Full length article

Gamma-ray spectrometric investigation of north El-Tor area, southwestern Sinai, Egypt

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ABSTRACT

Interpretation was executed on the airborne and ground spectrometric data of Abu-Zeneima/Al-Tor area for verifying the significant anomalies as it contains important targets for prospective nuclear materials. Airborne spectrometric survey revealed that younger granites, are characterized by increase in the three main radioactive elements up to 5.4% K, 10 ppm eU and 33 ppm eTh. The western part of the study area includes sedimentary section which contains uranium-bearing phosphate beds. They are characterized by increase of airborne uranium concentration up to 14.2 ppm without potassium or thorium enrichment. The airborne image maps for eU/eTh and eU/K as well as ternary composite map revealed also that there is a promising U-anomaly, associated with the sedimentary section.

Detailed ground spectrometric survey for the Cretaceous Nubian sandstone in Wadi Araba indicated that it is characterized by eU content reaches about 34 ppm, while eTh attains only about 9.8 ppm and potassium is 1.2%. Therefore, the eU/eTh ratio, reaches to a value of 3.4. The same sandstone bed in Abu - Durba Formation possesses eU values reach 67 ppm, whereas eTh values attain 38 ppm and average of potassium is 0.5%. The eU/eTh ratio is about 2, indicates also enrichment of uranium. The eU reaches a concentration of about 40 ppm in limestone of Matulla Formation whereas, the eTh values attains about 3 ppm and average K is 0.1%. Therefore, the eU/eTh ratio reached 13, due to the limestone is phosphatic. High eU value reaching to 80 ppm is recorded in the limestone facies of Sudr Formation, while the eTh values up to 11 ppm and potassium of about 0.9% are recorded. The eU/eTh ratio value reaching 7.3 indicates the high P2O5 content. A high uranium content is recorded at the northeastern part of El-Qaa plain area in the Sudr Formation reaching 47 ppm, while low eTh values attaining 7.5 ppm and potassium of 0.1% are recorded.

1. Introduction

Between March, 25th and April, 19th, 1998, the Airborne Geophysics Department (AGD), Nuclear Materials Authority of Egypt conducted an intensive uranium exploration survey, over Abu-Zeneima/Al-Tor area (4000 km²) located on the eastern side of the Gulf of Suez region, southwestern Sinai, Egypt. This survey is considered as a part of a comprehensive program for, evaluating the potentiality of uranium of the area. A total of 4500 line kilometers of aerial magnetic and gamma-ray spectrometric data were flown at 100 m terrain clearance (Elsirafy et al., 1998).

Detailed ground spectrometric survey for the Cretaceous Nubian sandstone in Wadi Araba indicated that it is characterized by eU content reaches about 34 ppm, while eTh attains only about 9.8 ppm and potassium is 1.2%. Therefore, the eU/eTh ratio, reaches to a value of 3.4. The same sandstone bed in Abu - Durba Formation possesses eU values reach 67 ppm, whereas eTh values attain 38 ppm and average of potassium is 0.5%. The eU/eTh ratio is about 2, indicates also enrichment of uranium. The eU reaches a concentration of about 40 ppm in limestone of Matulla Formation whereas, the eTh values attains about 3 ppm and average K is 0.1%. Therefore, the eU/eTh ratio reached 13, due to the limestone is phosphatic. High eU value reaching to 80 ppm is recorded in the limestone facies of Sudr Formation, while the eTh values up to 11 ppm and potassium of about 0.9% are recorded. The eU/eTh ratio value reaching 7.3 indicates the high P2O5 content. A high uranium content is recorded at the northeastern part of El-Qaa plain area in the Sudr Formation reaching 47 ppm, while low eTh values attaining 7.5 ppm and potassium of 0.1% are recorded.

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 gamma-ray spectrometric method is widely used in uranium exploration, geological mapping (IAEA, 2010; Gaafar, 2015), mineral exploration (Grasty and Shives, 1997), soil mapping (Wilford et al., 1997), and environmental radiation monitoring (Ford et al., 2001; Gaafar et al., 2016). The process of uranium mobilization is very important as such altered rocks were subjected to mineralized bearing solutions (Abdrabboh, 2017; Gaafar and Alshami, 2017).

Accordingly, after the airborne gamma-ray spectrometric survey, geological studies of the Southwestern Sinai area point out to the existence of some localities possessing high potentialities for U-mineralization. Consequently, a detailed ground gamma-ray spectrometric survey has been carried out for the area, in order to detect radioactivity variations, possible anomalous zones and the distribution of the radioelement variations over different lithologies and possible anomalous zones.

The present study lies to the north of Al-Tor City between latitude 28°20′N to 28°35′N and longitude 33°20′E to 33°45′E. The study area is mainly covered by sedimentary rocks of Phanerozoic era.

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2. Geologic setting

The north El-Tor area, SW Sinai, Egypt is enclosed between Wadi Feiran in the north, El-Tor City to the south, Gulf of Suez to the west and Gabal (G.) Safariat to the east (Fig. 1).

The exposed rock units in this area are mainly of sedimentary origin, with some basaltic injections. They range in age from early Paleozoic to middle Eocene. Basement rocks outcrop at G. Abu-Durba and G. Araba to the west as well as at G. Abbora to the southeast (Fig. 1).

There are three unconformities in the study area, the first one between granites of G. Araba and sandstones of Araba Formation, while the second one between Matulla and Sudr Formations and the third one between Sudr and Esna Formations. Generally, uranium accumulates in the phosphatic rocks in the studied area. Zaghloul and Mabrouk (1964) concluded that the fine-grained fraction of phosphatic rocks is more uraniferous. Gindy (1978) stated that the uranium content is related to the phosphatic forms. The surveyed succession starts by basement rocks of Precambrian to sedimentary rocks of Middle Eocene (Table 1). They can be discussed as follows.

2.1. Younger granites

G. Araba to the west and G. Abbora to the southeast represent younger granites in the study area. They occur as intrusive bodies and their composition ranges from monzogranites to syenogranites. The younger granite exposures are unconformably overlain by a succession of Paleozoic clastic, Cretaceous sandstones and Eocene carbonates. They are highly fractured in predominant trends NW-SE, NNW-SSE and NE-SW. The younger granites are more resistant to weathering and consequently form moderate to very high relief bodies.

2.2. Dykes

The dykes in the eastern part of the area are mostly encountered as basic dykes and porphyry aplite dykes cutting G. Abbora and striking N-S. In addition, secondary phases of fine-grained granites have been intruded in G. Abbora granites and filled the N-S trending fractures. A major basic dyke, with a thickness reaching 25 m, cut through G. Araba granites and sandstones of Araba Formation with a trend mainly of NE-SW.

2.3. Araba formation

Araba Formation is the oldest sedimentary rock unit in the study area, i.e., Lower Cambrian (Said, 1971). It is mainly exposed allover the study area above the basement complex. It is represented by a succession of coloured sandstones, siltstones and silty claystones with well-noticed ferruginous bands. It has a thickness ranging from 50 m to 60 m.

2.4. Naqus formation

It overlies the Araba Formation and unconformably underlies the Abu Durba Formation. It is related to upper Cambrian age (Said, 1971) and equivalent to Aidediya Formation (Kora and Jux, 1986). This Formation is characterized with thick black sandstones (nearly 230 m), with quartz pebbles scattered in the rock unit (Shata, 1999).

2.5. Abu-Durba formation

It was deposited in a shallow marine environment during early Carboniferous. It lies unconformably the Naqus Formation (Said, 1971). It is known as the Abu-Durba shale Formation and consists of high radioactive shale beds at the top with intercalations of sandstone beds at the base. Its thickness ranges from about 25 m to 75 m. It is capped by tube-like iron concretions.
Table 1
Summary of stratigraphic sequence in El-Qaa Plain, and Wadi Araba/Abu-Durba area, southwestern Sinai, Egypt (Shata, 1999).

| Age          | Formation                  | Lithology                              | Environment          |
|--------------|----------------------------|----------------------------------------|----------------------|
| Eocene       | Middle Samalute (5–30 m)   | Nummulitic Limestone (L-S)             | Marine               |
|              | Darat (40–75 m)            | Claystone at the base, L-S at the top  |                      |
|              | Early Thebas (110–190 m)   | Thinly bedded limestone with chert and phosphatic bed intercalations |                      |
|              | Esna (30–65 m)             | Green-grey shales with marl and limestone interbeds | Marine to deep marine |
| Cretaceous   | Late Matulla (100–160 m)   | Thick sandstone (S.S) at the base, thick shale at the middle and intercalations of shales L.S and S.S at the top | Marine               |
|              | Wata (50–75 m)             | Limestone at the base and top with sandstone at the middle | Regressive-Trans. Sea |
|              | Raha (40–70 m)             | Claystone, marl, and L.S at the base, L.S and shale at the top | Shallow marine       |
|              | Malha (20–50 m)            | White sandstone with pebbly beds       | Fluviatile to marine |
| Permo-triassic| Qusieb (35–85 m)           | Red beds of claystone, silty shale and silstone with S.S intercalations | Continental to fluviatile |
| Carboniferous| Upper Aheimer (50–60 m)    | Thick silty shales and claystones with thin sandstone intercalations | Transgressive - Regressive sea |
|              | Lower Abu-Durba (25–75 m)  | Thick silty shale at the base with thick sandstone at the top | Sallow marine         |
| Cambrian     | Naqqs (240–250 m)          | Thick S.S with pebbly horizon          | Fluvio-glacial       |
|              | Arbaa (55–75 m)            | Laminated S.S, silty S.S, silty shale and claystone intercalations | Sallow marine         |
| Pre-Cambrian | Basement rocks             |                                        |                      |

2.6. Qusieb formation

This Formation is of Permo-Triassic age, overlying Aheimer Formation (Abdallah and Eladindani, 1963). It consists of claystone and siltstone with sandstone bands intercalation at the base, thick sandstone at the middle and shale with sandstone intercalation at the top. Some plant remains are present in some beds of this Formation, which indicate their continental origin. The cross-bedded sandstone beds represent fluviatile channel sediments.

2.7. Matulla formation

This Formation is of Coniacian and Santonian of Late Cretaceous age (Ghorab, 1961). Its thickness reaches about 140 m, conformably overlies the Wata Formation, and is considered as marine environment. It is represented by sandstone with shale intercalations and thin beds of limestone, then thick shale with limestone intercalations. The top of this facies is shale with limestone and sandstone capped by radioactive phosphatic bed and bedded chert (Issawi and Jux, 1982).

2.8. Sudr formation

This Formation is of late Cretaceous (Campanian-Maastrichtian), with a thickness varying from 70 to 120 m. The Maastrichtian phosphatic beds occurred as a result of relative shallowing of the sea during Maastrichtian time. It overlies the Matulla Formation and underlies the Esna Formation. It could be subdivided into three members according to variation in lithology (Ghorab, 1961).

a. A lower chalky member, which is composed of chalk with claystone interbeds.

b. A phosphate member which consist of bedded limestone with lenticular interbeds of chert and a thick radioactive phosphatic bed.

c. An upper chalky member which is fractured and calcite’s filled the fractures.

2.9. Esna formation

This Formation is of late Paleocene to Early Eocene age (Saïd, 1962). It overlies the Sudr Formation, with an unconformity (boundary) and underlies the Thebas Formation (Abu Shama et al., 2007). It consists of grey shale with minor limestone interbeds (Issawi et al., 1981). The environment of deposition started as marine and graded into deep marine in Early Eocene.
crustal younger granites. It is clear that the remaining rocks of the study area display low eTh content. They show relative lateral variations that distinguish each rock unit from the others. This level is no longer relevant and is located within the background radiation, which do not represent any radiological risk to the environment.

3.3. Airborne eU (ppm) distribution map

The study of the distribution of the equivalent uranium (eU) in the study area shows clearly that its level ranges from less than 1 ppm to 14.2 ppm (Fig. 4). Sedimentary section that are located in the western part of the study area are characterized by the highest eU concentrations. These anomalies takes elongated form trending in the northwest-southeast direction parallel to the Gulf of Suez. Younger granites represent the second level which is located in the eastern part of the study area and its highest concentration reaches 10 ppm. Some of these U-signatures for the granites take elongated form in the northwest-southeast direction and others are semicircular shapes. Meanwhile random forms are linked largely with nearby rocks and represent the lowest level of eU content.

3.4. Airborne eU/eTh and eU/K ratio maps

The eU/eTh and eU/K image maps (Figs. 5, 6) show that there important anomalies located in the western part of the study area. This eU/eTh anomaly represents the most significant zone in the investigated area, because of its association with the sedimentary section enriched with phosphates which considered the lowest level of both K and eTh concentrations. Younger granites contain moderate concentrations of uranium, but they contain low values for eU/eTh and eU/K and this, reduces its importance as a source of uranium. The rest rock units do not represent any significant increases, but is distinct from each other relatively.

3.5. Airborne ternary composite map

Ternary composite image of K, Th and U (Fig. 7) was computed for mapping chemical variation between lithologies and data integration using Oasis Montaj 6.4.2 software. The red, green and blue channels were assigned to U, Th and K respectively. This implied that high areas in red, green and blue on a map would mean high concentration of U, Th and K respectively while those in white would mean high concentration of all three radioelements. Younger granites are characterized by an increase of the radioactivity content of the three radioactive elements so, they appear white in colour. Then, the radioactivity contents of the three elements decrease gradually westwards due to the low-land younger granites, which are characterized by yellow-white colour. Uranium and thorium elements decreases in G. Abu Durba, which are characterized by pale blue colour as a result of the predominance of potassium. Wadi sediments appear yellow in colour, which reflects the level of background radiation for the three radioactive elements in the study area. The western part of the study area includes the sedimentary belt of more than 30 km long that elongated in the NW-SE direction and includes uranium-bearing phosphate beds, characterized by an increase of uranium, without potassium or thorium.

Fig. 3. Airborne eTh (ppm) image map of Abu-Zeneima/Al-Tor area.

Fig. 4. Airborne eU (ppm) image map of Abu-Zeneima/Al-Tor area.

Fig. 5. Airborne eU/eTh image map of Abu-Zeneima/Al-Tor area.

Fig. 6. Airborne eU/K image map of Abu-Zeneima/Al-Tor area.

Fig. 7. Ternary (K, eU and eTh) image map of Abu-Zeneima/Al-Tor area.
and therefore, the colour is red.

4. Ground spectrometric survey of Wadi Araba/Abu-Durba area

4.1. General

According to the airborne significance anomalies of the study area, detailed ground gamma-ray spectrometric survey using highly sensitive portable gamma ray spectrometer of model Gs-512 was performed. The study area were strictly followed and lateral checks of the rocks were considered in order to detect any high or anomalous spectral radiation in between them or any lithologic variations. In the present study, the γ-ray spectrometric measurements were collected to determine the lithologic contacts, faults, γ-ray spectrometric anomalies and associated radioactive mineralizations.

Four γ-ray spectrometric significant anomalies were recorded, which have more than ten times the background. They are arranged from the oldest as follows:

1. Sandstones of the Araba Formation: The anomaly lies at the contact with a basic dyke, which cuts the Araba and Naqus formations, with a strike attaining N45°W-S45°E and more than 25 m width
2. Radioactive shale bed in Abu-Durba Formation.
3. Radioactive phospatic beds of Matulla Formation.
4. Radioactive phospatic limestone beds in Sudr Formation.

Different rock formations in Wadi Araba/Abu-Durba area were surveyed for verifying the significant anomalies deduced from the airborne γ-ray spectrometric maps of the area as the important targets. Table 2 and Figs. 8, 9, 10, 11 show the measured significant anomalies, including total count (in Ur), K (in %), eU and eTh (in ppm), as well as eU/eTh ratio for their respective rock types and exact locations through the ground γ-ray spectrometric measurements.

4.2. Ground γ-ray spectrometric measurements of younger granites

The Younger granites of G. Araba located in the eastern side of the study area possess a moderate level of spectrometry. The average radioelement concentrations are potassium is about 4.8%, uranium is about 6 ppm and thorium is about 20 ppm at location of latitude 28°24′36″N and longitude 33°26′52″E. The eU/eTh ratio (0.33) indicate a normal case of younger granite (according to Clarke et al., 1966).

4.3. Ground γ-ray spectrometric measurements of dykes

An important remarkable increase in radioactivity is recognized, associated with a basic dyke, which cuts each of G. Araba granite, and Araba sandstone. The highest eU anomalies that reach more than 33 ppm are recorded at the contact between the major NE-SW trending basic dyke with the Araba sandstone. Meanwhile eTh and potassium measurements are relatively low and reach to 9 ppm eTh and 1.2%K at the same location which lies at latitude 28°24′24″N and longitude 33°26′26″E. The eU/eTh ratio is considered high which attains more than 3.6.

4.4. Ground γ-ray spectrometric measurements of Araba formation

In Araba Formation, eU measurements are reached to 34 ppm while eTh attained 9.8 ppm and potassium is 1.2% (Table 2 and Figs. 8, 9, 10, 11). Therefore, the eU/eTh ratio (3.7) is high compared with a similar normal rock type. This occurrence is close to the basic dyke, which extends to several kilometers, striking in a N45°W-S45°E. This occurrence is recorded for the first time in this area, which is located at Wadi Araba area in the western part of the study area at latitude the intersection of 28°24′24″N and longitude 33°26′27″E.

4.5. Ground γ-ray spectrometric measurements of Naqus formation

Naqus Formation is nearly barren, where eU reaches 0.9 ppm, eTh 4.6 ppm and potassium 0.1% (Table 2 and Figs. 8, 9, 10, 11). It is located at Wadi Araba area in the western part of the study area, at latitude 28°24′36″N and longitude 33°28′30″E.

4.6. Ground γ-ray spectrometric measurements of Abu Durba formation

Abu Durba Formation possesses a wide extension of anomalous radioactive bed. eU anomalies in this facies reach more than 67 ppm, whereas eTh is 38 ppm and potassium is 0.5% (Table 2 and Figs. 8, 9, 10, 11). The eU/eTh ratio is about 2, which indicates a migration of uranium to this Formation. It is located at Abu-Durba area in the western part of the study area at latitude 28°24′22″N and longitude 33°27′55″E.

4.7. Ground γ-ray spectrometric measurements of Quseib formation

The eTh concentration in Quseib Formation reaching to about 37 ppm, the eU concentration attains about 18 ppm, while potassium content is about 1% (Table 2 and Figs. 8, 9, 10, 11). The increase of the thorium and uranium concentrations, with a normal eU/eTh ratio reaching about 0.5 in this Formation may be due to the increase of minerals-bearing these radioelements. It is located at Abu-Durba area, in the western part of the study area, at latitude 28°23′53″N and longitude 33°29′E.

4.8. Ground γ-ray spectrometric measurements of Matulla formation

The eU concentration in Matulla Formation reaching to about 40 ppm in the Matulla Formation, while the eTh concentration attains about 3 ppm and K content is 0.1% (Table 2 and Figs. 8, 9, 10, 11). The recorded high contents of uranium superimposed over low thorium concentration resulted in eU/eTh ratio which is very high reaching about 13. This suggests a migration of uranium to this Formation. This record is located at Wadi Araba area, at latitude 28°25′52″N and longitude 33°28′32″E.

4.9. Ground γ-ray spectrometric measurements of Esna formation

This facies (Esna Formation) is characterized with a moderate radioactivity level; where eU is about 15 ppm, eTh is about 5.8 ppm, while potassium is 0.5% (Table 2 and Figs. 8, 9, 10, 11). These measurements are record at Wadi Araba area, in the western part of the study area at latitude 28°22′12″N and longitude 33°31′33″E.

4.10. Ground γ-ray spectrometric measurements of Sudr formation

High eU concentrations reaching to 80 ppm were recorded in this facies (Sudr Formation). They are superimposed over low thorium contents of about 11 ppm, while potassium is 0.9%. The eU/eTh ratio attains about 7.3 which is very high and indicates the remobilization of uranium to that Formation, causing this high ratio which is more than ten times above the normal ratio of this type of rock. This anomaly is located at Wadi Araba area, in the western part of the study area at latitude 28°22′32″N and longitude 33°31′15″E (Table 2 and Figs. 8, 9, 10, 11).

4.11. Ground γ-ray spectrometric measurements of Thebes formation

The three radioelements concentrations in Thebes Formation are more or less high, reaching their highest levels at a location of latitude 28°22′16″N and longitude 33°31′21″E which lies, in Wadi Araba, at the western part of the study area. The eU concentration reached to 49.2 ppm, eTh concentration is about 9.6 ppm and potassium is 0.2%.
The eU/eTh ratio reaches 6.6 which gives an importance for this formation (Table 2 and Figs. 8, 9, 10, 11).

5. EL-QAA plain area

5.1. Ground γ-ray spectrometric measurements of younger granites

The studied Younger granites in El-Qaa plain area are represented by G. Abora, which located at the southeastern part of the study area. They possess a normal radioactivity level. The K content ranges between 3.7 and 5.2% with an average of about 4.5%. Whereas, eU ranges between 4.6 and 6.8 ppm with an average of about 5.2 ppm and eTh ranges from 10 to 20 ppm with an average of about 15 ppm. The eU/eTh ratio reaches about 0.45, which indicates a highly weathered granites. These measurements were acquired at a location of latitude 28°21'36"N and longitude 33°46'6"E (Table 3 and Figs. 12, 13, 14, 15).

5.2. Ground γ-ray spectrometric measurements of dykes

Basic dykes and a swarm of porphyry aplite dykes intrude the younger granites of G. Abora with a N-S major trend. These dykes are characterized by moderate radioactivity (Table 3 and Figs. 12, 13, 14, 15). In basic dykes, K attains about 2.7%, eU about 2.6 ppm and eTh 12 ppm. Meanwhile, in the porphyry dykes, the K reaches about 5.4%, eU about 8 ppm and eTh about 18 ppm. These measurements were achieved at a location of latitude 28°22'43"N and longitude 33°45'9"E.

5.3. Ground γ-ray spectrometric measurements of Sudr formation

A high anomaly is recorded in the northeastern part of El-Qaa plain area, at latitude 28°36'52"N and longitude 33°30'43"E. This anomaly is characterized by high eU concentrations reaching 47 ppm, while eTh content reaches 7.5 ppm and K reaching 0.1%. The eU/eTh ratio is
relatively high which reached 14 (Table 3 and Figs. 12, 13, 14, 15).

5.4. Ground γ-ray spectrometric measurements of El-Qaa plain sediments

El-Qaa plain covers a very large area with a flat surface. It has a relatively high radioactive level, which is a resultant of the accumulation of sediments, due to weathering from the surrounding granitic rocks. This resulted in a high level of K content than in the sediments, which ranges between 1.4 and 2.8%. In addition, an increase in both eU and eTh levels, was observed which ranged between 2.3 and 5.9 ppm eU and from 5.8 to 10.7 ppm eTh respectively (Table 3 and Figs. 12, 13, 14, 15). The average eU/eTh ratio reaches about 0.45.

5.5. Ground γ-ray spectrometric measurements of G. Safariat area

G. Safariat occurs on the east of El-Qaa plain, it is a sedimentary section of Cretaceous rocks. It is found to be much complicated by folding and faulting. It is composed of Cretaceous limestone and marls. It covers a wide area reaching about 4.5 km², with a semicircular shape and characterized with low to moderate topography. In this bed eU reached 22.5 ppm, while eTh attained 2.9 ppm and K is 0.5% (Table 3 and Figs. 12, 13, 14, 15). The highest eU/eTh ratio reached 7.8 and is associated with a bed from limestone with mica and chert intercalations. Shale and ferruginous sandstones possess a moderate level of radioactivity, where eU reaches about 8 ppm and eTh attains about 19 ppm but they have a normal eU/eTh ratio, of about 0.45.

6. Summary and conclusions

The principal aim of this work is to study the radioactivity of Wadi Araba-Abu Durba and El-Qaa plain areas located in the southwestern Sinai of Egypt. High-sensitivity airborne spectrometric survey showed a practical success to map basement sedimentary contact, delineate and subdivide various rocks in the study area. The resultant data indicate the association of younger granites with the highest levels of both eTh and K in the study area up to 33 ppm and 5.4% respectively, as well as high concentrations of eU up to 10 ppm. The western part of the study area is characterized especially phosphate-rich rocks of sedimentary rocks that contain the highest concentrations of uranium up to 14.2 ppm. Meanwhile, they represent the lowest level for each of the eTh and K concentrations of the study area.

Accordingly, ground spectrometric surveyed was performed for
verifying the significant anomalies deduced from the airborne γ-ray spectrometric survey. Younger granites of G. Araba possess a moderate level of spectral radioactivity, which is slightly higher than the background. The average measured radioelement concentrations are 4.8% K, 6 ppm eU, and eTh is 20 ppm. The eU/eTh ratio attains 0.33, which indicate a normal case of radioactive contents in the younger granites.

In the Araba Formation, eU content reaches to about 34 ppm, while eTh reaches about 9.8 ppm and potassium reaches 1.2%. Therefore, the eU/eTh ratio attaining more than 3.4 is very high compared with similar normal rock types. This occurrence is considered the first one recorded in the study area close to the basic dyke, which extends for several kilometers, and striking in a N45°W-S45°E direction.

Naquos Formation is nearly radioactivity barren, where eU is 0.9 ppm, eTh is 4.6 ppm and K is 0.1%. Abu-Durba Formation has a widely extended highly radioactive bed. The eU anomalous measurement in this facies attain more than 67 ppm, whereas eTh reach 38 ppm and potassium is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%. The eU/eTh ratio is about 2, which indicates a migration of uranium to this formation. Thorium contents in Quseib Formation reaches about 37 ppm is more than uranium concentration which attain about 18 ppm and the potassium content is 0.5%.
to this formation. The Esna Formation is characterized with a moderate ratio attain 7.3 in value which indicates the remobilization of uranium eTh contents of about 11 ppm, while potassium is 0.9%. The eU/eTh concentrations reaching to 80 ppm are recorded in Sudr Formation and low This suggests migration of uranium to this formation. High eU contents over low eTh concentration lead to an eU/eTh ratio reaches about 13. This suggests migration of uranium to this formation. High eU concentrations reaching to 80 ppm are recorded in Sudr Formation and low eTh contents of about 11 ppm, while potassium is 0.9%. The eU/eTh ratio attain 7.3 in value which indicates the remobilization of uranium to this formation. The Esna Formation is characterized with a moderate γ-ray spectrometric level where eU reaches about 15 ppm, and eTh attains about 5.8 ppm while potassium is 0.5%. The equivalent two radioelements concentration in Thebas Formation is slightly high. The eU content reaches 49.2 ppm, eTh is about 9.6 ppm and potassium is 0.2%. The eU/eTh ratio is more than 5, which is a very high value.

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