Journal of Geosciences and Geomatics, 2013, Vol. 1, No. 1, 41-46
Available online at http://pubs.sciepub.com/jgg/1/1/7

DOI:10.12691/jgg-1-1-7

Composition of Amphiboles from Toro Dioritic Complex, Northcentral Nigeria: A Potential Petrogenetic and Geothermobarometric Indicator

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Received December 29, 2012; Revised October 15, 2013; Accepted December 15, 2013

Abstract The Toro symmetrical complex is localized within the Precambrian Basement Complex of the north central Nigeria. The complex is composed of three granites types surrounding an orthoenstantite dioritic core. Amphiboles samples from the diorite have higher Mg/ (Mg+Fe) values and are richer in Si, Ti and poorer in Al and Na+K than those in the granites. The calculated P-T results show that diorite crystallized at pressures between 4.7 kbar and 5.4 kbar and temperatures of 796°C to 821°C. The hornblende-biotite granite crystallized at pressures between 5.8 kbar to 8.5 kbar and temperatures between 633°C to 771°C. The average pressure (5.1 kbar) for dioritic amphibole corresponds approximately to 19 km in depth of emplacement for the diorite and 24km in depth of emplacement for both hornblende-biotite (average pressure = 6.5 kbar) and porphyritic hornblende-biotite granites (average pressure = 6.4 kbar). Nature of dioritic amphibole evolution, coupled with its P-T suggests that the Toro diorite may have originated earlier with non consanguineous magma source different from the granites, which corresponds to a model of origin involving melting in the lower crust under granulite facies conditions.

Keywords: *amphibole composition, geothermobarometry, Toro diorite, northcentral Nigeria*

Cite This Article: O. A Dada, and E. C Ashano, “Composition of Amphiboles from Toro Dioritic Complex, Northcentral Nigeria: A Potential Petrogenetic and Geothermobarometric Indicator.” *Journal of Geosciences and Geomatics* 1, no. 1 (2013): 41-46. doi: 10.12691/jgg-1-1-7.

1. Introduction

The Toro symmetrical complex is localized at the north east of Jos in north central Nigeria. It occupies a low hilly area above the surrounding plains within the Precambrian Basement Complex of Nigeria. The hornblende-biotite granite of Neil valley of the Jos-Bukuru ring complex truncated its southern end Figure 1.

The Toro Complex has been classified with the Charnockites of Nigeria by workers who studied the Complex from other perspectives. Geochronological studies of the Complex was carried out by [1,2,3] while the structural studies was done by [4]. These studies link the emplacement of the charnockites and the “Older Granites” within the Nigerian basement migmatites to the waning phases of the Pan African thermo tectonic events. Borley [5] places the temperature of the formation of granites from the complex at between 600-900°C. Rahaman [6] from field studies of hybrid rocks is of opinion that either the granites and charnockites are contemporaneous or that the charnockites were emplaced shortly before the granites. Ashano et al. [7] postulates lack of consanguinity in magmatic sources of various rocks (diorites, dolerites and the granites) from the complex. They also confirmed crustal contamination of magmatic sources of the granites and very little contamination for the diorites.

In this study, we examined the chemistry of amphiboles in diorites and the granites (porphyritic hornblende-biotite and hornblende-biotite granites) from the Toro Complex, north central Nigeria, in order to throw more light on pressure and temperature, P-T condition of formation and its implications on the petrogenesis of the complex.

2. Geology of the Study Area

Ashano et al. [7] has described the geology of the study area. The Toro Complex is composed of three granite types surrounding an orthoenstatite dioritic core Figure 1. The complex is a symmetrical repletion of identical granite types on the two sides of the dioritic core, and the granites are discontinuous in many places. The rock types strike mainly in the north-south direction. The contacts between the rocks are sharp and dip almost vertically, and their age relationships are not quite certain, although the granites appear younger than diorites [7]. Wright [8], Cooray [9] and Rahaman [6] considered the diorites to be older than the granites as dioritic xenoliths are of ubiquitous occurrences in the granites. According to [7], the identification and naming of the rocks of the Toro symmetrical complex by the previous workers was done mainly on relative textural characteristics.

The rocks forming the outer ring is a dark grey, fine-medium grained (locally porphyritic) biotite-muscovite granite (very rarely with any hornblende), which exhibits some degree of foliation. The central ring is a light grey, coarse grained, equigranular hornblende-biotite granite while the inner ring is medium-grained porphyritic hornblende granite with greyish colour Figure 1. The inner ring shows a sharp contact with the diorite, but marginal exposures against the diorite are dark and mottled due to contamination (granodioritic). The outer ring differs from the other granite types by the absence of hornblende and it is characterized by foliation which is parallel to its margin. This informs its classification as anatectic granite (granite gneiss in old literature). Its contact with the central granite is sharp, but where it abuts against the innermost granite in the northwestern 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. The rock suites are discordantly cut at several places by dark grey to greenish, very fine to cryptocrystalline hyperbyssal doleritic rocks [7].

Dada et al. [2] suggested 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 outer ring. This is followed by the subsequent intrusion of the coarse grained equigranular granite between the outer sheared portion and the inner more massive portion. The process is seen as melting of lower crustal material during the Pan African thermo tectonic events, leading to the withdrawal of essentially silicic potassium liquids [2].

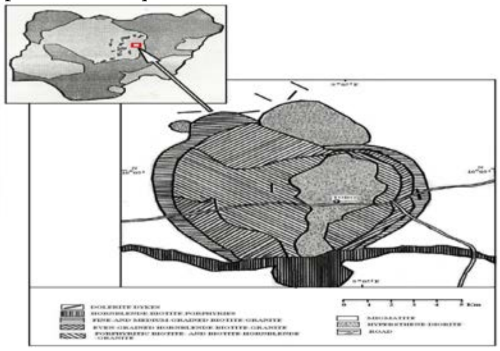

Figure 1. Geological Map of Toro Complex (Modified from Ashano et al. [7])

3. Analytical Methods

Fresh surface samples of diorite, porphyritic hornblende-biotite and hornblende-biotite granites were analysed, using a Camebax Electron Microprobe at the Clermont Ferrad University, France. The analytical conditions were 15KV high voltage with a current of 11 Na and a counting time limit of 10 seconds. Absolute error is estimated to be 2%, and the analyses were made on amphiboles present in the rocks. Representative and average microprobe analyses of amphiboles from hornblende-biotite and porphyritic hornblende-biotite granites are given in Table 1, Table 2 and Table 3. Structural formulae of the phases were computed and the rather large data summarized in the various plots displayed in Figure 2, Figure 3, Figure 4.

Table 1. Representative amphibole compositions of the investigated diorite (DI)

Sample number	DI01	DI02	DI03	DI04	DI05	DI06
SiO_2	41.87	42.20	43.59	42.53	42.58	42.84
TiO_2	1.92	1.80	1.54	1.55	2.02	1.72
Al_2O_3	9.07	9.37	9.07	9.80	9.57	9.66
Cr_2O_3	0.49	0.00	0.00	0.00	0.00	0.00
Fe_2O_3	5.66	3.57	5.09	5.65	6.90	5.62
FeO	16.50	18.45	17.65	16.54	15.59	13.72
MnO	0.45	0.33	0.41	0.36	0.54	0.41
MgO	7.51	7.59	7.94	7.86	8.07	8.01
CaO	10.66	11.25	11.43	11.02	10.72	11.08
Na_2O	1.45	1.55	1.41	1.46	1.63	0.00
K_2O	1.30	1.38	1.09	1.31	1.30	0.67
H_2O*	1.94	1.94	1.99	1.97	1.99	1.93
O=F, Cl	0.00	0.00	0.00	0.00	0.00	0.00
Total	98.83	99.44	101.21	100.04	100.91	95.66
No. of Oxygens	23	23	23	23	23	23
Si	6.477	6.507	6.573	6.478	6.429	6.669
Al^{IV}	1.523	1.493	1.427	1.522	1.571	1.331
	8	8	8	8	8	8
Al^{VI}	0.131	0.209	0.185	0.237	0.132	0.441
Ti	0.223	0.209	0.175	0.178	0.229	0.201
Cr	0.06	0	0	0	0	0
Fe^{3+}	0.659	0.415	0.578	0.647	0.784	0.659
Fe^{2+}	2.135	2.379	2.226	2.107	1.969	1.786
Mn	0.059	0.043	0.052	0.046	0.069	0.054
Mg	1.732	1.745	1.785	1.785	1.817	1.859
	4.999	5	5.001	5	5	5
Ca	1.767	1.858	1.847	1.798	1.734	1.848
Na	0.435	0.463	0.412	0.431	0.477	0
K	0.257	0.271	0.21	0.255	0.25	0.133
	2.459	2.592	2.469	2.484	2.461	1.981
OH*	2	2	2	2	2	2
Total	17.749	17.651	17.703	17.674	17.635	16.981
(Ca+Na) (B)	2.000	2.000	2.000	2.000	2.000	2.000
Na (B)	0.233	0.142	0.153	0.202	0.266	0.000
(Na+K) (A)	0.458	0.593	0.469	0.484	0.462	0.133
$Mg/(Mg+Fe^{2+})$	0.448	0.423	0.445	0.459	0.480	0.510
$Fe^{+3}/(Fe^{+3}+Al^{VI})$	0.834	0.665	0.758	0.732	0.856	0.599
Fe/(Fe+Mg)	0.617	0.616	0.611	0.607	0.602	0.568

4. Results and Discussion

4.1. Amphibole Chemistry

Amphiboles in Toro complex granitoids vary widely in composition (Table 1, Table 2, Table 3; Figure 2, Figure 3, Figure 4; Leake et al. [10]). Amphibole in the Toro diorite contains ferro edenite, ferro hornblende, magnesiohornblende and ferrotschermakite. The hornblende-biotite granite have amphibole ranging between hastingsite and ferrotschermakite while porphyritic hornblende-biotite granite amphibole contains crystal zoned between hastingsite and ferropargasite.

The amphiboles from diorite are chemically distinct from other rocks, going by their chemical compositions Table 1, Table 2, Table 3. In the diorite samples, the amphibole grains have the following average compositional range per formula unit (pfu): Si = 6.429-6.669, Al = 1.612-1.772, Ca = 1.734-1.859, (Na+K) = 0.133-0.593 and mg# = [Mg/(Mg+Fe)] = 0.423-0.510; in the hornblende-biotite granite sample, the values are Si = 5.979-6.371, Al = 1.847-2.419, Ca = 1.831-1.932, (Na+K) = 0.303-0.914 and mg# = [Mg/(Mg+Fe)] = 0.224-0.284. The porphyritic hornblende-biotite granite amphibole compositions are Si = 6.301-6.452, Al = 1.903-2.038, Ca = 1.866-1.941, (Na+K) = 0.619-0.794 and mg# = [Mg/(Mg+Fe)] = 0.218-0.272.

Toro diorite is poorer in Al and Na+K but richer in Si, Ti and higher in Mg/Mg+Fe than the hornblende-biotite and porphyritic hornblende-biotite granites. This suggests that diorite crystallizes from magma of higher silica activity and lower alkali contents. In the same vein, amphibole from hornblende-biotite granite shows low Si and Ca contents, and high Al, Na+K and #mg values compared with the porphyritic type.

4.1.1. Amphibole Geobarothermometry

Previous studies on parageneses of calacic amphiboles in mafic igneous rocks by [11-18] made it clear that, with increasing P-T conditions, calcic-amphiboles exhibit increases in (Mg/Mg+Fe) and in K, Al, Na and Ti contents and commensurate decreases in Si and total Fe+Mg+Mn+Ca. It has also been claimed that the total Al in hornblende may be used as a barometer in granitic rocks ([19]), and four calibrations have been proposed ([20,21,22,23]).

4.1.1.1. Geobarometry

In this study, Al in hornblende (A-H) calibration by [23] is chosen and results are compared to those obtained using other experimental calibration by [20,21].

Determined pressures for this study are: diorite varies from 4.7 Kbar to 5.4 Kbar, hornblende-biotite granite ranges from 5.8 Kbar to 8.5 Kbar and porphyritic hornblende-biotite granite varies from 6.1 Kbar to 6.7 Kbar Table 4. The average pressures are 5.1 Kbar for diorite, 6.4 Kbar for hornblende-biotite granite and 6.4 Kbar for porphyritic hornblende-biotite Table 4.

Table 2. Representative amphibole compositions of the investigated hornblende-biotite granite (HB)

Sample number	HB1	HB2	HB3	HB4	HB5	HB6	HB7	HB8	HB9	HB10
SiO_2	39.69	40.43	40.66	40.50	40.36	41.52	40.93	39.84	40.62	38.25
TiO_2	1.66	1.55	1.28	1.54	1.14	1.58	1.51	1.14	1.22	0.65
Al_2O_3	10.81	10.61	11.26	10.49	10.59	10.21	10.26	10.94	10.36	13.13
Cr_2O_3	0.04	0.08	0.00	0.00	0.00	0.01	0.04	0.00	0.00	0.00
Fe_2O_3	7.83	3.70	4.85	5.97	4.40	5.44	3.37	6.33	4.47	5.79
FeO	26.46	22.67	21.83	27.09	22.48	27.11	26.39	26.94	26.40	27.63
MnO	0.68	0.56	0.49	0.59	0.46	0.52	0.54	0.61	0.41	0.49
MgO	4.32	4.48	4.39	4.56	4.37	4.60	4.60	4.22	4.63	3.64
CaO	11.43	11.43	11.09	11.27	11.29	11.14	11.59	11.19	11.35	11.19
Na_2O	0.36	1.45	1.41	1.49	1.46	1.49	1.48	1.30	1.41	2.18
K_2O	1.36	1.52	1.72	1.55	1.57	1.59	1.63	1.59	1.65	1.90
H_2O*	1.91	1.92	1.93	1.94	1.91	1.95	1.93	1.91	1.92	1.92
O=F, Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	99.51	100.40	100.91	101.62	100.03	102.27	101.24	100.32	100.41	101.56
No. of oxygens	23	23	23	23	23	23	23	23	23	23
Si	6.227	6.328	6.311	6.27	6.343	6.371	6.367	6.245	6.35	5.979
Al^{IV}	1.773	1.672	1.689	1.73	1.657	1.629	1.633	1.755	1.65	2.021
	8	8	8	8	8	8	8	8	8	8
Al^{VI}	0.226	0.285	0.371	0.184	0.305	0.218	0.248	0.267	0.259	0.398
Ti	0.196	0.182	0.149	0.179	0.135	0.182	0.177	0.134	0.156	0.076
Cr	0.005	0.01	0	0	0	0.001	0.005	0	0	0
Fe^{3+}	0.925	0.435	0.566	0.696	0.52	0.628	0.394	0.747	0.536	0.681
Fe^{2+}	2.547	2.968	2.834	2.811	2.955	2.851	3.038	2.785	2.916	2.931
Mn	0.09	0.074	0.064	0.077	0.061	0.068	0.071	0.081	0.054	0.065
Mg	1.01	1.045	1.016	1.052	1.024	1.052	1.067	0.986	1.079	0.848
	4.999	4.999	5	4.999	5	5	5	5	5	4.999
Ca	1.921	1.917	1.844	1.869	1.901	1.831	1.932	1.879	1.901	1.874
Na	0.11	0.44	0.424	0.447	0.445	0.443	0.446	0.395	0.427	0.661
K	0.272	0.303	0.341	0.306	0.315	0.311	0.323	0.318	0.313	0.379
	2.303	2.66	2.609	2.622	2.661	2.585	2.701	2.592	2.641	2.914
OH*	2	2	2	2	2	2	2	2	2	2
Total	17.303	17.66	17.609	17.623	17.661	17.586	17.701	17.593	17.642	17.914
(Ca+Na) (B)	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Na (B)	0.079	0.083	0.156	0.131	0.099	0.169	0.068	0.121	0.099	0.126
(Na+K) (A)	0.303	0.660	0.609	0.623	0.661	0.586	0.701	0.593	0.642	0.914
$Mg/(Mg+Fe^{2+})$	0.284	0.260	0.264	0.272	0.257	0.270	0.260	0.262	0.270	0.224
$Fe^{3+}/(Fe^{+3}+Al^{VI})$	0.803	0.604	0.604	0.791	0.631	0.743	0.614	0.737	0.674	0.631
Fe/(Fe+Mg)	0.775	0.765	0.770	0.769	0.772	0.768	0.763	0.782	0.762	0.810

4.1.1.2. Geothermometry

Electron microprobe data for the amphiboles from diorite (DI), hornblende-biotite (HB) granite and porphyritic hornblende-biotite (pHB) granite from Toro Complex were used to determine temperature of formation using temperature calibration based on Ti content in hornblende by [24]. This is best used to determine magmatic versus secondary compositions. Temperature of formation estimates for diorite vary from 796°C to 821°C, 633°C to 771°C for hornblende-biotite (HB) granite and 714°C to 779°C for porphyritic hornblende-biotite (pHB) granite. The average temperature got from amphiboles for the diorite is 789°C; 728°C for hornblende-biotite (HB) granite and 750°C for porphyritic hornblende-biotite (pHB) granite.

Table 3. Amphibole compositions of the investigated porphyritic hornblende-biotite granite (pHB)

Sample number	pHB1	pHB2	pHB3	pHB4	pHB5	pHB6	pHB7	pHB8	pHB9	pHB10
SiO_2	39.21	40.37	40.53	40.42	40.43	40.46	40.44	40.67	40.42	40.51
TiO_2	1.62	1.49	1.42	1.43	1.59	1.46	1.50	1.20	1.42	1.65
Al_2O_3	10.64	10.73	10.30	10.37	10.67	10.76	10.29	11.02	10.92	10.33
Cr_2O_3	0.02	0.00	0.00	0.04	0.11	0.07	0.00	0.00	0.00	0.00
Fe_2O_3	2.71	3.26	1.72	2.67	2.92	3.57	2.99	4.08	1.36	3.04
FeO	25.00	25.44	24.95	24.90	25.54	25.89	26.54	22.79	24.50	23.51
MnO	0.40	0.38	0.35	0.47	0.44	0.55	0.45	0.48	0.58	0.39
MgO	4.47	4.51	4.54	4.72	4.24	4.27	4.40	4.12	3.84	4.43
CaO	11.10	11.16	11.23	11.24	11.08	11.09	11.31	11.28	11.44	11.40
Na_2O	1.57	1.46	1.56	1.47	1.48	1.47	1.86	1.31	1.52	1.61
K_2O	1.70	1.59	1.51	1.55	1.53	1.72	1.63	1.68	1.53	1.48
								1.92	1.89	1.91
H_2O*	1.87	1.90	1.88	1.89	1.90	1.91	1.91	1.92	1.89	1.91
O=F, Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	97.87	99.36	98.45	98.77	99.30	100.01	100.63	100.55	99.42	100.26
No of Oxygens	23	23	23	23	23	23	23	23	23	23
Si	6.301	6.365	6.452	6.407	6.383	6.354	6.347	6.352	6.402	6.359
Al^{IV}	1.699	1.635	1.548	1.593	1.617	1.646	1.653	1.648	1.598	1.641
	8	8	8	8	8	8	8	8	8	8
Al^{VI}	0.316	0.358	0.384	0.345	0.369	0.346	0.25	0.38	0.44	0.27
Ti	0.196	0.177	0.17	0.171	0.189	0.172	0.177	0.141	0.169	0.195
Cr	0.003	0	0	0.005	0.14	0.009	0	0	0	0
Fe^{3+}	0.328	0.387	0.206	0.318	0.347	0.422	0.353	0.479	0.162	0.359
Fe^{2+}	3.032	2.967	3.116	2.983	3.025	2.978	3.131	2.977	3.245	3.087
Mn	0.054	0.051	0.047	0.063	0.059	0.073	0.06	0.063	0.078	0.052
Mg	1.07	1.06	1.077	1.115	0.998	1	1.029	0.959	0.907	1.037
	4.999	5	5	5	5.127	5	5	4.999	5.001	5
Ca	1.911	1.885	1.915	1.909	1.874	1.866	1.902	1.888	1.941	1.917
Na	0.489	0.446	0.481	0.452	0.453	0.448	0.566	0.397	0.467	0.49
K	0.349	0.32	0.307	0.313	0.308	0.345	0.326	0.335	0.309	0.296
	2.749	2.651	2.703	2.674	2.635	2.659	2.794	2.62	2.717	2.703
OH*	2	2	2	2	2	2	2	2	2	2
Total	17.749	17.651	17.703	17.674	17.635	17.658	17.794	17.619	17.717	17.704
(Ca+Na) (B)	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000	2.000
Na (B)	0.089	0.115	0.085	0.091	0.126	0.134	0.098	0.112	0.059	0.083
(Na+K) (A)	0.749	0.651	0.703	0.674	0.635	0.658	0.794	0.619	0.717	0.704
Mg/(Mg+Fe2)	0.261	0.263	0.257	0.272	0.248	0.251	0.247	0.244	0.218	0.251
$Fe^{+3}/(Fe^{+3}+Al^{VI})$	0.509	0.519	0.349	0.480	0.485	0.550	0.585	0.558	0.269	0.571
Fe/(Fe+Mg)	0.758	0.760	0.755	0.748	0.772	0.773	0.772	0.783	0.790	0.769

Table 4. Results of geobarometry, Amph-Al (Total) of diorites (DI), hornblende-biotite (HB) granite and porphyritic hornblende-biotite (pHB) granite from Toro complex, north central Nigeria. The table shows Pressure Calculations using Hammarstrom and Zen [20], Hollister et al.([21] and Schmidt [23]

Pressure	Hammarstrom & Zen [20]	Hollister et al. [21]	Schmidt [23]
	Diorite (DI)		
Max (Kbar)	5.0	5.2	5.4
Min (Kbar)	4.4	4.3	4.7
Ave. (Kbar)	4.6	4.8	5.1
	Hornblende-biotite granite (HB)		
Max (Kbar)	8.2	8.9	8.5
Min (Kbar)	5.4	5.7	5.8
Ave. (Kbar)	6.1	6.5	6.5
	Porphyritic Hornblende-biotite granite (pHB)		
Max (Kbar)	6.2	6.7	6.7
Min (Kbar)	5.7	6.0	6.1
Ave. (Kbar)	6.0	6.4	6.4

4.2. Discussion

The Toro dioritic complex amphiboles represent a wide compositional range. The dioritic amphiboles contain ferroedenite, ferrohornblende, magnesiohornblende and ferrotschermakite members. The hornblende-biotite granite amphiboles range from hastingsites to ferrotschermakite while the porphyritic type clusters between hastingsite and ferropargasite, as shown in the Mg/ $(Mg+Fe^{2+})$ versus Si diagram (Figure 2; after Leake et al. [10]). All the amphiboles plot in the igneous field of Ca+Na+K versus Si diagram (Figure 3; Giret et al. [25]) and are calcic amphiboles Figure 4. This implies that the amphiboles are igneous in origin and must have formed from the intrusion of magma probably derived from the upper mantle into the pre-existing older rocks as suggested by [2]

Table 5. Calculated temperature using amphibole population in diorite, hornblende-biotite (HB) granite and porphyritic hornblende-biotite (pHB) granite from Toro complex, north-central Nigeria (Ti-Hbd geothermometer of Otten [24])

Temperature	Max °C	Min °C	Average (°C)
Hornblende-biotite (HB) granite	771	633	728
Porphyritic hornblende-biotite (pHB) granite	779	714	750
Diorite (DI)	821	796	789

Looking at the chemical compositions of amphiboles in the studied rocks, it can be deduced that the diorite crystallized from a different magma. Though the hornblende-biotite and porphyritic hornblende-biotite granites may have had a more direct relationship, going by the slight variation in their amphibole compositions, they grew at different stages of crystallization. If these magmas once had a common parentage, they evolved independently due to different magmatic conditions where mafic minerals subsequently crystallized with unique “finger prints”.

The calculated P-T results show that the diorite crystallized at pressures between 4.7 kbar and 5.4 kbar and temperatures of 796°C to 821°C. The bornblende-biotite granite crystallized at pressures between 5.8 kbar to 8.5 kbar and temperatures between 633°C to 771°C while the porphyritic hornblende-biotite granite crystallized at pressures between 6.1 kbar to 6.7 kbar and temperatures between 714°C to 779°C. The values shown in Table 4 and Table 5 are within the range given by [5]. Borley [5] stated that the temperatures of formation of the granites of the Toro complex are between 600°C and 900°C. The average pressure (5.1 kbar) for diorite amphibole corresponds approximately to 19 km in depth of emplacement for diorite and 24km in depth of emplacement for both hornblende-biotite (average pressure = 6.5 kbar) and porphyritic hornblende-biotite granites (average pressure = 6.4 kbar). The present chemical and P-T studies on the amphiboles of the Toro dioritic complex confirms that diorite is the earliest formed rock ([6,8,9]) and has non consanguineous magma source with the granites ([2,7]). This corresponds to a model of origin involving melting in the lower crust under granulite facies conditions of medium pressure and higher temperature.

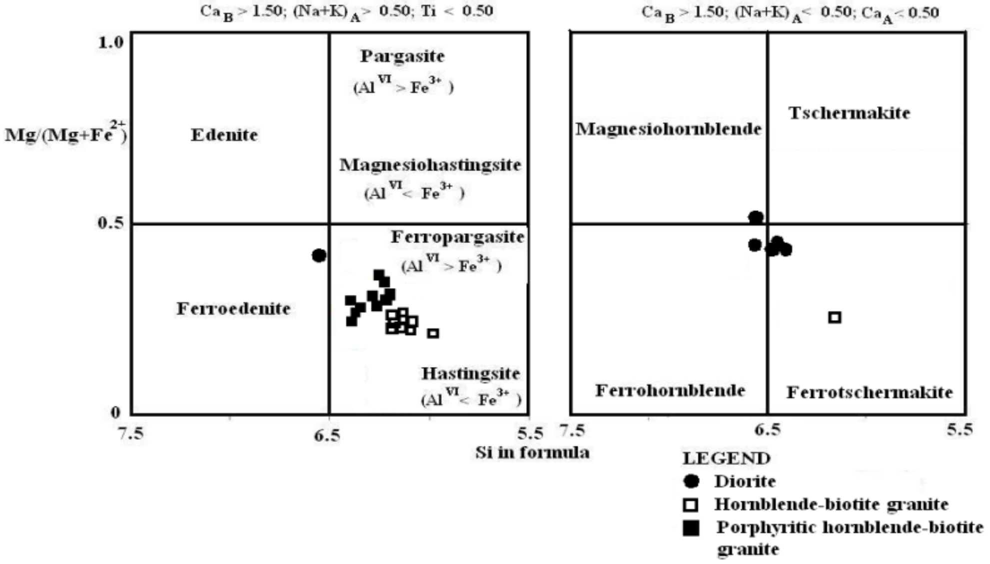

Figure 2. Compositional variations of calcic-amphibole from the Toro diorite (DI), hornblende-biotite (HB) and porphyritic hornblende-biotite (pHB) granites, North central Nigeria. Cation proportions are per formula unit. Amphibole classification after Leake et al. [10]

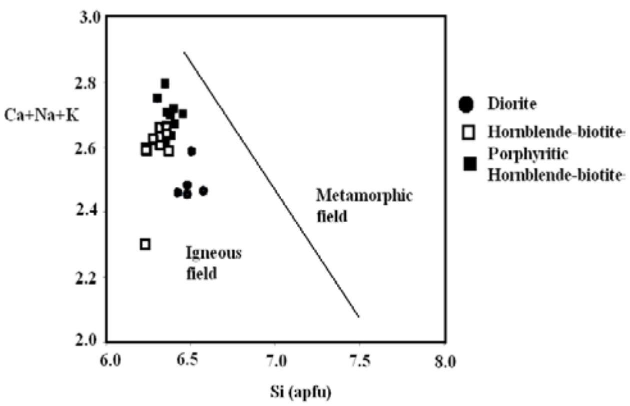

Figure 3. Compositional variations of amphibole from the Toro diorite (DI), hornblende-biotite (HB) and porphyritic hornblende-biotite (pHB) granites, Northcentral Nigeria plotted in terms of cations (Ca+Na+K) vs Si (apfu) diagram after Giret et al. [25]

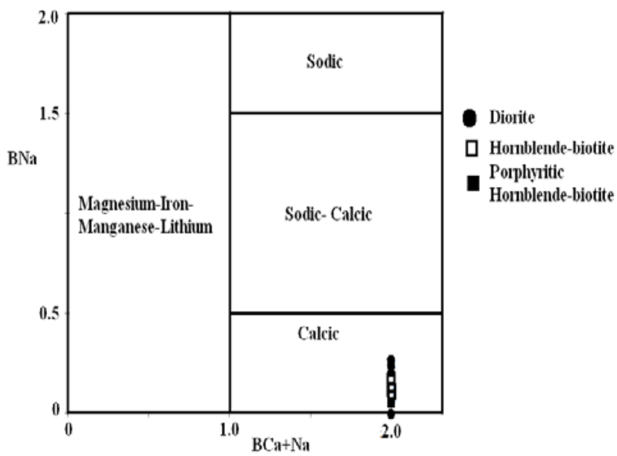

Figure 4. Composition and classification of amphiboles (After Leake et al. [10])

5. Conclusions

Following the amphibole characteristics displayed by the diorite and granites from the Toro dioritic complex and the discussions, it can be inferred that the diorite from the complex formed earlier than the granites and its magma source has no consanguinity with the granites from the same complex.

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