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PETROLOGY AND RADIOACTIVITY OF EL MAGAL GRANITOID ROCKS, QENA-SAFAGA ROAD, CENTRAL EASTERN DESERT, EGYPT

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ABSTRACT

The present work deals with the granitoid rocks of Gabal El Magal (35km²) which located along Qena-Safaga road, central Eastern Desert of Egypt.

Petrographically, the studied granites are composed essentially of perthite, quartz, plagioclase and amphiboles. Sphene and opaques are accessory minerals. The granites could be considered as subsolvus granites due to the presence of both orthoclase perthite and plagioclase. The petrographical observations indicate a hydrothermal alteration episode (sericitised plagioclase). Geochemically, the granites of Gabal El Magal area seem to have originated from peraluminous calc-alkaline magma with many chemical features similar to I-type granites. The granitoids magma was originated in an island arc tectonic setting. The studied granitoids were generated at somewhat intermediate depths (20-30 km) equivalent to 3-6 Kb, under temperature ranging from 760 °-840 °with multi-processes of both assimilation and fractional crystallization. This is consistent with the high K/Rb ratios, and the low K/Ba ratios.

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 in addition to weak negative relation between U and Th/U. They are also controlled by the presence of some accessory minerals e.g zircon, sphene and iron oxides. Iron oxides and hydroxides are known to absorb U from circulating fluids.

INTRODUCTION

The Precambrian rocks of Egypt represent the western part of the Arabian-Nubian Shield, which was formed during the Pan-African orogenic cycle (950-450 Ma, Kröner 1985) by the accretion of juvenile arc terrains, followed by crustal thickening accompanied by intrusion of batholiths of predominantly granitic composition. Generally, the Egyptian granitoids are broadly subdivided into three main groups: older, younger and alkali granitoids based on field relations, tectonic and geochronological determinations (Hussein *et al.*, 1982, El-Gaby *et al.*, 1988). The Egyptian Younger Granitoids attracted a great deal of interest because they mark a transitional stage from subduction-related magmatism to within-plate magmatism in the crustal evolution of the Nubian Shield (Beyth *et al.*, 1994) which make their origin and classification somewhat controversial.

The Gabal El Magal granitoids form an elongated mass (10 x3.5 km) located along Qena-Safaga road, and covering an area of about 35 km². (Fig.1).

Sabet (1961) grouped the intrusive rocks in this area into: 1) fine grained leucocratic and medium-grained biotite hornblende granites,, 2)granodiorites, quartz-diorite and diorite.

El Shazly (1964) recorded that the granitic rocks of Gabal El Magal area are arranged in a chronological sequence as 1)granodiorite (oldest), 2) biotite granite, 3)leucogranite and 4)alkali granite (youngest).

The aim of this work is to through more light on the petrological and geochemical characteristics of Gabal El Magal younger granitoids, the main evolutionary processes which have been responsible for their generation as well as their tectonic environment.

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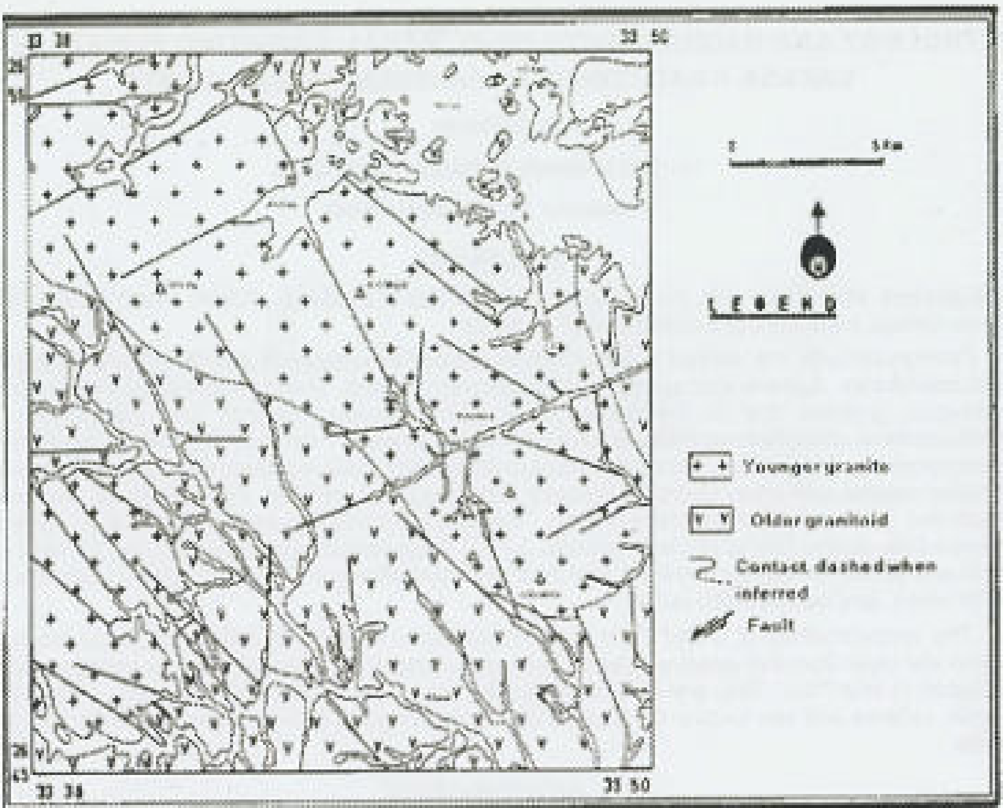


Fig. 1 Simplified geological map of El Magal area. (after Abdel Warith, 2000).

Geological setting

The granitoid mass of Gabal El Magal is located in the central Eastern Desert of Egypt (Fig.1), between long. 33° 42' to 33° 50' E and lat. 26° 47' to 26° 55' N. It appears as large island within the older granitoids (Fig. 2). There are several small granitic low hills scattered along wadis (Fig. 3a, b). The younger granitoids commonly show sharp intrusive contacts which usually dip towards the metavolcanic (Fig. 3c, d). The younger granitoids are characterized by exfoliation, cavernous and bouldary weathering with characteristic monumental shapes(Fig.3e, 4f), also they are characterized by intensive jointing (Fig. 4B). The younger granitoids enclose xenoliths of different shapes and sizes from older granites and metavolcanics (Fig. 3D, 4A).

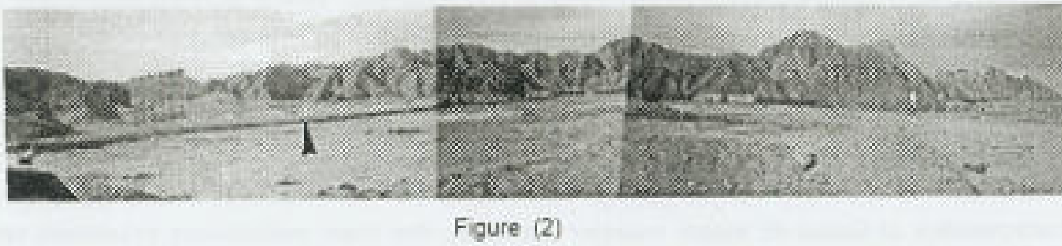


Figure (2)

Fig. 2 General view of G.El Magal showing younger granites (light) intruding older granites (dark). Photo looking NNW.

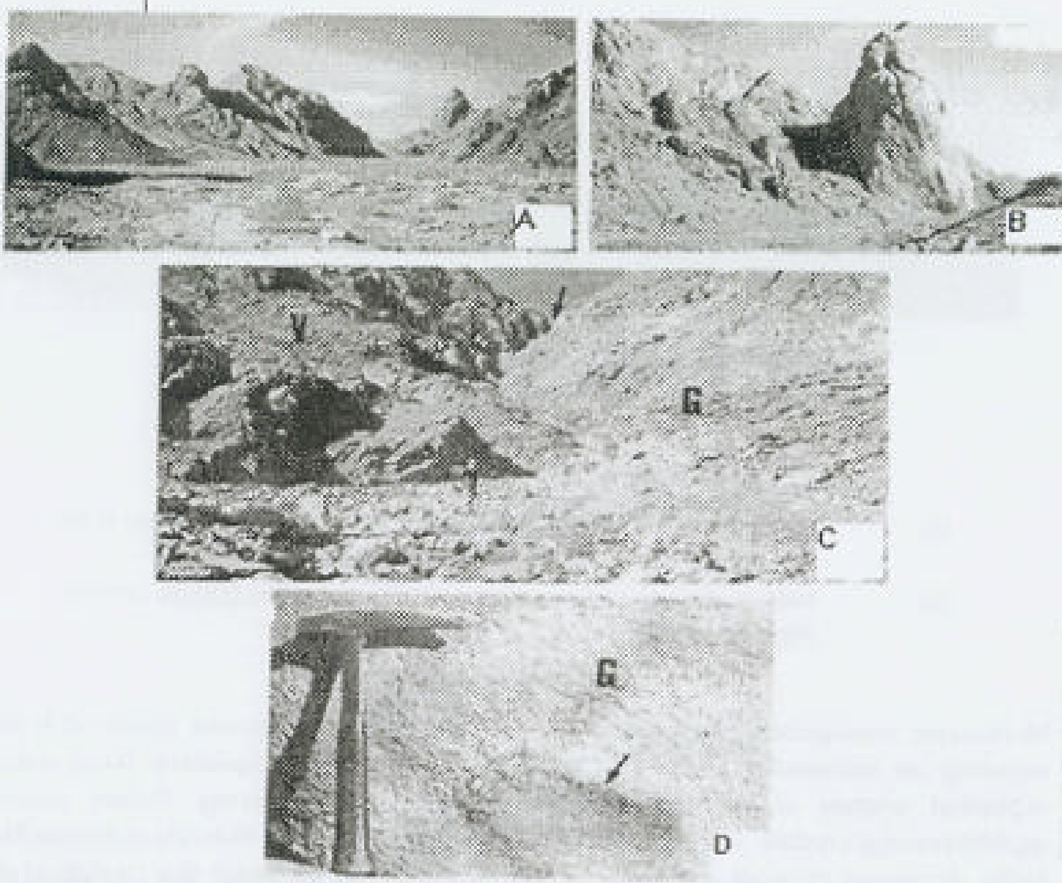


Figure (3)

(A) Field photograph showing several small granitic low hills scattered along wadis. Photo looking ENE.

(B) Field photograph showing monumental shapes of granites. Photo lookingENE.

(C) Field photograph showing sharp contact between younger granite and Dokhan Volcanics. Photo looking ENE.

(D) Field photograph showing oval shaped xenoliths of older granite within the younger granite Photo looking NW.

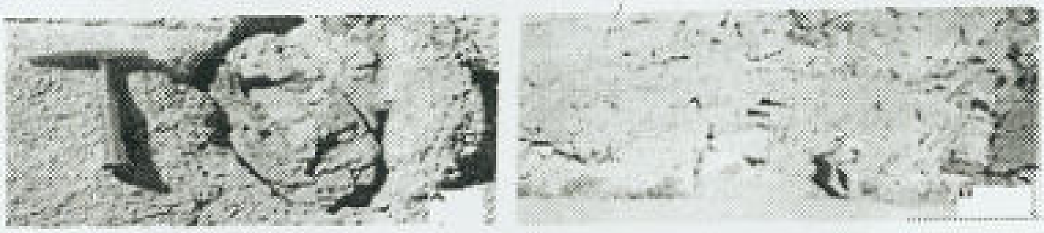


Figure (4)

(A) Field photograph showing oval shaped xenoliths of metavolcanic in the younger granite. Photo looking NW.

(B) Field photograph showing intensively jointed younger granites (arrows). Photo looking NE.

PETROGRAPHY

Microscopic investigation of granites showed that they are composed mainly of K-feldspar occurring as subhaedral crystals of string perthite (Fig.5a). Plagioclase (An[illegible]) occurs as subhedral crystals of oligoclase characterized by albitic twinning. Quartz occurrs as equidimensional crystals. The rock is characterized by scarce mafic minerals as minute flakes of biotite. Accessory minerals are mainly sphene which occurs as wedge like crystals of primary origin(Fig.5e). They also contains zircon as euhedral crystals.

The grayish samples are composed mainly of plagioclase and hornblende. Plagioclase (An_{25}) forms anhedral crystals characterized by albitic percline twinning (Fig. 5f). The constituting K-feldspar occurs as coarse crystals of antiperthite (Fig. 5b). The rocks is characterized by presence of brown hornblende as the main mafic minerals (Fig. 5c). Zircon represents the main accessory mineral which is partially metamectized and surrounded by pleochroic halos. Sphene occurs as euhedral crystals of wedge shapes(Fig. 5e).

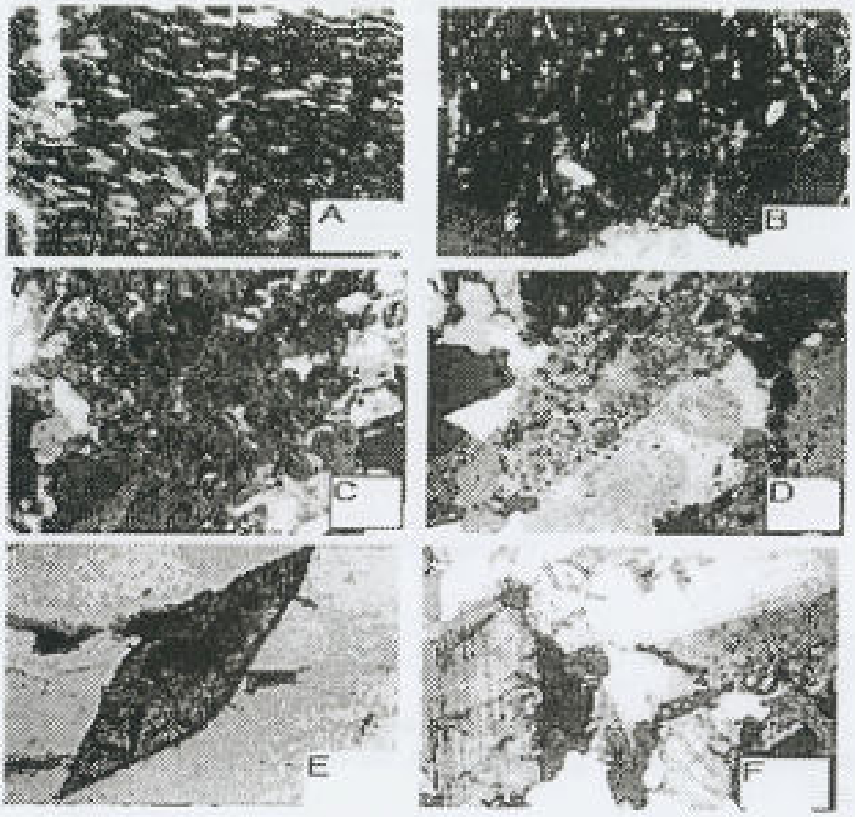


Figure (5)

(A) Microphotograph showing typical string perthite in alkali feldspar granite C.N. X50.

(B) Microphotograph showing typical flake perthite. Note slight deformation of sodic feldspar lamellae. C.N. X50.

(C) Microphotograph showing brown amphibole C.N. X50.

(D) Microphotograph showing high alterated plagioclase crystal. C.N. X50.

(E) Microphotograph showing euhedral sphene crystals having sphenoidal-shape enclosed in quartz. C.N. X50.

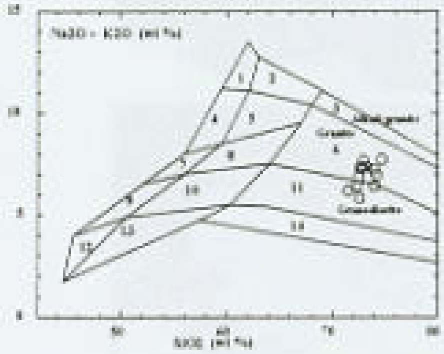
(F) Microphotograph showing Plagioclase crystals having lamaller and simple twinning C.N. X50.

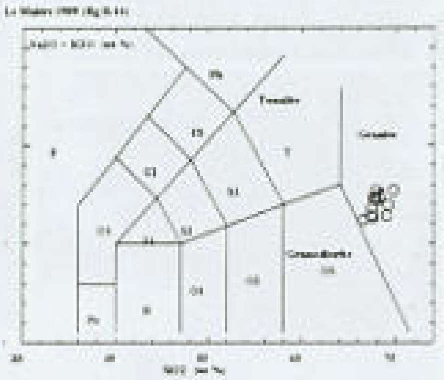
GEOCHEMISTRY

Chemical classification

13 samples were chemically analyzed in the laboratory of Nuclear Material Authority (NMA) for major oxides and some trace elements (Rb, Sr, Ba, Y, Zr and Nb). The analytical results of the major oxides and trace elements are shown in Table (1). The table also shows the CIPW normative compositions and some petrochemical parameters.

Middlemost (1985) used the binary relation between SiO2 and Na_2O+K_2O (wt%) to differentiate between different rock types (Fig.6). It is clear that the studied granites of Gabal El Magal lie in the granite field whereas some samples plot within the granodiorite feild.





(6): SiO2- Na2O+K2O (Middlemost 1985) (7): SiO2- Na2O+K2O (Le Maitre 1989)
O granites

Le Maitre, (1989) used the binary relation between SiO2 and Na_2O+K_2O (wt%) to differentiate between different rock types (Fig.7). It is clear that, the studied samples of Gabal El Magal lie in the granite field.

Variations in chemical composition

The contents of major and trace elements are plotted versus differentiation index (D.I.) (Fig.8&Fig.9). These giagrams show that the SiO_2, TiO_2, Na_2O, K_2O, Rb, Y and Baincrease with the D.I.,while Al_2O_3, FeO, CaO and, MgO decrease with the D.I.

It is also clear that the studied samples mostly show straight-line variations which may indicate co-magmatic differentiation.

Table (1): Chemical analysis of major and trace elements of granitoid rocks of G. El Magal granite, Qena-Safaga road.

S.No.	S1	S2	S3	S7	S8a	S9	S12	S13	S14	S15	S16	S17	S19a
SiO_2	73.23	73.88	74.14	74.66	71.46	72.51	72.58	73.96	72.35	72.61	72.84	72.73	72.73
TiO_2	00.03	00.04	00.16	00.05	00.08	00.17	00.09	00.16	00.12	00.14	00.08	00.07	00.05
Al_2O_3	13.85	13.89	13.97	12.54	14.42	14.33	14.13	13.91	14.12	14.21	13.46	14.37	14.75
Fe_2O_3	00.87	00.78	00.94	01.81	00.75	01.62	01.82	01.59	01.86	00.96	01.21	01.16	00.84
FeO	01.19	01.25	00.79	01.04	01.87	01.12	01.22	01.08	01.32	00.61	01.15	00.75	00.57
MnO	00.04	00.03	00.02	00.03	00.08	00.03	00.04	00.05	00.03	00.02	00.05	00.04	00.05
MgO	00.28	00.37	00.23	00.29	01.21	00.39	00.78	00.28	00.86	00.32	00.38	00.21	00.46
CaO	01.09	00.81	00.78	00.61	01.85	00.97	01.07	01.09	01.23	01.25	00.96	00.95	01.21
Na_2O	03.31	03.05	03.13	03.39	02.87	02.92	02.77	02.65	02.96	03.21	03.67	03.22	03.34
K_2O	04.05	04.16	03.83	04.31	03.31	03.89	03.56	03.75	03.46	04.08	03.99	04.15	03.96
P_2O_5	00.06	00.06	00.04	00.04	00.12	00.12	00.09	00.12	00.09	00.13	00.11	00.08	00.08
L.O.I	00.78	00.88	00.83	00.69	00.86	00.83	00.97	01.11	00.76	00.87	01.03	00.73	00.89
Total%	98.02	98.32	98.03	98.97	98.02	98.07	98.13	98.62	98.40	98.04	97.90	97.73	98.04
Qz	35.94	37.40	39.97	37.10	36.07	38.80	40.10	42.10	54.40	36.40	34.10	36.70	35.60
Or	24.44	25.30	23.10	25.80	19.97	23.50	21.46	22.50	17.80	36.40	24.10	25.12	23.90
Ab	28.60	26.50	26.99	29.01	24.75	25.20	23.86	22.70	10.60	24.70	31.68	27.90	28.80
An	05.20	03.80	03.71	02.83	08.65	04.20	04.90	04.80	00.00	27.80	04.21	04.30	05.70
Hy	02.23	02.63	01.04	01.13	05.97	01.50	02.66	01.18	00.83	05.60	07.06	00.92	01.54
Cor	02.20	03.06	03.40	01.28	03.10	03.87	04.01	03.81	09.03	00.96	01.62	03.08	02.99
Mt	1.29	01.16	01.39	02.66	01.11	02.40	02.69	02.34	02.74	02.57	01.79	01.72	01.24
Il	00.06	00.08	00.31	00.10	00.16	00.33	00.17	00.31	00.23	01.43	00.16	00.14	00.10
Ap	00.13	00.13	00.09	00.09	00.27	00.27	00.20	00.27	07.68	00.27	00.25	00.18	00.18
R0b	136	143	175	169	137	151	167	127	147	116	164	156	183
Ba	563	675	1022	453	1128	833	438	658	542	538	501	638	463
Sr	87	93	106	79	135	104	91	97	112	94	83	103	99
Nb	46	34	41	31	31	33	38	45	50	36	103	42	98
Zr	163	135	147	211	210	197	189	245	243	156	276	167	154
Y	13	15	13	19	10	12	12	16	11	15	32	16	31
U	9.5	11.6	14.2	13.8	22.4	16.7	8.2	10.9	8.6	7.6	9.8	7.9	11.5
Th	19.4	20.7	19.5	16.9	31.9	25.7	11.5	18.7	11.3	12.9	14.6	15.8	16.7
Th/ U	2.04	1.78	1.37	1.22	1.42	1.54	1.40	1.72	1.30	1.70	1.49	2.00	1.45
D.I.	88.96	89.24	90.06	92.28	80.79	87.48	85.39	85.39	84.71	88.40	89.92	88.62	88.31
R1	2489	2553	2630	2408	2540	2551	2681	2681	2596	2383	2303	2406	2364
R2	410	384	376	329	552	412	439	439	459	403	394	403	451
Agp .I	00.71	00.69	00.67	00.82	00.58	00.63	00.60	00.61	00.37	00.68	00.77	00.68	00.66

S.No sample number.

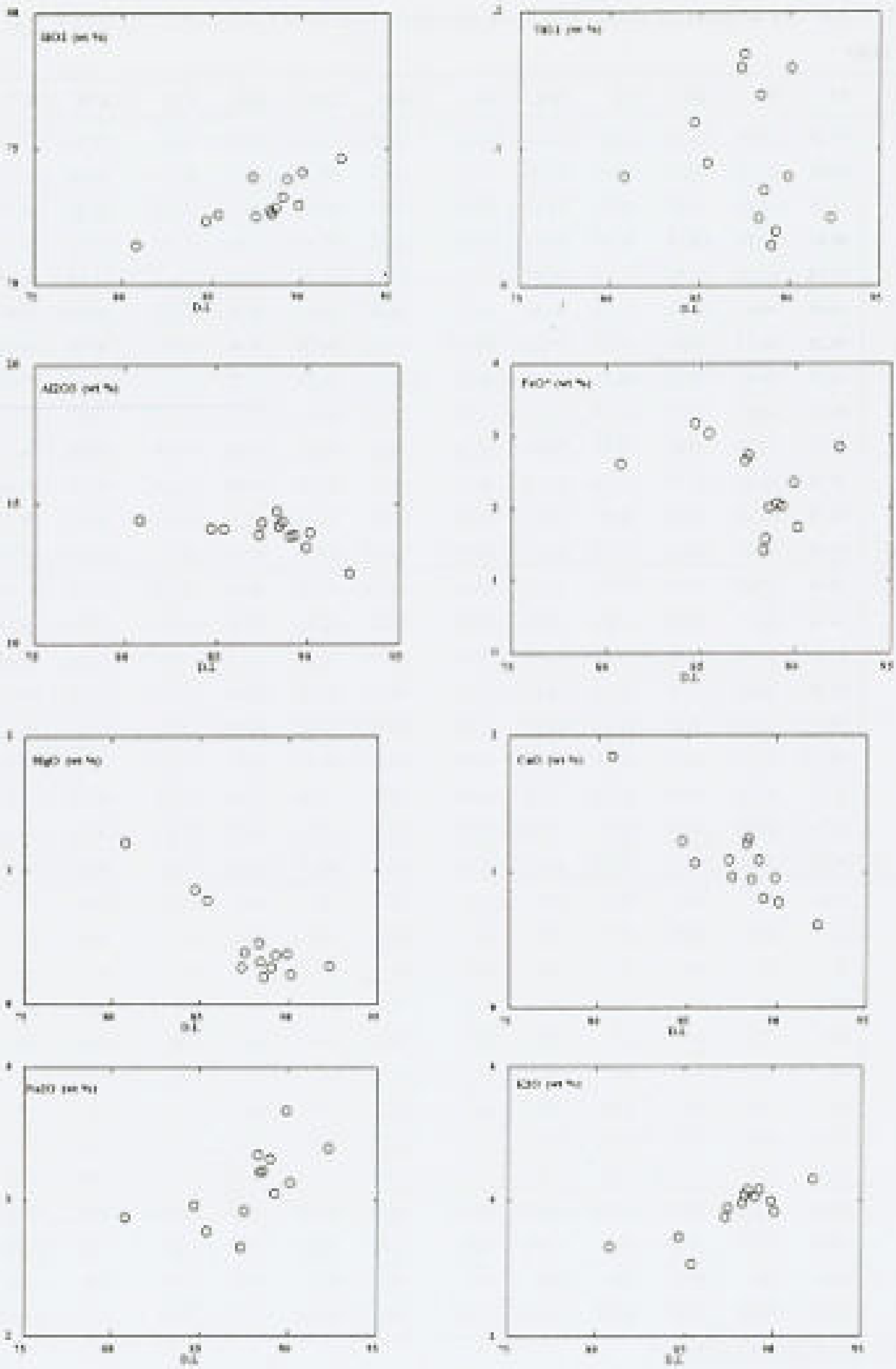


Fig. (8):- Plot of the contents of the major elements in the studied granites versus D.I.

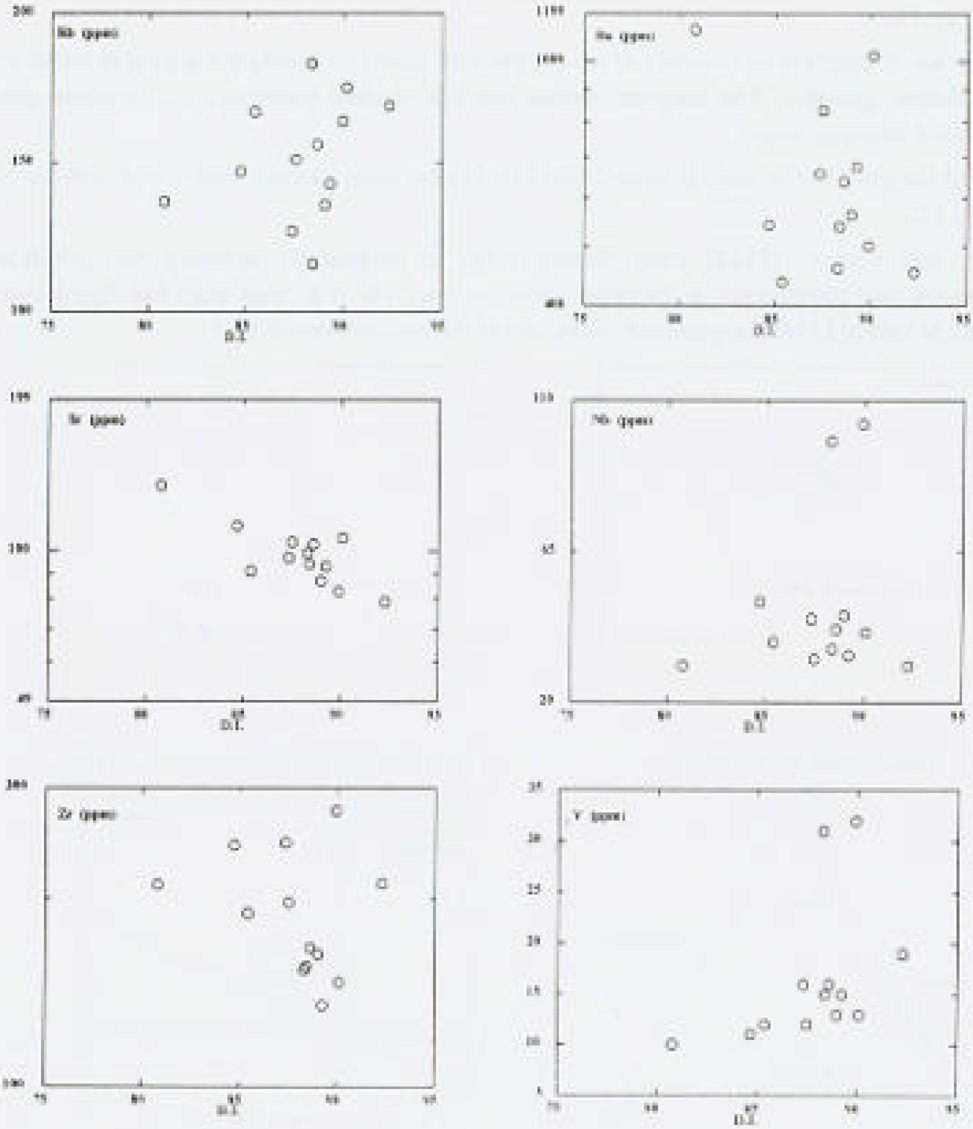


Fig. (9):- Plot of the contents of the trace elements in the studied granites versus D.I.

Geochemical characters

Magma types

Agpaitic index is a geochemical parameter which defined as [(Na_2O+ K_2O)/ Al_2O_3] (in molecular proportion), (Goldschmidt, 1954). The average agpaitic index of Gabal El Magal granites is about 0.65 which means that the studied granitoid rocks are miaskitic in nature.

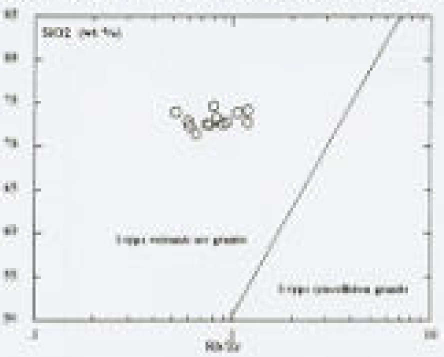
Harris *et al.*, (1984) used the binary diagram between Rb/Zr and SiO_2 to differentiate between S and I- types (Fig. 10). The I-type granites include those which represent mantle derived rocks, while S-type granites are products of partial melting of crustal material during continental collision

(Pitcher, 1983). It is clear that the studied samples plot within the field of I-type volcanic arc granites (Fig. 10)..

SiO_2 versus Y diagram of Gunther *et al.*, (1989) was used to classify the granitoid rocks into I-type and S-type granites. The diagram shows that the studied granitoids are of I-type granite reflecting their igneous origin.

On AFM diagram the studied granitoid rocks plot in the calc-alkaline field (Irvine and Baragar, 1971). (Fig 12).

Maniar and Piccoli, (1989) used Shand index to distinguish between the peralkaline, metaluminous and peraluminous rocks as shown in (Fig. 13). It is clear from this figure that the data points of Gabal El Magal granitoid rocks plot in the peraluminous field.



(10): Rb/Zr -SiO2 (Harris *et al.*, (1986)

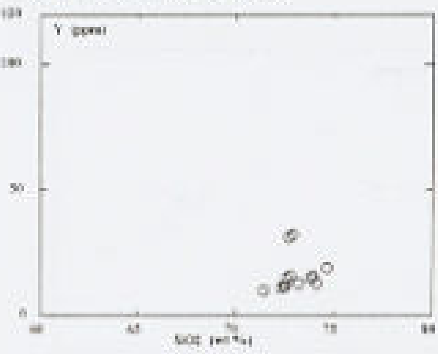


Fig. (11): SiO2-Y (Gunther *et al.*, (1989)

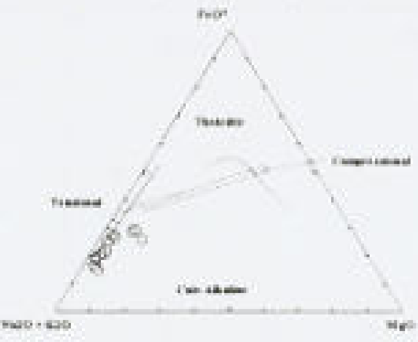


Fig. (12): AFM diagram (Irvine and Baragar, 1971)

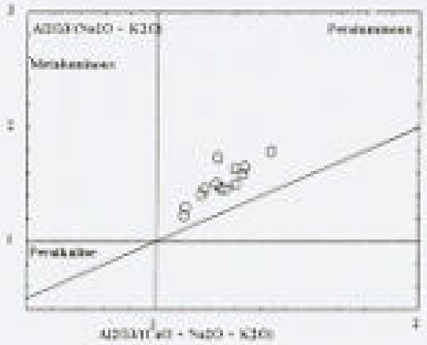


Fig. (13): Maniar and Piccoli (1989).

Tectonic Setting

The plot of Rb/Zr Vs. SiO_2 (Harris et al., 1986) is used to discriminate between the syn-collisional granite field (A) and volcanic arc granite field (B) (Figure 14). The studied samples plot in the volcanic arc granite (VAG) field.

The Rb-Y+ Nb variation diagram is used to discriminate between volcanic arc granites depleted in Rb contents and collision granites enriched in Rb (Fig. 15). The diagram indicate that the granitoid of Gabal El Magal are developed in volcanic arc setting.

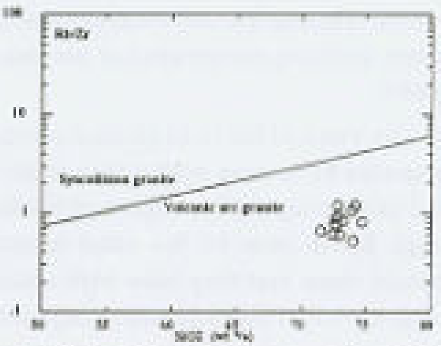


Fig. (14): SiO2-Rb/Zr (Harris *et al.*, (1986)

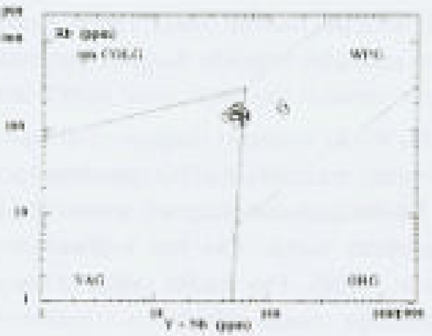


Fig. (15) : Rb-Y+Nb (Pearce *et al.*, (1984)

Crystallization conditions

The environmental conditions of the granitoid rocks can be deduced from the normative (Or– Ab– An) and (Qz–Ab–Or) systems as follow:-

Figure 16 shows the Ab-An-Or system with the fields of rock types after O'Conner (1965) and Barker (1979). The effect of P_{H2O} on the position of cotectic boundary between orthoclase and plagioclase at 1 Kb and 5Kb P_{H2O} are also shown after Tuttle and Bowen (1958). The Gabal El Magal samples plot in granite field and the magma was generated at somewhat intermediate depths equivalent to 3-6 Kb.

Figure 17 show the quartz–albite-orthoclase system illustrating the temperature isotherms. The studied samples crystallized under temperature ranging from 760°-840° (James and Hamilton, 1969 and Winkler *et al.*, 1975).

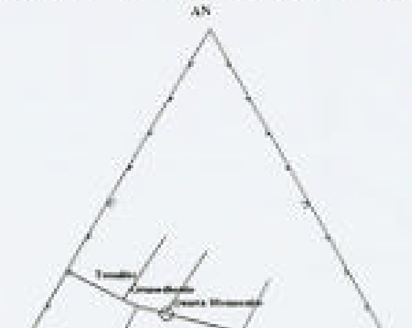


Fig. (16) : An-Ab-Or ternary diagram .

Fig. (17) . Qz- Or -Ab ternary diagram .

PETROGENESIS OF THE GRANITOID ROCKS

The K-Rb variation diagram of the studied granitoid rocks is shown in Figure 18. The average values of the studied granitoid are higher than the crustal average value of 250 (Taylor, 1965). The higher K/Rb ratio indicates sources regions for magma generation in the lower crust (Heier, 1973) or upper mantle (Gast, 1965). Also, the higher K/Rb ratios for the more fractionated granitic phase probably indicate magma generation mechanism involving dehydration of amphiboles at deeper levels in the lower crust (Griffin and Murthy, 1969).

The Rb-Sr variation diagram is shown in (Fig. 19). The valus of Rb/Sr of studied samples are >1.0 which indicates that the granitoid rocks were generated from more evolved magmatic fluids. The Ba-Rb variation diagram shown in Fig. 20 can be used to signify the degree of fractionation of granitoid rocks. The line representing the average Ba/Rb ratio for the crust is about 4.4 (Mason, 1966). The Ba/Rb ratios of the studied granitoid show that they have high values than the average crustal ratio that is consistent with the suggestion that these samples originated from a enriched Ba source.

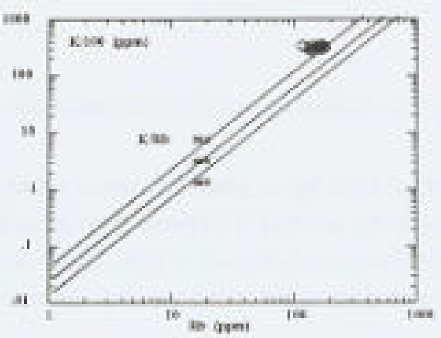


Fig. (18) : K-Rb variation diagram

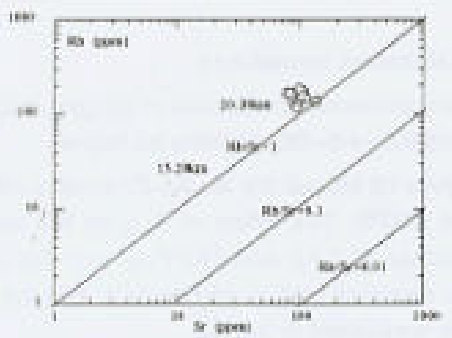


Fig. (19) : Sr-Rb variation diagram .

Fig. (20) : Ba-Rb variation diagram .

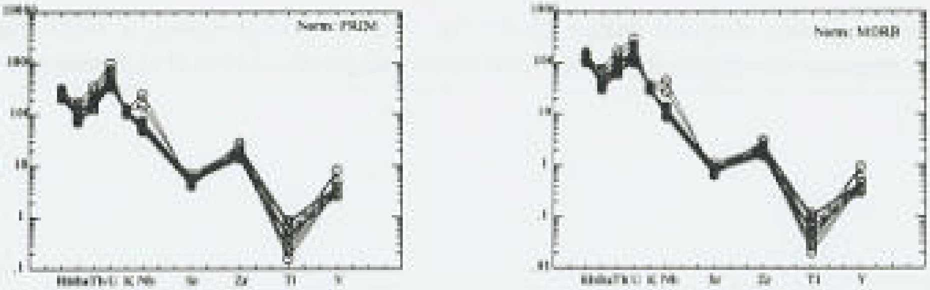


Fig. 21. Primitive-mantle normalized and N-MORB-normalized spider diagrams trace element plots for the El Magal granites. Normalization values are from Sun and McDonough (1989).

Relative to normal mid-ocean ridge basalts (N-MORB), the studied granites (Fig. 21) show: enrichment in the strongly incompatible LILE such as Rb, Ba, and K; strong depletion in Nb relative to K and Th. Except for the slightly wide range of large-ion lithophile elements (LILE) observed for El Magal granite samples. Negative Nb anomalies are observed in uncontaminated continental basalts (Condie *et al.*, 1987; Saunders *et al.*, 1992 and Kent, 1995), and pronounced negative Sr and Ti anomalies on primitive-mantle normalized plots are observed for these samples. These anomalies also suggest that El Magal granite samples have affinities with continental crust. Any crustal involvement during the emplacement of mafic magmas could give rise to larger negative Nb anomalies (Rollinson, 1993H). Large negative Sr anomalies occur in El Magal granite samples may be interpreted either by plagioclase fractionation in the parental magma chamber prior to the eruption or inheritance from their mantle source. (Rollinson, 1993H)

Geochemistry of U and Th.

Uranium and thorium contents were determined chemically in 13 samples. The obtained results of the uranium and thorium analyses are indicated by ppm (Table 1). From this table, the uranium content of Gabal El Magal ranges from 8.2 to 22.4 ppm with an average of 11.8ppm which is coincided with the average U of the granitic rocks of Clark *et al.* (1966), the acidic intrusive rocks of Adams *et al.* (1959) and the silicic intrusive rocks of Rogers and Adams(1967). The thorium ranges from 11.3 to 31.9 ppm with an average 18.1ppm.

The geochemical behaviour of U and Th in the studied areas can be examined as follows: The U-Th variation diagram for the studied rocks indicates strong positive relations due to magmatic origin as shown in (Figure 22). This reflects the enrichement with magmatic differentiation due to magmatic origin.

Figure 23 shows the variation of Th/U ratios versus U in the studied rocks . It is clear that the Th/U decrease with the enrichment in U. From the above and from the Figure 24, it is clear that the U and Th contents are controlled by the presence of some accessory minerals such as zircon, sphene and iron oxides. Iron oxide and hydroxides are known to absorb U from circulating fluids.

The U- FeO* variation diagram for the studied rocks indicates a weak positive relation due to magmatic origin as shown in Figure 24. This reflects that uranium may be adsorbed on the surface of iron oxides as most magmatic processes.

Figure 25 shows the relation between U and Zr for the studied rocks which indicate a weak positive relations due to magmatic origin.

The U-K/Rb variation diagram Figure 26 for the studied rocks indicates a weak negative relation. This negative correlation is a good evidence for magmatic control of U concentration.

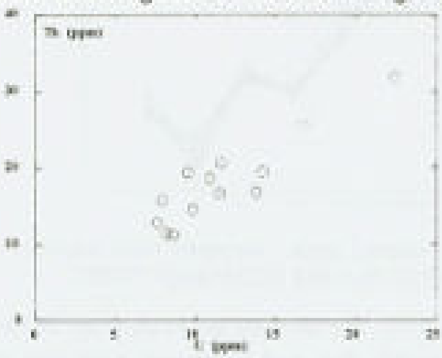


Fig. (22) : Th-U variation diagram .

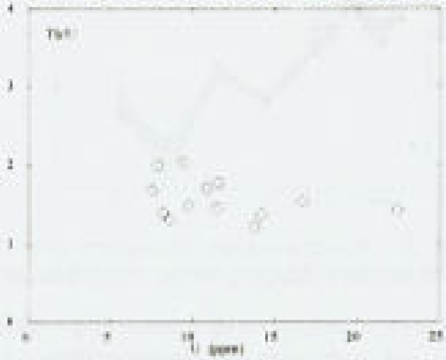


Fig. (23) : Th/U-U variation diagram

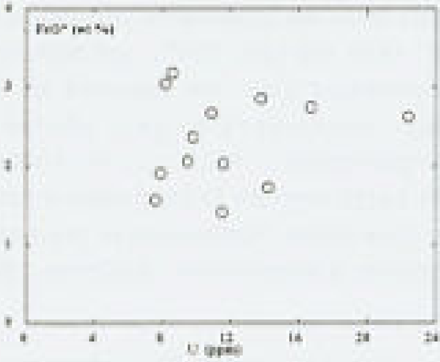


Fig. (24) : FeO*-U variation diagram .

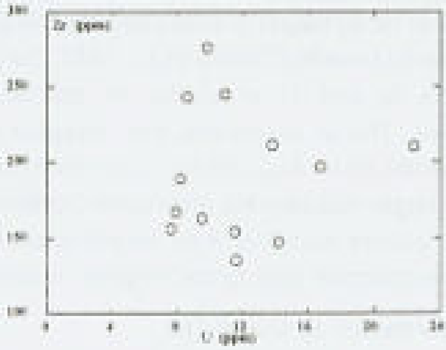


Fig. (25) : Zr-U variation diagram .

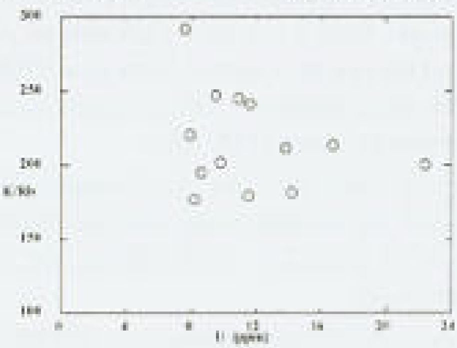


Fig. (26) : K/Rb-U variation diagram .

CONCLUSIONS

The Pan-African granitoid rocks of Gabal el Magal area, comprise an elongated NW mass belt covering about 35 km^2.

Geochmically, the granitoid rocks of G.El Magal area were determined to examine their tectonic setting and radioactivity of provenance and source area conditions. They have calc-alkaline chemistry, characterized by intermediate SiO_2 contents, high Al_2O_3 and low MgO.

The granitoids of Gabal el Magal area can be classified as I-type granite, originated from a peraluminous calc-alkaline magma and developed in volcanic arc. These rocks were generated at somewhat intermediate depths (20-30 km) equivalent to 3-6 Kb, under temperature ranging from 760°-840°. On the tectonic discrimination diagrams, most samples have volcanic-arc setting. The evolution of the Gabal El Magal granitoids may be predicted as follows: fractional crystallization processes.

The studied granites are characterized by low Ca, Mg, Fe,Nb, Sr and Ti contents. These negative anomalies suggests that the El Magal granite samples derivation have affinities with continental crust. Any crustal involvement during the emplacement of mafic magmas could give rise to larger negative Nb anomalies. Negative Sr anomalies may be interpreted either by plagioclase fractionation in the parental magma chamber prior to the eruption or inheritance from their mantle source. Petrochemical and geochemical features however, support a crustal melt origin.

The concentrations of U and Th in the studied granitoid rocks were controlled by magmatic processes which are clear from the positive relation between U and Th as well as controlled by the presence of some accessory minerals such as zircon and iron oxides whereas iron oxide.

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بترولوجية اشعاعية صخور جرانيت جبل المجال طريق قنا سفاجا الصحراء الشرقية الوسطى- مصر

عاطف عبد العزيز النحاس

هيئة المواد النووية – القاهرة

تناول هذا البحث بترولوجية صخور جرانيتية في جبل المجال الواقع على طريق قنا سفاجا – وسط الصحراء الشرقية بمصر. من الناحية البتروجرافية نجد أن الصخور الجرانيتية المدروسة تتكون أساسا من معادن البرثيت والكوارتز والبلاجيوكلاز وبعض المعادن المافية وتتواجد بها أنسجة صخرية جرانيتية واضحة كما تتضح بها ظاهرة التحلل الحرمائي من الناحية الجيوكيميائية نجد أن تلك الصخور الجرانيتية ذات ضمات كلسي – قلوي من حيث طبيعة الماجما وهي مشابهة لنوع الجرانيت I-type ومن الناحية التكتونية نجد أن قلل الصخور الجرانيتية انبعث تكونها في بيئة الأقواس الجزرية على أعماق تتراوح بين ٣٠-٢٠ كم٢ تحت درجة حرارة مائية ٧٦٠-٨٤٠° ونجد أن هذه الصخور قد تأثرت بعمليات متعددة من التلوث الجرانيتي والتلوث القشري من جهة أخرى نجد أن تركيزات اليورانيوم والثوريوم في تلك الصخور الجرانيتية يتحكم فيها العمليات الصهيرية وتعتبر من العمليات الأولية .