Mapping and Lithological discrimination using digital image processing and radioactive investigations of Wadi Um Giegh area, Central Eastern Desert, Egypt

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ABSTRACT

The present study aims to create the geological map of Wadi Um Giegh area by applying different image processing techniques for Landsat-8 ETM+ satellite, airborne gamma ray spectrometric survey and geological investigations to discriminate between the differently exposed lithological units. The mapping approach developed and applied in this study integrates resulted images from processed Landsat-8 ETM+ data and field data sets to produce a map showing the alteration zones at study area. The processed digital data of Landsat-8 ETM+ covering the study area have been used. Several products of Landsat-8 ETM+ digital data such as (7, 4 and 1 in RGB), false color composite images (8, 6, 1 in RGB) and (3, 2, 1 in RGB). Band rationing images (4/2, 5/4, 7/5), (6/7, 6/2, 4/2) and (5/7) are generated. Products of image processing improve lithological discrimination especially of serpentines, volcanics, metagabbro and granitic rocks and different varieties of intrusive rocks. The analysis of the gamma-ray spectrometric data, reveals that, there is an increase in the eTh content from 1.34 to 15.68 ppm. Whilst, the eU content increases from 0.17 to 7.84 ppm, the K%-content with an average of about 1.36 %, eU/eTh from 0.09 to 0.64 with an average 0.4 and eTh/eU from 1.57 to 11.41 with an average of 2.80. So, the different rock units of Wadi Um Giegh area are enriched in uranium. The eU-eTh(3.5) reaches 3.43 ppm over the rhyolite rocks and diminishes to (-0.40) ppm at the same rocks. This indicates that, the uranium migration (leach out) in these rocks less than the (leaching in). The granites at Wadi Um Giegh area show low degree of fractionation suggesting a source for further hydrothermal or supergene concentrations. Therefore, this study area is considered to be of low U-favourabily. The calculated dose rates in the study area, ranging between 0.1 and 1.1 mSv/year, which indicate that the study area as a whole remains in the safety limit (1.0 mSv/y).

Keywords: Landsat ETM+, Wadi Um Giegh, Radioactivity, volcanic, serpentines and uranium Mineralization.

1. Introduction

The basement rocks of Egypt are characterized by four main rock sequences, including a gneiss assemblage that comprises the core complexes, an island arc assemblage; an ophiolite assemblage; and syn- and post-tectonic intrusions (AbdNaby et al., 2000; AbdNaby and Frisch, 2002). Lithological mapping and mineral exploration are one of the most important targets of remote sensing and digital image processing techniques(Arnous 2000, El-Ghawaby et al., 2001 and Omer 2016). The main objectives of geological remote sensing researches are the development of methods for mapping rock types. Kent and Quinn (1983) applied remote sensing in geology and have been used Landsat satellite images to select potential areas for copper mineralization in southern Sinai. Hydrothermally altered rocks have considerable attention because of their potential economic implications and favorable spectral characteristics for remote identification (Rowan et al. 2003; Abrams et al. 1977, 1983; Goetz et al. 1983; Podwysocki 1983; Kruse et al. 1993; Crosta et al. 2003; and Galvao et al. 2005). Air-borne data is usually used for regional lithological, alteration mapping, and mineral exploration. Various image-processing techniques have been applied for Landsat OLI and ASTER imageries to discriminate between the differently exposed lithologies. The present study aims essentially to discriminate and differentiate the lithological units based on the digital image processing and radioactive examinations that may assist in developing the uranium exploration by using Landsat-8 ETM+ satellite images. These approaches able to prepare various geological spatial thematic maps to eliminate the probable zones of...
the radioactive mineralization at Wadi Um Gheig area Central Eastern Desert, Egypt. In addition to the
digital image processing of the remote, sensing satellite data has a lot of potential in providing several
solutions to overcome the difficulties and limitations associated with the geological field and mineral
exploration especially in the arid and semi-arid regions (Yamaguchi and Naito, 2003; Arnous and
Sultan, 2014; Pour et al. 2017; Sultan et al., 2017). Um Gheig area is located in the southern part of the
Central Eastern Desert of Egypt, between latitudes 25° 14’ 56” & 25° 24’ 05” N and longitudes 34° 3’& 34°
15 E (Fig. 1). It covers an area of about 340 square kilometers. The study area can be accessible from
the asphaltic road of Quseir-Marsa Alam, at km 50 from Quseir and turn right by a desert track through
Wadi Um Gheig area. Topographically, Many land marks exist in the area under consideration, the
most important of them are G. Um Samra (908 m) and G. Um Bakra (901 m) which are represent the
highest topographic features. The studied area is dissected by many wadis (dry valleys). The main of
these wadis are Wadi Siwiqat Um Lassaf, which traverses the area in a nearly NE-SW direction, W.
Um Samra, khur Um Safi which runs in NW-SE direction and a tributary of W. El Miyah, that partly
runs in NNE-SSW direction at the western part of the study area. W. Um Samra and W. Siwiqat Um
Lassaf Both are tributaries of W. El Miyah. All of the Wadis and their tributaries are usually covered
by sands and gravels, which are the erosion products of the country rocks. Abdalla (2001) considered
Um Safi as subvolcanic equivalent for the metaluminous alkali rare metal granites and is belonging to
the post-collision and orogenically related A2-type granites with only zircon and uranothorite as
radioactive minerals. Hassan (2001) proves petrographically that, the volcanics rocks of Um Safi area
are rhyolitic in composition and their associated pyroclastics. He stated that, the enrichment of
radioactive minerals in rhyolite is due to syngenetic concept. Ragab et al., (2010) stated that the
mineralogical studies on the altered rhyolite rocks of Um Safi area indicate the presence of kasolite,
zircon, monazite, xenotime, ferrocolumbite, thorit, uranothorite, cerianite and violet fluorite as well as
REE-arsenates and REE-ferromanaganese due to alkali metasomatism.

![Fig. 1: Location map of Um Giegh area, Central Eastern Desert, Egypt.](image)

2. Data Processing

The area of Wadi Um Giegh is covered in one scene of Landsat-8 Enhanced Thematic Mapper
plus (ETM+) data scene number (path/row = 174/42) consisted of nine bands. The acquisition date of
this data is 3 January 2020. The study area, have been radiometrically and geometrically rectified in UTM projection WSG84 zone 36 North. In addition to integrating and delineated probable sites of mineralization ENVI 5 and ArcGIS 10.3 software. The available airborne gamma ray radiospectrometric data represented at scale 1:50,000, were surveyed by Aero-Service Division, Western Geophysical Company of America, USA, in 1984 (Aero-Service 1984). The survey was conducted at a flight altitude of 120 m terrain clearance, 1.5 km of flight line interval, and 10 km of tie line spacing. These data have been prepared for subsequent processing by digitizing the maps in numeric format that permits the application of interpolation. Radio spectrometric data have been subjected to separation of the obtained radio spectrometric measurements over every lithological unit, determination of their characteristic statistics. Airborne spectrometric analysis and other ancillary geological data such as geological and geomorphological maps. These tools were used in the current study to discriminate and map the lithological units and the radioactive features. Various processing techniques have been applied for Landsat 8 ETM+ imagery of the study area to discriminate the different exposed lithologies (mapping) using spectrometric mapping methods, such as band ratio and minimum noise fraction (MNF) for bands. Each technique could differentiate between certain lithological units. Band ratios are utilized for the rock unit identification in a space-borne data where the various minerals reflect more brightly at various wavelength and exact ratios can identify the relative dissimilarity in reflectance values (Sultan et al. 1987a, b; Kusky and Ramadan 2002; Gad and Kusky 2006; Gad 2007; Arnous and Sultan 2014; Arnous 2016).

3. False color composite images (FCC)

Obviously, Correlation between band 1 and band 4 and also between band 7 and band 4 are weak. Consequently, the optimum triple band combination which is less correlated and contains abundant information with lowest or no redundancies are bands 7, 4, 1 that are assigned to RGB pseudocolor band combination, respectively. Different rock units are expressed by different colors; for instance, granitoids appear as brown whereas metavolcanics and metasediments appear as reddish brown while the serpentines appear as blue color (Fig. 2). The correlation coefficient and the scatterograms of the study area show that the lowest correlation is between bands 8 and 6 followed by band 1. Different rock units are expressed by different colors; for instance, granitoids appear as green whereas metavolcanics and metasediments appear as gray while the serpentines appear as violet color (Fig. 3).

**Fig. 2:** Landsat 8 ETM+ (FCC) image (bands 7, 4, 1 in R, G, B) of Wadi Um Gheig area, Central Eastern Desert, Egypt.
4. Band ratio images

Several workers dealt with the lithological mapping of Egyptian basement rocks using band ratio images, among them Sultan et al., 1987; Gad and Kusky, 2006; Sadek, 2005; Sadek and Hassan, 2012; Amer et al., 2010; Aboelkhair et al., 2010; Madani and Emam, 2011; Zoheir and Emam, 2012; Tolba and Kamel, 2014). The selection of bands that will be used in the present study depends essentially on the spectral characteristics of the material relative to their surroundings (Thurmond et al., 2006) to generate band ratios that can be useful for highlighting certain features due to Digital Number (DN) values of corresponding pixels in a band with low total reflectance (Jensen, 1996). Bands 3, 2, 1 in RGB (Fig. 4) and band ratio combination 4/2, 5/4, 7/5 in RGB are respectively utilized to display different lithological units and depict sharp contrast among them. The band ratio 4/2, 5/4, and 7/5 in RGB (Fig. 5) clearly display and increase the number of the exposed rock units. In Fig. 5, the metasediments appear as pale sky blue to pale green color, the metavolcanics appear in dark blue, the volcanic appears in dark red, the metadiorite appears in blue, metagabbro-diorite complex appears in pinkish blue, granitic orthogneiss appear in greenish yellow, quartz diorite and gabbro appear in pale blue, the calc-alkaline appears in yellow to greenish yellow, the alkali granite appears in pink color. Band ratios 4/7, 5/4, and 7/5 in RGB (Fig. 5) are successfully discriminate the different rock units, whereas, metavolcanics have green to dark green color, the metasediments appear in dark reddish blue, the volcanics appear in yellow, the older granites appears in pale green to dark green, metagabbro-diorite complex appears in pale green to pale blue, younger granites appear in red, quartz diorite and gabbro appear in pale green to pale blue. Generally, the basic rocks are rich in ferromagnesian and show high proportion of secondary iron minerals in their weathered surfaces, while granitic rocks are rich in silica and their weathering products are kaoline- rich beside silica (El Rakaiby, 1996). Drury and Hunt (1989) and Rothery (1987) denoted that the ETM+ bands 1 to 4 contain information on iron minerals. The rationing images bands were used for lithological discrimination; moreover, they helped in delimiting disturbed zones, potentially corresponding to hydrothermal alteration haloes that may comprise mineralizations. Results from ratio image bands (6/7, 6/2, 4/2) in RGB (Fig. 6), further validated during geological field surveys, discriminated between the different rock units and delineated two mineralized alteration zones. In this ratio image, the younger granite rocks appear in purple color, the metavolcanics rocks displayed in an
interference colors from yellow to brown, older granites appears as blue color and meta gabbro complex as reddish in color.

**Fig. 4:** Landsat 8 ETM+ image bands (3, 2, 1 in RGB) of Wadi Um Gheig area, Central Eastern Desert, Egypt.

**Fig. 5:** Landsat 8 ETM+ band ratio image (4/2, 5/4, 7/5in RGB) of Wadi Um Gheig area, Central Eastern Desert, Egypt.
The band ratios (5/7) of Landsat 8 ETM+ data helped in recognizing detailed discontinuous alteration zones clearly present in the study area; these appear as red colors (Fig. 7). The detected alteration zones are characterized by significantly altered minerals. The rhyolitic volcanic rocks and their alteration products are the main constituents of these trenches. Hematization is mostly present as well as other different types of alterations such as, kaolinitization, chlortization and limonitization. These alterations are concentrated along the fractures of altered rhyolite and are associated with mineralization.

5. Lineaments extraction from the enhancement images

Detection of structural lineaments important in mineral exploration because mineralization may occur pre or post folding and faulting. Early mineralization may be linked to stratigraphic changes whereas late mineralization may be related to fractures (veins) or folds that controlled the flow of hydrothermal fluids (Prost 2001). The term lineament is used to describe any linear feature such as segments of drainage, ridges, and escarpments, (Hill 1992). The spatial filtering techniques that applied on satellite images are very useful and assist in the extraction of the major and minor structural lineaments for the study area. The resulting images have higher contrast, looks sharper and correct the topography of the area and keep all lineaments in detail. The field verification was applied to the interpretation of the enhanced image of the study area. Also, recognition of linear feature in the image such as contacts between adjacent lithological units of different brightness, folding axial traces, regional faults and fractures can be recognized on the image. The extracted lineaments inferred from integrated enhanced satellite images is shown in (Fig. 8). There are three main trends in the study area. They are NW-SE, ENE-WSW, and NS respectively according to their predominance. They are collectively represented about seventy percent of the total lineaments trends.
Fig. 7: Landsat 8 ETM+ band ratio image (5/7 in RGB) of Wadi Um Gheig area, Central Eastern Desert, Egypt.

Fig. 8: Surface structural lineaments map integrated from enhanced images, of Wadi Um Gheig area, Central Eastern Desert, Egypt.
6. Verification of lithological map

A new modified geological map for the study area (Fig.9) was produced on the basis of field observations and remote sensing analysis. Many rock varieties of either volcanics and plutonic intrusions emplaced in an intrusive relationships in the study area, starting from oldest to youngest they based on the field geologic investigations. The rock types have been classified into three main rock units covering the study area. These rock units are arranged from the oldest as following, Serpentinite, Metavolcanics, Metagabbro-Diorite complex, Younger Granites, Hammamat Sediments, Rhyolite flow and related volcaniclastics and Trachyte Plugs, (Fig.10). All the previously mentioned rock types are mostly invaded by dykes and viens.

![Geological map of Wadi Um Gheig area, Central Eastern Desert, Egypt.](image)

7. Radioactivity

The measured gamma ray spectrometric data for the different studied rock units of Wadi Um Gheig area computed to establish descriptive statistical characteristics of the radioelements K (%), eU (ppm), eTh (ppm) and their ratios in the rocks of the study area. Also, enables to determine the relative degree of mobilization and uranium migration in the rocks. The calculated statistical parameters for the three radioelements, K (in %), eU (in ppm), eTh (in ppm) and their ratios for the main rock units of Wadi Um Gheig area are reported in Table (1). The eU value of rhyolitic rocks ranges from 1.81 to 7.47 ppm with an average of 5.13 ppm, eTh from 4.21 to 15.68 ppm with an average of 12.36 ppm, eU/eTh from 0.27 to 0.58 with an average of 0.41, and eTh/eU from 1.71 to 3.75 with an average of 2.59. So, it is enriched by uranium according to Clark et al. (1966) and Rogers and Adams (1969). The eU value of younger granites ranges from 1.06 to 6.94 ppm, with an average of 2.82 ppm; eTh from 1.92 to 12.29 ppm with an average of 7.29 ppm; eU/eTh from 0.27 to 0.58 with an average of 0.38 and eTh/eU from 1.73 to 3.71 with an average of 2.80. The eU value of older granites ranges from 0.78 to 2.28 ppm, with an average of 1.43 ppm; eTh from 2.04 to 6.39 ppm with an average of 4.05 ppm; eU/eTh from 0.22 to 0.53 with an average of 0.36 and eTh/eU from 1.87 to 4.65 with an average of 2.92. The eU value of metavolcanics ranges from 0.18 to 1.77 ppm, with an average of 1.00 ppm; eTh from 1.50 to 4.99 ppm with an average of 2.60 ppm; eU/eTh from 0.09 to 0.64 with an average of 0.38 and eTh/eU from 1.57 to 11.27 with an average of 2.97. The eU value of serpentinites ranges from 0.17 to 1.15 ppm, with an average of 0.77 ppm; eTh from 1.35 to 3.05 ppm with an average of 2.02 ppm; eU/eTh from 0.09 to 0.61 with an average of 0.38 and eTh/eU from 1.63 to 11.41 with an average of 2.92.
8. Radioelement Maps

8.1. (K %) Surface Distribution Map

The examination of the potassium (K %) surface distribution map (Fig. 11) shows that, the prominent area of low K values (<1 %) reflects the distribution of the metavolcanics and serpentinite rocks. The wadi sediments around the rhyolitic body are contoured with potassium percentages ranges from 1 to 2.26%. This level is encountered as a narrow elongated zone along the wadi sediments around the rhyolitic body of the area. The high range in K values (> 3.05% K) content reflects a broad distribution of potassium enrichment and they are associated with rhyolitic body. The broad potassium distributions are trending in NW-SE and NE-SW direction. This zone contains contoured values (locally exceed 3.05% K) and reflects a group of scattered strong potassium anomalies.

8.2. (eU, ppm) Surface Distribution Map

This map shows that, the values less than 0.4 ppm eU are directly associated with the metavolcanic, serpentinite rocks and the wadi sediments around the rhyolitic rocks. The values (from 1.1 to 2.9 ppm eU) are associated with older granites, whilst the values (between 2.9 and 3.7 ppm eU) are directly related to younger granites (Fig. 12). Most of the rhyolite rocks display eU content reaches more than 3.7 ppm and they occur as spreadic zone of high uranium content representing the high level of radioactivity. This anomaly has two main trends, NW-SE and NE-SW directions.

8.3. (eTh, ppm) Surface Distribution Map

Thorium is a stable element, and reflects the original (pre-alteration) rock compositions during the magmatic differentiation, so the spatial distribution of eTh reflects the geochemical differences of the investigated rocks. Therefore, eTh content distribution map (Fig. 13) shows a well discrimination between the rhyolite rocks, which have high eTh content, and the low eTh content of metavolcanic and serpentinites rocks. eTh- is low, with values lower than 1.4 ppm eTh, at outcrops of metavolcanic and serpentinite rocks. Whilst, the values between 1.7 and 2.9 ppm ath are directly related to the older

Fig. 10: A, B, C and D field photographs for different rock unites at study area.
gradients and the values ranging between 3.3 to 7.5 ppm eTh are associated with the younger granites. In contrast, the rhyolite rocks are characterized by highest level of eTh content more than 9.7 ppm eTh. Consequently, it appears clearly that the thorium concentrations increase toward the eastern part of the rhyolite rocks, as well as, some anomalies are trending in N-S and E-W directions.

8.4. eU-(eTh/3.5) Remobilization Map

The uranium migration value can be obtained by subtracting the original uranium content (eTh/3.5) from the present measured uranium content (eU). The original uranium content can be theoretically calculated by dividing eTh content by the eTh/eU which it is ranging from 3 to 4 in acidic volcanics (Wenrich, 1985). Also, a constructing the distribution map of the eU-(eTh/3.5) enables to delineate the limit between the negative values representing migration of- or leaching areas and positive values characterizing migration in or deposition areas, (Abdel Meguid et al., 2003). The negative values between -0.31 and -0.02 are encountered as zones with different shapes, distributed around the metavolcanic and serpentinite rocks (Fig. 14), so most of the U content is leaching out (depletion). The values between 0.12 and 0.65 ppm are related to older and younger granites. The high level of eU/eTh with positive values is related to the rhyolite more than 0.89. These high levels are located in the western, southern and southeastern parts of rhyolitic rocks. So, the U content is leaching in (enrichment). From the alternative negative and high positive anomalies, especially those associated with the altered rhyolite rocks, the direction of the uranium mobilization can be traced toward them with directions trending from the negative anomalies to the high positive ones inside each rock unit.

8.5. eU/ eTh Plots

The eTh/eU diagram of the different studied rock units of Wadi Um Giegh area (Fig. 15a) reveals an enrichment of uranium concentrations where the highest eU and eTh values are for the rhyolite samples. Most of the samples are in between 2.0 and 4.0 eTh/eU ratio with a simultaneous increase in both eU and eTh. Uranium remained relatively immobile in the original rock. According to this model, the radioelement increases gradually during magmatic fractionation, but the ratio changes due to different alteration processes (Heikal et al., 2019). The eU/eTh versus eTh diagram (Fig. 15b) indicates a reverse relationship, in which eU/eTh ratio decreases with increasing eTh for most plotted rock units, indicating the important role of hydrothermal solutions in redistribution of these elements and is proved that, there is a leaching of some of the uranium content from the altered rock units. On the other hand, the eU/eTh ratio versus eU diagram (Fig. 15c) reveals a strong direct relationship which shows hydrothermal U enrichment. So, different alteration processes play an essential role in U mobilization. Most samples of the studied different rock units of Wadi Um Giegh area have more uranium content (Table 1) that of the hypothetical uranium distribution (Fig. 14d) and so the mobilization gives positive values, which in turn show that U of these different studied rock units is leaching in (Cambon, 1994). Lastly, from the analysis of the gamma-ray spectrometric data, which is revealed on binary diagrams of eTh vs. eU, eU vs. eU/eTh and eU against eU-eTh/3.5 (Fig. 15) and listed in (Table 1), the rhyoites of Wadi Um Giegh area shows high enrichment by U and Th mineralization.

9. Mobilization and migration of uranium and thorium

There are two main topics to indicate the mobilization of both uranium and thorium; 1) eU/eTh ratio and 2) Type and amount of uranium mobilization. The ratio of eU/eTh is a very important geochemical indicator for U mobilization (Naumov 1959). The eU/eTh ratio for the granitic rocks is commonly about 0.33 (Stuckless et al. 1977; Boyle 1982; El Galy 2007 and El Nahas et al. 2011). In different studied rock units of Wadi Um Giegh area, eU/eTh ratio ranged from 0.09 to 0.64 with an average 0.4, suggesting a high degree of uranium mobilization.

10. Type and amount of uranium mobilization

The uranium mobilization rate (P%) is determined by P= Um/Up x 100%. The obtained results of Uo, Um and P for representative samples of the studied rock units are listed in (Table 2), where Uo is original uranium content, Um is amount of mobilized uranium, Up is present Uranium content and Up% is uranium mobilization rate. Dynamics of uranium-rich fluids and amount of mobilized uranium as well as uranium mobilization rate in the studied rocks are calculated through several steps using equations of Benzing Uranium Institute of China and CNNC (1993). The paleo-uranium background
(the original uranium content) is calculated by \( U_0 = e_{Th} \times e_{U/eTh} \), where: \( U_0 \) is the original uranium content, \( e_{Th} \) is the average of thorium content in certain geologic unit and \( e_{U/eTh} \) is the average of the regional \( e_{U/eTh} \) ratio in different geologic units. The amount of the mobilized (migrated) uranium (\( U_m \)) is calculated by \( U_m = U_p - U_0 \), where, \( U_m \) is the amount of the mobilized uranium and \( U_p \) is the average of the present uranium content in certain geologic unit. If \( U_m > 0 \): this indicates that U was gained or mobilized into the geologic body during late evolution (migration in). If \( U_m < 0 \): this means that U had been lost from the geologic body during late evolution (migration out). The data shows that the \( U_m \) values of rhyolites, younger granites and metavolcanics are > 0 revealing that, U was mobilized into the geologic unit (migration in) whilst, the \( U_m \) value of older granites is < 0 U was mobilized out from them (migration out), mostly to the stream sediments.

**Table 1:** Summary of the statistics for the surface distribution of the three radioelements K, \( e_{U} \), \( e_{Th} \) and their ratios for different rock units of Wadi Um Giegh area, Eastern Desert, Egypt.

| Rock type       | T.C  | K% | \( e_{U}(ppm) \) | \( e_{Th}(ppm) \) | \( e_{U/eTh} \) | \( e_{Th/eU} \) | \( e_{U}-(e_{Th}/3.5) \) |
|-----------------|------|----|------------------|------------------|----------------|----------------|---------------------|
| **Rhyolites**   |      |    |                  |                  |                |                |                     |
| Minimum         | 4.95 | 1.41 | 1.81             | 4.21             | 0.27           | 1.71           | -0.13               |
| Maximum         | 13.37| 3.66 | 7.44             | 15.68            | 0.58           | 3.75           | 3.43                |
| Mean(X)         | 11.41| 3.23 | 5.13             | 12.36            | 0.41           | 2.59           | 1.60                |
| No. of Reading  |      | 265 |                  |                  |                |                |                     |
| **Younger granites** |      |  |                  |                  |                |                |                     |
| Minimum         | 1.88 | 0.51 | 1.06             | 1.92             | 0.27           | 1.73           | -0.10               |
| Maximum         | 12.15| 3.62 | 6.94             | 12.29            | 0.58           | 3.71           | 3.43                |
| Mean(X)         | 7.14 | 2.26 | 2.82             | 7.29             | 0.38           | 2.80           | 0.74                |
| No. of Reading  |      | 260 |                  |                  |                |                |                     |
| **Older granites** |      |  |                  |                  |                |                |                     |
| Minimum         | 2.03 | 0.53 | 0.78             | 2.04             | 0.22           | 1.87           | -0.38               |
| Maximum         | 6.00 | 2.21 | 2.28             | 6.39             | 0.53           | 4.65           | 0.81                |
| Mean(X)         | 4.04 | 1.31 | 1.43             | 4.05             | 0.36           | 2.92           | 0.27                |
| No. of Reading  |      | 225 |                  |                  |                |                |                     |
| **Metavolcanics** |      |  |                  |                  |                |                |                     |
| Minimum         | 1.31 | 0.35 | 0.18             | 1.50             | 0.09           | 1.57           | -0.40               |
| Maximum         | 4.59 | 1.37 | 1.77             | 4.99             | 0.64           | 11.27          | 0.73                |
| Mean(X)         | 2.45 | 0.74 | 1.00             | 2.60             | 0.38           | 2.97           | 0.25                |
| No. of Reading  |      | 125 |                  |                  |                |                |                     |
| **Serpentinites** |      |  |                  |                  |                |                |                     |
| Minimum         | 1.28 | 0.34 | 0.17             | 1.35             | 0.09           | 1.63           | -0.38               |
| Maximum         | 2.40 | 0.89 | 1.15             | 3.05             | 0.61           | 11.41          | 0.58                |
| Mean(X)         | 1.84 | 0.53 | 0.77             | 2.02             | 0.38           | 2.92           | 0.19                |
| No. of Reading  |      | 100 |                  |                  |                |                |                     |

| **Table 2:** Average of the original uranium, the present uranium, the mobilized uranium and the uranium mobilization rate in the different studied rock units of Wadi Um Giegh area, Eastern Desert, Egypt. |
|-----------------|------|-----|-----|-----|-----|
| **Rock type**   | T.C  | K%  | \( e_{Th}(ppm) \) | \( U_0 \) | \( U_p \) | \( U_m \) | \( P\% \) |
| Rhyolites       | 12.36| 5.07 | 5.13 | 0.06 | 1.17 |
| Younger granites| 7.29 | 2.77 | 2.82 | 0.05 | 1.77 |
| Older granites  | 4.05 | 1.46 | 1.43 | -0.03| -2.10|
| Metavolcanics   | 2.60 | 0.99 | 1.00 | 0.01 | 1 |
| Serpentinites   | 2.02 | 0.77 | 0.77 | 0    | 0 |

\( U_0 = \) Original Uranium content \( U_p = \) Present Uranium content \( U_m = \) Amount of mobilized uranium \( P\% = \) Uranium mobilization rate
Fig. 11: Potassium (K) filled-color contour map, in %, of Wadi Um Giegh area, SED, Egypt.

Fig. 12: Equivalent uranium (eU) filled-color contour map, in ppm, of Wadi Um Giegh area, SED, Egypt.
Fig. 13: Equivalent Thorium (eTh) filled-color contour map, in ppm, of Wadi Um Giegh area, SED, Egypt.

Fig. 14: eU-(eTh/3.5) remobilization ratio filled-color contour map, in ppm, of Wadi Um Giegh area, SED, Egypt.
Fig. 15: Radioactive elements plot for airborne gamma-ray spectrometry measurements of different studied rock units of Wadi Um Giegh area, Eastern Desert, Egypt.

Symbols as:
- **Serpentinites**
- **Metavolcanics**
- **Older granites**
- **Younger granites**
- **Rhyolites**

11. Exposure rate and Dose rate values

The exposure rate ($E$) can be calculated from the apparent concentrations of $K$ ($\%$), $eU$ (ppm), and $eTh$ (ppm) using the relation (IAEA, 1991): $E (\mu R/h) = 1.505 K (\%) + 0.653 eU (ppm) + 0.287 eTh (ppm)$. The exposure rate can be converted to the equivalent dose rate by using a simple conversion factor (Grasty et al., 1991): the dose rate value, $D (mSv/y) = 0.0833^*E (\mu R/h)$. The highest dose rate intensity level, which is considered as high level of radiation, was associated mainly with the Rhyolites with value reaches $11.7 mSv/y$. Meanwhile, the lowest dose rate intensity level was recorded over the Serpentinite rocks with value reaches $0.7 mSv/y$, Table (3), shows the different values of dose rate in $mSv/y$ for each rock unit in Wadi Um Giegh area.

The International Commission of Radiological Protection (ICRP) has recommended that no individual should receive more than $5000$ millirems/year ($50 mSv/y$) from all natural and artificial radiation sources in his or her environment (IAEA, 1979). Currently, the recommended dose rate should not exceed one millisievert per year (5th International Conference on High Level of Natural Radiation, Munich, Germany, IAEA, 2000). Finally, Table (3) shows that, the study area has a relative high level
of dose rate especially over the rhyolite rocks which exceeds the safe limit (1.0 mSv/y). Therefore, the rhyolite zone of Um Safi area can be considered as harmful to the individuals.

Table 3: The dose rates (in mSv/y) for the main rock units in the rhyolite zone of Wadi Um Giegh area, Central Eastern Desert, Egypt.

| Rock Unit     | Dose Rate (mSv/y) |
|---------------|-------------------|
|               | Min | Max | Mean | SD    |
| Rhyolite      | 1.02| 11.7| 3.5  | 2.276 |
| Metavolcanic   | 0.045| 0.9  | 0.33 | 0.186 |
| Serpentinite   | 0.068| 0.7  | 0.25 | 0.159 |

Conclusion

The present study deals with the remote sensing and airborne gamma ray spectrometric analysis of the basement rocks at Wadi Um Giegh area, Central Eastern Desert of Egypt. Digital processing of Landsat ETM+ images for the study area generated several products such as true color image (7, 4, 1 in RGB), false color composite image (8, 6, 1 in RGB). Landsat ETM+ true color image is an image similar to that seen or perceived by the human eyes. False color composite image bands (7, 4, 2 and 7, 5, 1 in RGB) are suitable for delineating regional structure and provide an excellent base for geological mapping. Discrimination between different rock types is easily applied, where there are high contrasts between the different rocks images. Ratio image (6/7, 6/2 and 4/2 in RGB) was used to differentiate between serpentinites and different rock types. The color ratio composites of (4/2, 5/4 and 7/5) in RGB have been used in the present study to discriminate between the talc-carbonate rocks from the granite rocks, the talc-carbonate rocks exhibit light orange color while the granite rocks are cyan color. The color ratio composites of (5/7, 4/5 and 3/1) and (5/7) in RGB have been used in the present study to delineate the alteration zones of investigated area. Image processing and interpretation were used to produce a geological map that was used as a base map during the subsequent fieldwork. The measured spectrometric data for the different studied rock units of the studied area were cured statistically to indicate the distribution characteristics of the radioelements K (%), eU (ppm), eTh (ppm) and their ratios in the different rock types of the study area. Also, enables to determine the relative degree of mobilization and uranium migration in the rock unites. The analysis of the gamma ray spectrometric data reveals that, there is an increase in the eTh content from 1.34 to 15.68 ppm. Whilst, the eU content increases from 0.17 to 7.84 ppm, the K% content with an average of about 1.36 %, eU/eTh ratio from 0.09 to 0.64 with an average 0.4 and eTh/eU ratio from 1.57 to 11.41 with an average of 2.80. The resultant general anomalies of eU and eTh are concentrated along the fractures of the altered rhyolite. These fractures are trending in NW- SE directions. Environmentally, the radiation dose rates at the studied area ranging between 0.1 and 1.1 mSv/year, indicate that the study area as whole remains in the safe side and under the maximum permissible safe radiation dose rate without harm to the individual, except in the Um Safi rhyolite rocks, range from 1.0 to 11.7 mSv/y therefore, the rhyolite zone of Um Safi area can be considered harmful to the individuals.

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