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PAN-AFRICAN PLUTONIC SUITE OF UM SHAGHIR AREA, QUSSEIR DISTRICT, EASTERN DESERT, EGYPT: SUBDUCTION ZONE MAGMATISM

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ABSTRACT

The present work deals with the plutonic suite including granitoid and gabbro-dioritic rocks at Wadi Um Shaghir area. This suite comprises mappable intrusive bodies of granodiorite-tonalite association in combination with gabbro-diorite complex. No direct contact has been noticed between the two types of rocks.

Geochemically, the granitoids originated from peraluminous calc-alkaline magma with many chemical parameters similar to I-type granites. On the other hand, the studied gabbroids exhibit calc-alkaline nature with chemical characteristics identified to phase I of gabbros described by Heikal et al. (2000). Both types of magmas were developed in an island arc tectonic settins.

The concentrations of U and Th in the granitoid rocks were controlled by magmatic processes which are clear from the positive relation between U and Th and U-Zr in addition to the weak negative relation between U and K/Rb were obtained.

The granitoids like subduction-related rocks are enriched in LILE and depleted in HFSE suggesting their derivation by partial melting of subarc mantle source region highly metasomatized by aqueous fluids. The abnormally high Ba-content might suggest incorporation of plagic sediments into the melting zone. The dioritic rocks are enriched in both LILS and HFSE suggesting the metasomatizing fluids in the mantle source region were derived from rutile-free subducted slab causing enrichments in HFSE.

INTRODUCTION

The present plutonic suite comprises a mappable isolated irregular masses at Wadi Um Shaghir, 7km south the Qift-Quseiur road at 140 km mark from Qift (Fig. 1). It was previously mapped as Older Granites (Shazly, 1971; Akaad and Shazly, 1977).Essawy and Shazly (1978) considered these rocks as a rank of metagabbro-diorite complex.

In the present work, the intrusive bodies at Wadi Um Shaghir area represent a typical plutonic suite that comprises two or more associated plutonic classes. (article 35, 860, North American Stratigraphic Code, 1983).

In spite of the small size of the studied plutonic suite, yet it embraces a varied assortment of different rocks with clear cut demarkations between granitoid and gabbroid rocks in the exposures.

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The intent of this study is to present new geochemical data for elucidation the tectono-magmatic evolution and to discuss a model for the origin of these rocks.

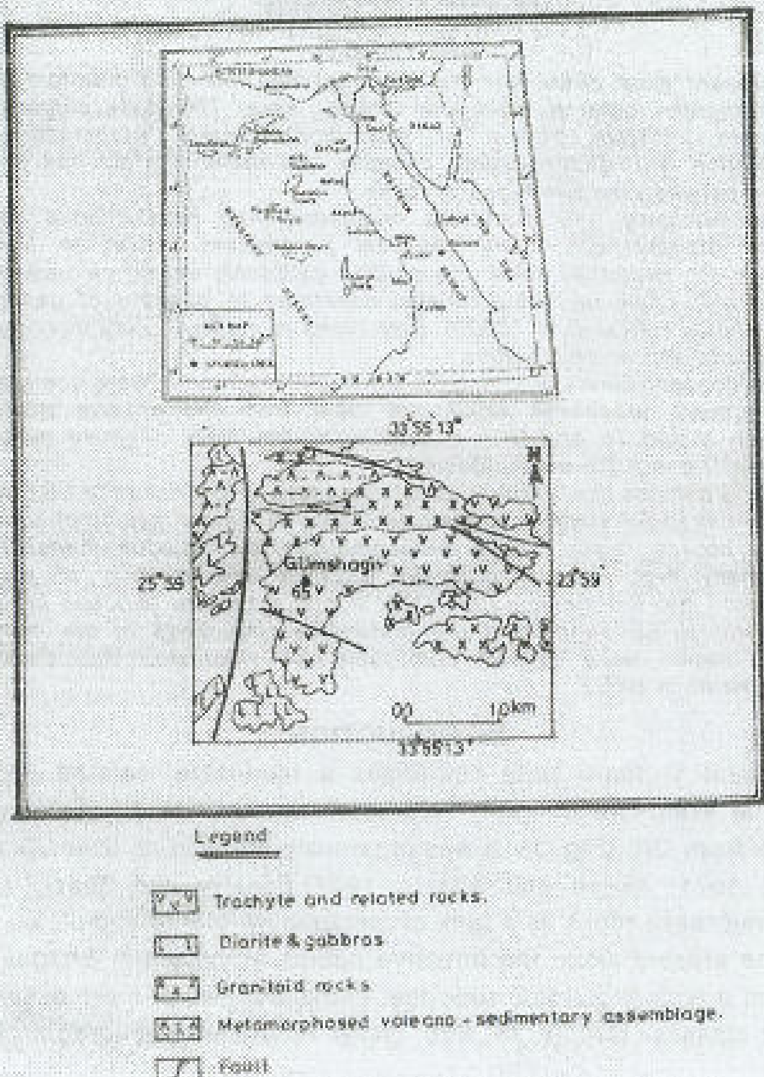


Fig. (1): Geological map of the Um Shaghir plutonic suite (granitoid gneissic rocks) and the neighbouring rock units (modified after Essawy and Shaab, 1978).

Field Aspects

The studied plutonic suite forms small isolated irregular masses (Figs. 1&2a). The granitoids under consideration were introduced at its northern and southern parts into metamorphosed volcano-sedimentary assemblage (Abu Fannani schist, Heikal, 1999) as well as trachyte and related rocks. The contacts mostly being irregular and sharp with slight thermal effect marked by variable degrees of alteration and colour (Heikal, 2003). The granitoid pluton was later invaded by numerous veins of quartz and carbonates trending NW and ENE.

On the other hand, the isolated gabbroid-dioritic association (Fig.2b) occupies the western and extreme southwestern part of the area (Fig.1). No apparent contact with the surrounding rocks. The intrusive masses constituting the plutonic suite froming low relief, severely weathered and surrounded by sandy plains.

Petrography

The classification of the present rocks is based on Streckeisen (1976). Figure (5) shows that samples representing the granitoid rocks plot within granodiorite and tonalite fields, whereas the gabbroid rock plot in the gabbro-diorite field.

Gabbros are composed of plagioclase, clinopyroxene with sporadic hornblende, biotite and quartz. Pyroxene is represented by augite (Fig. 3a) showing uralitized margins, where plagioclase of labrodoritic composition (An55) reflectts intense saussuritization. Diorites comprise plagioclase of andesine composition (An42) and dense assortment of biotite (Fig. 3b) and hornblende. Chloritization is well developed at the expense of biotite and hornblende.

Granodiorites and tonalites (Fig.3c-d) are characterized by hypidomorphic, vermicular, myrmekitic intergrowth, interstitial and poiklitic textures. In addition, zoning, resorbed rims (Fig. 3d), mantling and punctuates growth reflect disequilibria textures for both.

Throughout the petrographic investigation, there are good signs of alteration, in particular uritization, chloritization and serictization upon these rocks.

Geochemistry

Whole-rock major and trace elements and CIBW normative composition for selective samples of both granitoid-gabbroid rocks are given in Table 1. The chemical analyses of granitoid have been carried out at the Nuclear Material Authority, Cairo.

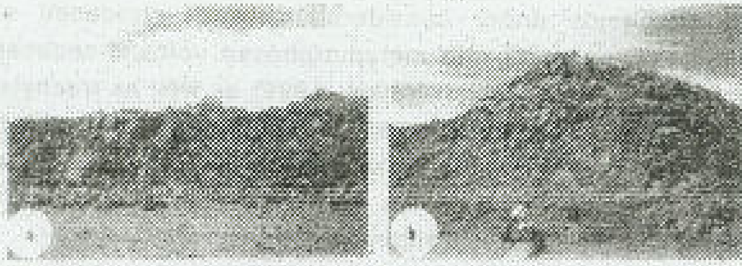


Fig2 : a) A part of granodiorite – tonalite pluton showing spheroidal weathering. Um Shaghir area . b) General view of diorite – gabbro association at Wadi Um Shaghir .

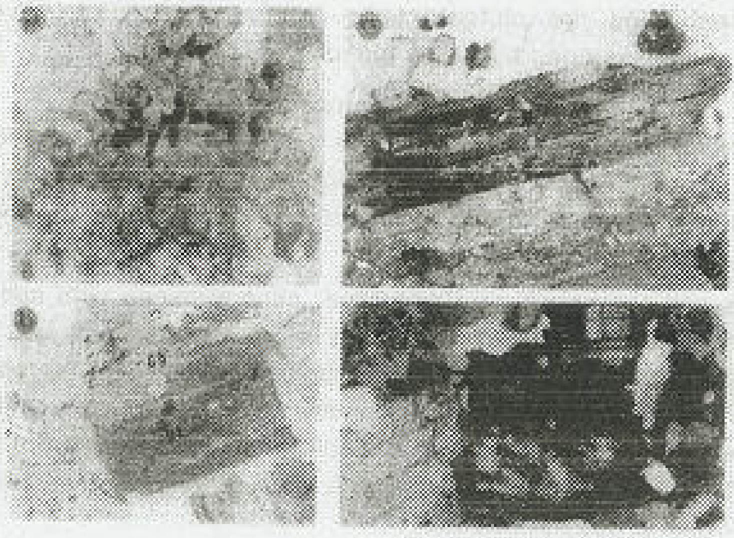


Fig 3 : a) Stubby crystals of augite associated with dense aggregates of opaques in gabbros. PPL., X 40. b) bold crystal of biotite (Bt) shows chloritized margins (Ch) in diorite . PPL., X 40. c) Large crystal of oligoclase showing high sericitization in granodiorite. C.N., X 40. d) tonalite carries variable proportions of quartz, plagioclase and mafic minerals . C.N., X 40

The most striking features of major and trace elements are the high contents of Na2O (up to 4.6 wt %) and LILE (Ba, Sr and K) (Table 1). The slight variation in K/Na ranging from 0.51 to 0.61 is consistent with the formation of intercumulus k-feldspar and plagioclase and biotite (El-Metwally and Ibrahim, 1995).

Table (1) Chemical analysis of major and trace elements of granitoids of Um Shaghir area.

	SG-1	SG-2	SG-3	SG-4	SG-5	SG-6	SG-7	SG-8	SG-10	SG-11	SG-12
SiO_2	67.20	66.98	67.01	65.89	66.65	66.01	66.81	64.14	67.30	66.57	66.48
TiO_2	0.65	0.74	0.58	0.74	0.59	0.46	0.50	0.38	0.55	0.71	0.70
Al_2O_3	15.81	14.98	15.18	15.61	15.08	14.85	15.37	15.06	15.39	15.12	14.99
Fe_2O_3	1.26	1.14	1.23	1.41	1.46	1.10	1.38	3.97	1.53	1.59	1.66
FeO	3.12	3.05	3.34	3.94	3.75	2.98	3.10	2.68	3.20	3.42	3.11
MnO	0.09	0.12	0.17	0.15	0.19	0.21	0.29	0.11	0.08	0.16	0.13
MgO	1.04	1.10	1.12	1.34	1.24	1.14	1.21	2.72	1.02	1.12	1.35
CaO	2.26	2.18	2.33	2.66	2.43	2.49	2.49	4.76	2.42	2.30	2.28
Na_2O	4.60	4.28	4.35	4.28	4.43	4.51	4.52	3.51	4.36	4.19	4.36
K_2O	2.54	2.62	2.42	2.61	2.61	2.49	2.60	2.10	2.31	2.44	2.61
P_2O_5	0.36	0.42	0.48	0.54	0.42	0.56	0.51	0.13	0.25	0.31	0.44
H_2O^-	0.19	0.21	0.35	0.29	0.31	0.48	0.34	0.25	0.29	0.36	0.42
L.O.T	0.98	0.89	0.73	0.67	0.71	0.68	0.61	0.46	0.62	0.62	0.63
H_2O^+	0.57	0.66	0.43	0.46	0.53	0.41	0.45	0.36	0.32	0.59	0.59
Total	100.75	99.36	99.72	100.51	100.33	100.41	100.16	100.65	99.64	99.50	99.66
					C.I.P.W. norm						
Qz	28.81	25.79	25.45	22.80	23.35	25.16	23.12	2.11	25.72	25.75	24.28
Or	15.16	16.66	14.57	16.50	15.04	14.84	15.57	12.47	13.68	14.74	15.74
Ab	39.29	37.06	37.43	36.51	37.92	38.57	38.68	29.79	37.44	36.16	37.56
An	9.20	8.56	6.81	9.63	8.72	9.06	9.43	19.23	10.72	9.50	8.90
Di	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hy	6.43	6.56	7.40	8.55	8.16	7.09	7.38	2.95	6.50	7.03	6.82
Cor	2.17	2.06	2.23	2.26	1.57	1.47	1.72	0.00	1.87	2.10	1.81
Mt	1.86	2.06	1.82	2.06	2.17	1.61	2.00	5.78	2.25	2.35	2.45
Il	1.25	1.69	1.82	1.42	1.14	0.92	0.96	0.73	1.06	1.38	1.36
Ap	0.79	0.94	1.07	1.19	0.93	1.26	1.13	0.28	0.55	0.69	0.96
					Some geochemical parameters						
K/Na	0.55	0.61	0.51	0.61	0.57	0.55	0.56	0.60	0.53	0.58	0.60
D.I	78.29	78.73	77.46	74.90	76.31	78.57	77.37	64.37	77.04	76.65	77.57
R1	1719	1850	1843	1696	1750	1816	1808	1740	1866	1876	1769
R2	611	597	614	663	626	622	636	946	622	612	617
					Trace element						
Zr	149	118	146	154	144	232	130	82	125	110	119
Y	10	8	11	11	10	16	9	6	9	6	8
Sr	231	204	245	240	224	238	206	204	579	486	436
Rb	32	28	43	39	34	30	26	28	26	42	36
Nb	4	3	4	<2	4	8	6	5	< 2	3	4
Ba	1849	1908	2013	1951	1996	1962	2315	3672	4518	4070	4094
Cu	137	71	122	132	63	62	68	244	183	73	279
Ni	12	11	10	13	11	6	16	25	6	13	11
Co	8	8	8	8	8	7	9	12	10	11	10
Cr	73	70	46	75	65	21	141	147	21	59	34
V	53	54	57	56	55	54	63	111	121	126	127
Zn	57	52	62	57	63	52	60	78	84	74	73
Ga	13	13	18	18	17	17	13	11	18	17	16
Pb	62	68	63	63	61	52	63	61	59	56	68
U	12	7	15	19	16	14	21	19	9	5	9
Th	36	21	37	70	50	49	60	47	38	18	32
Th/U	3.00	3.00	2.47	3.68	3.13	3.5	2.86	2.47	4.22	3.6	3.55

Table (1) Cont.

	SG-13	SG-14	SG-15	SG-16	SG-17
SiO_2	54.92	56.64	57.20	57.80	58.26
TiO_2	1.52	0.64	0.64	0.80	0.08
Al_2O_3	17.30	16.82	16.60	16.60	16.42
Fe_2O_3	4.39	3.42	3.30	3.10	2.83
FeO	4.55	4.24	4.50	4.60	4.25
MgO	3.08	4.36	4.10	3.80	3.26
CaO	5.16	7.40	6.80	6.60	6.44
Na_2O	4.32	3.30	3.20	3.40	3.35
K_2O	1.86	1.82	2.00	1.70	2.22
MnO	0.18	0.10	0.09	0.10	0.08
P_2O_5	0.86	0.20	0.19	0.20	0.41
L.O.I	1.82	1.16	1.39	1.30	1.97
Total	99.96	100.00	100.01	100.00	99.57
			C.I.P.W.norm		
Qz	8.8	8.6	10.00	11.20	10.90
Or	9.9	11.00	12.00	10.00	13.50
Ab	36.5	30.00	29.00	31.00	31.50
An	20.5	26.00	25.50	25.50	23.20
C	0.8	0.00	0.00	0.00	0.00
Hy	10.2	11.60	12.60	12.00	9.80
Di	0.00	7.60	6.00	5.20	6.40
Mt	6.40	3.60	3.40	3.30	3.00
Il	2.90	1.00	1.00	1.20	1.20
Ap	2.00	0.50	0.50	0.50	0.50
			Some geochemical parameters		
K/Na	0.43	0.55	0.62	0.50	0.66
D.I	56.62	48.06	49.83	50.94	54.30
			Trace element		
Zr	520	312	350	355	349
Y	44	41	44	40	44
Sr	290	340	350	355	360
Rb	180	175	160	166	170
Nb	16	12	10	14	15
Ba	1160	980	974	880	986
Cr	299	236	320	300	318
Ni	150	130	114	118	145

SG1- SG10: tonalite-granodiorite
SG11- SG17: diorite- gabbro

The geochemical Classification

The data in table (1) are used to determine the classification, magma type, tectonic setting and petrogenesis of the studied rocks. Streckeisen, (1976) used the normative Or-Ab-An ternary diagram for nomenclature of the plutonic rocks (Fig. 4)which indicates that the studied metagabbro-diorite samples plot within the gabbro-diorite field and the granitoids in the granodiorite field . Also, Hietanen,(1963) used the same diagram (Fig.5) to nomenclature plutonic rocks where the studied metagabbro-diorite samples plot in the normal gabbro- quartz diorite field and the granitoids plot in the granodiorite field.

The total alkalies (Na_2O + K_2O) versus SiO_2 diagram (Cox *et al.*, 1979), (Fig. 6) indicates that the metagabbro-diorite samples plot in the gabbro-diorite field and the granitoid samples plot in the granodiorite field .The K_2O-SiO_2 diagram (Fig.7) after (Le Maitre.,1989) shows that the studied rocks belong to the medium-K igneous rock series. K_2O-SiO_2 diagram (Chappell and White; 1974) (Fig.8) shows that the studied granitoid rock including the dioritic ones plot in I-type granitoid field. Also, the SiO_2 versus Rb/Zr (Harris *et al.*, 1984) (Fig. 9) shows that the studied granitoids plot in the I-type granites field reflecting their igneous origin as well as the island tectonic setting.

Magma Type

The magma type of the investigated metagabbro-diorite complex is determined using the following chemical variation diagrams.

On AFM diagram metagabbro-diorite rocks plot in the calc-alkaline field (Fig 10) whereas on the TAS diagram (Fig. 6) they plot in subalkaline field. The (FeOt/MgO) - SiO2 diagram of Miyashiro, (1975) shows that the studied rocks plot in the mild calc-alkaline field (Fig 11).

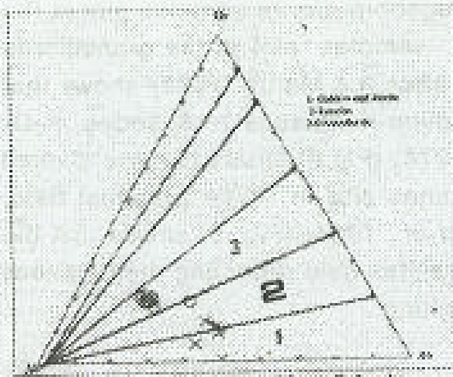
For the studied granitoids, the calc-alkaline nature of their magma is indicated by the above TAS, AFM and (FeOt/MgO)- SiO2 diagrams. The alumina saturation is shown by Shand indices (Fig.12) after Maniar and Piccoli, (1989). It is clear from the figure that the studied rocks plot in the peraluminous field.

From the above, it has been shown that the metagabbro-diorite complex rocks originated from calc-alkaline magma, whereas the granitoids originated from peraluminous calc-alkaline magma having I-type characteristics.

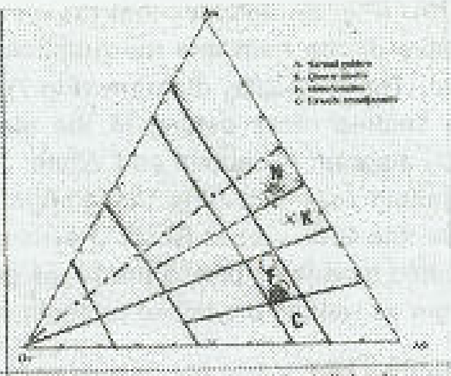
Tectonic Settings

The tectonic setting of the studied metagabbro-diorite complex rocks is indicated by the FeOt/MgO-Ni variation diagram (Miyashiro and Shido, 1975) and FeO-MgO-Al2O_3 discrimination diagram (Pearce *et al.*, 1977) as shown in figures (13&14) respectively where the studied rocks plot in volcanic island arc field.

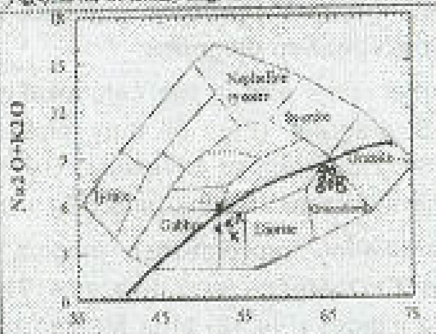
On the other hand the tectonic settings of the studied granitoids are determined by using the variation diagrams of (Nb-Y) and (Rb-Y+ Nb) (Pearce *et al.*, 1984), (Figs.15&16). The studied samples plot in the volcanic arc granite field.



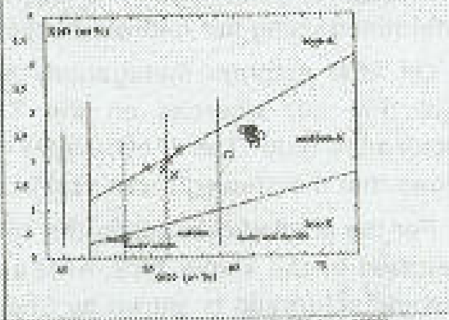
Fig(4): Ab-An-Or ternary diagram of the studied rocks.



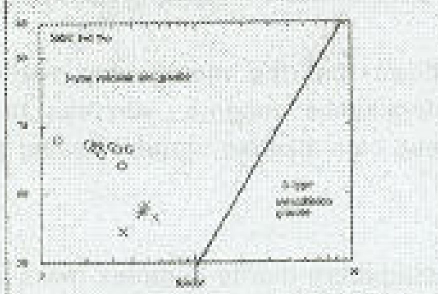
Fig(5): An-Ab-Or ternary diagram of the studied rocks.



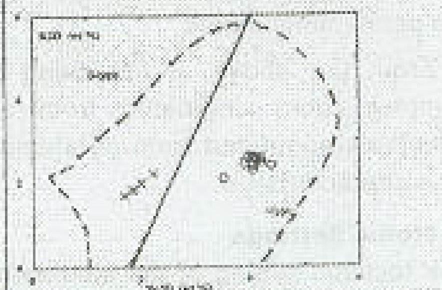
Fig(6): (Na2O+K2O)-SiO2 diagram. Cox et al 1979)



Fig(7): Na2O+K2O-SiO2 diagram. (Le Maitre, 1989).



Fig(8): Rb/Zr - SiO2 variation diagram of the studied rocks.



Fig(9): Na2O-K2O variation diagram of the studied rocks.

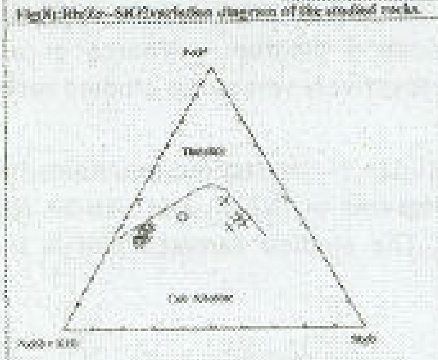
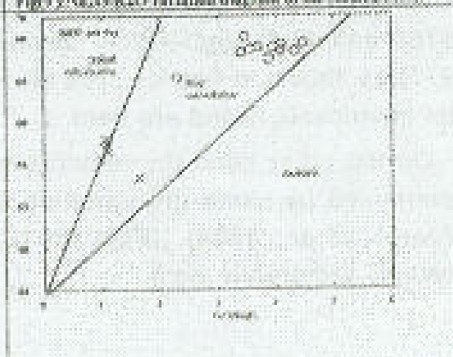


Fig. 10) AFM diagram of the studied rocks.



Fig(11): FeOt/MgO-SiO2 diagram of the studied rocks.

Geochemistry of U and Th

Chemical measurements uranium contents were determined chemically in 11 samples. The instrument used is UA3-Laser uranium analyzer. Thorium, on the other hand is determined by using U.V.visible spectrophotometer. The obtained results of the uranium and thorium analyses are indicated by ppm as well as Th/U are shown in Tables (1). From this table, the study samples have high U and high Th contents relative to those found in non-radioactive granitoids.

The result of chemical measurements for U and Th contents as well as Th/U in 11 samples of the rock types of G. Um Shaghir (tonalite-granodiorite) are shown in Table(1). Uranium content of tonalite-granodiorite ranges from 5 to 21 ppm with an average 13.3ppm; thorium ranges from 18 to 70ppm with an average 41.6 ppm. The averages of uranium of the rock types of G. Um Shaghir is coincided with the average U of the granitic rocks of Clark *et al.*(1966), and also introduce in the range of the acidic intrusive rocks of Adams *et al.*(1959) and the silicic intrusive rocks of Rogers and Adams (1967). The Th/U of the studied rocks range from 2.47 to 4.22 with an average 3.23 which is nearly reflect a magmatic suite.

The geochemical behaviour of U and Th in the studied areas can be examined as follows:

The U-Th variation diagrams for the studied rocks indicate strong positive relations between the two elements in G. Um Shaghir due to magmatic origin as shown in (Fig. 17). This reflects the enrichement with magmatic differentiation due to magmatic. (Fig. 18) show the variation of Th/U ratios versus U in the studied rocks . It is clear that from the figure the decreasing of Th/U accompanied with enrichment in U. The relation between U and F2O3 is plotted in (Fig. 19) which indicated curvilinear and parallel correlations for G. Um Shaghir reflecting magmatic origin. Figure (20) shows that U concentration tends to weak increase with the weak decreasing of K/Rb ratio for G. Um Shaghir. This weak negative correlation is a good evidence for magmatic control of U concentration.

The relations between U and Zr which indicate weak positive correlations and regular relation for G. Um Shaghir which may indicate magmatic origin and also that their magma differentiation at shallow depth (Briquieu *et al.*,1984). (Fig. 21).

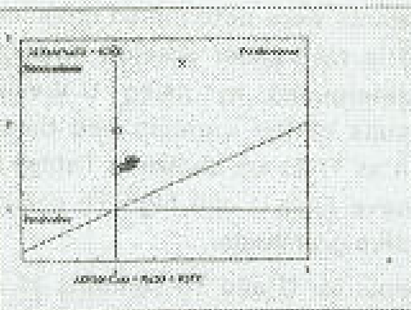
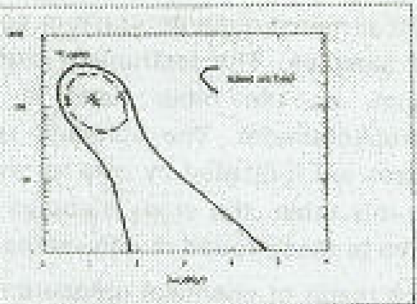
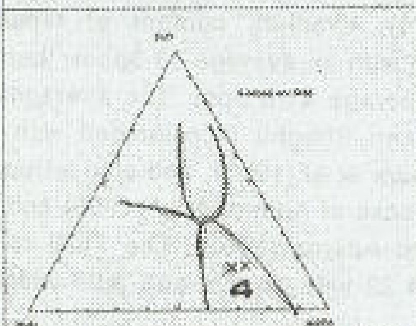
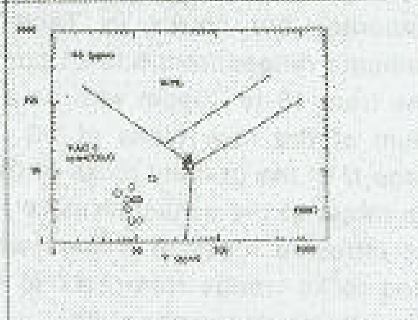
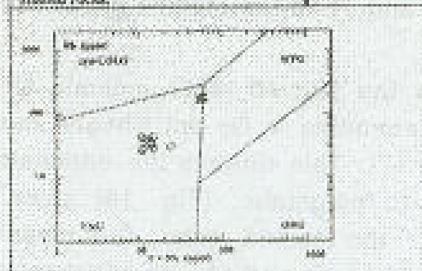


Fig. (12): Maniar and Piccoli (1989).


Fig(13): Ni-FeO/MgO variation diagram of the studied rocks.


Fig(14): FeO-MgO-Al2O3 discrimination diagram of the studied rocks.


Fig(15): Y-Nb diagram of the studied rocks(Pearce et al.,1984).


Fig(16): Rb (Y+Nb) diagram of the studied rocks(Pearce et al.,1984).

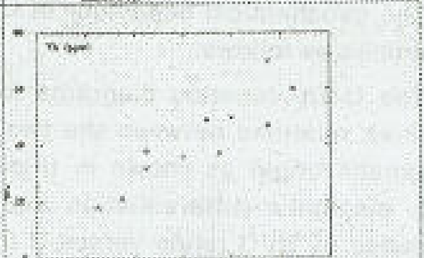


Fig.(17): U Vs Th variation diagram of the studied rocks.

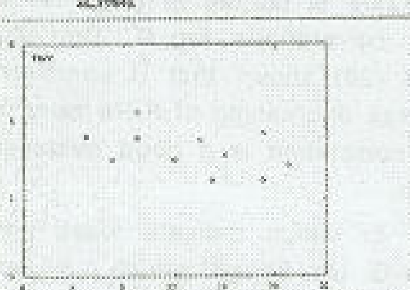


Fig. (18): U Vs Th/U variation diagram of the studied rocks.

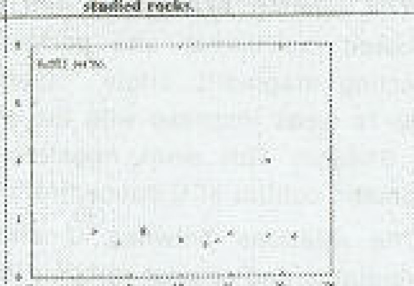


Fig. (19): U Vs Fe2O3 variation diagram of the studied rocks.

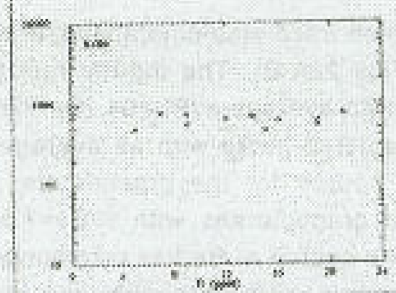


Fig. (20): U Vs K/Rb variation diagram of the studied rocks.

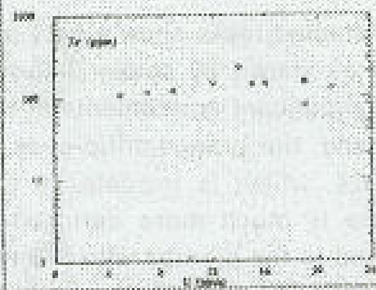


Fig. (21): U Vs Zr variation diagram of the studied rocks.

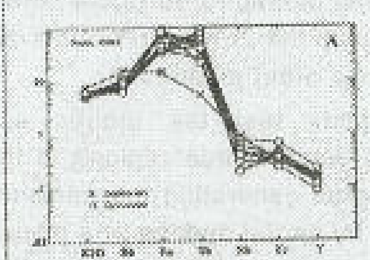


Fig. (22A) : ORG-normalized trace elements for the studied granitoid rocks.

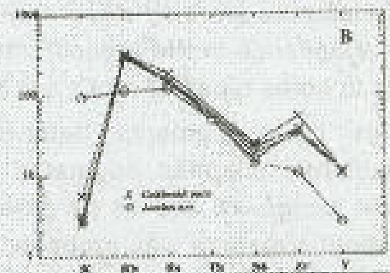


Fig. (22B) : Primative mantle-normalized trace elements for the studied gabbroid rocks.

Petrogenesis and Discussion

The most consistantly observed geochemical difference between arc and nonarc magmas is the depletion in HFS elements especially Zr, Nb,Y relative to LIL elements as well as LREE. The behavior of these elements during island arc magma generation processes is controversial. The seperation of different groups of trace elements during subduction-related enrichment processes or magma genesis is generally attributed to one of two mechanisms. The frist mechanism involves preferential enrichment in LIL elements by an aqueous phase relative to the HFS elements, controls the trace elements fractionation (Saunders *et al.*, 1991; Mc Culloch and Bennett, 1994; Hawkesworth *et al.*, 1994). In the second mechanism, patition of the HFS elements into a titanite phase in the mantle wedge and/or in the felsic melt residue during melting in the upper most part of the subducted slab effectively fractionates the trace elements groups, (Foley and Wheller, 1990; Stadler *et al.*, 1998; Klemme *et al.*, 2005). Therefore, the abundance of the LIL and HFS elements in the subduction–related magmatic rocks can be used as indicators of magma generation processes and/or characterizing the upper mantle source regions where such magmas were generated.

The studied rocks show a very uncommon trace elements abundance pattern as shown by spider diagrams (Figs 22A,B). The dioritic rocks exhibit significant enrichments in Rb with an average K/Rb=94. On the other hand, the granodioritic ones are depleted in Rb with an average K/Rb=624, which is indicates a deeper source for the granodiorites. Also, Ba is much more enriched in the granodiorites with K/Ba=7.5 compared to the diorites with K/Ba=16. The source of Ba has commonly been attributed to pelagic oceanic sediments which probably can be incorporated or contaminate magma generation regions in the mantle wedge (Hale *et al.*, 1984; Tera *et al.*, 1986; Morris *et al.*, 1990). The HFS elements are also more enriched in the dioritic rocks (2.5-4 times) their abundance in the granodiorites, although the Zr/Nb, Zr/Y and Y/Nb ratios in boths types of rocks are of the same order magnitude.

This trace elements behavior suggests that the dioritic and granodioritic magmas originated from different source regions in the mantle wedge as well as by different magma generating mechanisms. The dioritic magma was probably derived by partial melting of a mantle source in the subarc region which had been modified by selective enrichment in LIL and HFS elements by aqueous fluids derived from rutile-free subducted slab. This means that the LIL and HFS elements were not fractionated from each other during the magma generation and the behavior of the trace elements was mainly controlled by metasomatizing fluids (Stadlev *et al.*, 2005).On the other hand, the granodiorite magma which is relatively depleted in HFS elements can possibly be produced by partial melting of a mantle source in the subarc region modified by aqueous fluids released from a subducted slab that contains a residual Ti-rich accessory phase specifically retaining the HFS elements. Such aqueous fluids would selectively enrich the region of the arc magmas in LIL elements and generates HFS elements depletions. Also, contamination by the ocean sediments has to be invoked to account for the very high Ba contents. However the low Rb contents are not understood, unless K-feldspars were fractionated later during crystallization.

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دراسة لصخور الحزام أليان أفريقي في منطقة أم شاغر- طريق القصير – الصحراء الشرقية –مصر

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***هيئة المواد النووية – القاهرة**

هذا البحث يهتم بدراسة صخور القاع في منطقة أم شاغر التي تتمثل في صخور الجرانيتدات (التي تشمل صخور الجرانوديوريت والتوناليت) وصخور معقدات الديوريت والجابرو . ومن الدراسة الجيوكيميائية اتضح أن صخور الجرانيتدات قد نتجت من صهير مجماتي له خاصية كلس قلوية عالي الألومينا ولها صفات من نوع الجرانيت (I-type) . كذلك صخور الجابرو تكونت من مجما كلس قلوية وقد تدفقا في بيئة أقواس الجزر التكتونية.

يرجع تركيز وتوزيع عنصرى اليورانيوم والثوريوم في صخور الجرانيتدات إلى العمليات التفاضلية في المجما كما أن تركيز هذه العناصر محكوما بتواجدات المعادن الشحيحة (الزركون والأباتيت).

صخور الجرانيتدات المصاحبة للنطاقات الغاطسة (subduction zone) تتميز بأنها غنية بالعناصر الشحيحة الخفيفة وفقيرة بالعناصر الشحيحة الثقيلة وذلك يرجع الي أنها تكونت بواسطة الانصهار الجزئي لمنطقة تحت أقواس الجزر التي نتجت من الوشاح وتعرضت لعمليات الاثراء بالمحاليل المائية الحارة (metasomatism).