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Origin of plagiogranites in the mawat ophiolite complex,kurdistan region, NE Iraq

Tola A. Mirza*   and   Sabah A.Ismail**
****College of Science - University of Sulaimani***
*****College of Science - University of Kirkuk***

Abstract

The igneous mass in Mawat Ophiolite Complex (MOC) is built up by various basic and ultrabasic intrusions that are associated with minor acidic, intermediate and basic intrusion. The present study was examined the minor acidic intrusions (plagiogranite), with associated basic igneous rocks in order to understand the possible origin of these rocks. The plagiogranite in MOC composed mainly of quartz and alkali feldspar with rare Ca-plagioclase. These rocks are metaluminous, low-K calc-alkaline with mineralogical and geochemical characteristics of oceanic plagiogranite (trondhjemite). They are characterized by high Sr, Ba, Th, concentration and low Ni, and Cr contents. They are also display chondrite – normalized REE patterns characterized by LREE enrichment, moderate to minor HREE fractionation. Trace element distribution patterns show that these rocks are distinctively enriched in large ions lithophile element LILE compared to high field strength elements HFSE. This feature is commonly apparent in volcanic arc granite. The origin of plagiogranite in MOC explained as a result of partial melting of hydrated basaltic / gabbroic rocks.

Introduction

The Mawat Ophiolite Complex (MOC) is situated in north east Iraq 30km north of Sulaimani city, covering an area of about 250 km^2 (fig 1). The complex is part of the Iraqi Zagros Thrust Zone (IZTZ) which in turn is a member of Alpine-Himalayan Orogenic belt of Mesozoic Tethyan oceanic plate, Buda and Al-Hashimi (1977).The Zagros fold –thrust belt extends for about 2000 Km and developed in an epicontinental,synorogenic proforeland basin, whose evolution has been intimately related to tectonic and structural events of associated Zagros Orogen. The Zagros Orogen is interpreted by Alavi, (2004) as the product of major sequential geotectonic events (1) subduction of New-Tethyan oceanic plate beneath the Iranian lithospheric plates during Early to Late Cretaceous time (2) obduction of Neo-Tethyan oceanic slivers (ophiolites) over the Afro-Arabian passive continental margin in Late Cretaceous (Turonian to Companian) time and (3) collosion of Afro-Arabian continental lithosphere with Iranian plate that started in Late Cretaceous. Falcon, 1969, 1974 and Hessami et al. 2001 divided the Zagros Orogenic into three zones (the thrust zone, the Zagros imbricated zone and the Zagros fold thrust belt). While Alavi, 2004 divided the Zgros Orogeny into three parallel belts (Urmich –Dokhtar magmatic assemblage, the Zagros imbricatted zone (the Sanandaje-Sirjan zone as redefined by Alavi, 1994, after Stocklin, 1968a, 1977) and Zagros fold thrust belt). The MOC is a part of Zagros imbricated zone which is a zone of thrust faults that have transported numerous slices of metamorphosed and non-metamorphosed Phanerozoic stratigraphic unit's of Afro-Arabian passive continental margin, as well as its obducted ophiolites, from the collision suture zone on the northeast toward the interior parts of the Arabian cartons to the south west.The MOC consists of a thick sequence of serpentinized ultramafic rocks (> 2000m) and predominantly mafic rocks (~170 km^2) associated with acidic intermediat e and basic minor intrusions. These intrusive masses are emplaced within a sequence of green schist (metabasalt and amphibolites). These igneous rocks and probably part of their country rocks are allochthonous (Jassim, 1972; Jassim & Goff, 2006).The ophiolite rocks depositionaly overlapped by Gimo sequence. Both the ophiolite and Gimo sequence underwent low grade regional metamorphisim (Al-Mehadi, 1974). The MOC is sandwiched between two main thrust sheets Walash and Naopurdan groups in the east, west and south (fig.1).The acidic minor intrusions (plagiogranite) are well developed in the area between Amadin and Merawa village (Fig 2) where they form small bosses that are totally restricted to the shearing zone of the gabbro (fig 3). Although these bosses are found cutting most of the above mentioned rock types, they, themselves, are traversed by various sets of joints and shear zones. This paper presents field and geochemical data from the MOC fragment, focusing on the felsic rocks (acidic intrusions in the MOC between Amadin and Merawa) and discussing for the first time their possible origin, formation and their tectonic setting.

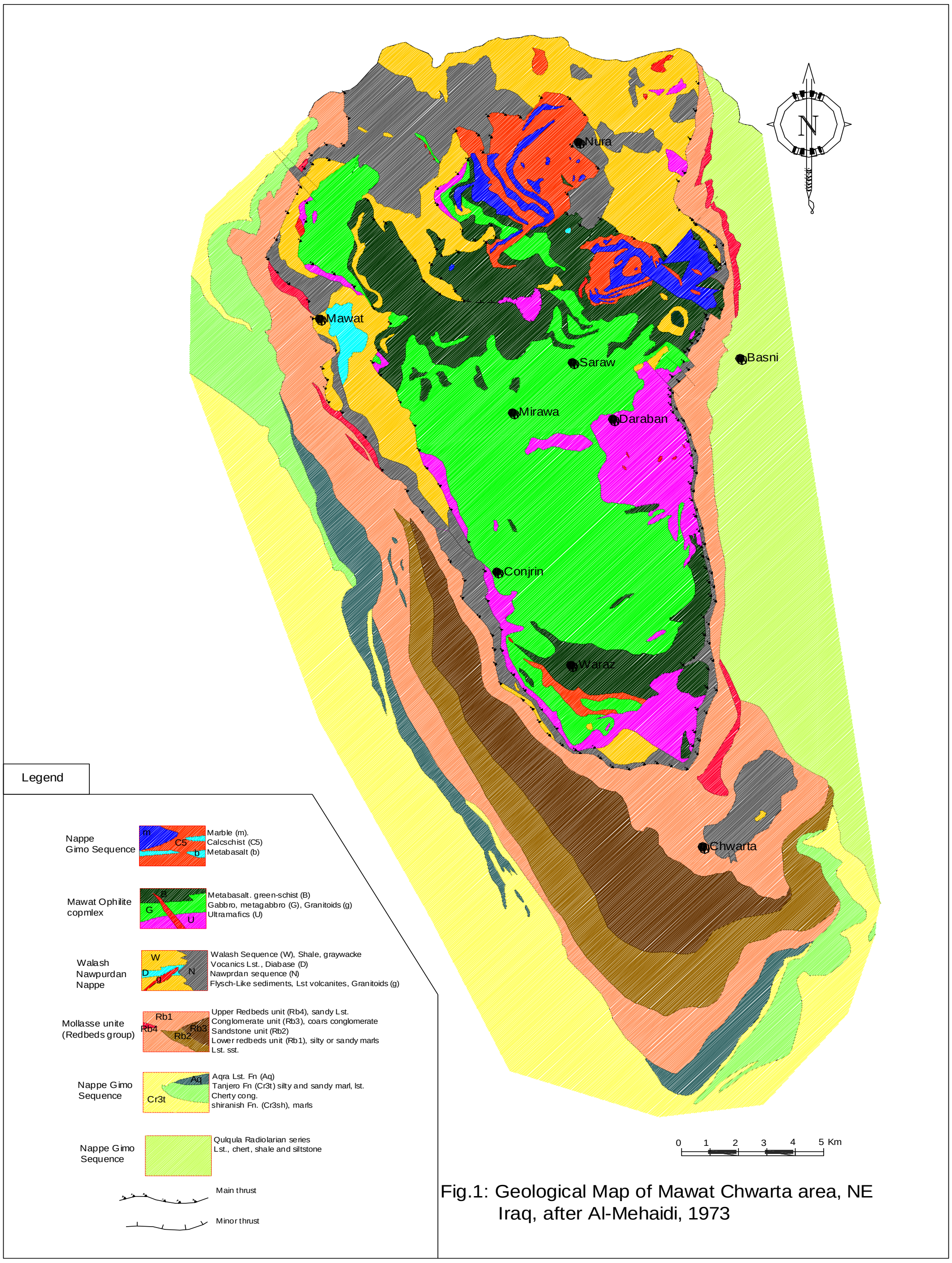


Fig.1: Geological Map of Mawat Chwarta area, NE Iraq, after Al-Mehaidi, 1973

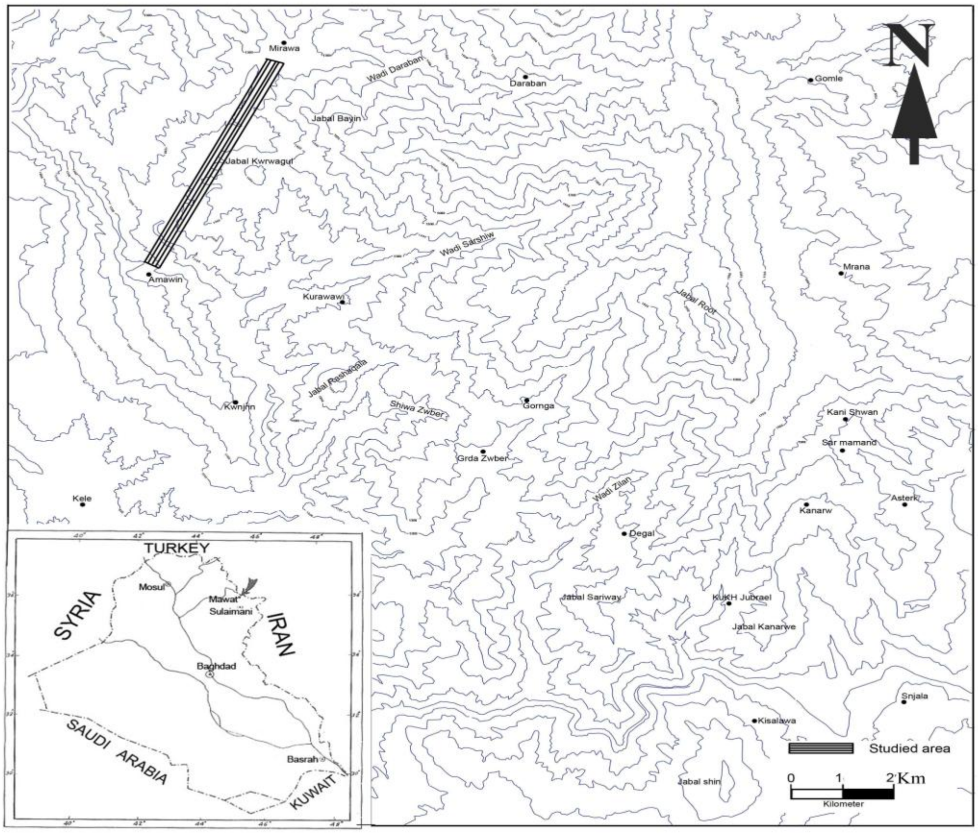


Fig. (2) The topographic map of MOC and location of the studied samples.

Fig.(3) Small bosses of plagiogranite associated with gabbro in MOC.

Geological background

The MOC represents an elevated area that is flanked by a relatively low topography. It is triangular in shape bordered by the Lesser Zab River (Iranian border) from the north and by a topographically low region composed of softer sedimentary rocks from the east, south and west. This complex is drained towards the Zab River from the north while the stream network in the central and southern part drains towards the plain of Choarta and finally into the Lesser Zab River. The highest peak in the MOC is situated in its central part, reaching a maximum elevation of 2750 meters above sea level (Al-Hassan, 1975).

The geology of MOC has been studied by some earlier workers (Jassim, 1972, Jassim & Al- Hassan 1977, Jassim & Goff, 2006, Al-Hassan, 1975, Asawd, & Ojha1984, Aswad & Elias, 1988, Aswad 1999, Al- Aqrawi, 1990,). All these workers focused on petrography, geochemical investigation and tectonic setting of ultrabasic and basic rocks. While the acidic rocks (plagiogranite) were described by Jasssim,(1972), and Jassim and Al- Hassan, (1977) petrographically as albite granites without any geochemical investigation.

Sampling and petrography

The investigated area lies between Amadine and Merawa village (fig 2) the most common rock types include gabbros which are progressively more sheared to the west of Merawa and also intruded by numerous small igneous bodies.The plagiogranites are well developed within the gabbro between Amadine and Merawa village. They occur as intrusive in the form of small bosses and veins (fig 3). They are medium to coarse grained, consisting predominantly of quartz and plagioclase with rare K-feldspar. They vary in width from few centimeters to few meters, and their length can seldom be traced for more than 50 m.The gabbroic rocks are traversed by joints and these joints are concentrated in acute and vertical shear belts.

Eleven samples were collected from the investigated area; seven samples (A1 to A7) from the plagiogranites and four samples (A2-2, A4-1, A5-1, A7-2) from the gabbros associating these plagiogranite rocks.Under the microscope the petrography of these samples is relatively simple.The plagiogranite exhibits granular hypidomorphic texture consisting predominantly of quartz and plagioclase (typically albite An_{0-5}), with rare K- feldspar.The subordinate minerals represented by, biotite, amphibole, clinopyroxene, and epidote.The albite forms between (50-65 %) of the rock, quartz forms between (18- 26 %), (table 1) they plot in the low pressure field on the normative Or-Ab-An triangular diagram,and represent a trondhjemite composition (fig 4). The associating sheared gabbroic rocks range in grain size from fine grained to medium.They are mainly composed of labrodorite ($An._{60}$ - $An._{70}$) and range between(19-48)percent in modal percentage.Amphibole which is present as fibrous and as small euhedral crystals ranging between 11-47 %,pyroxene is present as partially altered crystal of clinopyroxene to amphibole but they preserve their main structure as clinopyroxene ranging in modal volume % between 6-15%. Chlorite,epidote,quartz and opaque are presents as accessories(table 1). Some of plagioclase lath show alteration with development of sericite and epidote.Quartz is present in sheared gabbro reaching up to(20 %)of the mode.This mineral is interstitial and has been related to later magmatic activity that produced the plagiogranite(Jassim, 1972).The quartz grains have pronounced undulose extinction indicating later deformation.

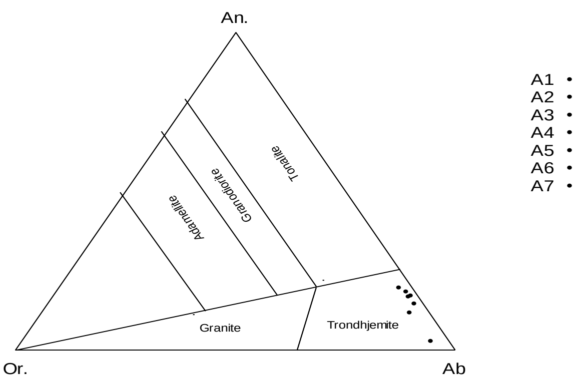


Fig.4. Normative Or-Ab-An triangular diagram showing plotting of plagiogranitesamples from MOC.

Table(1): Modal volume % of mineral composition of plagiogranite and gabbro

samples	Plagiogranite							Gabbro			
	A1	A2	A3	A4	A5	A6	A7	A2-2	A4-1	A5-1	A7-2
Ca-Plagioclase	12	11	11	12	9	2	8	41	19	48	20
Albite	58	52	56	50	51	65	59	0	0	0	0
Orthoclase	2	1	1	2	1	3	3	0	0	0	0
Quartz	18	24	22	25	26	22	18	0	8	26	20
Clinopyroxene	2	2	1	0	5	3	2	15	11	10	6
Biotite	1	2	2	2	1	1	1	0	0	0	0
Iron oxide	0	0	0	0	0	0	0	1	6	3	5
chlorite	0	0	0	0	0	0	0	4	5	0	1
Hornblend	5	7	5	6	3	4	5	39	47	11	46
Epidote	2	1	2	3	4	0	4	0	4	2	2

Analytical technique

Major and trace element composition of 11 samples including gabbro and felsic rocks were determined on fused glass beads and press powder pellets, respectively,on a Thermo-ARL Advant΄XP+ X-ray fluorescence spectrometer XRF)at GeoAnalytical laboratory,School of Earth and Environmental Sciences department,Washington State University Rare earth elements(REE),and Ba,Th,Nb,Y,Hf,Ta,U,Pb,Rb,Cs,Sr,Sc,and Zr were determined on subset of three felsic samples and four gabbros by Hewlett Packard(Agilent)HP 4600 inductive coupled plasma-mass spectrometer(ICP-MS)at Washington State University.Geochemical data are shown in Table 2& 3.

Table(2): The results of XRF analysis of plagiogranites and associated gabbros in MOC.

Oxides	Plagiogranite							Gabbro			
	A1	A2	A3	A4	A5	A6	A7	A2-2	A4-1	A5-1	A7-2
SiO2	67.36	69.5	70.2	71.6	70.8	70.48	68.21	52.85	35.57	58.13	48.16
TiO2	0.323	0.314	0.29	0.44	0.14	0.08	0.111	0.256	1.130	0.809	0.520
Al2O3	15.47	14.35	15.11	14	12.9	13.38	14.65	15.75	15.28	13.98	16.58
FeO*	1.69	1.72	1.45	1.8	2	1.05	2.01	6.14	22.34	10.12	9.69
MnO	0.026	0.024	0.023	0.04	0.06	0.003	0.033	0.104	0.177	0.108	0.188
MgO	2.89	2.65	2.84	2.1	1.39	1.89	2.43	8.31	7.66	3.79	6.00
CaO	2.79	3.01	2.88	2.6	3.079	1.31	3.1	13.81	6.65	9.46	15.81
Na2O	6.65	5.99	6.52	5.59	5.8	7.4	6.77	0.99	0.14	1.40	0.31
K2O	0.26	0.23	0.19	0.3	0.2	0.453	0.512	0.06	0.01	0.03	0.03
P2O5	0.072	0.065	0.081	0.01	0.04	0.147	0.033	0.020	0.016	0.053	0.028
Sum	97.53	97.853	99.584	98.48	96.409	96.193	97.859	98.28	88.97	97.88	97.32
LOI(%)	0.91	0.92	0.65	0.7	1.2	1.03	0.9	1.32	4.47	1.14	2.11
Traces(ppm)											
Ni	62	58	50	49	46	50	60	72	47	20	77
Cr	81	65	77	54	85	90	59	93	23	9	386
Sc	6	5	8	10	10	8	11	48	58	38	64
V	39	46	50	60	40	55	43	221	756	318	315
Ba	141	165	139	150	200	211	188	16	18	3	0
Rb	3	2	1	3	1	2	3	0	0	1	1
Sr	766	854	765	900	1000	978	798	117	125	139	206
Zr	63	55	61	80	72	62	77	20	8	32	19
Y	8	10	11	16	14	12	9	9	9	20	16
Nb	9.2	10	11	15	13	12	10	0.5	0.0	1.1	0.6
Ga	17	15	19	25	20	17	24	14	18	17	16
Cu	12	10	9	8	8	7	11	1	12248	7	3
Zn	7	8	5	4	6	5	7	19	95	13	39
Pb	5	2	4	5	7	6	9	0	2	0	2
La	15	20	17	21	21	33	18	1	2	2	1
Ce	27	32	35	22	29	32	31	1	1	5	1
Th	8	9	10	14	13	11	8.5	0	2	0	0
Nd	14	13	13	16	19	18	17	3	0	4	2

Table(3): The results of REE analysis(ICP-MS)of plagiogranite and associated gabbro in MOC.

Sample ICP- MS (ppm)	Plagiogranite			Gabbro			
	A1	A2	A4	A2-2	A4-1	A5-1	A7-2
La	14.39	11.56	10.11	0.46	0.45	1.11	1.11
Ce	26.59	23.25	15.21	1.45	1.31	3.41	2.89
Pr	2.91	2.45	1.9	0.25	0.21	0.6	0.44
Nd	10.35	8.88	6.78	1.47	1.23	3.53	2.32
Sm	1.95	1.95	1.52	0.65	0.54	1.59	1.01
Eu	0.57	0.63	0.45	0.26	0.34	0.57	0.48
Gd	1.68	1.5	1.11	1.06	1.03	2.49	1.71
Tb	0.24	0.21	0.14	0.22	0.22	0.52	0.38
Dy	1.25	1.11	0.88	1.61	1.55	3.68	2.7
Ho	0.24	0.22	0.18	0.36	0.37	0.83	0.63
Er	0.61	0.6	0.5	1.06	1.07	2.42	1.87
Tm	0.09	0.07	0.06	0.17	0.16	0.37	0.29
Yb	0.55	0.44	0.4	1.06	1	2.33	1.9
Lu	0.09	0.072	0.061	0.17	0.16	0.37	0.32
Other Elements							
Ba	141	165	150	18	3	6	6
Th	3.41	7	11	0.12	0.05	0.18	0.28
Nb	9.9	11	8	0.24	0.3	0.71	0.61
Y	6.34	5.2	4.7	9.19	9.07	20.9	16.18
Hf	1.82	3.22	2.53	0.63	0.31	1.07	0.62
Ta	0.89	0.78	0.76	0.02	0.02	0.06	0.04
U	0.58	0.44	0.51	0.06	0.22	0.12	0.14
Pb	2.6	2.4	2.8	0.16	0.31	0.39	0.67
Rb	2.5	2.5	2.7	1.1	0.1	0.6	1.7
Cs	0.02	0.04	0.03	0.24	0.26	0.13	0.46
Sr	726	750	900	120	143	141	215
Sc	5.7	5	6	52.9	62.2	41.7	71.9
Zr	53	55	80	16	7	28	16

Geochemistry

Major elements:

The plagiogranites are characterized by higher SiO_2 (67-71 %), Na_2O (5.59-7.4 %) and CaO (1.31-3.1 %) with lower K_2O (0.19-0.512 %) content when compared with normal granite. On using SiO_2 vs. K_2O diagram they plot in the field of oceanic plagiogranites (fig.5).

The plagiogranite and gabbroic rocks have low total alkali content. For the plagiogranite the total alkali contents is (5% < $Na_2O + K_2O$ < 10%), and for the gabbroic rocks it is between 0.15 to 1.43. They are poor in potassium and plot in the low- K- tholeiite felid (fig.6). The molar A / CNK ratios of plagiogranite vary between 0.85-1.0078. Thus all rocks are metaluminous (fig.7), (Debon & Lemmet, 1999).Major elements variation of the gabbroic rocks along with the plagiogranites is shown on Harker diagram (fig.8). Although they are generally scattered except for (Na, Mg, Fe) they do confirm the discrimination between two plutonic rock types. The element on these diagrams show that Na increases with increasing SiO_2 content, while elements like Mg, Fe shows negative behavior with SiO_2. This is an indication that Fe, Mg are not controlled by magmatic differentiations

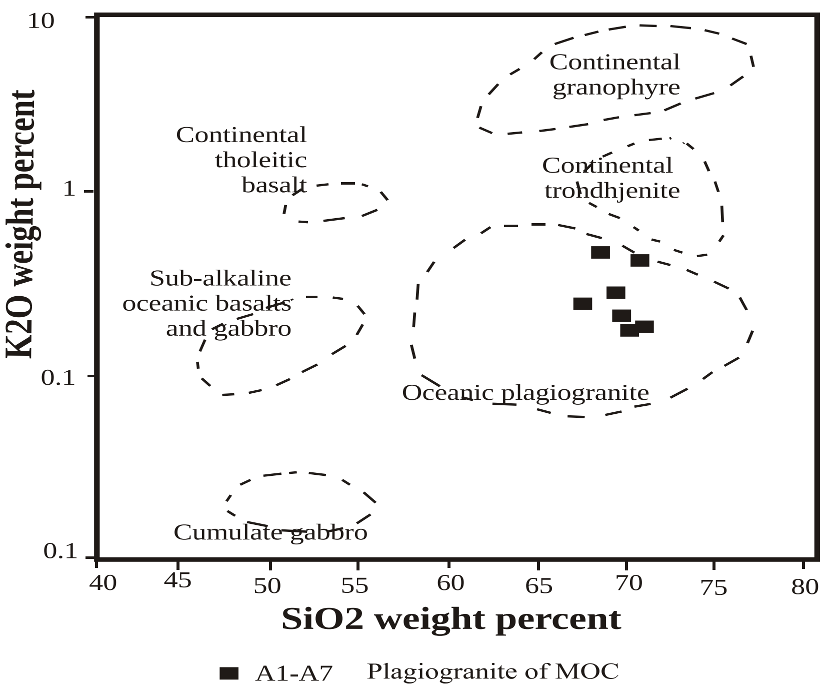


Fig.(5): Semi log plot of SiO_2 versus K_2O (Coleman, 1977) and location of the studied samples.

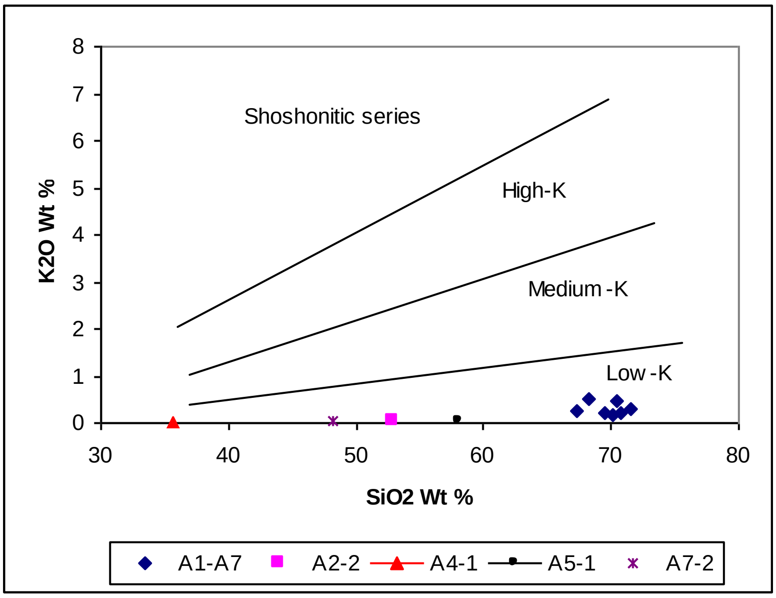


Fig.6. K_2O vs. SiO_2 showing the limits of the fields of calc-alkaline and shoshonitic series after (Le Maitre et.al, 1989 and Rick, 1989).

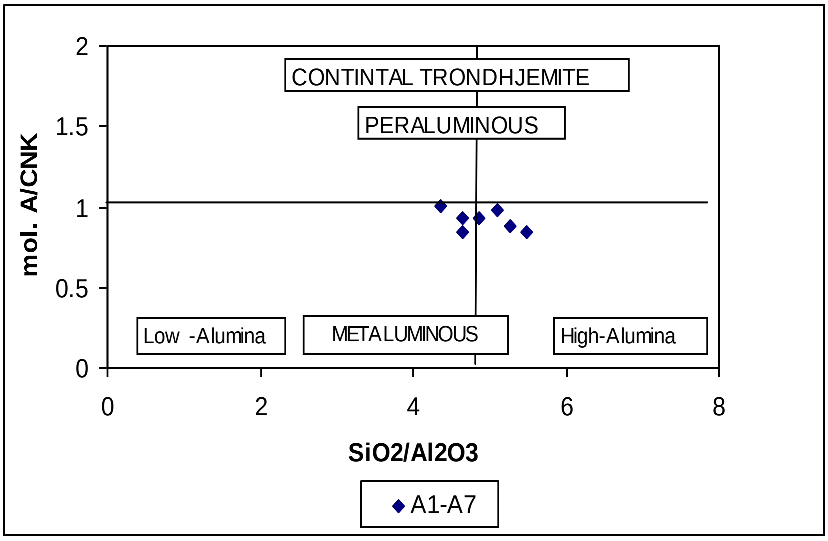


Fig.(7) SiO_2/ Al_2O_3 vs. mol. A/CNK showing plagiogranites from MOC. Field demarcations are after (Debon & Lemment,1999 in Rameshwar et al., 2004).

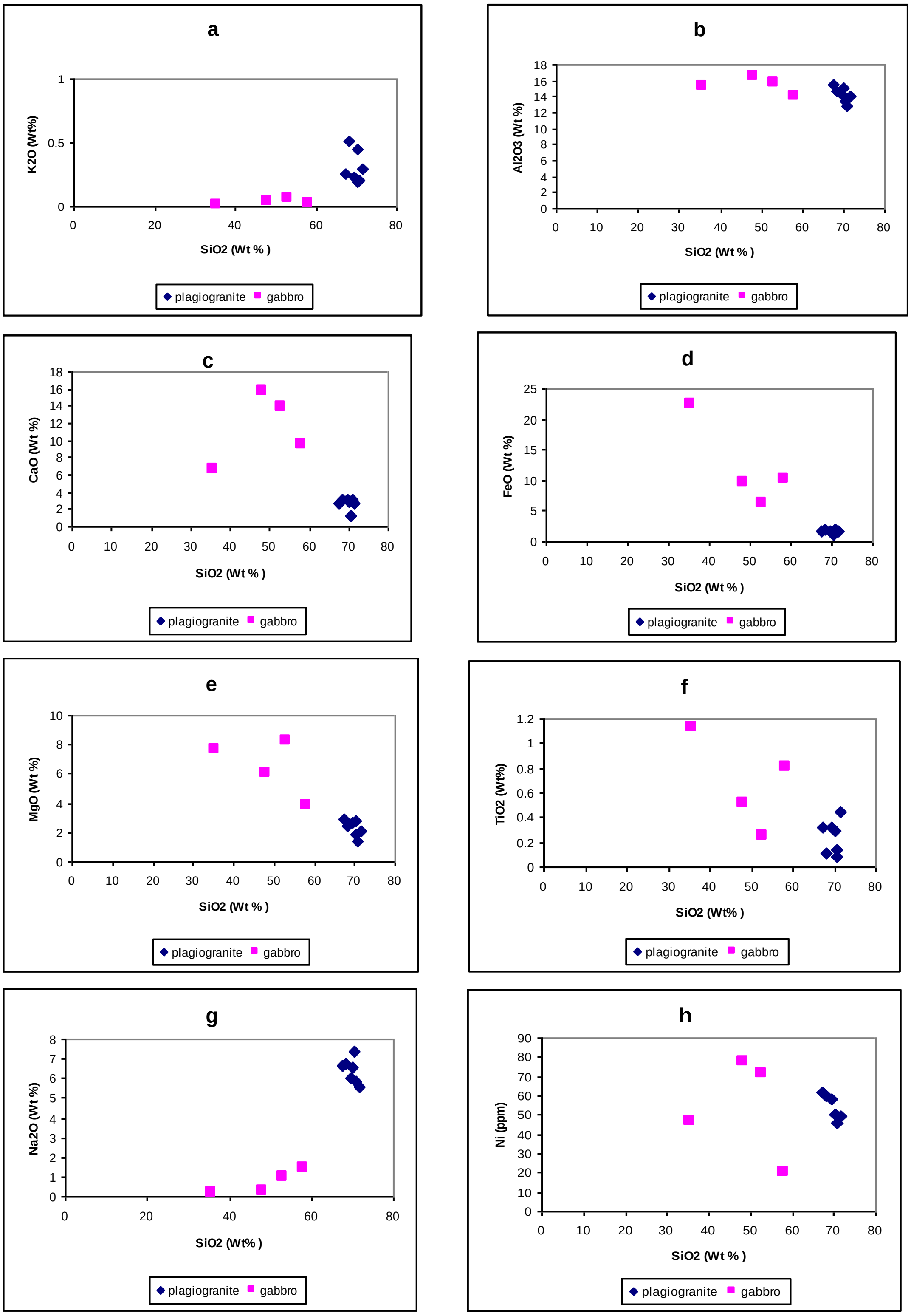
Trace and rare earth elements:

The variations of trace elements against SiO_2 are shown in (fig.8). The fractionation trends on variation diagrams of gabbroic rocks along with plagiogranites showing that elements like Nb, Y, Th, increase with increasing SiO_2 content. Elements like Zn, show negative behavior with SiO_2 and the elements Ga, Cu, Ni, Cr are show scatted relation with SiO_2. Reported data from analyzed elements (Y, Nb, Rb) versus SiO_2 discriminant diagrams and plots of Rb versus (Y+Nb) in (figs.9 a,b,c, and d) show a characteristic tendency of volcanic arc granite.

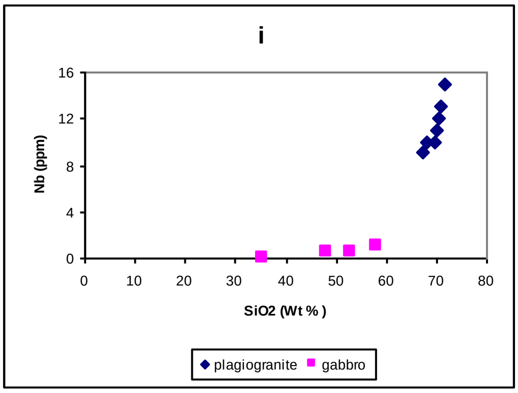
Trace elements distribution patterns (fig. 10a)show that the Mawat plagiogranite are enriched in large ion lithophile (LILE) elements Cs, Rb, Ba, Sr, over the other incompatible elements (Nb, Zr, Hf, Y). This feature is commonly apparent in volcanic arc granite that is normally characterized by enrichment in Rb, Ba, Th, typical in calc-alkaline series Nyamai et al. (2003).While the associated gabbro have negative anomalies Rb, Nb, Pb and positive anomalies in U, Sr, (fig.11a). The small negative Nb anomalies may be taken as indicator of the crust contamination of parent magma or island arc setting (Ahmad Hassan, University of Helwan, personal communication), and the strong positive Sr anomalies may be attributed to hydrothermal fluid affecting the gabbroic rocks and leads to metamorphism of lower crust mafic igneous rocks.

The REE patterns of plagiogranites (fig.9b) show steep REE patterns enriched in La-Sm and depleted in Gd-Lu with (La/Yb) ranging from 18.3 to 18.66.

The REE patterns and trace elements distribution patterns of gabboric rocks are compared with the REE patterns and trace elements distribution patterns of MORB (the compared MORB data from Workman and Hart, 2004). They show that gabbroic rocks of MOC have a MORB- like, slightly LREE depleted pattern (fig.11b) with $(La/Yb)_N$= 0.307-0.337), and the trace element distribution patterns of gabbroic rocks in MOC are in agreements with MORB trends.



Fig(8)Harker diagrams of selected major and trace elements in plagiogranite and associated gabboic rocks of MOC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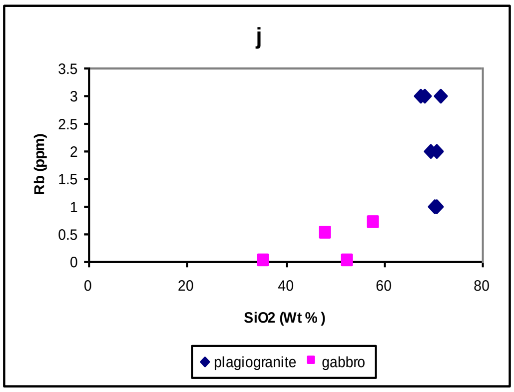
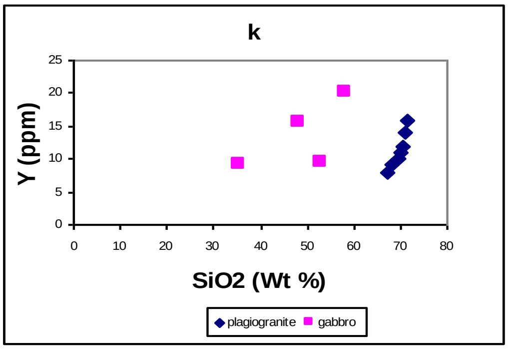
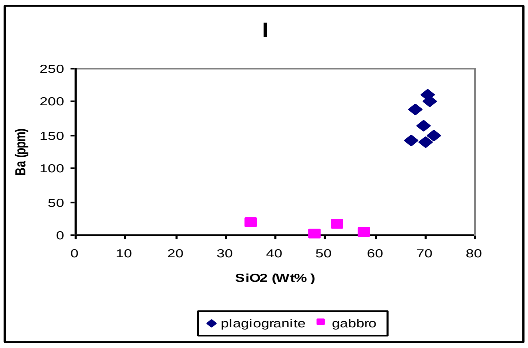
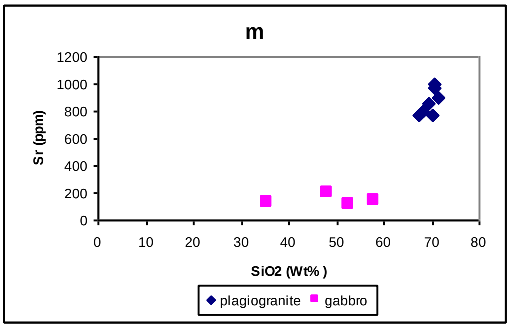
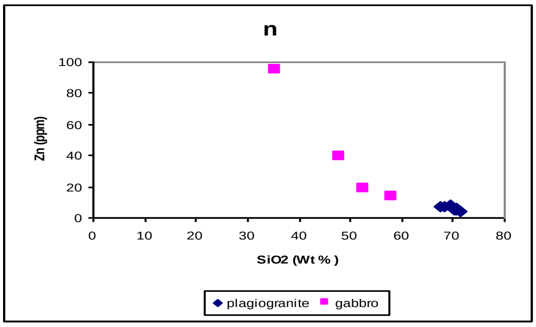
Nb (ppm)
SiO2 (Wt %)
plagiogranite
gabbro


j
Rb (ppm)
SiO2 (Wt %)
plagiogranite
gabbro


k
Y (ppm)
SiO2 (Wt %)
plagiogranite
gabbro


l
Ba (ppm)
SiO2 (Wt%)
plagiogranite
gabbro


m
Sr (ppm)
SiO2 (Wt%)
plagiogranite
gabbro


n
Zn (ppm)
SiO2 (Wt %)
plagiogranite
gabbro

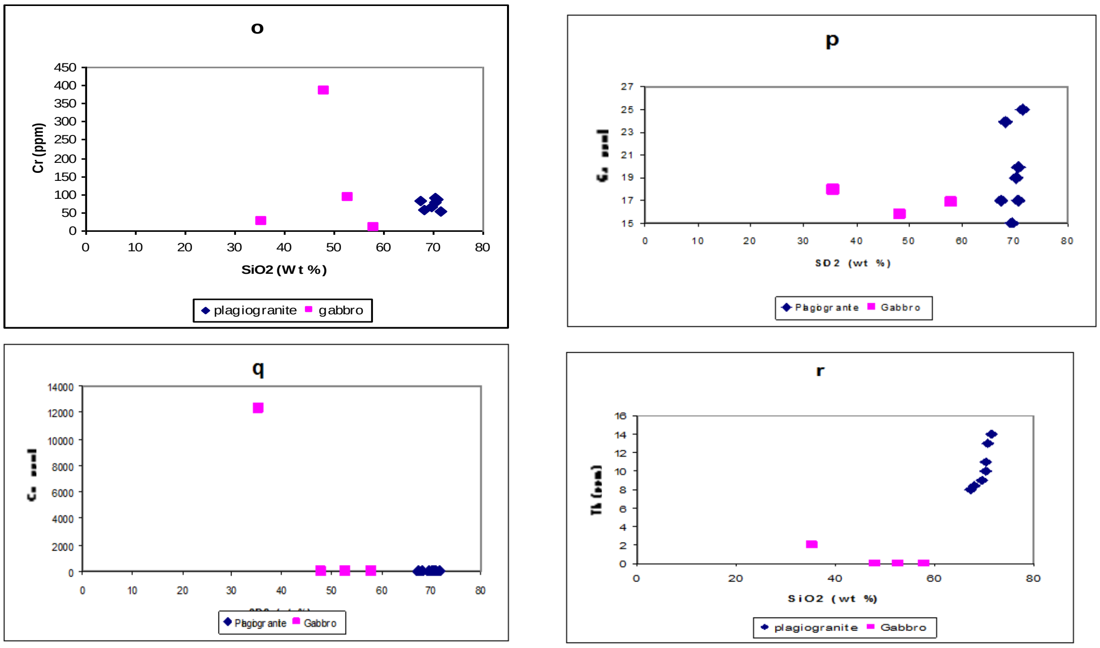


Fig. 8 continued

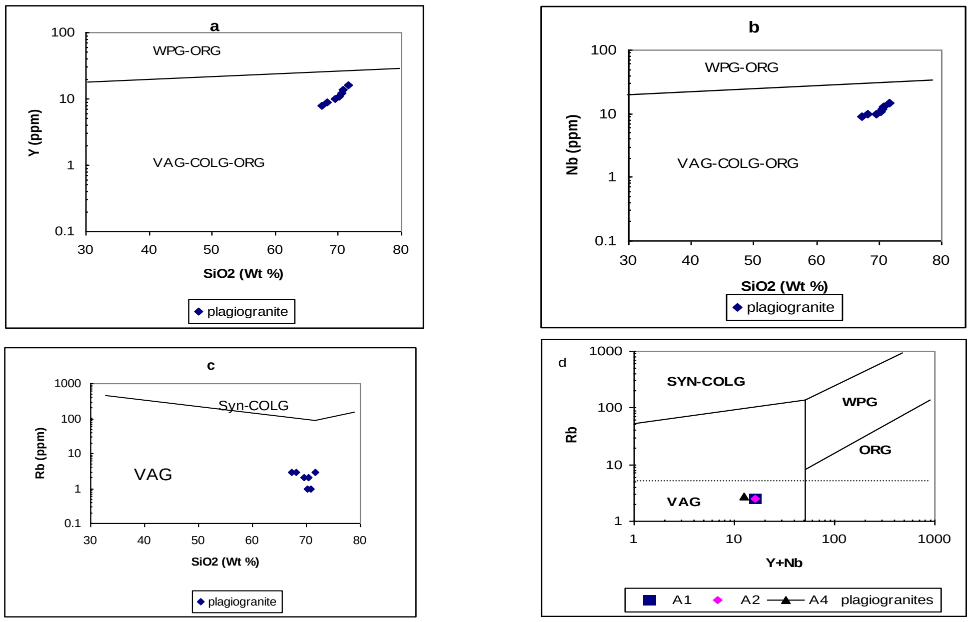


Fig. 9 SiO_2 variation diagram for Rb, Nb, Y and Rb versus Y+Nb on the granitic rocks of the Mawat area discriminating between the various tectonic environment VAG-volcanic arc granite, Syn-COLG, Syn Collision granite, ORG-Orogenic granite, WPG-Within plate granite (Diagram after, Pearce et al.1984)

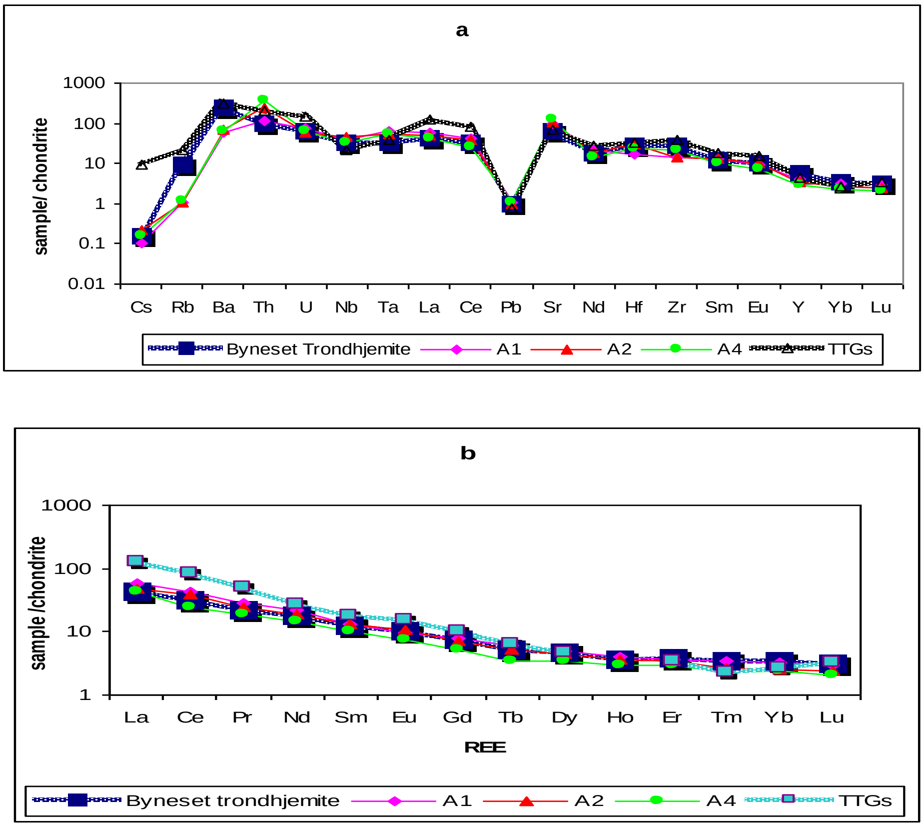


Fig.10. Chondrite – normalized trace elements contents (a) and REE patterns (b) of plagiogranite from Mawat Ophiolite Complex. The normalized values are from O'Neill and Palme (1998). The data are compared with Byneset trondhjemite(Slagstad, T.; 2003) and average TTGs (Drummond et al. 1996).

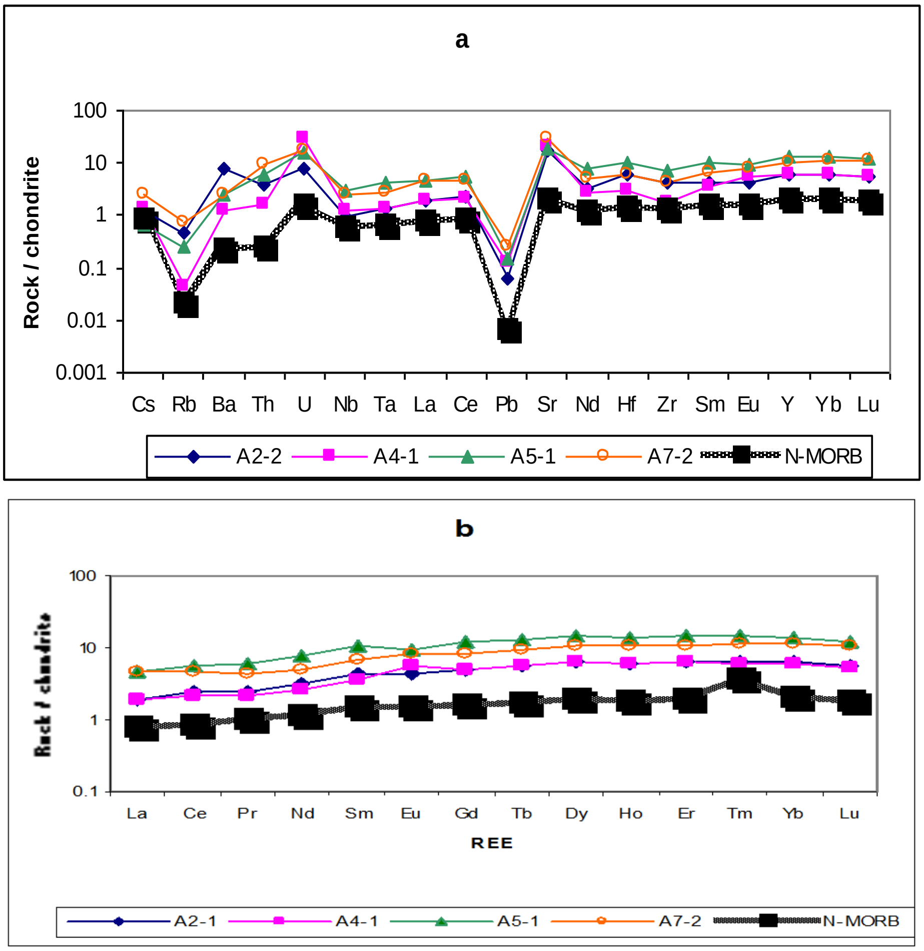


Fig.(11) Chondrite – normalized trace elements contents (a) and REE patterns (b) of gabboric rocks associated with plagiogranite in MOC.The normalized value from O'Neill and Palme (1998). The data are compared with the N-MORB (Workman &Hart, 2004).

Petrogenesis of Trondhjemite in MOC. :

The experimental studies suggest three principal mechanisms for the production of silica – rich magma leading to the generation of plagiogranites in the oceanic crust I- extreme crystal fractionation (Coleman & Petrrman, 1975, and Colleman,1977), II- liquid immiscibility (Dixon & Rutherford, 1979), and III- partial melting of basic rocks like amphibolites under hydrous conditions (Gerlach and et.al. 1981, Pedersen and Malpas, 1984), or of hydrated basaltic / gabbroic rocks (Payne, and Strong 1979). Other workers (Coleman and Donato, 1979, Brown and et. al, 1979, Sinton and Byerly, 1980) suggest that the high Na_2O and low K_2O content in plagiogranite is related to direct leaching of

K_2O from the magma into the circulating sea water that gained access to magma chamber, or to late magmatic vapor phase transport and removal of K_2O. A majority of them have attributed the origin of ophiolitic plagiogranites to the differentiation of subalkaline tholeiitic magma (Coleman & Donato, 1979).

(Rapp and Watson, 1995, Slagstad, 2003explaned that the trondhjemite and TTGs have a major and trace element composition similar to rocks formed by partial melting of mafic source leaving garnet – bearing amphibolitic or eclogitic residue. On using the Y vs. Sr/Y diagram (fig.12) the Mawat plagiogranite samples,plots in the field of Archean TTGs (tonalite-trondhjemite-granodiorite) and adakites (fig 12) this field is interpreted by Drrummond and Defant,(1990) to have formed by partial melting of mafic source in the stability field of garnet. However the concentration in HREE in Mawat plagiogranites less 10 times than the chondrite values and Y content do not support the assumption that the source contained garnet. Moreover, the spider diagrams (fig.9a) show no negative anomaly in Y suggesting that garnet was not involved in the residual phase. The same conclusion is noted by Nzenti and et.al, (2006) during their study on granitoids rocks in Pan – African shear zone in Cameron. Although most workers favor fractional crystallization of gabbroic magma as most likely petrogenetic model for plagiogranite, some workers have proposed that they can form by partial melting of mafic source (e.g. Gerlach et al, 1981 and Selbekk, et.al, 1998). Therefore the geochemical data of plagiogranite associated with gabbroic rocks from MOC comparable with average composition of Byneset trondhjemite given in Bymarka Ophiolite fragment in Norway and average trondhjemite tonalite and granodiorites (TTGs, Drummond et al. 1996) which are formed by (partial melting of thick pile of mafic ocean floor/island arc related rocks stacked onto continental or micro continental margion).

The comparison shows that the MOC plagiogranite is similar in REE and trace element distribution patterns to Byneset trondhjemite and TTGs (fig 9a, & b).

Also on using molar CaO / MgO+FeO vs. molar Al_2O_3 / MgO + FeO (Altherr, et.al, 2001) all samples of studied area plot in the field of partial melts of metabasaltic to metamorphic source (fig.13). Therefore we suggest that the genesis of Mawat trondhjemite rocks was partial melting of hydrated basaltic/ gabbroic rocks.

Geotectonic setting:

The available analytical data at the moment cannot provide an unambiguous answer about geotectonic setting of the MOC. Analyzed gabbro samples, which have been plotted on Nb*2-Zr/4-Y (Meshede 1986) (Fig 14-A) and Vvs.Ti (Shervais 1982) diagrams (Fig 14-B) represent MORB and VAB fields. The same is confirmed by chemical compositions of REE and trace elements distribution patterns of gabbroic rocks which is similar to the REE and trace elements pattern of MORB (figs 11a & b). The Mawat plagiogranites have geochemical characteristic in common with Byneset trondhjemite of Bymaka Ophiolite fragment and TTGs which is formed by partial melting of subducted oceanic crust. These melts must pass through the overlying mantle wedge and are likely to react with peridotite in the mantle wedge during their ascent (Rapp et.al, 1999). However, the relatively low Cr and Ni contents of the Mawat plagiogranite appear to rule out significant interaction with peridotite in the mantle wedge. The REE patterns of Mawat plagiogranite have light REE-enrichment (fig. 9b) and similar to Byneset trondhjemite and TTGs therefore we suggest that the Mawat plagiograniteare formed by partial melting of mafic rocks.

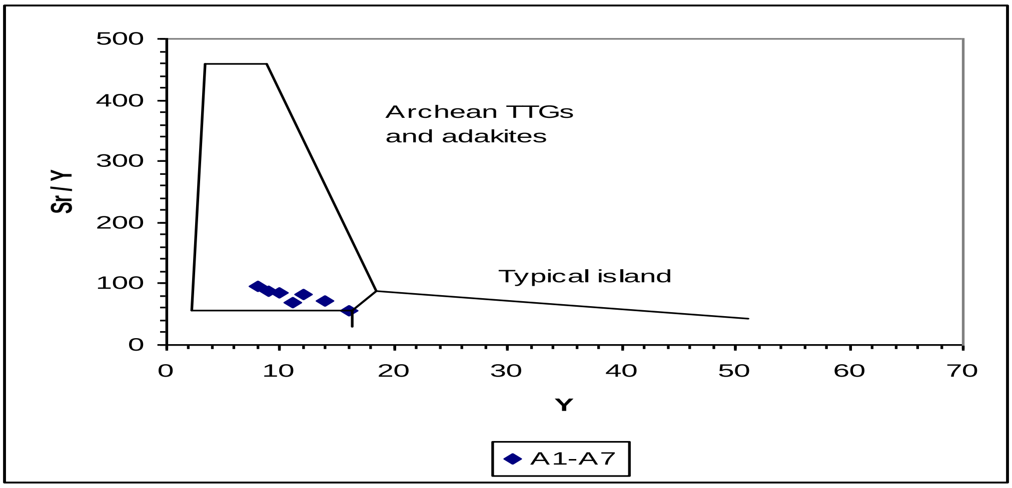


Fig.(12)Y- Sr/Y diagram showing that the Mawat plagiogranite in MOC is similar to Archean TTGS (tonalite-trondhjemite-granitoid) and interpreted to have formed by partial melting of mafic source (Drummond & Defant, 1990).Compositional fields after Hansen et al. (2002).

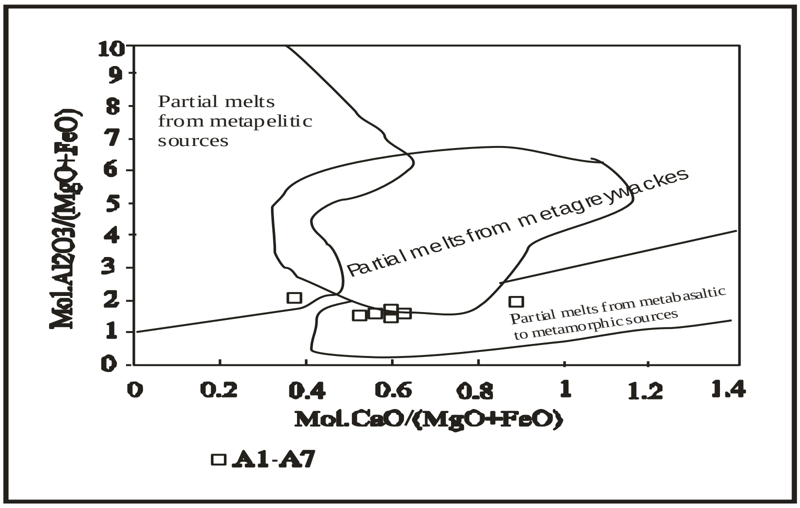
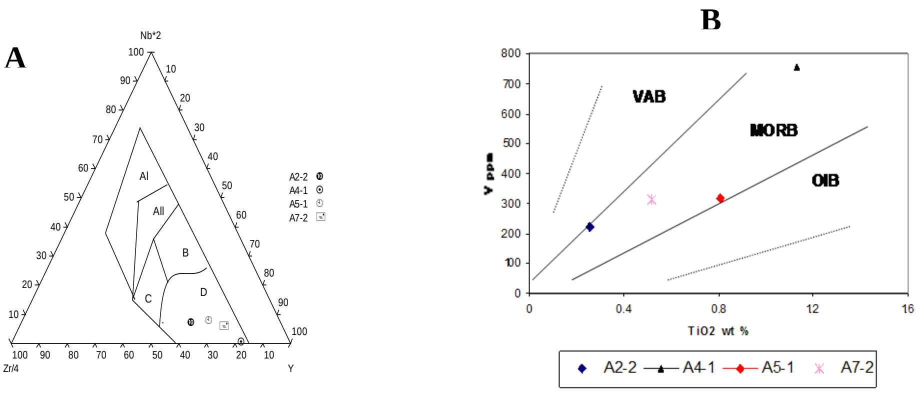


Fig.(13) Molar Cao / (MgO+ FeO) vs. Al_2O_3 (Altherr et al., 2000) for Mawat plagiogranite.



Fig(14) Diagram for analyzed rocks A&B shoing the geotectonicsetting of MOC. **A**: Nb*2-Zr/4-Y (Mseshed 1986) Al: within- plate alkali basalt, All: witin- plate alkali basalt and within-plate tholeiites,B: E-type MORB, C: within plate tholeiites and volcanic arc basin, D: N-type MORB and volcanic-arc baslt **B**:V vs Ti (shervais1982).VAB:volcan arc basalt, MORB: mid ocean ridge basalts, OIB:ocean island basalts

Conclusions

The plagiogranite from MOC are low – K tholeiite intrusions associated with gabbroic rocks in close special association with sheared gabbro between Amadine and Merawa of MOC.The data in this paper indicate that the plagiogranite of MOC are trondhjemite type.

REE data and their distribution pattern of plagiogranite show LREE depletion about 10 times than(fig. 10b) the chondrite values and plot in volcanic arc field in tectonic discrimination diagram.The data also suggest that the Mawat plagiogranites were derived from partial melting of hydrated basaltic / gabbroic rocks.Geochemical characteristic show the tholeiitic magmas have a MORB and VAB affinity.Therefore, determination of geotectonic setting cannot be done precisely.

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أصل صخور بلاجوكرانايت في معقد ماوات الاوفيولتي اقليم كردستان، شمال شرقي العراق

تولا أحمد ميرزا* و صباح أحمد اسماعيل**

***كلية العلوم ــ جامعةالسليمانية**

****كليةالعلوم ــ جامعة كركوك**

الخلاصة

تتكون كتلة الصخور النارية في معقد ماوات الاوفيولتي من اندفاعات مختلفة قاعدية وفوق قاعدية والتي تكون مترافقة مع اندفاعات نارية حامضية ومتوسطة فضلا عن القاعدية.شملت هذه الدراسة الاندفاع الناري الحامضي الثانوي(بلاجوكرانايت)المترافق مع الصخور النارية القاعدية وذلك لاجل تحديد الاصل المحتمل لهذه الصخور .ان اندفاع البلاجوكرانايت من المعقد اعلاه مؤلف بشكل رئيسي من معادن الكوارتز والفلدسيارالقلوي مع تواجد نادر من البلاجيوكليند الكلسي .هذه الصخور هي بالاصل صخور ذات المنيوم متحول ذي صفة كلسية قلوية واطئة البوتاسيوم مع ميزات معدنية وجيوكيميائية الكرانايت البحري (تورندجيمايت).اذ تميز باحتواءها على نسب عالية من Sr,Ba,Th مع نسب اقل من النيكل والكروم.تشير نمط توزيع العناصر الارضية النادرة و المعيارة بالنسبة الى النيازك بالاغناءمن العناصر الارضية النادرة الحقيقية (LREE) ونسبة اغناء متوسطة الى قليلة بالنسبة العناصر الارضية الثقيلة (HREE)انماط توزيع العناصر الاثرية اظهرت بان هذه الصخور غنية وبشكل متميز بالايونات الكبيرة للعناصر ليثوفايل (Lithophile) مقارنة بعناصر HFSE.هذه الصفة هي شائعة الظهور في كرانايت اقواس بجزر البركانية وفسرت اصل صخور بلاجوكرانايت في معقد ماوات الاوفيولتي على انها كنتيجة للانصهار الجزئي لصخور البازات / الكايرو المتميئة.