Asian Journal of Chemistry Vol. 6, No. 3 (1994), 549–562

On the Geochemistry and Potentiality of Uranium and Thorium in Granites from Aswan and El-Hudi, Eastern Desert, Egypt

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This work is a geochemical study of U and Th in two Egyptian U-rich granites, namely; Aswan and El-Hudi granites, eastern desert, Egypt in order to perform a preliminary evaluation of the ore-bearing potential of their U and Th contents.

These granites are of magmatic origin and belongs to the peraluminous type. The U and Th contents in the study granites are compared with U-rich granites in the world and it was safely concluded that, both local granites could be considered as suitable targets for future U and Th exploration.

INTRODUCTION

In Egypt, attention is now directed towards uranium (and thorium) present in local U-rich granites (as a potential low-grade ore). This work is a preliminary evaluation of the ore-bearing potential of U and Th contents of Aswan and El-Hudi granites, Eastern Desert, Egypt (Fig. 1) in the light of their geochemical characteristics. These granites have been previously[1] petrochemically and petrographically investigated.

EXPERIMENTAL

The obtainted samples representing the studied areas were subjected to the wet chemical analysis of their major elements, and their U and Th contents were analyzed by two methods: (a) chemically (fluorimetrically for U and gravimetrically for Th by the oxalate method) and (b) radiometrically (for determination of eU and eTh) using gamma-ray spectrometry.

RESULTS AND DISCUSSION

Geochemistry of Major Elements:

Major elements along with modal abundances (CIPW) of the two granites are presented in Tables 1, a and 1, b. In fact, the CIPW calculations on granites are reasonably satisfactory for chemically assessing the feldspar compositions. However, to interprete the mafic mineralogy, the normative minerals are

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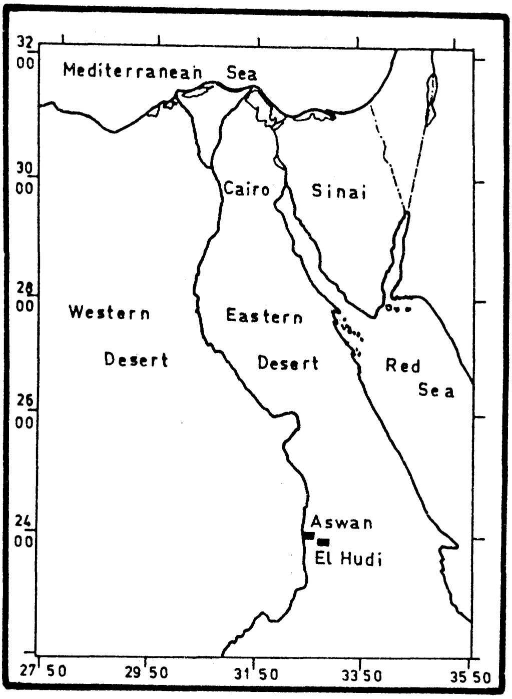

Fig. 1 Map of Egypt showing the situations of the study areas.

TABLE (1, a)
MAJOR ELEMENT COMPOSITION AND CIPW NORMS OF ASWAN GRANITIC SAMPLES.

Oxides, %	Sample no.					
	1	2	6	10	11	14
SiO_2	72.65	73.23	72.05	71.43	72.57	71.20
Al_2O_3	13.64	14.21	13.58	14.02	14.40	14.01
Fe_2O_3	1.19	1.33	1.18	1.40	0.75	1.15
FeO	2.23	2.60	1.91	2.50	1.63	2.47
MgO	0.22	0.15	0.30	0.24	0.15	0.30
CaO	0.95	0.78	1.62	1.01	0.70	1.46
Na_2O	2.78	2.56	2.88	3.20	2.96	3.18
K_2O	5.81	4.94	5.12	4.70	5.38	5.25
MnO	0.05	0.04	0.06	0.05	0.02	0.03
TiO_2	0.47	0.31	0.65	0.39	0.27	0.41
P_2O_5	0.09	0.14	0.09	0.18	0.09	0.24
H_2O	0.29	0.48	0.57	0.81	0.70	0.59
Total	100.37	100.77	100.01	99.95	99.62	100.29

Oxides, %	Sample no.					
	1	2	6	10	11	14
Norms						
Qz	30.99	36.33	31.49	31.63	32.24	28.40
Or	33.34	29.14	30.45	28.04	32.17	31.15
Ab	23.48	21.57	24.48	27.45	25.29	26.96
An	4.18	3.04	7.56	3.99	2.98	5.86
Hy	2.97	3.60	2.33	3.51	2.36	3.72
Cor	1.22	3.51	0.53	2.19	2.64	0.94
Ma	1.72	1.92	1.72	2.05	1.10	1.67
Ilm	0.89	0.59	1.24	0.75	0.52	0.78
Ap	0.20	0.30	0.20	0.40	0.20	0.53

TABLE (1, b)

MAJOR ELEMENT COMPOSITION AND CIPW NORMS OF EL-HUDI GRANITIC SAMPLES.

Oxides, %	Sample no.									
	22	23	26	27	30	33	42	48	55	62
SiO_2	71.93	72.08	73.02	72.68	72.63	72.13	72.91	73.36	71.94	72.96
Al_2O_3	14.02	14.03	13.88	13.83	13.78	13.65	14.40	13.78	13.86	14.02
Fe_2O_3	0.96	0.82	0.75	1.06	0.95	0.78	0.56	0.66	1.02	0.67
FeO	1.34	2.27	2.18	2.52	2.33	1.99	1.59	2.31	2.13	2.07
MgO	0.25	0.22	0.19	0.24	0.25	0.26	0.16	0.18	0.25	0.20
CaO	1.13	0.71	1.34	0.56	0.78	1.55	0.66	0.74	1.40	1.12
Na_2O	3.26	3.40	3.07	2.95	3.10	3.19	3.33	3.14	3.25	2.82
K_2O	5.32	5.18	4.39	5.05	5.40	5.52	5.52	5.01	4.91	5.08
MnO	0.07	0.04	0.04	0.02	0.02	0.06	0.01	0.01	0.05	0.04
TiO_2	0.34	0.39	0.31	0.41	0.30	0.47	0.22	0.19	0.25	0.33
P_2O_5	0.28	0.34	0.26	0.29	0.15	0.29	0.17	0.21	0.22	0.28
H_2O	0.51	0.45	0.66	0.36	0.46	0.62	0.41	0.48	0.47	0.31
Total	99.41	99.93	100.09	99.97	100.15	100.51	99.94	100.07	99.75	99.90
Norms										
Qz	30 31	30.34	34.75	34.11	31.00	28.46	30.40	33.21	30.42	34.02
Or	31.82	30.80	26.12	29.99	32.04	32.69	32.80	29.36	29.25	30.17
Ab	27.86	28.89	26.10	25.03	26.28	27.00	28.28	26.65	27.67	23.93
An	4.01	1.54	5.15	1.08	3.00	6.00	2.29	2.45	5.70	3.93
Hy	1.88	3.48	3.44	3.72	3.67	2.99	2.52	3.86	2.39	3.29
Cor	1.45	2.27	2.20	3.11	1.73	0.19	2.11	2.29	1.12	2.44
Ma	1.41	1.20	1.09	1.54	1.38	1.13	0.82	0.96	1.49	0.98
Ilm	0.65	0.74	0.59	0.78	0.57	0.89	0.42	0.36	0.48	0.63
Ap	0.62	0.75	0.57	0.64	0.33	0.63	0.37	0.46	0.48	0.61

Qz = quartz; Or = orthoclase; Ab = albite; An = anorthite; Hy = hyperthene; Cor = corundum; ma = magnetite; Ilm = ilmenite and Ap = apatite.

recalculated on the basis of the mesonorm (which is a modification of the Niggli molecular norm[2]). The normative minerals (mesonorm) are given in Table 2.

TABLE 2
MESONORM CALCULATIONS OF ASWAN AND EL-HUDI GRANITIC SAMPLES.

Norms	Aswan Samples					
	1	2	6	10	11	14
Qz	56.89	60.42	56.37	57.01	56.37	54.36
Or	16.73	13.25	14.60	12.55	12.83	14.60
Ab	14.80	13.60	15.35	17.30	21.05	16.95
An	3.25	2.70	5.35	3.60	2.60	4.85
Cor	0.48	1.94	—	0.93	0.95	—
Sph	1.17	0.78	1.62	0.99	0.66	1.02
Ma	0.74	0.71	0.74	0.87	0.47	0.72
Bio	5.79	6.40	5.36	6.48	4.27	6.72
Woll	—	—	0.44	—	—	0.46
Ap	0.12	0.16	0.12	0.21	0.12	0.26

Norms	El-Hudi Samples									
	22	23	26	27	30	33	42	48	55	62
Qz	55.96	55.82	56.23	55.56	56.50	54.89	56.81	58.64	55.93	54.81
Or	16.38	14.40	15.13	13.48	14.98	15.83	16.67	13.75	13.70	14.20
Ab	17.50	18.15	16.25	20.90	16.50	16.90	17.80	16.70	17.40	20.10
An	4.20	1.25	4.80	0.40	2.70	3.93	2.35	2.70	5.15	3.58
Cor	0.22	1.35	—	0.83	0.76	—	0.97	0.97	—	—
Sph	0.84	0.96	0.75	1.02	0.75	1.17	0.54	0.48	0.63	0.81
Ma	0.60	0.51	0.48	0.66	0.60	0.48	0.35	0.41	0.63	0.48
Bio	3.87	6.08	5.71	6.59	6.27	5.55	4.29	6.08	5.76	5.44
Woll	—	—	0.30	—	—	0.84	—	—	0.48	0.20
Ap	0.30	0.37	0.28	0.32	0.19	0.32	0.19	0.23	0.23	0.30

Qz = quartz; Or = orthoclase; Ab = albite; An = anorthite; Cor = corundum; Sph = sphene Ma = magnetite; Bio = biotite; Woll = wollastonite and Ap = apatite.

Clarke[3] who has reviewed granites (and stressed Shand's[4] classification) based upon the molecular proportion of Al_2O_3 (A), CaO (C), Na_2O (N) and K_2O (K): they are called peralkaline where $A < N + K$, meta-aluminous where $C + N + K > N + K$, subaluminous if $A = C + N + K$ and peraluminous where $A > C + N + K$. Thereupon, Aswan and El Hudi granites with average values of molecular proportion ($Al_2O_2/CaO + Na_2O + K_2O$) of 1.53 and 1.50 (Table 3) could be termed peraluminous. Also, according to Shand's[4] subdivision of igneous rocks using the triangular diagram $Al_2O_3 - CaO - (Na_2O + K_2O)$, the data from the granites in concern plot in the peraluminous field (Fig. 2). In fact, the presence of normative corundum in the study samples (Tables 1, a, 1, b and 2) indicate the distinctly peraluminous nature of the two granites as a whole.

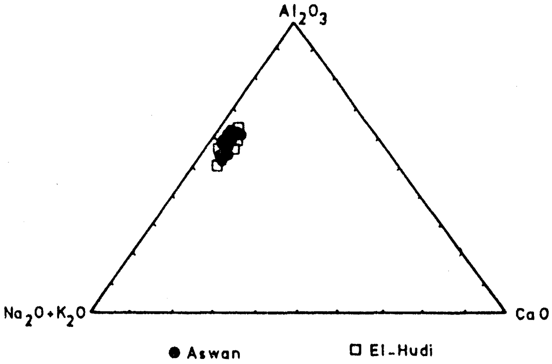

Fig. 2 Triangular diagram showing the relation between Al2O3, (Na2O + K2O) and CaO for the studied Aswan and El-Hudi granites.

It is important to mention herein that, Aswan pluton belong to the younger granite group III (subsolvus) of Greenberg[5].

From the Ab-Or-Qz diagram (Fig. 3) it is apparent that, the normal values of the analyzed Aswan and El-Hudi samples lies in the same region inside the contour distribution of granites showing a magmatic orgin of these rocks (Tuttle and Bowen[6]).

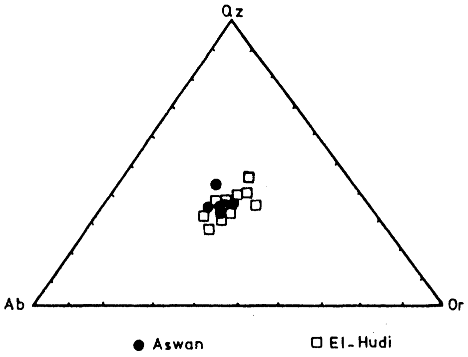

Fig. 3 Triangular diagram of Ab-Or-Qz normative values for the studied Aswan and El-Hudi granites.

The weight percent oxides of major elements (Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O and TiO_2) plotted versus SiO_2 (Fig. 4) display fairly continuous variation. As SiO_2 increases, nearly all major oxides decrease. The latter observation is clearly evident from the correlation coefficient matrices of SiO_2 with the latter mentioned oxides (beside P_2O_5, U, Th and Th/U) for the two granites (Tables 4, a and 4, b). In fact, the inter-element correlation coefficient (r) which are +1, −1 or 0; r = 0 means a complete independence between two elements, r = ±1 indicates a functional relationship, direct or inverse between them. Thus, it is clearly evident that, SiO_2 has either poor or negative correlation with the above mentioned oxides (Fig. 4).

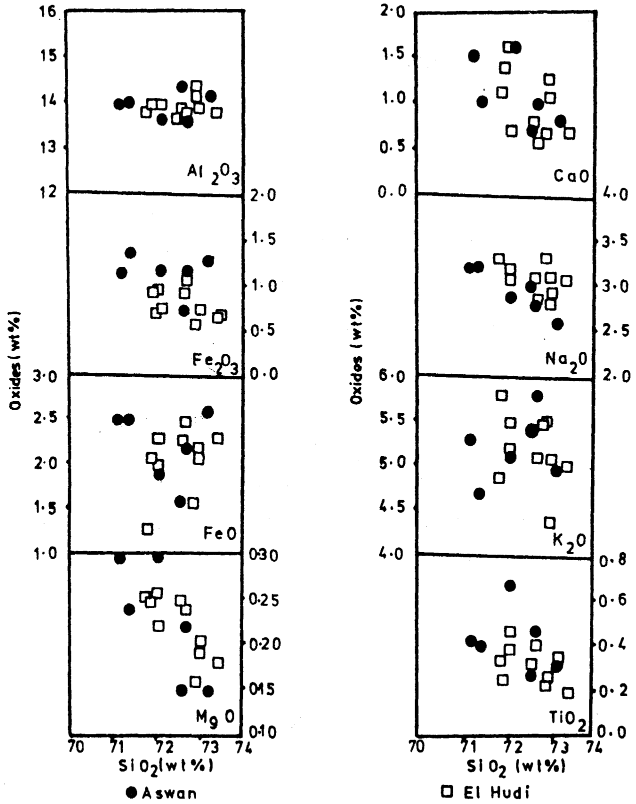

Fig. 4 Variation diagram of SiO_2 *vs* Al_2O_3, Fe_2O_3, FeO, MgO, CaO, Na_2O, K_2O and TiO_2 for the studied Aswan and El-Hudi granites.

On the basis of the obtained data of chemical analysis (Tables 1, a and 1, b), certain indices had been determined (Table 3).

Larsen's differentiation index (DI):

This index is a measure of rock's basicity (Larsen[7]), its average values are 24.34 and 24.46 for Aswan and El-Hudi samples respectively.

Felsic index (F)

The average values of this index for Aswan and El-Hudi samples are 88.34 and 89.31 respectively. However, considering the alkali and normal granites of Nockolds[8], their Felsic index values equal 92.30 and 86.53 respectively.

Mafic index (M)

The average values of this index for Aswan and El-Hudi samples are 92.41 and 90.27 respectively. The calculated Mafic index values of alkali and normal granites of Nockolds[8] are 88.02 and 82.95 respectively.

TABLE 3
SOME PETROCHEMICAL PARAMETERS (COMPOSITIONAL RATIOS AND INDICES) OF ASWAN AND EL-HUDI GRANITIC SAMPLES.

Sample No.	(1) potash/soda ratio	(2) Molecular proportion	(3) Larsen index	(4) Fesic index	(5) Mafic index	(6) Weathering index
Aswan						
1	2.09	1.43	24.98	90.04	93.96	40.70
2	1.93	1 73	24.94	90.58	95.32	43.90
6	1.78	1.41	23.72	83.16	89.05	39.90
10	1.46	1.57	23.63	88.69	94.20	38.20
11	1.82	1.59	24.96	92.25	88.15	38.80
14	1.65	1.42	23.78	85.24	93.78	41.50
average	1.79	1.53	24.34	88.34	92.41	40.50
El-Hudi						
22	1.63	1.44	24.14	88.36	82.73	41.50
23	1.52	1.51	24.82	92.36	93.35	40.20
26	1.43	1.58	24.27	84.77	93.91	37.10
27	1.71	1.62	25.11	93.46	93.72	37.00
30	1.74	1.49	24.81	91.59	88.65	39.80
33	1.73	1.33	24.07	84.89	91.42	43.40
42	1.66	1.51	23.90	93.07	89.96	41.10
48	1.60	1.55	25.13	91.68	92.24	38.30
55	1.51	1.45	23.71	85.36	85.98	40.00
62	1.80	1.55	24.61	87.58	90.73	38.00
average	1.63	1.50	24.46	89.31	90.27	39.64

(1) K_2O/Na_2O
(2) $Al_2O_3/CaO + Na_2O + K_2O$
(3) $1/3\ (SiO_2 + K_2O) - (CaO + K_2O)$
(4) $Na_2O + K_2O \times 100/Na_2O + K_2O + CaO$
(5) $FeO + Fe_2O_3 \times 100/FeO + Fe_2O_3 + MgO$

(6) $$\left[\frac{(Na)_a}{0.35} + \frac{(Mg)_a}{0.9} + \frac{(K)_a}{0.25} + \frac{(Ca)_a}{0.7}\right] \times 100;$$

(X) a indicates the atomic percentage of element X divided by its atomic weight, and the denominators in the function are the bond strength between the element and oxygen in each case.

Weathering index (WI)

The average values of this index for Aswan and El-Hudi samples are 40.50 and 39.64 respectively (Table 3). According to Parker[9], fresh granite may have a value of WI of about 80, completely weathered granite, 30. The index therefore provides a chemical index for mathematically describing weathering.

TABLE (4, a)
CORRELATION COEFFICIENTS FOR 6 SAMPLES OF ASWAN GRANITE.

Variable	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	U	Th
Th/U	-.08	.77	-.32	.13	-.22	-.14	.13	-.23	-.35	.55	-.43	.06
Th	.82	.11	.29	.33	-.55	-.38	-.91	-.04	-.43	-.26	.83	
U	.79	-.34	.33	.20	-.34	-.25	-.90	.28	-.18	-.52		
P_2O_5	-.68	.20	.38	.68	.40	.29	.58	-.42	-.62			
TiO_2	-.06	-.36	-.58	-.89	.29	.38	.09	.34				
K_2O	.28	-.29	-.51	-.41	-.05	-.08	-.24					
Na_2O	-.93	.04	-.04	-.01	.54	.36						
CaO	-.63	-.66	.21	.02	.95							
MgO	-.78	-.69	.29	.11								
FeO	-.16	-.03	.84									
Fe_2O_3	-.15	-.39										
Al_2O_3	.19											

TABLE (4, b)
CORRELATION COEFFICIENTS FOR 10 SAMPLES OF EL-HUDI GRANITE.

Variable	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	U	Th
Th/U	.34	.10	-.11	.17	-.33	-.07	-.46	.21	.09	.54	-.53	-.11
Th	.30	.39	-.43	-.27	-.40	.20	-.12	.14	-.64	-.41	.88	
U	.04	.35	-.29	-.32	-.28	.20	.21	.03	-.56	-.54		
P_2O_5	-.38	-.14	.16	.06	.27	.19	-.03	-.33	.72			
TiO_2	-.49	-.38	.36	.12	.60	.24	-.12	-.57				
K_2O	.20	.61	.06	-.07	-.32	-.68	.04					
Na_2O	-.50	.31	-.04	-.40	.07	-.04						
CaO	-.38	-.38	.05	-.25	.36							
MgO	-.77	-.60	.82	.08								
FeO	.30	-.55	.24									
Fe_2O_3	-.60	-.44										
Al_2O_3	.10											

Geochemistry of Uranium and Thorium

The chemically determined U, Th and K; and the radiometrically determined eU and eTh contents beside Th/U, U/K and Th/K ratios of the studied granites are shown in Table 5. From this Table, the average U contents of Aswan and El-Hudi samples (17.0 and 18.2 ppm) are more than the average content of U in granites 4.8, 4, and 5 ppm)[10–12]. On the other hand, the average Th contents of Aswan and El-Hudi samples (29.0 and 32.1 ppm) are also more than the average abundance of Th in granites (18, 20 and 15 ppm)[11–13]. Indeed, the anomalously high contents of U and Th indicate a high degree of evolution[14]. From the plots of Th vs U (Fig. 5), nearly a direct relationship could be observed. Returning to Tables 4, a and 4, b (of the correlation coefficients), one could observe that, U and Th are well correlated either in Aswan (0.83) or in El-Hudi (0.88) samples.

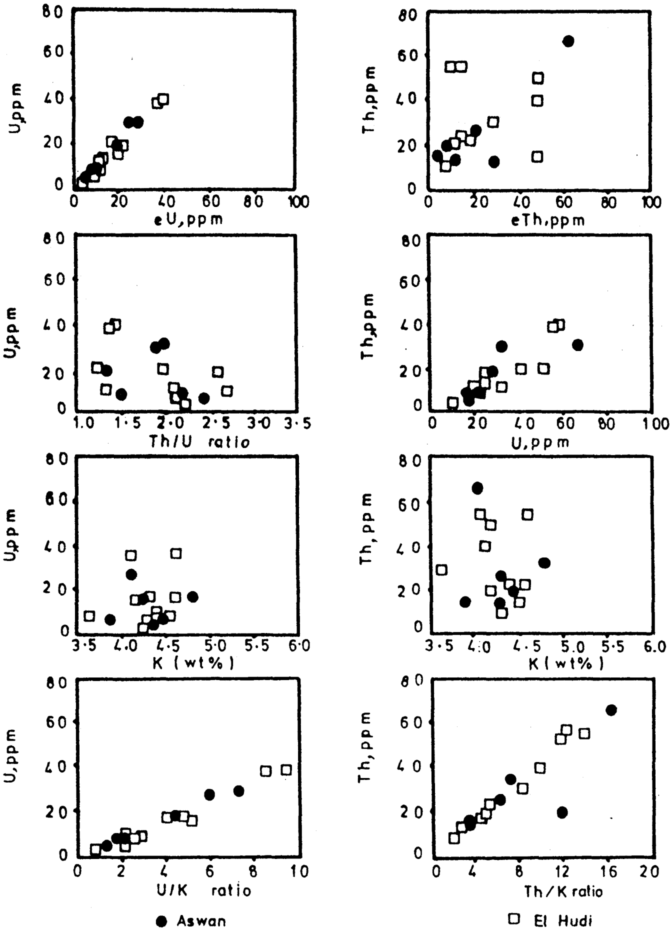

Fig. 5 Plots of U *vs* eU, Th/U ratios, K and U/K ratios, and Th *vs* eTh, U, K and Th/K ratios for the studied Aswan and El-Hudi granites.

Th/U ratios

From Table 5, the arithmatic means of Th/U ratios of the studied Aswan and El-Hudi samples are 1.97 and 1.94 respectively. These values are less than the average Th/U ratio for granites as taken from literature (3–4 in igneous rocks[15], 3.5, 5 and 3.3 ppm)[12,13,16]. In fact, Hassan and Hale[17] have mentioned that, Th/U ratio varies erratically with magmatic differentiation indices in the uraniferous granitic and rhyolite rocks of the Devonian-Carboniferous Age in the Southwestern New Brunswick, Canada. They attributed the variation as due to the complex history of uranium leaching and redistribution within plutonic rocks. They also attributed the greater Th/U ratio than the typical Th/U ratio (of 3.3)[13] in global average granites to higher thorium enrichment related to uranium at the time of the granitic rocks emplacement, or postcrystallization loss by weathering, metamorphism and alteration processes. It is worthy to mention that, in case of the studied Aswan and El-Hudi granites, the reverse is true (Table 5). The lower values of Th/U ratios means that these rocks tend to be more enriched in U relative to Th (U gain is pronounced than U loss). However, low Th/U ratios (of about 1) are indicators of U ore[18]. According to Steenfelt[19], a Th/U ratio greater than 6 may indicate loss of U. However, the range of Th/U ratio of 2–6 is commonly recorded in granites[10, 20–22]. This range is an evidence of removal of U from the magma and one may conclude that granite may originally have had some U in a relatively leachable form[23]. The plot of U vs Th/U ratios for the studied samples is shown in Fig. 5. Uranium and Th/U are negatively correlated for Aswan (–0.43) and El-Hudi (–0.53) samples (Table 4, a and 4, b).

TABLE 5

URANIUM, THORIUM AND POTASSIUM CONTENTS BESIDE Th/U, U/K AND Th/K RATIOS OF ASWAN AND EL-HUDI GRANITIC SAMPLES.

Sample no.	U ppm	Th ppm	eU ppm	eTh ppm	K %	Th/U	U/K x 10^4	Th/K x 10^4
Aswan								
1	29	33	28	31	4.80	1.94	6.04	6.88
2	30	66	27	64	4.08	2.02	7.35	16.18
6	19	26	19	22	4.28	1.37	4.49	6.15
10	9	14	10	13	3.88	1.56	2.32	3.61
11	9	20	8	9	4.44	2.22	2.03	11.51
14	6	15	4	5	4.34	2.50	1.38	3.46
average	17.0	29.0	16.0	24.0	4.30	1.97	3.94	7.97
El-Hudi								
22	11	23	10	20	4.40	2.09	2.50	5.23
23	4	9	2	7	4.28	2.25	0.94	2.10
26	11	30	10	30	3.63	2.73	3.03	8.26
27	9	20	8	10	4.17	2.22	2.16	4.80
30	11	15	12	50	4.46	1.36	2.47	3.36
33	19	24	18	13	4.56	1.26	4.17	5.26
42	39	55	37	11	4.56	1.41	8.55	12.06
48	20	40	20	50	4.14	2.00	4.83	9.66
55	39	55	40	15	4.06	1.41	9.61	13.55
62	19	50	20	50	4.20	2.63	4.52	11.91
average	18.2	32.1	17.7	25.6	4.25	1.94	4.28	7.62

Uranium and thorium in the younger granites

It is well known that, U and Th enrichment increase in the younger rocks.[17, 24, 25] According to Steenfelt[19], recent loss or gain of U in rocks can be indicated by plotting spectrometrically determined (eU) against chemically determined U. Ratios of eU/U greater than 1 indicate recent loss (while daughter products from the radioactive decay of U have remained). As U is less than Th in all granites, thus the U enrichment is therefore thought to be magnatic[19]. However, eU is relatively higher than eTh in three samples of El-Hudi granite suggesting the post-magmatic addition of U[19]. In fact, Greenberg[3] classified many granites lies in Eastern Desert, Egypt (including Aswan granite) as to be younger granites. In fact, the determination of eU and eTh (Table 5) for the study granites, and plots of U vs eU and Th vs eTh (Fig. 5) are comparable and probably reflect the state of radioactive equilibrium for U and Th. They plot close to the line of radioactive equilibrium (eU/U = 1) including that they are in a state of secular equilibrium with its daughters and they suffered no recent U loss. However, the trend of increasing eU and eTh contents with decreasing age of the rock is possibly related to secondary geological processes such as weathering, structural deformation and metamorphism[17]. In addition, the older igneous rocks are probably derived from an original source magma poor in U and Th, and they are apparently less differentiated than the younger igneous rocks and hence the older rocks contain less U and Th than the younger igneous rocks. However, the increase of both U and Th contents are gradual in volcanic rocks, but both U and Th contents increase markedly in the final stages of crystallization of the plutonic rocks[17]. This is to be expected because U and Th are both trace elements incompatible with the major rock-forming minerals.

U and Th relationships with K (and other major elements)

There is a general increase in the U and Th concentrations with K in granitic rocks[24]. On the other hand, Hassan and Hale[17] have mentioned that, Th in igneous rocks appears to be correlated with K contents whereas U shows little correlation with K suggesting a high mobility of U relative to Th and K in the post crystallization processes. According to Troeng[26], the U distribution in studied granites of Sweden correlated with K, Al, Fe and Mg whereas, P, Si and Na showed negative correlation. As an explaination, he postulated that, the fracture zones were probably rich in biotite, chlorite and sericite prior to the introduction of the U-bearing solutions. Permeation of the fracture zones by U-rich oxidizing solutions and precipitation of the U by these minerals would be reflected by positive correlation of U with K, Al, Fe and Mg. It is important to mention herein that, Carson[27] made a study of the igneous rocks, high grade metamorphic rocks of the Grenville series of the Hastings series of the Bancroft area, Canada and concluded that, high U/K and Th/K ratios are indicators of U ore in that area. The plot of U vs K, U vs U/K ratio, Th vs K and Th vs Th/K ratio for the studied Aswan and El-Hudi samples are shown in Fig. 5. Concerning Tables 4, a and 4, b, it is clearly evident that, U is well correlated with SiO_2, poorly correlated with Fe_2O_3, FeO, K_2O and negatively correlated with the remainder oxides of Aswan samples, and in case of El-Hudi samples, U is poorly correlated with SiO_2, Al_2O_3, CaO, Na_2O and K_2O and negatively correlated with the remainder oxides. On the other hand, Th is well correlated with SiO_2, poorly correlated with Al_2O_3, Fe_2O_3 and FeO and negatively correlated with the remainder oxides in Aswan samples, while in case of El-Hudi samples, Th is poorly correlated with SiO_2, Al_2O_3, CaO and K_2O and negatively correlated with the remainder oxides.

U and Th relationships with trace elements in granites

Armands and Drake[28] have studied both the major and trace elements compositions of a large number of Swedish granites and have demonstrated that, Li and Sn are high in many of the U-rich granites and that W is high in some of them. In the same granites, Wilson and Akerblom[14] have mentioned that, fluorite is a common accessory mineral and that F content can be as high as 0.5%. Similar results are reported from the younger granite of Nigeria by Olade[29] and Imeokparia[30]. The latter author has been demonstrated that, the younger granite of Nigeria appears to have the characteristics which appear to be describle in order to form Sn deposits. Indeed, the studied granitic samples of Aswan and El-Hudi (younger granites) could be compared with the younger granite of Nigeria. According to Bowden and Kinnard[31] and Imeokparia[32, 33] the relative abundance of either Na^+ or K^+ in the ore-forming fluids during evolution of the magmatic complexes exerts considerable influence on the form of mineralization; Na^+-rich fluid generated columbite mineralization associated with albitization, whereas K^+–rich hydrothermal fluids may be associated with Sn/W mineralization. According to Wilson and Akerblom[14], the high initial $^{87}Sr/^{86}Sr$ ratios commonly observed in U-rich granites, may be the results of the extra-radiogenic heat keeping the Sr-isotope system open for a longer than normal period (granites with high radio-element contents can be expected to take several million years to cool because of the radiogenic heat). The hydrothermal systems in these granites remain active for a longer period and might open or disturb the Rb-Sr system.

Origin of U and Th in granites

According to Stuckless and Ferreira[34], alkali affinity and high Th content have been considered important in distinguishing U source rocks. Thus, high K calcalkaline character, alkali enrichment, moderate to high Th contents and presence od U-bearing accessory minerals, though the rocks indicate a uraniferous magmatic source. Part of U initially contained in the magma was traped in the primary accessory phase observed; the rest fractionated into late-stage magmatic fluids. In Amo younger granite of Nigeria[30], there is a good correlation between the lithophile elements (including U and Th) and the alkalies. Since F (most granites have F as an accessory mineral) and alkalies promote solubilities in magma[35], their combined effect may lead to element mobility in the magma concerned. Thus, the increase in U and Th (the incompatible elements) may be attributed to the high alkalivolatile content of the magma, which has aided the mobilization of these incompatible elements.

Uranium in U-rich granites occurs mainly in accessory minerals, the commonest of which are: uraninite, thorite, monazite, xenotime, allanite, ziroon, apatite, sphene and Fe-Ti oxides. Indeed, Steenfelt[19] has suggested that, in granites from the Calidonides of East Greenland, the Devonian acid magma supplied the heat, U and F for hydrothermal fluids percolating in the joints and fractures along the faults. The U was possibly transported as F complexes subsequently precipitated in or along fractures. According to Troeng[26], the solutions responsible for the mobilization and concentration of U into the existing deposits in Olden granite, Sweden are thought to have been oxidizing carbonate-and F-rich, and formed as a result of the rise in temperature during and after Caledonian thrusting or, alternatively, that radiogenic heat has been responsible for the development of hydrothermal convection systems. Also, the cataclasis of the Olden granite would have created a permeable system for solutions to circulate. Uranium in the Elberton batholith of the Southern Appalachians, USA may have occurred as the hexavalent species during pegmatic formation; consistent with observations of the Fe-Ti oxide assemblages which suggest that the magma had high (fo) at the time of crystallization.

Conclusion

Aswan and El-Hudi granites are of magmatic origin and belongs to the peraluminous type. They are leucocratic[1] granites of calc-alkaline character and having potassic affinity. These granites exhibits geochemical characteristics including high SiO_2, high differentiation indices and high alkali contents. The average U and Th contents of these granites (17 ppm U, 29 ppm Th, 18.2 ppm U and 32.1 ppm Th for Aswan and El-Hudi samples respectively) are more than the average contents in granites, while their average Th/U ratios (1.97 and 1.94 respectively) are on the contrary less than the average Th/U ratio in granites as taken from literature.

The above mentioned geochemical characters have been considered important in distinguishing them as U sources rocks[34]. These U-rich (younger) granites could be termed 'hot granitoids'.[37] However, the Devonian granites of East Greenland (contains average U contents ranges between 5.8 to 16 ppm) could be considered as potential sources rocks[25]. In fact, a granite containing 8 ppm U or more is termed uraniferous[37]. Thereupon, it could be concluded that, Aswan and El-Hudi U- rich granites could be considered as suitable target for future U and Th exploration.

ACKNOWLEDGEMENTS

I am thankful to Prof. Dr. N.M.T. El-Hazek, Vice President of the Nuclear Materials Authority and Prof. Dr. A.S. Fouda, Chemistry Department, Faculty of Science, El-Mansoura University for their kind assistance.

REFERENCES

1. E.M. Hussein, and Y. Maliakov, *Arab J. Nucl. Sci. Appl.*, **23,** 1 (1989).
2. C.S. Hutchison, Laboratory handbook of petrographic technique. A Willey-Interscience Publication, (1974).

3. D.B. Clarke, *Can. Mineral.,* **19,** Part I (1981).
4. S.J. Shand, Eruptive rocks, Wiley, New york, (1951).
5. J.K. Greenberg, *Geol. Soc. Bull.,* **92,** Part II (1981).
6. O.F. Tuttle and N.L. Bowen, *Geol. Soc. America Mem.*, (1958).
7. E.S. Larsen, *J. Geol.,* 46, (1938).
8. S.R. Nockolds, *Geol. Soc. Amer. Bull.,* 65, (1954).
9. A. Parker, *Geol. Mag.,* 107, (1970).
10. S.R. Taylor, *Geochim. Cosmochim. Acta,* 2, (1964).
11. J.J.W. Rogers and J.A.S. Adams, Uranium. In: Handbook of geochemistry. (Ed. K.H. Wedepohl) Berlin, Springer-Verlag II–4, (1969, b).
12. K.B. Krauskopf, Introduction to geochemistrey. McGraw-Hill, London, 2nd, ed., (1979).
13. R.W. Boyle, Developments in Economic Geology, 16, Elsevier, Amsterdam, (1982).
14. M.R. Wilson and G.V. Åkerblom, *Mineral. Mag.,* 46, (1982).
15. L.H. Ahrens, R.D. Cherry and A.J. Erlank, *Geochim. Cosmo. Chim. Acta,* 31, (1967).
16. J.J.W. Rogers and J.A.S. Adams, Thorium, In: Handbook of geochemistry. (Edited by Wedepohl, K.H.) Berlin, Springer-Verlag II–4, (1969, a).
17. H.H. Hassan, and W.E. Hale, Uranium, 4, Elsevier Science Publications B.V., Amsterdam, (1988).
18. U. Aswathanarayana, *Econ. Geol.,* 66, (1971).
19. A. Steenfelt, *Mineral. Mag.,* 46, (1982).
20. M. Moreau, In: Geology, mining and extractive processing of uranium, M.J. Jones (ed.), London, (1976).
21. J.S. Stuckless, C.M. Bunkder, C.A. Bush, N.P. Dooring and J.H.S Scott, *J. Res. U.S. Geol. Surv.,* 5, (1977).
22. J.J.W. Rogers, P.C. Regland, R.K. Nishimori, J.K. Greenberg and S.A. Hauck, *Econ. Geol.,* 73, (1978).
23. D.S. Wenner and J.D. Spaulding, *Mag. Mineral.,* 46, (1982).
24. K.S. Heir and J.M. Rhodes, *Econ. Geol.,* 61, (1966).
25. B.L. Nielsen, and A. Steenfelt, In: Recognition and Evaluation of Uraniferous Areas. Int. Atomic Energy Agency, Vienna (IAEA-TC-25/3), (1977).
26. B. Troèng, *Mineral. Mag.,* 46, (1982).
27. J.M. Carson, M.Sc. Thesis, Univ. of Western Ontario, London, Canada, (1969).
28. G. Armands, and K.M. Drake, STU (Styrelsen för Teknisk Utveckling) Report No. 77, (1978).
29. M.A. Olade, *Econ. Geol.,* 75, (1980).
30. E.G. Imeokparia, *Chem. Geol.,* 40, (1983).
31. P. Bowden and J.A. Kinnard, *Inst. Min. Metall. Trans. Sect.,* **B,** 87, (1978).
32. E.G. Imeokparia, *Geol. Mag.,* 119, (1982).
33. ________, *Inst. Min. Metall. Trans.,* **B,** 91 (1982, b).
34. J.S. Stuckless and C.P. Ferreira, In: Exploration for uranium ore deposits IAEA, Vienna, (1976).
35. J.C. Bailey, *Chem. Geol.,* 19, (1977).
36. M. Pagel, *Mineral. Mag.,* 46, (1982).
37. A.G. Darnley, In: Uranium in granites., *Geol. Surv. of Canada,* paper 81–23, (1982).

(*Received:* 5 March 1993; *Accepted:* 30 September 1993) AJC-691