Egyptian Geophysical Society
EGS Journal, Vol. 20, No. 1, 75-87 (2022)

ELECTROMAGNETICAND GAMMA-RAY SPECTROMETRIC STUDIES FOR WEST UM-TOMYEM AREA, SOUTHWESTERN SINAI, EGYPT

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الخلاصة: تقع منطقة غرب ام تميم فى جنوب غرب سيناء وتواجد بها صخور حقب الحياة القديمة ويظهر بها مكشف لطبقة ام بجمة الحاملة للتمعدنات الإشعاعية وقد تم عمل مسح إشعاعى طيفى لتحديد النطاقات ذات الشاذات الأشعاعية ومسح كهرومغناطيسى لتتبعها تحت السطح. تم تحليل بيانات قياس طيف أشعة جاما الأرضية نوعياً وكمياً من خلال تطبيق تقنيات تفسير محددة. كشفت الدراسة أن منطقة الدراسة بها تركيزات اشعاعية واسعة النطاق ، تتراوح من ٠,٩ إلى ٦٥,٣ وحدة إشعاعية ، ٠,٥ إلى ٥٥,٧ جزء في المليون مكافئ يورانيوم ٠,٣ إلى ٣٠,٣ جزء في المليون مكافئ ثوريوم ومن ٠,١ إلى ٦,٨٪ بوتاسيوم ٤٠. وكذلك تم عمل خرائط نسبه اليورانيوم إلى الثوريوم ونسبه الثوريوم إلى اليورانيوم، وإنتاج بعض الخرائط ذات الدلالة والتي تعتمد أساسا علي خلط صور الالوان المختاره للعناصر الإشعاعية الثلاثة (البوتاسيوم واليورانيوم والثوريوم). وأظهرت هذة الخرئط وجود مستويات مختلفة من النشاط الإشعاعي، وبينت هذه الخرائط أن الأجزاء عالية النشاط الإشعاعي مرتبطة بشكل أساسي بمتكون أم بجمة والجرانيت الحديث وراسب الوادي. كما تم عمل ثلاث خطوط مسح كهرومغناطيسى افقى حلقى سجلت بواسطة الترددات الأربعة المستخدمة (١١٠ هرتز ، ٤٤٠ هرتز ، ١٧٦٠ هرتز ، ٧٠٤٠ هرتز) ، واوضحت النتائج وجود شاذات سالبة من الخطين الممسوحين من الشرق الى الغرب لجسم موصل رفيع يميل باتجاه الغرب وعلى الخط الممسوح من الشمال الى الجنوب تواجد الجسم الموصل بزاوية ٢٠° باتجاه الشمال وكانت قيم التوصلية تتراوح من ١٢ إلى ١٦,٨ سيمنز/ متر للخطوط الثلاثة. وقد تم إيجاد توافق بين الشاذات الأشعاعية السطحية وبين الشاذات السالبة للاجسام الموصلة على اعماق أكبر. وبينت تكامل الدراسات ان مكون أم بجمة هو الأعلى فى القيم الأشعاعية الطيفية وممتد لاعماق تتراوح ما بين ١٠ الى ٢٠ متر باتجاه الشمال الغربى (أسفل مكون أبو ثورا)

ABSTRACT: *Gamma-ray spectrometric and horizontal loop electromagnetic (HLEM) surveys were carried out to determine the radioactive anomalous zones and follow their lateral and vertical extensions west Um-Tomyem, southwestern Sinai, Egypt. The lithologic nature of the Paleozoic rocks played an important role in the localization of the various mineralizations associated with them such as manganese, iron ores, kaolin, turquoise, coal and glass sand. Recently, the uranium and thorium occurrences which are discovered in the Paleozoic sedimentary rocks (specially associated with um Bogma Formation) raised the economic potentiality of the area.*

The ground gamma-ray spectrometric data have been analyzed qualitatively and quantitatively by applying specific interpretation techniques. These data revealed that, the study area has wide range concentrations, oscillating from 0.9 to 65.3 Ur, 0.5 to 55.7 ppm, 0.3 to 30.3ppm and from 0.1 to 6.8%, for the total count, equivalent uranium (eU), equivalent thorium (eTh) and potassium (K), respectively. The uranium composite image showed that, the high radioactive parts are mainly associated with Um-Bogma Formation, younger granites and wadi sediments. Also, the coefficient of variability and the uranium favorability index have been carried out and showed that Um Bogma is the highest Formation of all formations and rock units in uranium potentiality.

The result of HLEM has shown significant and well-defined conductive zones that are recorded along with the four used frequencies (110 Hz, 440 Hz, 1760 Hz, and 7040 Hz) at the stations 531950, 531900 and 3202200 of the three (HLEM) profiles (3202300 E, 3202220 E and 531630N) respectively. This may reflect the sources of the conductive bodies are situated at shallow depths and continued to considerable depths. A fair agreement was found among the radiometric and HLEM anomalies at some places of the study area. This may indicate that the surface radiometric mineralization continued to deeper depths at these parts.

1- INTRODUCTION

The study area lies at the southwestern part of Sinai lies at the intersection of latitude 28°56'50"N and longitude 33° 19'30"E. It is at about 20 km to the Southeast of Abu Zenima town, on the Gulf of Suez (Fig. 1). This area is known as containing many mineralization zones such as: manganese, iron ores beside uranium and thorium occurrences in um Bogma formation.

Many authors were discussed the mineralization potentiality in this area as Abdel Monem et al., 1958, EL Sokkary (1963) and Abd Elhadi 2020

The Paleozoic succession in the southwestern Sinai (up to 520 m thick) unconformably the basement complex and covered by the Triassic- Jurassic basalt sheets and sills.

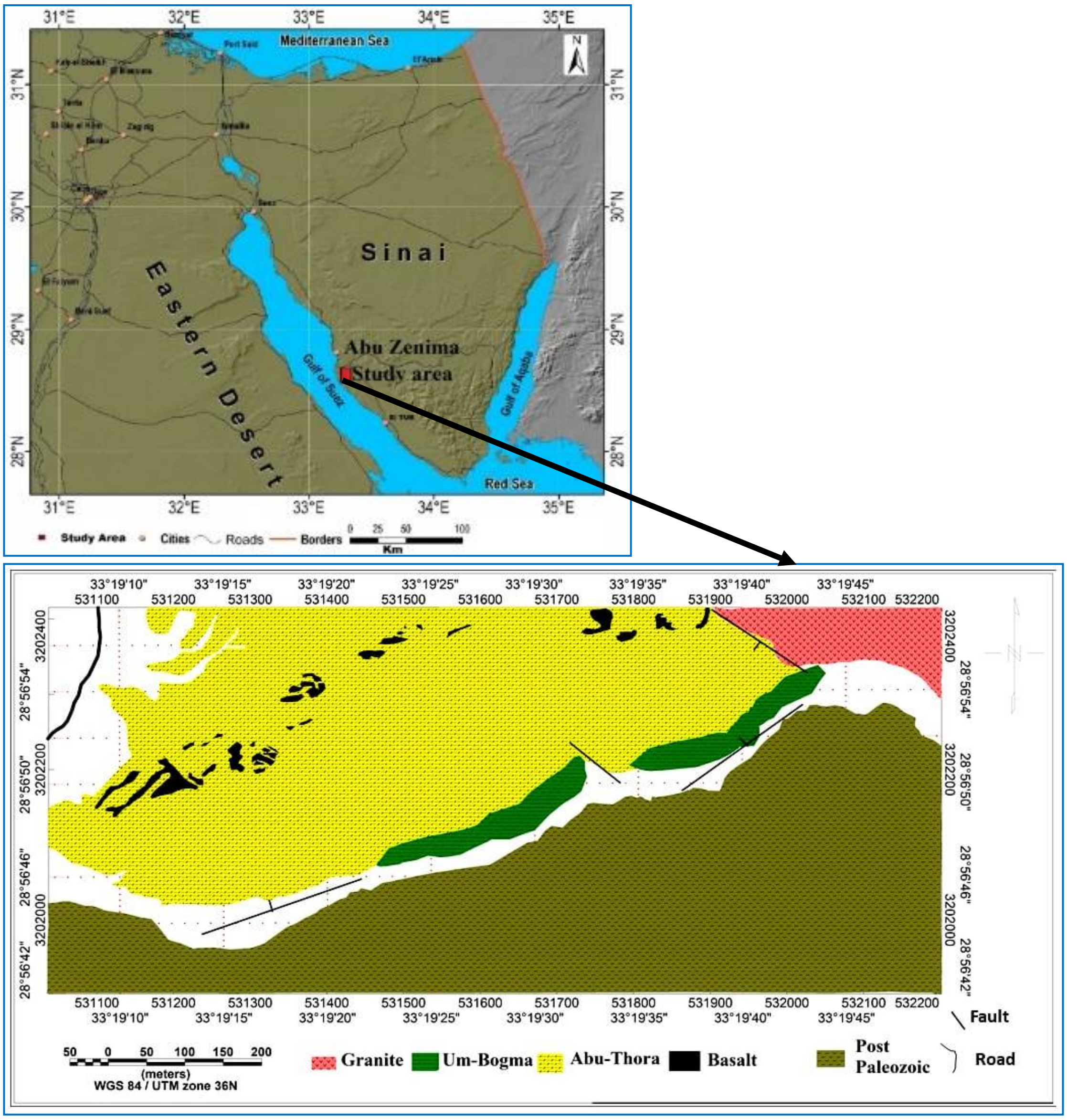

Fig. (1): (a) Location Map of West Um-Tomyem,(b) Geologic map of West Um-Tomyem, Southwestern Sinai, Egypt (modified after Al Shami, A.S., 2003).

The lithologic nature of the Paleozoic rocks played an important role in the localization of the various mineralizations associated with them such as manganese, iron ores, kaolin, turquoise, coal and glass sand. Recently, the uranium and thorium occurrences which are discovered in the Paleozoic sedimentary rocks (specially associated with um Bogma Formation) raised the economic potentiality of the area. Abdel Monem et al., 1958 recorded radioactive black sandstone lenses in wadi El Seih, Southwestern Sinai. In addition, several radioactive anomalies were discovered in W.Allouga, Southwestern Sinai by EL Sokkary (1963).

The high radioactivity of siltstones of Um-Bogma Formation at Wadi Elseih area is attributed to the presence of uranium minerals like uranophane, meta-autunite, sklodowskite and other associated uranium bearing minerals like xenotime and zircon. Gold is detected in the present ferruginous siltstones with significant concentrations reach up to 1.04 ppm. The presences of iron minerals are playing an important factor in capturing uranium and other elements (Abd Elhadi, 2020).

Manganese, iron ores, kaolin, turquoise, coal and glass sand provinces were extensively investigated using different geochemical and geophysical techniques, while uranium poses a particular problem regarding the subsurface geophysical exploration. So, the objectives of the present study are to identify the concentrations of the radioactive elements uranium (U), thorium (Th) and potassium (K), using the ground gamma-ray spectrometry method and to delineate any possible spatial relation with the observed manganese, iron mineralization in the area, and to follow the exposed surface mineralization at deeper depths and to obtain information about the probable lateral and vertical extensions through the application of the horizontal-loop electromagnetic (HLEM) method.

2. GEOLOGIC SETTING

The main rock units in the study area as shown on the detailed geologic map (Fig. 1) can be arranged from the oldest to the youngest as follows:

2.1. Basement Rocks

Younger granites

These rocks occupy one exposure along the northeastern part of the study area. They are medium to coarse-grained, pink to reddish pink in color, sheared, cavernous highly weathered and composed mainly of quartz, subhedral crystal of antiperthite, potash feldspars, plagioclases and rare primary and secondary muscovite. The post magmatic hydrothermal alteration features are mainly represented by secondary silicification, hematization and kaolinization.

2.2. Sedimentary succession

Sarabit El Khadim Formation

According to Soliman and Abu Elfetoh (1969), the Lower boundary of Sarabit EL Khadim Formation is represented by the un conformity with the underlying Precambrian granitic rocks. The upper boundary is the conformable contact with the shale of Abu Hamata Formation. This Formation consists of thick cross-bedded sandstones of different sizes with conglomerate alternated with sandstone beds. The pinkish to brownish color is dominated. It has a thickness about 10 m thick.

Abu Hamata Formation

Abu Hamata Formation is conformably over lies Sarabit El Khadim Formation and conformably underlies Adedia Formation with thickness up to 12m. It is a fossiliferous unit, where several fossils were recorded by several authors.

Adadia Formation

It Overlies Abu Hamata Formation and uncoformably underlies Um Bogma Formation. It is made up of coarse to fine grained, hard ferruginous sandstone, siltstone, pink to brown in colour with tabular and trough cross-bedding. The copper mineralization (turquoise) was recorded in the upper part of this Formation. Some radioactive anomalous spots were also recorded.

Um Bogma Formation

This Formation is the most important rock unit in the Paleozoic sedimentary section in southwestern Sinai due to its hosting the radio-elements and several metal mineralization. It includes Fe-Mn ore deposits, secondary Cu mineralization and some occurrences of uranium. It is unconformably overlies Adadia Formation and underlies Upper sandstone series. It exhibits a thickness of about 10 m at the extreme northern part of the study area and gradually decreases towards the south.

Upper Sandstone Series (Abu Thora Formation)

Upper Sandstone Series in the light of uranium mineralization is considered less important than the lower part of the Paleozoic section in the area (Lower sandstone series and Um Bogma Formations) owing to its rare content of radioactive anomalies. It has oscillatory thickness ranging between 25m and 40m (Fig. 1b). It unconformably overlies Um Bogma Formation and is covered by basaltic sheet. Upper sandstone series is characterized by small scale sedimentary structures that include mainly hummocky cross-lamination and tabular cross-bedding (Soliman and Abu El Fetouh,1969).

Basaltic sheets and sills

They are capping Abu Zarab Formation and is cropping out at W.Elshallal, G.Abu Qafas, El Dehesa area and W.Abu Natash. They are mainly composed of olivine basalt or diabase and shows about 30 m thick (Hussein et al., 1971). They are crystallized of mesh texture surrounded by fine crystals of plogiclase of labradorite composition and diopsidic augite. Some pyroxene and plagioclase crystals alter to chlorite and kaolinite respectively.

Wadi sediments

Both the crystalline and sedimentary rocks are generally traversed by several dry valleys (wadis) filled with Quaternary alluvial sediments. They constitute the surficial cover in the main wadis and their tributaries and formed of loss sands, gravels, pebble, cobbles and boulders.

3.GROUND GEOPHYSICAL SURVEYS

3.1. Gamma-Ray Spectrometric Survey

Gamma-ray surveying is widely used for geological and geochemical mapping as well as exploration of radioactive minerals. Also, gamma-ray survey is conducted for environmental studies to the evaluation of the radon risk (Moxham, 1965; Charbonneau et al., 1976; Durrance, 1986; Grasty et al., 1991 and IAEA, 2003).

Hence, systematic ground gamma-ray measurements for the total gamma-ray activity (total-count) and the three individual radioactive elements (K, eU and eTh) were taken along nearly east-west profiles, on a grid pattern of 20 m station separation and 20 m line spacing forwest Um-Tomyem. Gamma-ray measurements were carried out, using a portable hand-held radiation spectrometer, model GS (512), with internal data storage and PC data retrieval (Fig. 2).

3.2. Horizontal-Loop Electromagnetic (HLEM) (Slingram) Method

It is perhaps the most popular among the mobile transmitter-receiver methods operating in the frequency domain. In this method, the source of the primary field (transmitter coil) is moved simultaneously with the receiver coil along the traverse with a fixed spacing between them. A battery-powered portable oscillator (usually multi-frequency) delivers current to the transmitter coil. The receiver, identical in design, is separated from the transmitter by a fixed distance. The transmitter and receiver coils are coplanar, and in most surveys, the coils are held horizontal. A reference signal is fed to the receiver by a cable attached to the oscillator, against which the real and imaginary parts of the received signal are successively measured. The connecting cable also controls the separation between the two coils (Sharma, 1997).

Hence, the measurements were acquired at four frequencies (110 Hz, 440 Hz, 1760 Hz and 7040 Hz), with a coil separation of 100 m and station separation of 20 m for three profiles as shown in (Fig. 2). The HLEM measurements were carried out using a portable Max-Min 1 - 8 EM systems. Max-Min 1 - 8 system is designed for groundwater and mineral exploration, as well as for geoengineering applications.

4. DISCUSSION AND INTERPRETATION

4.1. Interpretation of the Gamma-Ray Spectrometric Data

4.1.1 Qualitative Interpretation

a) Total-count and radioelements maps

The Qualitative interpretation of ground gamma-ray survey data depends mainly upon the excellent correlation between the general pattern of the recorded measurements and the surface distribution of the various types of rock units recorded in the geologic map (Fig. 1). The investigation of the texture of the radiospectrometric contour lines and their signatures could be an aid in interpretation of the surface geology (lithology and structure) of the surveyed area.

Close investigation of the various radiospectrometric maps (T.C., eU, eTh andK,) shows that there is a great similarity between these four maps (Figs. 3,4,5 and 6), as concerning the relief of general features, the gradient of contours, the distribution of anomalies, and the trend of radiometric surficial structures…, etc. The four maps were thoroughly investigated, especially where the agreement is best, to establish the general radiometric characteristic features and levels for the different rock types in the study area. It has been recognized that the careful inspection of the total-count and the three-radioelement maps (eU, eTh and K) could show- at a glance-that the distribution of the high radioelement concentrations is highly controlled by Um-Bogma Formation, younger granites, wadi sediments and their tributaries dissected the study area which are exposed generally on the central and northeastern parts of the study area. This indicates that K, U and Th are collectively contributing to the measured total gamma-ray flux as for as lithology is concerned

Generally, all the radiometric maps (Tc, K, eu, eTh) of the surveyed area display very wide range of radioactivity range from about 0.9 to 65.3 Ur, 0.5 to 55.7 ppm and 0.3 to 30.3 respectively. By correlating with the geologic map of the area (Fig. 1), these wide ranges reflect different radioactivity levels within and between the different rock types in the area. Generally, the three maps can be divided into three zones with overlap radioactivity levels. The first is alow level radioactivity, which is recorded over the post Paleozoic sediments. The second is intermediate radioactivity zone, which is represented Abu Thora Formation. The third and highest radioactivity zone, is associated with Um-Bogma Formation, younger granites, Wadi sediments. On the other hand, the potassium map shows a narrow range of concentrations (from 0.1 to 6.8 %) allover the exposed rock units in the study area. Despite this narrow range, there is a good agreement with the previous total-count, eU and eTh maps as concerning the highest and lowest levels and the distribution of the radiation anomalies.

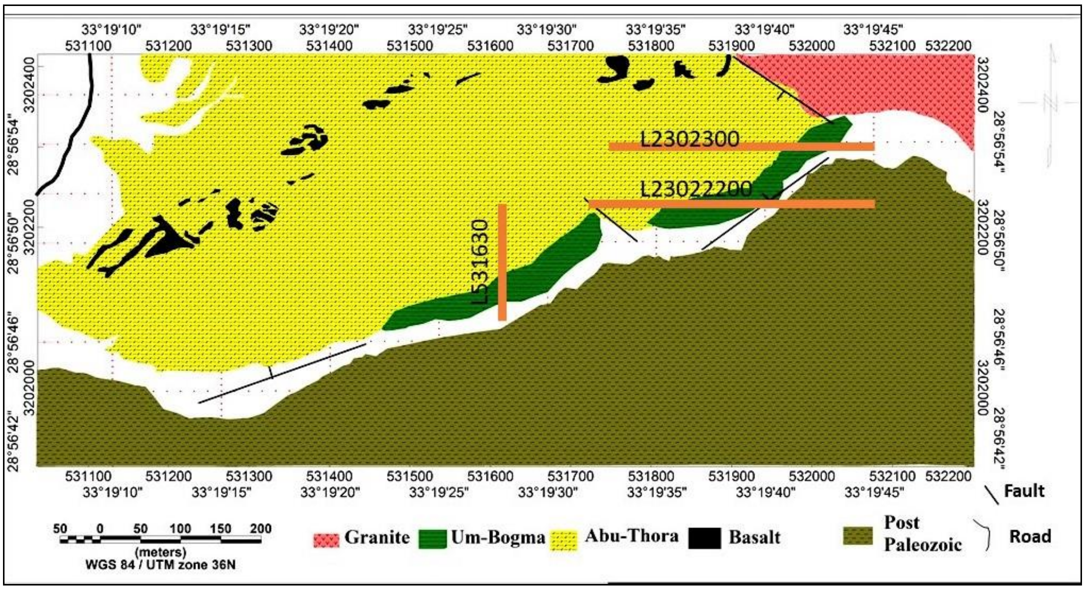

Fig. (2): Three electromagnetic profiles located on Geologic map of West Um-Tomyem, Southwestern Sinai, Egypt.

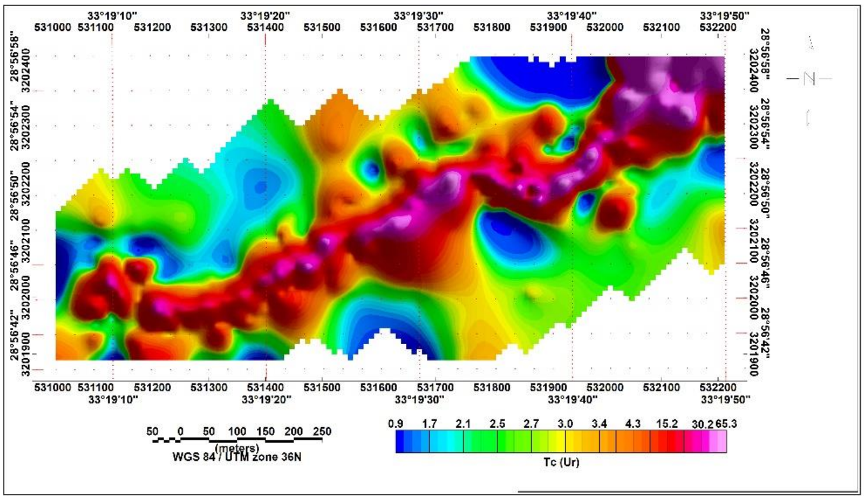

Fig. (3): Total-count (TC) filled colored contour map (in Ur), West Um-Tomyem, Southwestern Sinai, Egypt.

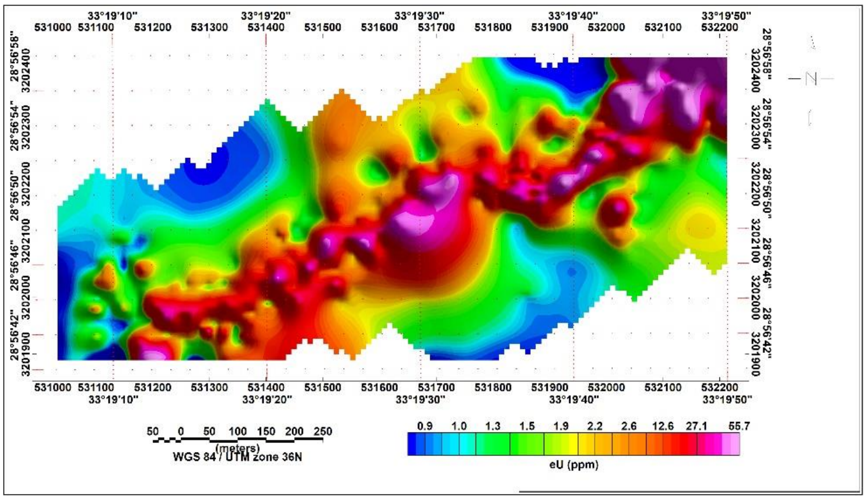

Fig. (4): Equivalent uranium (eU) filled colored contour map (in ppm), West Um-Tomyem, Southwestern Sinai, Egypt.

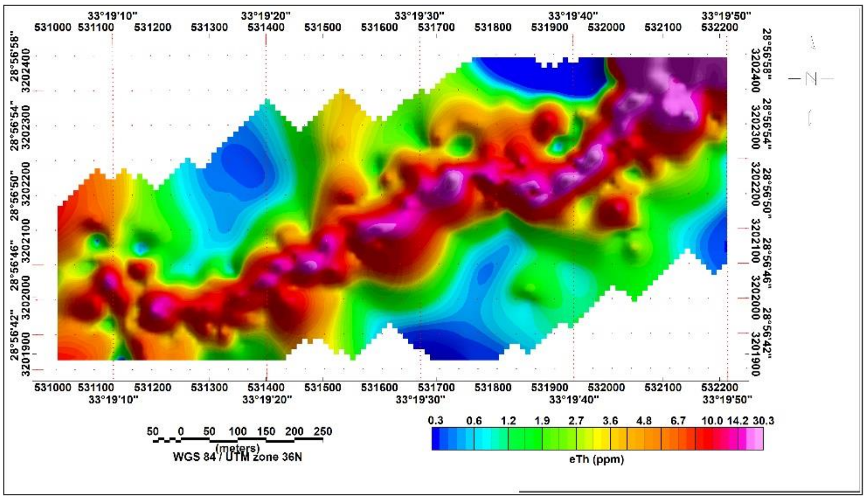

Fig. (5): Equivalent thorium (eTh) filled colored contour map (in ppm), West Um-Tomyem, Southwestern Sinai, Egypt.

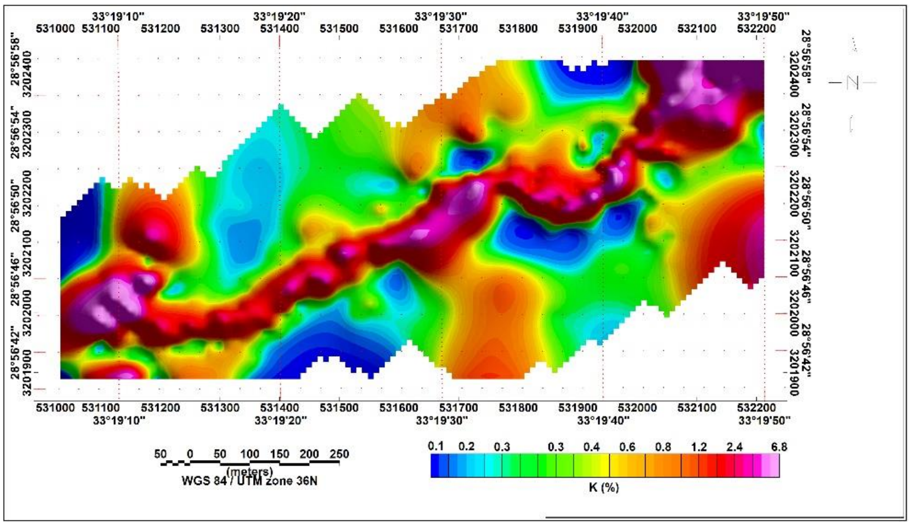

Fig. (6): Potassium (K) filled colored contour map (in %), West Um-Tomyem, Southwestern Sinai, Egypt.

b) Ratios maps

In this study both of the eU/eTh and eU/K ratio maps (Figs. 7 and 8) confirmed the presence of high eU zones of increased uranium content superimposed on the relatively constant thorium and potassium contents. These anomalous zones may have been produced by solutions, highly enriched in uranium, which have permitted the mobilization and concentration of uranium.

c) Ternary radioelement maps

A ternary radioelement map is a color composite image generated by modulating the red, blue and green phosphors of the display device or yellow, cyan and magenta dyes of a printer in proportion to the radioelement concentration values of the K, U and Th grids. The use of red, blue and green for K, U and Th, respectively, is standard for displaying gamma-ray spectrometric data (IAEA,2003).

1) False- color radioelement composite image

It is denoted as composite image of absolute radioelement K, eU and eTh. The red, blue and green (RBG) color combination was used to produce this composite image (Fig. 9). It illustrates that the dark color, which indicates low concentrations of three radioelements, allover the mapped area is closely related to post Paleozoic sediments. The moderate colors which appear as green and violet colors are associated with Abu Thora Formation, indicating moderate concentrations of the three radioelements. The highly white color, which indicates an increase of the three radioelement concentrations, is mainly related the Um Bogma Formation, younger granites and Wadi sediments.

2) False-color uranium composite image

The relative concentration of uranium with respect to both potassium and thorium is an important diagnostic factor in the recognition of probable zones of enriched uranium concentration, which could provide good prospects for further uranium exploration (IAEA, 2003). Therefore, the uranium composite image (Fig.10) provides useful information regarding the identification of anomalous zones of enriched uranium concentration. The uranium composite image combines eU (in red) with two ratios eU/eTh (in green) and eU/K (in blue). As illustrated from the image, the uranium anomalous zones are displayed as bright white color areas, coinciding with the Um-Bogma Formation, younger granites and Wadi sediments of the study area. On the other hand, the dark colors areas are distributed in the other parts of the study area.

4.1.2 Quantitative Interpretation of the Gamma-Ray Spectrometric Data

The quantitative interpretation of the gamma-ray spectrometric data depends principally upon the fact that, the concentrations of the radioelements (K%, eU and eTh) vary measurably and significantly with lithology (Darnley and Ford, 1989). The quantitative treatment of the spectrometric data in the present study is discussed on the light of statistical treatment. Statistical computation was applied to the original spectrometric data without applying any transformation, in accordance with the recommendation given by Sarma and Kock (1980).

With the help of Geosoft package (Geosoft, 2010), gamma-ray spectrometric data within every rock unit have been extracted in XYZ format and evaluated with simple statistics applications. Calculations of the arithmetic mean, X standard deviation, S, and Coefficient of Variability (C.V) (Clarke et al., 1983) have been carried out on the TC, eU, eTh, and K, for each of the different formations and rock units in the study area. Also, the statistical analysis of the data includes minimum (Min.), maximum (Max.) (Table 1).

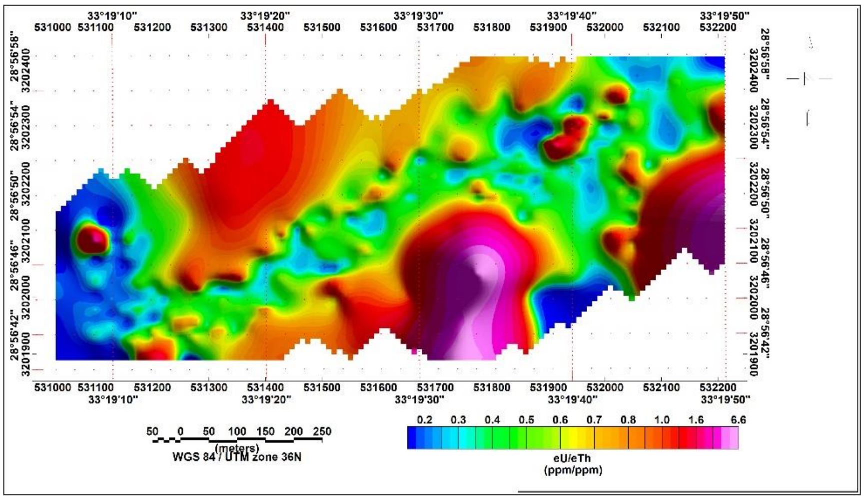

Fig. (7): eU/eTh radio-spectrometric ratio map ,West Um-Tomyem, Southwestern Sinai, Egypt.

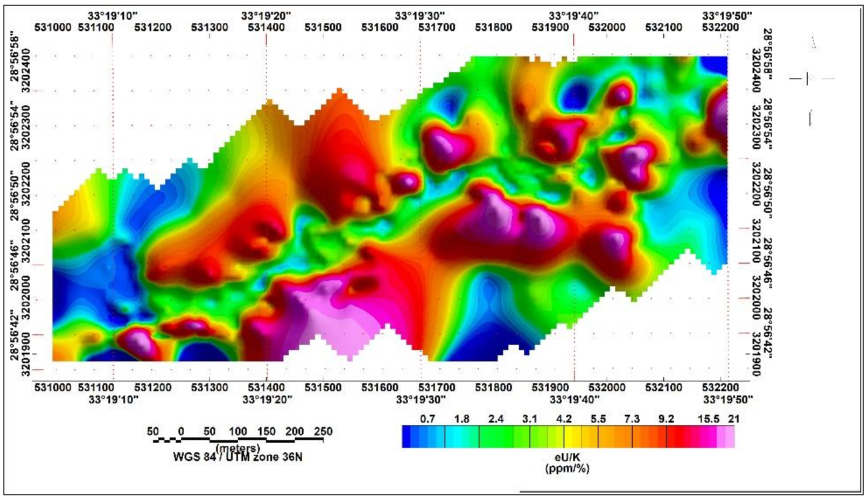

Fig. (8): eU/K radio-spectrometric ratio map, West Um-Tomyem, Southwestern Sinai, Egypt.

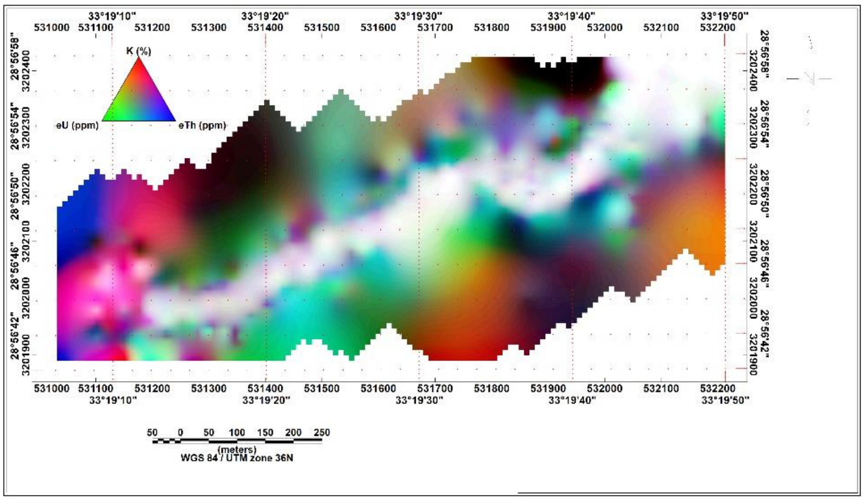

Fig. (9): False – Color radioelement composite image, West Um-Tomyem, Southwestern Sinai, Egypt

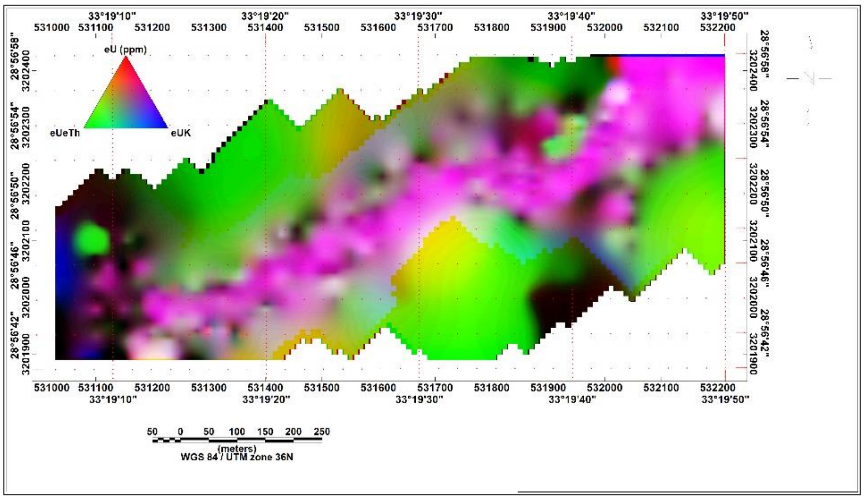

Fig. (10): False - Color uranium composite image, West Um-Tomyem, Southwestern Sinai, Egypt.

Table 1: Gamma-ray spectrometry data for the different formations and rock units West Um-Tomyem, Southwestern Sinai, Egypt.

Rock Unit	Statistical elements / Variables	TC (Ur)	K (%)	eU (ppm)	eTh (ppm)
Granites	No. of readings	50	50	50	50
	MIN.	2.3	0.9	2.0	1.3
	Max.	35.5	4.6	27.9	15.2
	X	7.3	1.6	4.8	4.2
	S	7.1	0.9	4.3	2.7
	C.V.%		55	89	65
Um Bogma Formation	No. of readings	65	65	65	65
	MIN.	15.2	1.0	10.5	3
	Max.	65.3	6.5	55.7	30.3
	X	13.56	4.2	12.8	10.0
	S	12.9	2.7	12	8.0
	C.V.%		65	95	80
Abu Thora Formation	No. of readings	290	290	290	290
	MIN.	1.1	0.4	0.9	0.9
	Max.	14.0	1.8	8.2	4.3
	X	6.53	1.2	3.0	2.2
	S	5.5	0.5	1.8	1.1
	C.V.%		40	60	50
Post Paleozoic Sediments	No. of readings	310	310	310	310
	MIN.	1.1	0.1	0.8	0.7
	Max.	11.5	1.0	5.2	4.5
	X	4.5	0.55	2.1	1.8
	S	2.3	0.2	1.0	0.8
	C.V.%		35	48	44
Wadi Sediments	No. of readings	80	80	80	80
	MIN.	7.00	0.8	1.8	2.2
	Max.	23.40	4.0	15.3	8.3
	X	6.3	1.5	4.3	3.5
	S	4.9	0.7	3.0	2.0
	C.V.%		45	70	57

Min = minimum, Max= maximum, X= arithmetic mean,

S = standard deviation and C.V. = Coefficient of Variability.

a) Coefficient of Variability (C.V) Analysis of the different rock units

Saunders and Potts (1978) concluded that the median values of aerial gamma-ray spectrometer parameters for geological map units could be used as guide to identify uraniferous provinces, reasoning that where the crustal abundance of uranium is high, it is available to be chemically concentrated in economic deposits**.** They added that the parameters which generally increase with increasing uranium potentiality are: MeU, MeTh, MK, RSD (eU), RSD (eU/eTh), and RSD (eU/K). The relative standard deviation (RSD) or coefficient of Variability (C.V) could be defined by the following formula:

RSD = (S/ X) *100

where: C.V = RSD = Relative standard deviation,

S = Standard deviation, and X = Arithmetic mean.

The statistical treatment of the ground gamma-ray spectrometric data depends mainly on the use of the coefficient of variability (CV) value to define the variability distribution of the measured radioactive elements within the study area or within individual rock unit (Sarma and Kock (1980).

In this study, the C.V. (%) of the Gamma-ray spectrometric variables (eU, eTh and K) of the different rock units has been calculated and illustrated as bar chart (Fig. 11). By examination of the bar graph for the study area, the following conclusions have been extracted:

1- Within all the different rock units in the study area, the higher C.V. value was related to uranium and thourium while the lowest C.V. value was related to potassium.

2- Um Bogma Formation considered is the highest Formation of its uranium and thorium variability and consequently potentiality due to its higher and relatively close C.V. values in the study area.

3- Younger granites and Wadi sediments exhibit remarkably higher C.V. values for the three radioelements than those of post Paleozoic sediments and Abu Thora formations.

b) Uranium Favorability Index of the rock Units

Saunders and Potts (1978) attempted to determine a general uranium favorability index for about 30 different areas, where existing mines and occurrences were known to be favorable. Based on their observations that high mean uranium content indicates that there is sufficient uranium for possible geochemical concentrating processes to work, and that low mean eU/eTh and eU/K values indicate that these processes took place, they derived the index, U2, which is given by the equation:

$$U2 = \frac{MeU}{\frac{MeU}{MeTh} * \frac{MeU}{MK}} = \frac{MeTh * MK}{MeU}$$

Generally, calculation of the radioelement indices is considered as a simple interpretation technique to delineate as rapidly as possible the areas of radioelements enrichment and locating favuorable areas for uranium exploration. In the present study U2 was calculated for the different rock units in the prospect area and represented as vertical bar chart (Fig. 12) to enhance the interpretation.

In this study area the uranium favorability index can be divided into three levels. The first (highest) level related to Um Bogma Formation, the second is associated with younger granites and Wadi sediments, Abu Thora Formation, and the third (lowest) level is related to post Paleozoic sediments. Accordingly, Um Bogma Formation is considered the main source of the radioactive uranium in the study area.

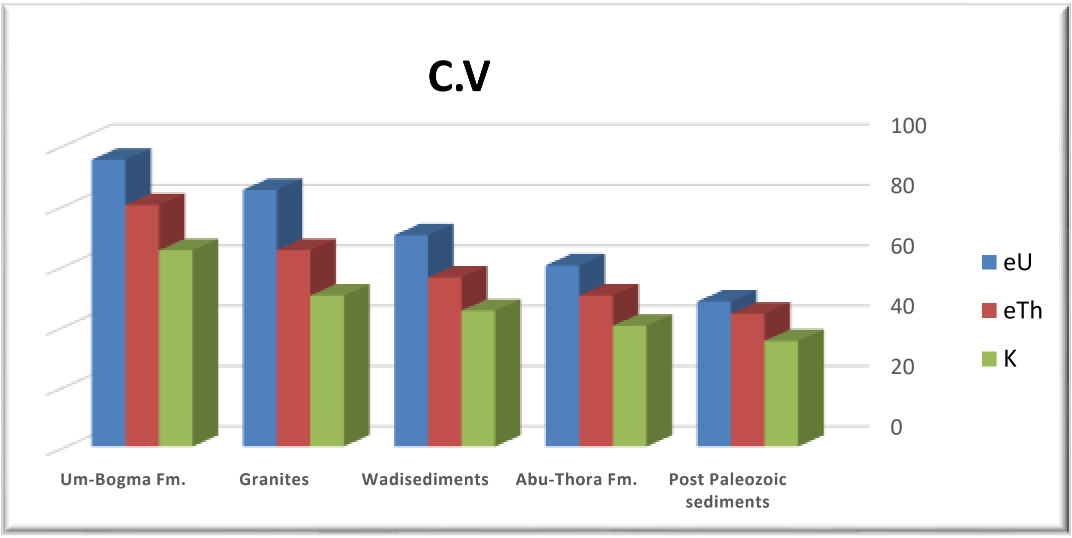

Fig. (11): Vertical chart showing Coefficient of Variability (C.V) of all formations and rock unitsWest Um-Tomyem, Southwestern Sinai, Egypt.

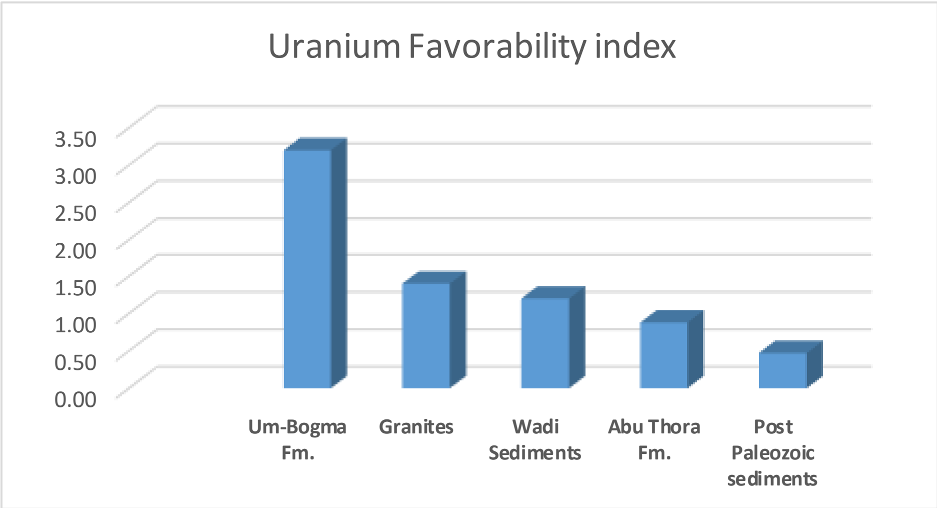

Fig. (12): Vertical chart showing Uranium Favorability Indexof all formations and rock unitsWest Um-Tomyem, Southwestern Sinai, Egypt.

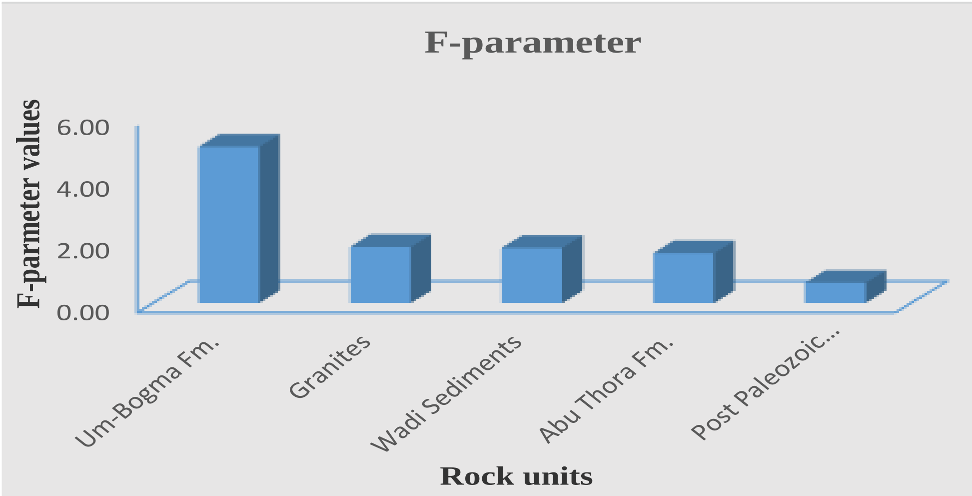

Fig. (13): Vertical chart showing Three elemental effective parameter (F) of all formations and rock unitsWest Um-Tomyem, Southwestern Sinai, Egypt.

c) Three elemental effective parameter (F)

The most effective parameter of the three radioelement is the (K*eU)/eTh parameter, which was proposed by Efimov (1978) as the socalled F- parameter (Gnojek, et al., 1985). This F-parameter seems to be very useful, because it comprises two important characteristics of the rock environment, i.e., the potassium abundance to the eTh/eU ratio and the uranium abundance to the eTh/K ratio, as expressed in the relation:

F= (K*eU)/eTh= K/ (eTh/eU) =eU/ (eTh/K).

Efimove (1978), who quantified the F-parameter showed that it can acquire values up to 1.2 or 1.3 in common non-altered rocks, while in altered rocks it may attain 2 or 5, exceptionally 10. The use of this method for geological and mineral exploration is based on the assumption that different rock types or ore-bearing rock types are composed of certain amounts of rock forming minerals which comprise specific quantities of radioactive elements as K, U and Th. The equation derived by Efimove, (1978) for the F-parameter was computed, established and illustrated on vertical bar chart (Fig. 13), which displays the general variation in the values of F-parameter for the different rock units in the study area. The F-parameter values for the different radiometric lithologic units were found to oscillate between 0.4 and 5.04. For granitic rocks, Abu Thora Formation, post Paleozic sediments and Wadi sediments these values less than 1.8. This may indicate that they have not been influenced by alteration processes on the basis of Efimov's quantification of the F- parameter. On the other hand, Um Bogma Formations shows high values reaching up to 5.04, which may suggest that they undergo alteration processes. The relatively high F-parameter values associated with Um Bogma Formation indicate its high potentialities for uraniferous occurrences.

4.2. Interpretation of Horizontal-Loop Electromagnetic (HLEM) data

Profile (3202300 E)

This line was selected to confirm the obtained results appeared obviously on gamma-ray spectrometric maps. It was carried out from west to east with a length of 350 m and four frequencies (7040 Hz, 1760 Hz, 440 Hz and 110 Hz). The investigation of the HLEM data of this line (Fig. 14) indicates a well-defined EM anomaly data at the four frequencies centered at station 531950 which may reflect that the causative source is a good conductor, situated at shallow depth.

The EM anomaly has a negative peak centered at station 531950 on the four frequencies (7040 Hz, 1760 Hz, 440 Hz and 110 Hz). The amplitude of the negative peak increases downwardly to give a well-defined anomaly on frequency 110 Hz (deeper depth of penetration). Meanwhile, the out-of-phase component shows low EM response at low frequency 110 Hz at this zone. This may reveal that good conductor (metallic), which buried at shallow depth. The 110 Hz curve is selected in the calculations. The shape of the in-phase component of this anomaly reveals a thin conductive body with a dip (40°) to the west direction obtained from the master curves (Nair et al., 1974) for a rapid evaluation of the dip of half-plane conductor, the depth to surface of conductor is 20 m. The conductivity thickness 15 siemens/m.

Profile (3202220 E)

This line was conducted with a length of 370 m and was measured from the west to follow the near surface radiometric anomalies which are recorded at Um Bogma Formation and obviously appeared from the gamma-ray spectrometric maps which have values of 55.7 ppm eU and 57.5 ppm eTh. Close examination of the in-phase and out-phase components of this line (Fig. 15) shows the following observations:

- The in-phase components indicate that there is a well-defined conductive zone with maximum negative peak centered at station 531900.
- The shape of in-phase components along the four frequencies for conductive zone reveals that the causative source has relatively good intensities.
- The defined EM anomaly data at the four frequencies, which may reflect that the causative sources is a good conductor and situated at shallow depth.
- The 440 Hz curve was selected in calculations. The shape of the in-phase component reveals that the conductive body has a thin width with a dip (20°) to the west direction obtained from the master curves for a rapid evaluation of the dip of half-plane conductor, the depth to top of conductor is 17m.The conductivity thickness is 12 siemens/m.

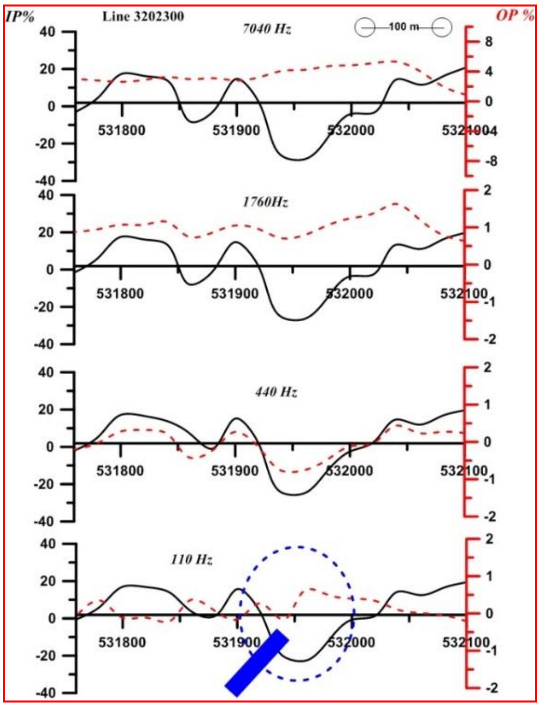

Fig. (14): Horizontal-loop electromagnetic profile along line (3202300), West Um-Tomyem, Southwestern Sinai, Egypt.

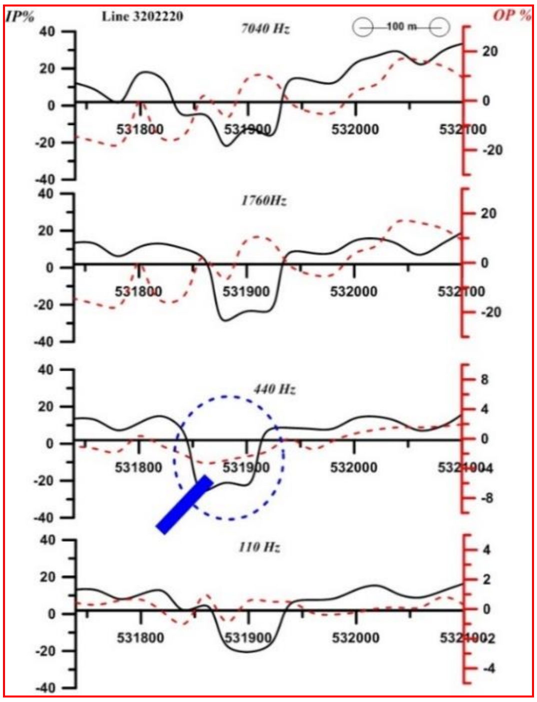

Fig. (15): Horizontal-loop electromagnetic profile along line (3202220),West Um-Tomyem, Southwestern Sinai, Egypt.

Profile (531630 N)

This line was conducted with a length of 120 m. It was measured from the south to detect the mineralization that is associated with Um Bogma Formation, which obtained and obviously appeared from the gamma-ray spectrometric maps. Close examination of the in-phase and out-phase components of this line (Fig. 16) shows the following observations:

- The in-phase components indicate that there is a broad conductive zone with maximum negative peaks centered at station 3202200.
- The defined EM anomaly is observed along the four frequencies. This may reflect that the causative source is a good conductor. The amplitudes of the in-phase components along the four frequencies are relatively high (-40%). Meanwhile, the out-of-phase component shows low EM response at low frequency 440 Hz at this zone. This may reveal that the causative source is a good conductor and situated at shallow depth.
- The 440 Hz curve was selected in the calculations. The shape of the in-phase component reveals that the conductive body has a thin width with dip (40°) to the north direction. The depth to top of conductor is 10m and the conductivity thickness is 16.8 siemens/m.

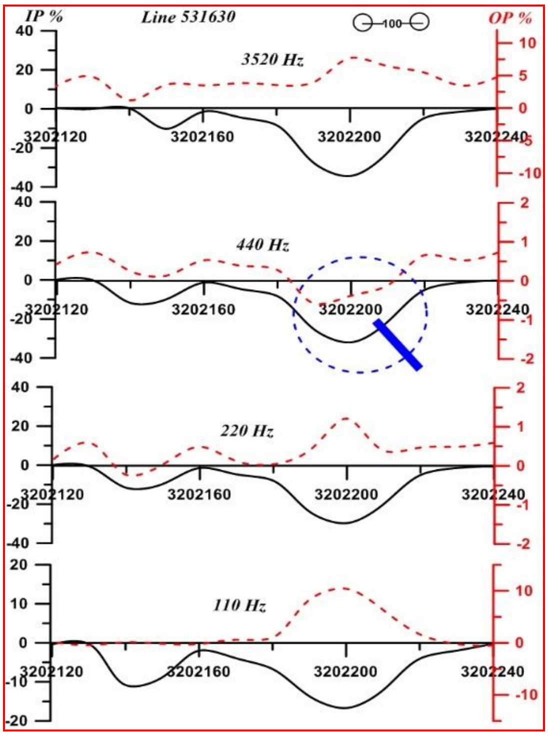

Fig. (16): Horizontal-loop electromagnetic profile along line (531630),West Um-Tomyem, Southwestern Sinai, Egypt.

CONCLUSIONS

The integration between Gamma-ray spectrometry and Horizontal Loop Electromagnetic (HLEM)data for West Um-Tomyem, Southwestern Sinai, Egypt enabled the identification of the concentration and spatial distribution of the three radioactive elements eU, eTh and K in the area, and obtaining information about the extension variations for both the lithology and anomalously high radioactive localities at depth. In general, results of these studies can be outlined in the following conclusions:

- The gamma-ray spectrometry data revealed that the study area has a wide radioactivity range, oscillating *from 0.9 to 65.3 Ur, 0.5 to 55.7 ppm, 0.3 to 30.3ppm and from 0.1 to 6.8*for the total count (Tc), equivalent uranium (eU), equivalent thorium (eTh) and potassium (K), respectively.
- The different radioelement concentration maps and composite images showed that the anomalously high radioactivity parts are mainly associated with Um Bogma formation andyounger granite rocks.
- Significant and well-defined conductive zones are recorded along the four used frequencies (110 Hz, 440 Hz, 1760 Hz and 7040 Hz), at the stations 531950, 531900 and 3202200 of the three (HLEM) profiles (3202300 E, 3202220 E and 531630N) respectively. This may reflect the sources of conductive bodies are situated at shallow depths and continued to considerable depths.
- There is a good correlation between the anomalously high radioactivity parts, as inferred from the ground gamma-ray spectrometric survey and the HLEM anomalies in the study area.

REFERENCES

Abdel Elhadi (2020): Geology and Mineralogy of the Radioactive Ferruginous Siltstones at Wadi El Seih Area, Southwestern Sinai, Egypt. Journal of Applied Geology and Geophysics (IOSR-JAGG),2321–0990, p-ISSN: 2321–0982.Volume 8, Issue 6 Ser. I (Nov. – Dec. 2020), PP 29-42

Abdel Monem, A.A., Hashad, A.H. and El Kiki, M.F. (1958): The radioactive exploration and the radioactivity of West Central Sinai; Unpublished Report, U.A.R. A., Atomic Energy Establishment, Cairo Egypt.

Al Shami, A.S. (2003): Structural and lithological controls of uranium and copper mineralization in Um Bogma environs, southwestern Sinai, Egypt. Unpublished Ph.D. Thesis, Faculty of Science, Mansoura University.

Charbonneau, B.W., Killeen, P.G., Carson J.M., Cameron, G.W., and Richardson, K.A. (1976): Significance of radioelements concentration measurements made by airborne gamma-ray spectrometry over the Canadian Shield; in Exploration for Uranium Deposits, International Atomic Energy Agency, SM-208/3, p 35-53.

Clarke, G.M., and Cooke, D., (1983): A basic course in statistics. English Language Society/Edward Arnald (publisher) Ltd., London, England.

Darnley, A.G. and Ford, K.L. (1989): Regional airborne gamma-ray surveys, a review. Proceedings of Exploration, 87, Third Decennial

International Conference on Geophysical and Geochemical Exploration for Minerals and Groundwater, edited by G. D. Garland, Ontario, Canada, Geol. Sur. Can., Special V.3, pp. 229-240.

Durrance, E.M., (1986): Radioactivity in Geology: Principles and Application. Ellis and Horwood, Chichester, England, Ellis Horwood, Ltd., 441 p.

Efimov, A.V. (1978): Multiplikativniyj pokazatel dlja vydelenija endogennych rud aerogamma-spectrometriceskim dannym, in Metody rudnoj geofiziki: Lenigrad, Naucno-proizvodstvennoje objedinenie Geofizica Ed., 59–68.

El Sokkary, A.A. (1963): Geologic and mineralogical studies of some radioactivedeposits in West Central Sinai, Unpublished M.Sc. Thesis, Faculty Science, Alexandria University, Egypt, 132p. (in Arabic).

Hussein, H.A., Anwar, Y.M. and El-Sukkary, A.A., (1971): Radiogeologic studies of some Carboniferous rocks of west central Sinai. U.A.R. J. Geol., Vol. 15, No. 2, pp. 119-127.

Geosoft Inc., (|2010): Geosoft mapping and processing system. Geosoft Inc., Toronto, Canada.

Grasty, Holman, P.B., and Blanchard, Y.B., (1991): Transportable calibration pads for ground and airborne gamma-ray spectrometers. Geol. Sur. Can., Ottawa, Canada, pp.19-21

International Atomic Energy Agency (IAEA) (2003): Guidelines for Radioelement Mapping Using Gamma-ray Spectrometry Data, Technical Reports Series No., IAEA-TECDOC-1363, Vienna, Austria, 179 p.

Moxham, R.M., Footh, R.S. and Bunker, C.M. (1965): Gamma-ray spectrometer studies of hydrothermally-altered rocks. Economic Geology, V. 60, No. 4, pp. 653-671.

Nair, M.R., Biswas, S.K. and Mazumdar, K. (1974): Standard curves for interpretation of horizontal loop electromagnetic anomalies. Geol. Surv. India, Miscellaneous publication.n.25.

Sarma, D.D. and Kock, G.S. (1980): A statistical analysis of exploration geochemical data for uranium; Mathematical Geology, 12 (2), pp. 99-114.

Saunders, D.F. and Potts, M.J., (1976): Interpretation and application of high sensitivity airborne gamma ray spectromettic data. In: IAEA Symp. Exploration for Uranium Ore Deposits, Vienna, pp. 107-124.

Soliman, M.S. and Abu El Fetouh M.A. (1969) : Petrology of Carboniferous sandstone in West Central Sinai. J. Geol. UAR, 13, 43-61.

Sharma, P.V. (1997): Environmental and engineering geophysics, Cambridge University Press, 475 p.