Radioactive mineralization of granitic rocks and their surrounding stream sediments at Gabal Rei El-Garrah area, Central Eastern Desert, Egypt

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Abstract: Gabal (G.) Rei El-Garrah area lies in the Central Eastern Desert (CED) of Egypt south Qena-Safaga road just east the western boundary between the Precambrian basement rocks and the Nubian sedimentary cover. Based on field relations and observations, the rock types in the study area comprise metavolcanics, older granitoids, younger gabbros, monzogranites, quartz-feldspar porphyry dykes and syenogranites. The basement rock units of G. Rei El-Garrah area, exhibiting high, moderate and low relief, are dissected by several wadis namely; Wadi Rei El-Garrah, Wadi El-Missikat, Wadi El-Markh and Wadi El-Gidami. The directions of these wadis are coincident with the large-scale faults and covered mainly by stream sediments. It is worthy to mention that, there is a notable difference between laboratory and field radiometric measurements. Generally, eU, eTh, Ra (eU) and K contents of tonalite and granodiorite are lower than their corresponding international contents where monzogranites and syenogranites have higher concentrations. The variation between eU, eTh contents and eTh/eU ratios of the older granitoids and the younger granites show positive correlation between eU and eTh indicating that magmatic processes played an important role in the concentration of radioelements while the ill-defined relation between eU, eTh and eTh/eU ratios, suggesting that the distribution of radioelements not only magmatic but also due to hydrothermal redistribution of radioelements. The studied stream sediments in most wadis show high uranium contents more than the worldwide averages and generally they are enriched in thorium than uranium. The common heavy minerals related to high radioactivity obtained from the studied stream sediments and granitic rocks in G. Rei El-Garrah area could be classified into two mineralogical groups namely; radioactive and radioelements-bearing minerals besides the non-radioactive minerals (hematite, magnetite, ilmenite, rutile, garnet, apatite, titanite and cotunnite). The radioactive minerals include thorite and uranothorite beside the uranophane while the radioelements-bearing minerals are represented by zircon and allanite as well as fluorite.

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1. INTRODUCTION

Egyptian granitic rocks have been formed during the Pan-African age; occupy about 40% of the exposed Precambrian rocks of the Eastern Desert. They can be subdivided into two distinct major groups, namely the older and the younger granites **(Ali et al., 2012)**. The younger granite was previously mapped as Gattarian, red and pink granites, **(Akaad and El-Ramly, 1960)**, late-to post- orogenic granites, **(El-Gaby, 1975)** and G-II to G-III granites, **(Hussein et al. 1982)**. G. Rei El-Garrah area is bounded by Longitudes 33° 21` 30`` and 33° 26` 40`` E and Latitudes 26° 23` 30`` and 26° 31` 30`` N. Several studies have been made about Rei El Garrah area and its surroundings regarding the regional geology, petrology, geotectonics, geochemistry, mineralogy and radioactivity **(e.g. Ammar, 1973; Bakhit and Guirguis, 1983; El-Mansi, 1993; Mohammed, 1995; Abu Dief et al., 1997; Dardier and El-Galy, 2000; El-Mansi et al., 2004; Mousa, 2008; Hegazy, 2014; Awad, H.A., 2015; Lasheen, 2015)**. The Precambrian rocks of Eastern Desert and Sinai are highly dissected by dry valleys (wadis) that are filled with a wide variety of stream sediments. The Arabic term ''wadi'' is always dedicated to dry streams and hence the expression ''wadi deposits'' is sometimes used instead of ''stream sediments''. Studying the stream sediments and their mineralogy and radioactivity were a matter of interest as their important role in mineral exploration **(e.g. Ammar, et al., 2006: El Nahas, et al., 2011; Soliman, et al., 2012; Mansour, et al., 2016).**

The present study aims to study the radioactivity and the distribution of the radioelements in both the granitic rocks and the stream sediments of G. Rei El-Garrah area. Focusing on the high radioactivity zones of high equivalent uranium contents is done to identify the reasons of these high U-contents and the minerals responsible for these high contents either in the granitic rocks or in the stream sediments.

2. METHEDOLOGY

Twenty-five granitic rock samples representing the studied older granitoids and younger granites and forty-one stream sediments samples representing the main wadis and their tributaries were collected for radiometric and mineralogical investigations.

A field radiometric survey is applied on the collected stream sediments and their country rocks using gamma ray spectrometer (model GS-512) instrument to differentiate between the normal radioactivity and the radioactive anomalies by measuring equivalent uranium (eU in ppm), equivalent thorium (eTh in ppm) and potassium content (K%) in the field.

Selected samples from different granitic types and stream sediments have been chosen for the radiometric analysis by a multichannel analyzer gamma-ray spectrometer that used to determine the eU, eTh, Ra in (ppm) and K (%) concentrations in the laboratory. The system consists of NaI-Tl Bicron scintillation detector connected with NE-4658 amplifier and a high voltage power supply with HV digital display.

The collected samples of the stream sediments are prepared and subjected to heavy mineral separation using bromoform solution (sp. Gr. 2.85 gm/cm^3) followed by mineralogical investigation using binocular microscope, X-ray diffraction technique (XRD) and Environmental Scanning Electron Microscope technique (ESEM) in order to throw a light on the economic importance of these obtained minerals.

All chemical and radiometric analyses as well as the microscopic investigations are carried out in the Laboratories of the Egyptian Nuclear Materials Authority (NMA).

3. GEOLOGIC SETTING

G. Rei El-Garrah area lies in the CED of Egypt south Qena-Safaga road just east the western boundary between the Precambrian basement rocks and the Nubian sedimentary cover (Nubian Sandstones). Based on field relations and observations, the rock types in the study area comprise metavolcanics, older granitoids, younger gabbros, monzogranites, quartz-feldspar porphyry dykes and syenogranites ***(Fig. 1)***.

The Metavolcanics represent the oldest rock unit in the study area and are represented by metabasalts and meta-andesites alternating with their equivalent pyroclastics. Several irregular offshoots extend from younger granites (syenogranites) into metavolcanics**.** In addition, they may be found as xenoliths in the older granitoids and the first phase of younger granites (monzogranites). Older granitoids are represented by quartz-diorites and granodiorites. The older granitoids show clear low-lying hills of heterogeneous nature. Younger gabbros found as elongated mass intrude and carry roof-pendants of the metavolcanics and in turn they are intruded by the younger granites.

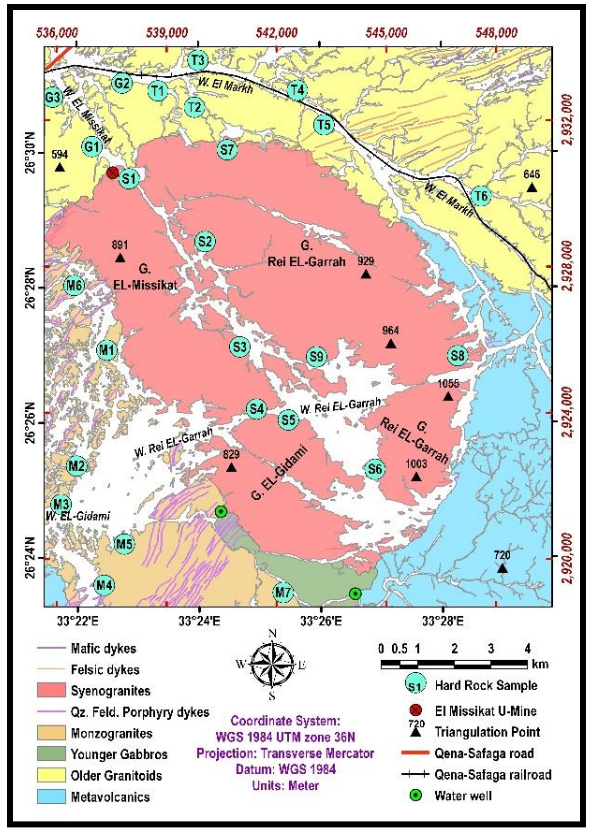


Figure 1: Geological and sample location map of granitic rocks of G. Rei El-Garrah area, CED, Egypt

Two varieties of the younger granites are identified; monzogranites and syenogranites. These granites in general, are characterized by their massive nature and sharp intrusive contacts with all surrounding rocks. Alteration processes are local and restricted along fractures, fault planes and shear zones. These alteration processes are represented by silicification, hematitization and kaolinization. Several zoned and unzoned oval-shaped and/or elongated pegmatite pockets and veins are also encountered in syenogranites. They are mainly composed of quartz and K-feldspars with little mica and green to violet fluorite.

The basement rock units of G. Rei El-Garrah area, exhibiting high, moderate and low relief, are dissected by several wadis namely; Wadi Rei El-Garrah, Wadi El-Missikat, Wadi El-Markh and Wadi El-Gidami. The directions of these wadis are coincident with the large-scale faults and covered mainly by stream sediments. The thickness of the stream sediments of the studied area ranges from 5 to 30 meters as estimated from the groundwater wells. They are composed mainly of loose sand with gravels, pebbles and rarely cobbles, which embedded in sandy matrix. The samples are collected following the drainage pattern of the study area ***(Fig. 2)***; the average weight of each sample is about 7kg.

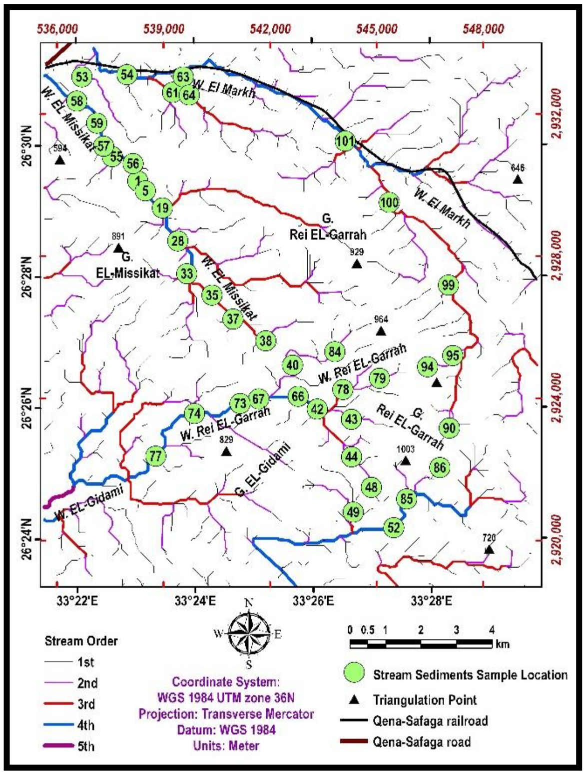


Figure 2: Sample location map of stream sediments of G. Rei El-Garrah area, CED, Egypt

4. RADIOACTIVITY

4.1. Distribution of radionuclides in the studied granitic rocks

A total number of twenty-five readings on granitic rocks of G. Rei El-Garrah area were measured radiometrically for eU, eTh (ppm) and K-content (%) in the field. The same radioelements besides Ra-content (in ppm) were measured in the laboratory for comparison ***(Table 1)***.

A. Older granitoids:

Uranium and thorium are generally enriched in the youngest, felsic and potassic members of igneous rocks (Rogers and Ragland, 1961). The average of eU, eTh, Ra (ppm) and K (%) increases in the studied granitic rocks gradually from older granitoids to syenogranite as shown in *table (1).*

The average contents of eU, eTh and K of granodiorites (measured in the field) are 1.27 ppm, 2.77 ppm and 3.5 %, respectively while those (measured in the laboratory) are 3 ppm, 4.67 ppm and 1.17% respectively. The eTh/eU ratio for field measurements (2.37) is relatively higher than that of the laboratory (1.56).

Table (1): Field and laboratory radiometric measurements of eU (ppm), eTh (ppm), Ra (ppm) and K% for the granitic rocks of G. Rei El-Garrah area, CED, Egypt

Rock type		Sample No.	Field measurements				Laboratory measurements						
			eU	eTh	K (%)	eTh/eU	eU	eTh	Ra	K (%)	eU/Ra	eU/eTh	eTh/eU
Older Granitoids	Granodiorites	G1	1	3.1	2.9	3.10	2	3	3	1.2	0.67	0.67	1.5
		G2	1.6	1.6	3.6	1.00	4	6	2	0.9	2	0.67	1.5
		G3	1.2	3.6	4	3.00	3	5	4	1.4	0.75	0.6	1.67
		average	*1.27*	*2.77*	*3.50*	*2.37*	*3.00*	*4.67*	*3.00*	*1.17*	*1.14*	*0.65*	*1.56*
	Tonalites	T1	0.3	0.3	0.8	1.00	1	2	1	0.3	1	0.5	2
		T2	0.4	1.1	0.6	2.75	2	4	1	0.56	2	0.5	2
		T3	0.7	0.9	0.8	1.29	1	3	1	0.72	1	0.33	3
		T4	0.6	1.2	0.7	2.00	1	1	1	0.35	1	1	1
		T5	0.5	0.8	1	1.60	2	5	1	0.6	2	0.4	2.5
		T6	0.4	0.7	0.9	1.75	3	4	2	0.43	1.5	0.75	1.33
		average	*0.48*	*0.83*	*0.80*	*1.73*	*1.67*	*3.17*	*1.17*	*0.49*	*1.42*	*0.58*	*1.97*
Younger Granites	Monzogranites	M1	7	19	13.3	2.71	20	33	10	2.54	2	0.61	1.65
		M2	5	21	11.4	4.20	4	8	1	2.8	4	0.5	2
		M3	6	20	16.5	3.33	17	34	11	2.46	1.55	0.5	2
		M4	8	25	12	3.13	10	28	11	3.75	0.91	0.36	2.8
		M5	3	9	12.2	3.00	12	21	8	2.26	1.5	0.57	1.75
		M6	4	13	11.5	3.25	6	18	4	3.91	1.5	0.33	3
		M7	8	13	13	1.63	2	12	3	2.55	0.66	0.17	6
		average	*5.86*	*17.14*	*12.84*	*3.04*	*10.14*	*22.00*	*6.86*	*2.90*	*1.73*	*0.43*	*2.74*
	Syenogranites	S1	7	31	14.3	4.43	11	19	10	3.18	1.1	0.58	1.73
		S2	9	37	13.6	4.11	16	24	5	3.05	3.2	0.67	1.5
		S3	9	23	14.7	2.56	9	19	7	3.31	1.29	0.47	2.1
		S4	7	29	11.7	4.14	16	21	9	3.05	1.78	0.76	1.3
		S5	7	31	12.6	4.43	10	19	8	3.79	1.25	0.53	1.9
		S6	12	23	10.3	1.92	13	14	10	3.59	1.3	0.93	1.08
		S7	17	24	12.7	1.41	14	22	12	3.87	1.2	0.64	1.57
		S8	8	30	12.7	3.75	9	20	10	3.68	0.9	0.45	2.2
		S9	8	20	14.8	2.50	11	19	9	3.5	1.2	0.58	1.73
		average	*9.33*	*27.56*	*13.04*	*3.25*	*12.11*	*19.67*	*8.89*	*3.45*	*1.47*	*0.62*	*1.68*

Tonalites have average contents of eU, eTh and K (measured in the field) about 0.48 ppm, 0.83 ppm and 0.8 %, respectively while those (measured in the laboratory) are 1.67 ppm, 3.17 ppm and 0.49% respectively. The eTh/eU ratio for field measurements (1.73) is relatively lower than that of the laboratory (1.97). Comparing the eU and eTh concentrations of the studied older granitoids with their corresponding data of **(Clarke et al., 1966)** and **(Rogers and Adams, 1969)**, the studied granodiorites and tonalites have lower uranium and thorium contents as well as eTh/eU ratio.

B. Younger granites:

The field measurements averages of eU, eTh, and K in monzogranites are 5.86 ppm, 17.14 ppm and 12.84%, respectively whereas the laboratory ones are 10.14 ppm, 22 ppm and 2.74 % respectively

The eTh/eU ratio for field measurements (3.04) is relatively higher than that of the laboratory (2.74). The field measurements averages of the eU, eTh, and K in syenogranites are 9.33 ppm, 27.56 ppm and 13.04%, respectively whereas the laboratory ones are 12.11 ppm, 19.67 ppm and 3.45 % respectively. The eTh/eU ratio for field measurements (3.25) is relatively higher than that of the laboratory (1.68). It is noticed that the laboratory measurements are more accurate than those of the field.

The average values of eU, eTh, and K of the older granitoids are lower than that reported for Earth's crust, 2.9 ppm, 10.8 ppm and 2.7 %, respectively, while the younger granites have higher contents (**Killeen and Cameron, 1977).** Ratios of eTh/eU< 2 are highly suggestive of relative uranium enrichment and implicates reducing conditions, but ratios >7 indicate preferential removal of uranium, possibly by leaching (**Adams and Weaver, 1958**). Typical eTh/eU ratios in igneous rocks are 3:1 or 4:1 whereas eTh/eU ratios of the studied granitic rocks are 1.56, 1.97, 2.74 and 1.68 ppm for granodiorites, tonalites, monzogranites and syenogranites, respectively, which may indicate relative enrichment of uranium in the older granitoids and syenogranites and normal eTh/eU ratios of the monzogranites.

4.2. Geochemistry of eU and eTh in the studied granites

The geochemistry of eU and eTh during magmatic differentiation has been studied in many types of granites from different areas. Generally, during magmatic differentiation, the Th/U ratio remains constant. **(Rogers and Adams 1969)** suggested 3.5 to 4 for the Th/U ratios in the granites. These ratios can either increase **(Rogers and Ragland, 1961)** or decrease **(Larsen and Gottfried, 1960),** depending on the redox conditions, the volatile contents, or alterations by endogenic or supergene solutions **(Falkum and Rose-Hansen, 1978)**. Typical Th/U ratios in igneous rocks are 3:1 or 4:1 whereas eTh/eU ratios average of the studied granitic rocks are 1.56, 1.97, 2.74 and 1.68 for granodiorites, tonalites, monzogranites and syenogranites, respectively, which may indicate uranium enrichment in reducing conditions.

The geochemical behavior of U and Th in the studied granitic rocks are examined by plotting variation diagrams of eU and eTh with their ratios, which used to indicate the amount of U remobilization that occurred within the magmatic plutons **(Charbonneau, 1982; El-Galy, 2007).**

The variation diagrams, between eU, eTh contents and eTh/eU ratios of the older granitoids, show strong positive correlation between eU and eTh indicating that magmatic processes played an important role in the concentration of radioelements. There are ill-defined relations between eU, eTh and eTh/eU ratios, suggesting that, the distribution of radioelements not only magmatic but also due to hydrothermal redistribution of radioelements ***(Fig. 3)***. In addition, eU-eTh variation diagrams show positive magmatic trend in the monzogranites and syenogranites as shown in ***(Figs. 4 and 5)*** respectively while eTh in monzogranites clarifies negative correlation with eTh/eU ratio and ill-defined trend in syenogranites. However, eU in monzogranites and syenogranites shows strong negative correlation with eTh/eU ratio indicating that radioelement distributions were not only governed by magmatic processes ***(see Figs. 4 and 5)*** but also the hydrothermal alteration processes play their role in radioelements remobilization.

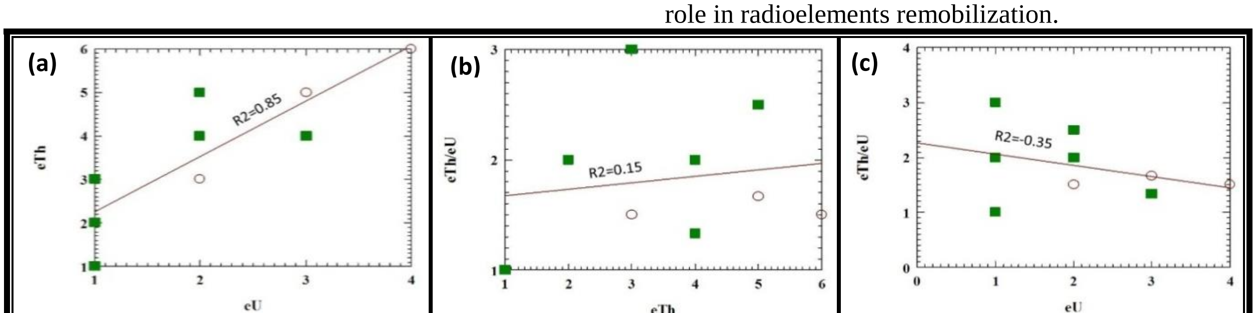


Figure 3: Variation diagrams for; a) eU versus eTh, b) eTh versus (eTh/eU) and c) eU versus (eTh/eU) of the older granitoids, G. Rei El-Garrah area, CED, Egypt (○ Granodiorites ▪ Tonalites)

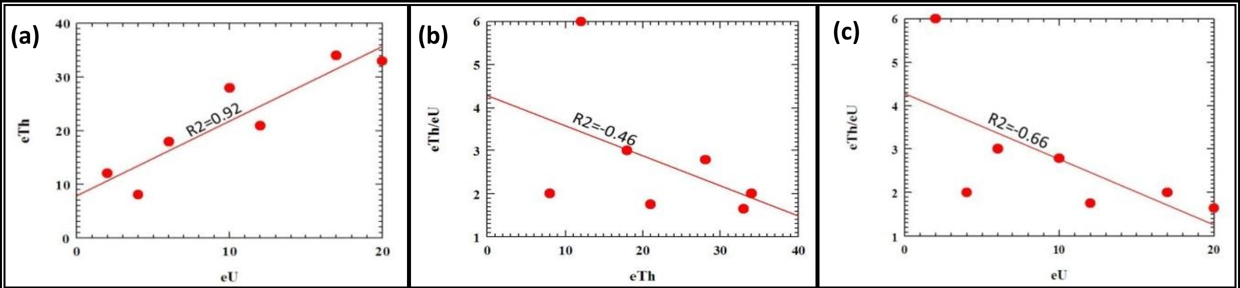


Figure 4: Variation diagrams for; a) eU versus eTh, b) eTh versus (eTh/eU) and c) eU versus (eTh/eU) of the monzogranites, G. Rei El-Garrah area, CED, Egypt

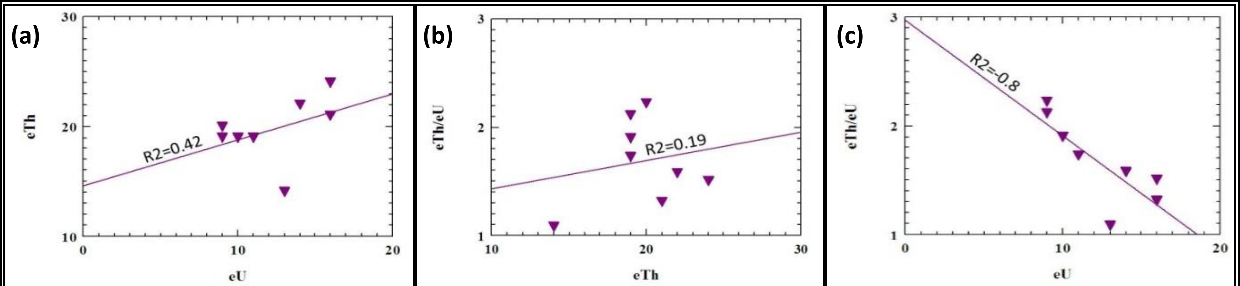


Figure 5: Variation diagrams for; a) eU versus eTh, b) eTh versus (eTh/eU) and c) eU versus (eTh/eU) of the syenogranites, G. Rei El-Garrah area, CED, Egypt

Post orogenic granites are of high potentiality to identify vein-type uranium deposits especially at the marginal zones of the plutons **(Fawzy, 2017)**. Hence, the eU- and eTh-contents of the studied younger granites could be correlated with some major oxides and trace elements. The chemical analyses for major oxides and trace elements of the studied younger granites are presented in ***(Table 2)***.

Table 2: Chemical composition (major oxides and trace elements) of G. Rei El-Garrah younger granites, CED, Egypt

Rock type	Younger Granites															
	Monzogranites							Syenogranites								
Sample No.	M1	M2	M3	M4	M5	M6	M7	S1	S2	S3	S4	S5	S6	S7	S8	S9
Major Oxides (wt. %)																
SiO_2	73	71.9	72.5	72.3	72.66	72.4	72.6	74.17	74	73.68	73.59	75.1	76	74.47	73.9	74.6
TiO_2	0.7	0.5	0.35	0.42	0.46	0.5	0.31	0.3	0.24	0.3	0.4	0.3	0.5	0.4	0.47	0.48
Al_2O_3	13.8	13.73	13.4	13.9	13.8	14.1	14	13.1	13.0	13.4	13.3	13.0	12.85	13.1	13.3	13.2
Fe_2O_3	1.21	1.38	1.46	1.5	1.66	1.52	1.49	0.9	0.9	1.4	1.3	1.5	0.45	1.0	0.7	0.9
FeO	0.56	1.13	0.95	0.41	0.54	0.41	0.54	0.8	0.8	0.9	0.8	0.2	0.4	0.7	0.6	0.3
MnO	0.01	0.06	0.08	0.09	0.04	0.05	0.01	0.02	0.01	0.04	0.05	0.01	0.05	0.02	0.05	0.01
MgO	0.45	0.5	0.39	0.48	0.42	0.5	0.41	0.9	0.9	0.7	0.5	0.4	0.9	0.6	0.6	0.44
CaO	1.8	1.77	1.84	1.68	1.65	1.71	1.6	1.0	1.0	0.9	0.81	0.86	1.0	0.7	0.8	0.82
Na_2O	4.3	4	3.96	4.2	4.1	4.1	42	4.2	4.3	3.6	4.3	3.6	3.9	4.0	4.2	4.0
K_2O	3.65	3.8	3.7	3.8	3.45	3.7	3.7	3.0	3.6	4.1	3.8	3.4	3.6	4.18	4.1	4.18
P_2O_5	0.4	0.04	0.07	0.05	0.02	0.02	0.04	0.4	0.02	0.03	0.04	0.02	0.02	0.03	0.01	0.03
L.O.I	0.9	1.14	1.2	0.9	1.2	0.95	1.0	1.1	1.21	0.8	1.1	1.4	0.3	0.8	1.2	1.0
Total	99.88	99.95	99.9	99.73	100	99.96	99.17	99.89	99.98	99.85	99.99	99.79	99.97	100	99.93	99.96
Trace elements (ppm)																
Sr	35	43	55	33	52	47	40	23	25	21	17	15	18	27	19	22
Ga	17	19	22	23	25	20	18	31	26	31	26	28	25	29	27	32
Ba	550	448	466	530	441	370	487	62	57	47	50	52	44	53	60	48
Rb	88	92	78	99	83	107	95	211	232	237	217	222	242	210	235	240
Zr	270	255	310	283	199	218	257	300	288	295	342	350	299	277	320	333
Nb	35	33	31	28	37	42	38	46	50	53	44	55	41	55	52	43
Zn	43	48	52	43	55	44	32	67	58	49	57	55	63	66	47	56
Cu	7	8	3	3	2	2	4	4	3	2	4	5	3	3	2	1
Pb	17	15	13	11	18	17	14	18	23	17	22	25	26	19	21	20
Y	76	85	63	54	73	62	77	88	110	94	83	77	95	81	78	99

In the studied monzogranites, eTh exhibits positive correlation with SiO_2, CaO, P_2O_5, Ba and Zr while it has negative correlation with Y ***(Fig. 6)***.

In the studied syenogranites, eU shows positive trend with MgO, Na_2O and Sr while it clarifies negative trend with Rb, while eTh has negative correlation with SiO_2, MgO and Rb while it shows positive correlation with Ba ***(Fig. 7)***. All the foregoing relations in monzogranites and syenogranites indicate the redistribution of most elements during the post-magmatic alteration processes.

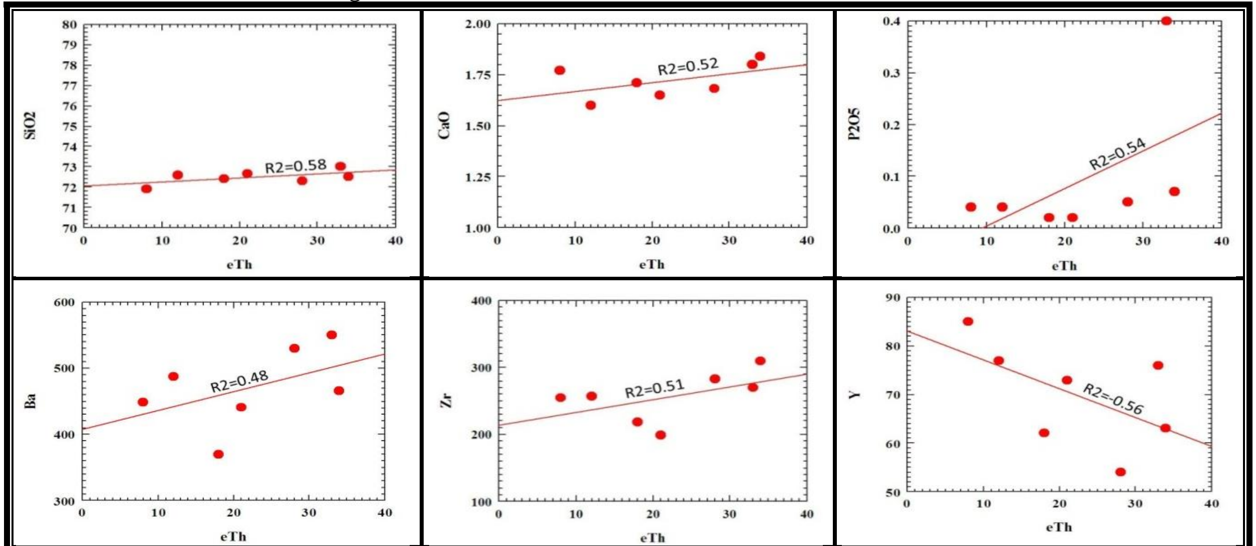


Figure 6: Variation diagrams of eTh versus some major oxides and trace elements of G. Rei El-Garrah monzogranites, CED, Egypt

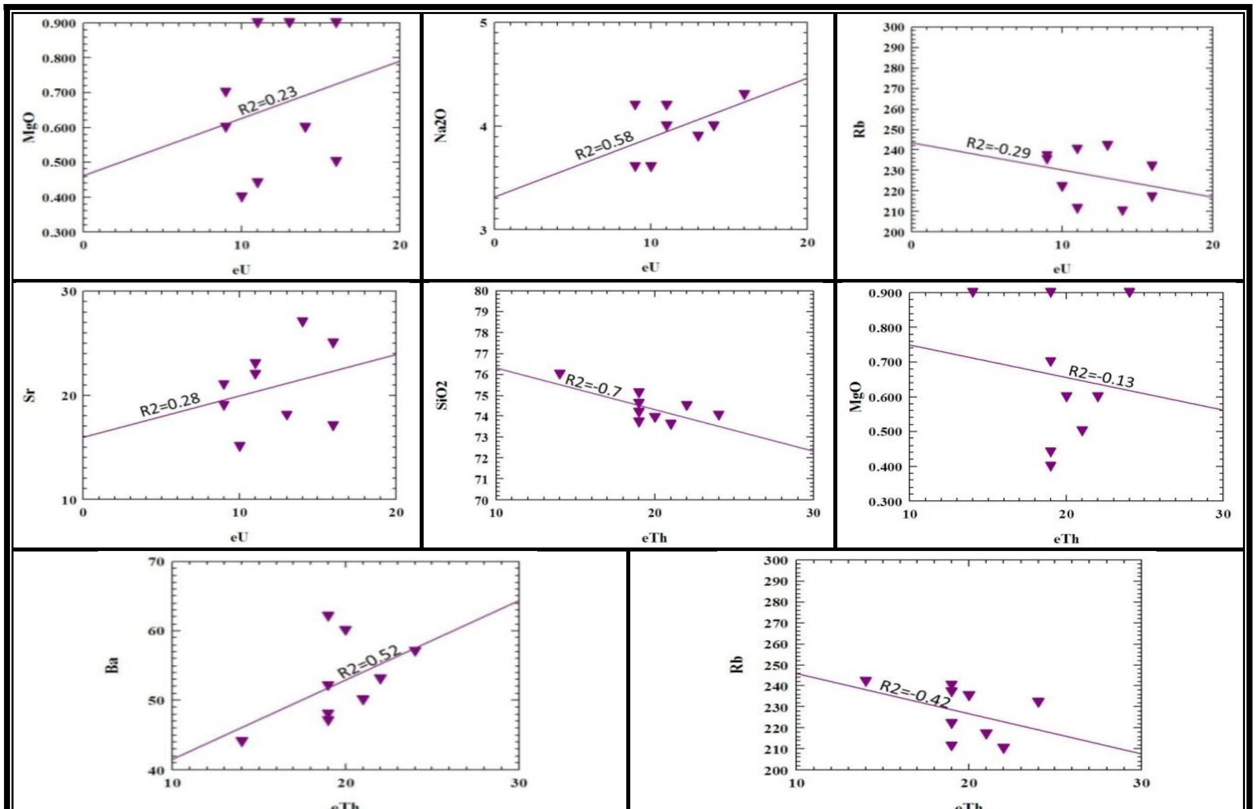


Figure 7: Variation diagrams of eU, eTh versus some major oxides and trace elements of G. Rei El-Garrah syenogranites, CED, Egypt

4.3. Distribution of radionuclides in the studied stream sediments

The field radiometric survey of the studied stream sediments is carried out along the main wadis (along the drainage system). All the radiometric measurements recorded during this regional survey in the study area as well as those measured for stream sediment samples in the laboratory are tabulated in ***(Table 3)***. The studied stream sediments are collected from four main wadis namely; Wadi El-Missikat, Wadi Rei El-Garrah, around Rei El-Garrah and Wadi El-Markh. Each of them has its own characteristics from the radioelements concentration point of view.

Table (3): Field and laboratory radiometric measurements of eU (ppm), eTh (ppm), Ra (ppm) and K (%) for the stream sediments of G. Rei El-Garrah area, CED, Egypt

Main Wadis	Sample No.	Field measurements				Laboratory measurements						
		eU	eTh	K	eTh/eU	eU	eTh	Ra	K	eU/Ra	eU/eTh	eTh/eU
Wadi El-Missikat	1	7	19	10.9	2.71	5	17	7	1.89	0.71	0.29	3.4
	5	4	25	16.4	6.25	2	16	5	3.73	0.4	0.13	8
	19	7	23	18.2	3.29	9	21	6	4.23	1.5	0.43	2.33
	28	3	20	16.4	6.67	7	17	5	2.44	1.4	0.41	2.43
	33	5	12	13.8	2.40	3	15	3	2.43	1	0.2	5
	35	7	17	12.7	2.43	3	19	7	4.13	0.43	0.16	6.3
	37	6	20	14.8	3.33	4	20	8	3.5	0.5	0.2	5
	38	7	15	13.3	2.14	12	22	7	1.88	1.71	0.55	1.8
	40	6	13	17.2	2.17	11	23	6	2.77	1.8	0.48	2.1
	53	3	13	8.1	4.33	5	8	4	2.19	1.25	1.63	1.6
	55	9	14	10.2	1.56	7	16	7	2.72	1	0.44	2.29
	56	9	14	10.3	1.56	6	18	8	4.05	0.75	0.33	3
	57	5	20	11.2	4.00	8	12	6	3.04	1.33	0.67	1.5
	58	3	20	11.4	6.67	7	20	7	3.4	1	0.35	2.86
	59	4	13	12.5	3.25	9	18	9	3.03	1	0.5	2
	average	*5.67*	*17.20*	*13.16*	*3.52*	*6.53*	*17.47*	*6.33*	*3.03*	*1.05*	*0.45*	*3.31*
Wadi Rei El-Garrah	42	3	9	13.2	3.00	8	15	4	2.46	2	0.53	1.9
	66	6	17	13.8	2.83	6	22	8	3.27	0.75	0.27	3.7
	67	5	16	14.7	3.20	4	14	5	3.85	0.8	0.29	3.5
	73	5	15	14.7	3.00	2	13	6	3.57	0.33	0.15	6.5
	74	7	14	11.3	2.00	10	13	7	2.1	1.43	0.77	1.3
	77	1	4	8.4	4.00	1	5	2	2.65	0.5	0.2	5
	78	3	15	14.5	5.00	2	11	6	3.98	0.33	0.18	5.5
	79	7	27	15.4	3.86	19	45	1	4.63	1.36	0.42	2.37
	84	4	22	11.2	5.50	4	20	9	3.84	0.44	0.2	5
	94	4	19	15.5	4.75	5	14	8	3.49	0.63	0.21	4.8
	95	4	15	16.1	3.75	7	16	6	3.37	1.17	0.44	2.29
	average	*4.45*	*15.73*	*13.53*	*3.72*	*6.18*	*17.09*	*5.64*	*3.38*	*0.89*	*0.33*	*3.81*
around Rei El-Garrah	43	3	17	15.6	5.67	5	13	6	3.6	0.83	0.38	2.6
	44	3	15	14.1	5.00	7	15	4	2.33	1.75	0.47	2.14
	48	3	7	18.5	2.33	8	10	3	3.35	2.7	0.8	1.25
	49	3	14	14.6	4.67	7	17	3	2.09	2.3	0.41	2.43
	52	1	3	3.7	3.00	2	4	2	1.05	1	0.5	2
	85	2	20	15.8	10.00	8	16	5	2.44	1.6	0.5	2
	86	7	14	12.4	2.00	6	15	7	3.47	0.86	0.4	2.5
	90	4	18	11.8	4.50	9	15	6	2.43	1.5	0.6	1.67
	average	*3.25*	*13.50*	*13.31*	*4.65*	*6.50*	*13.13*	*4.50*	*2.60*	*1.57*	*0.51*	*2.07*
Wadi El-Markh	54	1	7	8.7	7.00	4	7	1	1.13	4	0.57	1.75
	61	7	12	9.4	1.71	1	10	5	2.24	0.2	0.1	10
	63	6	15	10.8	2.50	6	10	5	2.44	1.2	0.6	1.67
	64	3	15	11.3	5.00	4	10	5	2.26	0.8	0.25	4
	99	4	18	15.1	4.50	12	25	6	2.85	2	0.48	2.1
	100	3	12	17	4.00	2	14	5	3.79	0.4	0.14	7
	101	4	15	13.5	3.75	7	14	4	2.16	1.75	0.5	2
	average	*4.00*	*13.43*	*12.26*	*4.07*	*5.14*	*12.86*	*4.43*	*2.41*	*1.48*	*0.38*	*4.07*
Averages of Clarke et al. (1966) and Rogers and Adams (1969)						4	17	-	-	-	-	3.5

A. Wadi El-Missikat:

The averages of the eU, eTh and eTh/eU ratio in the field (5.67 ppm, 17.2 ppm and 3.52 respectively) are nearly similar to those measured in the laboratory (6.53 ppm, 17.47 ppm and 3.31 respectively).

B. Wadi Rei El-Garrah:

The averages of the eU, eTh and eTh/eU ratio in the field (4.45 ppm, 15.73 ppm and 3.72 respectively) are relatively lower than those measured in the laboratory (6.18 ppm, 17.09 ppm and 3.81 respectively).

C. Around Rei El-Garrah:

The averages of the eU, eTh and eTh/eU ratio in the field are 3.25 ppm, 13.5 ppm and 4.65 respectively whereas those measured in the laboratory are 6.5 ppm, 13.13 ppm and 2.07 respectively. The average equivalent uranium from the laboratory is twice that from the field whereas those of the eTh are approximately similar. Hence, the eTh/eU ratio of the field is twice that of the laboratory or greater.

D. Wadi El-Markh:

The averages of the eU, eTh and eTh/eU ratio in the field (4 ppm, 13.43 ppm and 4.07 respectively) are more or less similar to those measured in the laboratory (5.14 ppm, 12.86 ppm and 4.07 respectively).

The average contents of K% measured in the field in all wadis are four times or greater than those measured in the laboratory.

The notable difference between field and laboratory measurements in the study area may be attributed to the following reasons:

1- The first is the high background radiation in the study area, which arising from primordial radionuclides (uranium, thorium, their decay products and potassium) as well as cosmic radiation.
2- The second is related to the laboratory preparation for measuring the samples, where in the laboratory taking into account the background radiation created by cosmic radiation, contamination of natural or manmade radionuclides in the environment of the detector and subtracting it from the obtained concentrations.
3- The third reason may be attributed to that measured samples in the laboratory represent a small part of the whole area which measured by in situ gamma ray and also the mass or bulk effect of the field measured samples.

The obtained mean values for the studied stream sediments are higher than that reported for Earth's crust, 2.9 ppm, 10.8 ppm and 2.7 % for eU, eTh and K, respectively. In general, average value of eTh/eU ratio for the studied stream sediments (3.31, 3.81, 2.07 and 4.07 for Wadi El-Missikat, Wadi Rei El-Garrah, around Rei El-Garrah and Wadi El-Markh, respectively) are higher than Clarke value (3.5) which indicates that the radioelements in these sediments have not been significantly remobilized during weathering or involved in metasomatic activity in Wadi El-Missikat, Wadi El-Markh and Wadi Rei El-Garrah and the radioelements in these sediments are confined to the accessory minerals rather than mobile elements except around Rei El-Garrah which has U-enrichment **(Clarke et al., 1966)**. The main factors controlling the distribution of the radioelements in the studied streams are the geomorphological features of the basin of deposition, radioelements content of the source rocks, grain size of these sediments, the dominant mechanical weathering affecting the sediments, the alkalinity of the surface groundwater and to a lesser extent the organic matter content **(El Nahas, 2006)**.

It is clear that the studied Wadis are enriched in thorium than uranium and the studied stream sediments have uranium-contents more than Clarke value of uranium (4×10^{-6}) **(Clarke et al., 1966).**

eTh, eU relationships ***(Fig. 8)*** indicate positive correlation suggesting the accommodation of the two radioelements in the same accessory minerals. On the other hand, eU and eTh relation with eTh/eU illustrates that the radioelements are redistributed by the effect of weathering processes ***(Figs. 9 and 10)***.

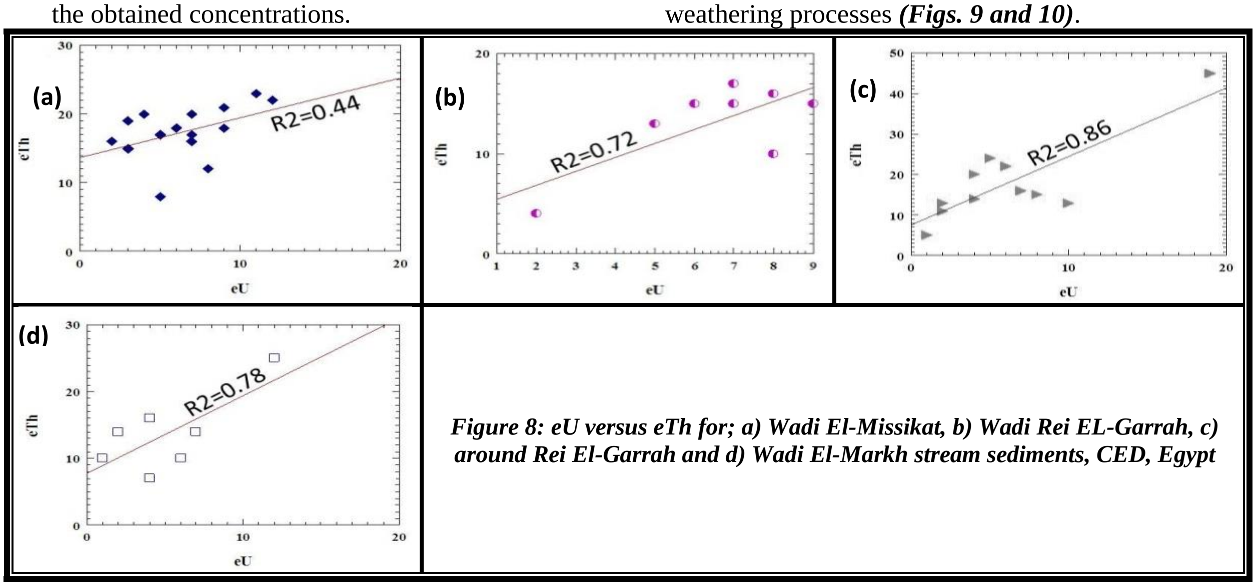


Figure 8: eU versus eTh for; a) Wadi El-Missikat, b) Wadi Rei EL-Garrah, c) around Rei El-Garrah and d) Wadi El-Markh stream sediments, CED, Egypt

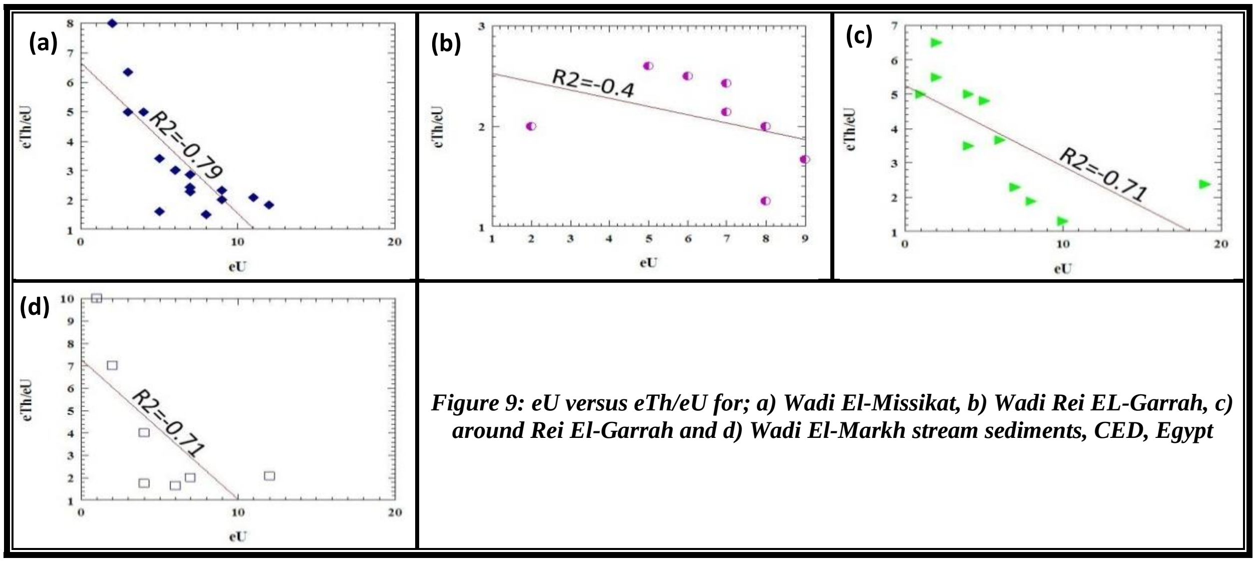


Figure 9: eU versus eTh/eU for; a) Wadi El-Missikat, b) Wadi Rei EL-Garrah, c) around Rei El-Garrah and d) Wadi El-Markh stream sediments, CED, Egypt

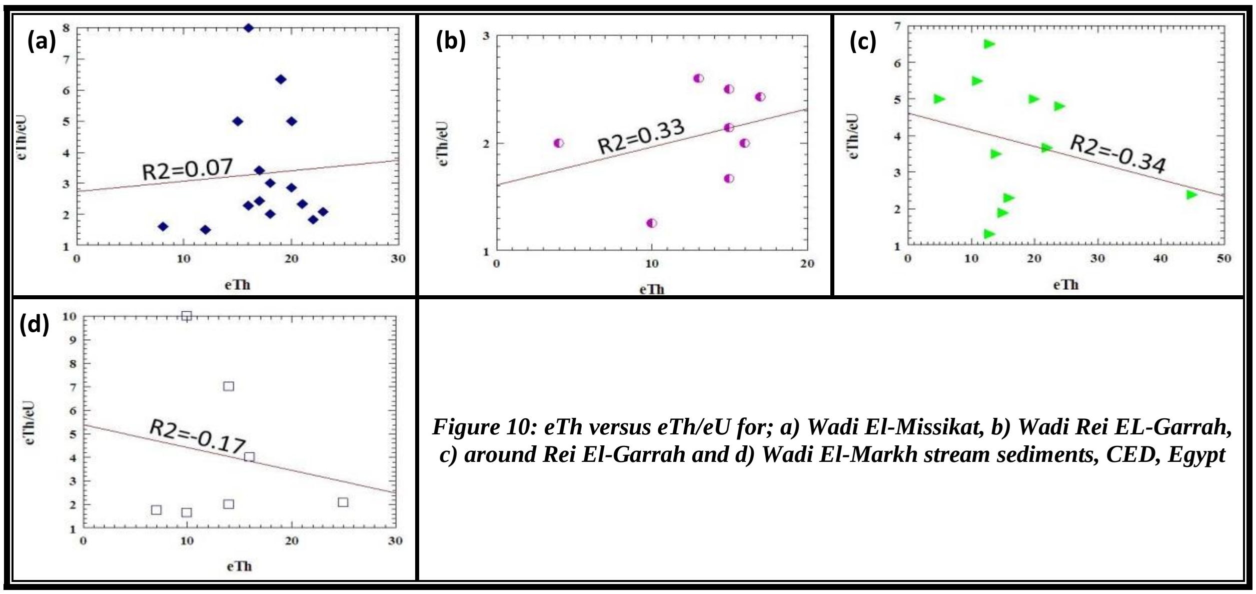


Figure 10: eTh versus eTh/eU for; a) Wadi El-Missikat, b) Wadi Rei EL-Garrah, c) around Rei El-Garrah and d) Wadi El-Markh stream sediments, CED, Egypt

5. MINERALOGICAL INVISTIGATIONS:

The mineralogical investigations revealed the presence of several radioactive and non-radioactive minerals. The common heavy minerals related to high radioactivity obtained from the studied stream sediments and granitic rocks in G. Rei El-Garrah area, besides the well referenced uranophane mineral **(e.g. Abdalla and El-Afandy 2004; Abu-Deif et al., 2007; Raslan, 2009; Ammar et al., 2016)**, could be classified into two groups (radioactive minerals and radioelements-bearing minerals). The identified radioactive minerals are thorite and uranothorite while the radioelements-bearing minerals are zircon, allanite and fluorite which enclosed radioactive inclusions. The non-radioactive minerals are represented by apatite, garnet, cotunnite, titanite, hematite, magnetite, ilmenite, rutile, and leucoxene as an alteration product of ilmenite.

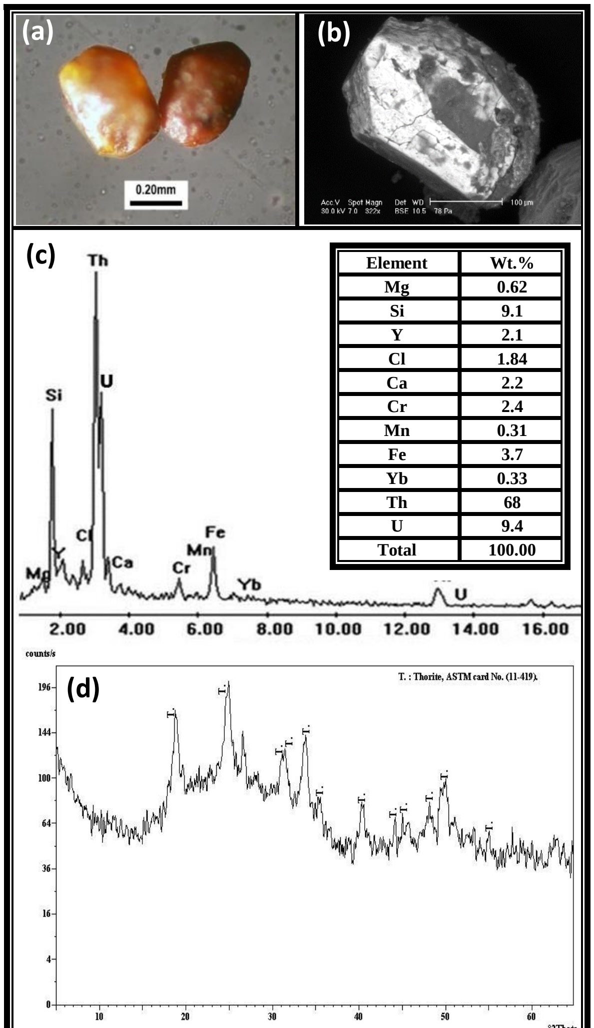
5.1. Radioactive Minerals

A) <u>Thorite: ThSiO₄</u>

Thorite usually formed in the latest stages of crystallization of certain acidic and alkaline magmatic rocks. It is highly radioactive mineral due to the existence of thorium as a common radioactive element and uranium as a minor one. Thorite contains impurities of U, Ca, Fe, Ce, Ti, Zr, Pb, P and rare earths in variable amounts **(Heinrich, 1958)**.

El Balakssy (2006) revealed that thorite from stream sediments of Wadi El-Shallal, South Western Sinai displays different verities as uranothorite (Th, U) SiO_4, calciothorite (Th, Ca) SiO_4, ferrothorite (Th, Fe) SiO_4, freyalitethorite (Th, Ce) SiO_4 and parathorite (Th, Ti) SiO_4 beside thorite-zircon solid solution series (Th, Zr) SiO_4.

Thorite in G. Rei El-Garrah area occurs as angular to subangular prismatic crystals and the colors ranging from reddish-brown to orange-yellow. They are confined to sand size fraction ***(Fig. 11a)***. The BSE image of the studied thorite shows a mixture of thorite and xenotime ***(Fig. 11b)*** and the EDX chart with semi quantitative microanalysis is shown in ***(Fig. 11c)***. The XRD analysis confirms the obtained results ***(Fig. 11d)***.

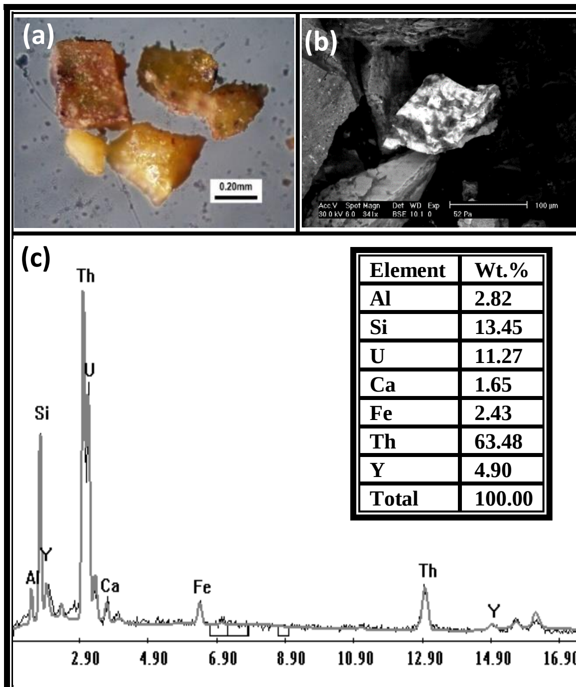


Element	Wt.%
Mg	0.62
Si	9.1
Y	2.1
Cl	1.84
Ca	2.2
Cr	2.4
Mn	0.31
Fe	3.7
Yb	0.33
Th	68
U	9.4
Total	100.00

Figure 11: Stereo photomicrograph (a); Scanning electron microscope BSE image (b), EDX (c) and X-ray diffractogram pattern (d) of thorite from G. Rei El-Garrah area, CED, Egypt

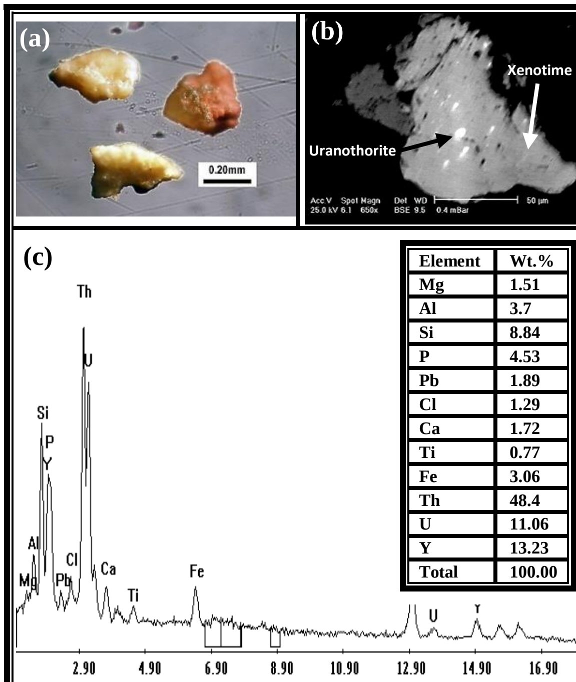
B) <u>Uranothorite: (Th, U)SiO_4</u>

Uranothorite is a radioactive mineral that consists mainly of Th and U silicates present in amounts up to 10% (Heinrich, 1958). Uranothorite was recorded in both the studied stream sediments and the granitic rocks in the studied area. It occurs as angular to subangular crystals with yellow and red colors ***(Fig. 12a)***. The EDX and BSE image of the studied uranothorite are shown in ***(Figs. 12b and c)***. Also, uranothorite occurs as inclusions in xenotime ***(Figs. 13a, b and c)***.



Element	Wt.%
Al	2.82
Si	13.45
U	11.27
Ca	1.65
Fe	2.43
Th	63.48
Y	4.90
Total	100.00

Figure 12: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of uranothorite from G. Rei El-Garrah area, CED, Egypt



Element	Wt.%
Mg	1.51
Al	3.7
Si	8.84
P	4.53
Pb	1.89
Cl	1.29
Ca	1.72
Ti	0.77
Fe	3.06
Th	48.4
U	11.06
Y	13.23
Total	100.00

Figure 13: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of uranothorite inclusion in xenotime from G. Rei El-Garrah area, CED, Egypt

5.2. Radioelements-bearing Minerals

A) Zircon: $ZrSiO_4$

Zircon is a common accessory mineral in most felsic igneous rocks especially granites. Due to its hardness, durability and chemical inertness, it can persist in sedimentary deposits as well as beach sands. Zircon has played an important role during the evolution of radiometric dating. It contains trace amounts of uranium and thorium.

Zoning is common in some cloudy zircon variety. Zoning may be attributed to heterogeneous distribution of trace elements in the parent magma during the crystal growth **(El Balakssy, 2010)**.

Most of zircon grains in the studied stream sediments and granitic rocks have euhedral prismatic habit. Zircon is commonly deep brown in color and translucent to opaque. It is characterized by different crystal forms **(El-Mansi, et al., 2004)** varying from prismatic to oval and rounded grains that may be due to abrasion during transportation. Also, some characteristic colors have also been recorded comprising brownish yellow, yellow, and pale yellow ***(Fig. 14a)***. The variation in color may be due to the density of fine inclusions or the intensity degree of iron oxide staining **(El-Balakssy, 2003)**.

Zircon inner structure was studied by back-scattered electrons image (BSE) under ESEM ***(Fig. 14b)***. Also, the semi quantitative of studied zircon obtained by (EDX) microanalysis is shown in ***(Fig. 14c)***. The XRD analysis confirms the obtained results ***(Fig. 14d)***.

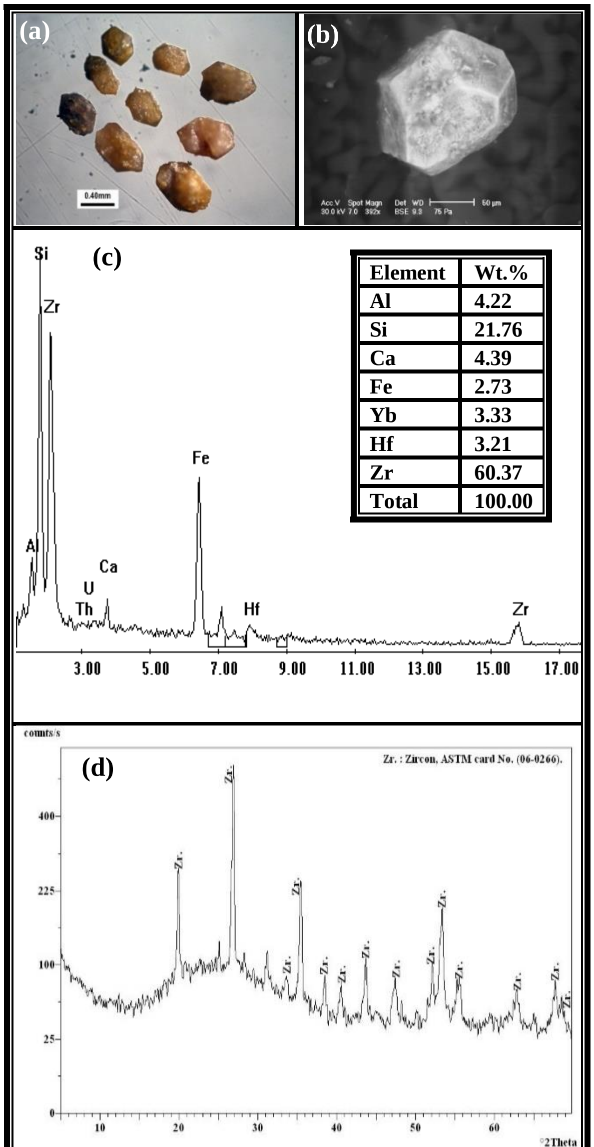
B) Allanite: (Ce, Ca, La, Y)$_2$ (Al, Fe^{3+})$_3$ (SiO_4)$_3$(OH)

Allanite, also called orthite, belongs to a sorosilicate group of minerals within the broader epidote group. Generally, it mainly occurs in metamorphosed clay rich sediments and felsic igneous rocks. It contains a significant amount of light rare earth elements, U and Th. **El Balakssy et. al. (2012)** reported that allanite from Um Lassifa granites, Central Eastern Desert, contains 242609 ppm, 1357 ppm and 13350 ppm of LREE, U and Th respectively.

In the present study, allanite is recorded in both stream sediments and granitic rocks as an accessory mineral exhibits color varies from reddish brown to black with vitreous luster. It has tabular crystal form ***(Fig. 15a)***. It is commonly metamict as a result of radiation damage caused by the radioactive decay of thorium, allanite accumulated in the surface of potash feldspar grain. The EDX and BSE image of the studied allanite are shown in ***(Figs. 15b and c)*** and revealing the cerium rich variety.

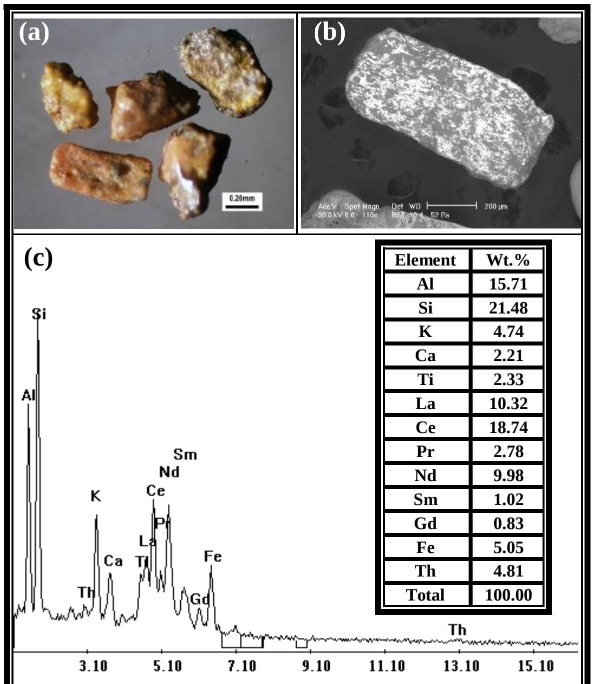
C) Fluorite: CaF_2

El-Mansi (2000) studied the coloration of fluorite and its relation to radioactivity. He classified fluorites into two groups; group (A) with total REE > 100 ppm and is associated with Sn and rare metal mineralization in albitized granites and group (B) with total REE < 100 ppm is associated with U mineralization or barren of any mineralization. He stated that the presence of blue fluorite containing REE < 100 ppm could be helpful in prospecting for uranium mineralization. Fluorite is recorded in stream sediments samples of G. Rei El-Garrah area as well as the granitic rock samples. It is a common accessory mineral in the sand size, fluorite grains exhibit irregular form with transparency ranges from transparent to translucent.



Element	Wt.%
Al	4.22
Si	21.76
Ca	4.39
Fe	2.73
Yb	3.33
Hf	3.21
Zr	60.37
Total	100.00

Figure 14: Stereo photomicrograph (a); Scanning electron microscope BSE image (b); EDX (c) and X-ray diffractogram pattern (d) of Zircon from G. Rei El-Garrah area, CED, Egypt, CED, Egypt



Element	Wt.%
Al	15.71
Si	21.48
K	4.74
Ca	2.21
Ti	2.33
La	10.32
Ce	18.74
Pr	2.78
Nd	9.98
Sm	1.02
Gd	0.83
Fe	5.05
Th	4.81
Total	100.00

Figure 15: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of allanite from G. Rei El-Garrah area, CED, Egypt

Its color varies from colorless to violet with vitreous luster ***(Fig. 16a)***. The color variations are caused by various impurities, and may reflect the strong effect radioactive mineralization of uranium and thorium in the host rock **(Phillips and Griffen 1981; Hassan 2005)**.

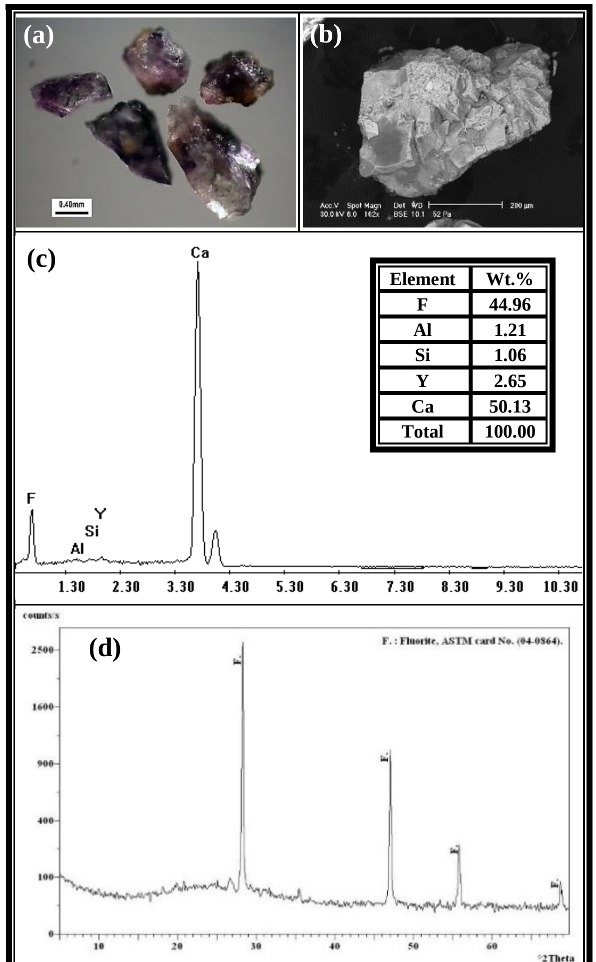
The BSE image and EDX (with semi quantitative microanalysis) illustrates the fluorite grains ***(Figs. 16b and c)***. The XRD analysis for fluorite confirms the obtained results ***(Fig. 16d)***.

5.3. Non-Radioactive Minerals

A) <u>Apatite: $Ca_5(PO_4)_3(OH,F,Cl)$</u>

Apatite is a widespread detrital mineral in sedimentary rocks. It may be formed either authogenically **(Weissbrod and Nachmias, 1986)** or as a secondary deposit. Apatite is a common accessory mineral of all types of igneous rocks. In nature, apatite is an important mineral of phosphorus in the phosphate rocks.

Apatite was recorded in the studied stream sediments as well as the granitic rocks in the studied area as rounded and spherical grains. It is colorless to yellowish brown in color ***(Fig. 17a)***. The EDX and BSE image of the studied apatite are shown in ***(Figs. 17b and c)***.

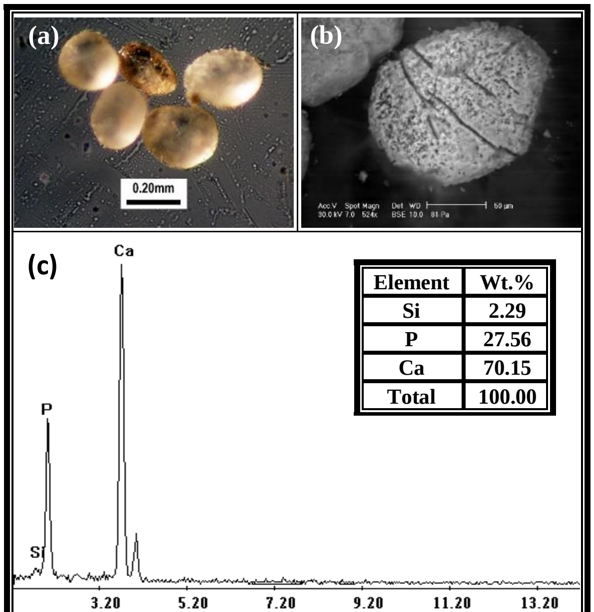


Element	Wt.%
F	44.96
Al	1.21
Si	1.06
Y	2.65
Ca	50.13
Total	100.00

Figure 16: Stereo photomicrograph (a); Scanning electron microscope BSE image (b); EDX (c) and X-ray diffractogram pattern (d) of fluorite from G. Rei El-Garrah area, CED, Egypt

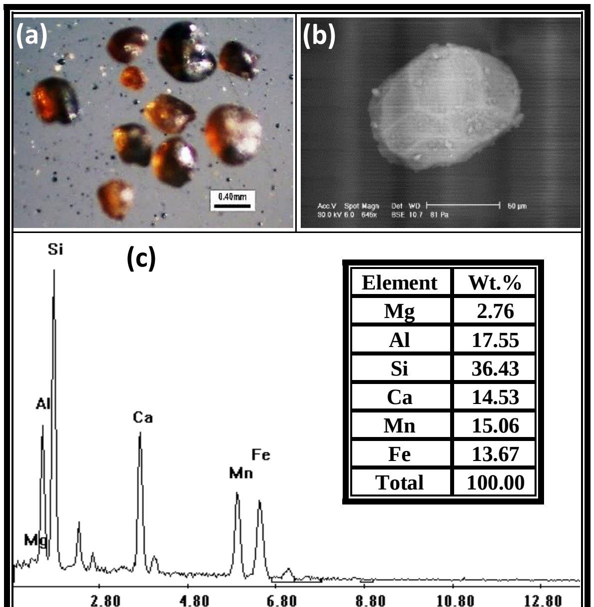
B) <u>Garnet: $X_3Y_2(SiO_4)_3$</u>

Garnet is a group of the (Fe, Mg, Mn, Ca and Al) silicate minerals which have the same crystal structures (cubic) but differ in the chemical compositions "isomorphism". They are in solid solution. Garnets are common accessory minerals in metamorphic and high-pressure igneous rocks and a major constituent of the Earth's mantle **(El Hadary, 2008)**. Because of their resistance to chemical and mechanical breakdown, they occur as detrital grains in sedimentary rocks. **Winchells (1933)** and **Deer et al. (1992)** divided garnet into two main groups; the first one is pyrolusite group, which includes pyrope, almandine and spessartine while the second group is ugrandite group that comprises grossularite, andradite and uvarovite. The microscopic study of garnet from the studied stream sediments and granitic rocks reveals that it is characterized by different habits; euhedral crystal, sharp irregular fragments to sub-angular grains with characteristic colors varying from rose to reddish brown and cloudy color *(Fig. 18a)*. The variation in color may be related to the variation in chemical composition. Some of the garnet grains of Rei El-Garrah area are analyzed by (ESEM). The EDX and BSE images of garnet revealed the presence of almandine-andradite and spessartine solid solution *(Figs. 18b and c)*.



Element	Wt.%
Si	2.29
P	27.56
Ca	70.15
Total	100.00

Figure 17: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of apatite from G. Rei El-Garrah area, CED, Egypt

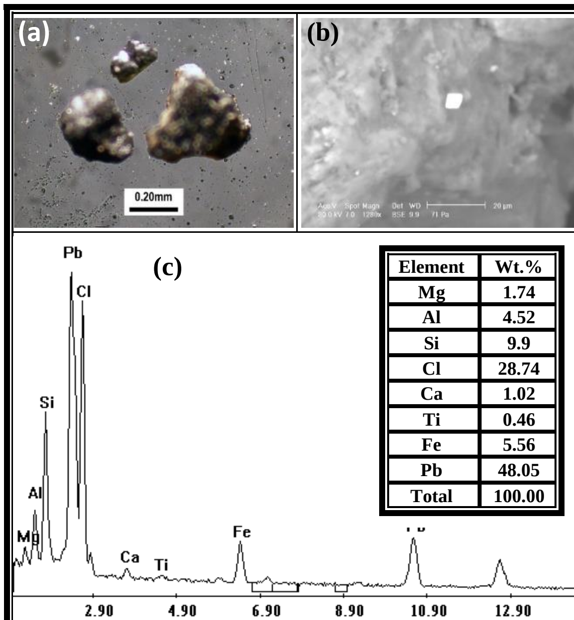


Element	Wt.%
Mg	2.76
Al	17.55
Si	36.43
Ca	14.53
Mn	15.06
Fe	13.67
Total	100.00

Figure 18: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of garnet from G. Rei El-Garrah area, CED, Egypt

C) Cotunnite: $PbCl_2$

Cotunnite is found as an accessory mineral, in the studied stream sediments only, their color is white and colorless *(Fig. 19a)*. The EDX (with a semi quantitative microanalysis) and BSE image of the studied cotunnite are shown in *(Figs. 19b and c)*. This mineral only encountered in samples collected from wadi El-Missikat.



Element	Wt.%
Mg	1.74
Al	4.52
Si	9.9
Cl	28.74
Ca	1.02
Ti	0.46
Fe	5.56
Pb	48.05
Total	100.00

Figure 19: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of cotunnite from G. Rei El-Garrah area, CED, Egypt

D) Titanite: $CaTiSiO_5$

Titanite is a widespread accessory mineral which occurs in acidic and intermediate igneous rocks, metamorphic and low temperature hydrothermal veins **(El-Nahas, 2006).** In the studied sediments, their color ranges from red to yellow, with irregular wedge shape *(Fig. 20a)*. The BSE image and the EDX (with a semi quantitative microanalysis) of titanite are shown in *(Figs. 20b and c)*. The XRD analysis confirms the obtained results *(Fig. 20d)*.

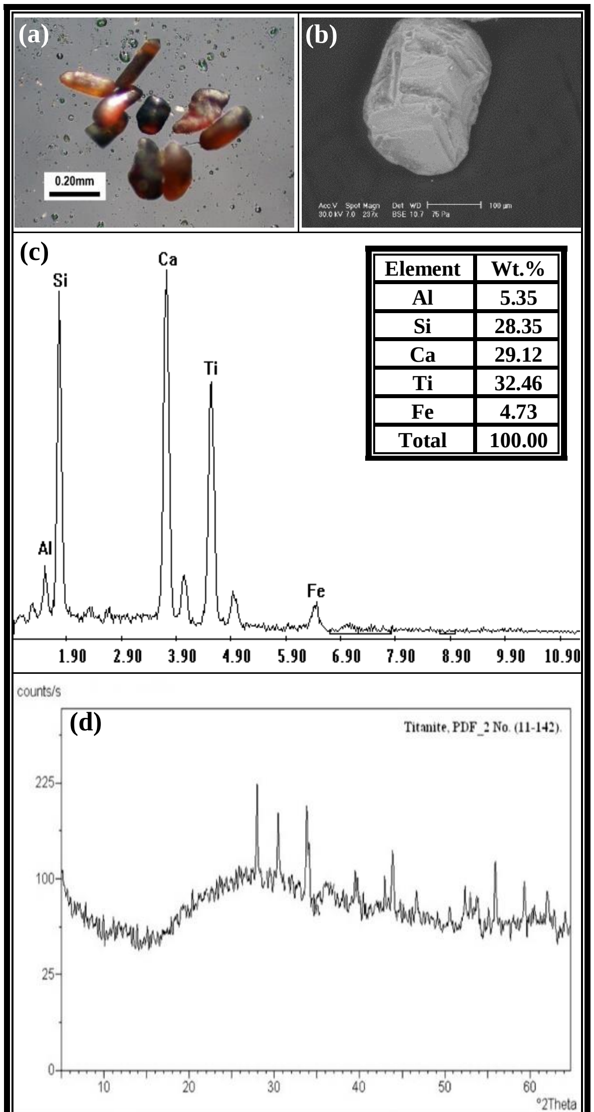
E) Hematite: (Fe_2O_3)

Hematite is the most common opaque minerals in the studied area; revealing their reddish appearance. Hematite is recorded in both the stream sediments and the granitic rocks of the studied area. It occurs as a reddish-brown color, with irregular particle habit *(Fig. 21a)*. The BSE image and the EDX (semi quantitative microanalysis) of the studied hematite are done by scanning electron microscope *(Figs. 21b and c)*.

F) <u>Leucoxene</u>

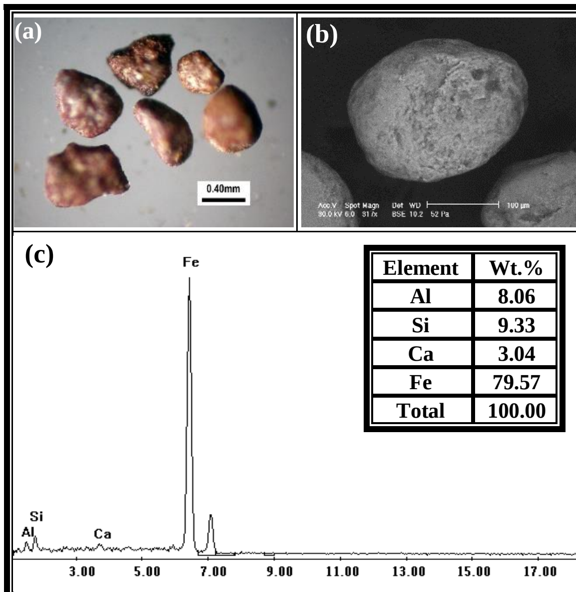
Leucoxene is not a mineral but it represents the transitional phase during the alteration of ilmenite to form the secondary rutile. Leucoxene is recorded in both the studied stream sediments and the granitic rocks. It is recorded as rounded to subrounded grains with yellowish brown, brown and dark brown colors under the stereomicroscope ***(Fig. 22a)***.

The BSE image and the EDX chart with semi quantitative microanalysis of the studied leucoxene are shown in ***(Figs. 22b and c)***.



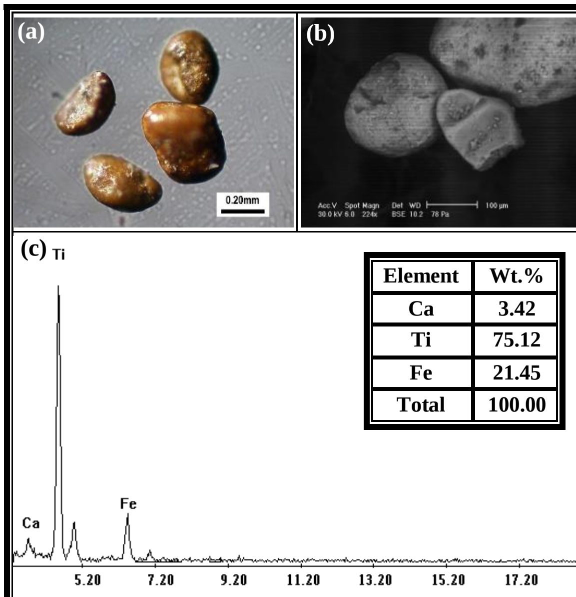
Element	Wt.%
Al	5.35
Si	28.35
Ca	29.12
Ti	32.46
Fe	4.73
Total	100.00

Figure.20: Stereo photomicrograph (a); Scanning electron microscope BSE image (b); EDX (c) and X-ray diffractogram pattern (d) of titanite from G. Rei El-Garrah area, CED, Egypt



Element	Wt.%
Al	8.06
Si	9.33
Ca	3.04
Fe	79.57
Total	100.00

Figure 21: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of hematite from G. Rei El-Garrah area, CED, Egypt



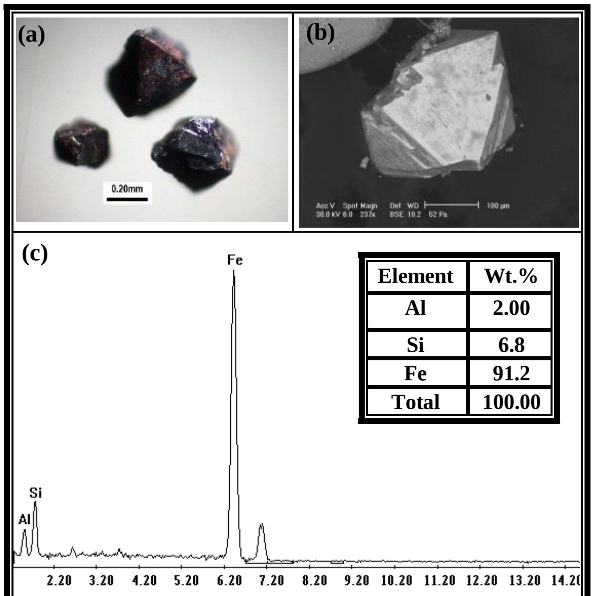
Element	Wt.%
Ca	3.42
Ti	75.12
Fe	21.45
Total	100.00

Figure 22: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of leucoxene from G. Rei El-Garrah area, CED, Egypt

G) <u>Magnetite: Fe_3O_4</u>

Generally, magnetite is a major constituent of iron oxides. It is considered as one of the less stable minerals and mainly altered to hematite, ulvospinel, maghemite and finally titanmagnetite **(El-Balakssy, 2003)**. Moreover; **Lindsley (1991)** stated that magnetite occurs as solid solution with many spinel components and has the inverse spinel structure.

In the studied stream sediments as well as the granitic rocks of Rei El-Garrah area, the microscopic studies show that magnetite exhibits euhedral and subhedral crystals of octahedron form with black color ***(Fig. 23a)*** as well as the aggregates of ideal magnetite grains showing the authigenic characters. The BSE image illustrates the octahedron magnetite crystals ***(Fig. 23b)*** and the EDX chart with semi quantitative microanalysis of the studied magnetite is shown in ***(Fig. 23c)***.



Element	Wt.%
Al	2.00
Si	6.8
Fe	91.2
Total	100.00

Figure 23: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of magnetite from G. Rei El-Garrah area, CED, Egypt

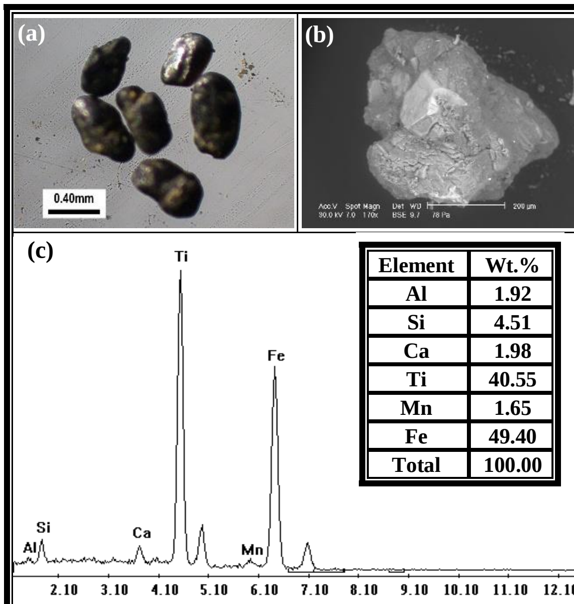
H) <u>Ilmenite: $FeTiO_3$</u>

Ilmenite is one of the most common Fe-Ti-oxide minerals with black color and metallic luster. In the studied stream sediments samples and the granitic rocks, ilmenite occurs as bladed and sub-rounded grains as shown in ***(Fig. 24a)***. The BSE image and the EDX chart with semi quantitative microanalysis of the studied ilmenite are shown in ***(Figs. 24b and c).***

I) <u>Rutile: TiO_2</u>

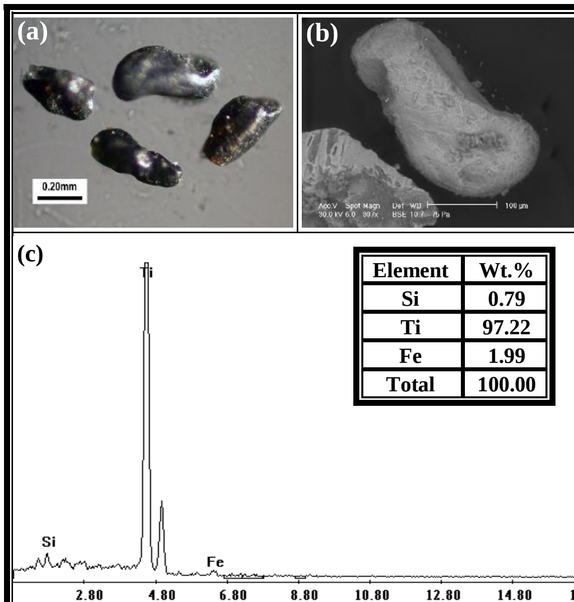
Rutile is one of the most stable detrital minerals. The sedimentary rocks contain originally detrital rutile and authigenic cryptocrystalline rutile forming clusters of needles or thin laths that result from the alteration of other titanium-bearing minerals; ilmenite and leucoxene **(El-Balakssy, 2003)**. Moreover, it is a widespread accessory mineral in metamorphic rocks. **Force (1980)** stated that the detrital rutile occurrence is predominat in the source rocks of high-grade regionally metamorphosed terrains.

The studied stream sediments samples and granitic rocks show that the rutile grains are characterized by a sub-angular, long prismatic and bladed grains varying in color from yellowish black to black which may denote to primary origin ***(Fig. 25a)***. The BSE image and the EDX chart with semi quantitative microanalysis of the studied rutile are shown in ***(Figs. 25b and c)***.



Element	Wt.%
Al	1.92
Si	4.51
Ca	1.98
Ti	40.55
Mn	1.65
Fe	49.40
Total	100.00

Figure 24: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of ilmenite from G. Rei El-Garrah area, CED, Egypt



Element	Wt.%
Si	0.79
Ti	97.22
Fe	1.99
Total	100.00

Figure 25: Stereo photomicrograph (a); Scanning electron microscope BSE image (b) and EDX (c) of rutile from G. Rei El-Garrah area, CED, Egypt

6. CONCLUSIONS

G. Rei El-Garrah area is bounded by longitudes 33° 21` 30`` and 33° 26` 40`` E and latitudes 26° 23` 30`` and 26° 31` 30`` N. Based on field relations and observations, the rock types in the study area comprise metavolcanics, older granitoids, younger gabbros, monzogranites, quartz-feldspar porphyry dykes and syenogranites. Field and laboratory radiometric measurements indicate that the activity concentrations of radionuclides decrease gradually from tonalite to granodiorite and reach up to its highest contents in the younger granites especially the syenogranites. The variation between eU, eTh contents and eTh/eU ratios of the older granitoids and younger granites show positive correlation between eU and eTh indicating that magmatic processes played an important role in the concentration of radioelements while the ill-defined relation between eU, eTh and eTh/eU ratios, suggesting redistribution of radioelements. The studied wadis are enriched in thorium than uranium though the studied sediments contain uranium contents more than Clarke value of uranium (4×10^{-6}). Also, positive correlation between eU and eTh in the studied stream sediments clarify the accommodation of the radionuclides in the same accessory minerals.

The mineralogical investigations of both the stream sediments and the granitic rocks indicated the presence of garnet, cotunnite, titanite, apatite as important accessory minerals. The encountered iron-titanium minerals are comprising hematite, magnetite, ilmenite, leucoxene and rutile.

Also, the high radioactivity, in the studied rocks and stream sediments, is mainly attributed to the presence of radioactive minerals; such as thorite, uranothorite besides uranophane and the radioelements-bearing minerals such as; zircon, allanite and fluorite which sometimes, contain inclusions of radioactive minerals. The random distribution and the low concentration of either radioactive and the radioelements-bearing minerals indicate the noneconomic importance of the stream sediments from the radioactivity point of view.

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