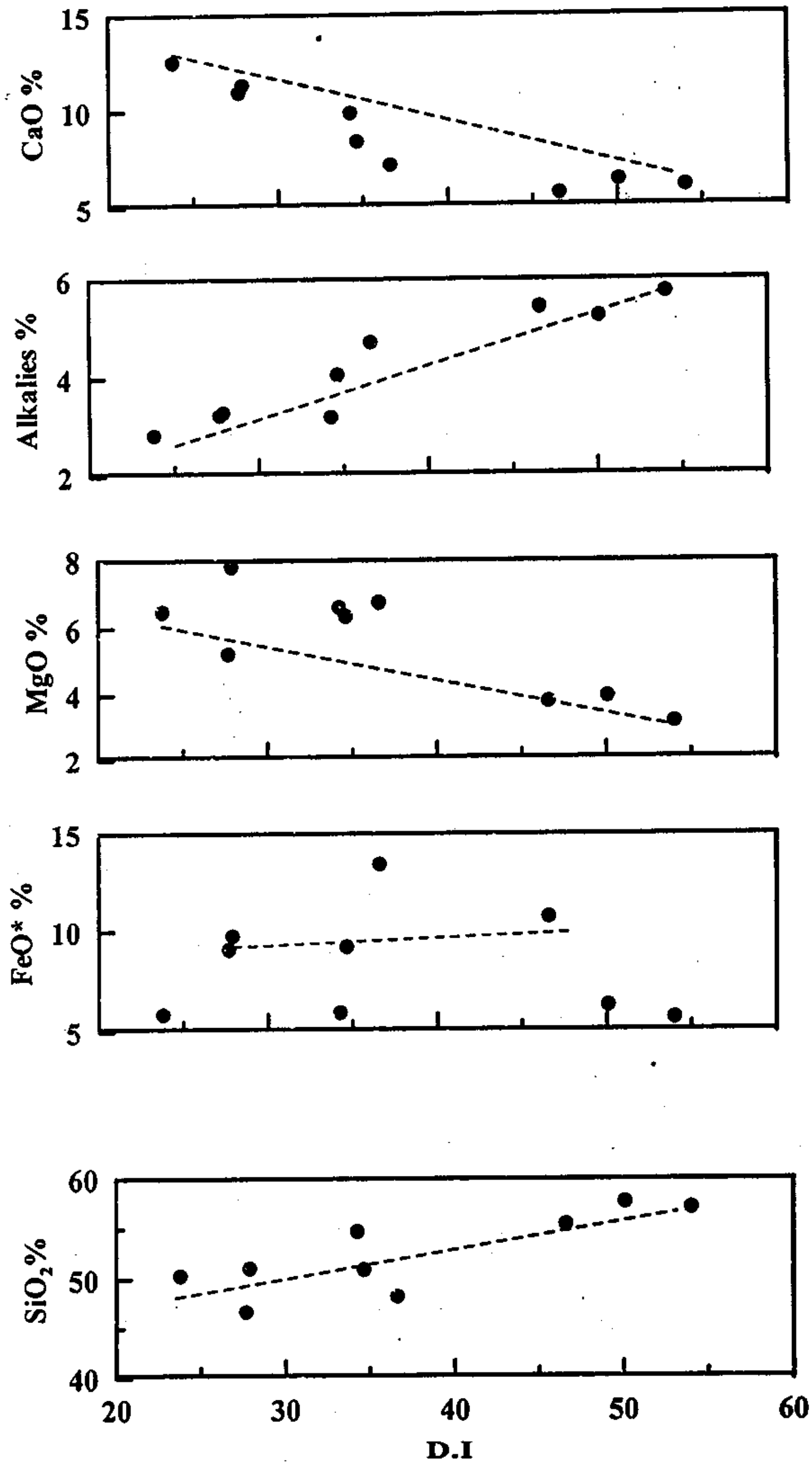

Fig (97): Variation diagram of D.I. (after Thornton and Tuttle, 1960) versus major oxides for the studied metagabbros.

(FeO* represents the total iron as FeO)

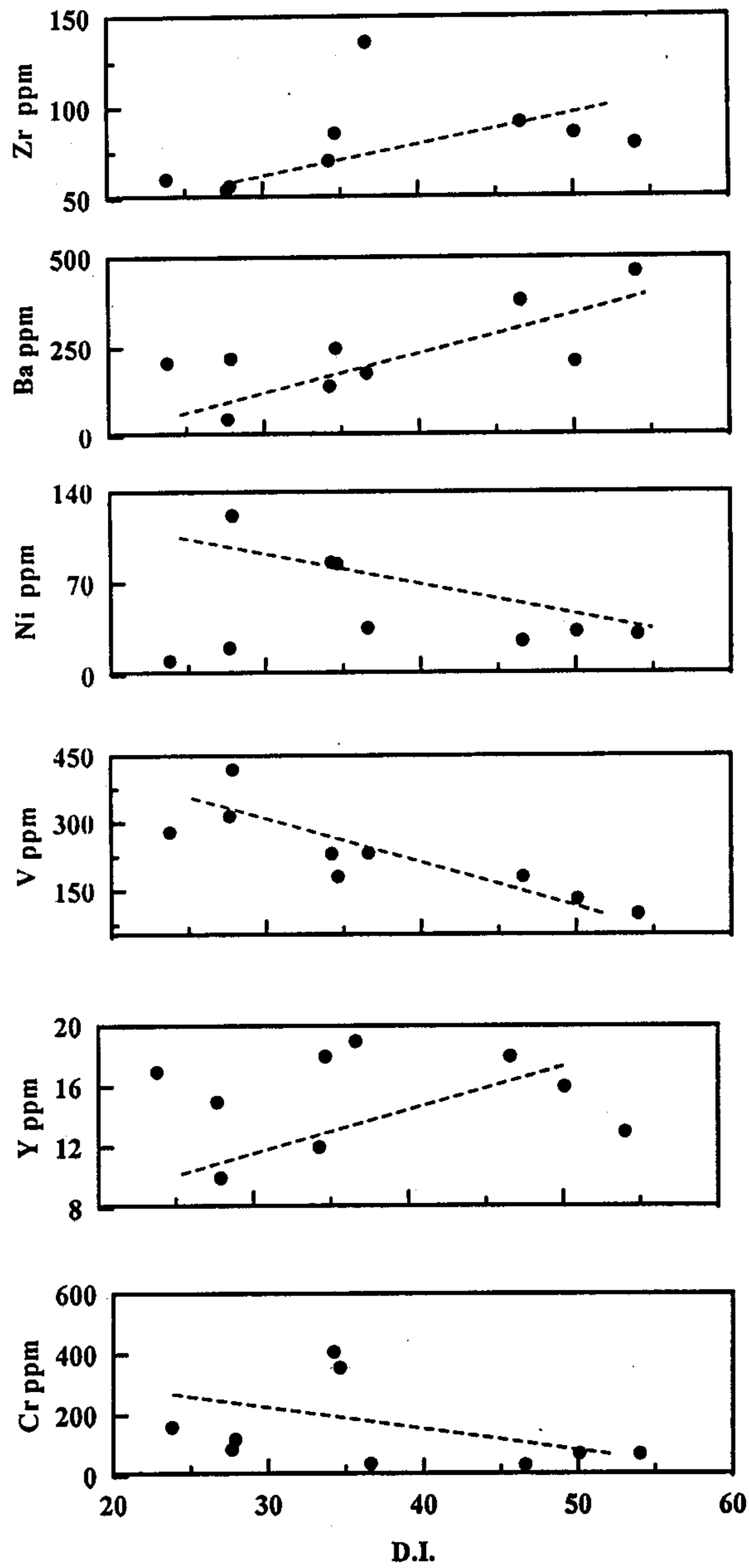

Fig. (98): Variation diagram of D.I. (after Thornton and Tuttle, 1960) versus trace elements for the studied metagabbros.

AFM Ternary Diagrams.

On the AFM ternary diagram (Fig. 100) suggested by **Irvine and Baragar (1971)** to discriminate between tholeiitic and calc alkaline series, most of the data points of the analyzed samples fall in the calc alkaline field (have calc alkaline nature), whereas three samples occupy very close position near the dividing line. i.e. they have weak tholeiitic affinity (mild tholeiite).

SiO_2 versus Cr Diagram.

Based on the relationship between SiO_2 and Cr **Miyashiro (1975)** suggested the diagram (Fig. 101) to discriminate between tholeiitic and calc alkaline fields. The samples points of the examined metagabbros are scattered on both sides of the dividing line between tholeiitic and calc alkaline fields, but the majority of the samples are located in the calc alkaline field. except 2

4.3.5. Tectonic Setting.

The tectonic setting of the studied metagabbros are depicted from the following relationships:

AFM Ternary Diagram.

On the AFM ternary diagram (Fig. 102) proposed by **Coleman (1977)**, which exhibits several fields of well known geotectonic settings; plotting of the present data reveals that most of the samples lie inside the field of oceanic gabbros. Three samples that show relatively higher contents of total alkalies fall outside of the field of oceanic gabbros.

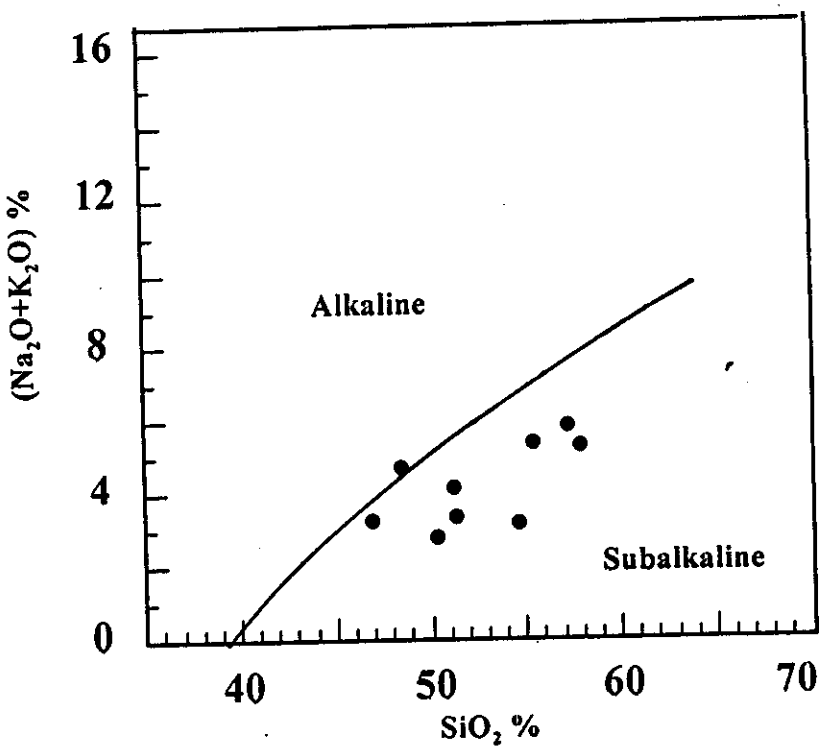

Fig. (99) : Total alkalies versus silica diagram for the studied metagabbros. The dividing line after Irvine and Baragar (1971).

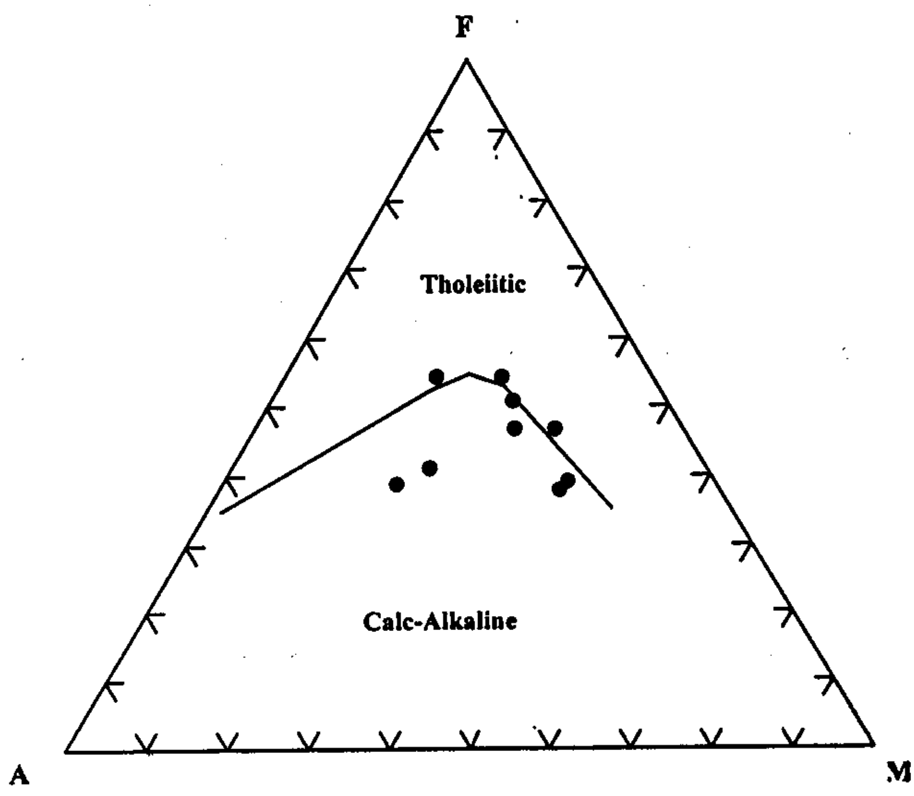

Fig (100) : AFM ternary diagram for the studied metagabbros. Dividing line between tholeiitic and calc alkaline fields after Irvine and Baragar (1971).

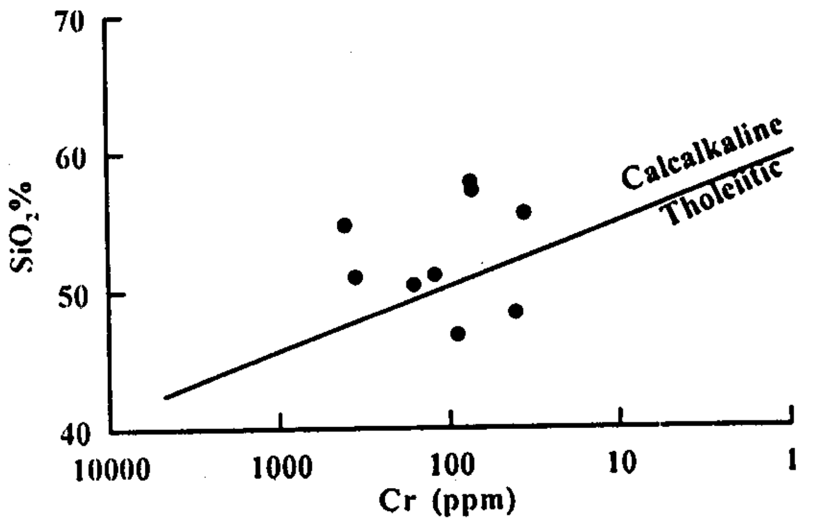

Fig (101) : Silica versus Cr diagram for the studied metagabbros after Miyashiro (1975).

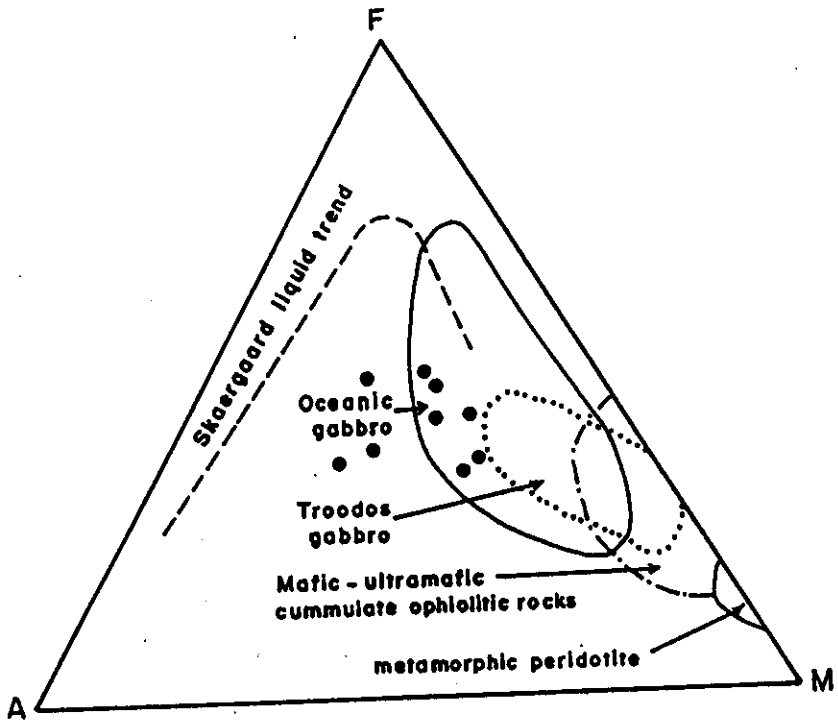

Fig (102) : AFM ternary diagram for the studied metagabbros after Coleman (1977).

TiO_2 versus P_2O_5 Diagram.

Bass et al., (1973) presented the variation between TiO_2 and P_2O_5 contents to differentiate between calc alkaline island arc, mid oceanic ridge basalts (MORB), oceanic island tholeiites and alkali basalt magma types. Figure (103) demonstrates this relationship and shows that, the present sample points exhibit calc alkaline trend (Cascades trend)

Nb*2 - Zr/4 - Y Diagram.

Nb*2 - Zr/4 - Y ternary diagram was suggested by **Meschede (1986)** to discriminate between the basalts of different tectonic settings (Fig. 104). On this diagram, the studied metagabbros fall in the volcanic arc basaltic fields (VAB) which are the volcanic equivalent of gabbroic rocks of the same tectonic settings

Ti/100 – Zr - Y*3 Ternary Diagram.

Ti/100 - Zr - Y*3 ternary diagram (Fig. 105) of **Pearce and Cann (1973)**, by using this diagram the analyzed samples fall in the calc alkaline basaltic field (B, C).

MnO*10 - TiO_2 - P_2O_5*10 Ternary Diagram.

The MnO*10 - TiO_2 - P_2O_5*10 ternary diagram was suggested by **Mullen (1983)** to discriminate between the basalts of different tectonic settings (MORB= mid oceanic ridge basalt; OIT= ocean island tholeiite; OIA= ocean island alkali basalt; CAB= calc alkaline basalt and IAT= island arc tholeiite). On this diagram (Fig. 106), the studied metagabbros fall in the island arc tholeiite (IAT) and calc alkaline basaltic (CAB) fields.

Mullen (op.cit) stated that in island arc rocks MnO is enriched relative to TiO_2 due to the early crystallization of titanomagnetite. The present

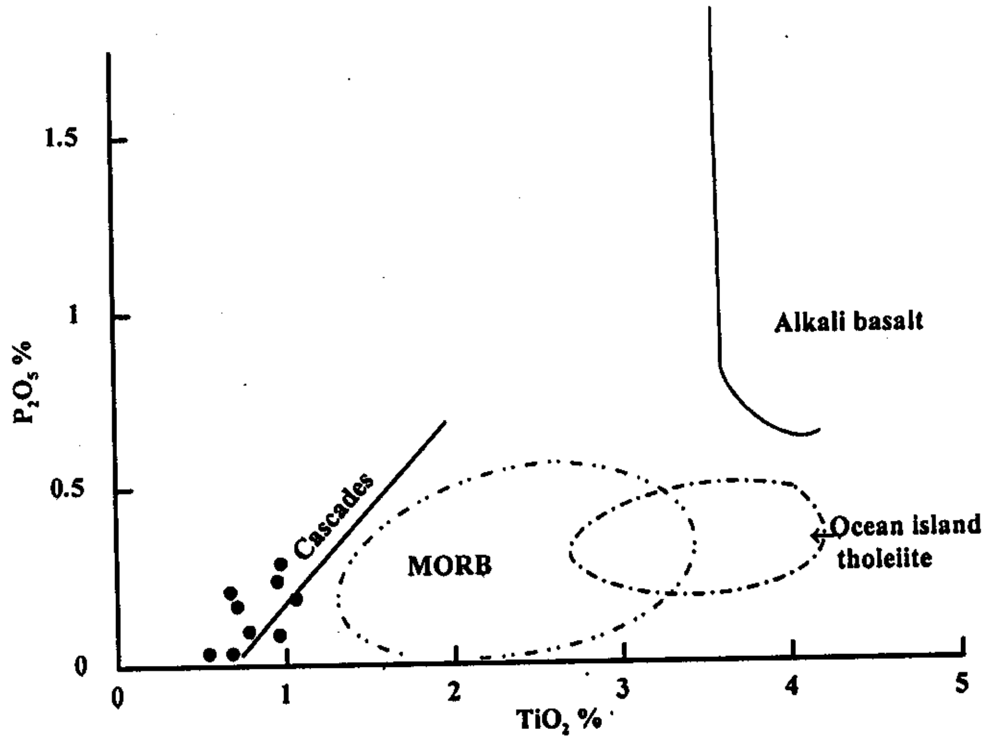

Fig. (103) : TiO2 versus P2O5 diagram for the studied metagabbros after Bass et al., (1973).

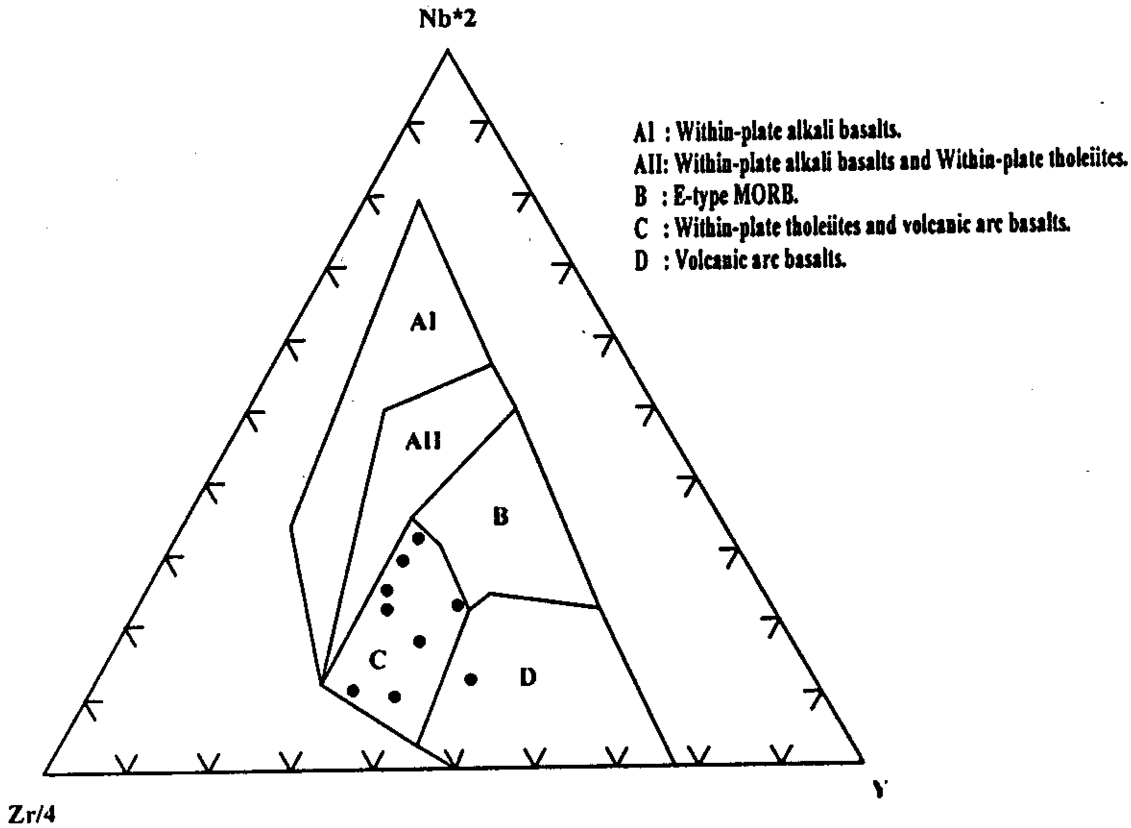

Fig. (104) : Nb*2 - Zr/4 - Y diagram for the studied metagabbros after Meschede (1986).

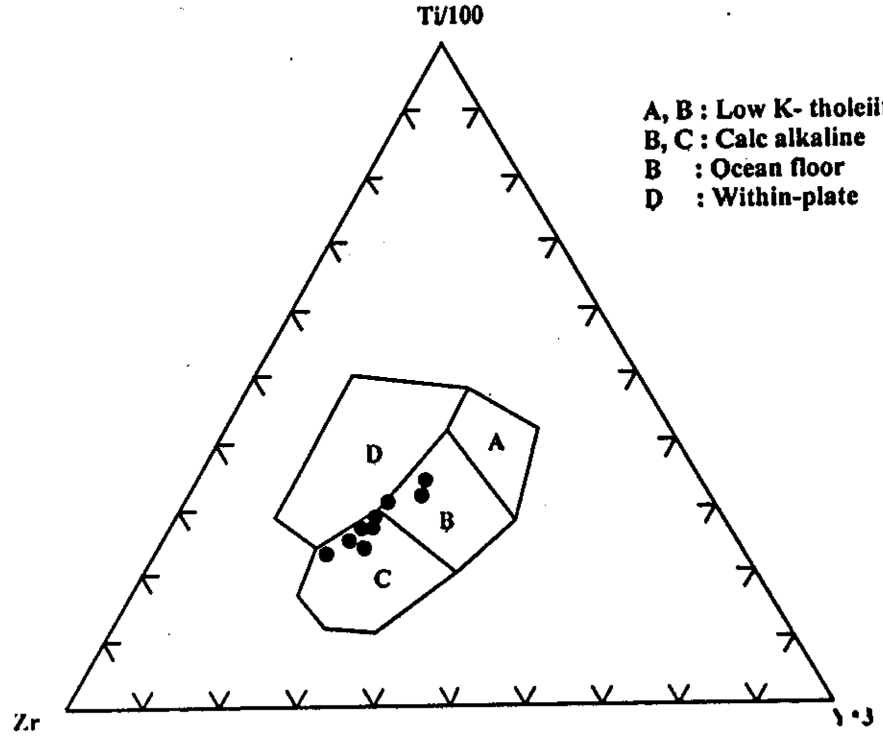

Fig. (105) : Ti/100 - Zr - Y*3 discrimination diagram for the studied metagabbros after Pearce and Cann (1973).

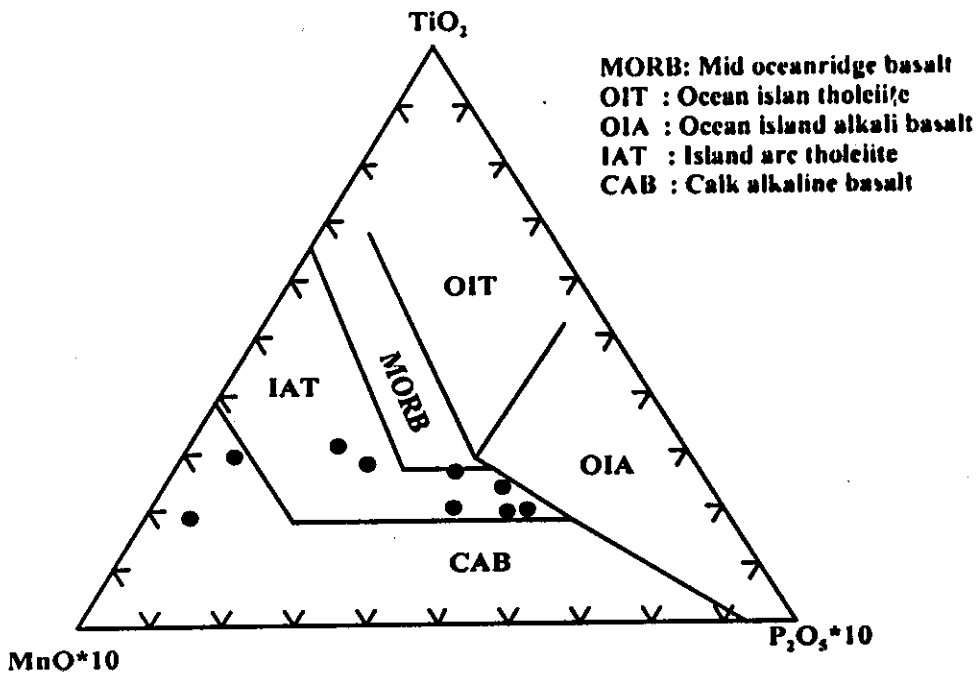

Fig. (106) : MnO - TiO_2 - P_2O_5 discrimination diagram for the studied metagabbros after Mullen (1983).

metagabbros exhibit enrichment in MnO relative to TiO_2. This coincides with the result obtained from the previous diagram (Fig. 106).

From the previously mentioned relationships, it is evident that the studied metagabbros are originated from tholeiitic to calc alkaline magma that developed within the ocean environment and equivalent to the basalt of island-arc tectonic setting.

4.4. Syn-tectonic Granitoids.

The geochemical characteristics of the investigated syn-tectonic granitoids are determined through the analyses of eleven representative samples for their major oxides and trace element contents. The results of these analyses are listed in tables (6 and 7). Average values of the major oxides of these rocks as well as the average of some reference analyses for comparison are also listed in table (6).

4.4.1. Chemical Features of Syn-tectonic Granitiods.

From table (6), it could be noticed that there is quite similarity between the average chemical composition of the investigated granitoids and average of the older granites in Egypt given by **El Gaby (1975)**, especially in the amounts of SiO_2, TiO_2, MgO and Na_2O but they are poorer in Fe_2O_3 and K_2O and richer in Al_2O_3, FeO and CaO. On the other hand, the studied granitoids are conformable with the older granites of **Le Maitre (1976)**, in their amount of SiO_2, Al_2O_3, MnO, CaO and P_2O_5 whereas TiO_2, MgO and K_2O are notably lower and Fe_2O_3, FeO and Na_2O are higher in the investigated granitoids.

Table (6): Major oxides (wt%) of the studied syn-tectonic granitoids and the average of some reference analysis.

Major oxides (Wt %)	Syn-tectonic Granitoids											Averages		
	131	135	139	143	190	213	112	1	2	3	4	I	II	III
SiO_2	65.84	66.45	67.11	68.03	67.10	68.20	67.50	68.54	68.52	64.19	66.06	67.05	69.70	✓66.09
TiO_2	0.56	0.11	0.57	0.18	0.44	0.28	0.23	0.1	0.32	0.6	0.44	0.35	0.47 ✓	0.54
Al_2O_3	16.08	16.03	15.32	15.47	16.14	16.67	16.01	15.61	15.15	16.45	17.35	16.02	14.90	✓15.73
Fe_2O_3	0.71	0.47	0.83	0.55	0.58	0.33	0.37	0.45	0.44	0.67	0.46	0.53	1.70	✓0.21
FeO	3.03	2.29	3.71	2.65	2.56	1.45	1.69	2.23	1.980	2.89	1.94	2.4	1.60 ✓	1.06
MnO	0.06	0.03	0.08	0.06	0.06	0.05	0.0	0.07	0.05	0.08	0.04	0.05	0.08	0.08
MgO	1.34	1.23	1.06	1.57	1.71	0.88	1.55	0.36	1.87	1.91	1.35	1.3	0.98	1.74
CaO	4.05	4.79	2.80	3.65	3.70	4.01	3.03	3.96	3.23	4.55	4.04	3.8	2.60	✓3.83
Na_2O	4.16	4.38	4.45	4.73	4.67	5.86	4.76	4.45	4.52	3.9	4.62	4.59	4.50 ✓	3.57
K_2O	1.49	0.3	1.87	1.3	1.27	0.63	2.1	1.71	1.21	0.94	1.37	1.29	2.40 ✓	2.73
P_2O_5	0.15	0.02	0.13	0.09	0.15	0.10	0.10	0.25	0.15	0.14	0.12	0.13	0.13 ✓	0.18
H_2O	0.67	0.64	0.83	0.79	0.82	0.37	0.86	0.35	0.65	0.84	0.66	0.68	-	-
L.O.I	0.76	0.7	0.91	0.91	1.02	0.51	0.99	1.41	0.92	1.85	1.4	1.04	-	-
Total %	98.23	96.8	98.84	99.19	99.4	98.97	98.33	99.14	98.36	98.17	99.19	98.60	-	-

I- Average of 11 samples of the studied granitoids.
II- Average of the Older granites in Egypt (El Gaby, 1975)
III- Average of the world Older granites (Le Maitre, 1976).

Table (7): Trace element (ppm) contents of the studied syn-tectonic granitoids.

Trace element (ppm)	Syn-tectonic Granitoids										
	131	135	143	190	139	213	112	1	2	3	4
Cr	28	15	33	33	29	22	24	63	174	116	86
Ni	5	0.00	0.00	26	6	25	0.00	0.00	.00	8	6
V	48	0.00	11	57	31	19	12	5	39	81	47
Pb	7	19	0.00	8	11	17	11	10	13	13	20
Zn	60	10	28	44	79	26	37	49	62	73	61
Rb	36	17	5	25	39	14	55	40	20	19	33
Ba	362	92	124	360	745	138	461	670	389	227	330
Sr	464	508	505	549	340	900	516	215	685	506	711
Co	7	0.00	7	0.00	7	0.00	2	2	0.00	2	3
Nb	8	13	6	8	7	9	5	6	7	6	9
Zr	165	57	71	124	486	117	80	71	97	140	117
Y	29	5	8	7	33	20	6	17	5	16	9

4.4.2.Normative Components.

The CIPW norm values computed for these rocks are given in table (8). Norm values of analyzed sample show that, the average of quartz is 24.83% and relatively low average of orthoclase content with value 8.36%. The normative plagioclase of these rocks ranging from 51.28 to 67.86% with average 57.66. Normative Ab is much higher in these rocks than An content. Most of these samples are peraluminous with normative corundum but consequently without normative diopside while the rest of the samples show normative diopside and absence of normative corundum. The Mt values are generally higher than Il revealing I-type granite.

4.4.3. Chemical Classification.

The classification of the investigated granitoids could be chemically confirmed by plotting the data on the following diagrams:

CaO-Na_2O-K_2O Diagram.

On the discrimination diagram (Fig. 107) suggested by **Hunter et al., (1978)**, most of the granitoid samples plot in the field of tonalite and two samples lie in the field of granodiorite. It is easily noticed that one sample of the tonalites is shifted to the Na_2O-K_2O side line.(i.e. show enrichment in Na_2O content) probably as a result of albitization process, which only restricted along the shear zone.

Na_2O versus K_2O Diagram.

Condie and Hunter (1976) suggested this diagram by using Na_2O and K_2O contents to differentiate between the different types of granitic rocks. On this diagram (Fig. 108) the data points of the studied granitoids plot in the tonalite field.

Table (8): CIPW norm values for the studied syn-tectonic granitoids.

CIPW norm	Syn-tectonic Granitoids											Average
	131	135	143	139	190	213	112	1	2	3	4	
Q	24.44	23.74	24.24	24.95	23.76	21.96	22.76	26.84	27.72	24.83	22.96	24.38
Or	9.03	7.92	7.82	11.29	7.64	3.78	12.76	10.35	7.35	5.77	8.29	8.36
Ab	36.04	38.13	40.67	38.41	40.12	50.3	41.33	38.48	39.20	34.22	39.93	39.71
An	19.70	20.81	17.41	13.41	17.78	17.56	14.85	17.94	15.55	22.60	19.79	17.95
Plagioclase	55.74	58.94	58.08	51.82	57.90	67.86	56.18	56.42	54.75	56.82	59.72	57.66
D.I	69.51	69.79	72.73	74.65	71.52	76.04	76.85	75.67	74.27	64.82	71.18	72.46
C	0.58	0.00	0.00	1.17	0.67	0.00	0.61	0.00	0.86	1.07	1.19	0.56
Di (wo)	0.00	1.49	0.20	0.00	0.00	0.86	0.00	0.00	0.00	0.00	0.00	0.23
Di (en)	0.00	0.67	0.10	0.00	0.00	0.44	0.00	0.28	0.00	0.00	0.00	0.14
Di (fs)	0.00	0.80	0.10	0.00	0.00	0.40	0.00	0.06	0.00	0.00	0.00	0.13
Diopside	0.00	2.96	0.40	0.00	0.00	1.70	0.00	0.34	0.00	0.00	0.00	0.49
Hy (en)	3.43	2.50	3.90	2.71	4.35	1.80	3.98	0.24	4.80	4.96	3.45	3.28
Hy (fs)	4.11	2.99	4.19	5.44	3.65	1.65	2.48	0.86	2.90	4.05	2.59	3.17
Hypersthene	7.54	5.49	8.09	8.15	8	3.45	6.46	1.10	7.70	9.01	6.04	6.47
Olivine	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mt	1.05	0.70	0.81	1.23	0.85	0.49	0.55	0.67	0.66	1.01	0.68	0.79
Il	1.27	0.22	0.35	1.11	0.85	0.54	0.45	0.19	0.62	1.18	0.85	0.69
Ap	0.34	0.04	0.20	0.29	0.33	0.22	0.22	0.56	0.34	0.32	0.27	0.28

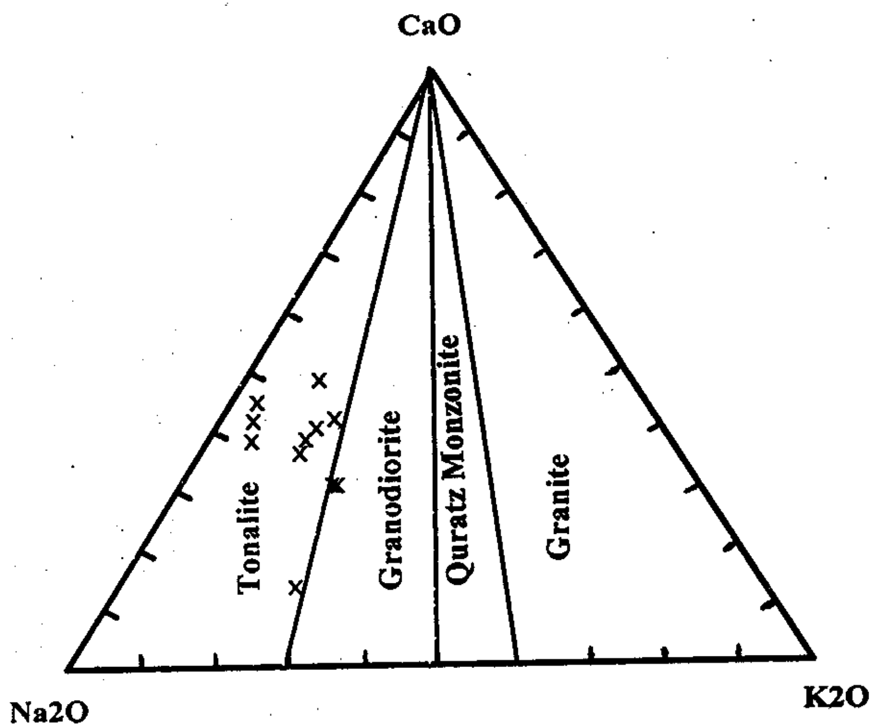

Fig. (107): CaO-Na_2O-K_2O discrimination diagram for the studied granitoids after Hunter et al., (1978). (The same symbol as shown here are used throughout the section dealing with syn-tectonic granitoids)

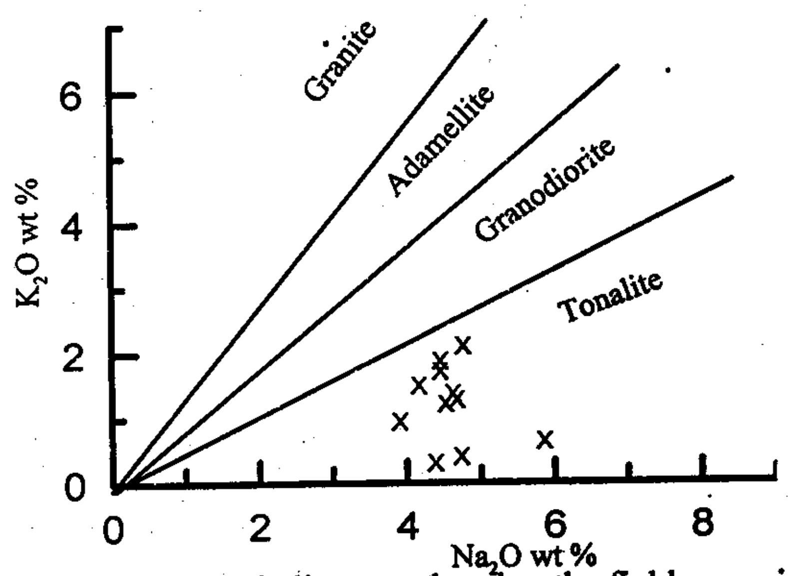

Fig. (108) : K_2O versus Na_2O diagram showing the field occupied by the studied granitoid rocks., after Condie and Hunter (1976).

Streckeisen's Classification.

On the ternary diagram (Fig. 109) suggested by **Streckeisen (1976),** the normative contents of quartz, alkali feldspar and plagioclase occupy the corners of the triangle. The majority of the plotted granitoid samples are located in the tonalite field, whereas two samples fall in the granodiorite field. On the other hand, the plots of the samples reveal their low contents of alkali feldspars and their wide compositional range of silica content.

Ab-An-Or Diagram.

Figure (110) shows the Ab-An-Or ternary diagram of **Barker (1979).** On this diagram nine samples of the investigated granitoid rocks fall in the tonalite field, whereas, two samples plot in the granodiorite field.

From the foregoing diagrams, it is clear that the investigated granitoids are represented mainly by tonalite with subordinate granodiorite. **Hussien et al., (1982)** stated that, the subduction related granitoids of immature and mature island arcs plot dominantly in the trondjemite, granodiorite and tonalite fields respectively.

Ragab and El Gharabawi (1989), stated that "the subduction related granitoids rang from diorite to granitic composition". Thus, the studied granitoids are subduction related granites of mature island arc.

4.4.4. Magma Characterization and Variation Diagrams.

It has been generally inferred that the principal factors controlling the configuration of the major oxides curves is related to fractional crystallization. Thus, using variation diagrams for the chemical components of the studied

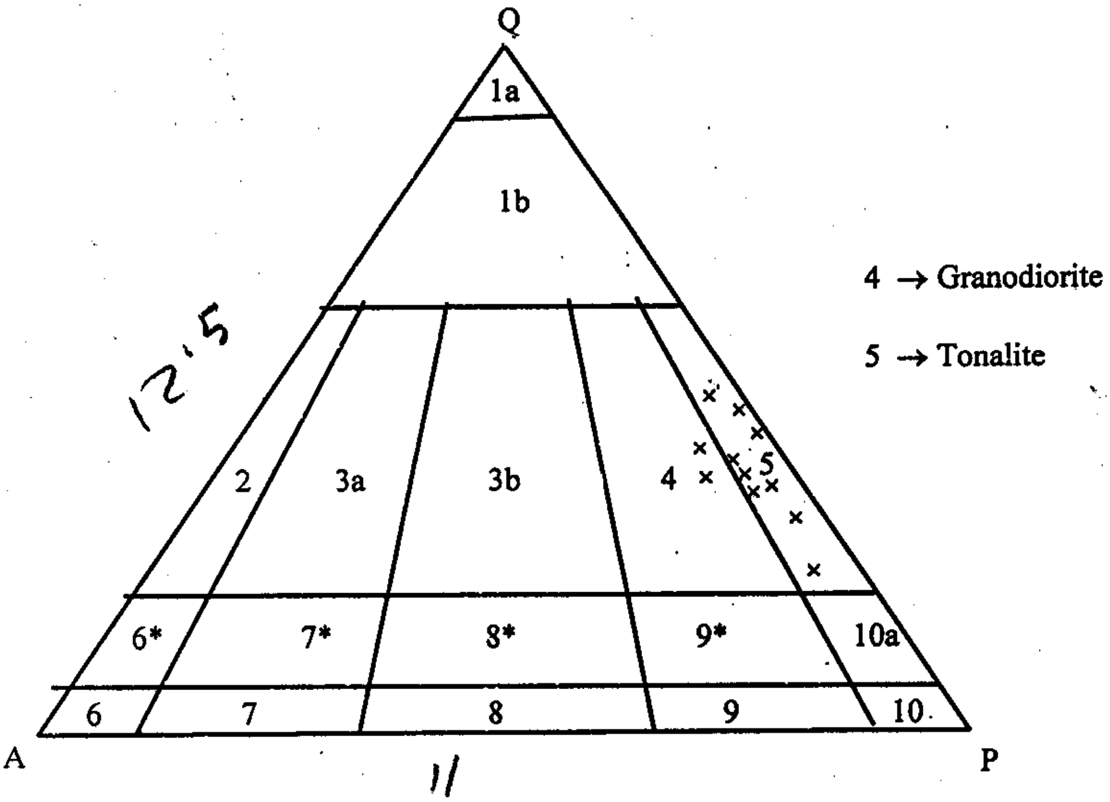

Fig. (109) : Normative Q-A-P ternary diagram for the studied syn-tectonic granitoids after Streckeisen (1976).

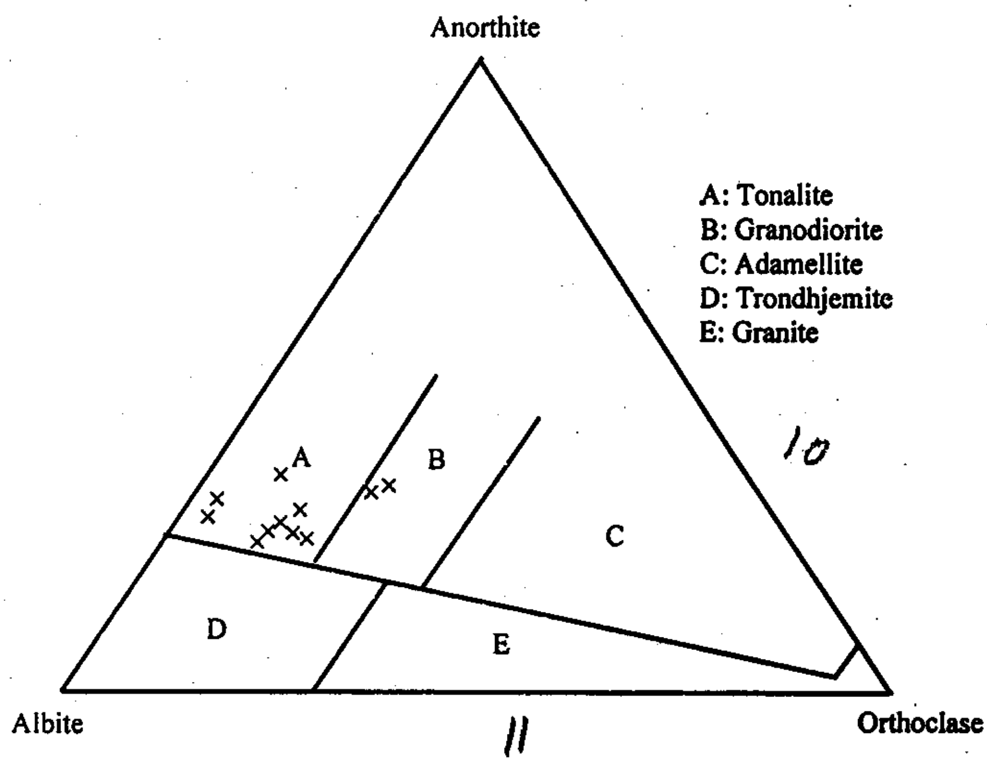

Fig (110) : Ternary plot of normative feldspar contents for the studied syn-tectonic granitoids. The classification boundaries after Barker, (1979).

granitoids may help to clarify their geochemical characteristics and geotectonic environments.

SiO_2 versus Major Oxides Diagram.

SiO_2 contents of the examined granitoids are plotted against the corresponding contents of femic component (the sum of FeO, Fe_2O_3, MgO and MnO), Al_2O_3, CaO, K_2O and Na_2O. The relationships are shown in the conventional variation diagram (Fig. 111). From this diagram it is evident that the present granitoids have normal trends with the general trend of differentiating granitic magma. It is clearly that Na_2O and K_2O show positive correlation with SiO_2, whereas CaO and femic have negative correlation with SiO_2. On the other hand, Al_2O_3 does not appear to vary with increasing of SiO_2.

Differentiation Index.

The differentiation index (D.I.= Qz+Ab+Or) of Thornton and Tuttle (1960) were calculated for the studied granitoids which ranging from 649.82 to 76.85 and plotted against their major oxides. The differentiation index is an ideal parameter, which illustrates the variation in the chemical composition of the igneous rocks.

On the diagram (Fig. 112) the plots of the studied granitoids indicates that there are increasing in SiO_2, K_2O and Na_2O contents with the increasing of D.I., whereas; MgO, TiO_2, CaO and FeO* contents decrease with increasing of D.I. On the other hand, the data points of Al_2O_3 constant with increasing D.I. and do not show a definite trend.