Egyptian Geophysical Society
EGS Journal, Vol. 21, No. 1, 39-47 (2023)

APPLICATION OF GROUND GAMMA-RAY SPECTROMETRIC AND HORIZONTAL-LOOP ELECTROMAGNETIC TECHNIQUES OF WADI BUDRA AREA SOUTHWESTERN SINAI, EGYPT

H.M. EL SHAYEB[1], A.A. HASSAN[2], A.S. EL SHAMI[2], M.A.M. ZAEIMAH[2] and A.M. EL HAWARY[2]

(1) Menofeya University, Shebeen Elkoom, Egypt.
(2) Nuclear Materials Authority, Cairo, Egypt.

تطبيق تقنيات المسح الارضى الإشعاعى الطيفى لأشعة جاما والكهرومغناطيسي الحلقى الافقى بمنطقة وادى بودرا، جنوب غرب سيناء، مصر

الخلاصة: تم إجراء المسح الإشعاعي الطيفي لأشعة جاما وكذلك خطوط مختارة لطريقة المسح الكهرومغناطيسي اعتمادا على التردد بطريقة المسح الكهرومغناطيسي الحلقى الأفقي لتحديد المناطق الشاذة المشعة وتحديد امتداد النطاقات الموصلة لمنطقة وادي بودرا، جنوب غرب سيناء، مصر. هذه المنطقة مغطاة بتتابع صخري من صخور حقب الحياة القديمة.

وقد أجري المسح الإشعاعى الطيفي لأشعة جاما على امتداد عدد من خطوط المسح شمال –جنوب N-S، بطول 1100 متر، المسافة البينية بين خطوط المسح 40 مترا تكون فيها محطات القياس كل 20 مترا. وتبين الخرائط الطيفية لأشعة غاما مستويات مختلفة للقياس الإشعاعي، تعكس محتويات الإشعاع مختلف أنواع الصخور على امتداد أسطح المسح . تقع أعلى المستويات الإشعاعية في الجزء الشمالى الغربي والجنوبي الشرقي وبعض الأجزاء المتناثرة في جميع أنحاء منطقة الدراسة. ترتبط بشكل أساسي بمستكشف تكوين أم بوجما تُظهر منطقة الدراسة أن إشعاع جاما يتراوح من 1.6 إلى 216 ميكرو رونتيجن/ساعة 0.1 إلى 5.5٪ بوتاسيوم مشع ، 0.1 إلى 203 جزء في المليون من مكافئ اليورانيوم ، 0.1 إلى 50.3 جزء في المليون من مكافئ اليورانيوم. وبالتالي، يتم إنشاء خريطة صورة مركبة لليورانيوم عن طريق خلط نسب الألوان وتحديد المناطق الشاذة لليورانيوم. تشير هذه الخريطة إلى أن سبع مناطق يورانيوم شاذة، يبدو أن المستويات العامة للنشاط الإشعاعي تتحكم فيها اتجاهات NNW إلى NW مع مستكشف تكوين Um-Bogma، ووجود الجرانيت الحديث في الجزء الجنوبي الشرقى. كشفت خطوط (HLEM) أن شكل الجسم الموصل في الجزء الشمالي الشرقي عرض رقيق مع انحدار منخفض تقريبًا إلى الاتجاه الغربي ومنتج سمكي جيد للتوصيل وعمق ضحل (11 م). كشف الجزء الجنوبي من المنطقة عن جسم موصل على عمق 42 مترًا يميل بإتجاه الجنوب مع منتج سمكى منخفض التوصيل.

ABSTRACT: *Gamma-ray spectrometry and Horizontal-Loop Electromagnetic (HLEM) surveys were carried out, to determine the radioactive anomalous zones and to define the extension of the conductive zones for Wadi Budra area, southwestern Sinai, Egypt. This area is covered by Paleozoic rocks which covered by basaltic sheets.*

The gamma-ray spectrometric survey were conducted along a number of N-S profiles, with a profile length of 1100 m, line spacing of 40 m and station intervals of 20 m. The gamma-ray spectrometric maps show different radiometric levels, which reflect the radioelement contents of the various exposed rock types. The highest radiometric levels are located along the northwest-southeast trend and of some scattered parts all over the study area. They are mainly associated with the outcrops of Um Bogma Formation The study area shows that the gamma radiation ranging from 1.6 μR/h to 216 μR/h as a total count, 0.1 to 5.5 % K, 0.1 to 203 ppm eU, 0.1 to 50.3 ppm eTh. Thus, uranium a composite image map is constructed to identify and outline the uranium anomalous zones. This map indicates that seven anomalous uranium zones, it appears that the general levels of radioactivity are controlled by the NNW to NW trends with the exposure of Um-Bogma Formation, and the presence of younger granite in the southeastern part. The (HLEM) maps revealed that the shape of the in-phase component at the northeastern part indicates that the conductive body has a thin width with nearly low dip to the west direction, good conductivity thickness product and shallow depth (11m). Menwhile the southern part of the area revealed a conductive body at a depth of 42 m with low conductivity thickness product.

1. INTRODUCTION

Wadi Budra area is located at 18 km to the east of Ras Abu Rudeis town on the Gulf of Suez between longitudes 33° 20' 53"E and 33° 21' 30" E., latitudes 28° 52' 55"N and 28° 53' 34" N (Fig. 1). The highest elevation recorded in the study area reaches to about 410 m above sea level, and is located at the northwestern part, while the lowest one is about 240 m situated at the southern part.

The, Paleozoic section at Wadi Budra, area can be subdivided according to the studies El-Rakaiby and El-Aassy, Kora et al., 1994; El-Agami, 1996 into two main types of sediments: Early and Late Paleozoic. Early Paleozoic sediments (Cambro-Ordovician) are subdivided into three formations namely: Sarabit El-Khadim, Abu-Hamata, and Adedia (Kora, 1984). These sediments were called as lower sandstone series since (Barron, 1907). Late Paleozoic (Carboniferous) sediments are represented by two main formations: Um-Bogma of Early Carboniferous (Middle Visean), and Abu-Thora Formation (Upper Visean). These two formations were called middle carbonate and upper sandstone series (Barron, 1907). The objectives of the present study are to identify the surface radioactive anomalous zones by applying gamma-ray spectrometric survey, and to follow the exposed surface radiometric anomalies at deeper depths and to detect any possible subsurface mineralizations and their probable extensions. Also, to fefine the conductive zones through the application of (HLEM) method.

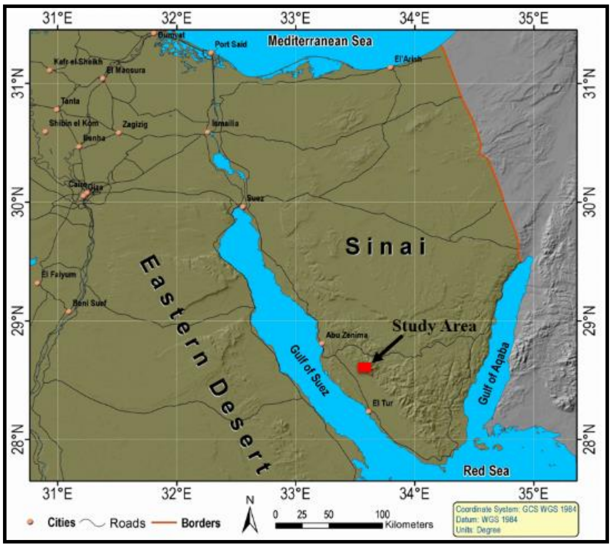

Fig. (1): location map of Wadi Budra area, Southwestern Sinai, Egypt.

2. GEOLOGIC SETTING

The study area is covered by different exposed rocks ranging in age from Precambrian to Quaternary (Fig. 2). The Precambrian is represented by the granitic rocks at the southwestern part. The Paleozoic rocks are classified into five formations from base to top: Sarabit El-Khadim, Abu-Hamata, Adadia, Um-Bogma, and Abu-Thora. (Fig. 2). In addition, the post Paleozoic are occured in the south of the study area. A brief description of these rock units is as follows:

Younger granites are composed of monzogranite and syenogranite. They represent the main basement rock within the mapped area, forming high rugged mountains. The younger granites are mainly medium to coarse–grained, buff and pink to reddish pink in colour. Sarabet Elkhadim Formation, the lower boundary is represented by an unconformity with underlying basement rocks. It appears as cross-bedded sandstone, with a conglomerate layer alternating with sandstone in most localities that possesses pinkish to brownish colour. Abu Hamata Formation, it conformably overlies and underlies Sarabit El-Khadim and Adadia Formations respectively. It is easily distinguished by its characteristic greenish colour and lithology, which can be used as a marker bed in the field. Adadia Formation, the lower contact of Adadia Formation is well defined, but the upper is highly ferruginated and in some parts, show signs of paleosoil, it consists of sandstone, very thickly bedded, fine grained, yellow, red and white colours. These sandstones were used as building stones for an "Ancient Egyptian Temple" at Gabal Sarabit El-Khadim. Um-Bogma Formation, the lower boundary is represented by an unconformity surface, with the underlying Adadia Formation, Um Bogma Formation unconformably overlies Adadia Formation and underlies Upper Sandstone Series. It is considered the important Paleozoic rock unit in the area due to its content of uranium, Fe-Mn ore deposits and secondary copper mineralization. It exhibits a thickness about 10m at the extreme north which gradually decreases to the south. Abu-Thora Formation, is easily identified, this is mainly attributed to marked differences in lithology between its sandstone and dolomite of Um-Bogma formation. It consists of brownish cross-laminated sandstones, intercalated with thin shale and siltstone. Ripple marks, troughs, and tabular planar cross stratifications are observed in the lower parts of this Formation.

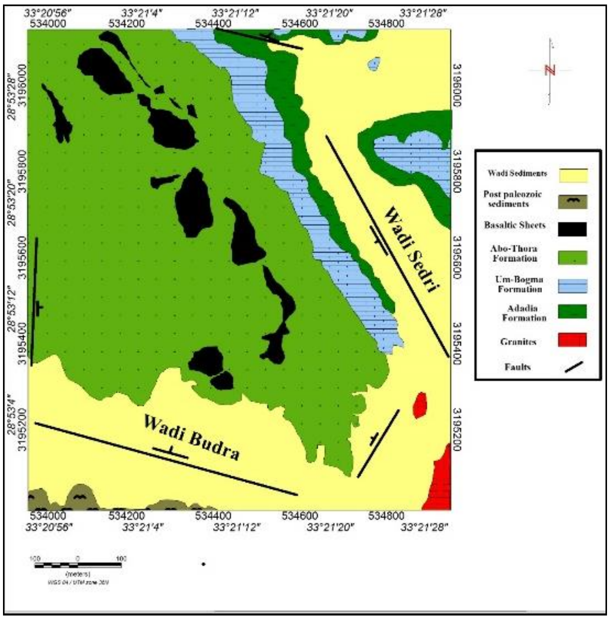

Fig. (2): Detailed geologic map of Wadi Budra area, Southwestern Sinai, Egypt.

In the central part; shale, siltstone, sandstone, kaolin, claystone and carbonaceous shale occur. Meanwhile, in the upper parts it consists of white semi-friable (glass sand) sandstones, with siltstones and shales, beside some sandstone beds that wedge out. . Upper Sandstone Series was studied by Soliman and Abu El Fetouh (1969). They subdivided it into three Formations comprising from base to top, El-Hashash, Magharet El-Maiah and Abu-Zarab Formations.

3. GROUND GAMMA-RAY SPECTROMETRIC SURVEY

The ground gamma-ray spectrometric surveys assist considerably in the search for uranium ores and therefore, have importance to mineral exploration in general and geological mapping in particular. It should be considered as a standard requirement to complement ordinary geological mapping (IAEA, 1979). Ground gamma-ray survey was selected as a rapid and powerful tool for providing information about the spatial distribution and concentration of the radioactive elements and to define the lithological variations and degree of alterations associated with uranium mineralization. Hence, systematic ground gamma-ray measurements for the total-count (TC) gamma activity and the three radioactive elements (K, U and Th) were taken along nearly N-S profiles on a grid pattern of 40 m line spacing and 20m station intervals. Gamma-ray measurements were taken using a portable, hand-held radiation spectrometer, model RS-230, with internal data storage and PC data retrieval in addition to a system that works with the GPS unit.

3.1. Total-Count radiometric (T.C.) map

The total-count radiometric contour map and geologic map (Figs. 2 and 3) show that, the radioactivity of the study area ranges from 1.0 µR/h over Wadi sediments and basaltic intrusions to 135µR/h over Um-Bogma Formation. It appears that the general levels of radioactivity are controlled by the NNW to NW trends with the exposure of Um-Bogma Formation, and the exposure of younger granite in the southwestern part. The total-count radiometric map can be divided into three radioactive levels.

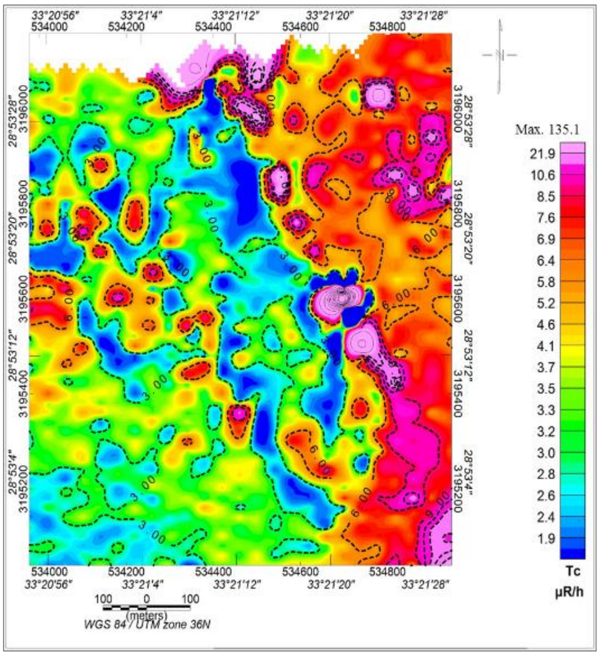

Fig. (3): Total count radiometric map in µR/h of Wadi Budra area, Southwestern Sinai, Egypt.

The low level (blue colour) ranges from 1.0 µR/h to 3.0µR/h and is located over basaltic sheets and the basaltic fragments. The second level (green to orange colour) ranges from 3.0 µR/h to 8.5 µR/h. It is occured in the southwestern part, at Wadi Budra, some scattered parts in Abo-Thora Formation, Wadi Sedri in the eastern part. The third and highest level (>8.5 µR/h,) is mainly associated with Um-Bogma Formation, upper part of Adadia Formation, and younger granite at southeastern part.

3.2. Equivalent Uranium (eU) radiometric map

The equivalent uranium (eU) content reaches to about 203 ppm and is recorded at the central part over Um-Bogma Formation. The (eU) radiometric map (Fig.4) can be divided into four radioactive levels. The first low level (blue colour) ranges in values from 0.1 ppm to 1.8 ppm. It is mainly recorded in the central part over basaltic sheet and the basaltic fragments with a NNW direction. The second level (green to yellow) ranges from 1.8 ppm to 2.6 ppm. It is located in the southwestern part, at Wadi Budra, some scattered parts in Abu-Thora Formation. The third level (orange color) ranges from 2.7 ppm to 4 ppm, located in the eastern parts at Wadi Sedri over wadi sediments. The fourth (the highest level < 8 ppm) has a violet colour is associated with Um-Bogma Formation and upper part of Adadia Formation and younger granite at southeastern part.

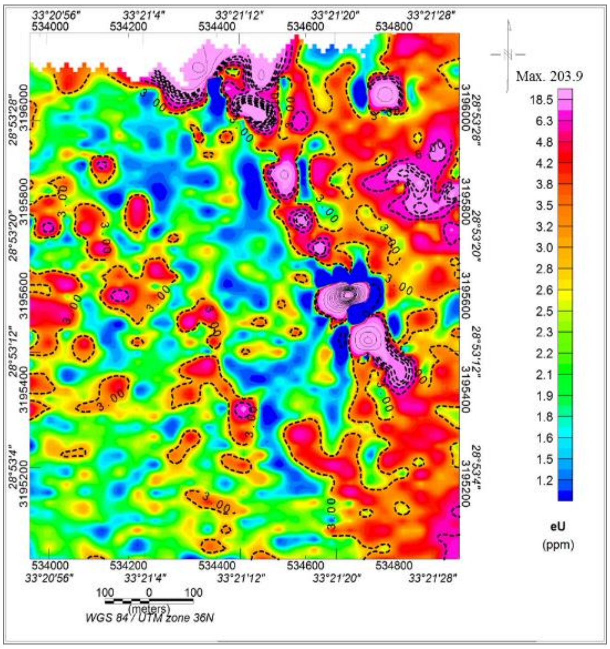

Fig. (4): Equivalent uranium (eU) radio-spectrometric map in ppm of Wadi Budra area, Southwestern Sinai, Egypt.

3.3. Equivalent Thorium (eTh) radiometric map

The equivalent thorium (eTh) map (Fig. 5) shows values ranging from 2.1 ppm to 50.3 ppm, with an average value of about 6.5 ppm. The high values (> 9 ppm red and violet colour) are located at the eastern part associating with Um-Bogma Formation, the upper part of

Adadia Formation, and granites at southeastern part. Meanwhile, the lowest values (1-5.1ppm blue and green colures), are situated at the central and western parts. The intermediate values (5- 9 ppm yellow and orange colures), are associated with the scattered zones in Abo-Thora Formation in the western part and eastern part at Wadi Sedri due to weathering products of granitic rocks.

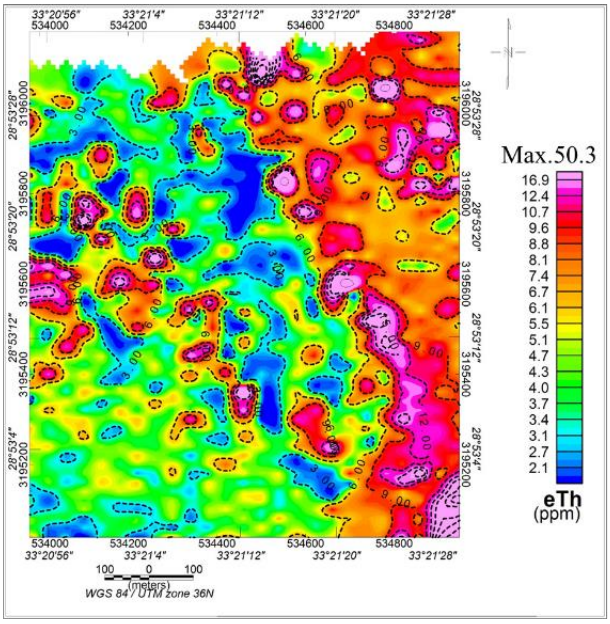

Fig. (5): Equivalent thorium (eTh) radio-spectrometric map in ppm of Wadi Budra area, Southwestern Sinai, Egypt.

3.4. Potassium (K%) radiometric map

The potassium (K) map (Fig. 6) shows values varying from 0.1 % to 5.8%, with an average value of about 0.6 %.

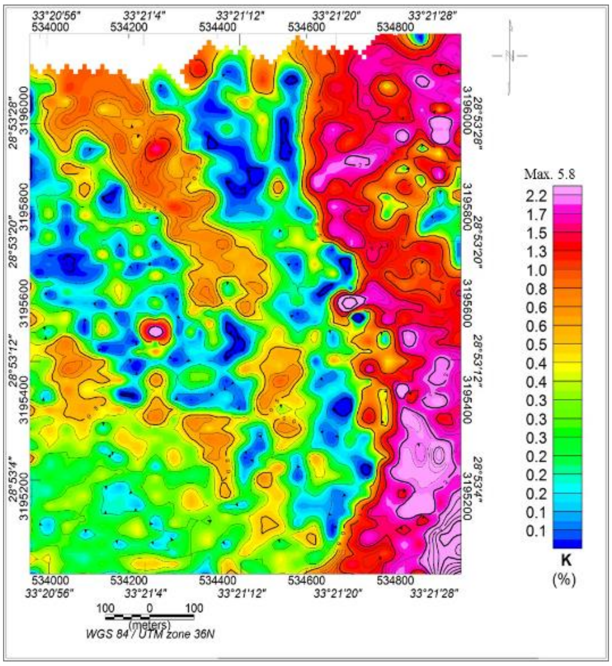

Fig. (6): Potassium (K) radio-spectrometric map in % of Wadi Budra area, Southwestern Sinai, Egypt.

The high values are located at the eastern parts. Meanwhile, the lowest values are situated at the central and western parts.The potassium (K) map can be classified into two levels. The first level (blue to orange colour) varies from 0.1% to 1% and is located over higher topography of all the sedimentary succession, and the southern part. The second level (> 1.0 ppm- red and violent colours) is occurred at the eastern part over the granites and Wadi Sedri.

3.5. False- colour three radioelement composite image map

The three-radioelement composite image map of the study area (Fig. 7), as generated from the gamma-ray spectrometric data of K, eU, and eTh, shows the general variation occurring collectively in the three radioelements concentrations, which mainly reflect lithological variations (IAEA, 1988). The colours, shown at each corner of the triangle legend (K in red, eU in blue and eTh in green), indicate a 100% concentration of the indicated radioelement. The colour at each point inside the triangle represent different ratios of the three radioelements. Integration or mixing the colours produces a dark colour of the zone, indicating low concentrations of the three radioelements. These zones are closely related to some parts of sandstones of Abu-Thora Formation. The intermediate colors, which monitored as red and violet colours are associated with basalt and basaltic products. The white colour, which indicates an increase of all three radioelements, is found at the southeastern part of the study area due to the presence of granites, Meanwhile, the blue colour is associated with high uranium concentrations connected with Um-Bogma Formation.

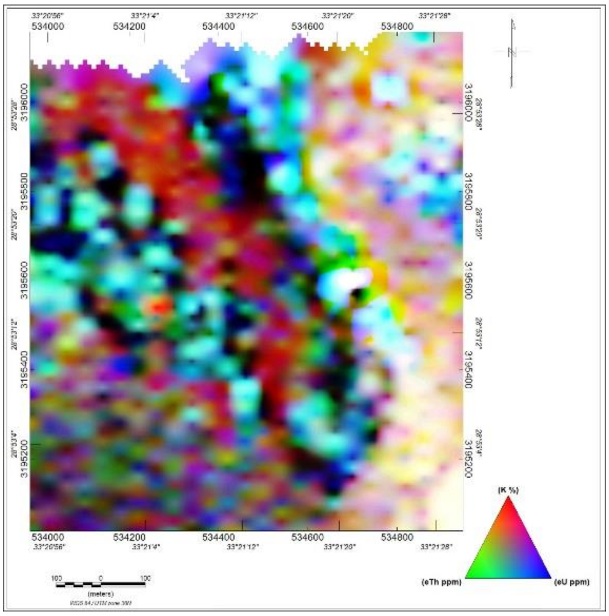

Fig. (7): False Colour Radioelement composite image map of Wadi Budra area, Southwestern Sinai, Egypt.

3.6. False-colour eU composite image map

The two relative concentrations of uranium with respect to both potassium and thorium are important diagnostic factors in the recognition of possible uranium deposits (IAEA, 1988). The examination of high zones of eU, eU/eTh, and eU/K indicates uranium enrichment over the other two natural radioelements (Th and K). As for economic potential, the most promising uranium anomalies should have a high eU abundance coinciding with high eU/eTh and eU/K ratios (Saunders and Potts, 1976). Meanwhile, a uranium composite image map (Fig. 8) is constructed to identify and outline the uranium anomalous zones. The red, green and blue colour combination was used to produce these image. An equal mixture of all three parameters (eU, eU/eTh and eU/K) produces white colour. The false colour eU composite image map (Fig.8) can provide useful information regarding the identification of anomalous zones of enriched uranium concentration. This map combines eU (in red) with the two ratios, eU/K (in blue) and eU/eTh (in green). Uranium anomalous zones are displayed as white regions on this map. The map shows that the white bright zones are mainly associated with anomalous lenses of Um-Bogma Formation, at the center, north and northeastern parts. So, these zones can be interpreted as reflecting good geochemical environments, favorable for the formations of uranium deposits and can, therefore, be used as exploration guides to search for additional uranium deposits (Duval, 1983).

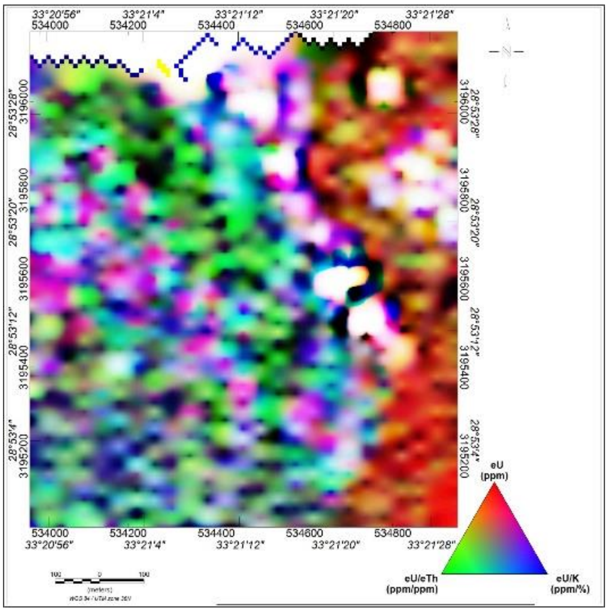

Fig. (8): False Colour eU composite Image map of Wadi Budra area, Southwestern Sinai, Egypt.

3.7. Uranium Index

The way to identify and outline the significant uranium anomalies, is on the basis of exceeding the three standard deviation levels above the means for single points, which showing local enrichment of eU. This type of statistical treatment of data provides means of searching for areas showing high uranium content within the study area.

Wadi Budra area (Table 1) yields, wide range of variations uranium and thorium channels. The calculated arithmetic mean of eTh is 6.71 ppm while that of eU attain to 3.96 ppm. Most radiometric anomalies are recorded over Um-Bogma Formation

Table (1): Summary of statistical treatments of gamma-ray spectrometric data of Wadi Budra area, Southwestern Sinai, Egypt.

	K	eU	eTh	Tc
Mean	0.70	3.96	6.71	5.56
Standard Error	0.02	0.27	0.14	0.19
Standard Deviation	0.70	9.42	4.79	6.74
Minimum	0.10	0.10	0.50	1.00
Maximum	5.80	203.90	50.30	135.10
$\bar{x}$+s	1.40	13.37	11.50	12.30
$\bar{x}$+2s	2.10	22.79	16.29	19.04
$\bar{x}$+3s	2.80	32.20	21.08	25.78

A local point equivalent uranium spectrometric anomaly map (Fig. 9) shows the location and magnitude of deviation from the mean for eU. It shows the anomalies that > $\bar{X}$+ S value have symbols, the anomalies that > $\bar{X}$+2S, and the anomalies that > $\bar{X}$+3S. This figure shows the location of uranium enrichment related to Um-Bogma Formation and some locations in the upper part of Adadia Formation.

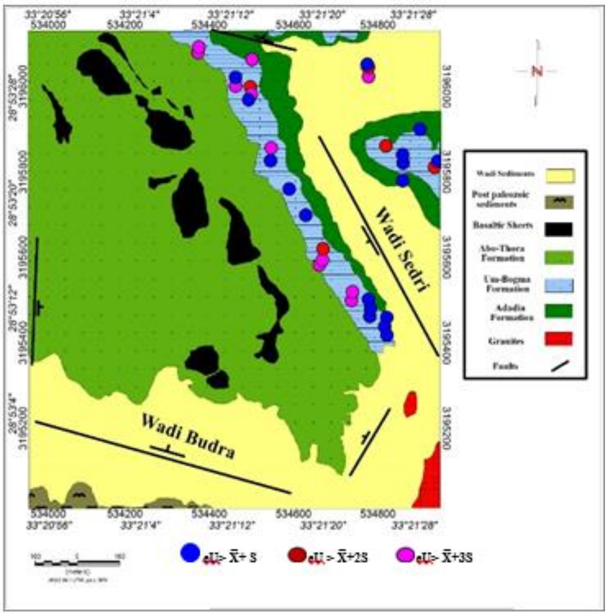

Fig. (9): Point anomaly equivalent uranium (eU) map in ppm of Wadi Budra area, Southwestern Sinai, Egypt.

3.8. Radiation exposure rate and equivalent dose rate

According to IAEA (1991), the radiation exposure rate (E) can be calculated from the apparent concentration of K (in %), eU (in ppm) and eTh (in ppm) using the following relation:

E (μR/h) = 1.505 K (%) + 0.653 eU (ppm) + 0.287 eTh (ppm).

It should be noted that, the calculated radiation exposure rate using this equation, come only from radioactive sources in the earth and does not include cosmic ray component or any cesium fallout on the ground. The radiation exposure rate can be converted to equivalent radiation dose rate in millisievert per year (mSv/y) through the use of another simple conversion factor (Grasty et al., 1991) as follows:

Dose rate (mSv/y) = 0.0833*exposure rate (μR/h).

Consequently, the radiation exposure rates and their equivalent radiation dose rates were calculated using the apparent radioelement concentrations of the three radioactive elements K, U and Th obtained through the present study. Finally, the radiation dose rate maps were constructed for the study area.

The radiation dose rate map (Fig 10) shows variable intensity values, ranging from 0.2 to 47 mSv/y.. By correlation with geologic map (Fig. 2), the low dose rate intensity levels (⩽ 0.5mS/y) were recorded over the Basalt, Abu-Thora Formation. The intermediate level (from 0.5 to1 mS/y) is recorded over Adadia and Eastern wadi deposits. The high dose rate intensity levels (⩾1 mS/y) are recorded over Um-Bogma Formation, and granitic rocks.

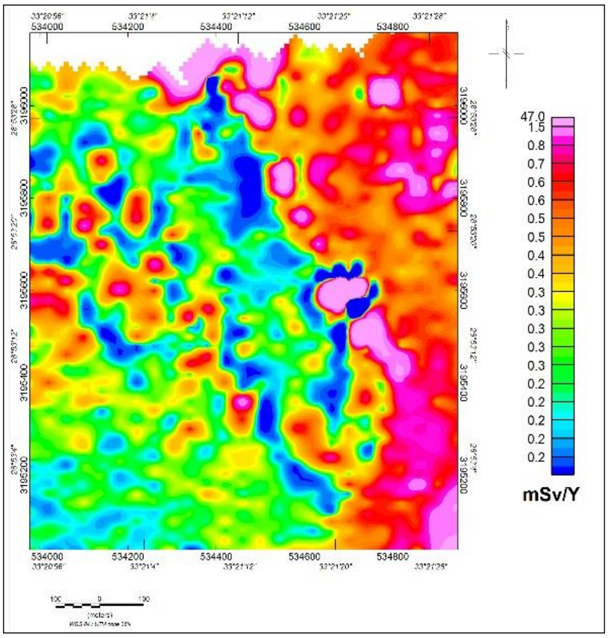

Fig. (10): Dose rate map of Wadi Budra area, Southwestern Sinai, Egypt.

The International Commission of Radiological Protection (ICRP) has recommended that, no individual should receive more than 5000 miilirems/year (50 mSv/y) from all natural and artificial radiation sources in his or her environment (IAEA, 1979). Currently, the recommended dose rate should not exceed one millisievert per year (IAEA, 2000). Concerning the study area, southwestern part remains on the safe side and within the maximum permissible safe radiation dose, without harm to the individual, but in the eastern and northeastern parts have dose rate intensity values more than 1.0 mSv/y. Therefore, these places are considered as harm to the individual.

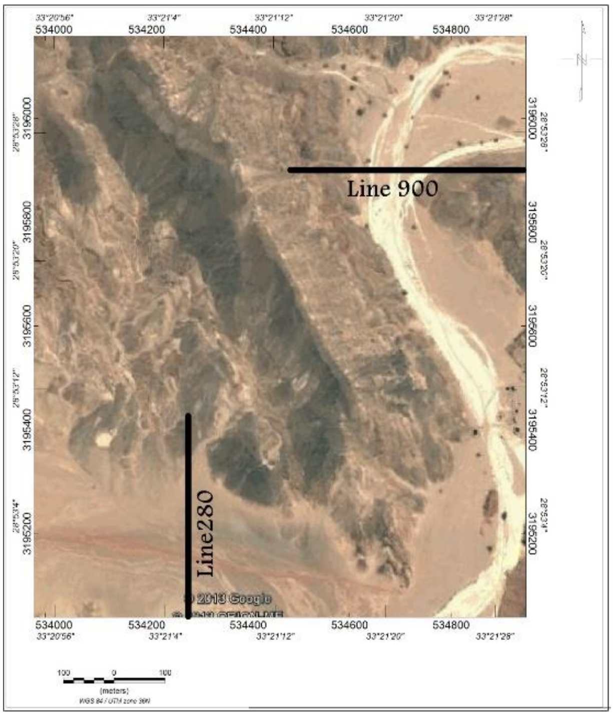

Fig. (11): Google earth map of selected Electromagnetic (EM) profiles, Wadi Budra area, Southwestern Sinai, Egypt.

4. GROUND HLEM METHOD

The Horizontal Loop Electromagnetic (HLEM) method has been extensively used over many years for locating conductive ore-bodies. Systems based on this technique have also been used to map faults and shear zones. Two Horizontal-loop Electromagnetic (HLEM) profiles (Fig. 12) were performed using four frequencies (110Hz, 440Hz, 880Hz, and 3520Hz) to detect the conductive bodies from shallow to considerable depths. The dip mode was auto mode in order to correct the effect of topographic changes and the elevation differences between receiver and transmitter.

Profile 900

The profile is measured from the east to the west from station 4945to station 4535 using coil separation 50m and the station intervals of 10m. The line passing throw wadi deposit in order to locate the best anomalous zone for conductive body (in Um-Bogma. The HLEM data acquired along this line indicate that two well-defined EM anomalies centered at stations 4565, and 4755 (Fig. 12). These anomalies are recorded along all frequencies (110, 440, 880, and 3520 Hz), this may reflect that the causative sources are good conductors, situated at shallow depths. The first anomaly is incompleted EM anomaly, where one positive peak is occurred (Fig. 12). Therefor, it cannot determine its parameter, because the calculation required negative peak between two positive peaks (shoulders). The slandered curves of Nair et al, 1974 were used to determine the parameters of the detected conductive bodies. We select the curves of frequency 440 Hz to calculate the parameters of the second anomaly that centered at station 4755. The shape of the In-phase and out -of- phase component reveals the causative source has a thin width with dip angle of 20 to the west. The depth to the top of the causative source is about 11m and the conductivity thickness is 18.9 seimens.

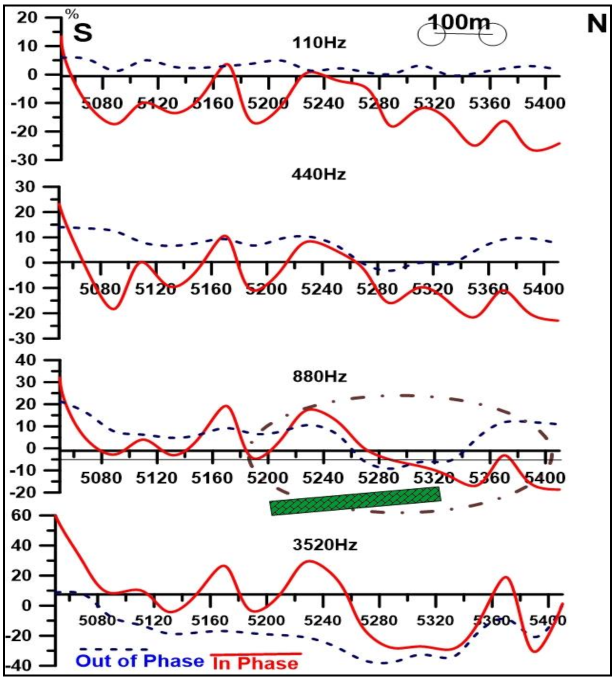

Fig. (12): Horizontal Loop Electromagnetic profile line (900E_W) Wadi Budra area, Southwestern Sinai, Egypt

Profile 280

This profile was selected to pass through wadi sediments in order to detect any possible mineralization associating with fault zone. It was performed from south to north between station 5050 and 5410 using coil separation of 100 m and station intervals of 20 m. the HLEM data acquired along this line indicate the presence of three negative peaks of the In-phase component that centered at stations 5090, 5190 and 5350 (Fig. 13). These anomalies are recorded along the four used frequencies, which may reflect the causative sources of three anomalies are good conductors situated at shallow depths. The quantitative interpretation of the HLEM of the anomaly at station 5350 exhibits the causative sources has a thin width, dip angle of 20 to the south, depth to top of 42 m and conductivity thickness of about 4.7 seimens.

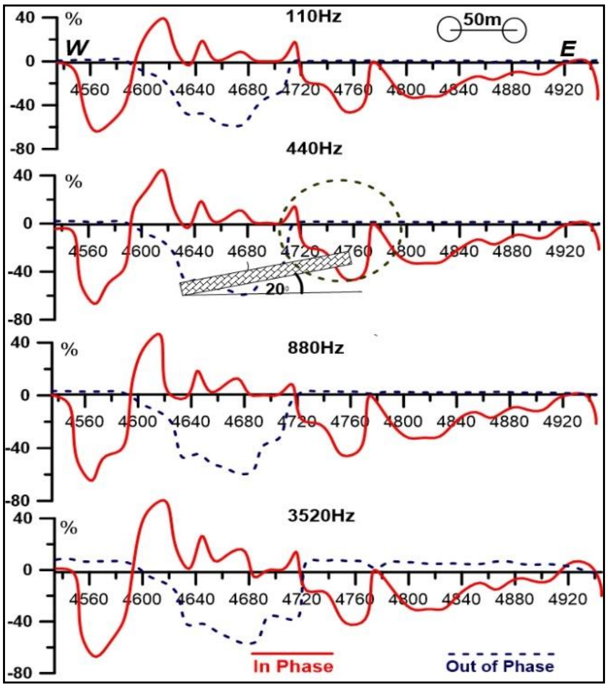

Fig. (13): Horizontal Loop Electromagnetic profile line (280 N-S) Wadi Budra area, Southwestern Sinai, Egypt.

5. SUMMARYAND CONCLUSIONS

The total-count radiometric contour map shows that, the radioactivity of the study area ranges from 1 μR/h over Wadi sediments and basaltic intrusions to 135μR/h over Um-Bogma formation. It appears that the general levels of radioactivity are controlled by the NNW to NW trends with the exposure of Um-Bogma formation, and the presence of younger granite in the southwestern part of the study area.

The (eU) radiometric map of the study area can be divided into four levels. The first level changes in values from 0.1 ppm to 1.8 ppm, locates mainly in the central part over basaltic sheet and the basaltic fragments trends to the NW direction. The second level ranging from 1.8 ppm to 2.6 ppm and located at the southwestern part and some scattered parts in Abu-Thora formation. The third varying between 2.7 ppm and 4 ppm. These values recorded over wadi sediments at the eastern part of study area. The fourth level (8 to 203 ppm) represents the highest values and is associated with Um-Bogma Formation, upper part of Adadia Formation and younger granite at the extreme southeastern part.

The equivalent thorium (eTh) map shows that values varying from 2.1 ppm to 50.3 ppm, with an average value of about 6.5 ppm. The lowest values (1ppm to 5.1ppm) are located at the central and western parts of the study area. The intermediate values (5.1ppm to 9 ppm) are located in scattered zones in Abu-Thora Formation in the western part and also in the eastern part at Wadi Sedri due to granite wash, and it`s weathering products. While, the highest values (9 to 50 ppm) recorded over the eastern parts of the study area and associated with Um-Bogma Formation, upper part of Adadia Formation and granites.

The Potassium (K) map shows values varying from 0.1 % to 2.5 %, with an average value of about 0.6 %. The highest values are located at the eastern parts of the study area. Meanwhile, the lowest values are situated at the middle and western parts of the study area.

Um-Bogma Formation recoded fairly high radioactivity ranges: TC (2.2-135.1 μR/h), eU (1.5-203.9 ppm) with mean value 20.88ppm, eTh (1.2-50.3 ppm) and K (0.1-3.7%). Despite the high eU/eTh mean (1.78), which reflects uranium enrichment, the mean of eU/K ratio (40.92) indicate very high U-mobilization and enrichment. Thus, this Formation is considered a promising target for uranium exploration.

The radiation dose rate map shows variable intensity values, range from 0.2 to 54.8 mSv/y. By comparison with geologic map, the lowest dose rate intensity levels ($\leqslant$ 0.5mS/y) were recorded over the Basalt, and Abu-Thora Formation, while the intermediate level (from 0.5 to1 mS/y) was recorded over Adadia and Eastern wadi deposits. The highest dose rate intensity levels ($\geqslant$1 mS/y) which are considered as high levels of radiation were recorded over Um-Bogma formation, and granitic rocks.

Following these methods by (HLEM method revealed that. The shape of the in-phase component indicate that the conductive body has a thin width with nearly low dip to the west direction, good conductivity thickness product and shallow depth11m. Applying this method on the Southern part of the area gives the conductive body at depth 42 m with low conductivity thickness product.

REFERENCES

Afifi, S.Y. (1991): Geochemical investigation of some radioactive Lower Carboniferous sedimentary rocks of Wadi Nasib area,West central Sinai, Egypt, M. Sc. Thesis, Suez Canal Univ., Egypt. 253 p.

Barron, T. (1907): The topography and geology of the peninsula of Sinai (Western portion). Egypt. Surv. Dept., Cairo, 24pp.

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

Dabbour, G.A. and Mahdy, M.A. (1988): Mineralogical studies on the Carboniferous uraniferous sediments in west central Sinai, Egypt.4. Th. Conf. Nucl. Sci. and Appl., Egyp.1 (p.201 – 316), pp. 230 – 237

Darnely, A.G. and Ford, K.L., 1989. Regional airborne gamma -ray surveys, a review. Proceedings of Exploration, 87; Third Decennial Inter –national 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.

Duval, I.S. (1983): Composite colour images of aerial gamma-ray spectrometric data. Geophysics, Vol. 48, No. 6, pp. 722-735.

El Aassy, I. E., Botros, N.H, Abdel Razik, A, Sherif, H, Al Moafy, A., Atia, K., El Terb, R. and Ashami, A.S. (1986): Report on the prospection and proving of some radioactive occurrences in West Central Sinai, Egypt. Internal Report, Nuclear Materials Authority (NMA), Cairo.

El Agami, N.L. (1996): Geology and radioactivity studies on the Paleozoic rock units in the Sinai peninsula, Egypt Ph.D. Thesis, Fac. of Science, Mansoura Univ., Egypt, 302p

El Rakaiby, M.I., El Aassy, I.E. (1990): Structural interpretation of Paleozoice Mesozoic rocks, Southwestern Sinai, Egypt. Ann. Geol. Surv. Egypt XVI.

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", (1979): Gamma-ray surveys in uranium exploration. Technical Report Series No. 186, Vienna, Austria, 90p.

International Atomic Energy Agency "IAEA", (1991): Airborne gamma-ray spectrometer survey. Technical Reports Series No. 323, Vienna, Austria, 97 p.

International Atomic Energy Agency "IAEA", (2000): From 5th International Conference on High Level of Natural Radiation, Munich

International Atomic Energy Agency (IAEA), (1988): Geochemical exploration for uranium.

Technical Reports Series No. 284, Vienna, Austria, 96 p

Kora, M. (1984): The Paleozoic outcrops of Um Bogma area, Sinai, ph. D. Thesis, Mansoura Univ., Egypt, 208 pp.

Kora, M., El Shahat, A. and Abu Shabana (1994): Lithostratigraphy of the manganese bearing Um Bogma Formation. West Central Sinai, Egypt.

Mart, J. and Sass, E. (1972): Geology and Origin of the Manganese Ore of Um-Bogma, Sinai, Econ. Geol. 67, 145-155.

Omara, S. and Conil, R. (1965): Lower Carboniferous Foraminifera from Southwestern Sinai, Egypt. Annals Soc. Geol. Belgique 88p, 221 – 240.

Sarma, D.D. and Koch, G.S. (1980): A statistical analysis of exploration geochemical data for uranium: Mathematical Geology, V.12, No.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.

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

Soliman, M.S. and Abu El-Fetouh M.A. (1969): Petrology of Carboniferous sandstone in west central Sinai. J. Geol.UAR 13, 61 – 143.

Weissbrod, T. (1969): The Paleozoic outcrops in south Sinai and their correlation with those of southern Israel. In: The Paleozoic of Israel and adjacent countries. Bull. Geol. Surv. 17, pat. 2, 2, 32pp.