airborne magnetic data. The base station magnetometer was located in an area which is acceptably free from cultural interference and which is also a local area of low natural magnetic gradient at Assiyut area. Novatell DL-4 base station GPS system, with a position sampling accuracy of better than 3.0 m., was also used for the subsequent flight path recovery. The base station system was located at the operations base Asyut to monitor GPS satellite correction data. Records from the GPS base station were used with the aircraft GPS files to determine the differential correction (DGPS) to the flight path.

Magnetic Data Processing and corrections:

The airborne magnetic observations were corrected for the diurnal variations day by day and formerly levelled using the tie lines then the data subjected to the following corrections:

- Aircraft and Magnetometer Compensation
- Compensation of Magnetometer Heading Effect
- Lag Correction
- International Geomagnetic Reference Field (IGRF)

After applying all previous corrections, the total magnetic intensity (TMI) map was produced (Fig. 4). Because of the inclination of the earth's magnetic field, most magnetic anomalies show a dipolar responses, which are usually offset from the center of the causative body along the magnetic meridian. In order to correct that offset effect, a reduction to the north magnetic pole was applied to remove this effect, so that the data appear as if observed at the pole, where the magnetic field is vertical (Kaerey and Michael, 1994). Therefore, the TMI map was reduced to the north magnetic pole, using inclination (I^o) = (39^o) and declination (D^o) = (3^o) at the survey date to obtain the reduced to the north magnetic pole (RTP) map (Fig. 5). Then, the RTP map was treated by the power spectrum technique (Spector and Grant, 1970; Treital et al., 1971; Sadek et al., 1984) using FFT (Fast Fourier Transform) and the resulted spectrum is shown on Figure (6). The power spectrum curve was used to separate the shallow magnetic sources (residual magnetic map, Fig. 7), from the deep-seated component (regional magnetic map, Fig. 8). It worth to mention that the Gaussian technique was used to carry out the regional-residual interval separation, because of its perfect separation, with lowest effect from any surrounding noise.

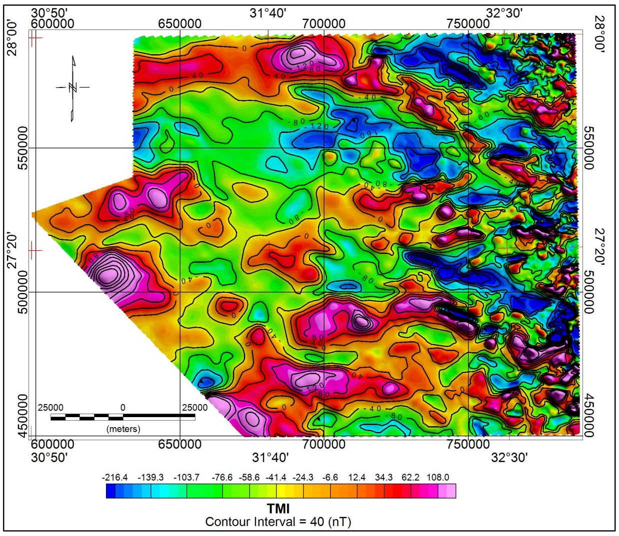

Fig. 4: Total Magnetic Intensity (TMI) map of the study area, ED, Egypt.

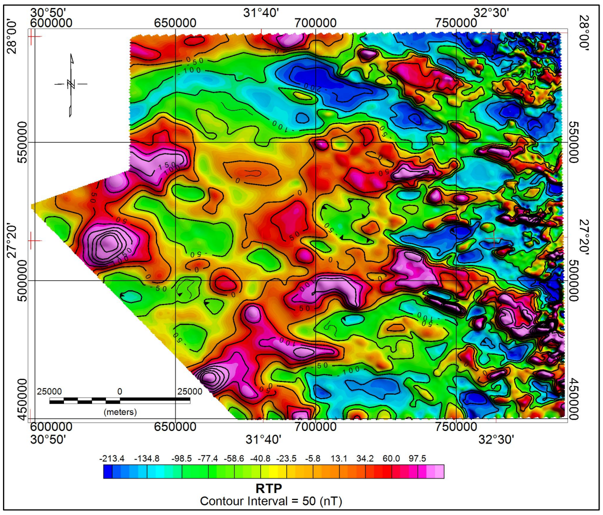

Fig. 5: Reduced to the North magnetic pole (RTP) map of the study area, ED, Egypt.

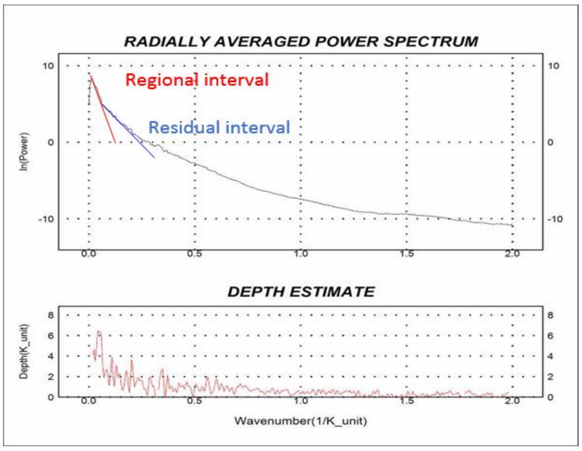

Fig. 6: Power spectrum for TMI data of the study area, ED, Egypt.

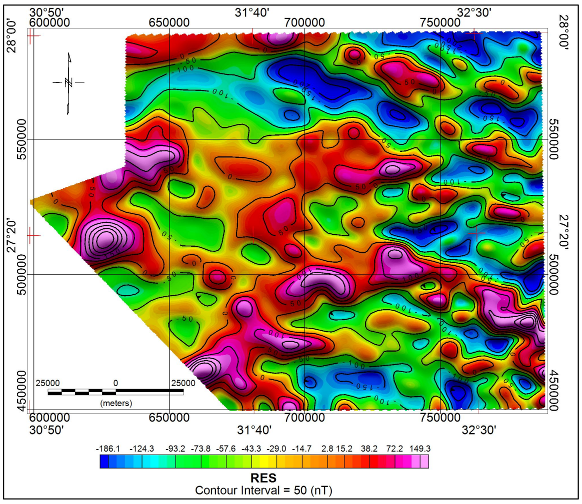

Fig. 7: Residual component map of the study area, ED, Egypt.

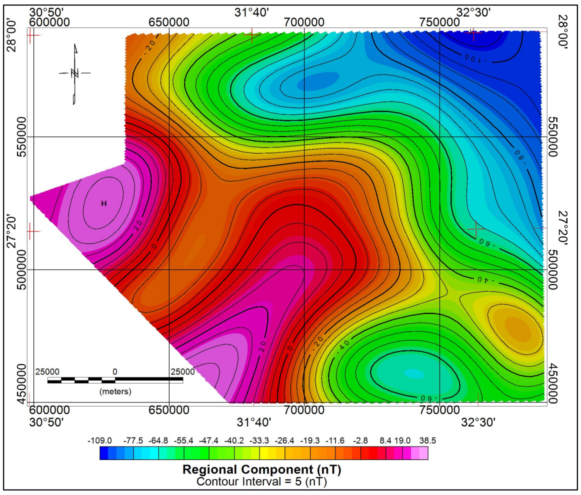

Fig. 8: Regional magnetic component map of the study area, ED, Egypt.

Magnetic Data Interpretation

The purpose of any magnetic survey is to inspect the subsurface structural pattern and basement topography on the basis of anomalies in the earth's magnetic field, resulting from the various magnetic properties of the underlying rocks. Magnetic survey, thus, has a broad range of applications, from small-scale engineering or archaeological surveys to detect buried metallic objects, to large-scale surveys carried out to investigate regional geological structures (Kearey and Michael, 1994).

Qualitatively, the RTP magnetic map of the study area (Fig. 5), there are 3 zones that can represent the distributions of the magnetic susceptibilities in the area, prevailing rock units and / or due to geologic structures. The first zone, with magenta and red colours represents the highest magnetic susceptibility seated mainly in the southern part of the study area, taking an arc shape form and also at its western part having an elongated oval shape. The second zone, with a green colour, represents a moderate magnetic susceptibility. The third zone, with a blue colour has the lowest magnetic susceptibility in the study area and is situated mainly at its eastern part.

On the regional component map (Fig. 8), there are two main zones that display the distributions of the magnetic susceptibilities in the study area due to the lithological and structural changes in the deep-seated basement rocks. The first zone, with magenta and red colours, represents the high magnetic anomalous area, situated mainly in the southwestern part of the study area and representing uplifted basement rocks at this part. The second main zone, with blue colour, is situated mainly at the northeastern part of the study area and represents downthrown basement blocks. These two zones are nearly similar to the zones revealed from the RTP map (Fig. 5), which means that the features which have high magnetic susceptibilities shown the same roots.

The RTP, the regional and the residual component maps (Fig. 5, 7 & 8), show various magnetic anomalous zones directed mainly from NW to SE and, from NE to SW which emphasize that the dominant structural framework in the study area trends meanly to these directions. Another E-W trend is shown in these maps especially in the Northern part of the study area.

Close examination to the RTP, regional and tilt derivative magnetic (Fig. 9) (deduced from the regional component) component maps, it is noticed that the major structural framework of the study area (Fig. 10) have nearly NE-SW, NW-SE and E-W directions.

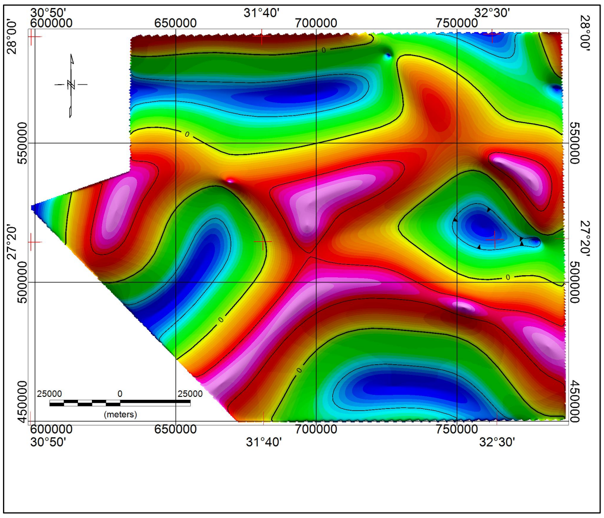

Fig. 9: Tilt Derivative map of the regional magnetic component of the study area, ED, Egypt.

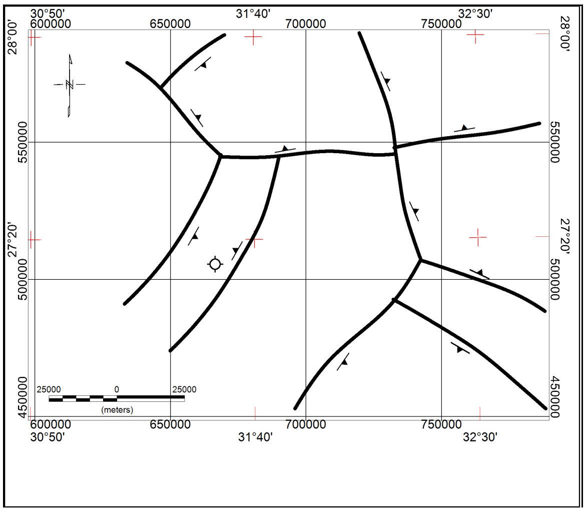

Fig. 10: Regional structural framework map as deduced from regional magnetic component map of the study area, ED, Egypt.

Magnetic Modeling

Five magnetic models (Fig. 3) were carried out in order to calculate the depth to basement surface and estimate the approximate basement relief. GM-SYS software was used to reach the best fit model for basement surface. The basement rocks were classified as one rock category, with a magnetic susceptibility equal 0.05, depending on the variation with observed magnetic values and considering the interpreted structural lineaments. The study depends upon the magnetic modelling to determine the depth to the surface of basement rocks in an accurate way. In order to reveal more accurate estimation for depth values estimated from magnetic modeling processes, it was used the only available W. Habib well record as a control point, where the well tapped the basement rocks at a depth of 2279 m below the ground surface at the western part of the study area near profile (C-C'), Fig. (3). Consequently, the other four models were controlled and precisely weighed using the resulting depths of Model (C-C') at their intersections.

A-A` magnetic model reaches about 152 Km in length, and is directed E-W (Fig. 2). The total thickness of the sedimentary cover under this model ranges from 1975 m to 3482 m. Meanwhile, the surface topography along the model A-A' increases steadily eastward, the depth to the basement rocks increases, inversely, towards the east (Fig. 11).

B-B` magnetic model attains about 155 Km and is directed also E-W but in the southern part of the study area, Fig (3). At the western part of this model, the sedimentary succession reaches its minimal thickness as 1139 m, while it increases towards its eastern side to reach 2269 m. The basement surface shows a gentle slope towards the east, while it shows some irregularities especially at the central and eastern part of the model.

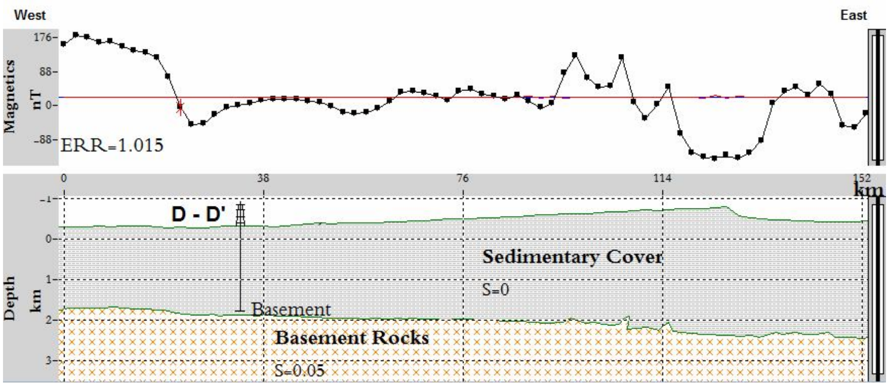

Fig. 11: Magnetic model (A-A`) of the study area, ED, Egypt.

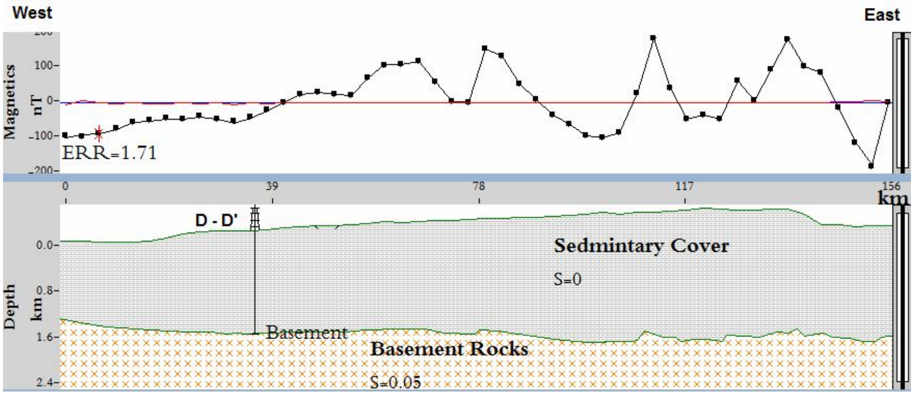

Fig. 12: Magnetic model (B-B`) of the study area, ED, Egypt.

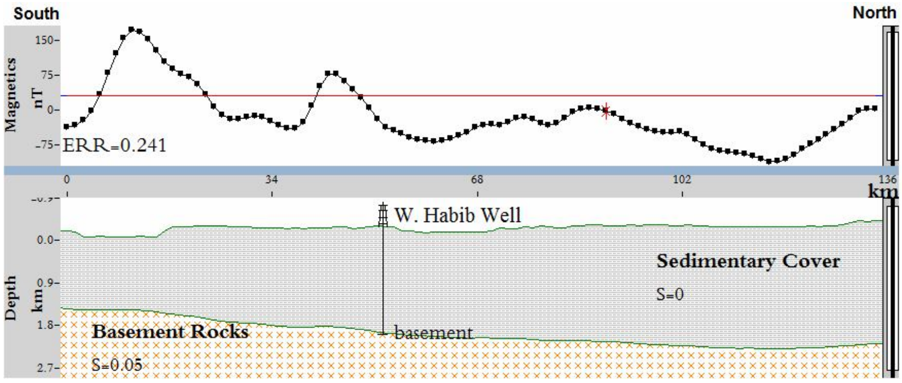

Fig. 13: Magnetic Model (C-C`) of the study area, ED, Egypt.

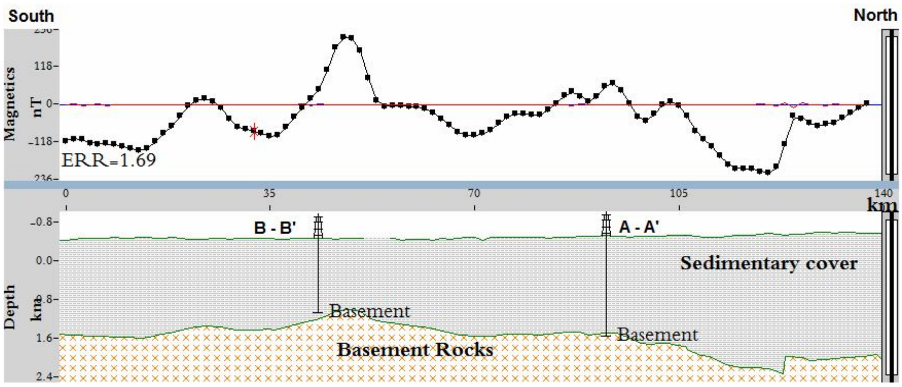

Fig. 14: Magnetic Model (D -D`) of the study area, ED, Egypt.

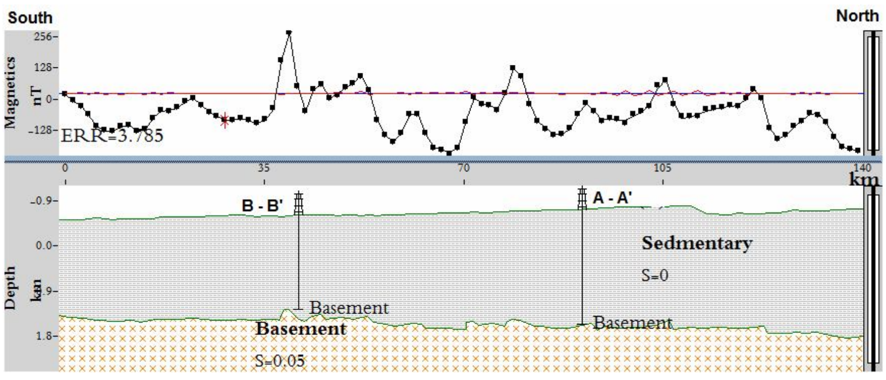

Fig. 15: Magnetic Model (E-E`) of the study area, ED, Egypt.

C-C'` magnetic profile extends about 134 Km and is directed N-S (Fig. 2). The calculated thickness of the sedimentary cover under this model ranges from 1268 m to 2600 m. The basement surface gently slopes towards the northern direction, Fig. (13).

D-D` magnetic model, Fig. (14), reaches about 139 Km in length, and is directed N-S (Fig. 3). The depth to basement rocks as computed from this model oscillates from 1022 m to 2331 m under the sea level. The surface of basement rocks under D-D' model is uplifted at the southern corner of the model till its central part then it is down-thrown towards the northern corner of the model.

E-E` magnetic model, Fig (15), attains about 139 Km in length, and is directed N-S (Fig. 3). The sedimentary cover has a thickness that ranges from 1850 m to 2805 m. The basement surface is gently sloping towards the north and shows some lateral variations at the central part of the model.

SUMMARY AND CONCLUSIONS

The interpretation of the airborne magnetic survey that was conducted by NMA at the study area shows that the structural framework of the study area is represented in a form of normal faults, which are directed mainly towards the NW-SE, NE-SW, and E-W. In addition, it emphasizes that these interpreted structural lineaments continue beneath the ground surface till basement rocks. Magnetic models deduced from the airborne data survey show that the total thickness of the sedimentary cover in the study area ranges from 1139 m to 3148 m with an average thickness reaching 2186 m. It also shows that the sedimentary basin in the study area gets shallower towards the southwestern corner and increases towards the northeastern corner of it.

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