

Effects of Hydrothermal Solutions on Syenogranite, Abu Harba Area, North Eastern Desert, Egypt.

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Abstract

The area is located between latitudes $27^{\circ} 16'$ and $27^{\circ} 22'$ N and longitudes $33^{\circ} 06'$ and $33^{\circ} 14'$ E, in the north Eastern Desert of Egypt. Abu Harba area granites mainly composed of syenogranite, which have alkaline suite. Syenogranite is cut by sets of faults in addition to obvious network microfissures and joints that play a role of pathways to fluid flows. These structures dominate in the syenogranite and are causing effects of hydrothermal alterations (kaolinization and silicification), however the syenogranite still preserve its original texture. Violet fluorite mineral occurs in the syenogranite as disseminated large crystals with micro-crystals of phosinaite as secondary mineral in fluorite crystals in addition to the zircon and magnetite crystals. Abu Harba granites are display characteristics of A-type granitoids as a post subduction reduced peraluminous syenogranite. It has a high content of SiO_2 , alkalis with low Al_2O_3 , CaO , MgO , TiO_2 , FeO , and Fe_2O_3 contents. It has a low, FeO_t/MgO and K/Na ratios with reduced peraluminous nature. The syenogranite probably reflects the end product of extreme fractionation environment. The altered syenogranite show relative abundance of Rb, Zr, Zn and Y elements. zircon crystals usually occurs as solitary (monocrystal) and/or zoned aggregates crystals habit.

Keywords: Fluorite, hydrothermal alterations, syenogranite, Egypt.

1-Introduction:

Abu Harba area is located in the North Eastern Desert of Egypt, northwest of Hurghada City (Fig. 1). Field and petrographic observations showed the first insights on the dynamic processes involved in the generation of the granitoid facies. Syenogranite is cut by sets of faults in addition to the observed network of microfissures and joints which play a role of pathways to fluid flows.

Abu Harba granites are mainly composed of syenogranite, which have alkaline suite which still preserve their original texture in spite of the effects of hydrothermal alterations.

Abd El Aty, (2013) revealed that the syenogranite of Abu Harba and Al Shagola have the chemical characteristics of calc-alkalic to alkalic calcic and metaluminous to slightly peraluminous rocks. It was generated and

emplaced in post orogenic environment and described as highly fractionated I-type granites. The objectives of the present work are to discuss the role of hydrothermal solutions and their effects on the syenogranite rocks. In order to attain these purposes 12 representative samples were collected. These objectives were achieved by studying the mineralogical, petrographical and geochemical characters of the representative collected samples of the study area.

2-Geologic Setting:

The studied area is a mountainous region in the north Eastern Desert of Egypt between latitudes 27° 16` and 27° 22` N and longitudes 33° 06` and 33° 14` E. (Fig. 2). Syenogranite rocks in the studied area are coarse-grained and porphyritic with pink to red colors but turn to brownish red when stained with hematite along joints and fractures and speckled with many xenoliths.

Syenogranite rocks are cut by one or more sets of faults mostly directed to the NE-SW. The contact between syenogranite and the alkali feldspar granite type especially at the western parts is gradational. On the other hand, this granite intrudes the Dokhan volcanics at its eastern and southern boundaries with irregular contacts.

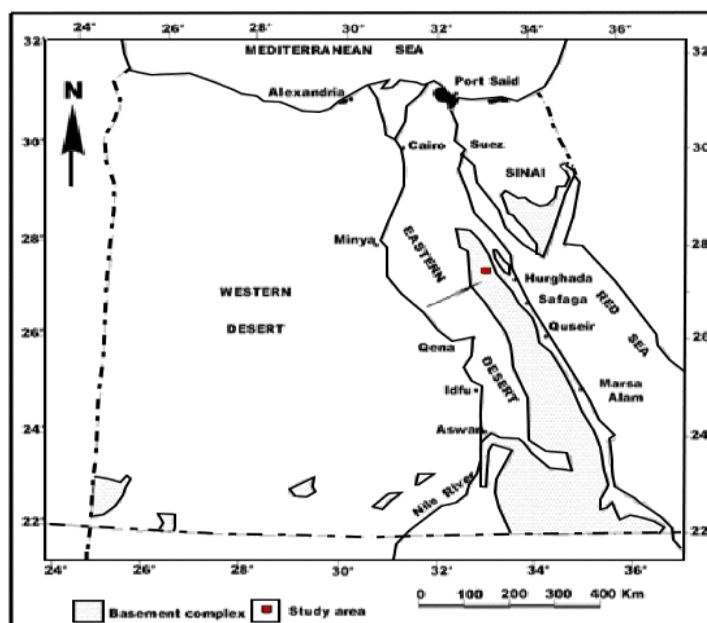


Fig. 1: Location map of Abu Harba area, North Eastern Desert, Egypt.

Abu Harba granites altered in some sheared parts due to hydrothermal processes, especially along the fault planes and contacts. The most common alteration features are, kaolinitization, silicification sericitization and chloritization as well as iron and manganese oxides.

Syenogranite is intensely crossed by dyke swarms which are mainly of basic composition. These dykes occur as long ribbons and ridges responsible for the many long narrow parallel ridges seen in the area. They are mostly following the NE-SW and ENE-WSW directions (Abd El Aty, 2013).

3-Sampling and Analytical Techniques:

This work investigates 12 samples. All these samples represented a syenogranite suite (Fig. 2). Six samples were subjected to investigate the petrography and mineralogy characteristics.

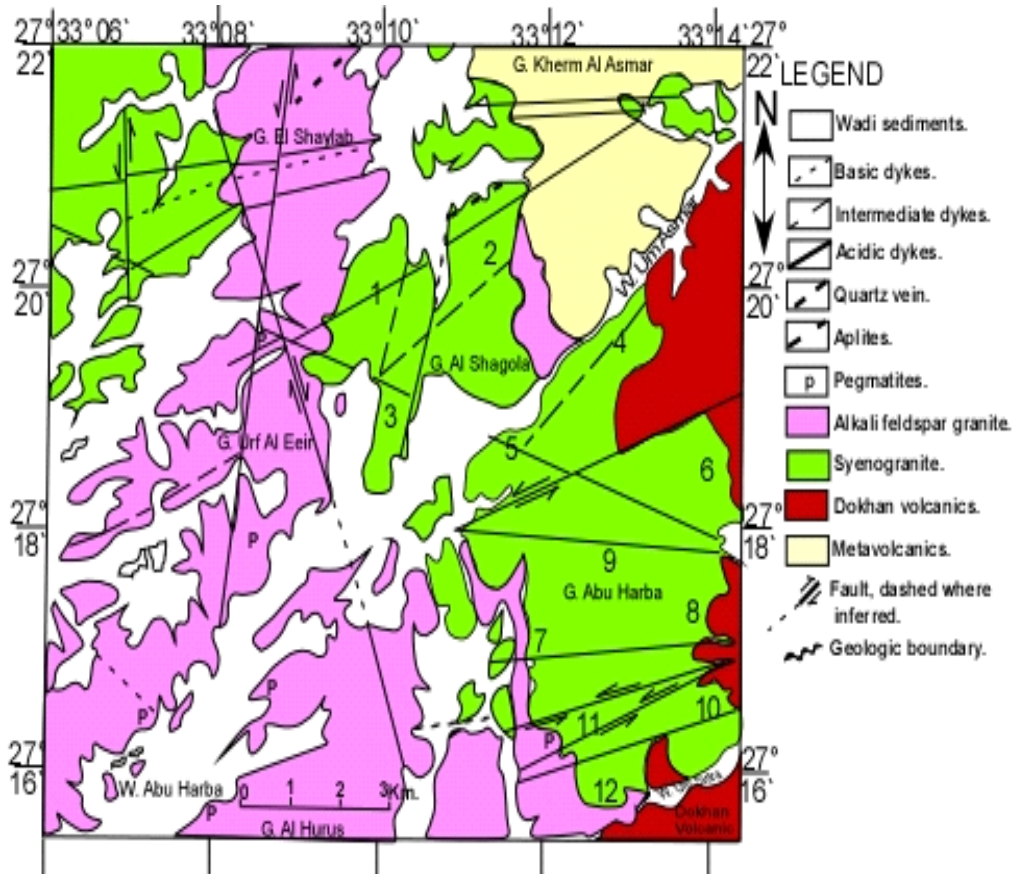


Fig. 2: Geologic map of Abu Harba area, north Eastern Desert (Abd El Aty, 2013).

Eight samples are selected to describe the chemical and radiometric nature of the studied granite. The major oxides were determined using the atomic absorption and wet chemical techniques, while the trace elements were analyzed using the X-ray fluorescence. eU and eTh contents were determined radiometrically using gamma-ray spectrometer; also U and Th was chemically determined using a spectrophotometer analysis. Radiometric investigated are prepared for crushing and separating grains, which were then hand-picked under a binocular microscope. The mineralogical identification was achieved by X-ray diffraction (XRD) and environmental scanning electron microscope (ESEM) from Chemical War Laboratory on the separated grains.

4- Petrography

Microscopic investigation on the selective representative studied fresh and altered samples were carried out to study the mineralogical composition, textures and the effects of hydrothermal solutions on these samples.

Syenogranite exhibits hypidiomorphic granular texture. Some samples are porphyritic with orthoclase phenocrysts. They are mostly medium but some-times coarse-grained. They are mainly composed of K-feldspars (orthoclase and microcline with coarse patchy string and ripple perthites) and quartz (undulose extinction due to strain or deformation), with subordinate plagioclase (An₁₀₋₁₈), having carlsbad and albite twinning (Fig. 3-1). Microcline crystals are microfractured due to strain effects (Fig. 3-2). Biotite crystals have generally green brownish colors (Fig 3-3). Few of plagioclase crystals show bended subhedral to anhedral flaky crystals due to deformation (Fig. 3-4). Microcline has a tartan twinning (Fig. 3-5).

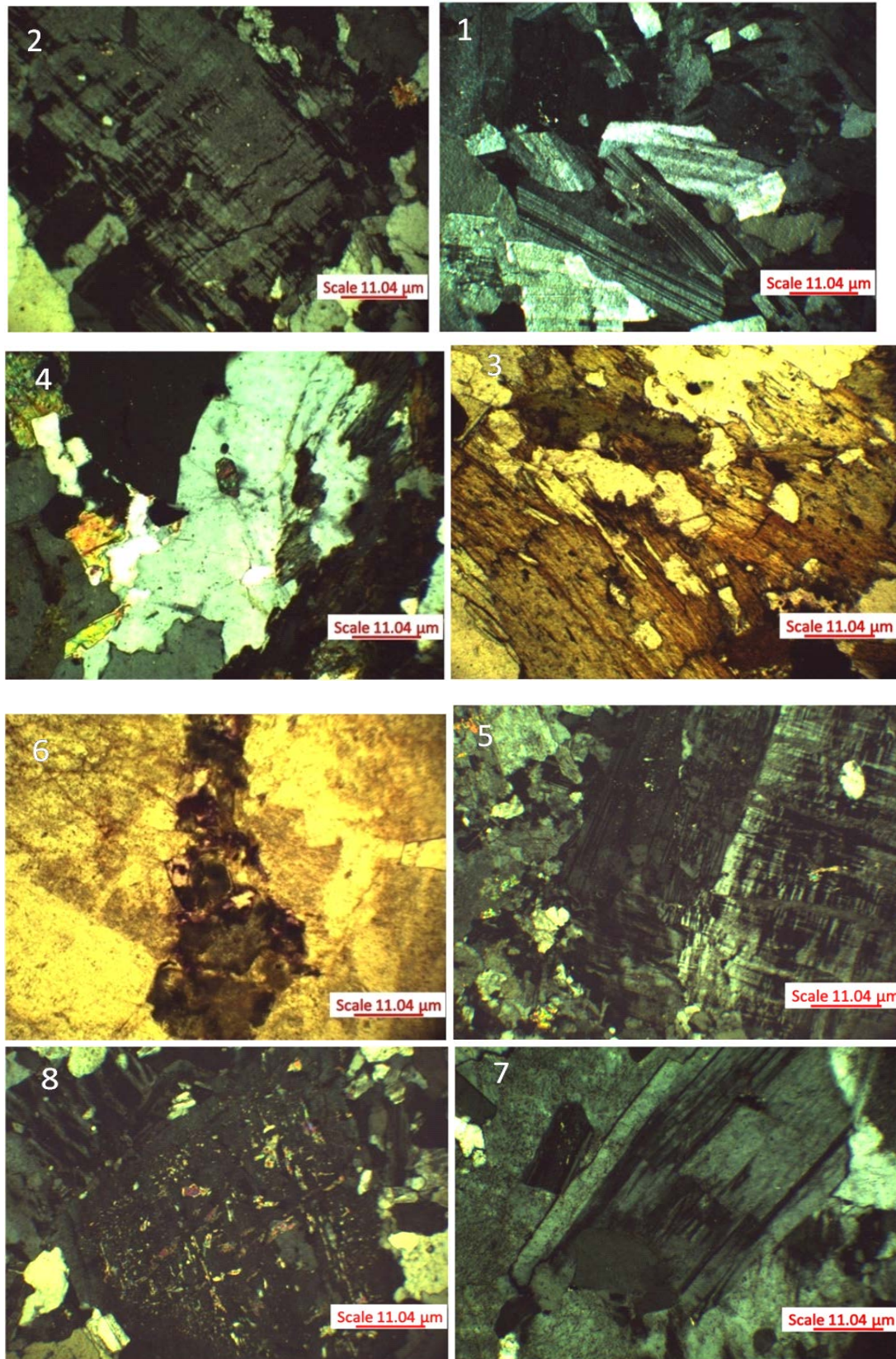


Fig. 3: Photomicrographs of characteristic features.

3-1: Plagioclase crystals with albite twinning.

3-2: Microfractures in microcline crystal.

- 3-3: Biotite crystal with chlorite crystal.
- 3-4: Subhedral zircon crystal in feldspar.
- 3-5: Tartan twinning in microcline.
- 3-6: Violet fluorite crystal with clay materials.
- 3-7: Plagioclase with mottled extinction in core.
- 3-8: Sericitization (small birefringent needles of potassic-muscovite) in plagioclase crystal (sieve texture), the feldspar crystal around, have perthitic texture.

5- GEOCHEMISTRY

5A- Geochemical characteristics

Generally, the present granite display characteristics of A-type which have high contents of SiO₂, alkalis (Na₂O+K₂O) wt %, Rb, Nb, Y and Zr. With low contents of Al₂O₃, CaO, MgO, TiO₂, FeO, Fe₂O₃, Sr and Ni. It has low FeO_t/MgO and K/Na ratios, **Table (1&2)**.

Table 1: Major oxides (wt %), and trace elements (ppm) analysis for Abu Harba area granites.

Major oxides									
Oxides	1	2	3	4	5	6	7	8	Av.
SiO ₂	73.9	74.01	74.06	73.11	73.50	73.55	73.00	72.92	73.50
TiO ₂	0.11	0.12	0.11	0.10	0.11	0.13	0.15	0.15	0.12
Al ₂ O ₃	12.85	13.10	12.82	12.97	13.23	13.10	13.11	13.37	13.06
Fe ₂ O ₃	0.66	0.64	0.67	1.28	0.81	0.85	1.11	1.08	0.88
FeO	1.98	1.79	1.99	1.95	2.09	1.75	1.95	1.81	1.91
MnO	0.06	0.06	0.07	0.08	0.08	0.08	0.09	0.09	0.07
MgO	0.71	0.54	0.65	0.78	0.55	0.62	0.82	0.8	0.68
CaO	0.86	0.91	0.86	0.90	0.88	0.80	1.11	0.98	0.91
Na ₂ O	3.79	3.81	3.86	3.80	3.80	3.76	3.74	3.70	3.78
K ₂ O	4.00	3.98	4.02	4.02	3.96	3.99	3.91	4.00	3.98
P ₂ O ₅	0.05	0.14	0.18	0.19	0.15	0.18	0.15	0.20	0.15
L.O.I	0.23	0.24	0.15	0.65	0.40	0.57	0.69	0.67	0.45
Total	99.22	99.34	99.47	99.83	99.56	99.38	99.73	99.87	99.55
Trace elements									
Cr	16	39	17	13	15	12	14	17	18
Co	3	4	3	4	4	4	4	4	4
Ni	11	11	12	10	13	14	14	13	11
Cu	11	12	12	11	12	11	12	12	11
Zn	25	35	26	38	40	50	35	44	36
Zr	160	155	145	153	165	165	154	165	157
Rb	292	265	305	283	249	239	250	233	264
Y	57	61	59	55	59	66	65	60	60
Ba	160	173	140	200	170	230	194	175	180
Pb	8	6	7	8	5	11	6	8	7
Sr	40	45	38	45	44	50	45	41	44
Ga	23	22	24	21	25	20	23	22	22
Nb	35	33	35	30	33	29	33	25	31
U	7	8	6	7	6	8	5	6	6
Th	16	16	15	12	16	17	15	14	15

Table (2): Some geochemical ratios of the studied granites.

	1	2	3	4	5	6	7	8	Av.
K/Na (Mol.)	0.69	0.68	0.68	0.69	0.68	0.69	0.68	0.71	0.68
FeO_t/MgO	3.62	4.38	3.98	3.97	5.12	4.01	3.27	3.47	3.97
Ga/Al	3.40	3.19	3.55	3.07	3.59	2.85	3.33	3.12	3.26
Y/Nb	1.62	1.84	1.68	1.83	1.78	2.53	1.96	2.40	1.95
D.I.	89.25	89.89	90.08	88.48	89.16	89.47	87.5	87.94	88.79

The average of whole-rock major composition of the selected analyzed granites, are listed on table (3). The average of the studied granite are compared with those of comparable Egyptian and world granites, indicate it has comparable the studied granites display comparable values of SiO₂, Al₂O₃, F₂O_t, MnO and P₂O₅, While it has lower Σ Alkalies and higher value in MgO, than the rest of the granites (Table 3).

Table (3): Comparison of the average composition of Abu Harba area granites with other comparable grantoids.

References (Average)	1	2	3	4	5	6
SiO₂	73.20	74.27	73.81	73.38	70.60	76.34
TiO₂	0.12	0.20	0.26	0.30	0.39	76.34
Al₂O₃	13.09	13.61	12.40	12.88	14.08	12.13
Fe₂O₃	1.24	-	1.24	-	2.82	1.72
FeO	1.59	2.03	1.58	2.44	-	-
MnO	0.07	0.05	0.06	0.06	0.11	0.07
MgO	0.73	0.27	0.20	0.30	0.58	0.14
CaO	0.93	0.71	0.75	1.06	1.43	0.33
Na₂O	3.77	3.48	4.07	3.50	4.38	4.09
K₂O	3.97	5.06	4.65	4.62	4.28	4.57
Σ Alkalies	7.75	8.54	8.72	8.12	8.66	8.66
P₂O₅	0.16	0.14	0.04	0.07	0.11	0.04

- 1- The present Abu Harba area A- Type granite.
- 2- Low -Ca granite (Turekian & Wedepohl, 1961).
- 3- A - Type granite (Whalen et al., 1987).
- 4- A- Type granite (Chappel & White, 1992).
- 5- Earlier phase of Abu Harba granite (M. Roz, 2005).
- 6- Later phase of Abu Harba granite (M. Roz, 2005).

5B - Chemical Classification

Middlemost (1985) proposed a classification of igneous rocks based on the binary relation between (Na₂O+k₂O) and SiO₂ (wt.%), as shown in Fig.(4). This diagram display that Abu Harba area granites fall within the granite field, and confirmed in more specific nature which show as a syenogranite in the ternary discriminated Or-Ab-An diagram (Streckeisen, 1976b) Fig. (5).

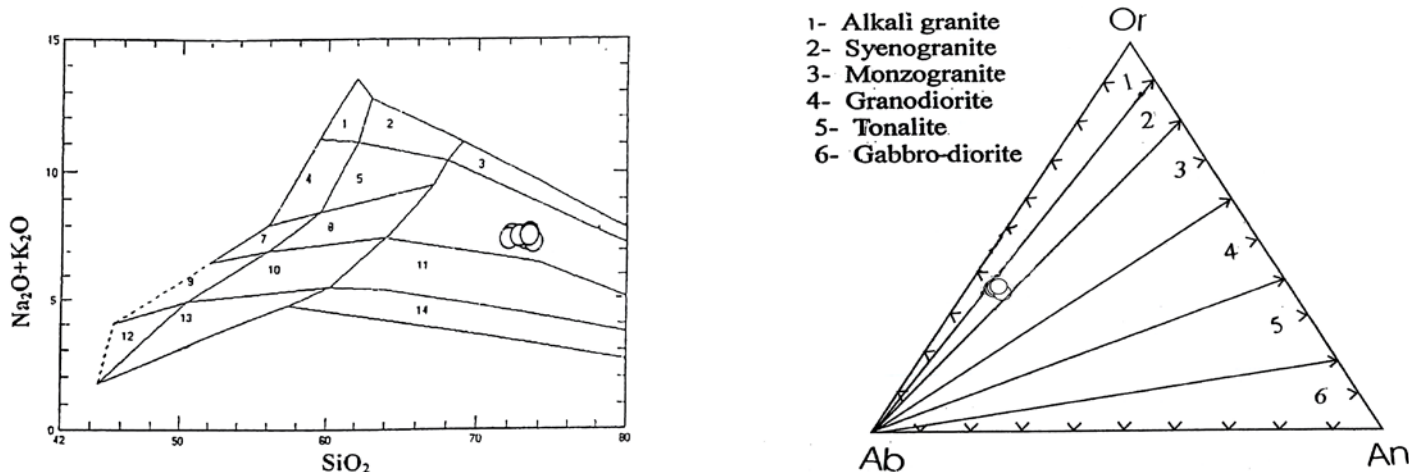


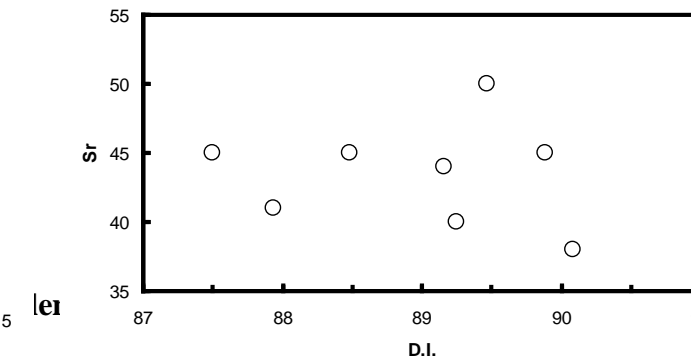
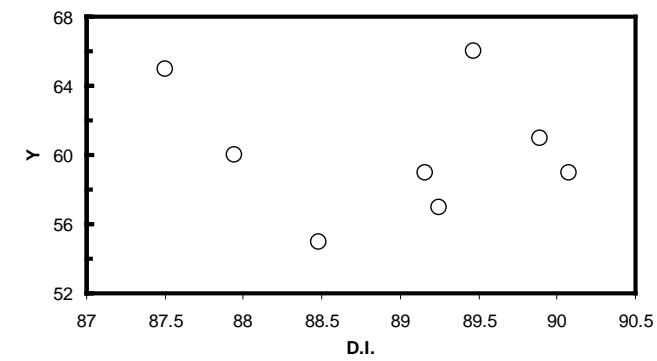
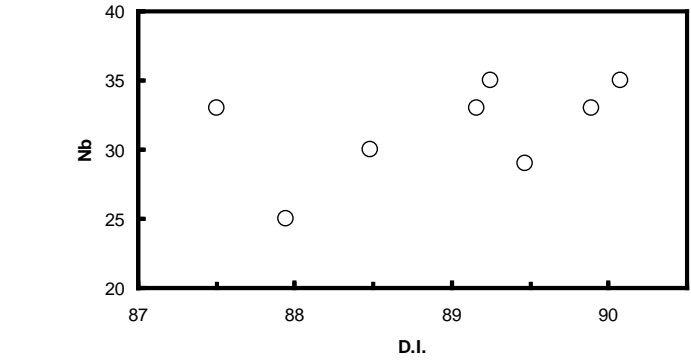
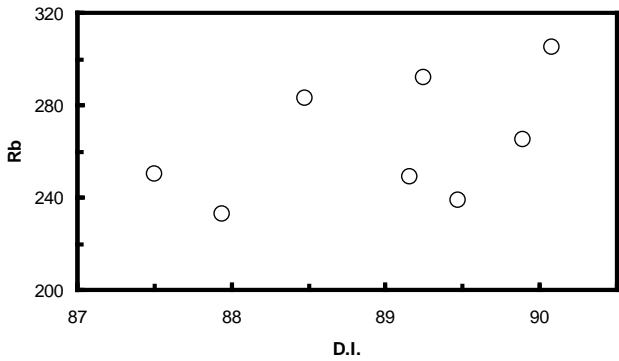
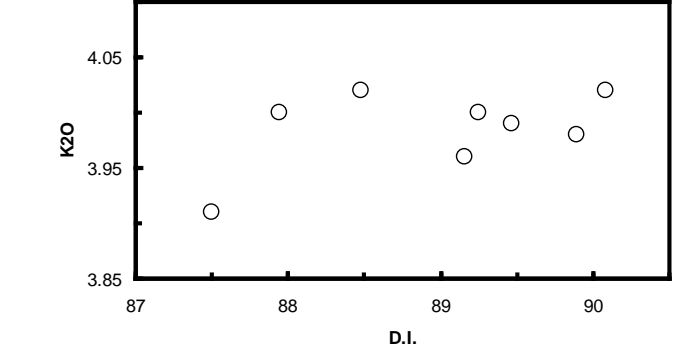
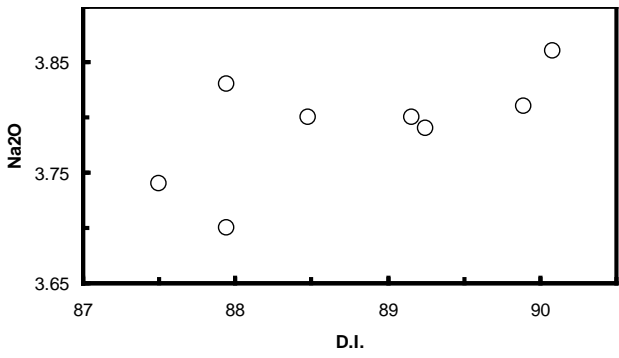
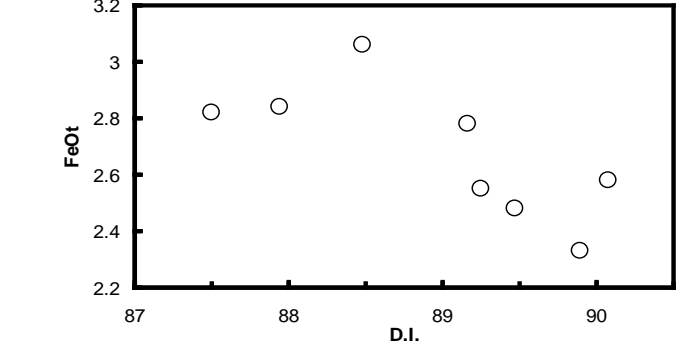
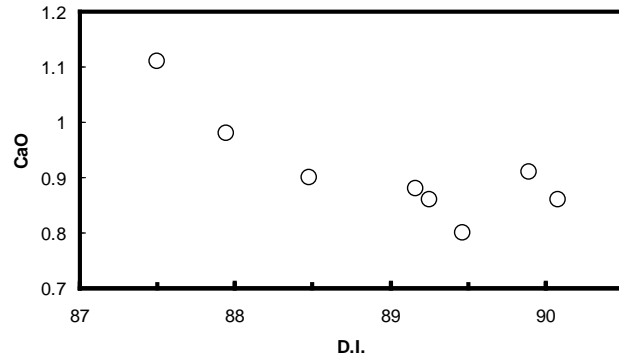
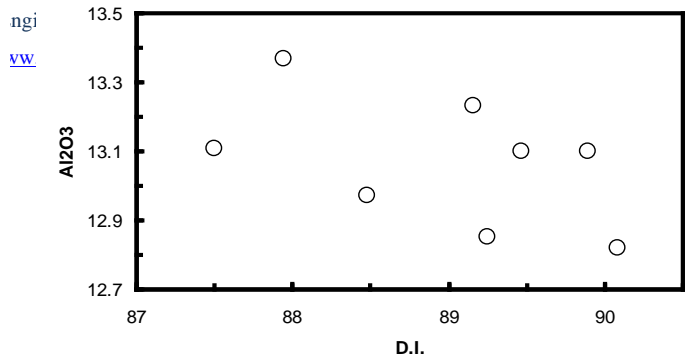
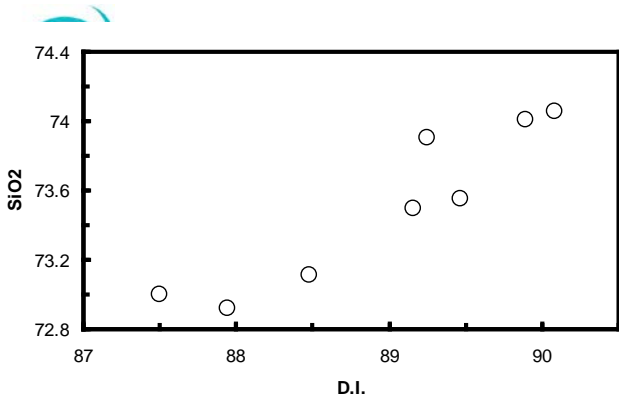
Fig. (4): Chemical classification of the studied granite (after Middlemost, 1985).

Fig. (5); The studied granite plotted on the Or-Ab-An ternary diagram (after Streckiesen, 1976a).

5-C Geochemical variation and magmatic type.

Geochemical variation

Some major oxides and trace elements are plotted in Fig. (6). It is noticed from these variation diagrams that; Abu Harba area granites having a narrow D.I. range values from 87.5 to 90.08 with average 88.79, reflected a homogeneous nature of Abu Harba area. Generally, It having a high SiO_2 , $\Sigma(K_2O, Na_2O)$, Rb, Zr, Nb and Y, moderately MgO , Al_2O_3 , while they possess lower values in TiO_2 , FeO_t , MgO , CaO , P_2O_5 and Sr. D.I. values display correlate positively with SiO_2 , K_2O , Na_2O , Rb, Nb, linear correlation with Zr, while it shows negative correlation with Al_2O_3 , TiO_2 , FeO_t , MgO , CaO , Zr, Pb, Ni, Sr and Y.



Magma Series

The investigated granites are display an alkaline nature in which are documented with the following discriminated diagrams. Plots of the investigated granites on the Wright's alkalinity ratio diagram show that the all eight samples fall in the strong alkaline fields by plotting SiO_2 versus $\text{Log} (\text{K}_2\text{O}/\text{MgO})$. Maniar and Piccoli (1989) using the molar A/NK and A/CNK ratios to discriminate between granitoid rocks, and show peraluminous nature among the studied granitic samples Fig. (7). On plotting Abu Harba granitic samples on the discriminated diagram, (after Whalen et al., 1987), and later Hong et al., (1996) delineated the (AA) anorogenic and (PA) post orogenic fields, it fall in the A-type granite and post orogenic type Fig (8). In recent years of the past century, there has tendency to subdivide the A-type granites into two major clans: post orogenic and anorogenic types. Eby (1992) subdivided A-type

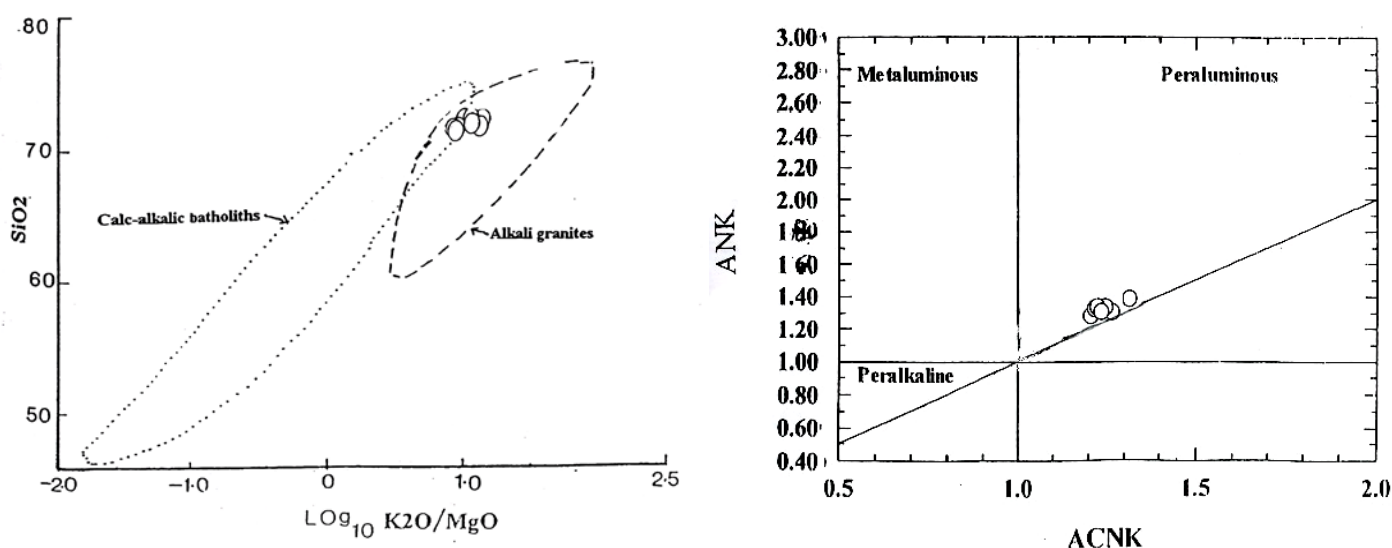


Fig. (7): The studied granites plot on the SiO_2 versus $\text{Log} \text{K}_2\text{O}/\text{MgO}$ diagram (after Rogers and Greenberg, 1981).

Fig. (8) The studied granite plot on the ACNK-ANK diagram (after Maniar and Piccoli, 1989b).

granites into A1 and A2 groups. The A1 group refers to differentiates of magmas derived from sources like those of oceanic–island basalts but emplaced in continental rifts or during intraplate magmatism. The A2 group, on the other hand represents magma derived from continental crust or under plated crust that has been subjected through a cycle of

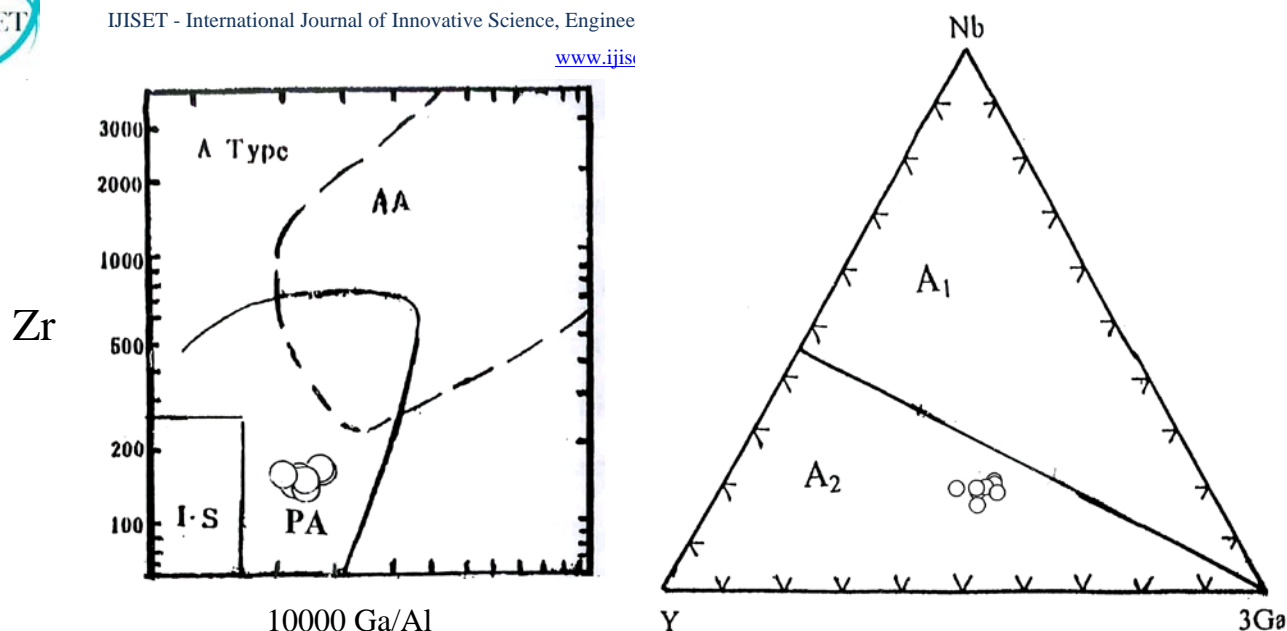


Fig. (9): The studied granite plotted on the 10000Ga/Al versus some trace element (Whalen et al., 1987), AA, PA fields redrawn after Hong et al., (1996).

Fig. (10): The studied granite plotted on the Y-Nb-3Ga ternary diagram (after Eby, 1992).

continent-continent collision or island-arc magmatism (Eby 1992) Fig. 10. On plotting the studied granitic samples, they fall totally on the post orogenic with Y/Nb ratios greater than 1.2 on the (Nb-Y-3Ga) diagram Fig. (9). Recently, a few useful discrimination diagrams were designed by (El Dabe 2015), and employed successfully to optimal subdivision among various A-type according to their magma and tectonic setting regimes used "element screens" such as Y/Nb, K/Na (Mol), FeO_t/MgO ratios and differentiation index values (D.I.). El Dabe (2015), suggest that the post orogenic and anorogenic A-type granitoids, can be further classified into the four known following types: Hot spot (HSR), and rift (RRG) related to the anorogenic type, while the post subduction (PSRG) and post continent collisions (PCCCRG) are belong to the post orogenic alkaline granitoids. He (op.cit) add that both of rift and post subductin groups have peraluminous, metaluminous and peralkaline varieties, while the hot spote and post continent- continent collision groups possess only metaluminous and peralkaline varieties. On the Y/Nb and K/Na (Mol) binary diagram El Dabe (2015), the investigated samples plot close to post subduction alkaline granite field (PSRG) (Figs. 11&12) on the overlap

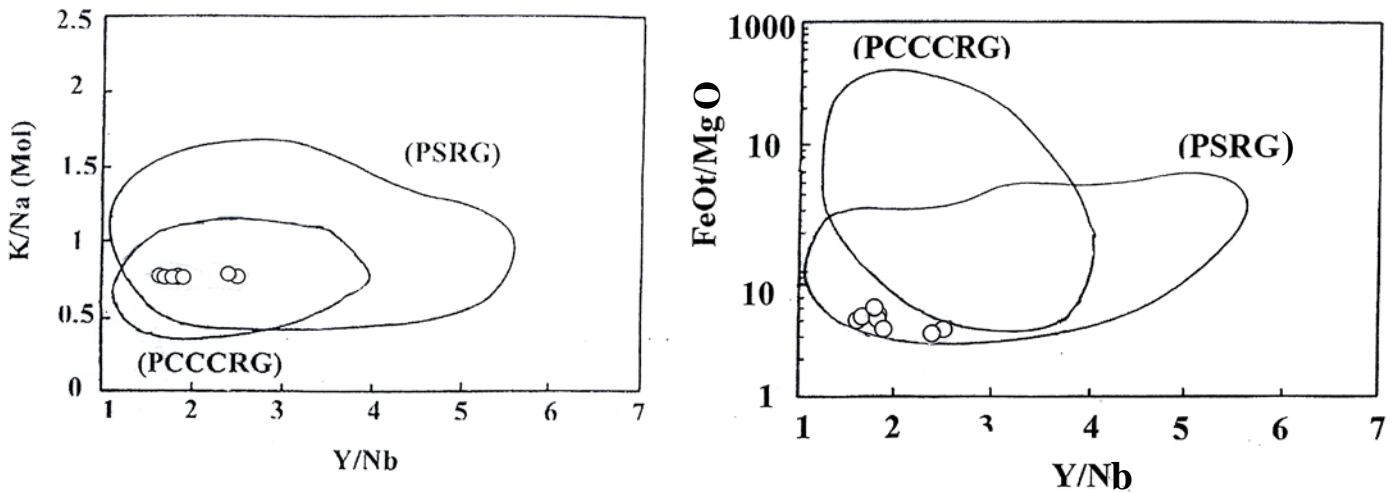


Fig. (11): The studied granite plotted on the Y/Nb and K/Na (Mol) binary diagram (after El Dabe, 2015).

Fig. (12): The studied granite plotted on the Y/Nb and FeO_t/MgO binary diagram (after El Dabe, 2015).

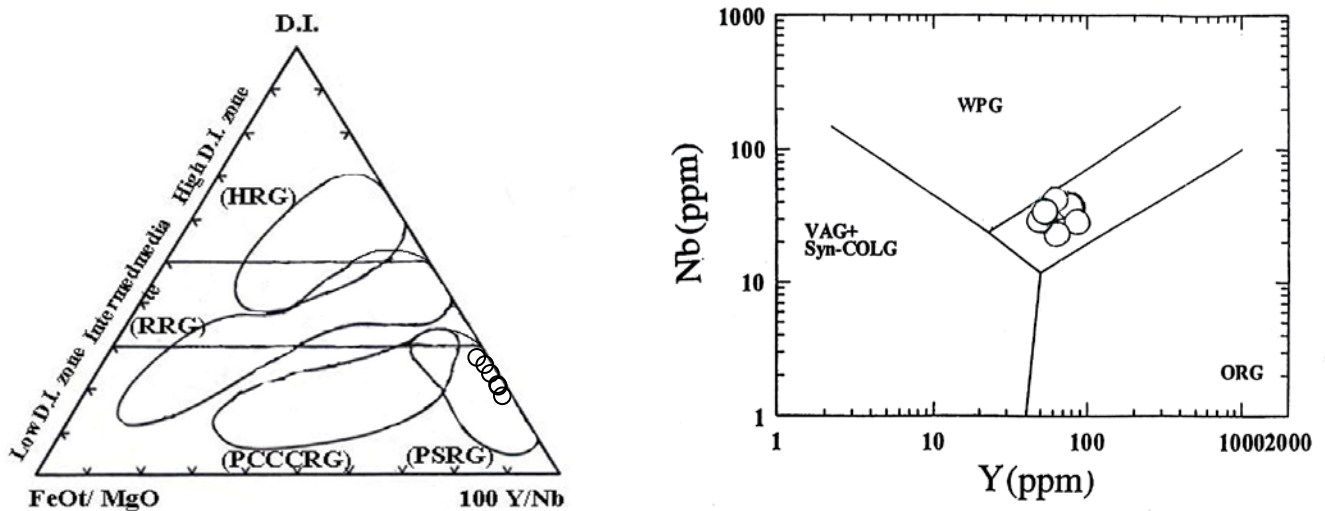


Fig. (13): The studied granite plotted on the D.I., FeO_t/MgO and 100Y/Nb ternary diagram (after El Dabe, 2015).

Fig. (14): The studied granite plotted on the on Y and Nb diagram (Pearce et al., 1984).

area with the post continent –continent granites field, due to low (K₂O) values, while it fall totally on the post subduction alkaline granite field (PSRG), due to its low FeO_t/MgO values on the Y/Nb and FeO_t/MgO diagram. Finally, Abu Harba granites fall totally on the post subduction alkaline magma type field (PSRG) and low D.I. value zone on the most discriminated D.I., FeO_t/MgO and 100Y/Nb ternary diagram

Figs. (10&11&12&13), due to its high Y/Nb have values lesser than 4, accompanied with low D.I. and FeO_t/MgO values El Dabe (2015).

5D-Tectonic setting and tectonic setting regimes

Generally, all A-type granitoids should located on the within plate field (Pearce et al 1984), Abu Harba granitic samples plot in the within plate field, on Y+Nb and Rb diagram (Pearce et al., 1984) Fig. (14). Recently, El Dabe (2015), employed Rb, $10 FeO_t/MgO$ and Y+Nb diagram to distinguished among the four hot spot, rift, post subduction and post continent- continent collision A-types. Plotting Abu Harba granites straddle on the boundary line between post subduction (PSRG) and rift (RRG) type fields Fig. (15). To demonstrate the regime in which associated with the A-type granite magma and tectonic types, El Dabe (2015) suggest that both of rift and post subductin groups have both reduction and oxidation tectonic regimes,

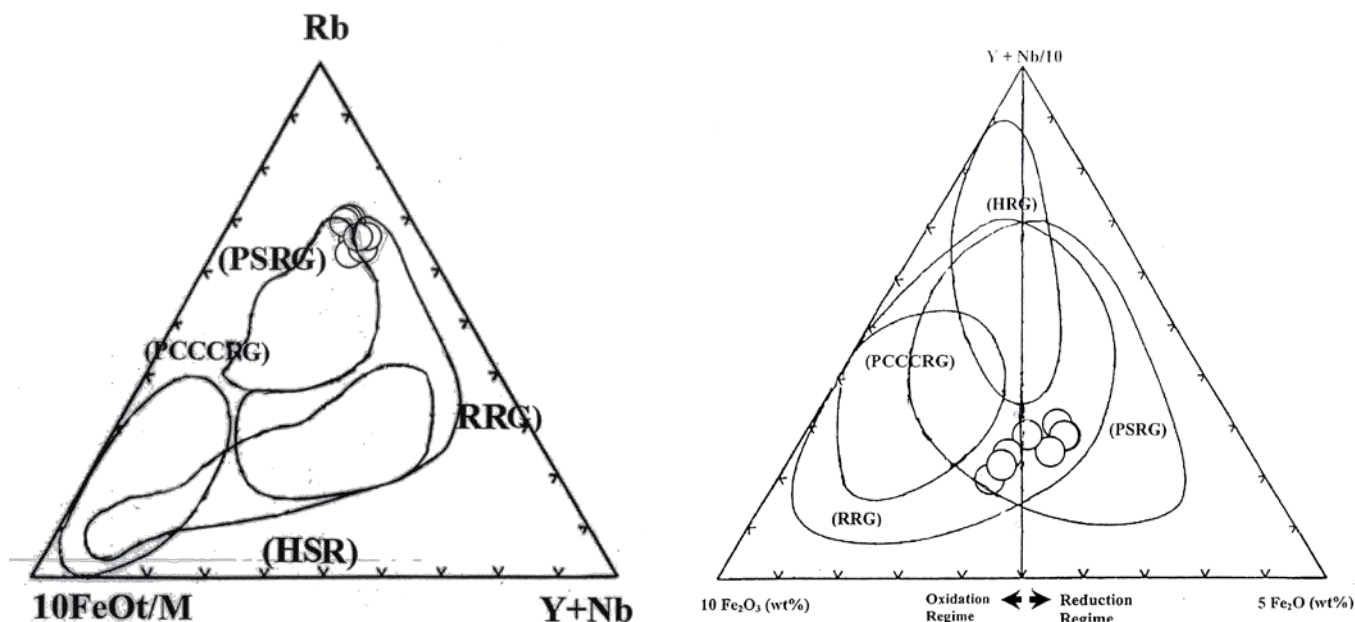


Fig. (15): The studied granite plotted on the on Rb, $10 FeO_t/MgO$ and Y+Nb diagram (after El Dabe, 2015).

Fig. (16): The studied granite plotted on the on Y+Nb/10, $10Fe_2O_3$ and $5 Fe_2O$ ternary diagrams (after El Dabe, 2015).

due to their involved reduced peraluminous and oxidized metaluminous, and peralkaline varieties, alternatively, while the hot spot and post continent- continent collision types possess only oxidized regime, due to their involving oxidized

metaluminous and peralkaline varieties. Most of investigated samples display slightly reduced peraluminous regime, except three samples are fall in the oxidized condition regime, due to relatively high FeO values on the Y+Nb/10, $10\text{Fe}_2\text{O}_3$ and $5\text{Fe}_2\text{O}$ ternary diagram Fig. (16).

6-Radioactivity:

Generally, the same samples which chemically analyzed are subjected to the radiometric analyses to determine their uranium and thorium contents Table (1 & 4). Abu Harba area granites contains a narrow range values of chemical uranium (U_c) ranging from 5 ppm to 8 ppm with an average values of 6 ppm, and Th content ranging from 14 ppm to 24 ppm with an average values of 15 ppm. The Th /U ratios range from 1.70 to 3.00. Abu Harba area granites posses eU content ranging from 7 ppm to 11 ppm , with an average of 9 and eTh content ranging from 14 to 24 , with an average of 18 ppm . Equivalent Th/U ratios values, have a rang varying from 1.55 to 3 ppm. The obviously gap between the (chemical and equivalent) U and Th contents indicating a high degree of disequilibrium state which describes the environments enclosing both U, Th and the hydrothermal solutions associated the studied granite (Table 4). The disequilibrium stat was described with the equilibrium factor (D), which is expressed by the ratios of chemically analyzed uranium (U_c) over radiometrically (eU) , i.e. D-factor + U_c/U_r (Hansink, 1976). If the D-factor is higher or lower than unity, then addition or removal of uranium has occurred, respectively. The calculated (D) factor with an average of 0.72 is indicating removal of uranium from the studied granites, and its concentration probably along fracture zones. Atwiya (1984) mentioned that uranium could be released from the granite itself by dissolution of accessory uranium- bearing minerals and redeposition in fractures and shear zones by percolating solutions. According to the inter elements relationship, the following variation diagrams describe the behaviors of both uranium and thorium element with the other elements. On plotting the U_c content versus Th_c values, show a clear positive correlation with each other, indicating that U and Th distribution were essentially controlled by the magmatic processes control the exist the two elements Fig. (17).

Table: (4) Chemical and radiometric uranium and thorium contents of the studied granites.

Serial	Chemical analysis			Radiometric analysis			D-factor
	Uc	Thc	cTh/U	eU	eTh	eTh/U	
1	7	16	2.28	9	16	1.77	0.77
2	8	16	2.00	11	14	1.27	0.72
3	6	15	2.50	6	18	3.00	1.00
4	7	12	1.70	11	21	1.91	0.63
5	6	16	2.66	7	22	3.14	0.85
6	8	17	2.10	10	24	2.40	0.80
7	5	15	3.00	9	14	1.55	0.55
8	6	14	2.33	8	17	2.12	0.75
Av.	6	15	9.00	9	18	2.00	0.75

While plotting the Uc content against Zr Fig.(18), shows a moderately positive correlation with some degree of scattering, suggesting leaching and redistribution of uranium probably under the influence of hydrothermal solutions. The same result is consistent with plotting the Uc versus the P₂O₅ Fig. (19), which display almost slightly linear trend with scattered pattern, due to the effect of the post magmatic processes.

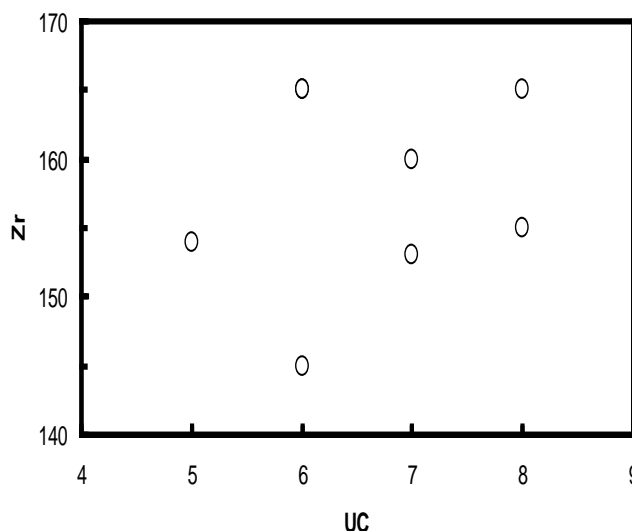
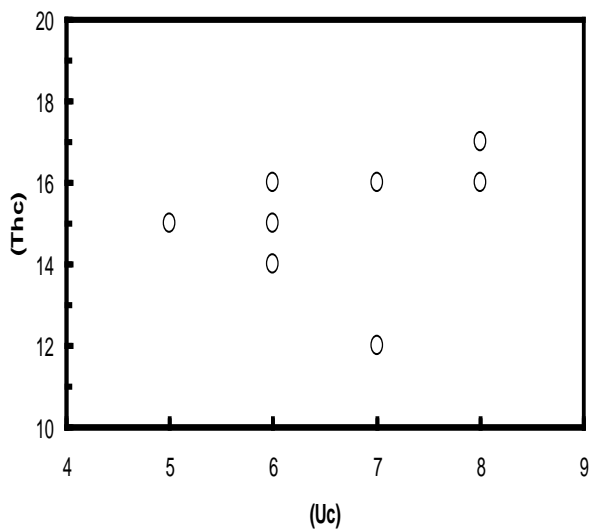


Fig. (17): Uc content versus Thc content variation diagram for the studied granites.

Fig. (18): Uc content versus Zr content variation diagram for the studied granites.

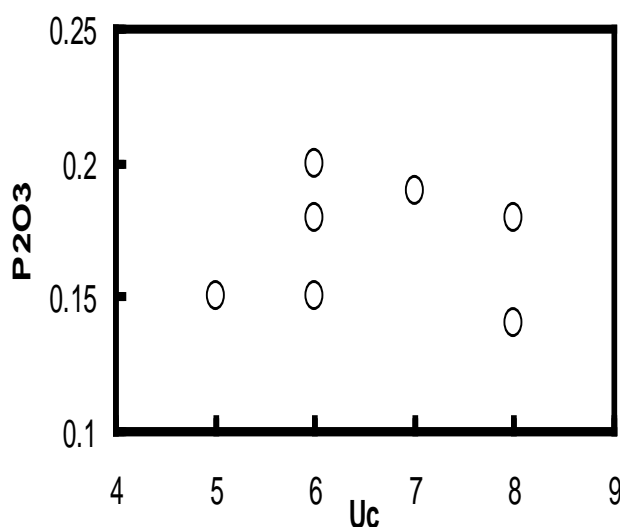


Fig. (19): Uc content versus P₂O₅ content variation diagram for the studied granite

7- Mineralogy

Mineralogical identification was done by using binuclear microscope, X-ray diffraction (XRD) and environmental scanning electron microscope (ESEM). The ESEM techniques are used on the separated grains from the anomalous samples in the syeogranite.

Scanning electron microscope data indicate that zircon crystals usually occurs as solitary (monocrystal) and/or zoned aggregates crystals habit. Microparticles of zircon occur in fluorite crystal as inclusions. These microparticles are crystalline calcium phosphosilicate formed as ghost mirmaktic texture in fluorite crystals. However the crystal structure of fluorite permits incorporation of many genetically important trace and rare-earth elements (Möller et al. 1998). These nanocrystalline mineral is phosinaite (Figs. 20&21).

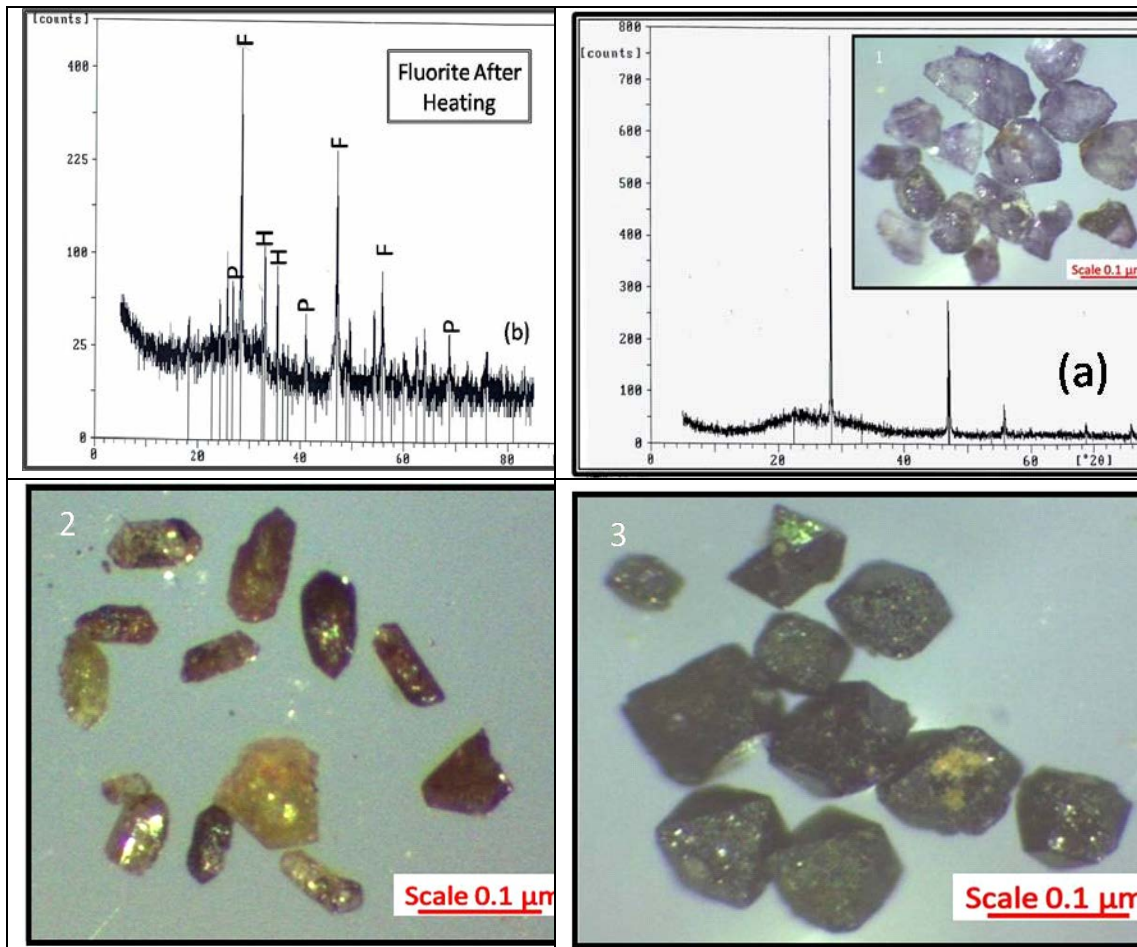


Fig 20: Images of selected fluorite crystals separated from studied syenogranite

20-1: Image of violet fluorite grains.

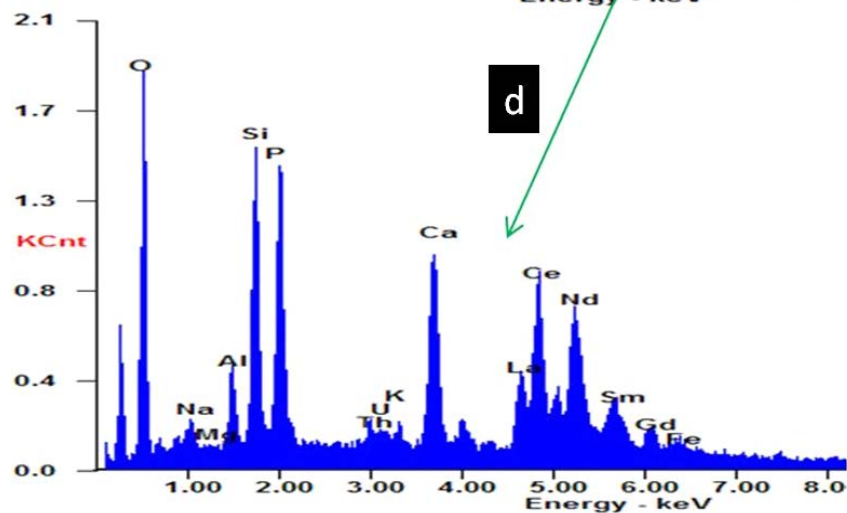
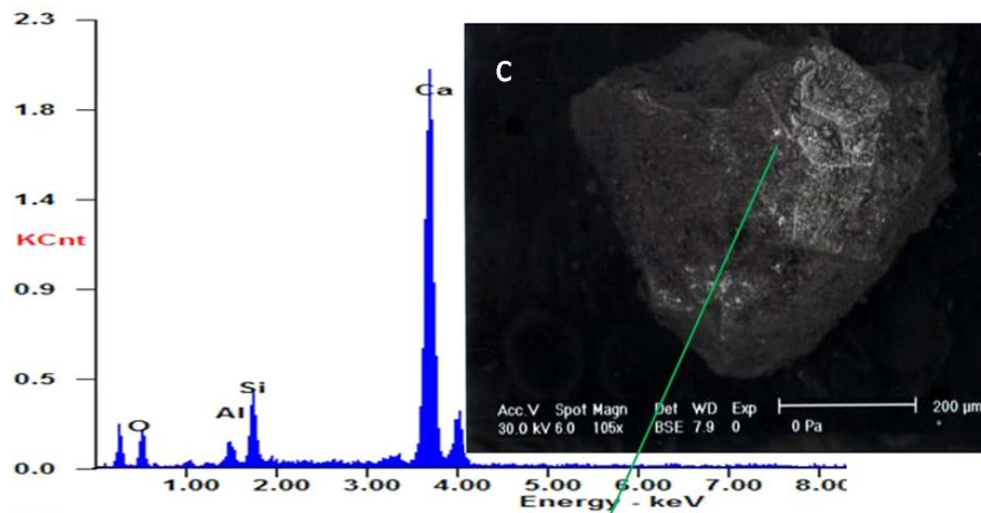
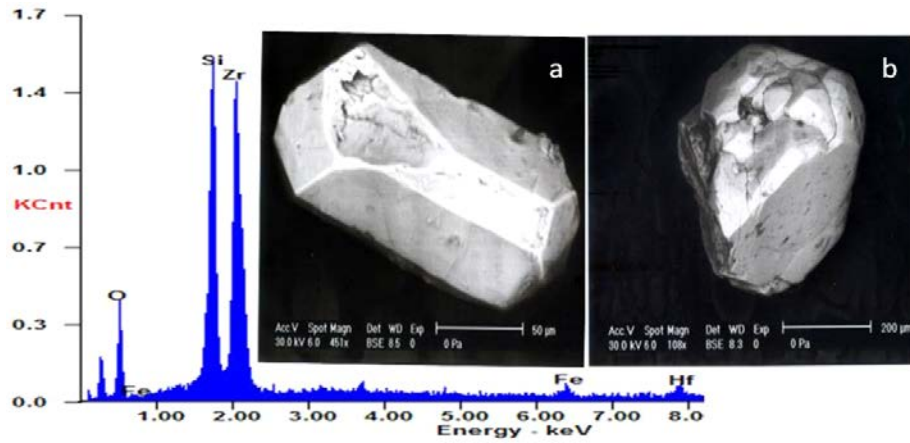
20-1-a: XRD of fluorite.

Abbreviation:

20-1-b: XRD of fluorite after heating. F: Fluorite, H: hematite, P: Phosinate.

20-2: Image of zircon crystals.

20-3: Image of bipyramidal magnetite crystals.



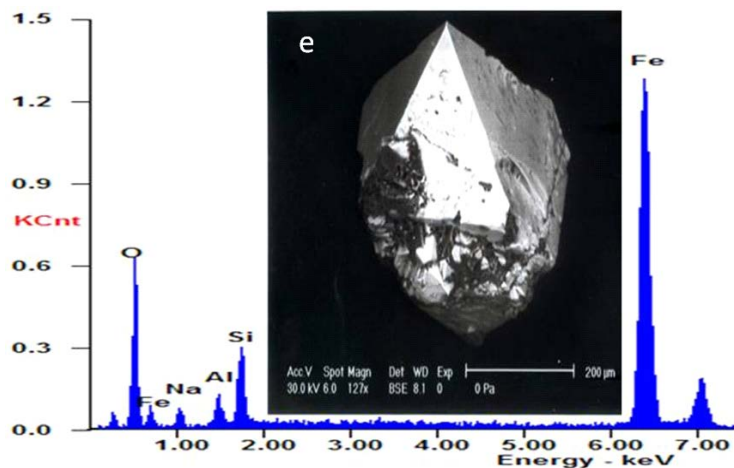


Fig 21: ESEM images for distinct morphological forms of zircon crystals separated from studied syenogranite

Fig 21-a: solitary zircon (monocrystal).

Fig 21-b: Twinning zircon (aggregates crystals).

Fig 21-c: Anhedral fluorite grain.

Fig 21-d: Phosinate nanomineral association with fluorite grain as inclusion.

Fig 21-e: Bipyramidal magnetite crystal.

Altered granites

Field studies indicated that the Abu Harba granites have suffered from hydrothermal alterations, especially along faults and fractures zones. The fresh granite is usually characterized by its pink to slight reddish pink color, while the lighter tones such as creamy and brownish yellow colors could be attributed to the destruction of feldspars by kaolinization. The silicified granite is characterized by its hardness and lighter rosy tones.

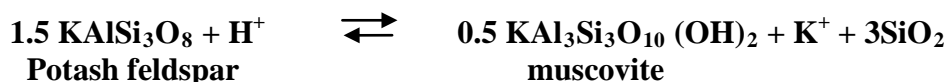
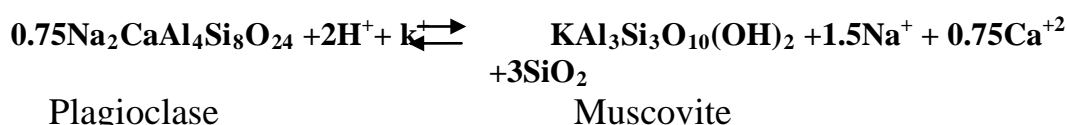
From the above description, the alteration processes that affected the studied rocks could be classified into two main types in decreasing order of predominance as follow:- kaolinization and silicification. The different alteration features, in the study area, are always strongly associated with shear zones. Some alteration features are also noticed such as chloritization, and epidotization, but are of less importance of except fluoritization besides the presence of Mn dendrites. The presence of fluoritization mainly associated with uranium mineralization indicates that the alteration processes are mainly due to hydrothermal activity.

Samples representing the main two types of alterations were collected separately and analyzed for major oxides and trace elements (table 5), in order to study their geochemical behavior. The altered samples are plotted on the AKF ternary diagram after (Meyer and Hemely,1967) (Fig. 22) where $A=Al_2O_3$, $K=k_2O+Na_2O$, and $F=FeO_t + MnO +MgO$. They show that, all samples fall in sericite facies. On the $(Na_2O+CaO)- Al_2O_3- K_2O$ ternary diagram (Nesbitt and young, 1989), (Fig. 23) all samples plot

parallel to advanced weathering trend. The initial stages of weathering from a trend parallel to the (Na₂O+CaO)-Al₂O₃ side of the diagram, where as advanced weathering shows a marked loss in K₂O and CaO+Na₂O compositions and moves more towards the Al₂O₃ apex. Accordingly, all-previous diagrams, revealed that the alteration processes in Abu Harba granites are mainly due to hydrothermal activity.

Silicification process

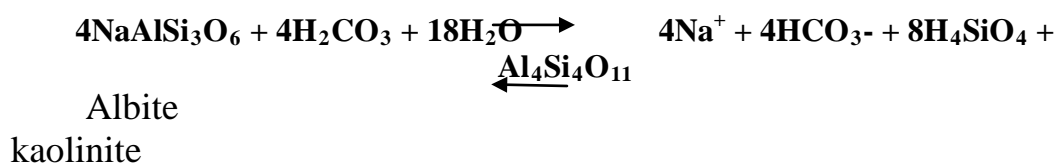
The silicified granites in Abu Harba area are characterized by their creamy color and light tone as their silica content could reach as much as 80%. Exley (1976), jasinski (1988) and pier et al.(1992) reported that SiO₂ could develop due the hydration of feldspars as follows :-



Bucanan (1982) stated that the silicification process may result from strong acidic hydrothermal solutions with temperatures varying between 300° and 400°C and a pH of 1-3. The silicification process results in an increase of SiO₂, TiO₂,P₂O₅ and L.O.I. at the expense of the other major oxides .This is always accompanied with the increase of some trace elements such as Zr,Y,Nb,Hf,Ta,Pb and F.

Kaolinization process

Helgeson (1974) stated that the presence of kaolinite indicates that the rocks were affected by strong acidic solution at PH from 2 to 3 and low temperatures varying between 200° and 250° C. He added that kaolinite is not stable with quartz at temperatures above 300° C. The temperature of the hydrothermal solutions responsible for kaolinization could have varied between 150° and 250° C. Rice (1973) pointed out that kaolinite may be formed in granite due to hydrolysis of albite. In this reaction, the silica precipitates as an amorphous phase.



The kaolinization process causes an increase an of TiO_2 , P_2O_5 and L.O.L. at the expense of the other major oxides .This is always associated with an increase of some trace elements such as Ba,Zr,Hf,Ta,Pb and F. This enrichment may be referred to the alteration of feldspars and mica or could be due to the effect of hydrothermal activity.

Table 5: Major elements (oxides wt %) and trace elements for studied altered granites.

Rock type	Silicified granites					Kaolinized granites				
Sample No	1	2	3	4	5	6	7	8	9	10
SiO ₂	78.90	79.60	78.77	79.26	79.55	73.55	74.02	73.71	72.99	73.20
TiO ₂	0.13	0.14	0.13	0.14	0.13	0.11	0.11	0.13	0.11	0.14
Al ₂ O ₃	12.04	12.77	12.23	12.45	12.30	13.66	13.45	13.47	13.53	13.69
Fe ₂ O ₃	0.65	0.59	0.61	0.57	0.57	0.82	0.79	0.80	0.82	0.83
FeO	0.60	0.58	0.60	0.62	0.60	0.44	0.42	0.43	0.43	0.44
MnO	0.03	0.04	0.04	0.03	0.04	0.03	0.02	0.03	0.03	0.03
MgO	0.24	0.25	0.24	0.23	0.22	0.21	0.22	0.20	0.23	0.23
CaO	0.33	0.32	0.32	0.31	0.32	0.50	0.51	0.48	0.52	0.50
Na ₂ O	2.49	2.33	2.47	2.40	2.42	3.63	3.60	3.59	3.63	3.57
K ₂ O	2.70	2.45	2.66	2.52	2.63	3.64	3.60	3.57	3.62	3.57
P ₂ O ₅	0.14	0.12	0.12	0.13	0.12	0.14	0.13	0.14	0.14	0.14
L.O.I.	1.60	1.18	1.35	1.22	1.21	3.40	3.11	3.36	3.55	3.48
Total	99.85	100.37	99.54	99.88	100.11	100.13	99.98	99.91	99.60	99.82
Trace elements										
Rb	195	200	199	196	211	222	230	199	221	209
Ba	29	22	26	25	30	56	58	46	50	48
Sr	8	7	7	9	7	5	8	7	9	10
Zr	170	185	177	180	184	188	170	190	176	187
Y	110	99	100	103	111	86	88	85	79	88
Nb	86	98	95	90	83	60	63	66	70	69
Ga	21	22	22	21	24	25	25	22	27	25
Hf	15	15	14	14	15	15	15	13	14	15
Ta	10	10	11	10	11	7	7	9	10	8
Zn	50	55	54	51	50	72	76	77	70	66
Pb	33	40	35	42	39	44	46	47	43	55
F	20	22	24	20	25	26	23	21	22	26

Radioactivity of altered granites

The studied radioactive occurrence in Abu Harba area associated with strongly altered granites, mainly characterized by their intense, kaolinization and silicification .Table (6) shows the eU, eTh contents and eTh/eU ratio of the altered granites of Abu Harba area.

Table (6): eU, eTh, eTh/eU distribution in the altered granites

Rock type	Sample No.	eU	eTh	eTh/eU
Silicified granites	1	35	22	0.62
	2	31	21	0.67
	3	25	19	0.76
	4	39	24	0.62
	5	44	27	0.62
Kaolinized granites	6	36	23	0.63
	7	42	24	0.57
	8	33	40	1.21
	9	40	23	0.58
	10	51	30	0.59

In the silicified granite, the eU content ranges from 25 to 44 ppm and eTh content is between 19 and 27 ppm. The kaolinized granite, the eU content ranges from 33 to 51 ppm, while the eTh content varies from 23 to 40 ppm..

Generally, in the altered granites, the effect of hydrothermal solutions is obvious through the mobilization and redistribution of uranium by hydrothermal solutions during post magmatic processes.

Conclusion:

The detailed petrographic, mineralogical and chemical studies are applied on Abu Harba granite. The main objective of this study is to clear the role of hydrothermal solutions and its effect on Abu Harba granite. It represents a post subduction peraluminous alkaline biotite syenogranite. Subsidiary alterations are the main features of this syenogranite. The main accessory minerals are fluorite, zircon and magnetite. Two main types of alterations kaolinization and silicification. Some alteration features are also noticed such as chloritization, epidotization, and fluoritization. The presence of fluoritization mainly associated with uranium mineralization indicates that the alteration processes are mainly due to hydrothermal activity. The effect of hydrothermal solutions is obvious through the mobilization and redistribution of uranium by hydrothermal solutions during post magmatic processes.

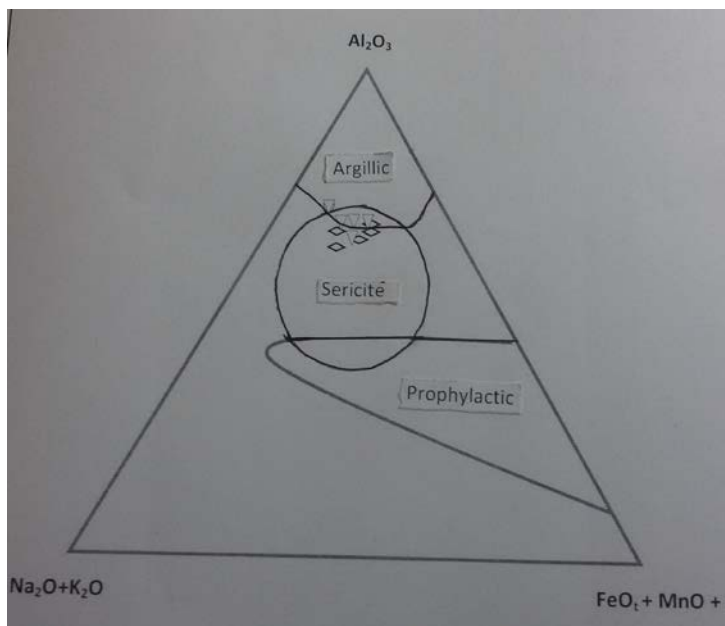


Fig. 22: Al_2O_3 -(K_2O+Na_2O)-($FeO_t+MnO+MgO$) ternary diagram (Meyer and Hemly, 1967) for altered granitic rocks

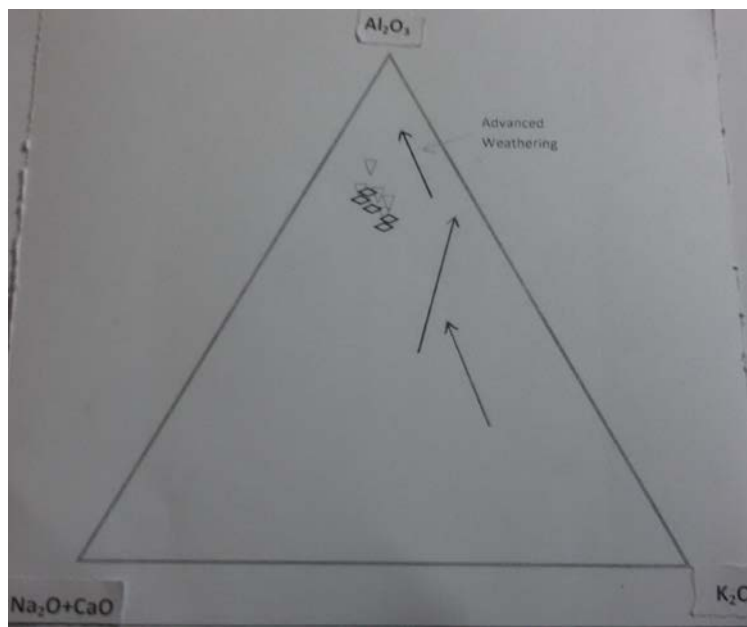


Fig. 23: Al_2O_3 -($CaO+Na_2O$)- K_2O ternary diagram (Nesbit and Young, 1989) for altered granitic rocks

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