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Application of Biotite Composition in Determination of Petrogenesis of Diorites from Toro and Dass, North Central, Nigeria

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ABSTRACT

The compositional systematics of biotites from diorites of Toro and Dass, north Central Nigeria have been examined for the purpose of describing the nature of the granitic magma. Based on chemistry of biotites, Toro and Dass diorites are formed from the transition between peraluminous and calc-alkaline magmas. This type of magma is typically produced in subduction environments. It means that the diorites could have formed in an orogenic suit from calc-alkaline magma derived from melting in a subduction zone slab. There is little evidence of either magma mixing or large-scale crustal contamination.

The petrographic studies of the representative samples of diorite from Toro show biotite replacing pyroxenes, which necessarily produce a biotite-pyroxene-plagioclase paragenesis from pre-existing assemblage. The Dass diorite samples show biotite overgrowing amphiboles and also replacement of biotite by chlorite.

Keywords: *Biotite composition, petrogenesis, diorites, Toro and Dass, North-central Nigeria.*

I. INTRODUCTION

The composition of minerals provides a means of evaluating the nature and conditions that existed at the time of magma emplacement.

Biotite is a significant ferromagnesian mineral in most intermediate and felsic igneous rocks (Masoudi and Jamshidi Badr, 2008). Biotite compositions depend largely upon the nature of magmas from which they have crystallized (Abdel-Rahman, 1994; Moazamy, 2006; Shabbani and Lalonde, 2003). Its potential to reflect both the nature and the physicochemical conditions of magmas from which it formed is high (Masoudi and Jamshidi Badr, 2008).

In this study, we present electron microprobe data of biotites from diorites of Toro and Dass, which constitute magmatites intruded into the Basement at the closing phases of the Pan African Orogeny, to investigate the nature and conditions of the magma vis-à-vis their affliations.

II. GEOLOGICAL SETTING

The Toro and Dass study areas are situated in north central Nigeria. Toro diorite complex occupies a low hilly area above the surrounding Basement about 28 km NE of the Jos Younger Granite Magmatic Centre. Dada et al. (1989) said that Toro diorite forms a near Annular Complex, which constituted into a circular mass of about 9km across and is composed of three types of granites and a hypersthene-diorite (Fig. 1). The inner ring shows a sharp contact with the diorite, but marginal exposures against the diorite are dark and mottled due probable to contamination (granodioritic) (Ashano, 2008). The outer ring differs from the other granite types by the absence of hornblende and its characteristic foliation is parallel to its margins. This informs its classification as an anatectic granites (Ashano, 2008).

Its contact with the central granite is sharp, but where it abuts against the innermost granite in the north-western portion of the Complex, the degree of exposure precludes adequate evaluation of the relationship. The diorite outcrops in four main areas. It is typically equigranular, fine to medium grained and sometimes porphyritic. It is dark green in colour.

It is suggested by Dada et al. (1989) that the Complex was formed by the initial intrusion of the medium-grained porphyritic granite (inner ring) whose outer sheared margin is now represented by the outer ring, with the subsequent intrusion of the coarse grained, equigranular granite between the outer sheared portion and the inner more massive portion.

Dass study area forms part of the Nigerian Basement Complex, which is underlain by gneisses, migmatites and metasediments of Pre-Cambrian age. The major rock units of the area include granite gneiss, migmatite gneisses and diorite. Others include pegmatites and dolerites (Haruna et. al, 2008). Migmatite gneiss occurs in the northcentral and northeastern parts of the area. Texturally, they are medium to coarse grained, dark to light coloured and occur as low-lying outcrops.

Granite gneiss covers almost the whole of the eastern and southern parts of Dass. They are generally medium to coarse grained and strongly foliated. Pegmatites ranging from a few metres to tens of metres in length and oriented SW-NE are concentrated in the western part of the area. Diorites are restricted to the western part where they occur as coarse grained bouldery rocks in granite gneiss terrane.

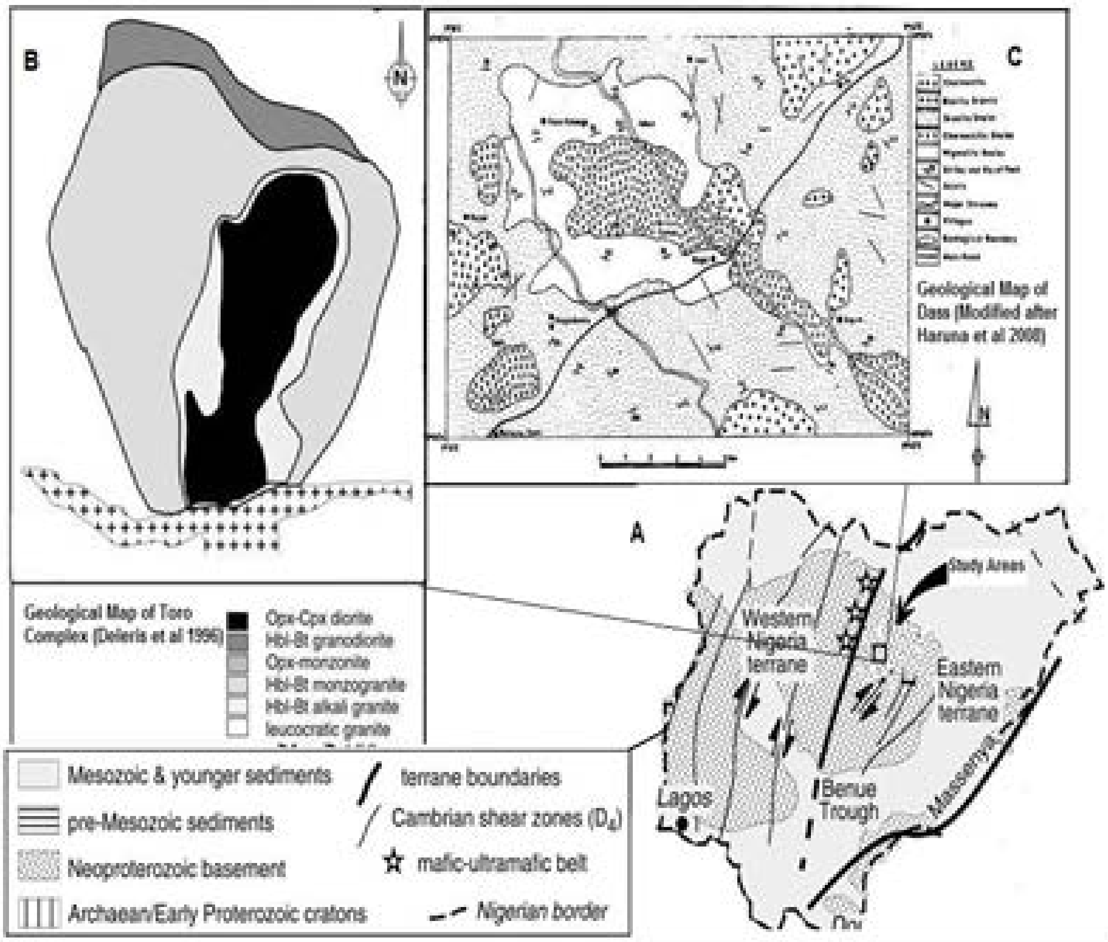

Fig. 1: (A.) Generalized Geological Map of Nigeria showing the study areas (Modified from Wright, 1985); (B.) Geological Map of Toro Complex (Deleris et al 1996 and (C.) Geological Map of Dass (Modified from Haruna et al 2008).

III. MATERIALS AND METHODS

Fresh representative surface samples were collected from both the Complexes, from which 10 samples were selected for analysis. For the purpose of this work, representative samples of Toro and Dass diorites were collected and polished thin sections made from selected samples. This aspect covers a more detailed microscopic description of selected representative samples from dioritic and charnockitic rocks of the study areas. This involves more precise quantitative mineralogical composition and other possible properties of component minerals in diorites of the study areas. It entails observation of individual sample on thin section (slides) with the aid of a petrographic microscope.

Mineral analysis was carried out using the JXA JEOL-8900L electron microprobe at the Electron Microprobe Laboratory, McGill University, Montreal, Canada. The quantitative analyses of selected minerals were performed with a 15KV accelerating voltage, a 20Na beam current and a 10um beam size. The counting time at each peak was 20seconds.

IV. RESULTS

Petrography

Photomicrographs of selected slides are shown in (Figures 2a-b & 3a-b). The petrographic studies of the representative samples of diorite from Toro show biotite replacing pyroxenes, which necessarily produce a biotite-pyroxene-plagioclase paragenesis from pre-existing assemblage (Figures 2a-b). The Dass diorite samples show biotite overgrowing amphiboles (Figures 3a-b) and also replacement of biotite by chlorite.

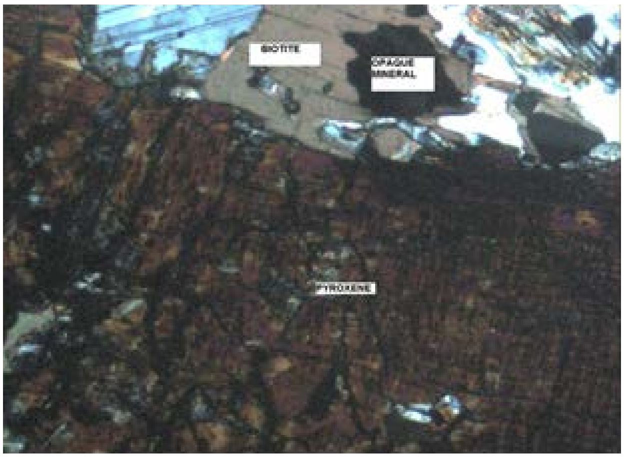

Fig. 2a: Photomicrograph of diorite from Toro study area (T1), showing orthopyroxene, biotite and plagioclase x 20 (XPL)

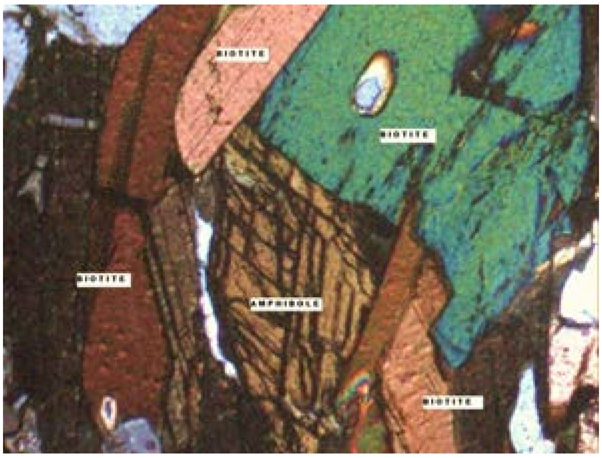

Fig. 3a: Amphibole in contact with biotite. Alteration of biotite to chlorite is taking place at its boundary (D3) x 20 (XPL)

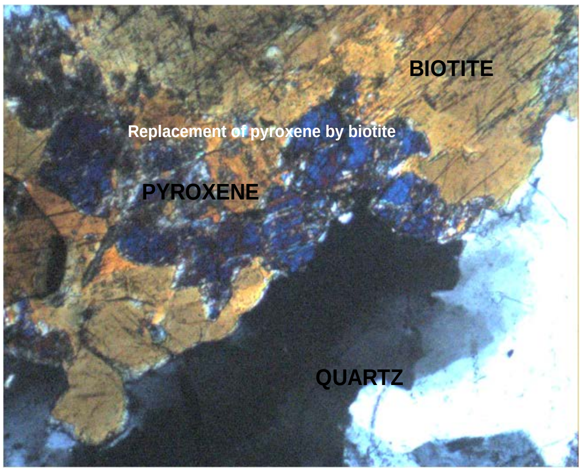

Fig. 2b: Pyroxene-biotite contact, with pyroxene been replaced by biotite (T5) x20 (XPL)

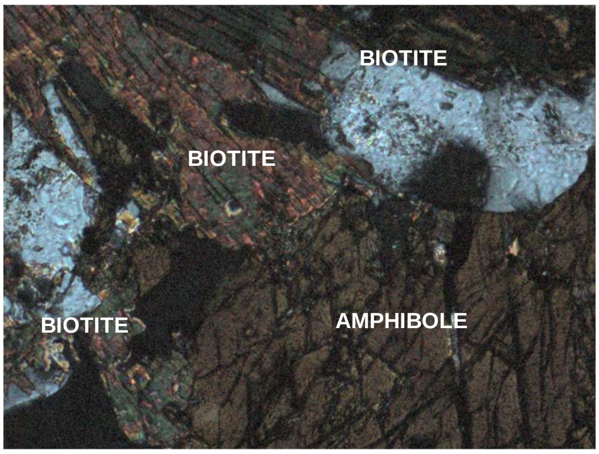

Fig. 3b Photomicrograph of diorite from Dass study area (D1), showing Amphibole and biotite x 20 (XPL)

Table 1: Representative Analyses of Biotites from Toro and Dass, North Central, Nigeria

	TORO DIORITE						**DASS DIORITE**				
Sample	**T1**	**T2**	**T3**	**T4**	**T5**		**D1**	**D2**	**D3**	**D4**	**D5**
SiO_2	36.27	36.44	36.36	35.65	35.67		35.74	35.85	35.50	35.34	35.07
TiO_2	5.20	3.33	3.36	2.85	3.01		4.56	3.36	3.55	4.38	4.76
Al_2O_3	13.84	15.68	15.57	16.23	15.99		14.57	14.22	14.8	13.61	13.77
Cr_2O_3	-	0.035	0.009	0.018	0.024		-	-	0.010	-	0.003
FeO	19.88	20.45	21.37	24.24	24.97		21.71	23.9	24.38	26.62	26.67
MnO	0.069	0.332	0.329	0.248	0.282		0.219	0.225	0.231	0.326	0.313
MgO	11.22	10.40	9.92	6.64	6.70		9.98	8.10	7.92	6.31	6.25
CaO	0.009	-	-	-	-		0.002	0.003	-	0.035	0.004
K_2O	9.70	9.60	9.60	9.80	9.77		9.80	9.76	9.82	9.39	9.39
Na_2O	0.073	0.068	0.068	0.046	0.065		0.049	0.027	0.043	0.045	0.036
F	0.476	0.106	0.106	0.471	0.582		0.146	0.656	0.593	0.624	0.386
Cl	0.087	0.005	0.005	0.181	0.186		0.100	0.185	0.183	0.154	0.182
FeO/MgO	1.77	2.06	2.15	3.65	3.73		2.18	2.95	3.08	4.22	4.27
Average FeO/MgO=2.67							**Average FeO/MgO=3.34**				

Si	5.54	5.58	5.60	5.53	5.60		5.55	5.56	5.56	5.58	5.55
Al^{IV}	2.45	2.42	2.40	2.47	2.40		2.45	2.44	2.44	2.42	2.45
Al^{VI}	0.05	0.41	0.43	0.49	0.57		0.21	0.16	0.30	0.11	0.12

Ti	0.60	0.38	0.39	0.33	0.36		0.53	0.39	0.42	0.52	0.57
Cr	-	0.004	0.002	0.002	0.003		-	-	-	-	-
Fe^{2+}	-	-	-	1.23	0.45		-	1.12	0.45	1.16	0.95
Fe^{3+}	2.68	2.88	3.09	1.92	2.83		3.11	1.99	2.74	2.36	2.58
Mn	0.01	0.04	0.04	0.03	0.038		0.029	0.033	0.03	0.04	0.04
Mg	2.51	2.37	2.28	1.53	1.57		2.31	1.87	1.85	1.48	1.47
Sum Oct.	**5.80**	**5.674**	**5.802**	**5.042**	**5.251**		**5.979**	**5.403**	**5.49**	**5.56**	**5.61**
Ca	0.002	-	0	-	-		-	-	-	0.006	0.002
Na	0.022	0.014	0.02	0.013	0.019		0.015	0.007	0.01	0.013	0.001
K	1.90	1.87	1.89	1.94	1.96		1.94	1.93	1.96	1.89	1.90
Sum W	**1.924**	**1.884**	**1.91**	**1.953**	**1.979**		**1.955**	**1.937**	**1.97**	**1.909**	**1.903**
F	0.231	0.07	0.052	0.23	0.29		0.072	0.32	0.29	0.31	0.10
Cl	0.023	0.03	0.001	0.048	0.049		0.03	0.48	0.05	0.04	0.05
OH	3.48	3.61	3.44	4.00	3.18		3.32	4.07	3.41	3.66	3.57
Sum	**3.734**	**3.71**	**3.493**	**4.278**	**3.519**		**3.422**	**4.87**	**3.75**	**4.01**	**3.72**

Mineral Chemistry

Using the Minpet 2.02 program designed by Richard (1995), structural formulae of biotite were calculated on the basis of 24 (O, OH, Cl, F) and 8 cations. According to the nomenclature of Speer (1984) and Deer et al(1986), the biotites of Toro and Dass are classified as biotite (Annite-Siderophyllite). Although two samples (D3 &T5) show a phlogopite composition.

Biotites are rather homogeneous and their compositions are uniform throughout individual samples. Most analyses represent averages of four or more individual several spot analyses from different biotites. Representative analytical data are listed in (Tables 1).

V. DISCUSSIONS

Biotite composition has been used to describe the nature of granitic magma (Abdel-Rahman, 1994; Barrier & Cotton, 1979; De Albuquerque, 1973; Foster, 1960; Kabesh & Refaat, 1975; Masoundi & Jamshidi Badr, 2008; Moazamy, 2006; Nachit et al., 2005; Neiva, 1976; Nockolds, 1947; Sapountzi, 1976; Shabbani & Lalonde, 2003; Speer, 1984).

Abdel-Rahman (1994) suggested discrimination diagrams on the basis of major elements (FeO, MgO, Al2O3) of biotites in igneous rock crystallized from A, P and C magma types. Based on his classification; biotites in anorogenic alkaline suites (Field A) are mostly iron-rich, siliceous biotites (near annite) with an average FeO/MgO ratio of 7.04; those in peraluminous (including S-type) suites (Field P) are siderophyllitic in composition and have an average FeO/MgO ratio of 3.48; whereas biotites in calc-alkaline orogenic suites (Field C) are moderately enriched in Mg; with an average FeO/MgO ratio of 1.76. It should be noted that the average FeO/MgO ratio in biotite doubles from calc-alkaline suites (FeO=total Fe) (Mausoudi & Jamshidi Badr, 2008).

The investigated biotites are found in fields P and C (Figures 6-9). The average FeO/MgO ration for Toro diorite is 2.67 while the value for Dass diorite is 3.34 (Table 1). They are higher than the average value for calc-alkaline (Field C) but lower than the average value for peraluminous (Field P). It means that based on chemistry of biotites, Toro and Dass diorites are transitional between peraluminous and calc-alkaline magmas. In such magma, dissociation of H_2O and the release of H would enrich the system in oxygen at an early stage. The availability of oxygen leads to early crystallization of iron-rich pyroxenes, amphibole and iron 0xides (magnetite) which in turn precludes the build up of iron in peraluminous –calc- alkaline melts from which low-moderately Mg-rich biotite crystallizes (Abdel-Rahman, 1994; Lalonde, 1993; Shabbani & Lalonde, 2003).

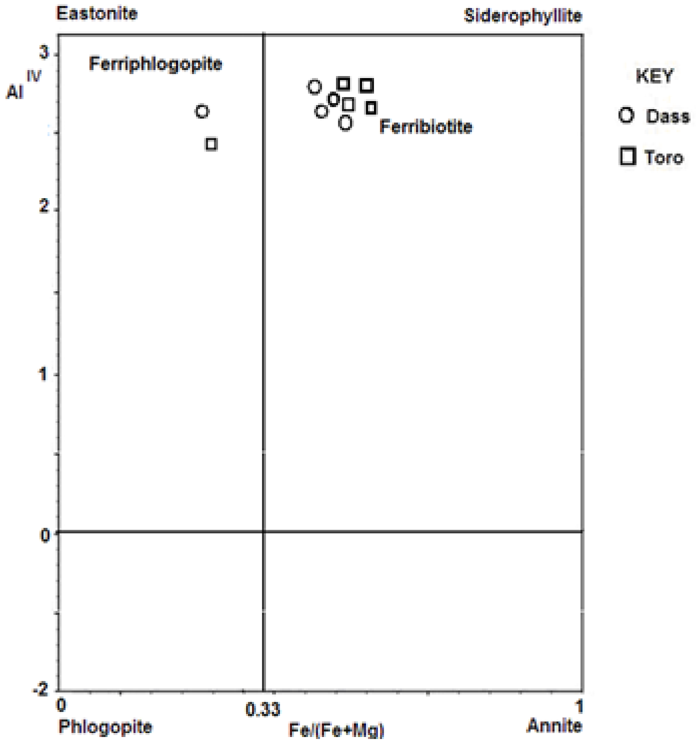

Figure 4: Diagrams showing the classification of biotite according to the nomenclature of Speer (1981) and Deer et al., (1986).

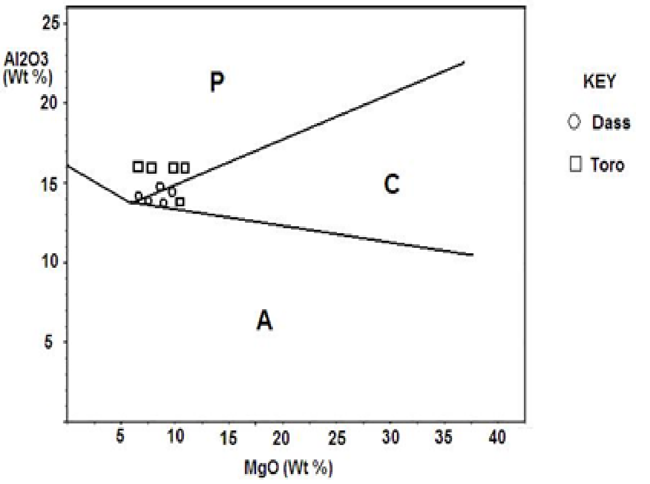

Figure 6: Al_2O_3-MgO biotite discrimination diagram (After Abdel-Rahman, 1994).
A= Alkaline suites; P= Peralkaline suites; C=Calc-alkaline orogenic suites

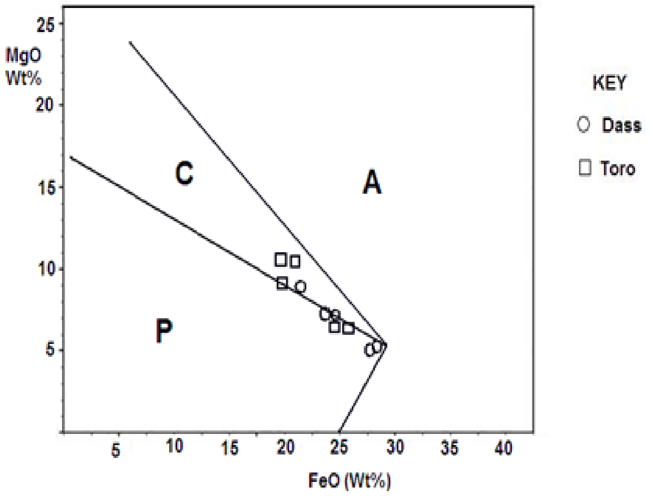

Figure 7: MgO-FeO biotite discrimination diagram (After Abdel-Rahman, 1994).
A= Alkaline suites; P= Peralkaline suites; C=Calc-alkaline orogenic suites.

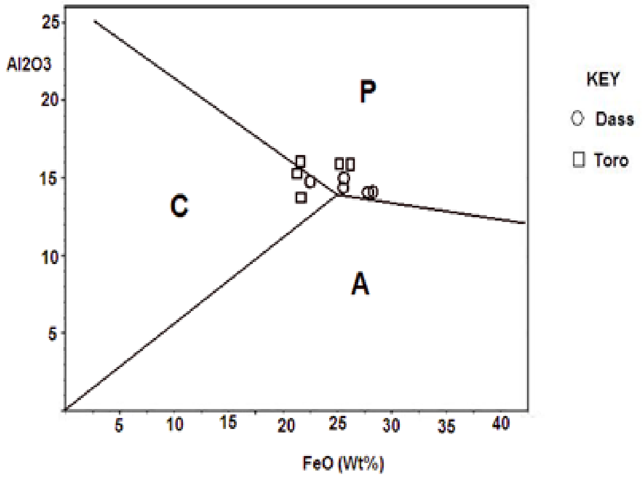

Figure 8: Al_2O_3-FeO biotite discrimination diagram (After Abdel-Rahman, 1994).
A= Alkaline suites; P= Peralkaline suites; C=Calc-alkaline orogenic suites

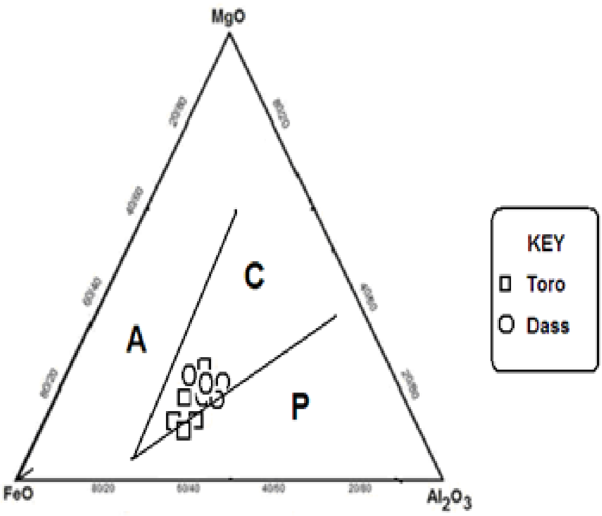

Figure 9: MgO-FeO-Al_2O_3 biotite discrimination diagram (After Abdel-Rahman, 1994).
A= Alkaline suites; P= Peralkaline suites; C=Calc-alkaline orogenic suites

VI. CONCLUSIONS

Biotite compositions clearly define the nature of magmas from which they have crystallized. Based on chemistry of biotites, it appears that the bioties of Toro and Dass diorites are transitional in nature and they have probably been associated with magmas having physicochemical properties between peraluminuous and calc-alkaline series. The diorites could have formed in an orogenic suit from calc-alkaline magma derived from melting in a subduction zone slab. There is little evidence of either magma mixing or large-scale crustal contamination (Altherr et al., 2000, Barbarin, 1990, 1999, Chappell & White, 1974, John & Wooden, 1990, Petro et al., 1979, White, 1979, White & Chappell, 1983).

Though Toro diorite has been classified as eclogitic based on the presence of Omphacite found there, the author is currently working on the chemistry of amphiboles and pyroxenes from Toro diorite to ascertain whether it is eclogitic as classified or granulitic in nature.

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