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DELINEATION OF SURFACE RADIOACTIVE OCCURRENCES USING AERO-SPECTROMETRIC MEASUREMENTS, EASTERN QENA, CENTRAL EASTERN DESERT, EGYPT

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تحديد التواجدات الإشعاعية السطحية باستخدام القياسات الجوية الطيفية فى وسط الصحراء الشرقية، مصر

الخلاصة: تتميز المسوحات الإشعاعية الطيفية الجوية بقدرتها علي تغطية مساحات شاسعة في اقل وقت ممكن، لهذا السبب قد استخدمت بيانات المسوحات الجوية الخاصه بشركة ايرو–سيرفيس لسنة ١٩٨٤ المكونه من العد الكلي، تركيز البوتاسيوم، تركيز اليورانيوم المكافيء بالإضافه إلي تركيز الثوريوم المكافيء لمنطقة الدراسة. تم معالجة ورسم و تفسير هذه البيانات بإستخدام الحسابات الإحصائية المناسبة للتفسيرات الكيفية و الكمية. قد كان من الواضح في خرائط الأطياف الإشعاعية الجوية المختلفة أن مكون الضوي و كذا طفلة الدخلة يتميزان بأعلي القيم في تركيز اليورانيوم المكافيء، اليورانيوم المكافيء بالنسبة للثوريوم المكافيء و كذا بالنسبة لتركيز البوتاسيوم بحيث سجلا (٩ و ٤,٤ جزء في المليون جزء مكافيء يورانيوم) ، (٢,٢ و ١,٤) و (١٨,٤ و ١٢) بالترتيب. كما تبين أن تركيزات اليورانيوم الواعده كانت في مكون الضوي و كذا طفلة الدخلة بالإضافة إلي بعد الشاذات في طفلة الإسنا و مكون الطيبة و أيضا العسوية. كما بين التتبع الأرضي لهذة الاماكن ذات التركيزات العاليه لليورانيوم المكافيء بإستحدام جهاز جي – اس ٥١٢ ، أن مكون الضوي و طفلة الدخلة سجلا (١١٢ و ٢٥,١ جزء في المليون جزء مكافيء يورانيوم) بالترتيب.

ABSTRACT: *The airborne gamma ray spectrometric data, are mostly used in covering large areas in short time. The area under investigation was surveyed by Aero-service Company 1984, and the acquired data were the (TC, K, eU and eTh). These sets of data are processed, gridded and interpreted qualitatively and quantitatively, after applying the proper statistical calculations. It is clear from the different aero-spectrometric maps that the Duwi Formation and Dakhla shale show the mean values of eU (9 & 4.4 ppm eU), eU/eTh (2.2 & 1.3) and eU/K as (18.4 & 11.6), respectively. In addition to the uranium province map, which delineate, the Duwi Formation, Dakhla shale and some spots in Esna shale, Thebes Formation and Issawia Formation are the main uranium province zones. Finally, the ground following upon the most provinces zones as Duwi Formation and Dakhla shale using the (GS-512) spectrometer could give values of (112 and 25.1 ppm eU), respectively.*

INTRODUCTION

The airborne gamma ray spectrometry is a very important method that provide measuring of the equivalent uranium (eU), the equivalent thorium (eTh), the potassium (K) and (TC) total counts, these measured variables vary with radioelements concentrations changes according to lithological variations, (Ammar and Rabie, 1991). It could lead directly to uranium and thorium mineralization, also for Sn, W, REE, Nb and Zr. In addition to, Au, Ag, Hg, Co, Ni, Bi, Cu, Mo, Pb and Zn mineralization by in direct ways, as they could be associated with the radioelements causing a change in their ratios in the surrounding environment, (Darnley and Ford, 1989).

The presence of the considerable and remarkable exposures of the Duwi Formation and Dakhla shale, while these formations are enriched with radioactive minerals as interbeds of the uranium bearing phosphates.

Area of study

The area under study (Fig. 1) is locates at east of Qena city in the Eastern Desert of Egypt, it's enclosed betwen latitudes 25º 58′ 3.79″ N & 26º 19′ 60″ N and longitudes 32º 50′ 42.58″ E & 33º 14′ 60″ E. The sedimentary rocks cover all the study area as no igneous exposures.

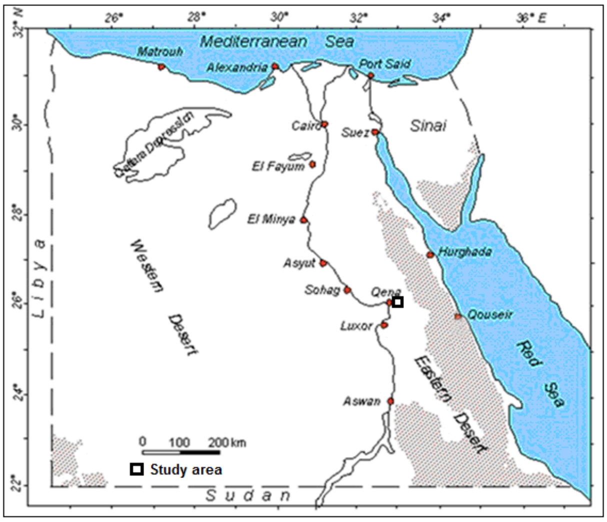

Figure (1): Location of the area under study.

Geologic settings

The study area extends to 40 km in northern and eastern directions from Qena, the geologic setting could be summarized in two terms; litho-stratigraphic and structural settings. There are many previous geologic studies on the area under study as Youssef (1957), Said (1961 and 1962), Abdel Razik, (1972), Fans (1974), Abdel Gawad (1980), Issawi (1983 and 1989) and Salwa et al. (2011).

The litho-stratigraphic setting of the surveyed area could be characterized by the out cropping of the Cretaceous, Tertiary and Quaternary sediments. In addition to, absence of igneous out cropping. The surface and subsurface litho-stratigraphic units (Figs. 2 & 3) could be sorted according to the geologic age descending from bottom to top as follow:

1- Nubia Formation

a- Taref sandstone.

b- Quseir clastics (variegated shale).

2- Duwi Formation.

3- Dakhla shale.

4- Tarawan chalk.

5- Esna shale.

6- Thebes Formation.

7- Issawia Formation.

8- Qena Formation (Pre-Nile).

9- Quaternary fanglomerates.

10- Quaternary wadi sediments.

The general structural setting of the area under study could be summarized into the dominant trends of the surface structural lineaments and their representative rose diagram as shown in (Figs. 2 & 4). Careful examination of the surface structural lineaments imposed in the study area using the rose diagram, show that the dominant trends are NE-SW, NNW-SSE and NW-SE. while, the less dominant trends are N-S, NNE-SSW and WNW-ESE.

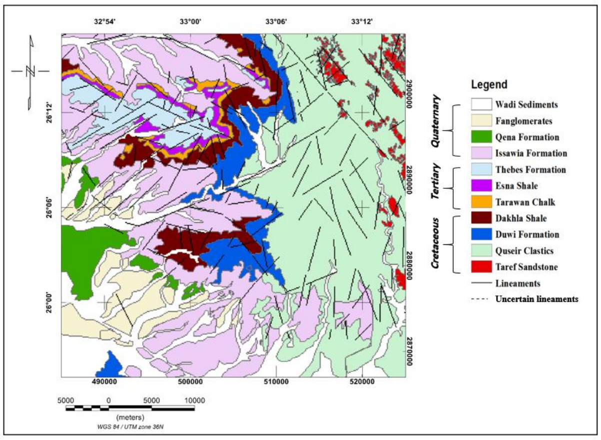

Figure (2): Compiled surface geological map of East Qena, Central Eastern Desert, Egypt.

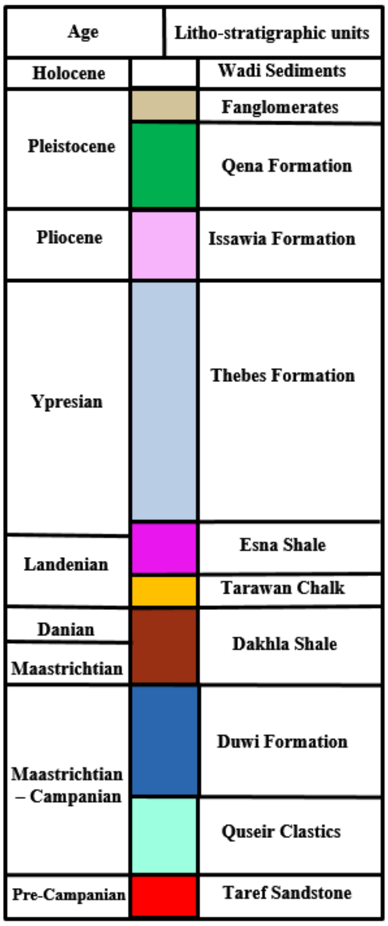

Figure (3): Subsurface litho-startigraphic units prevailing East Qena, Central Eastern Desert, Egypt (after Abdel Gawad, 1980).

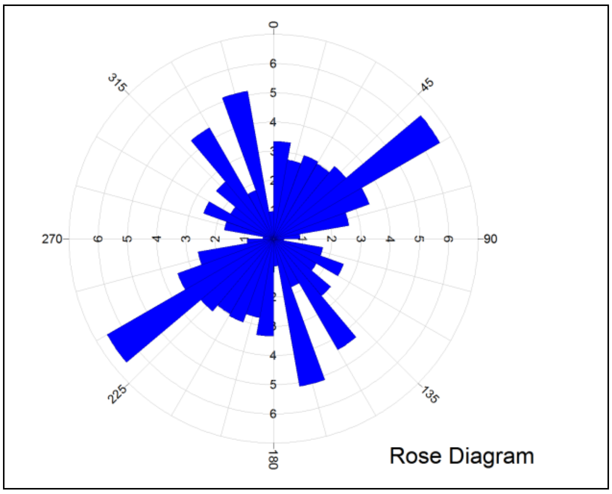

Figure (4): Rose diagram of surface structural lineaments of East Qena, Central Eastern Desert, Egypt.

Instrumentation and Data Acquisition

The gamma ray spectrometer used in this survey is composed of sodium iodide (NaI) activated by thallium detectors in 256- channels system, including the shielded detectors from the terrestrial to measure the radon in atmosphere. The primary detector packages comprise groups of NaI detectors of individual dimensions (10.2x10.2x40.6 Cm) (4x4x16 inches, 256 cubic inches), each coupled to an individual photomultiplier tube with an integral video driver (preamplifier). Groups of crystals (generally four) comprise a detector package, with each crystal in intimate contact to form a detector slab of 16x16x4 inches (1024 cubic inches). Each package is thermally insulated, with thermostatic heater control to assure system spectral stability (Aero- Service, 1984). The secondary or atmospheric (upward-looking) detector consists of two groups of sodium iodide (NaI), thallium activated detectors of individual dimensions 4x4x16 inches. Total crystal volume of the secondary detector is 512 cubic inches (8.4 liters).

These gamma ray spectrometric measured data carried out by Aero-Service Division of the Western Geophysical Company of America in 1984, conducted along parallel traverse flight lines oriented in a NE-SW direction, with an azimuth of 45º and 225º from the true north with 1 km in line spacing and about 92.65m station separation. (Aero Service, 1984). The conducted gamma ray spectrometric data provide valuable information about four variables, named as total counts (TC) in unit of radiation (Ur), potassium (K) in (%), equivalent uranium (eU) and equivalent thorium (eTh) in (ppm), as shown in (Fig. 5).

The ground verification is carried out using the GS-512 spectrometer in such a way to check the high spectrometric values and its associated surface lithological units from the spectrometric point of view, this spectrometer detect the total counts in (μR/h), potassium K in (%), equivalent uranium eU in (ppm) and equivalent thorium eTh in (ppm).

The GS-512 spectrometer uses Cesium 137 as a reference radiative source, which has the ability to detect the radioactivity between zero and 750 ppm, and over this range it gives values stated as out of range, States Geo (2003). While, the areas under study has no source of radiation that could exceed the 750 ppm, so it was appropriate for carrying out the ground spectrometric check in. This device was calibrated in the nuclear materials authority (NMA) calibration four pads to detect the stripping ratios and for sensitivity purposes.

Methodology

a- Aero-spectrometric maps

The gamma ray spectrometric data provide the total counts of the gamma radiation in (Ur), besides the distribution of the three different radioactive elements K in (%), eU and eTh in (ppm), in addition to three ratios of the radioelements as eU/eTh, eU/K and eTh/K as shown in (Figs. 5 to 11) respectively. These data have been subjected to qualitative and quantitative interpretations to differentiate between various lithological units from the gamma ray spectrometric point of view.

b- Composite imaging

The Ternary colour composite image map is generated by modulating the red, green and blue phosphors or yellow, magenta and cyan dyes to the radio elements concentration values as K, eTh and eU to produce the radio elements color composite image as in (Fig. 12), or a radio element and its ratio to the other radio elements as i.e. eU, eU/eTh and eU/K for eU colour composite image map in (Fig. 13). Using the same manner eTh and K colour composite image maps could be generated as shown in (Figs. 14 and 15), respectively.

These colour composite images have a great interference by differentiating the different lithological units and the contacts between contrasting lithology, depending on each particular lithology characterized by signature through the radio elements concentrations and their ratios to each other, (Duval, 1983). Also it could be used in geochemical mapping and mineral exploration, (Dickson and Scott, 1997).

c- Factor Analysis Technique

It has been used before on airborne gamma-ray spectrometric data by (Duval 1976, Wecksung 1982, Mostafa 1988 and Mostafa et al. 1990). Act as a multivariate statistical technique that combine (T.C, K, eU, eTh, eU/eTh, eU/K and eTh/K) into three factors (F1, F2 and F3), these factors could be interpreted into geological reasoning.

These factors are clustered after being rotated using the varimax method. The main goal for this technique is just reducing the independent variables into minimum numbers, which adequately described the data (Klovan 1968). The factor analysis technique consists of three major steps; the correlation matrix, factor extraction and factor rotation. The correlation matrix measures the relation between the variables and each other. While, the factor extraction determines how many factors are needed to deal with the pattern values in the correlation matrix. Factor loadings are then calculated by the coefficients in the (R) matrix using a numerical procedure.

Table (1) represents the correlation matrix of the spectrometric variables of the area under study. While, Table (2) expresses the three factors extracted from Table (1) after being rotated using the varimax method. The estimated scores of the three factors (F1, F2 and F3) are represented in three colored grid maps as shown in (Figs. 16, 17 and 18) respectively. The first factor (F1) can be recalled as a factor of integrated radioactivity. The second factor (F2) and the third factor (F3) are recalled as factors of differentiating rock types. The correlation matrix as shown in Table (1), illustrate that the total counts (TC) is highly positively correlated with the (eTh) as (66%), moderately with the (K %) by (50%). While, it shows low correlation with (eU, eU/eTh, eU/K and eTh/K) by (20, 5, 5 and 41 %) respectively.

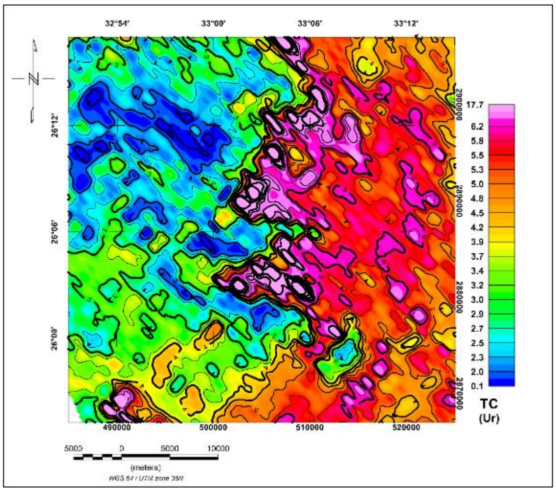

Figure (5): Filled color contour map of Total Count (T.C.) in Ur.

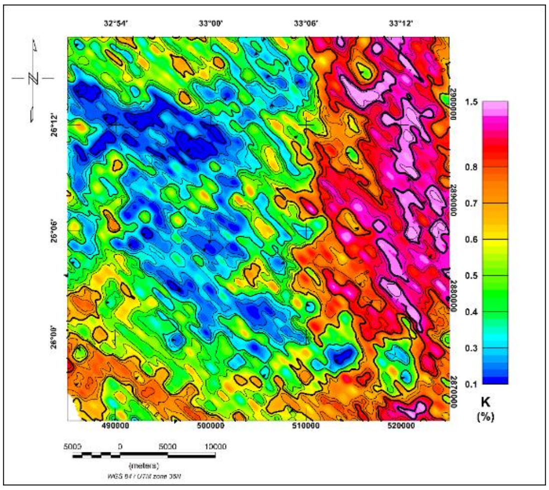

Figure (6): Filled color contour map of potassium (K) in (%).

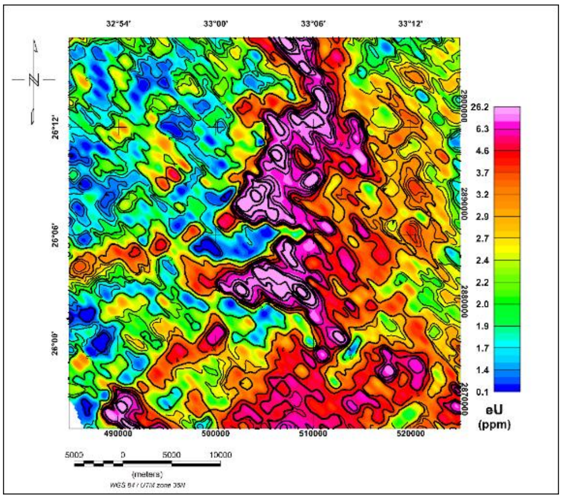

Figure (7): Filled color contour map of equivalent uranium (eU) in (ppm).

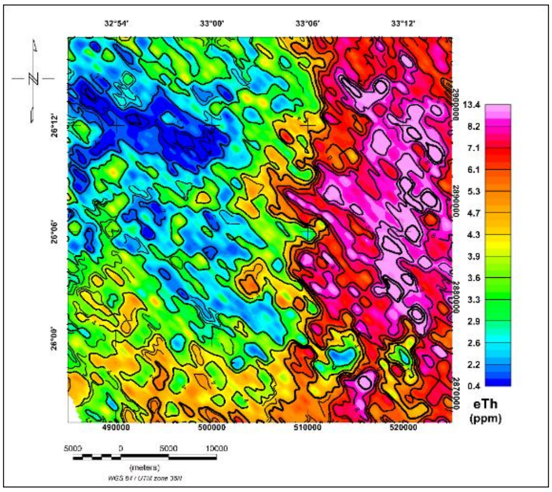

Figure (8): Filled color contour map of equivalent thorium (eTh) in (ppm).

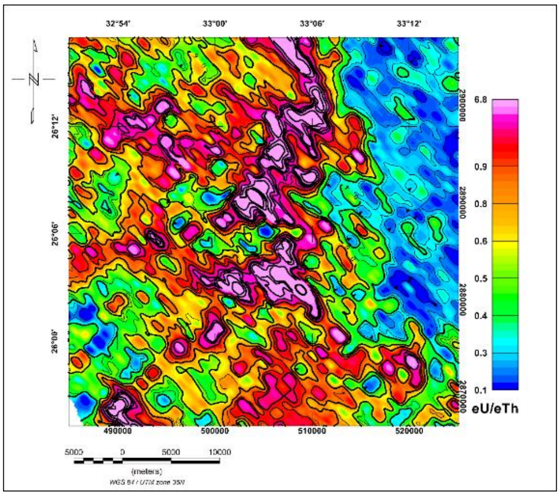

Figure (9): Filled color contour map of (eU/eTh) ratio.

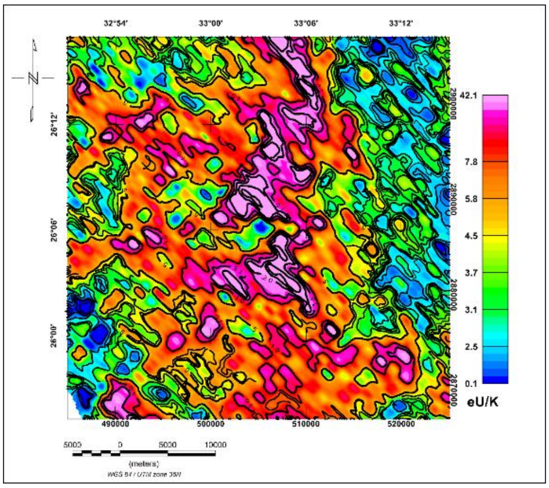

Figure (10): Filled color contour map of (eU/K) ratio.

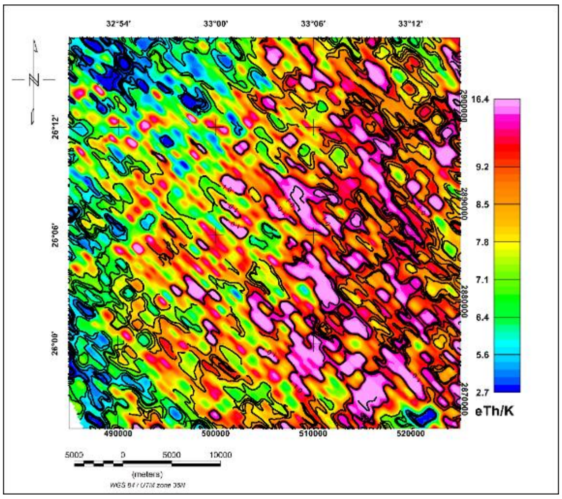

Figure (11): Filled color contour map of (eTh/K) ratio.

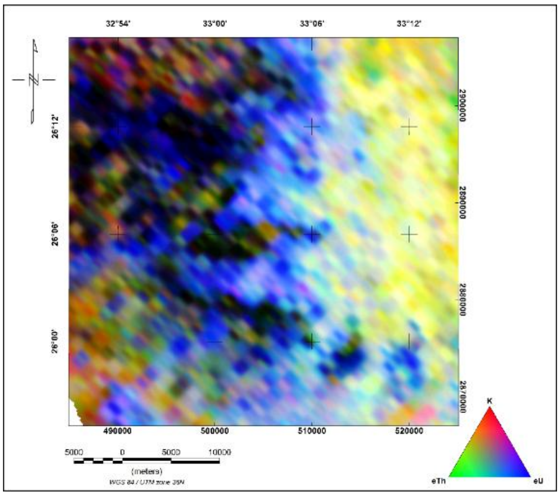

Figure (12): False color radioelements composite image map.

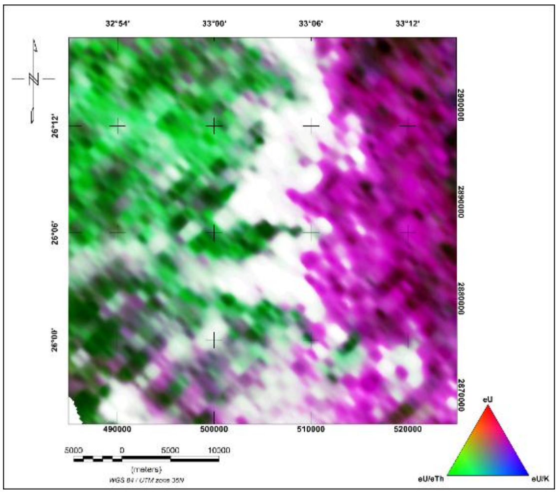

Figure (13): False color equivalent uranium composite image map.

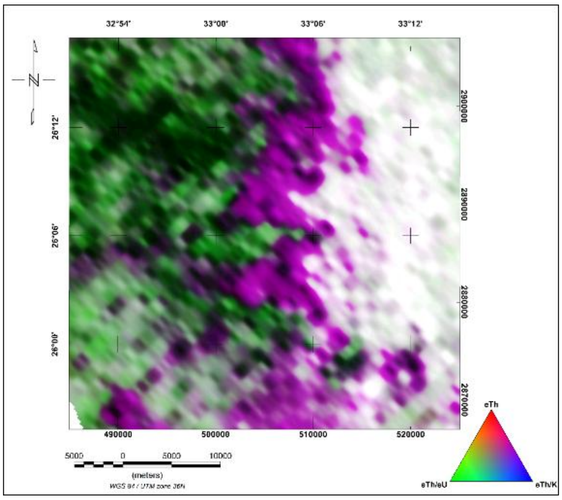

Figure (14): False color equivalent thorium composite image map.

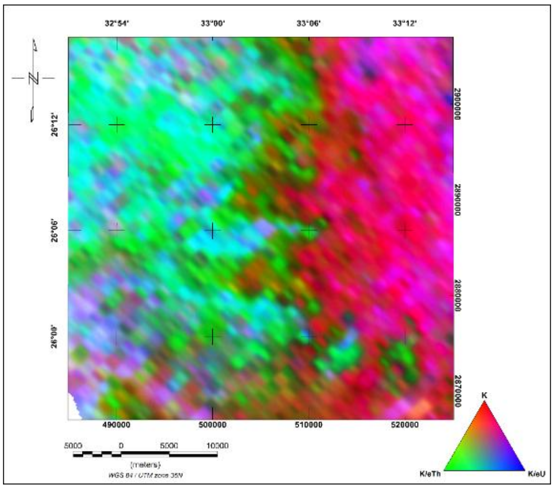

Figure (15): False color potassium composite image map.

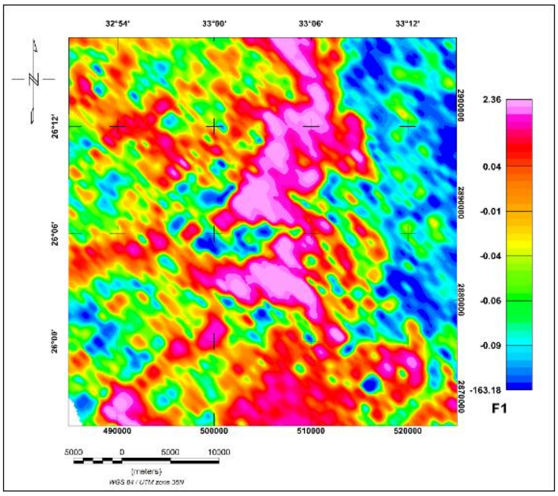

Figure (16): Filled color map of the first factor (F1).

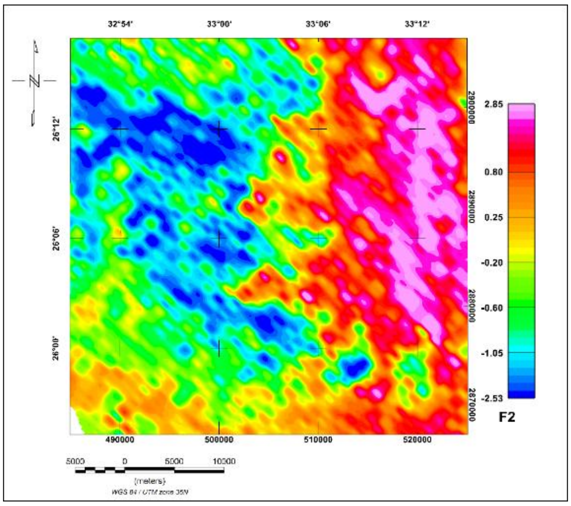

Figure (17): Filled color map of the second factor (F2).

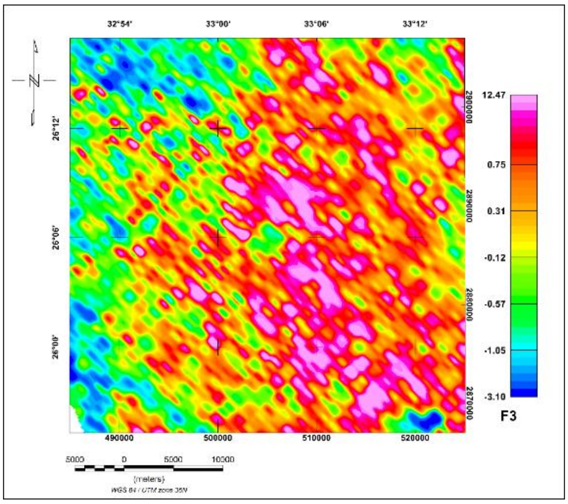

Figure (18): Filled color map of the third factor (F3).

Table (1): represents the correlation matrix of the spectrometric variables

Variables	T.C	K	eU	eTh	eU/eTh	eU/K	eTh/K
T.C	1.00						
K	0.50	1.00					
eU	0.20	-0.002	1.00				
eTh	0.66	0.81	0.04	1.00			
eU/eTh	0.05	-0.31	0.85	-0.02	1.00		
eU/K	0.05	-0.03	0.72	-0.009	0.97	1.00	
eTh/K	0.41	-0.07	0.08	0.48	0.008	0.03	1.00

Table (2): Varimax factor loadings matrix for the seven variables.

Variables	F1	F2	F3
T.C	0.10	0.72	0.43
K	-0.03	0.95	-0.24
eU	0.90	0.06	0.09
eTh	-0.02	0.91	0.32
eU/eTh	0.99	-0.02	-0.02
eU/K	0.95	-0.01	-0.01
eTh/K	0.02	0.13	0.97

The (eU) show highly positively correlation with (eU/eTh and eU/K) with (85 and 72 %) respectively. While, negatively weakly correlation with the (K %) as (-0.002 %). The (eTh) emphasizes positively highly correlation with (K %) as (82 %). But shows positively moderately correlation with the (eU and eTh/K) with (42 and 48) %. In addition to the (eU/eTh) which gives positively highly correlation with the (eU/K) by (97%).

The three factors extracted from Table (1) (F1, F2, and F3) after their being rotated by the Varimax method as shown in table (2), could be described as follow; (F1) shows positively highly loading for (eU, eU/eTh and eU/K) with (90, 99 and 95 %) respectively. While the (F2) gives highly positively loading for (TC, K and eTh) by (72, 95 and 91 %) respectively. Furthermore, (F3) reflects highly positively loading with (eTh/K) with (97%).

In such a way to display overall radioactive elements spatial distribution for the area under investigation, the factor scores (F1, F2 and F3) are combined in colour composite image map (Fig. 19) as (red, green and blue). The careful examination of the compiled colour composite image map of the three factors as in (Fig. 19), could summarize into identification some rock units while others were hard to differentiate in a comparison with the surface litho-stratigraphic map of the area under study, so from the aero-spectrometric point of view the interpreted surface litho- radiometric unit map is generated as shown in (Fig. 20).

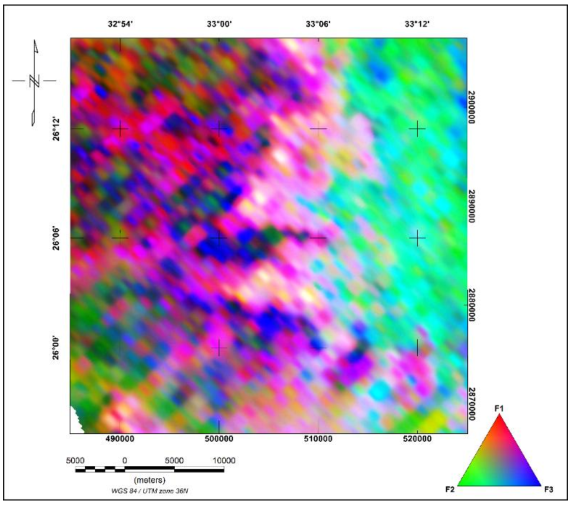

Figure (19): False color composite map of F1, F2 and F3 factor scores.

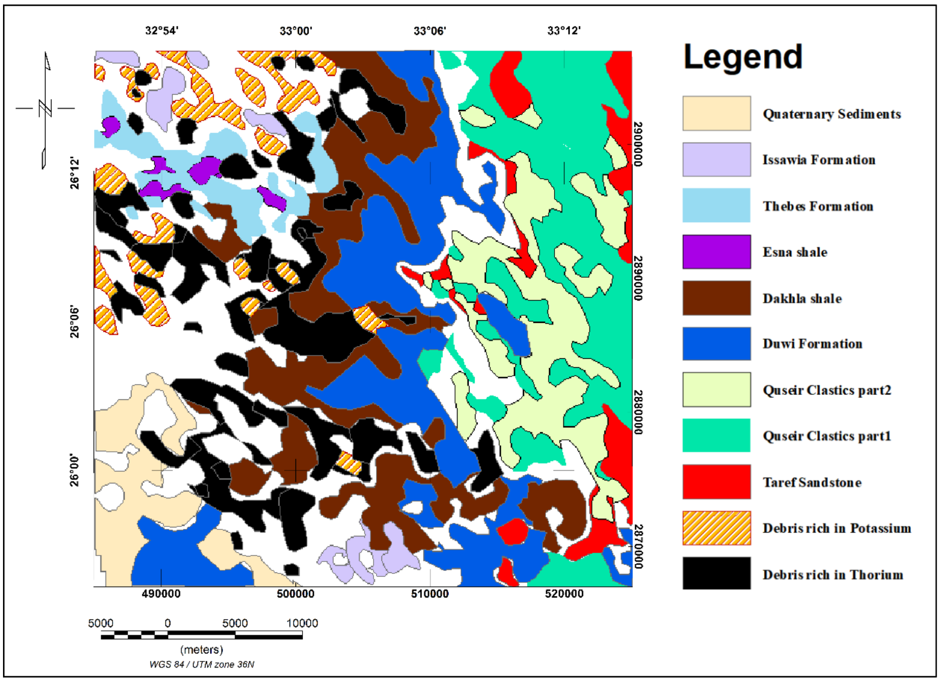

Figure (20): Interpreted litho-radiometric units (ILRU) map of the study area.

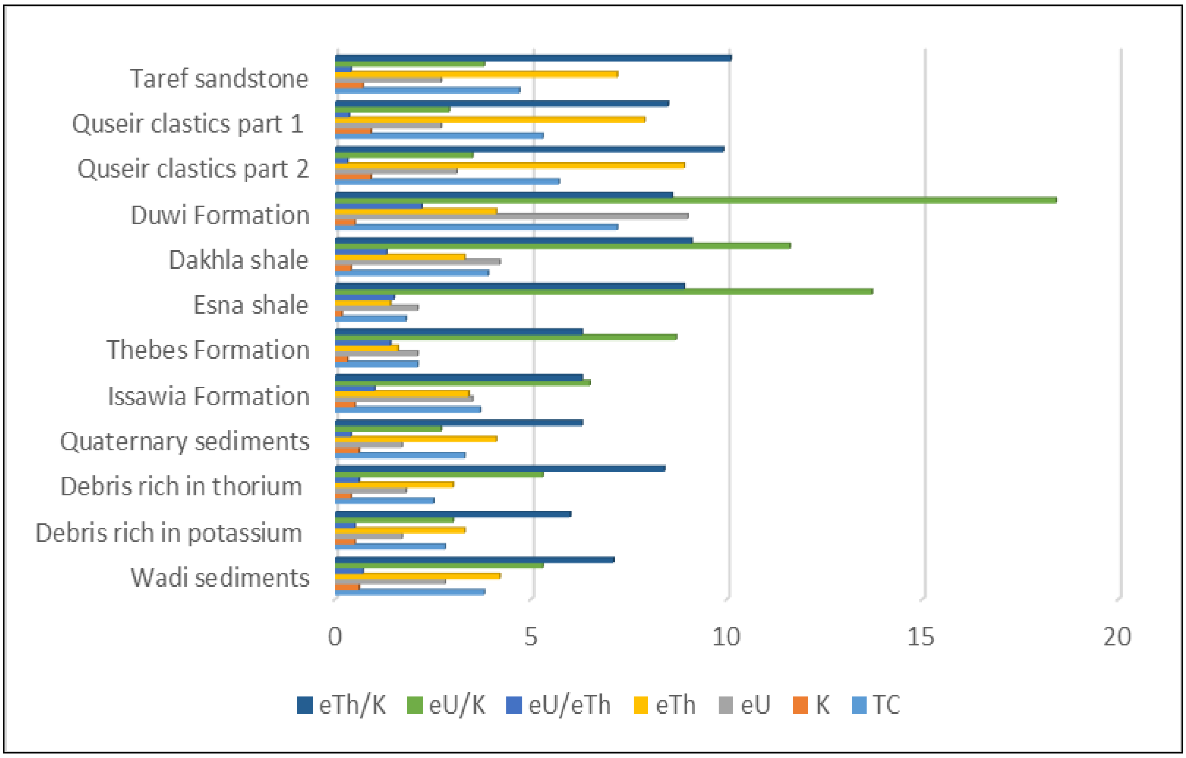

Figure (21): Frequencies histograms of mean values of the aero-spectrometric variables and the correspondence ILR units of the study area.

d- Statistical calculations

The aero-radioactivity pattern is discussed from the statistical point of view by determining the minimum (min), maximum (max), mean (X), standard deviation (S) and the coefficient of variability (CV) for each surface lithologic unit. While,

CV % = (S/X) x 100

These statistical calculations applied on the TC, eU, eTh, K, eU/eTh, eU/K and eTh/K variables correspond to each surface lithologic unit extracted from the ILRU map of the area under study, which generated in Table (3), and represented by the frequency histogram as shown in (Fig. 21).

e- Uranium provinces

One of the best aims in the gamma-ray spectrometric data interpretation is delineating areas of uranium enrichment rather than broad areas of high uranium content and decline the false and misleading anomalies (Saunders and Potts, 1976). The high uranium concentrations taken in consideration with the ratios of eU/eTh and eU/K, the high values of these three variables could lead to anomalous uranium zone (Darnley, 1973).

These zones could be delineates using statistical calculations as the values equal to or exceeds 2 or 3 times standard deviation over the mean value (X+2S or 3S) of eU, eU/eTh and eU/K variables for each certain rock unit as in Table (3). All values of located beyond (X+2S) and (X+3S) are significantly important. (Gharieb and Gouda, 2007).

Qualitative and quantitative interpretation

Total Counts (TC) Contour Map

The investigation of the total count contour map (Fig. 5) shows values range from 0.1 to 17.7 (Ur), this range could be divided into high, moderate and low zones according to the TC values. The high zone of total counts ranges from 5-17 (Ur), is related to the Duwi formation and the Quseir clastics occupied by the red to magenta colour, while the moderate zone range from 3-5 (Ur), associated with Taref sandstone, Dakhla shale, Issawia Formation, Qena Formation and Qena fanglomerates marked by green to yellow colours. The low zone of TC values ≤ 3 (Ur), correlated with the corresponding lithological units of Tarawan chalk, Esna shale and Thebes Formation colored by cyan to blue colours.

Potassium (K %) Contour Map

The careful examination of the K % colored contour map (Fig. 6), shows that the distribution of the K concentration over the area under study could be classified into three zones as high, moderate and low concentration zones. The high zone of (K %) range from 0.75 to 1.5 (%), associated mainly with the Quseir clastics and Qena fanglomerates, while the moderate K concentrations range from 0.4 to 0.75 (%), associated with Taref sandstone, Duwi Formation, Dakhla shale, Qena Formation, Qena Fanglomerates and the wadi sediments across drainage patterns. The last zone characterized by low potassium concentrations up to 0.4 (%), related lithologically to Tarawan chalk, Esna shale, Thebes Formation and Issawia Formation.

Equivalent Uranium (eU) Contour Map

The equivalent uranium colored contour map (Fig. 7) of the area under study could emphasizes that, the high uranium concentrations are associated with the Duwi Formation and Dakhla shale with an eU values range from 4 -26.2 (ppm), while the moderate uranium concentrations are related to Quseir clastics, Esna shale and along drainage patterns across the study area with a range values from 2 – 4 (ppm). The Taref sandstone, Tarawan Chalk, Thebes Formation, Issawia Formation, Qena Formation and Qena fanglomerates are characterized by low uranium concentrations with values up to 2 (ppm).

Equivalent Thorium (eTh) Contour Map

The equivalent thorium colored contour map (Fig. 8), shows that the Quseir clastics and Taref sandstone are associated with high thorium concentrations range from 6 to 13.4 (ppm), while Duwi Formation, Qena Formation Qena fanglomerates and the wadi sediments across the area under study show moderate thorium concentrations with values range from 3 to 6 (ppm). The low thorium concentration zone is associated with the Dakhla shale, Tarawan chalk, Esna shale, Thebes Formation and Issawia Formation with values up to 3 (ppm).

Equivalent Uranium/ Equivalent Thorium (eU/eTh) Contour Map

By examination of the equivalent uranium ratio to the equivalent thorium colored contour map (Fig. 9), the high ratio prevails the Duwi Formation, Dakhla shale, Esna shale, Thebes Formation and the wadi sediments across the drainage patterns of the study area, these high values of ratio range from 1 to 6.8, while the Issawia Formation, Qena Formation and Qena fanglomerates occupy the moderate ratio values range from 0.4 to 1. The low ratio values distributed along Taref sandstone and the Quseir clastics with values up to 0.4.

Equivalent Uranium/ Potassium (eU/K) Contour Map

The eU/K colored contour map (Fig. 10), show a high correlation with the previously mentioned eU/eTh colored contour map especially in the distribution of the high, moderate and low ratio values as, Duwi Formation, Dakhla shale, Esna shale and Thebes Formation, but the Issawia Formation give a high ratio values unlike the eU/eTh map, these high ratio values range from 6 to 42.1. Also, the moderate ratio values range from 3 to 6, related to some parts of the Quseir Clastics, Qena Formation and Qena fanglomerates, finally the low eU/K parts are associated with Taref sandstone and parts of Quseir Clastics, with values up to 3.

Equivalent Thorium/ Potassium (eTh/K) Contour Map

The eTh/K colored contour map (Fig. 11), elucidates high ratio values range from 9 to 16.2 are associated with Taref sandstone, Quseir Clastics, Duwi Formation and Dakhla shale, while the moderate ratio values range from 6.5 to 9 are associated with Tarawan chalk, Esna shale, Thebes Formation, Issawia Formation and Qena Formation. The low ratio values occupy the wadi sediments across the drainage patterns and Qena fanglomerates with values up to 6.5, so overall the area under study show that, the thorium exceeds the Potassium concentrations.

Radioelements Colour Composite Image

The careful examination of this map in (Fig. 12) could delineate that the Duwi Formation, Dakhla shale, Esna Shale, Thebes Formation and some Wadi sediments that extends along the drainage pattern from center of the study area toward the western corner, are occupied mainly by the blue colour refer to enrichment in uranium rather than thorium and potassium minerals. Beside emphasizing that Taref sandstone, Quseir clastics, Qena Formation, Qena fanglomerates and wadi sediments across most of drainage patterns, are characterized by high concentrations of the eTh and K rather than eU as corresponding to the yellow, green orange and some spots of red colours that are set to be in between the red and green colours whose related to the K and eTh respectively. The dark zones are mainly refer to low radioelements concentrations, are related to Issawia Formation and Tarawan chalk. Small bright spots are only related to the Duwi Formation represents high in the three radioactive elements.

Equivalent Uranium Colour Composite Image

This colour composite image map as shown in (Fig. 13) emphasizes that the uranium concentration and its ratio to thorium and potassium are relatively high in Duwi Formation and Dakhla shale, characterized at this map by bright zones. While, the Quseir clastics show that the concentration of the uranium is less than the thorium and potassium ones, also the Taref sandstone shows low concentration in the eU and both ratios eU/eTh & eU/K appear as dark areas. Tarawan chalk, Esna shale, Thebes Formation, Issawia Formation, Qena Formation and Qena fanglomerates are characterized by relatively high uranium concentration with respect to thorium one.

Equivalent Thorium Colour Composite Image

The equivalent thorium colour composite image map (Fig. 14), is a combine of eTh, eTh/eU and eTh/K in red, green and blue colours respectively. This map show that the eTh and its ratios to eU and K are high in Quseir clastics and Taref sandstone delineated by bright colour. While, the Duwi Formation and Dakhla shale give low values in eTh/eU, as eU exceeds the eTh concentration, but they show high eTh and eTh/K values. Tarawan chalk, Esna shale and Thebes Formation expressed as dark zones, reflect the low concentrations of eTh and its ratios to eU and K. furthermore, the Issawia Formation, Qena Formation and Qena fanglomerates show that the eTh exceeds relatively the eU concentration.

Potassium Colour Composite Image

The potassium colour composite image map (Fig. 15), combines the K in red, K/eTh in green and K/eU in blue colours, the careful examination of this map show that the K concentration is high in Quseir clastics and Taref sandstone more than eU concentration, but doesn't exceeds the thorium content. The Duwi Formation, Dakhla shale, Tarawan chalk, Esna shale, Thebes Formation and Issawia Formation show high K concentration with respect to eTh content. The Qena Formation and Qena fanglomerates emphasized by exceeding of the K content relatively with respect to the eTh and eU concentrations.

Factor Analysis Technique

The provided factor analysis maps as shown in (Figs. 16 to 18) could reveal an interpreted litho-radiometric unit map by companioning them as three variables in a false colour composite image map that consists of F1, F2 and F3 in RGB, respectively as previously shown in (Fig. 19). The interpreted litho-radiometric unit map (Fig. 20) is just reflects the spectral power in differentiation between different surface lithologic units, as it could divide one surface lithologic unit into 2 units, or merge two or more rock units in one, when it could be hard to distinguish between them.

This map in the area under study succeed in divide the Quseir clastics into two rock units, beside differentiate them from the Taref sandstone, Duwi Formation and Dakhla shale. Also, it succeeds in delineation the Esna shale, Thebes Formation and Issawia Formation. While, it failed in delineation Tarawan Chalk and differentiation between the Qena Formation and Qena Fanglomerates, so Qena Formation and Qena fanglomerates interpreted as Quaternary sediments. In addition to, reduced the extensional area of the Issawia Formation in comparison with the surface lithological map of the study area.

Uranium provinces

The probable values of significant uranium, uranium ratios to thorium and potassium are located on the base map of the area under study as shown in (Fig. 22). The careful examination of this map could lead to that the uranium province zones are related to the Duwi Formation, spots in Dakhla shale, spots in Esna shale and spots in Thebes Formation, as they correspond to values of eU, eU/eTh and eU/K that exceeds X+2S and X+3S.

Ground spectrometric verification

Several measurements are carried out on the different rock units exposed in the area under study, and it was noticeable that the high spectrometric values through the airborne gamma ray spectrometric measurements are ensured by the ground spectrometric verifications by carrying out the ground spectrometric measurements in many locations within the area under study as shown in (Fig. 23), which represent some of these locations. The highly uranium concentrations were related to the upper cretaceous rock units as Duwi Formation and Dakhla shale reach (112.6 and 25.1) ppm eU. While the rest of results are summarized in Table (4). In addition to the representative frequency histogram as shown in (Fig. 24).

Sample comparison between the radioactive elements concentrations within different rock units obtained by the airborne gamma ray spectrometric and the ground spectrometric obtained data, it's clearly that the ground spectrometric values show an increase in all radioactive elements concentrations, especially for the equivalent uranium concentrations within the Duwi Formation and Dakhla shale, which gives at the same locations 24.6 and 11.1 ppm eU respectively, for the airborne gamma ray spectrometric data. While, they gives 112.6 and 25.1ppm eU respectively for the ground obtained one.

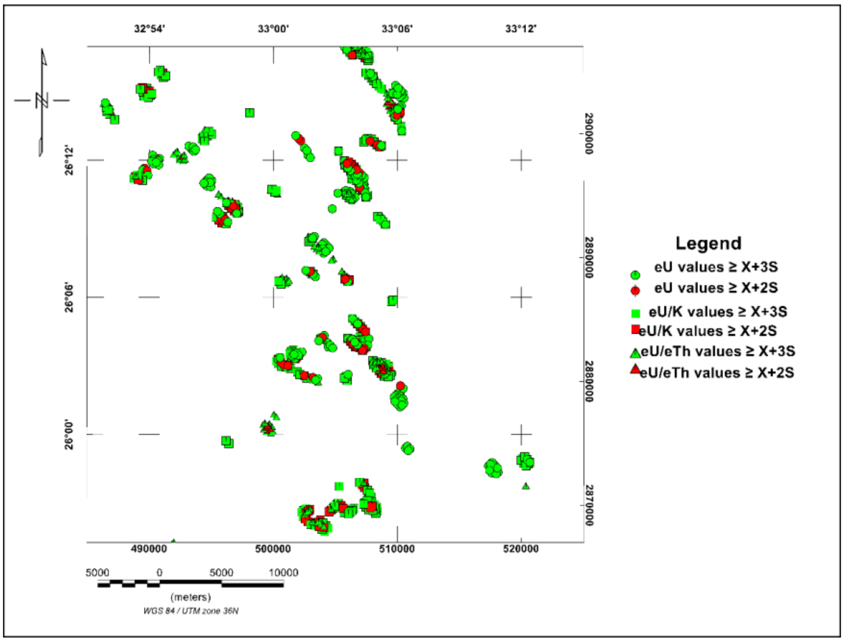

Figure (22): The uranium province map pf the study area.

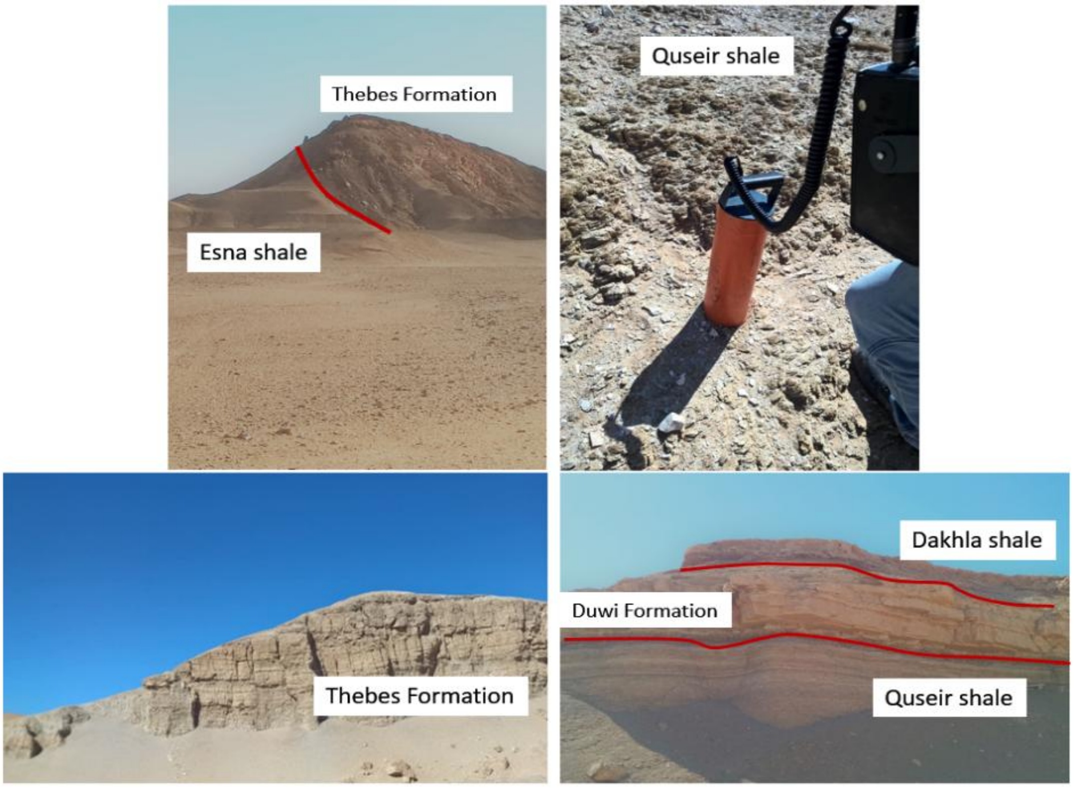

Figure (23): Selected locations form the ground verification trip in the study area.

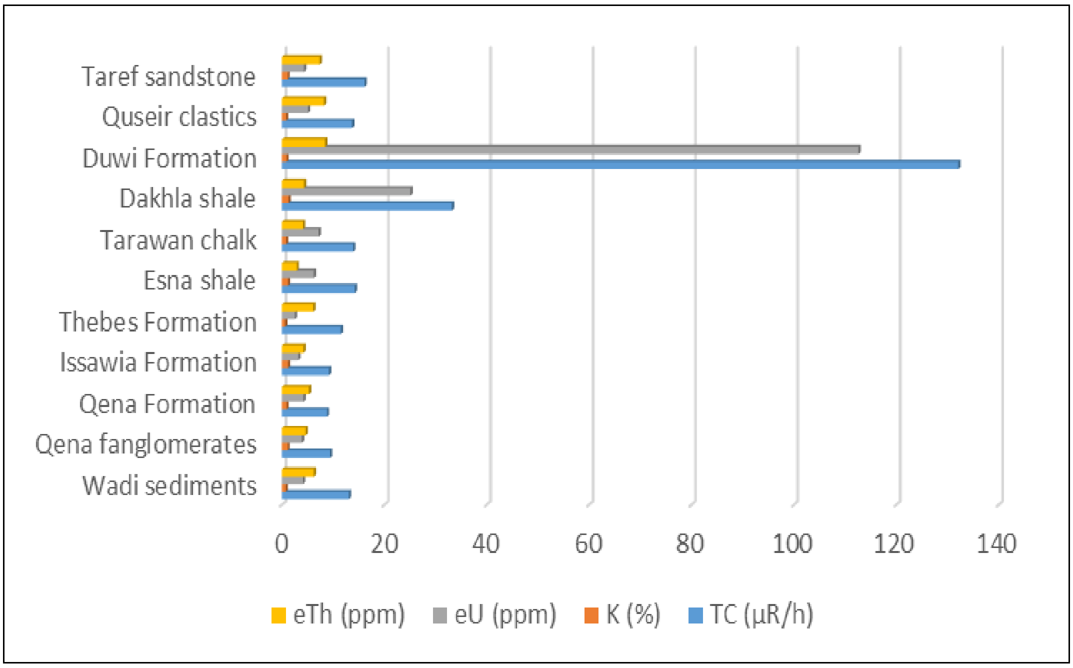

Figure (24): Frequencies histograms of the mean values of TC, K, eU and eTh in correspondence to surface lithological unit.

Table (3): Statistical analysis of the different radiometric variables content in the different surface lithological units obtained from the ILRU map of the study area.

Rock unit	No.	variable	min	max	X	S	CV	X+S	X+2S	X+3S
Taref sandstone	1115	TC	3.7	7.2	4.7	0.6	12.7	5.3	5.9	6.5
		K (%)	0.4	0.9	0.7	0.08	11.4	0.78	0.86	0.94
		eU (ppm)	1.4	5.8	2.7	0.6	22.2	3.3	3.9	4.5
		eTh (ppm)	5.3	13.4	7.2	1	13.8	8.2	9.2	10.2
		eU/eTh	0.2	0.67	0.4	0.09	22.5	0.49	0.58	0.67
		eU/K	1.7	8.3	3.8	0.98	25.7	4.78	5.76	6.74
		eTh/K	6.89	16.5	10.1	1.4	13.8	11.5	12.9	14.3
Quseir clastics part 1	3650	TC	4.1	7	5.3	0.5	9.4	5.8	6.3	6.8
		K (%)	0.6	1.1	0.9	0.08	8.8	0.98	1.06	1.14
		eU (ppm)	1.25	6.4	2.7	0.6	22.2	3.3	3.9	4.5
		eTh (ppm)	4.2	12.6	7.9	1.1	13.9	9	10.1	11.2
		eU/eTh	0.1	1	0.35	0.1	28.5	0.45	0.55	0.65
		eU/K	1.1	10.6	2.9	0.8	27.5	3.7	4.5	5.3
		eTh/K	4	13.5	8.5	1.1	12.7	9.6	10.7	11.7
Quseir clastics part 2	2365	TC	4.3	7.7	5.7	0.4	7	6.1	6.5	6.9
		K (%)	0.65	1.1	0.9	0.08	8.8	0.98	1.06	1.14
		eU (ppm)	1.3	5.1	3.1	0.5	16.1	3.6	4.1	4.6
		eTh (ppm)	6.2	13.2	8.9	1.1	12.3	10	11.1	12.2
		eU/eTh	0.2	0.7	0.3	0.08	26.6	0.38	0.46	0.54
		eU/K	1.6	7.6	3.5	0.8	22.8	4.3	5.1	5.9
		eTh/K	8.1	13.6	9.9	0.8	8	10.7	11.5	12.3
Duwi Formation	1679	TC	1.7	17.5	7.2	2.4	33.3	9.6	12	14.4
		K (%)	0.2	0.7	0.5	0.1	20	0.6	0.7	0.8
		eU (ppm)	1.4	25.9	9	3.7	41.1	12.7	16.4	20.1
		eTh (ppm)	1.5	7.5	4.1	0.8	19.3	4.9	5.7	6.5
		eU/eTh	0.4	6.9	2.2	0.89	40.4	3.1	4	4.96
		eU/K	3.3	42.6	18.4	6.4	34.7	24.8	31.2	37.6
		eTh/K	4.8	14.2	8.6	1.4	12	10	11.4	12.8
Dakhla shale	3435	TC	1.6	8.1	3.9	1.1	28.2	5	6.1	7.2
		K (%)	0.2	0.7	0.4	0.08	20	0.48	0.56	0.64
		eU (ppm)	0.9	12.1	4.2	1.6	38.1	5.8	7.4	9
		eTh (ppm)	1.3	7.4	3.3	0.8	24.2	4.1	4.9	5.7
		eU/eTh	0.3	4.2	1.3	0.5	38.5	1.8	2.3	2.8
		eU/K	2.1	36.2	11.6	4.6	39.6	16.2	20.8	25.4
		eTh/K	4.8	16.1	9.1	1.5	16.4	10.6	12.1	13.6
Esna shale	202	TC	1.3	3	1.8	0.3	16.6	2.1	2.4	2.7
		K (%)	0.08	0.3	0.16	0.04	25	0.2	0.24	0.28
		eU (ppm)	1.2	3	2.1	0.3	14.2	2.4	2.7	3
		eTh (ppm)	0.9	2.3	1.4	0.3	21.4	1.7	2	2.3
		eU/eTh	0.8	2.6	1.5	0.3	20	1.8	2.1	2.4
		eU/K	5.4	25.9	13.7	3.8	27.7	17.5	21.3	25.1
		eTh/K	5.9	13.5	8.9	1.5	16.8	10.4	11.9	13.4

Thebes Formation	**922**	**TC**	1.2	3.6	2.1	0.4	19	2.5	2.9	3.3
		K (%)	0.1	0.5	0.3	0.08	26.6	0.38	0.46	0.54
		eU (ppm)	1.1	5.2	2.1	0.47	22.3	2.57	3.04	3.5
		eTh (ppm)	0.6	3.4	1.6	0.4	25	2	2.4	2.8
		eU/eTh	0.5	6	1.4	0.5	35.7	1.9	2.4	2.9
		eU/K	3.9	24.1	8.7	2.6	29.8	11.3	13.9	16.5
		eTh/K	3.6	9.5	6.3	0.9	14.2	7.3	8.1	9
Issawia Formation	**532**	**TC**	1.7	5.7	3.7	1.2	32.4	4.9	6.1	7.3
		K (%)	0.3	0.7	0.5	0.09	18	0.59	0.68	0.77
		eU (ppm)	1.2	5.9	3.5	1.3	37.1	4.8	6.1	7.4
		eTh (ppm)	1.2	5.9	3.4	1.1	32.3	4.5	5.6	6.7
		eU/eTh	0.6	1.6	1	0.1	10	1.1	1.2	1.3
		eU/K	2.6	12.4	6.5	2	30.7	8.5	10.5	12.5
		eTh/K	3.1	9.3	6.3	1.4	22.2	7.7	9.1	10.5
Quaternary sediments	**1137**	**TC**	2.3	4.4	3.3	0.4	12.1	3.7	4.1	4.5
		K (%)	0.5	0.9	0.6	0.07	11.6	0.67	0.74	0.81
		eU (ppm)	0.3	3.4	1.7	0.5	29.4	2.2	2.7	3.2
		eTh (ppm)	2.8	5.7	4.1	0.5	12.2	4.6	5.1	5.6
		eU/eTh	0.1	0.7	0.4	0.1	25	0.5	0.6	0.7
		eU/K	0.5	5.3	2.7	0.7	25.9	3.4	4.1	4.8
		eTh/K	3.7	8.9	6.3	0.8	12.6	7.1	7.9	8.7
Debris rich in thorium minerals	**3306**	**TC**	1	5.4	2.5	0.6	24	3.1	3.7	4.3
		K (%)	0.1	0.6	0.4	0.1	25	0.5	0.6	0.7
		eU (ppm)	0.5	4.8	1.8	0.5	27.7	2.3	2.8	3.3
		eTh (ppm)	1.2	7.2	3	0.8	26.6	3.8	4.6	5.4
		eU/eTh	0.2	1.3	0.6	0.1	16.6	0.7	0.8	0.9
		eU/K	1.6	13	5.3	1.7	32	7	8.7	10.4
		eTh/K	5.1	15.7	8.4	1.4	16.6	9.8	11.2	12.6
Debris rich in potassium minerals	**1069**	**TC**	1.9	4.3	2.8	0.4	14.2	3.2	3.6	4
		K (%)	0.3	0.7	0.5	0.06	12	0.56	0.62	0.68
		eU (ppm)	0.5	3.5	1.7	0.4	23.5	2.1	2.5	2.9
		eTh (ppm)	2.1	4.6	3.3	0.4	12.1	3.7	4.1	4.5
		eU/eTh	0.2	0.9	0.5	0.1	20	0.6	0.7	0.8
		eU/K	1.1	6.2	3	0.6	20	3.6	4.2	4.8
		eTh/K	3.5	8.5	6	0.7	11.6	6.7	7.4	8.1
Wadi Sediments	**24016**	**TC**	0.25	12.25	3.8	1.4	36.3	5.2	6.5	7.9
		K (%)	0.08	1.5	0.6	0.2	33.3	0.8	1	1.2
		eU (ppm)	0.01	21.6	2.84	1.8	63.7	4.6	6.4	8.2
		eTh (ppm)	0.46	12.8	4.2	1.6	38	5.8	7.4	9
		eU/eTh	0.01	5.8	0.7	0.4	57.1	1.1	1.5	1.9
		eU/K	0.03	39.9	5.3	3.8	71.6	9.1	12.9	16.7
		eTh/K	2.76	15.54	7.1	1.7	23.9	8.8	10.5	12.2

Table (4): mean values of the ground radio-spectrometric variables and the correspondence rock units of the study area

Rock unit	TC (μR/h)	K (%)	eU (ppm)	eTh (ppm)
Wadi sediments	13.1	0.7	4.1	6.2
Qena fanglomerates	9.4	1.1	3.9	4.6
Qena Formation	8.8	0.9	4.2	5.3
Issawia Formation	9.2	1.2	3.2	4.2
Thebes Formation	11.5	0.6	2.5	6.1
Esna shale	14.2	1.2	6.2	2.9
Tarawan chalk	13.9	0.8	7.2	4.1
Dakhla shale	33.2	1.3	25.1	4.3
Duwi Formation	132.1	0.9	112.6	8.4
Quseir clastics	13.7	0.8	5.1	8.2
Taref sandstone	16.1	1.1	4.3	7.4

SUMMERY AND CONCLUSION

The airborne gamma ray spectrometric survey over the area under study provide the TC, K, eU and eTh maps, in turn the spectrometric ratio maps eU/eTh, eU/K and eTh/K could be easily estimated. The careful examination of these maps could reveal that the maximum eU concentrations are related to the Duwi Formation and Dakhla shale as 26 and 17.7 ppm eU, with mean values of (9 and 4.4 ppm eU), respectively. While, the highest mean K% is noticed accompanied with the Taref sandstone and Quseir clastics as (0.8 %) for both, as well as, the highest mean eTh concentrations as (7.6 and 7.4 ppm eTh), also the maximum mean values obtained for the eTh/K ratio as (9.2 and 9.1), respectively. In addition to the eU/eTh and eU/K ratios, which give the highest mean ratio values with Duwi Formation as (2.2 & 18.4), and Dakhla shale with (1.4 and 12), respectively.

The colour composite imaging technique is an easy way to detect the radioactive elements relative concentrations by derive the radioelements, eU, eTh and K colour composite maps. These maps could illustrate that the Duwi Formation and spots of Dakhla shale occupied by the high eU concentrations relative to their content of eTh and K. besides emphasizing that the maximum eTh and K concentrations are mainly associated with the Taref sandstone and the Quseir clastics, but the K doesn't exceed the eTh content.

Finally the uranium province map could illustrate that the eU, eU/eTh and eU/K values exceeds the mean by 2 and 3 times of the standard deviation are mainly accompanied with the Duwi Formation, spots in Dakhla shale, spots in Esna shale and spots in Thebes Formation.

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