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GROUND GAMMA-RAY SPECTROMETRIC SURVEY OF SOME URANIUM ANOMALIES, EAST ABU-ZENEIMA AREA, SOUTHWESTERN SINAI, EGYPT

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ABSTRACT

The aim of this work is to conduct a ground follow up for four airborne γ-ray spectrometric anomalies located in east Abu-Zeneima area, southwestern Sinai, Egypt. To achieve this goal, the selected localities were first geologically studied, then field γ-ray spectrometric measurements were carried out along a number of profiles, in a direction at high angle to the main structural and radiometric features.

Four horizons in the Paleozoic section were identified with high uranium contents. They include Gabal (G.) Khamela, Ramlet Homayer, G. Homayer and G. Ghorabi, all are characterized by high uranium anomalies. The older horizon represents the top most parts of Adadia Formation and is represented by a highly ferruginous sandstone bed which is recorded in G. Khamela, Ramlet Homayer and at the base of G. Homayer. The second horizon is located in Adadia Formation and is represented by sandstone which recorded in G. Ghorabi. The third horizon is the yellowish and whitish sandstone of El-Hashash Formation at G. Homayer and very close to the doloritic dyke situated at its eastern side. The fourth horizon is located at Magharet El-Maiah Formation and is represented by shale and kaolin at G. Homayer.

G. Khamela zone shows high eU/eTh ratios reaching more than 9.5, which are associated with the Adadia sandstone and display elongated E-W and NW-SE trends. There are high eU/eTh anomalies in the Ramlet Homayer zone, which reach more than 5 in value and represented by ferruginous sandstone of Adadia Formation. The excavated trenches situated at the contact between Adadia sandstone and the basic dyke in the G. Homayer anomalous zone are characterized by high eU/eTh ratio reaching 12.5. The significant anomalies of eU/eTh ratio in the G. Ghorabi zone reached 3 in value and possess different shapes. They are distributed in the siltstone, which is controlled by NW-SE trend.

INTRODUCTION

The study area is located in the southwestern part of Sinai Peninsula 50 km to the east of Abu-Zeneima town between lat. 29° 00' and 29° 04' N and long. 33° 28' and 33° 34' E (Fig. 1).

Between March, 25th and April, 19th, 1998, the Airborne Geophysical Department (AGD), Nuclear Materials Authority (NMA) of Egypt conducted an intensive uranium exploration survey, over Abu-Zeneima/Al-Tor area (4000 km2), southwestern Sinai, Egypt. This survey is considered as a part of a comprehensive program for evaluating the uranium potential of the area. A total of 4500 line kilometers of aerial magnetic and gamma-ray spectrometric data were flown at 100 meters terrain clearance. Airborne gamma surveys are most commonly used for mineral exploration (Smith, 1985). However, several recent studies have shown their usefulness for abandoned mine site characterization (e.g. Winkelmann

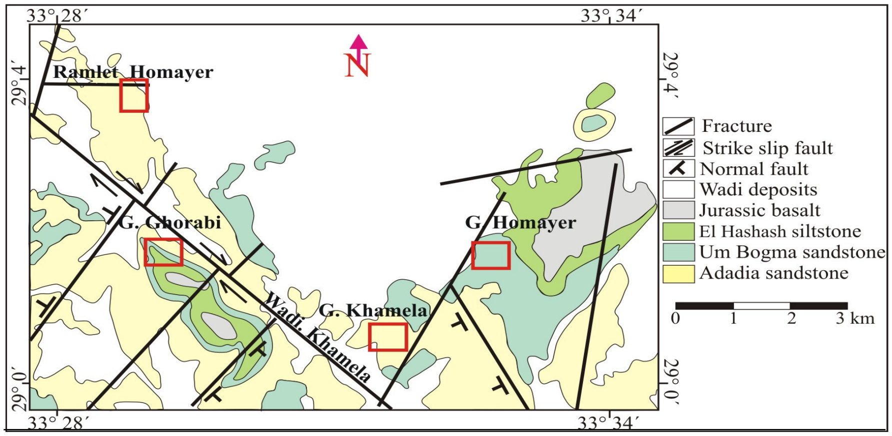

Fig. 1: Geologic map of Gabal Ghorabi, Gabal Khamela, Ramlet Homayer and Gabal Homayer, East Abu Zeniema area, Southwestern Sinai, Egypt (Modified after CONOCO, 1987)

et al., 2001; Pfitzner et al., 2001; Martin et al., 2006). Large areas of the world have been covered by ground and airborne gamma ray surveys and many national and regional radiometric maps have been compiled and published (IAEA, 2003). The use of gamma ray spectrometry as a tool for geological mapping, environmental monitoring and exploring radioelement concentrations has found widespread acceptance over several decades and continues to be developed (IAEA, 2010).

The process of uranium mobilization is very important as such altered rocks were subjected to mineralized bearing solutions (Gaafar et al., 2014). Ground spectrometric measurements were conducted to cover a variety of lithologies and various degrees of alterations associated with the uranium mineralization in the study area. The shear zone is characterized by abnormally high eU content (Gaafar el al., 2015). Radioactive minerals occur naturally in the geological environment associated with geological features like unconformity contact, veins, shear zones, and so forth (Bhaumik et al., 2004, Tuncer, et al., 2006).

Accordingly, after the airborne gamma-ray spectrometric survey, geological studies of the southwestern Sinai area achieved some of the airborne surveyed area and possessing high potentialities for U-mineralization. Consequently, a detailed ground gamma-ray spectrometric survey (using highly sensitive portable gamma ray spectrometer of model GS-512) has been carried out for a part of the airborne surveyed area, in order to detect radioactivity variations, possible anomalous zones and the distribution of the radioelement variations over different lithologies.

GEOLOGIC SETTING

Four horizons from the Paleozoic Era in the studied area (Table 1) are characterized with some high uranium zones (Fig. 1). The older horizon is located near the top of Adadia Formation and is represented by a ferruginous sandstone bed that contains uraniferous xenotime, as in G. Khamela, Ramlet Homayer, G. Ghorabi and at the base of G. Homayer. The second horizon is located in Um-Bogma Formation and is represented by siltstone with uraniferous xenotime as in Khamela area. The yellowish and whitish sandstone, with a rel-

Table 1:Lithostratigraphy of the Paleozoic Succession in Southwestern Sinai, Egypt (Al Shami, 2003)

Age	Fm	Lithology	Environment
Permo-Triassic	Qiseib (20-110m)	Red beds, Pebbly Sandstone and Mudstone In finning upward Cycles	Fluviatile
Triassic-Jurassic	Farsh El-Azraq Fm (0-60m)	Basaltic Sill extrusions and Lava Flows, with columnar joints	
Lower Carboniferous	Abu Zarab Fm (100 m)	Glass Sand	Delta Plain
	Magharet El Maiah Fm (33 m)	Carbonaceous Shale-Plant Remains, Coal, Kaolinitic Claystone in some parts	Swamp
	El-Hashash Fm (59 m)	Brownish Sandstone	Aeolian
	Um Bogma (0 - 40m)	Upper: yellow Sandy Dolostone-Shale Middle: Intercalation of Marl with Shale Lower: Pink Dolostone-Shale-Mn-Fe Ore, Karstification in parts	Shallow Open Marine
Cambrian	Adadia Fm (18-100 m)	Cross-bedded Sandstone, Ferruginous Siltstone and Sandstone near the top	Fluviatile
	Abu-Hamata (12-35 m)	Shale and Siltstone, two horizons, red at the base and green at the top with Cruziana	Subtidal, Tidal Channel
	Sarabit El-Khadim (5-18 m)	Alternation of Conglomeratic S.S with S.S	Braided Streams
Precambrian Basement		Igneous and Metamorphic Rocks	

atively high uranium content, was known in El-Hashash Formation at G. Homayer area situated at the eastern side. Besides, the fourth horizon is located at Magharet El-Maiah Formation and represented by shale and kaolin at G. Homayer. The following are the exposed sedimentary rock units.

Adadia Formation (Cambrian)

It represents the base of the studied area, and is equivalent to Naqus Formation (Beleity et al., 1986). Most workers agree with an early Cambrian age for this Formation (e.g., Klitzsch, 1990). This formation is highly ferruginous, light brown in color, moderately hard, medium-grained, cross-bedded and contain flint pebbles.

Um-Bogma Formation (Lower Carboniferous)

It is equivalent to Khaboba Formation of Soliman and El-Fetouh (1969). The type section is located at Gabal Nukhul and consists mainly of carbonate rocks (dolostone) which attain 43 m in thickness. This rock unit decreases in thickness towards east and south from the type section and shows lateral variation in lithology to clastics. The studied area represents the extreme eastern part of this formation and reaches 0.6 m thick of siltstone. It contains a radioactive anomaly with an eU reaching up to 236ppm.

El Hashash Formation (Lower Carboniferous)

The type section is located at El-Hashash area (W. Sahu) and is formed of sandstone 59 m thickness (Soliman and El-Fetouh, 1969). The sandstone is yellowish in color, moderately hard, medium-grained. El Aassy et al., 1997, recorded an anomaly in this formation reaching 84 ppm eU but the authors recorded 437 ppm eU in it.

Magharet El Maiah Formation (Lower Carboniferous)

It conformably overlies El Hashash Formation and easily identified in the field by its dark appearance or kaolinitic composition. It has a thickness of 33 meter in type locality Magharet El Maiah area. While in G. Homayer area, it reaches 20 m. Also El Aassy et al (1997); recorded 26 ppm in this formation but the authors recorded 247ppm in the same locality, but it is very close to a basic dyke. Accordingly, it appears that the basic dyke may play an important role in the concentration of radioactivity around it.

GROUND GAMMA-RAY SPECTROMETRIC SURVEY

General

The distribution of radioelements in common rocks is tabulated by IAEA (1979).

The naturally radioactive elements ^{40}K, ^{238}U and ^{232}Th are the main contributors to the natural radioactivity of rocks. Their distributions in the rocks depend on the rock type. Two of them (^{40}K and ^{238}U) are sensitive to alteration processes and could be remobilized and redistributed in rocks, reflecting alterations and associated tectonic features. The gamma-ray spectrometric method is an effective method for recognizing localities where there are unusual rock types or where there has been strong alteration. These can be direct pointers to mineralization.

Methodology

The γ- ray spectrometric survey was carried out using a high-sensitivity 512-channel portable gamma-ray spectrometer (K sens. = 3.036 cps/% K, U sens = 0.34 cps/ppm eU, Th sens = 0.131 cps/ppm eTh) with 21- cubic inch -size detector of NaI (Tl) crystal. The ranges of the windows are commonly set as: total count, K (^{40}K) 1.37-1.57 MeV; U (^{214}Bi) 1.66-1.86 MeV and Th (^{208}Tl) 2.4-2.72 MeV.

The grid was constructed of 10 m spacing on an equal grid pattern for all zones, and decreasing of the grid stations to about 5 m spacing on the areas showing high values. In the present study, the γ-ray spectrometric maps for each zone were prepared and subjected to qualitative and quantitative interpretation to determine the radiometric anomalies and associated radioactive mineralization.

RESULTS

Khamela Zone

Khamela zone is located between lat. 29º 0′ 25″ to 29º 0′ 32″ N and long. 33º 31′ 38″ to 33º 31′ 46″ E. Khamela zone shows low to moderate topography, with flat top. It starts with the upper part of Adadia Formation, which consists of ferruginous, brownish and medium-grained sandstone (Fig. 2). Um Bogma Formation consists of highly ferruginated sandstone. El-Hashash Formation is

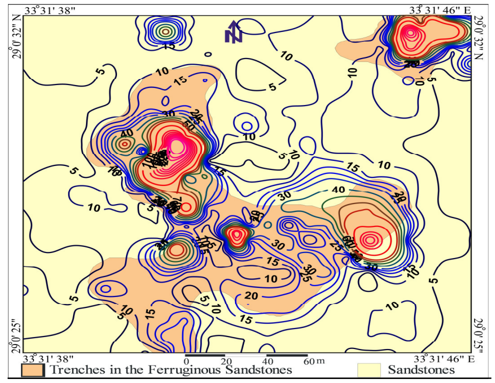

Fig. 2 : TC (Ur) distribution map of Gabal Khamela, with lithological background Southwestern Sinai

formed of sandstone and is very low of uranium in this zone.

The γ-ray spectrometric survey data are represented by four maps: the Total radioactivity (T.C) and the two radioelements (eU & eTh) and their geochemical ratio (eU/eTh). The K-content is very low, ranging between 0.1 % and 0.8 %. It doesn't show any significant discrimination between the rock units in the study zone.

The eU content ranges between 0.3 ppm (El Hashash S.S) and 260 ppm (Adadia S.S), and its average abundance reaches about 21 ppm (Table 2). The eTh content reaches 46 ppm as a maximum value in Adadia S.S and diminishes to 0.5 ppm as a minimum value in El Hashash sandstone (Table 2). The average of eTh content in the study area attains about 7.3 ppm. Besides, there is a high variability in the computed values of eU/eTh ratio (Table 2), which shows high anomalous values in Adadia ferruginous sandstone reaching to 9.7. This value is higher than that computed for El Hashash sandstone, where it reaches to about 1.0 only.

Total-Count radiometric (TC) contour map for G. Khamela

The qualitative interpretation, which means

Table 2: Summary of statistics for the radioelements and eU/eTh ratio in Gabal Khamela

	T.C	K	eU	eTh	eU/eTh
El-Hashash Sandstone (No. of measurements = 146)					
Min.	**0.6**	**0.1**	**0.3**	**0.5**	**0.07**
Max.	**15**	**0.7**	**7.9**	**17**	**6.8**
Mean	**6.6**	**0.15**	**3.6**	**4.5**	**1.0**
St Dev.	**3**	**0.11**	**1.9**	**2.5**	**0.8**
Adadia Ferruginous Sandstone (No. of measurements=88)					
Min.	**8.1**	**0.1**	**9.9**	**2.0**	**0.9**
Max.	**320**	**0.8**	**260**	**46**	**9.7**
Mean	**65**	**0.2**	**52**	**11.8**	**3.8**
St Dev.	**85**	**0.1**	**58**	**9.0**	**1.7**

the radiometric–lithologic mapping, has some difficulties in the radiometric delineation of the boundaries between the different rock types due to the gradual change in the radioactivity levels within some rock units. The correlation between the T.C radiometric contour map with its respective geologic map shows that the radioactivity of the study area ranges between 0.6 Ur over the El-Hashash sandstone and 320 Ur over the Adadia ferruginous sandstone (Fig. 2 & Table 2). It is also evident, throughout the study of this map, that the T.C radiometric contours show a remarkable separation of the contacts between the Adadia ferruginous sandstone and the surrounding country rocks represented by the contour line of 10 Ur value. Generally, El-Hashash sandstone and Adadia sandstone possess the lowest T.C radioactivity level within the study area, ranging between 0.6 and 10 Ur. The T.C radioactivity ranges between 8.1 and 320 Ur with an average value of about 40 Ur is observed over Adadia ferruginous sandstone. The T.C radioactivity contours reflect a gradational increase in radioactivity towards the old trenches, which are responsible for the highest values in the studied zone. These high radioactivity levels are shown as narrow segments having elongated shapes.

Equivalent thorium (eTh) distribution map for Gabal Khamela

In such a case of the G. Khamela, the eTh content reflects the original rock variety. Therefore, the content of the Th-bearing minerals in Adadia ferruginous sandstone increases as the eTh-content increases. Generally, the eTh content map shows that Adadia ferruginous sandstone is bounded by the eTh content 6 ppm (Fig.3). Consequently, the country rocks are limited by the lines ranging between <1 and 6 ppm. They are represented by Adadia sandstone and El Hashash sandstone and show sharp contacts with the intervening high levels. The Adadia ferruginous sandstone is characterized by a wide range of eTh content, which can be separated into two major levels. On the map (Fig. 3) the lower level ranges in intensity between 6 and 13 ppm eTh. Meanwhile, the higher level is characterized with values ranging between 13 and 46 ppm eTh. It is evident that the eTh -concentrations increase in five separated anomalies represented by old trenches. They are elongated in the NW-SE trend. Three of these anomalies are located at the center of the zone. The remaining two anomalies are located at the NE-corner of the zone with concentrations reaching to 46 ppm eTh.

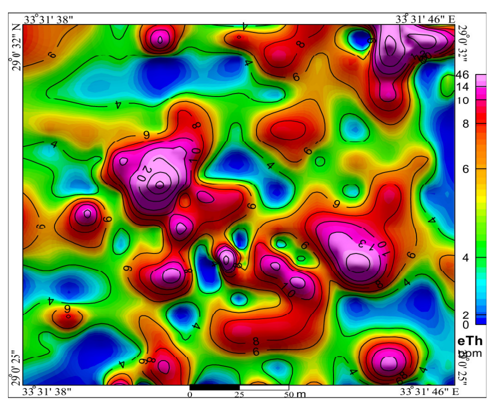

Fig. 3 : eTh (ppm) distribution map of Gabal Khamela zone, Southwestern Sinai, Egypt

Equivalent uranium (eU) distribution map for Gabal Khamela

The eU level value of 10 ppm can separate the Adadia ferruginous sandstone from the El Hashash and Adadia sandstones (Fig. 4). The eU content measured over the country rocks (El Hashash & Adadia) varies between <2 and 10 ppm, with an increase in the eU level of Adadia sandstone than in El Hashash sandstone. The eU content range between 10 and 40 ppm eU in Adadia sandstone in the central and northeastern of the Khamela zone comprise some eU anomalies. These anomalies are encountered as patches with different shapes, controlled by the main NW-SE structural trend. Most of the main four sublocalities of higher eU contents with values varying between 50 and 240 ppm eU. They are also encountered as elongated spots trending in a NW-SE trend, with nearly oval shapes, and mainly associated with the present trenches.

eU/eTh ratio distribution map for Gabal Khamela

The eU/eTh ratio increases in some parts and decreases in others than the uranium and thorium distribution. Some anomalies on the Adadia and El-Hashash sandstones are mainly thorium and though displayed in the eU/eTh map as low values. Whereas, other anomalies in the Adadia ferruginous sandstone are mainly uranium and consequently they are properly represented on that map as high values. Figure (5) shows high prominent anomalies associated with the Adadia ferruginous sandstone, which exhibit similar sharp increases on the eU concentration map resulting the high eU/eTh ratios. Most of the anomalies, possessing high eU/eTh ratios lie in the central and northeastern corner of the map. These anomalies posses ratios > 9.0 of eU/eTh and have different shapes and elongation's ranging in trend from east-west to northwest.

Ramlet Homayer Zone

Ramlet Homayer zone is located between lat. 29º 3′ 35″ to 29º 3′ 55″ N and long. 33º 28′ 58″ to 33º 29′ 5″ E (Fig. 6). It is represented by Adadia Formation, which is constituted from ferruginous sandstones, with some violet to grey sandstones, moderately hard and fine to medium grained. There are two trenches in Adadia ferruginous sandstone to the south of this zone. A thick accumulation of sands and an elongated ridge of Adadia sandstone separate them from each other.

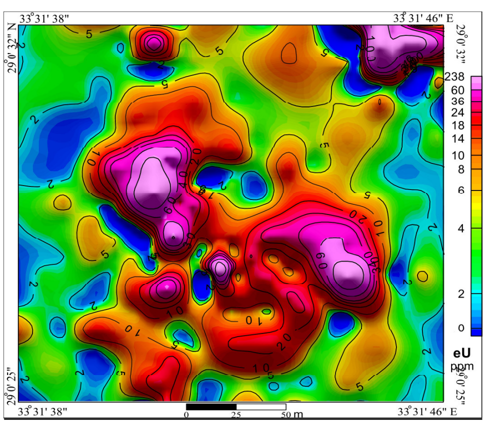

Fig. 4 : eU (ppm) distribution map of Gabal Khamela zone, Southwestern Sinai, Egypt

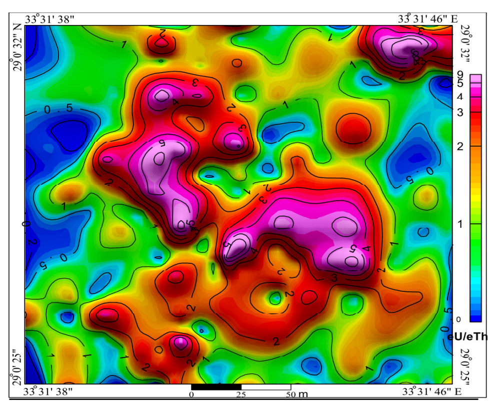

Fig. 5 : eU/eTh (ppm) distribution map of Gabal Khamela zone, Southwestern Sinai, Egypt

It is necessary, to determine accurately major trends of the ground γ- ray spectrometric survey data in order to find features along which anomalous zones of enriched radioactive concentrations could have been developed.

Table (3) indicates that the total-count radioactivity (T.C. in Ur) in the zone oscillates between 0.2 Ur over Wadi sediments and 780 Ur in the Adadia ferruginous sandstone within the trenches with an average of about 26 Ur. The K-content is very low for Adadia sandstone and Wadi sediments, ranging between 0.1 % and 0.5 %. It shows slightly increase in the excavated trenches reaching to 0.9 % with an average of 0.2 %. The eU content ranges between 0.1 ppm over Wadi sediments and 740 ppm in Adadia ferruginous sandstone within the trenches, with an average abundance attaining 22 ppm (Table 3). The eTh content reaches 73 ppm as a maximum value over the Adadia ferruginous sandstone and diminishes to 0.1 ppm over Wadi sediments (Table 3). The average abundance of eTh in the studied zone is 8.0 ppm. Besides, there is a high change in the computed values of the eU/eTh ratio from the Adadia ferruginous sandstone (trenches) to the Adadia sandstone (Table 3). The eU/eTh ratio has high values reaching 2.8 over fractures Adadia the ferruginous sandstone and has low values of about 0.3 over Wadi sediments.

Table 3: Summary of statistics for the radioelements and eU/eTh ratio in the Ramlet Homayer

	T.C	K	eU	eTh	eU/eTh
Wadi Sediments (No. of measurements = 65)					
Min.	0.2	0.1	0.1	0.1	0.0
Max.	8.5	0.4	2	10.2	0.6
Mean	1.6	0.1	0.7	1.6	0.3
St Dev.	1.3	0.1	0.5	1.5	0.1
Trenches in Adadia Ferruginous sandstone (No. of measurements = 139)					
Min.	11.8	0.1	9.8	0.5	0.8
Max.	780	0.9	740	73	10.1
Mean	54	0.2	45.7	14.3	2.8
St Dev.	82.1	0.2	77.5	11.4	1.5
Adadia Sandstone (No. of measurements = 116)					
Min.	2.5	0.1	2.2	0.2	0.2
Max.	15.8	0.5	9.0	13.7	0.9
Mean	7.8	0.1	5.3	3.9	0.4
St Dev.	2.9	0.1	1.9	2.2	0.2

Total-count radiometric contour map for Ramlet Homayer zone

On the T.C. contour map (Fig. 6), there are three main levels of ground radioactivity. The first level is the lowest (< 6 Ur), surrounds to the Ramlet Homyer zone which is mainly associated with Wadi sediments. The second level ranges in T.C. radioactivity between 6 and 15 Ur. It is encountered as rims of different shapes surrounding the high anomalies and coincides with Adadia sandstones. It is also encountered as an elongated zone trending in the E-W and located in the central part

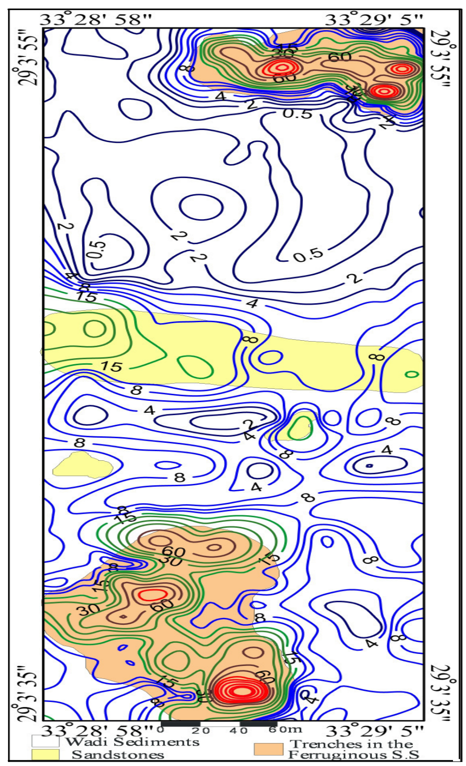

Fig. 6 : TC (Ur) distribution map of Ramlet Homayer zone, with lithological background Southwestern Sinai, Egypt

of the studied area, which coincides with the Adadia sandstone ridge. The third level has a wide range of radioactivity varying between 16 and 780 Ur. It is mainly located over Adadia ferruginous sandstones and especially at the encountered trenches. It is represented as four elongated high anomalies trending in E-W, NE-SW and N-S. High radioactive anomaly is located at the northern part of the studied area, with an elongated shape in the E-W trend. This anomaly is associated with the Adadia ferruginous sandstones, but most of its outcrop is subjected to overburden of sands. The other three anomalies are located at the southern part of the studied area. Two of them are elongated in the N-S and E-W trends and associated with two trenches in the Adadia ferruginous sandstone. The third one is located between both of them where it is elongated in the NW direction and associated with Adadia ferruginous sandstones.

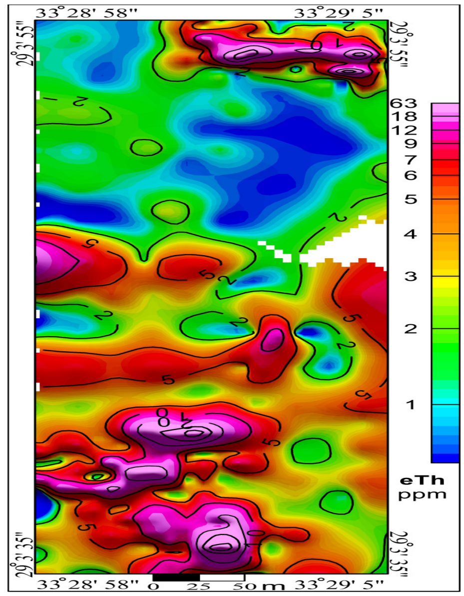

Fig. 7: eTh (ppm) distribution map of Ramlet Homayer zone, Southwestern Sinai, Egypt

Equivalent thorium (eTh) distribution map for Ramlet Homayer zone

According to the equivalent thorium (eTh) map (Fig. 7), it could be divided into four eTh levels. The first very low eTh level varies in intensity < 2 ppm. It is encountered as rims surrounding the relatively high eTh levels. It is represented as zones with different shapes distributed allover the wadi sediments. The second eTh level possesses intensity ranges between 2 and 5 ppm eTh (Fig. 7). It covers a large surface in the southern part of the study area and coincides with the Adadia sandstones located around Adadia ferruginous sandstones of Adadia Fm. The third eTh level ranges between 5 and 20 ppm eTh. It is encountered as zones with different shapes, mostly coinciding with Adadia ferruginous sandstones located in the northeastern and southwestern parts of the study area. The fourth high eTh level possesses intensities more than 60 ppm eTh (Fig. 7). It is located as scattered spots with oval shapes coinciding with the trenches dug in the Adadia ferruginous sandstones.

Equivalent uranium (eU) distribution map for Ramlet Homayer zone

The correlation between the levels on the equivalent uranium (eU) map with various rock units shows that there are three main levels of radioactivity (Fig.8). The relatively very low level (< 2 ppm eU) is encountered as rims surrounding the Wadi sediments and represented as zones with different shapes. The second radioactivity level possess intensities ranging between 4 and 20 ppm eU. It is represented as zones with different shapes and coincides with the Adadia sandstones. It is mostly found in the central and southern parts of the study area. The third radioactivity level is high ranging in eU concentration between 20 and 740 ppm. It is encountered as scattered four anomalies: the first one is an elongated zone in the E-W trend located at the northeastern part of the study area. The other three zones are elongated in the N-S and E-W trends and are situated at the southern part of the area. All these zones are associated

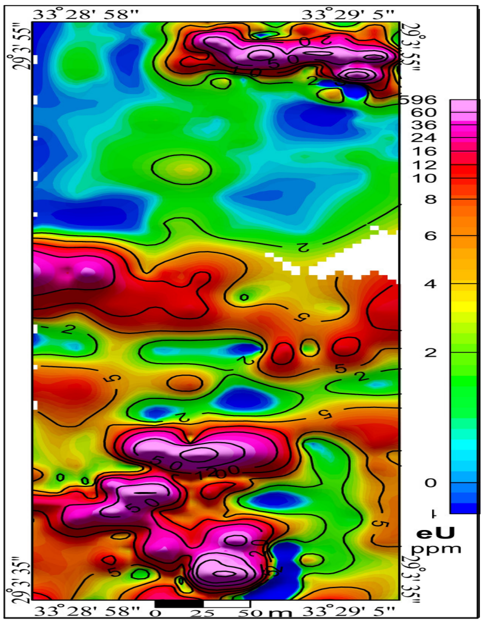

Fig. 8 : eU (ppm) distribution map of Ramlet Homayer zone, Southwestern Sinai, Egypt

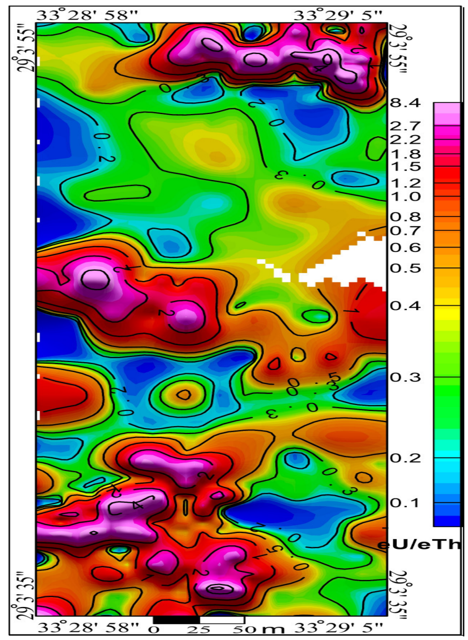

Fig. 9 : eU/eTh distribution map of Ramlet Homayer zone, Southwestern Sinai, Egypt

with ferruginous sandstones of Adadia Fm., which show sharp contacts with the surrounding country rocks.

eU/eTh ratio distribution map for Ramlet Homayer zone

The eU/eTh ratio distribution map (Fig. 9) shows and confirms the presence of high eU/eTh ratio signatures coinciding with portions of high eU concentrations, reflecting the increase uranium content at constant thorium content. This relationship-of increasing uranium content and invariable thorium content is, however, not a characteristic feature of the entire studied zone. The high anomalies of eU/eTh ratio are elongated in shape and reach the value of 10 (Fig. 9). They are associated with the excavated trenches in the ferruginous sandstones of Adadia Fm. There are other high anomalies, which reach 3 (eU/eTh) and coincide also with the ferruginous sandstones of Adadia Fm. The remaining parts, which possess eU/eTh ratios < 0.3 are represented by zones of different shapes and correspond to Adadia sandstones and wadi sediments.

Gabal Homayer

Gabal Homayer anomalous zone is located between lat. 29º 1′ 30″ to 29º 1′ 35″ N and long. 33º 32′ 29″ to 33º 32′ 38″ E (Fig. 10). The represented units in this zone are sands, Adadia sandstone, basic dyke and ferruginous sandstone of Um Bogma Fm. There are two trenches in the studied zone; the first trench is located at its northeastern part and coincides with the Um Bogma ferruginous sandstone and the other one is located at its southeastern part and associated with a basic dyke at its contact with the Adadia sandstone.

This zone starts with the top of Adadia

Formation till Abu-Zarab Formation, which is overlain by a basaltic sill. The exposed rock types in Gabal Homayer area are related to the Paleozoic except the basaltic sill, which is related to the Triassic-Early Jurassic (Weissbrod, 1969). The main rock types are sandstone, siltstone, shale, conglomerate and basalt. The bedding planes in this sequence are inclined approximately 15º to the N or NNE (El-Aassy et al., 1997).

A Tertiary basic dyke of about 5 to 10 m width is cutting all the succession of Gabal Homayer starting by Adadia Formation to Abu-Zarab Formation. This basic dyke is highly weathered and plays an important role in the radioactivity of all rock units close to it. In this study, the classification of Soliman and El-Fetouh (1969) was followed for the Paleozoic rock units, except Um-Bogma Formation, which named by Wiessbrod (1969).

Table (4) shows that the total-count radioactivity in the studied zone ranges in intensity between 1.2 Ur over wadi sediments and 560 Ur within the contact between Adadia sandstone and the basic dyke, with an average value reading about 24 Ur.

The K-content ranges between 0.1 % and 0.5 % over Wadi sediments and Adadia sandstone and reaching its maximum value (0.7 %) over the excavated trenches. The eU content ranges between 0.4 ppm over the sand and 490 ppm within a trench located at the contact between Adadia sandstone and the basic dyke. The average abundance of eU attains about 19 ppm. The eTh content reaches 75 ppm as a maximum value over the ferruginous sandstone and diminishes to 0.4 ppm over the sand. The average abundance of thorium in the studied zone reaches about 7 ppm. Besides, there is a considerable change in the values of the eU/eTh ratio from the two trenches to the country rocks. The eU/eTh ratio shows high values attaining 12.6 over Um Bogma ferruginous sandstone and display low values of about 0.2 on the sands.

Table 4 : Summary of statistics for the radioelements and eU/eTh ratio of Gabal Homayer zone

	T.C (Ur)	K (%)	eU (ppm)	eTh	eU/eTh
Wadi Sediments (No. of Measurements =75)					
Min.	1.2	0.1	0.4	0.4	0.26
Max.	17	0.5	3.8	11	2.8
Mean	4	0.15	2	2.4	1.1
St Dev.	2.5	0.1	0.92	1.8	0.7
Um Bogma Fm, Trenches of ferruginous Sandstone (No. = 49)					
Min.	12	0.1	9.6	1.8	0.5
Max.	560	0.7	490	75	12.6
Mean	110	0.24	95	17	3.5
St Dev.	77	0.15	96	12.1	1.9
Adadia Fm, Sandstone (No. of Measurements =68)					
Min.	2.7	0.1	4	0.8	0.57
Max.	20	0.5	9.5	16	6.6
Mean	10.1	0.15	6.5	6.4	1.3
St Dev.	3.6	0.08	1.7	3.3	0.95

Total-count radiometric distribution map for Gabal Homayer

On the T.C. contour map, there are four main levels of ground radioactivity. The first is the lowest level, ranging in intensity between < 5 Ur and 10 Ur, with an average value of 10 Ur is mainly associated with sands (Fig. 10). The second T.C. radiometric level is ranging in radioactivity between 10 Ur and 20 Ur with an average value of 10 Ur. It is encountered as rims of having different shapes and located surrounding to the whole studied zone and coincides with Adadia sandstone. The third T.C. radiometric level ranges in radioactivity be-

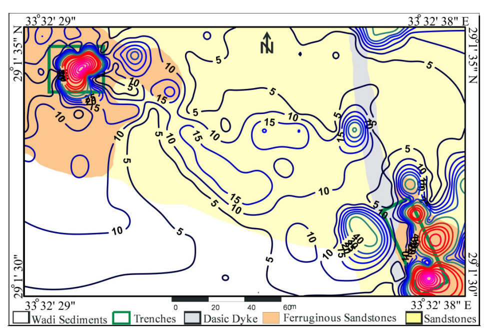

Fig. 10 : TC (Ur) map of G. Homayer zone, with lithological background Southwestern Sinai, Egypt

tween 20 Ur and 30 Ur. It is located mainly over Um Bogma ferruginous sandstone as well as some parts of the basic dyke-Adadia sandstone contact. It is characterized with elongated shapes surrounding the highest anomalies and their associated trenches. The fourth level is the highest one in the studied area ranges in T.C. radioactivity between 40 Ur and 560 Ur (Fig.10). It is represented as two high anomalies. The first one is located in the northwestern part of the studied zone, approximately circular in shape, reaching 470 Ur in value and coincides with the trench excavated in Um Bogma ferruginous sandstone. The latter one is reaching 560 Ur in value, located at the southeastern part of the zone, elongated in shape and trending in a N15˚W direction. This anomaly is associated with an old trench excavated between the basic dyke and Adadia sandstone.

Equivalent thorium (eTh) distribution map for Gabal Homayer

According to the equivalent thorium (eTh) map (Fig. 11), four main eTh levels could be distinguished. The very low eTh level ranges in intensity < 5 ppm eTh. It is associated with sands, which are located in the northeastern and southwestern parts of the studied zone. The second eTh level has intensities ranging between 5 ppm and 10 ppm eTh. It coincides with Adadia sandstone, which cover a large part in the studied zone with elongated shapes trending in the NW direction. The third eTh level ranges in intensity between 10 ppm and 20 ppm. It is encountered as scattered nearly rounded portions, mostly coinciding with Um Bogma ferruginous sandstone located in the northwestern and southeastern parts of the studied zone. The fourth eTh level is very high, and possesses an eTh content attaining more than 20 ppm and reaching occasionally 63 ppm. It is located in two main spots in the studied zone. The first one is located in the northwestern part of the studied zone and is associated with Um Bogma ferruginous sandstone whereas the second spot is situated in its southeastern part and coincides with the basic dyke- Adadia sandstone contact.

Equivalent uranium (eU) distribution map for Gabal Homayer

According to the equivalent uranium (eU) map (Fig.12), there are four main levels of eU. The very low eU level varies in intensity < 2 ppm. It is encountered as elongated shapes surrounding the Adadia sandstone in the northeastern and southwestern parts of the studied zone. The second eU level has intensi-

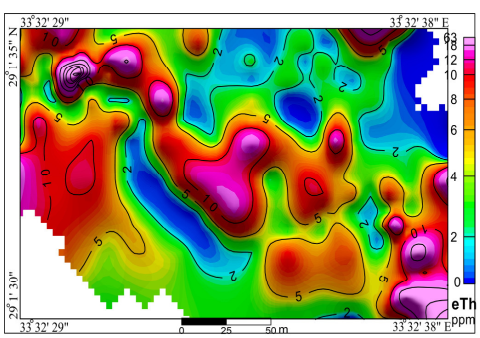

Fig. 11 : eTh (ppm) distribution map of Gabal Homayer zone, Southwestern Sinai, Egypt

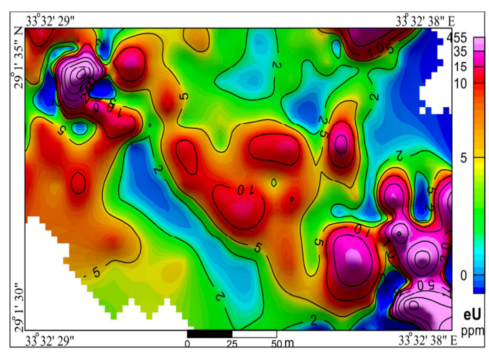

Fig. 12 : eU (ppm) distribution map of Gabal Homayer zone, Southwestern Sinai, Egypt

ties ranging between 2 ppm and 5 ppm. It is represented as zones with different shapes, elongated mainly in the NW direction and coincides with Adadia sandstone. The third eU level ranges in intensity between 5 ppm and 20 ppm. This level is scattered in oval-shaped portions; three of them are located in the eastern part and the other two in the western part of the studied zone. Most of these portions are associated with Um Bogma ferruginous sandstone, while the others with the basic dyke.

The fourth eU level is very high, ranges in eU content between 20 ppm and 455 ppm. It is represented as two anomalies with very sharp contacts with the country rocks. The first one is an oval shape anomaly reaching 400 ppm in value, is associated with the trench excavated in Um Bogma ferruginous sandstone and located in the northeastern part of the studied zone. The latter anomaly is elongated in shape, trending in a N15˚W direction and located in the southeastern part of the studied zone. It is associated with the contact between the basic dyke and Adadia sandstone, which reach in eU intensity to 455 ppm.

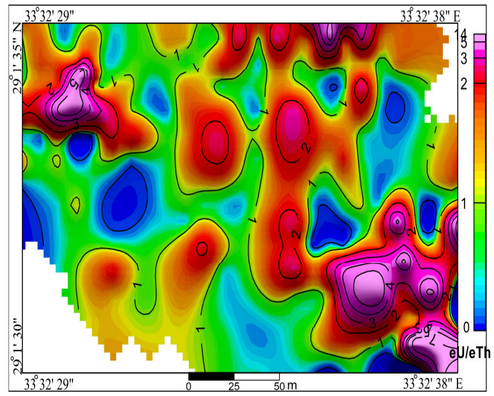

Fig. 13 : eU/eTh (ppm) distribution map of Gabal Homayer zone, Southwestern Sinai, Egypt

eU/eTh ratio distribution map for Gabal Homayer

The eU/eTh ratio distibution map (Fig.13), indicated and confirmed the existence of very high uranium contents, which are mainly associated with the two significant excavated trenches in the studied zone. The highest anomaly of eU/eTh ratio is elongated in shape, reaching to 14 in value, and associated with the excavated trench at the contact between Adadia sandstone and the basic dyke. Another very high anomaly reaching to 10 in eU/eTh ratio is associated with a trench dugged in Um Bogma ferruginous sandstone.

Consequently, Adadia sandstone and Um Bogma ferruginous sandstone of Um Bogma Fm. in the studied zone are characterized by high values of eU/eTh ratio, which varies between 1.0 and 3.0 in value and represented by zones possessing different shapes and trends.

Gabal Ghorabi

Gabal Ghorabi zone is located between lat. 29º 2′ 20″ & 29º 2′ 26″ N and long. 33º 29′ 45″ to 33º 29′ 53″ E (Fig. 14). The zone is represented by various units including sands, sandstone and shale and siltstone. At G. Ghorabi, the geologic section starts by Adadia Formation (the lowest part) till the basaltic sill. The Adadia sandstone is brownish, moderately hard, and medium- grained. The recorded data are represented by four maps showing the two radioelements (U & Th) and their geochemical ratio eU/eTh in addition to the T.C. radiometry (Figs.14 to 17).

Table (5) shows that the measurements of the total-count radioactive range in intensity between 2 Ur and 73 Ur, with an average value of 23 Ur. K-content ranges in intensity between 0.1 % and 0.7 %, with an average value of 0.18 %. The eU content ranges between 0.7 ppm and 59 ppm, with an average abundance of about 16 ppm. The eTh content reaches 24

Table 5 :Summary of statistics for the radioelements and eU/eTh Ratio in the Gabal Ghorabi

Total area	T.C (Ur)	K (%)	eU (ppm)	eTh (ppm)	eU/eTh
Wadi sediments, Sands (No. of Measurements = 51)					
Min.	2	0.1	0.7	1	0.06
Max.	16	0.5	4.8	21	1.8
Mean	7.1	0.17	2.8	6.11	0.64
St Dev.	4	0.12	1.22	4.72	0.36
El Hashash Fm., Siltstone (No. of Measurements = 48)					
Min.	25	0.1	20	7.5	1.05
Max.	52	0.6	29.2	22	3.6
Mean	32.75	0.21	24	15.2	1.67
St Dev.	4.9	0.15	3.	3.44	0.49
Um Bogma Fm., Ferruginous Siltstone (No. of Measurements = 48)					
Min.	26.4	0.1	30	9	1.25
Max.	73	0.7	59	24	5
Mean	44.4	0.19	36.5	17	2.27
St Dev.	8	0.16	6.6	4.14	0.7
Adadia Fm., Sandstone (No. of Measurements = 117)					
Min.	6.4	0.1	5	2.7	0.26
Max.	38	0.6	19.8	21	3.7
Mean	17.11	0.18	10.9	11.2	1.11
St Dev.	5.59	0.12	4.03	4.13	0.57

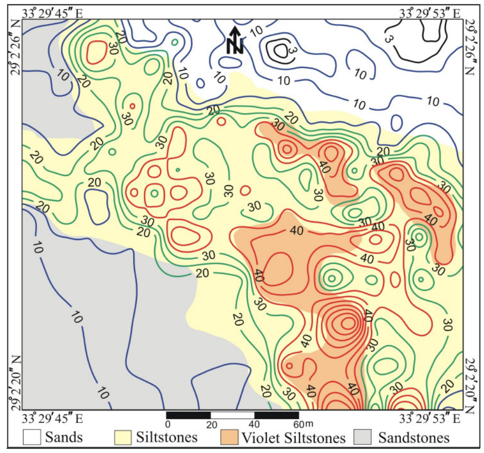

Fig. 14 : TC (Ur) distribution map of Gabal Ghorabi zone, with lithological background Southwestern Sinai

ppm as a maximum value and diminishes to 1 ppm as a minimum value, with an average abundance attaining 12 ppm. There is a great change in the value of eU/eTh ratio from 0.1 to 5.0 with 1.3 average value.

Total- count radiometric distribution map for Gabal Ghorabi

The T.C. radioactivity of the studied zone ranges in intensity between 3 Ur over sands and 73 Ur over shale and siltstone (Fig. 14). The T.C radiometric contours show a remarkable delineation of the contacts between the violet siltstone and the country rocks represented by the contour line having a value of 20 Ur. The lowest T.C radioactivity level ranges in intensity between 5 Ur and 20 Ur and is associated with Adadia sandstone, which surround to the El-Hashash siltstone. The El-Hashash violet siltstone show elongated shapes trending in N-S & NW-SE trends. They reach to its highest values of about 73 Ur in the southern part of the studied zone.

Equivalent thorium (eTh) distribution map for Gabal Ghorabi

The eTh content map (Fig. 15) shows that Um Bogma ferruginous siltstone is bounded by the 10 ppm limit. The country rocks have eTh content ranging in their intensity between 1 ppm and 8 ppm. They are represented by Adadia sandstone, which shows sharp contacts with the surrounding high levels. Um Bogma ferruginous siltstone is characterized with a wide range of eTh contents. They cover a large part of the studied zone and take different shapes, with values ranging between 9 and 24 ppm.

Equivalent uranium (eU) distribution map for Gabal Ghorabi

The eU map of G. Ghorabi (Fig. 16) shows that concentration of 15 ppm can separate Um Bogma ferruginous siltstone from the surrounding Adadia sandstone. The eU-content over the country rocks varies between <1 ppm to 5 ppm. The eU range (10-59 ppm) is located over Um Bogma ferruginous siltstone,

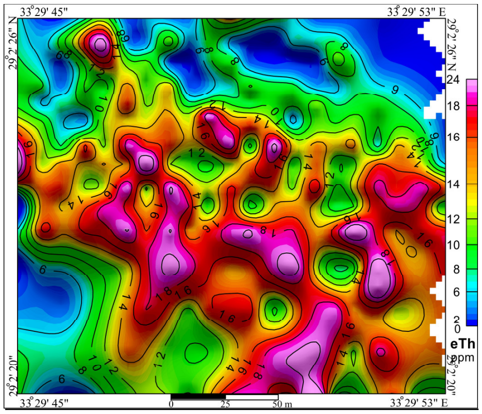

Fig. 15 : eTh (ppm) distribution map of Gabal Ghorabi zone, Southwestern Sinai, Egypt

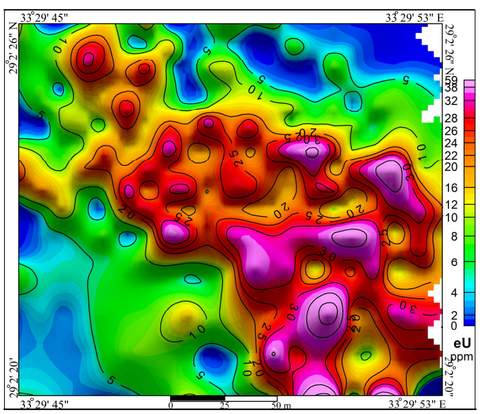

Fig. 16 : eU (ppm) distribution map of Gabal Ghorabi zone, Southwestern Sinai, Egypt

which shows sharp contact with the country rocks. This range is encountered as zones with different shapes, which are mainly controlled with NW-SE trend.

eU/eTh ratio distribution map for Gabal Ghorabi

The eU/eTh ratio increase according to the increase of eU content over a low level of eTh contents (Fig. 17). These increases are associated with Um Bogma siltstone. The significant anomalies of eU/eTh ratio are reaching 3 in value and have different shapes. They are distributed in Um Bogma siltstone which is controlled with NW-SE trend.

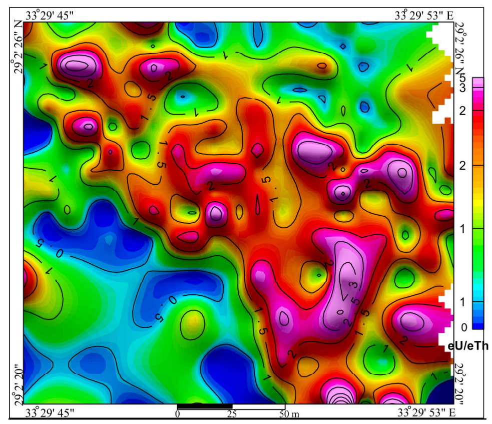

Fig. 17 : eU/eTh (ppm) distribution map of Gabal Ghorabi zone, Southwestern Sinai, Egypt

SUMMARY AND CONCLUSIONS

The principal aim of this work is to study some specified zones located in the eastern portion of southwestern Sinai of Egypt according to the resultant NMA airborne γ-ray spectrometric survey conducted in 1998. These zones comprise G. Khamela, Ramlet Homayer, G. Homayer, and G. Ghorabi. To achieve this goal, these zones were geologically mapped and surveyed using a well calibrated field γ-ray spectrometer.

Khamela zone starts with the upper part of Adadia Formation, which consists of ferruginous, brownish and medium-grained sandstone. The eU content rangs between 10 ppm (El-Hashash Fm.) and 40 ppm, which was registered over the Adadia sandstone, located in the central and northeastern parts of the Khamela zone, surrounding the elevated eU anomalies. Most of the main four patches of elevated eU content display values varying between 50 ppm and 260 ppm of Adadia Fm. They are also encountered as elongated spots trending in a NW-SE, and mainly associated with the present excavated trenches. Most of the anomalies show high eU/eTh ratios reaching more than 9.5 in value.

Ramlet Homayer zone is represented by Adadia Formation, which is constituted from ferruginous sandstone, with some violet to grey sandstone. The eU concentration is very high in the Ramlet Homayer zone and ranges between 20 and 740 ppm. The location of the anomalies are scattered and elongated in an E-W trend in the NE part of the Ramlet Homayer zone and in N-S and E-W in the southern part of the zone. All these anomalies represented as patches and spots are associated with Adadia ferruginous sandstone, which shows sharp contacts with the surrounding country rocks. The highest anomalies of eU/eTh ratio reaching to about 10 in value are associated with the trenches dugged in the ferruginous sandstone.

G. Homayer starts by Adadia Formation to Abu-Zarab Formation and cuts by basic dyke that reaches to about 5 to10 m in width. This basic dyke is highly weathered and plays an important role in the radioactivity of all rock units close to it. Adadia sandstone has eU intensities ranging between 4 ppm and 9.5 ppm. Um Bogma ferruginous sandstone acquire 27 ppm eU, while the basic dyke acquire 9.6 ppm eU. The recorded very high eU values ranging in intensity between 33 and 490 ppm are located as two anomalies with very sharp contacts with Adadia sandstone. The trench situated at the contact between the Adadia sandstone and the basic dyke is characterized by eU/eTh ratio anomaly reaching to 12.5 in value. Another very high anomaly reaching to 10 of eU/eTh ratio is associated with the trench that dugged in Um Bogma ferruginous sandstone.

The G. Ghorabi zone starts by Adadia Formation to the basaltic sill. The eU content, ranges between 10 ppm and 60 ppm, is located over Um Bogma siltstone, which shows a sharp contact with Adadia sandstone. Um Bogma siltstone is characterized with a wide range of eTh content ranging between 10 ppm and 24 ppm. The highest eU/eTh ratio, attaining 3, is associated with Um Bogma siltstone.

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المسح الإشعاعى الجيمى الطيفى الأرضى لبعض شاذات اليورانيوم بمنطقة شرق أبو زنيمة، جنوب غوب شبه جزيرة سيناء، مصر

إبراهيم محمد جعفر و عبد الله الشامى

تقع منطقة الدراسة شرق منطقة أبو زنيمة، جنوب غرب سيناء، مصر، بين خطي طول٢٨' ٣٣° -٣٤' ٣٣° شرقاً وخطي عرض ٥٩' ٢٨°- ٤' ٢٩° شمالاً. يهدف هذا العمل إلى إجراء تتبع حقلى أرضى لأربعة شاذات من اليورانيوم الناتجة من المسح الطيفي الجيمى الجوى لمنطقة الدراسة. وتشمل هذه المنطقة كل من جبل خَميلا، رملة حمير وجبل حمير

بالاضافة الى جبل غرابي. وتتميز جميعها بمحتوى عالى من اليورانيوم. لتحقيق هذا الهدف، تم دراسة التوزيع الصخرى والتراكيب الجيولوجية، وتجميع قياسات حقلية تفصيلية للتوزيع السطحى للعناصر المشعة على شبكية منتظمة بمسافات بينية ١٠م وتقطع الشاذات المشعة في اتجاهات متعامدة.

اتضح من خلال رسم خرائط التوزيع السطحي للعناصر المشعة لمنطقة خَميلا، ارتباط شاذات اليورانيوم بصخور الحجر الرملي حيث يصل تركيز اليورانيوم الى(٢٦٠ جزء في المليون) في حين أن تركيزات الثوريوم كانت قليلة وتزيد أحياناً عن الخلفية الإشعاعية، إلا أن نسبة توزيع اليورانيوم المكافئ إلى الثوريوم المكافئ في هذا الصخر كانت دائماً مرتفعة (٩,٥).

تم إجراء تقييم دقيق لشاذات الإشعاع الطيفى العالية لنطاق رملة حُمَيِّر، وتحديد نوعية الصخور المسئولة عنها. نتج عن هذا المسح التوصل إلى تحديد عدد من الشاذات التى ترجع إلى الارتفاع الكبير في تركيز عنصر اليورانيوم، الذى وصل إلى (٧٤٠ جزء في المليون)، مع زيادة قليلة أحياناً في عنصر الثوريوم الذى وصل إلى(٧٣ جزء في المليون) ، إلا أن محتوى البوتاسيوم ظهر أنه قليل جداً (٠,٢ %) .لوحظ الإرتفاع الكبير فى نسبة اليورانيوم المكافئ إلى الثوريوم المكافئ والتي وصلت إلي (١٠) نتيجة إعادة تركيز اليورانيوم وترسيبه في هذه الصخور الحاملة لها.

أوضح المسح التفصيلي لنطاق جبل حُمَيِّر، أن هناك شاذتان رئيسيتان لليورانيوم ترتبط إحداهما بصخور الحجر الرملي الحديدي والأخرى على الحد الفاصل بين صخر الحجر الرملي وجدة قاعدية كبيرة من البازلت، حيث يصل تركيز عنصر اليورانيوم الى (٤٥٠جزء في المليون). بينما يحتوى على نسبة أقل من الثوريوم المكافئ بمتوسط حوالي (٧,٧ جزء في المليون) وبالتالى فإن نسبة اليورانيوم المكافئ إلى الثوريوم المكافئ تصل إلى(١٢,٥) وهي نسبة مرتفعة جداً.

تبين من إجراء التخريط السطحي لتوزيعات العناصر المشعة الثلاثة بنطاق جبل غرابي، أن زيادة تركيز عنصر اليورانيوم تصل الى (٦٠ جزء في المليون) مع عدم زيادة ملحوظة عن الخلفية الاشعاعية فى تركيزات كل من الثوريوم والبوتاسيوم، وهي مرتبطة بحجر الغرين البنفسجي.