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Radiological Impact of Natural Radioactivity in White Granite at Um Baanib area, Southeastern Desert, Egypt

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In this study, the ground spectrometric surveying shows the distribution of uranium, thorium and their ratios in the studied white granite, which reflect the addition amount of uranium to the granite from the surrounding rocks. The activity concentrations of the natural radionuclides were measured using a high-purity germanium detector (HPGe). The average activity concentrations of ^{235}U, ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K were found as (27.01, 83.29, 90.08, 11.59 and 490.75 Bq/Kg) for nine white granite samples obtained from the studied area. The radium equivalent (Ra_{eq}) in Bq/Kg, external hazard index (H_{ex}), radioactivity level index (I_{γ}), the absorbed dose rate (D) and the annual effective dose (AED) in outdoor environment were estimated. The annual effective dose was found to be high for all samples due to high concentration of ^{238}U in the area under investigation which represent radiological risk for the health of population. The concentrations of major oxides (%) and trace elements (ppm) have been determined by X-ray fluorescence spectrometry. High average value for Na_2O and Al_2O_3 which are useful in ceramic's industry, high average values of Sr and Ba are useful to many important industries.

Keywords: *Um Baanib/ Peraluminous/ White granite/ HPGe Detector/ Annual effective Dose rate/ X-ray fluorescence.*

Introduction

Um Baanib area is a part of the Migif-Hafafit-Wadi El Gemal- Wadi Ghadir district, which belongs to the Arabian Nubian Shield. It is bordering to the major shear zone known as Nugrus thrust fault [1] or Nugrus strike-slip fault [2] and or Sha`it–Nugrus shear zone. This shear zone separates high-temperature metamorphic rocks of the Hafafit complex in the SW from mainly low-grade ophiolitic and arc volcanic assemblages known as Ghadir group [3]. The Nugrus thrust runs along the upper part of Wadi Sikait in NW direction till the southern tip of Gable RasSha`it, then swings to a south westward direction along WadiSha`it west of Gable Migif. The Migif-Hafafit gneisses comprise the foot wall of the Nugrus thrust, while the Ghadir group comprises its hanging wall [4].

Uranium (U), thorium (Th) and potassium (K) represent the most abundance naturally radioelements occurring in the upper earth crust. ^{238}U, ^{235}U and ^{234}U are the most abundant isotopes of uranium. Most of the gamma emission that is

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useful for uranium exploration originates from the decay of lead (^{214}Pb) and bismuth (^{214}Bi), (^{226}Ra was measured). In respect to thorium, the most useful gamma ray emitter is thallium (^{208}Tl). Uranium is the most mobile element compared to potassium and thorium. It can remobilize and redistribute in rocks according to tectonic activities and alteration processes, while thorium does not oxidized and remains stable, which permits the formation of secondary uranium minerals [5].

Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil and rocks plays an important role in radiation protection magnets. As radiation of natural origin is responsible for most of the total radiation exposure, knowledge of the dose received from natural sources is very important for not only of its effects on health but also for incidence of other radiation from man-made sources [6].

Measurement of natural radioactivity in rocks is important to determine the amount of change of the natural background activity with time as a result of any radioactive release. The levels due to the terrestrial background radiation are related to the types of rock from which the soils originate. Higher radiation levels are associated with igneous rocks such as granite and lower levels with sedimentary rocks. There are some exceptions however, since some shales and phosphate rocks have a relatively high content of radionuclides [7].

Aim of work

This work aims to study the spectrometric distribution for naturally radioactive nuclei on the radiation exposure levels in the white granite at Um Baanib area may increase using it as construction and industrial material.

Geology

Location

Um Baanib area is located between latitude 24˚36′ 33‶, 24˚ 38′15‶ N and longitude 34˚ 49′ 57‶, 34˚ 51′ 45‶ E, Southwest Marsa Alam City. Wadi Um Baanib is a tributary of Wadi Um Gameil, which connected with Wadi Erier at about 30 km., from the entrance of Wadi Erier at the Red Sea highway. Wadi Um Baanib is accessible for cars, but it is possible to reach the white granite exposure on foot from Wadi Um El Kheran or Wadi Sikait to the northeast for about 4km., across very hard topography and gullis filled with boulders.

Field description

At the downstream of Wadi Um Baanib, the white granite appears as masses intruded in ophiolitic mélange rocks (Fig.1).White granite was cutting by pink granite (Fig. 2).Geologic map was constructed to show the litho-stratigraphic rocks in the study area (Fig.3), which are ophiolitic mélange, white granite and pink granite. The white granite is relatively small in size (<1.0 km^2) intruded and emplaced along the lewiwi thrust zone. It occurs as dike-like bodies as well as rounded masses; reached to 20-10 m. in width and 10-100 m. in length, striking NW-SE. Um Baanib white granite shows low to-moderately reliefs, highly deformed, stretched and elongated in NW-SE direction. It is characterized by fine-to medium grained and highly fractured due to intensive deformation. NW-SE and NE-SW faults dissect Um Baanib white granite with obvious displacement, and could be affected by E-W stress. The main mineral constituents of white granite are quartz, sodic feldspar and a minor amount of mica minerals (muscovite).

The investigation of field spectrometric data at Um Baanib white granite

Field gamma-ray spectrometric surveying has been carried out on the Um Baanib white granite using portable GS-512 spectrometer, which spectrometer GS-512 is a digital portable instruments designed for gamma ray energy spectra measurement. It is powered by internal batteries or external power supply. The GS-512 basic setup with GSP-3 scintillation probe is designed for field measurements of natural and artificial radionuclides and their quantitative determination.

The GS-512, in standard outfit, comprises the measuring probe with the scintillation NaI (Tl) 76x76mm detector and a 512-channel amplitude analyzer controlled by microcomputer. The GS-512 calibration is for the user simplified and calibration constants calculation is fully automated. The results of the measurements and their statistical analysis of the various radioelements and their ratios of the studied white granite at Um Baanib area are listed in table (1).

Fig. (1): photograph showing the exposure of white granite intruded in ophiolitic mélange at Um Baanib area

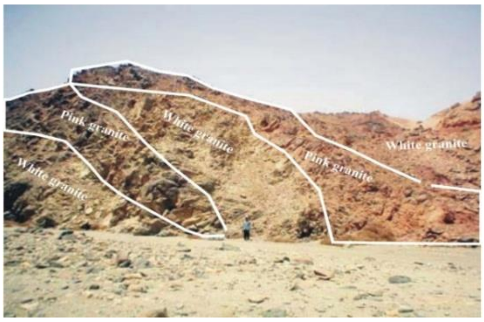

Fig.(2): photograph showing the exposure of white granite cutting by pink granite at Um Baanib area

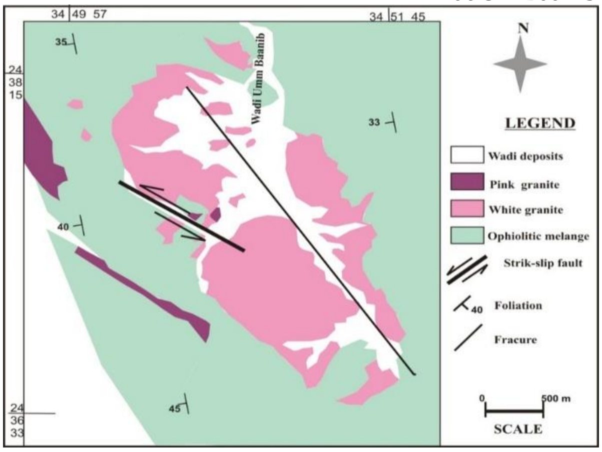

Fig. (3): Geologic map of Um Baanib area, south Eastern desert (Modified after Mahmoud, 2009) [8]

Table (1): Minimum, Maximum, and Average values of ground spectrometric data and their ratios in Um Baanib white granite (N=40)

	K%	***eU (ppm)***	***eTh (ppm)***	***eU/eTh***	***eTh/eU***
Minimum (Min.)	3.0	11	5		
Maximum (Max.)	3.7	16	8		
Avg.	3.3	14.8	6.7	2.2	0.5

N = number of measured stations

From table (1), the radioelements of the white granite at Um Baanib area possess low average values of *K%, eU& eTh* contents and their ratios. They contain a narrow range of the radioactive elements, varies between 3.0-3.7 % for *K*, 11-16 ppm for *eU*, and 5-8 ppm for *eTh*. While *eU/eTh* and *eTh/eU* ratios are 2.2 and 0.5 respectively. From Table (1), uranium mobilization (eU_m) in the white granite at Um Baanib area was calculated and the the following equation was applied;

$eU_m = eU - eTh/3.5$
$eU_m = 14.8-6.7/3.5 = 2.3$

Positive value of (eU_m) indicates that the Um Baanib white granite gains uranium by mobilization from the surrounding sources.

Germanium method

Sampling

Nine samples were collected from white granite of the studied area. They were prepared for $\gamma - r$ay spectrometric analyses by HPGe detector where the samples first dried, crushed and sieved through -200 mesh sizes. Weighted samples were placed in polyethylene bottles of 250 cm^3 volume. The bottles were completely sealed for more than one month to allow radioactive equilibrium to be reached before measured by the gamma spectrometer. This step was necessary to ensure that radon gas is confined within the volume and the daughters still also remain in the samples.

The activity concentration C_U, C_{Th}, and C_K (in Bq/kg) of ^{238}U, ^{232}Th and ^{40}K respectively, in the samples under investigation are listed in table (2).

From table (2) the concentration of ^{235}U ranged between1.38 and 10.54 with an average values of 27.01, for concentration of ^{238}U ranged between 30.85 and 223. with an average 83.29units, the concentration of ^{226}Ra ranged between 35.56 and 225.56 with an average 90.08, while the concentration of ^{232}Th ranged between 7.38units and 19.04units with an average 11.59units and the concentration of ^{40}K ranged between 107.53unitsand 1018.87 units with an average 490.75. The average activity concentration of the studied samples is higher than the permissible level (33 Bq/kg) for ^{238}U. The average activity concentration for ^{232}Th is lower than the permissible level (45 Bq/kg) for all studied samples, while the average activity concentration of ^{40}K is higher than the permissible level (412 Bq/kg). The permissible levels are based on [9] ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K are 32, 33, 45 and 412 Bq/kg respectively.

The activity ratios for $^{226}Ra/^{214}Pb$ and $^{214}Pb/^{214}Bi$ were calculated for all studied samples (Table 3). The data show that the activity ratios in the ^{238}U series are near from unity. This confirms that the state of radioactive between ^{226}Ra and ^{214}Pb and between^{214}Pb and ^{214}Bi are in equilibrium except sample No. (4). The concentrations of ^{238}U (ppm), ^{232} Th (ppm), ^{40}K% and $^{232}Th/^{238}U$ (Clark value ratio) for the studied samples are shown in table (4). From table (4), the concentrations (this is ratio or concentrations? Should be revised of ^{238}U ranged between 2.487and 18.037 with an average 7.027, the concentrations of ^{232}Th ranged between 1.826 and 4.712 with an average 2.921 and K% ranged between 0.343 and 3.225 with an average 1.564, while the $^{232}Th/^{238}U$ ratios ranged between 0.179 and 1.114units with an average 0.561units, which is lower than Clark's value (3.5) indicates that the Um Baanib white granite relatively enriched in uranium.

Table (2): The activity concentration of ^{235}U, ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K in(Bq/kg) for the white granite samples at Um Baanib area

S.no.	^{235}U (Bq/Kg^{-1})	^{238}U (Bq/Kg^{-1})	^{226}Ra (Bq/Kg^{-1})	^{232}Th (Bq/Kg^{-1})	^{40}K (Bq/Kg^{-1})
1	2.19	49.22	47.53	7.38*	1018.87**
2	3.37	74.88	77.96	19.04**	631.24
3	4.72	103.86	112.5	13.02	779.8
4	1.38*	30.85*	36.04	9.20	932.91
5	3.00	67.92	72.76	11.75	348.45
6	1.61	34.64	35.56*	8.39	107.53*
7	2.73	59.34	57.07	12.91	109.33
8	6.47	139.96	145.80	8.17	131.16
9	10.54**	223.66**	225.56**	14.38	357.54
Aver.	27.01	83.29	90.08	11.59	490.75

The lower value* ***The higher value*****

Table (3): The activity ratios of some radionuclides for the studied samples of Um Baanib white granite

S.no.	$^{226}Ra/^{214}Pb$	$^{214}Pb/^{214}$ Bi
1	0.97	0.980
2	1.06	0.953
3	1.099	0.970
4	1.28**	0.830*
5	1.10	0.972
6	1.038	0.977
7	0.956*	1.011**
8	1.042	0.998
9	1.004	1.008
Aver.	1.061	0.966

The lower value* ***The higher value*****

Radiological hazard indices

Radium equivalent activity (Ra_{eq})

Assuming case of uniformity distribution of the natural radionuclides are not uniform in the studied samples at Um Baanib white granite, thus a radiological index called radium equivalent activity (Ra_{eq}) has been defined to estimate the radiation risk associated with these radionuclides. The radiological index is calculated by the following equation:

$$Ra_{eq} = C_{Ra} + (C_{Th} \times 1.43) + (C_k \times 0.077) \quad (1)$$

Where, C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg respectively. This common index is convenient for comparing the specific activities of materials containing different concentrations of these radionuclides [10].

External hazard index

The external hazard index due to the emitted γ-rays of the studied samples is calculated and examined according to the following criterion:

$$H_{ex} = \left(\frac{C_{Ra}}{370} + \frac{C_{Th}}{259} + \frac{C_K}{4810}\right) \leq 1 \quad (2)$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively [11].

Representative level index

This index can be used to estimate the level of γ-radiation hazard associated with the natural radionuclides in the studied samples is given by the following equation;

$$I\gamma = \left(\frac{C_{Ra}}{150} + \frac{C_{Th}}{100} + \frac{C_K}{1500}\right) \quad (3)$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq/kg, respectively [11].

The calculated values of the radium equivalent (Ra_{eq}), the external hazard index (H_{ex}), and the representative level index ($\mathbf{I}_\gamma$) for all studied samples are given in table (5).

The average value (144.42) of radium equivalent (Ra_{eq}) of the studied samples is lower than the permissible level [370 Bq/kg] [9]. The average value of radioactivity level index (Iγ) (1.039) is nearly equal to unity, while the average value of external hazard (H_{ex}) (0.389) is found to be lower than unity.

Estimation of γ-radiation dose and Annual Effective Dose

The absorbed gamma dose rates in air at 1m above the ground surface for the uniform distribution of radionuclides, ^{238}U,^{232}Th and ^{40}K are calculated using equation (4);

$$D = 0.427\, C_U + 0.662\, C_{Th} + 0.043\, C_K \quad (nGy/h) \quad (4)$$

Where, C_U, C_{Th} and C_K are the activity concentrations of ^{238}U, ^{232}Th and ^{40}K in (Bq/kg), respectively using data of Table (3) [10].

The annual outdoor effective dose (E_{out}) is estimated from the outdoor external dose rate (D_{out}), time of stay in the outdoor or occupancy factor (OF =20% of 8760h in a year) and the conversion factor (CF= 0.7Sv Gy^{-1}) to convert the absorbed dose in air to effective dose. During the present study, the (E_{out}) was calculated using the following equations based on [12].

$$E_{out} = D_{out}(nGyh^{-1}) \times 0.2 \times 8760\ h \times 0.7\ (SvGy^{-1}) \quad (5)$$

From Table (6), the average value of Dose rate (65.93) (D nGy/h) for the studied samples is higher than the permissible level of 59 [9]. The outdoor effective dose rate $E_{(out)}$ (mSv/y) ranged between 0.0305 and1.477 with an average 0.0807. This value is slightly higher than the world average of 0.07 (mSv/y) [9].

The fractional contributions of the radionuclides (^{238}U, ^{232}Th, ^{40}K) to the absorbed dose rate and (^{226}Ra, ^{232}Th, ^{40}K) to the external hazard factor were listed in Table (7). In case of absorbed dose rate, for the ^{238}U ranges from 0.22 to 0.84, ^{232}Th ranges from 0.07 to 0.223 and ^{40}K ranges from 0.07 to 0.67. These data leads to conclude that the relative contributions due to ^{238}U were 54% followed by contributions due to ^{232}Th and ^{40}K as 13.1% and 31.3% respectively.

In case of external hazard, for the ^{226}Ra ranges from 0.26 to 0.86, ^{232}Th ranges from 0.06 to 0.22 and ^{40}K ranges from 0.10 to 0.59. These data leads to conclude that the relative contributions due to ^{226}Ra was 59.2 % followed by contributions due to ^{232}Th and ^{40}K as 12.55% and 33.11% respectively.

Table (5): The radium equivalent in Bq/kg, the external hazard index, the representative level index and dose rate for white granite samples at Um Baanib area that table shows only three parameters while the author wrote in the text four(4) parameters.

S.no.	Ra_{eq} (Bq/kg)	H_{ex}	I_γ
1	136.45	0.368	1.06
2	153.63	0.415	1.12
3	191.53	0.517	1.40
4	120.88	0.326	0.953
5	116.52	0.314	0.835
6	55.722*	0.150*	0.391*
7	83.38	0.225	0.578
8	167.76	0.453	1.14
9	273.94**	0.740**	1.88**
Avg.	144.42	0.389	1.039
P.L	370	1	1

The lower value* ***The higher value*****

Table (6): the values of outdoor effective dose rate in (mSv/y) in Um Baanib white granite

S.no.	D (nGy/h)	$E_{eff(out)}$ (mSv/y)
1	69.67	0.0854
2	71.65	0.0878
3	86.66	0.1062
4	59.31	0.0727
5	51.43	0.06305
6	24.91*	0.0305*
7	38.32	0.0469
8	70.89	0.0869
9	120.53**	0.1477**
Avg.	65.93	0.0807

The lower value* ***The higher value*****

Table (7): The fractional contribution of natural radioactive nuclide in the total absorbed dose rate as well as external hazard in Um Baanib white granite

S.no	D_R			H_{ex}		
	^{238}U	^{232}Th	^{40}K	^{226}Ra	^{232}Th	^{40}K
1	0.30	0.07*	0.62	0.34	0.07	0.57
2	0.44	0.17	0.37	0.50	0.17	0.31
3	0.51	0.09	0.38	0.58	0.09	0.31
4	0.22*	0.10	0.67**	0.29*	0.10	0.59**
5	0.56	0.15	0.29	0.62	0.14	0.23
6	0.59	0.222	0.18	0.64	0.21	0.14
7	0.66	0.223**	0.12	0.68	0.22**	0.22
8	0.84**	0.076	0.07*	0.86**	0.06*	0.51
9	0.79	0.078	0.12	0.82	0.07	0.10*
Avg.	0.54	0.131	0.313	0.592	0.125	0.331

The lower value* ***The higher value*****

Geochemistry

Geochemical analyses have been obtained for nine samples of the white granite of Um Baanib area. The major and trace elements were determined using a rigaka X-ray Fluorescence spectrometer (3100) (XRF), at department of Earth Resources Engineering, Kyushu University, Fukuoka, Japan and in laboratories of Geological Surveying Authority –Egypt. The minimum (Min.), maximum (Max.) and average (Aver.) contents of the analyzed samples are listed in table (8).

Some geochemical imprints

The major elements composition of the studied white granite display a very limited variation, where silica content is greater than 65%, ranging from 68.75% to 76.15% averaging 72.89 %.

The white granite at Um Baanib area has high alkali content ranging from 4.23% to 8.07% averaging 6.33%. Um Baanib granite possess high Al_2O_3 content ranging from 14.73% to 19.20% averaging 17.20 % and relatively high Na_2O content ranging from 3.59% to 6.44% averaging 4.88%. So they are useful in ceramic industry.

For trace element concentrations, Um Baanib granite possesses a low and narrow range of Zircon (*Zr*) content (Table 8), which decreases steadily during differentiation, indicating that zircon was present throughout crystallization. This is in compatible with expected low solubility of zircon in low–temperature peraluminous melt [13].

Sr, and Ba are highly trace elements in Um Baanib white granite (table 8), with averages 732.9 ppm and 178 ppm are useful to many important industries.

Conclusion

- The white granite of Um Baanib has an irregular shape being emplaced into the Lewiwi thrust zone
- In addition to quartz and alkali feldspar, the white granite consists of variable contents of muscovite, biotite, and accessories as allanite, zircon, and fluorite.
- Ground spectrometric surveying shows enrichment in uranium than thorium indicating addititiion of uranium from outer source (may be pink granite).
- The area under investigation showed a case of radioactive equilibrium between different daughters in the U-series. All samples are less than Clark's value of $^{232}Th/^{238}U$ which indicates that the white granite of Um Baanib area is enriched in uranium. The dose rate has a high values for most studied samples.
- A greet take care must be taken in account when dealing with the white granite in the studied area, the precautions of radiation protection procedures should be taken in consideration. The samples collected from these areas are not safe and cannot used as a construction or industrial material because it possess a great radiological threat to population and great care when handling is required.

Table (8): Minimum (Min.), Maximum (Max.) and Average (Aver.) contents of the nine analyzed samples of White granite in Um Baanib area

Major Oxides (%)					***Trace Elements (ppm)***			
	Min.	Max.	Avg.			Min.	Max.	Avg.
SiO_2	68.75	76.15	72.89		V	3	30	9
TiO_2	0.05	0.10	0.07		Cr	2	4	2.9
Al_2O_3	14.73	19.20	17.20		Ni	3	5	3.7
FeO	0.26	0.53	0.39		Cu	3	6	4.4
MnO	0.01	0.01	0.01		Zn	7	29	12
MgO	0.43	0.63	0.58		Pb	15	27	17.7
CaO	1.63	3.53	2.79		Rb	17	42	25.7
Na_2O	3.59	6.44	4.88		Sr	208	1499	732.9
K_2O	0.64	1.63	1.45		Ba	79	357	178
P_2O_5	0.01	0.04	0.09		Y	22	42	31.8
LOI	0.38	0.92	0.69		Zr	32	103	72.3
ALK	4.23	8.07	6.33		Nb	37	49	42.1

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