Egyptian Geophysical Society
EGS Journal, Vol. 15, No. 1, 175-184 (2017)

GROUND MAGNETIC AND GAMMA-RAY SPECTROMETRIC STUDIES OF EAST WADI NASSEIB AREA, SOUTHWESTERN SINAI, EGYPT

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دراسات جيوفيزيائية وجيولوجية لمنطقة شرق وادي نصيب، جنوب غرب سيناء، مصر

الخلاصـــة: تقع منطقة شرق وادي نصيب في الجزء الجنوبي الغربي من شبه جزيرة سيناء، وهذه المنطقة تحتوي على صخور القاعدة ذات العمر ما قبل الكمبري والتي يعلوها سطح عدم توافق مع صخور حقب الحياه القديمة. وتتابع حقب الحياه القديمة في منطقة الدراسة يتكون من خمسة تكوينات وهي من القاعدة إلى أعلى، سرابيت الخادم، أبو حماطة، العديدية، أم بجمه، والحشاش, حيث ان ام بجمه والاعدادية وهي مناطق واعدة لتواجد اليورانيوم. اجريت دراسات ارضية اشعاعية طيفية ومغناطيسية لمتابعة وتحديد مناطق الشاذات الاشعاعية والتراكيب الجيولوجية والتي تلعب دورا مهما في توزيع التمعدنات في منطقة الدراسة. تهدف الدراسة إلى شرح الوضع الجيولوجي السطحي و تحت السطحي للمنطقة و تحديد النطاقات المشعة ذات الأهمية . أوضحت خرائط أشعة جاما الطيفية أن المنطقة لها عدة مستويات إشعاعية مختلفة مما يوحي أن هناك تباين في المحتوى الاشعاعي لمكاشف الصخور المختلفة في المنطقة. ولوحظ أن أعلى المستويات الاشعاعية تقع في مناطق تواجد تكوين ام بجما المحتوي على الجبسيت. تم تسجيل شاذات إشعاعية لأول مرة في الحجر الرملي لمكون العديدية والحجر الرملي لمكون الحشاش ومكون ام بجما المحتوي على الجبسيت. من نتائج المسح المغناطيسي يظهر تباين واضح لقيم الشـــدة المغناطيسية حيث توجد الشاذات المغناطيسية المرتفعة مرتبطة مع العرق القاعدي او الحجر الرملي المحتوي على اكاسيد الحديد. تم حساب أعماق الأجسام المسببة للتغيرات المغناطيسية التي وجدت على هيئة تجمعات عند سطحين على عمقي ٨م و ٢٤ م وقد تم هذا باستخدام تقنية طيف القدرة و قد تم أيضا فصل المجال المغناطيسي على عمقي السطحين المذكورين للتمييز بين مصادر الشاذات و التباينات الضحلة (المتبقية أو القريبة من السطح) والعميقة (الإقليمية أو الغائرة في العمق). واستخدمت هذه الأعماق لرسم خريطتين أحدهما للشاذات المغناطيسية الضحلة والأخرى للعميقة. كما طبقت تقنية تحليل الاشارة لخريطة شدة المجال المغناطيسي الكلي.

ABSTRACT: *East Wadi Nasseib area is located in the southwestern part of Sinai Peninsula, Egypt. It is occupied by Paleozoic rocks, which unconformably overlie basement complex rocks. The Paleozoic rocks, in the study area, consist of five formations, which are from base to top, Sarabeit El Khadim, Abu Hamata, Adediya, Um Bogma, and El Hashash. Um Bogma and Adediya formations are very promising facies for U, some trace elements and REEs .The lithology and structure play very important role in the localization and distribution of various mineralizations (Mn, Fe, Cu, U, Th and REEs). inthe present study, ground spectral gamma-ray and total magnetic field surveys were conducted to follow and delineate uranium anomalous zones as well as the structural setting, which may control the distribution of these mineralizations in the study area. The results of spectral gamma-ray survey show that the radio spectrometric values vary for each of K from 0.1 % to 1.7 % , total count from 0.8 Ur to 239 Ur, eU from 0.9 ppm to 211 ppm, and eTh from 0.4 ppm to 70 ppm. The highest values are associated with Um Bogma Formation. However, the results of magnetic survey demonstrate that the high magnetic anomalies are associated with ferruginous sandstones with magnetic values, which are ranging from 42850 nT to 42900 nT. The ground magnetic data were subjected to classic and modern techniques of spectral and filtering analyses in order to describe the subsurface geological and structural features. The estimated average depths to the regional and residual sources reach to24 m and 8 m respectively.*

INTRODUCTION

Since ancient Egyptian times, Sinai Peninsula was considered as an important target for the occurrence of some economic ores, minerals and elements such as: copper, manganese, iron, kaolin, coal, glass sands, and recently uranium and REEs. All these are incorporated in Paleozoic rocks (Fig. 1). Kaolin and coal are associated with Magharet El-Maiah Formation, glass sand with Abu-Zarab Formation. These two formations are not found in the study area, but near to i. Mn-Fe, copper and uranium are associated mainly with Um Bogma Formation. REEs are found in the sandstones of Adediya Formation, gibbsite bearing sediments, ferruginous siltstones of Um Bogma Formation and carbonaceous shales of Magharet El Maiah Formation.

Ground geophysical and geological studies of Southwestern Sinai, in general were carried out to discover the existence of some localities possessing high potentialities for U-mineralization. A reconnaissance survey was conducted for East Wadi Nasseib area (Fig. 1). This survey was done by a portable gamma-ray total count model GR 101 equipment to the study area reaching about 20 km^2 in order to detect radiometric anomalous zones. Consequently, a detailed ground gamma-ray spectrometric survey of the same area using highly sensitive portable gamma ray spectrometer model GS-512, was carried out for the area between latitudes 29° 03' 14.4'' N to 29° 03' 43.4” N and longitudes 33° 24' 43.8'' E to 33° 25' 7.5'' E in order to detect radioactivity variations, possible anomalous zones and the distribution of radioelements over the different lithologic units.

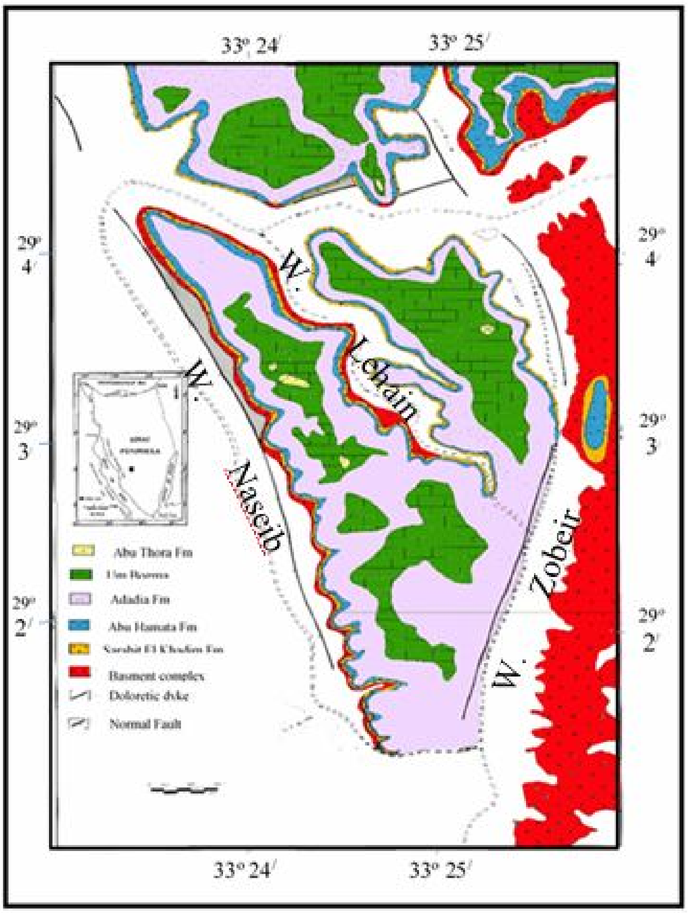

Fig. (1): Geologic map of east Wadi NasseibArea, Southwestern Sinai, Egypt.

Geologic outline

The study area is covered by Paleozoic rocks comprise five formations from base to top Sarabeit El Khadim, Abu Hamata, Adediya, Um Bogma, and El Hashash. (Fig. 4). The following is a brief description for these formations:

1- El Hashash Formation: It consists of brownish, cross laminated sandstones intercalated with thin shale and siltstone beds. Ripple marks, trough and tabular plannar cross stratification are observed in this formation. The thickness of this Formation is 25 m at the study area.

2- Um Bogma Formation: The lower boundary is represented by an unconformity surface, with the underlying Adediya Formation. This formation can be regarded as a poly-mineralized rock unit (U, Th, Cu, and REEs,). Due to the economic importance of Um Bogma formation, the following paragraphs exhibit more detailed descriptions. This formation can be classified into three members as follows:

Upper dolostone, Member:

It is mainly composed of pinkish brown, hard and compact crystalline-bedded dolostone. The thickness of this formation is 2 m at the study area.

Middle marl, dolostone Member:

It is a yellow bed that consists mainly of marl and dolostone with some intercalated shale. Gypsum, anhydrite and halite are also found. The marl is soft and highly fossiliferous. The thickness of this formation reaches 10 m at the study area.

Lower siltstone, dolostone, claystone Member

The dolostone is compact, fractured and jointed with patches of different green colours. Besides, the ferruginous siltstone is large and extends at most parts of the study area. The thickness of this formation is 10 m at the study area.

3- Adediya Formation

The lower contact of Adediya Formation is well defined, but the upper is highly ferruginated and in some parts, shows indication of paleosoil. It consists of sandstone, very thickly-bedded, fine-grained, yellow, red and white in colour. These sandstones were used as building stones for an "ancient Egyptian Temple" at Gabal Sarabeit El khadim near the study area. Fe-Mn ore appears as spots at the surface and disseminates at the sand stone. The thickness of this formation is 100 m at the study area.

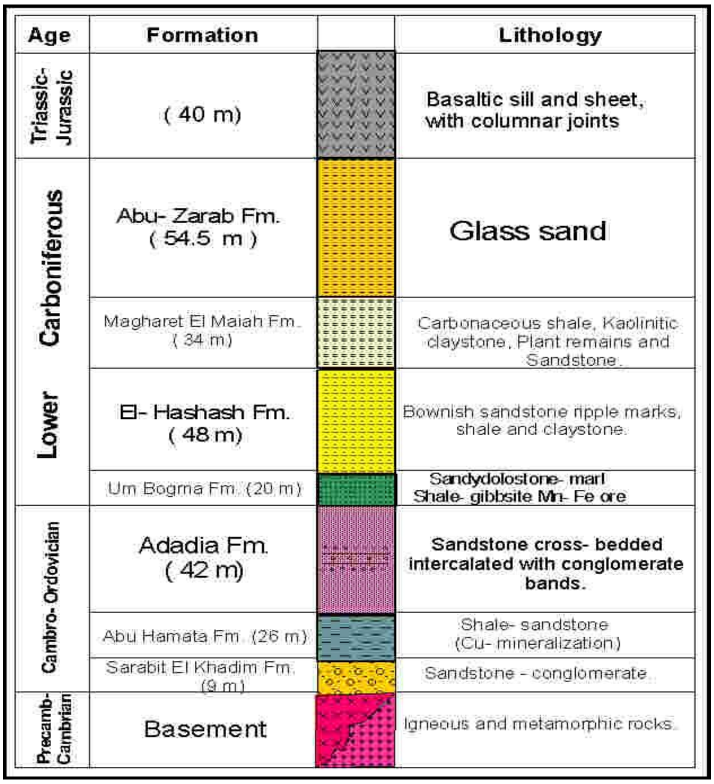

Fig. (2): Litho-stratigraphic succession of around East Wadi Nasseib Area, Southwestern Sinai, Egypt.

4- Abu Hamata Formation:

It conformably Sarabeit El khadim and overlies Adediya Formations. It is easily distinguished by its characteristic greenish colour, which can be used as a marker in the field. From field observations, Mn-Fe found as spots and staining at the surface of shale. This formation is found in the form of two units reddish sandy shale and greenish sandy shale. Sandstone is interbeded with shale. Some burrows are found on the surface of reddish shale. The thickness of this formation is 50 m at the study area.

5- Sarabeit El khadim Formation:

The lower boundary of this formation is represented by nonconformity with the underlying basement rocks. Cross-bedded sandstone with a conglomerate layer alternating with the sandstone in most localities. It has pinkish to brownish colour. The thickness of this formation is 15 m at the study area.

GROUND GAMMA-RAY SPECTROMETRIC survey General:

Natural sources of radiation came from radioisotopes which were synthesized during the creation of the solar system. Because of their long half-lives, they still exist today. Of these, potassium (^{40}K), uranium (^{238}U and ^{235}U and their daughters), and thorium (^{232}Th and its daughters) are the only radioisotopes that produce high-energy gamma rays of sufficient intensity to be used for gamma ray mapping (IAEA, 2003).

The main objectives of gamma-ray spectrometric survey are to locate anomalous gamma radiation zones and determine the nature and concentration of the radioisotopes, which give rise to them. The gamma-ray spectrometric survey technique is simply to move the appropriate spectrometer system across (or through) the area of interest. This may be done in a systematic manner on a grid pattern for both prospecting and mapping purposes (IAEA, 1979).

Instrumentation:

Spectral gamma-ray measurements were conducted using a portable gamma-ray spectrometer; model GS-512, manufactured by Geofyzika Brno, Czeck Republic. The survey was conducted along many profiles directed E-W direction. These profiles cut across the surface mineralization and the recorded structural features in the study area. The space between these4 profiles were 10 m separation, while the interval between stations were also 10 m. The spectrometer calibrated using the locally constructed Nuclear Materials Authority of Egypt transportable concrete calibration pads.

Qualitative Interpretation:

Qualitative interpretation of the ground gamma-ray spectrometric data depends mainly upon the excellent correlation between the general pattern of recorded measurements and the surface distribution of rock units.

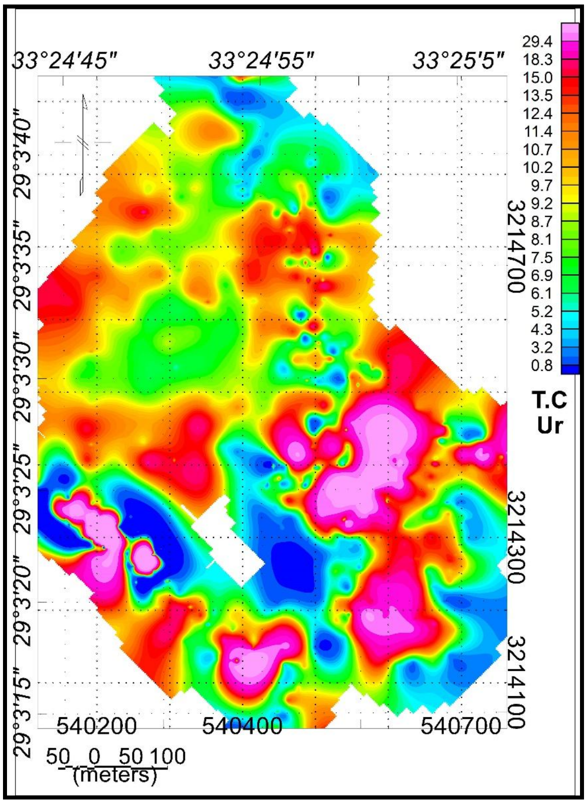

Fig. (3): Filled colour contour map of Total Count (T.C.) radiometric data, East Wadi Nasseib Area, Southwestern Sinai, Egypt.

The texture of the radio-spectrometric contour lines (signatures) could be an aid in the course of interpretation of surface geology (lithology and structure) (IAEA, 1979).

The gamma-ray spectrometric maps (Figs. 3 to 6) show different colour levels over the surveyed area, which reflect contrasting radioelement contents for the exposed various rock types. It is shown that two high radiospectrometric zones are located in the southwestern and southeastern parts of the study area, associated mainly with Um Bogma formation bearing gibbsite occurrences**.** Some other high anomalies are scattered in the southern part of the study area, associated with ferruginous sandstones.

The T.C. radiometric contour map (Fig. 3) shows a wide range of measurements, oscillating from very low level (blue) reaching 0.8 Ur to very high level (violet) attaining 239 Ur. The low level is located approximately at the central part of the investigated area (Fig. 3), while the high level is situated mainly, in its southeastern and some scattered parts and is associated with Um Bogma formation bearing gibbsite, with an average value of about 15 Ur.

The potassium (K, %) contour map of the study area (Fig. 4) exhibits its maximum value (1.7 %) at its western part , and its minimum value (0.1 %) in its eastern part. The (K, %) mean content value attains 0.33 % of the whole area.

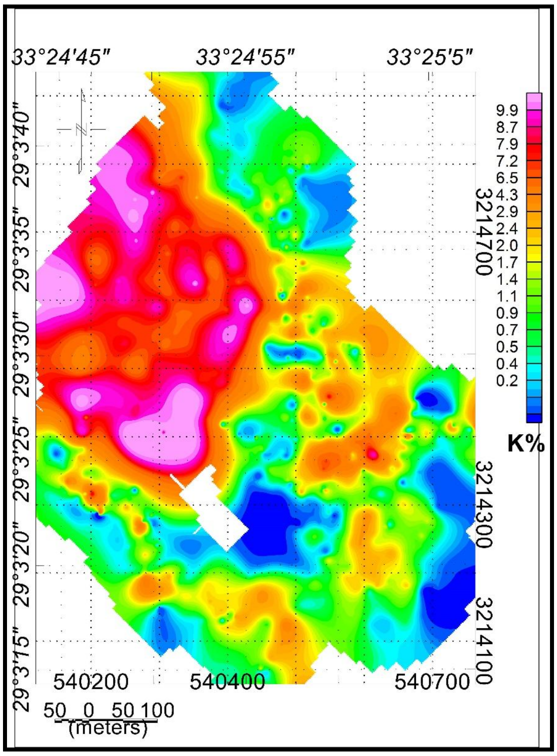

Fig. (4): Filled colour contour map of potassium, east Wadi Nasseib Area, Southwestern Sinai, Egypt.

The equivalent uranium (eU, in ppm) contour map of the study area (Fig. 5) whose maximum value reaches 211 ppm in its eastern part and its minimum (eU) value reaches 0.9 ppm in its western part. The mean value of (eU) in the investigated area reaches 11.0 ppm.

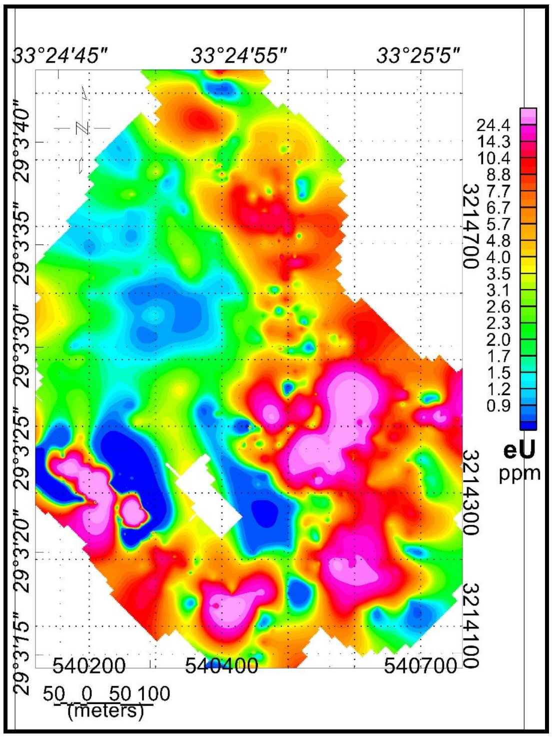

Fig. (5): Filled colour contour map of equivalent uranium, East Wadi Nasseib Area, South-western Sinai, Egypt.

The equivalent thorium (eTh, in ppm) contour map of the study area (Fig. 6) has a mean value of 9.2 ppm with a maximum value reaching 74.2 ppm at its western and eastern parts. The highest equivalent thorium anomalies are associated with Um Bogma formation bearing gibbsite. The minimum value attaining 0.4 ppm.

Quantitative Interpretation:

The results of gamma-ray spectrometric data, acquired over the investigated area were quantified through the application of some appropriate statistical analysis techniques. These techniques include conventional standard statistics as well as bivariate correlation.

The gamma-ray spectrometric maps (T.C., K, eU and eTh) were plotted for the surveyed area (Figs..3-6). The three ratios (eU/eTh, eU/K and eTh/K) were calculated on the basis that null values are inserted in places where K is less than 0.1 %. A composite data file was prepared to include the seven variables (T.C., K, eU, eTh, eU/eTh, eU/K and eTh/K). The number of valid data points per element was 449 points along seven columns. Conventional standard statistics were applied to the data to compute arithmetic means ($\overline{X}$) and standard deviations (S) for each variable (table 1).

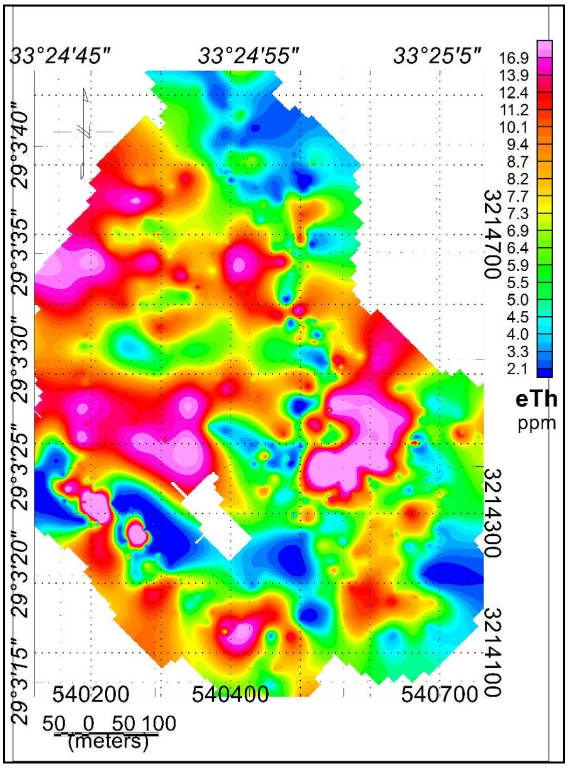

Fig. (6): Filled colour contour map of equivalent thorium, East Wadi Nasseib Area, South-western Sinai, Egypt.

Comparative examination of the results of bivariate correlation indicates that:

1. Significant positive correlations (direct relationships) do exist between t.C. and other six variables.
2. No significant correlations, either positive or negative, exist between K and eTh/K, while negative correlations exist between K and eU/eTh and eU/K.
3. Significant positive correlations exist between eU and the other variables.
4. Significant positive correlations exist between eTh and three variables expect eTh/K.

The basic dyke strikes N 40 E direction, through Paleozoic sediments in all successions in the study area. For Adediya Formation K values range from 0.1 % to 0.6 %, their arithmetic mean reaches 0.3 %, eU values change from 35.6 ppm to 101.6 ppm, their arithmetic mean attain 69.3 ppm, while eTh values vary from 5.3 ppm to 11.5 ppm with an arithmetic mean reaching 7.6 ppm.

On the other hand, for El-hashash Formation, K measurements range from 0.1 % to 0.4 % with arithmetic and the mean reaching 0.3%, eU value change from 3.4 ppm to 93.5 ppm with an arithmetic mean attaining 51.5 ppm, while eTh content oscillates from 1.3 ppm to 7.9 ppm with an arithmetic reaching 4.6 ppm.

From field observations, there are three anomalies horizons arranged from base: the sandstone of Adediya Formation where its eU value reaches 101 ppm, Um Bogma Formation where the eU value reaches 211 ppm and El Hashash Formation where the eU value reaches 93 ppm.

Radiation Exposure Rate (E) and Equivalent Radiation Dose Rate (D):

The radiation exposure rate (E) can be calculated from the apparent concentrations of K (%), eU (ppm) and eTh (ppm), using the following expression (IAEA, 1991):

$$E\ (\mu R/h) = 1.505\ K\ (\%) + 0.653\ eU\ (ppm) + 0.287\ eTh\ (ppm)$$

The radiation exposure rate can be converted to equivalent radiation dose rate (D) through the use of the following relation (Grasty et al., 1991)

$$D\ (mSv/y) = 0.0833 * E\ (\mu R/h).$$

From Dose rate map (Fig. 8), the mean natural equivalent radiation dose rate from terrestrial gamma-radiation attains 1.1 mSv/y. Most parts of the study area remain on the safe side and within the maximum permissible safe radiation dose rate, without harm to the individual. However, there are some parts of the study area that possess values reaching more than this limit, and may cause some harm for anyone exist in these places

Fig. (7): Basic dyke at East Wadi Nasseib Area, Southwestern Sinai, Egypt.

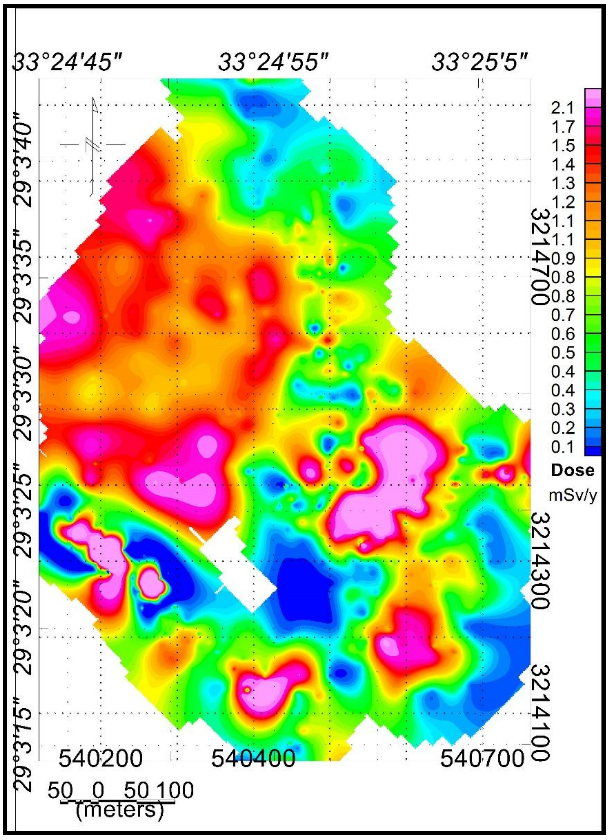

Fig. (8): dose rate D (in mSv/y) map of East Wadi Nasseib Area, Southwestern Sinai, Egypt.

GROUND MAGNETIC SURVEY

All magnetic anomalies caused by rocks are superimposed on the geomagnetic field of the Earth. A magnetic anomaly is now superimposed on the Earth's magnetic field causing a change in the strength of the total field intensity (Kearey and Brooks, 1998). The main target of application of a magnetic survey is to determine the configuration of basement rocks and their structural characteristics. The study of basement-rock configuration generally involves determining the depth of radiometric anomalies, according to their magnetic responses.

The ground magnetic survey was conducted along numerous profiles in the study area. These profiles cut across most of the surface mineralizations and structural features, which were recorded in the study area. As a result of this survey, a total-intensity ground magnetic contour map (Fig. 9) was constructed and interpreted to obtain the subsurface information about the extensions and depths of the recorded magnetic anomalies, which may represent an insight to the subsurface distribution of radiometric anomalies beneath the surface.

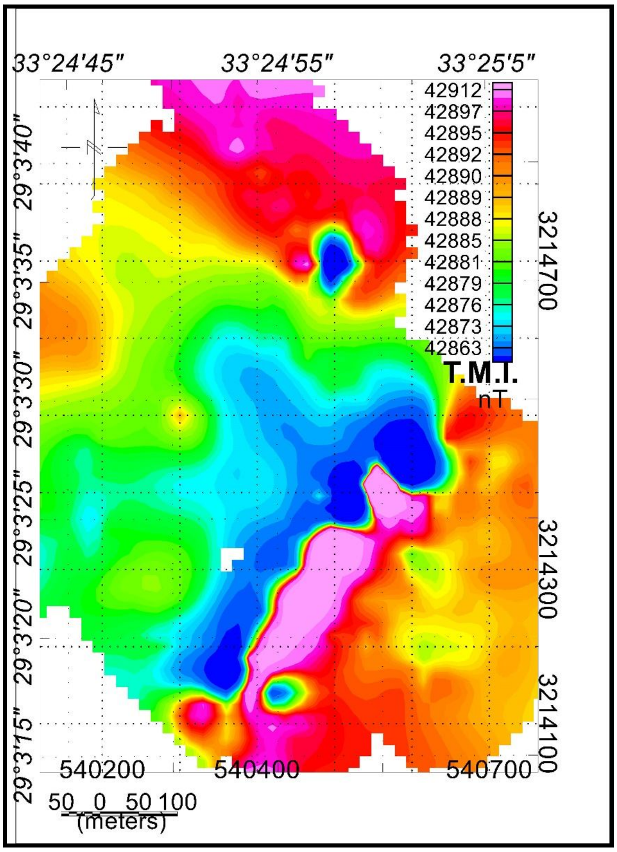

Fig. (9): Filled colour contour map of ground total magnetic intensity, East Wadi Nasseib Area, Southwestern Sinai, Egypt.

The aim of this magnetic study is to define the most significant magnetic anomalies, which may be related to surface and/or subsurface radiometric anomalies and to delineate the structural setting, which may control the distribution of these mineralizations in the study area. The present study deals with the use and correlation between the obtained data and the geology of the study area to infer the relation, which might exist between the mapped surface geologic structures and the interpreted subsurface structures.

According to the geologic map (Fig. 1), the lithological composition of the study area runs through different types of rock units possessing different properties, each of which owns its special magnetic character. In addition, the subsurface structural features, i.e., faults, fractures and dykes also have some distinctive effects on the total magnetic field. Therefore, the main purpose of this ground magnetic survey is to explore the subsurface structural features along the study area.

The ground magnetic survey was conducted along the study area using two proton precession magnetometers; model PMg-1, one for recording variations of the total magnetic field, and the other for recording its diurnal variations in a selected base station sited near the study area. These two instruments are sensitive to any changes of the total magnetic field intensity of the earth's magnetic field and its accuracy reaches about 0.1 nT. Accordingly, the corrected ground magnetic field intensity measurements at the study area were plotted in the form of a contour map (Fig 9).

Magnetic Data Analysis:

i- Qualitative Interpretation:

The ground total-intensity magnetic field recorded over the area under investigation represents the combined contribution of the surface magnetic sources and deep-seated sources (basement rocks). The total-intensity magnetic map (Fig. 9) shows a number of different magnetic anomalies, with different amplitudes and frequencies. The magnetic anomalies are found as elongated shapes, parallel to structural trends at the southeastern and northern parts of the study area due to basic dyke and ferruginous sandstones with Mn deposits.

The reduced to magnetic pole field intensity contour map (Fig. 10), was prepared to overcome the inclination problems of intermediate latitudes, so the magnetic anomalies became centered directly above causative sources.

ii- Quantitative Interpretation:

Analytic signal:

Nabighian (1972, 1974) introduced the concept of the analytic signal for magnetic interpretation. The determination of these analytical signal parameters is not affected by the presence of remnant magnetization. This signal exhibits maxima directly over the edges of the source bodies. Locations of these maxima thus determine the outlines of magnetic sources. A geologic contact or fault with significant susceptibility contrast is also detected by mapping the maxima of the analytic signal. From the analytic signal contour map (11) there are two high magnetic zones, the first at the southern part takes NE-SW trend related to the basic dyke. The second high magnetic zone lies at the northern part which determines the zone of Fe-Mn deposits.

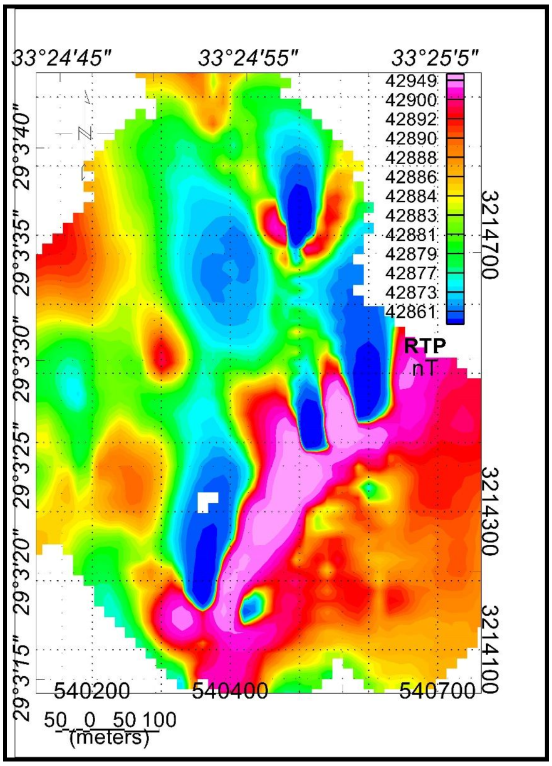

Fig. (10): Filled colour contour map of Reduced to the Magnetic Pole (RTP), East Wadi Nasseib Area, Southwestern Sinai, Egypt.

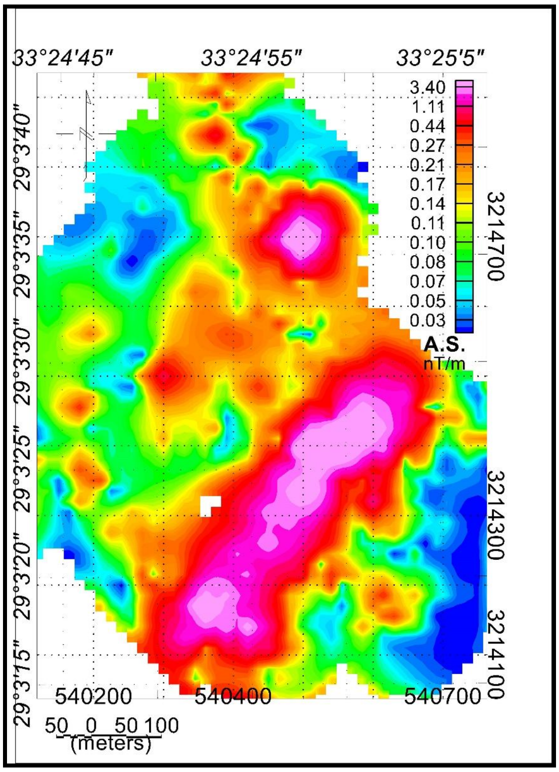

Fig. (11): Filled colour contour map of analytic signal, East Wadi Nasseib Area, East Wadi Nasseib Area, Southwestern Sinai, Egypt.

Frequency analysis

There are many techniques to separate the regional and residual magnetic components from the total-intensity magnetic data. Fast Fourier Transform (FFT) is one of these techniques. The ground total magnetic intensity data were analyzed using the Transform (FFT) to determine the filtering parameters. These parameters are the average depth of deep-seated geological structures and the average depth of near surface geological structures along the area under study.

The ground total intensity magnetic map (Fig. 9) indicates that there are distinctive changes in the amplitudes and frequencies. These changes return to the variation in depth levels, as well as lithologic and structural features of the basement rocks at the study area. Therefore, the average depths of magnetic anomalies along the study area were determined using Fast Fourier Transform (FFT) technique.

The analysis of the power spectrum curve (Fig. 12) shows that, the deep-seated magnetic component frequency varies from 0.0 to 0.0025cycles/km, while the near-seated magnetic component frequency ranges from 0.0025 to 0.007cycles/km. These bands of frequency were used to produce the regional and residual filtered maps (Fig.13 and 14). These maps are easier to interpret than the original total magnetic intensity map.

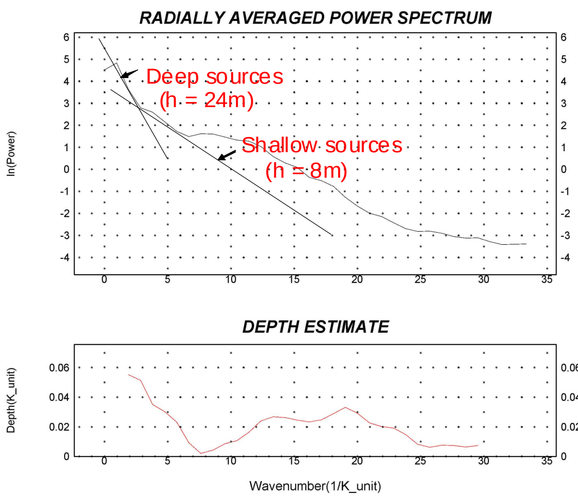

Fig. (12): Radially averaged power spectrum and depth estimation of the total magnetic map.

The resulting regional and residual magnetic-component maps were interpreted in terms of lithology and structure. Deep major structures will be resolved and interpreted through the regional (deep-seated) magnetic-component map. Meanwhile, the near-surface (shallow) structures will be detected through investigation of the residual magnetic-component maps.

Review of the estimated depths indicates that the magnetic signals in the studied area originate from two average depth levels, one is deep (24 m) and the other is shallow (8 m). These depths are calculated relative to the mean measuring surface.

The regional magnetic component :

The low-pass (regional) and high-pass(residual) magnetic anomaly maps were prepared using of the Fast Fourier Transform (FFT) in the frequency domain (Gaussian filter) using Geosoft Package (2007). The regional magnetic component intensity contour map (Fig. 13) represents the deep-seated magnetic response at an average depth of 24 m. This map shows that the study area could be divided into three main zones based on magnetic character of the causative sources. The first zone is located in the southeastern side of the study area, and is characterized by high to very high magnetic response that may be due to the structure effect of basic dyke. The second zone is located in the northern part and is characterized by high magnetic response that may be due to lithologic effect. The third zone is situated in the central part of the map and is characterized by low to moderate magnetic response of more acidic nature.

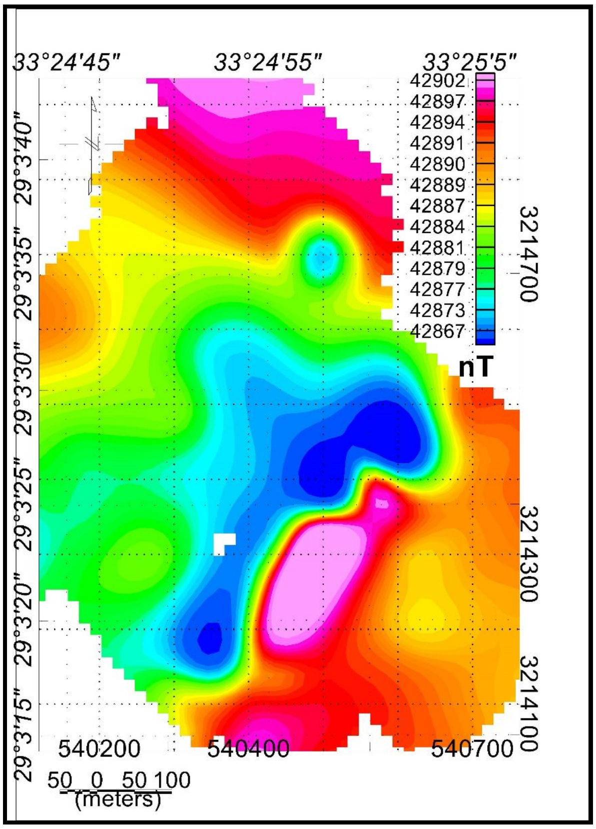

Fig. (13): Filled colour contour map of regional component magnetic field intensity, East Wadi Nasseib Area, Southwestern Sinai, Egypt.

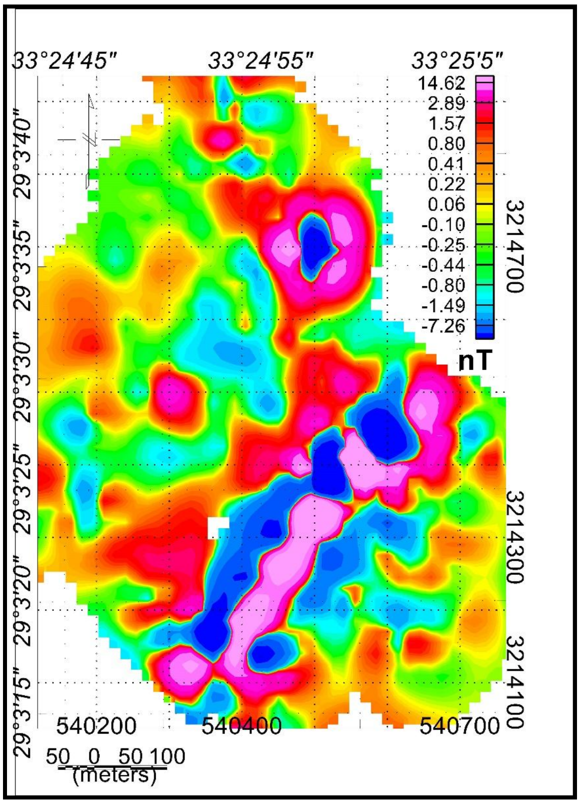

Fig. (14): Filled colour contour map of regional component magnetic field intensity, East Wadi Nasseib Area, Southwestern Sinai, Egypt.

The residual magnetic component :

The residual magnetic intensity contour map (Fig. 14) represents the shallow magnetic response at an average depth of 8 m. The residual magnetic component map shows high and low responses arranged in the NE-SW direction. The high magnetic anomaly observed at the southeastern part of the study area, on the regional and residual component maps, is related to the structural that effects. Small basic exposures are observed at this part indicating this anomaly is associated with a basic dyke (Fig. 7).

CONCLUSIONS

There are three anomalous radiometric horizons in the study area. These horizons are found at sandstone of Adadeia Formation, gibbsite bearing sediments of Um Bogma Formation and sandstone of El-Hashash Formation. These three horizons give important vision for exploration of uranium at other localities.

The factors affected the localization of anomalous uranium zones in the study area are the lithologic nature of the Paleozoic rocks, which played a very important role in localization of the various mineralizations associated with Um Bogma Formation as claystone, Fe-Mn ores and gibbsite bearing sediments. The structure is very important factor for localization of anomalous uranium zones (El Seih fault, Lehian fault and Zobeir fault) around the study area, where the high eU values are found along the faults and dyke from the field observations. The topography is also localized anomalous uranium zones, where most at the high eU values are found near the wadies.

Finally, the basic dyke makes as a barrier and plays an important role in distribution of the eU anomalies.

Most parts of the study area remain on the safe side and within the maximum permissible safe radiation dose, without harm to the individual, but there are some parts of the study area have values of more than 1.0 mSv/y, and may cause some harm for anyone found in these places.

The ground magnetic data have been subjected to classic and modern techniques of spectral and filtering analyses in order to describe the subsurface geological and structural features. The estimated average depths to the regional and residual sources are 24 m and 8 m,

On the other hand, the study area needs more detailed geophysical studies such as electrical methods to follow the observed anomalies to deeper depths.

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