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Article

Geochemical characteristics of the basin-type granitoids in the Winneba Area of Ghana

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Abstract

Representative rocks of the metasediment suite granitoids (basin-type granitoids) were selected from the Winneba area in the Central part of Ghana for geochemical analyses. The rocks contained plagioclase, K-feldspar, amphibole, Biotite and titanite as the main mineral phase. The CIPW normative mineral shows that the rocks are granodiorite, monzogranite, and quartz –monzonite. The geochemical classification of the basin-type granitoids based upon the Fe-Number, the modified alkali-lime index and the aluminium saturation index, defined the rocks as ferroan, alkali-calcic to calc-alkali and peraluminous respectively. The rocks also showed a calc-alkaline affinity. The aluminous character by the molar ratio Al/ (Na+ K+ Ca/2) show I-type characteristics of the rocks which is a characteristic of basin type granitoids in Ghana. The major element composition of the whole rock and Biotite mineral revealed that the basin- type granitoids are from metagreywackes, and or metabasaltic to metatonalitic and calc-alkaline to peraluminous source.

Keywords granitoid; rock; geochemical; characteristic; Ghana.

1 Introduction

In Ghana, granitoids are found within the birimian rocks which form a substantial part of the Man Shield (Leube et al., 1990) which occupies the southernmost of the West Africa craton. The granitoids occurs as intrusive bodies which occurred about 2.1Ga ago during the Eburnean Orogeny.

Over the years, it has been establish that Eburnean granitoids can be group into:

(1) Sedimentary-basin granitoids (previously called the Cape Coast type, G1)
(2) Sedimentary-basin granitoids of the Winneba type, and,
(3) Volcanic-belt granitoids (previously called the Dixcove type, G2)

Isotope data obtained by Taylor et al. (1992) demonstrated that despite the similarities in field characteristics, petrography and geochemistry, the Winneba granitoids (restricted to a single locality, the Winneba town) are entirely of different origin from the sedimentary –basin granitoids of the Cape Coast type.

Sedimentary –basin granitoids (including the Winneba-type) refers to large granitoids batholiths emplaced within the basin sediment. They tend to coincide with the central axes of sedimentary basin. Rock types include quartz diorites, tonalities and trondhyemites and granites. Quartz diorites are rare; granites are more frequent than in the other group of granitoids.

In contrast to the Volcanic-belt granitoids, the main ferromagnesian mineral is Biotite, which is commonly accompanied by muscovite. Geothermobarometric studies by Nyarko et al. (2012) demonstrated that the basin granitoids were emplaced with a temperature of 1.3-2.8 kbars and at a pressure of about 776^{o}C with a very low oxygen fugacity.

Several studies have shown that the sedimentary-basin granitoids are peraluminous (plots in the peraluminous domain of the characteristic mineral diagram of Debon and Le Fort (1983). Generally, granitoids plotting in the peraluminous domain have been derived from anataxis of continental crust (Debon and Le Fort, 1983). Isotopic data, however do not confirm such a mode of formation for most of the basin granitoids (Leube et al., 1990) although it certainly played a role in the case of the Winneba granitoids.

It has been established that most of the basin-granitoids seem to be Juvenile and that their peraluminous character might result from large-scale contamination of the ascending granitoids magmas by first-cycle assimilation intermediate to acid Volcaniclastic basin sediment.

The composition of minerals provides a means of evaluating the nature of magma during the emplacement of granites. Biotite is a significant ferromagnesian mineral in most intermediate and felsic igneous rocks. Its composition depends largely upon the nature of magmas from which they have crystallized. It is potential to reflect both the nature and the physicochemical conditions of magmas from which it formed. Igneous Biotite can also be used to provide valuable petrogenetic information (Masoudi and Jamshidi Badr, 2008).

In this study we will present the SEM data of Biotite on the basin-type granitoids and XRF data on the major elements of the whole rock to examine the geochemical nature and source of the basin-type granitoids so as to establish if they are Juvenile.

2 Geology of the Study Area

The rocks of the Winneba area (Fig. 1) may be classified in order of increasing age as follows: Tertiary to Recent (Lagoonal deposits, alluvium, gravels , salt beds, beach and raised beach sands, laterites, Boulder beds, bedded and laminated sands, clay of uncertain age), the Togo Series (Quartzites, purple + white facies, breccias, sericite phyllite near base) which is in unconformity with Tarkwaian and the Acids intrusive (aplites and pegmatites, quartz reefs, series of granites veins quartz , migmatites and the Western gneiss),then, the Post Birimian (Basic intrusive- Dykes now amphibolites, Epidiorites dykes Takwanian), underlain by the Birimian supergroup (Metamorphosed porphyritic and vesicular lavas, quartz Biotite and hornblende schist; hornblende schist, coarse amphibolites, actinolites schites, quartz schist. Gondites, manganiferous phyllite, epidosites and granulites, Mica schist finely laminated (Ahmed et al., 1977; Layton, 1958). The granites in the area forms part of the acid intrusion in the Birimian. The junction between the granites and the surrounding rocks is a sharp one, though a slight veining of the coarse amphibolites with which it is in contact on the western part of the area exist. The granites as describe by Layton (1958) are porphyroblastic microcline-biotite adamellite. The Western and northern margins of the granite are relatively fine grained and non-porphyroblastic, while the margin at the east show similar characteristics but microcline granite may occur (Layton, 1958).

Apart from linearly arranged Biotite-rich ghosts, there are larger inclusions of hornblende schists often contorted, finely schistose and cut by irregular feldspar veining. Typically, the porphyroblastic granite of the Winneba area is grey in colour and medium to coarse grained in hand specimen. They contain minerals such as Biotite, microcline, amphibole, feldspar (plagioclase is more abundant than other feldspars). Apatite, sphene, and rare magnetite are also occasionally seen as accessory minerals (Ahmed, 1977; Layton, 1958).

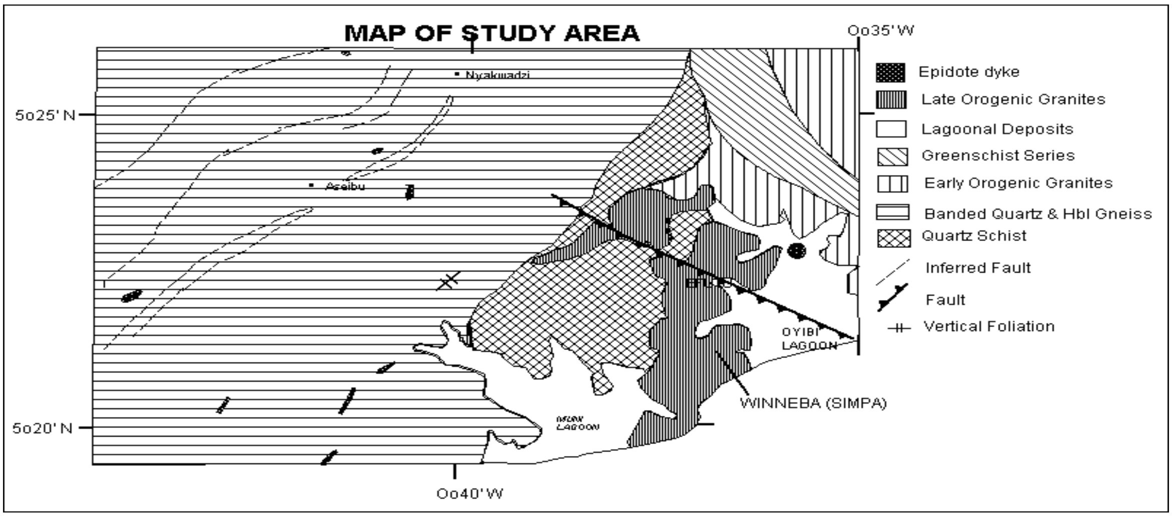


Fig. 1 Geological map of study area

3 Materials and Methods

There was abundance of rock exposures, however fresh rock exposure was scarce due to extended settlement to the areas of exposed rocks. However relatively fresh samples were obtained form along the coast.

Thin sections of the representative rock samples were prepared for the mineral composition analysis using SEM. Ten representative samples were also selected, crash and grounded into powder form for the whole rock analysis.

3.1 Scanning electron microscope

Prior to analysis by Scanning Electron Microscope (SEM), the thin section were washed with deionized water in an ultrasonic bath and coated with carbon film to eliminate electrostatic charge-up on the sample surface.

Mineral analyses were performed at the Institute for the Earth's Interior, Okayama University, Misasa, Japan. Back-scattered electron (BSE) images and major element compositions of all mounted grains were obtained using a HITACHI S-3100H Scanning Electron Microscope coupled with an EMAX-7000 Energy Dispersive X-ray Spectrometer, which operated at an accelerating voltage of 20 kV and 0.3 nA beam current. Correction for the major element compositions was done by the standard-less ZAF correction method of the EMAX-7000 program (HORIBA Ltd., Ver. 1.32). Analytical points on the mounted grains were pre-recorded using a Visual Stage system that was developed to support the probe analyses using the SEM-EDX and SIMS with extremely high spatial resolution.

Chemical compositions and structural formulae of biotite, calculated on the basis of 11 oxygen is listed in Table 2.

The mineral chemistry analyses were carried out at the Institute for Study of the Earth's Interior, Okayama University at Misasa, Japan.

3.2 X-Ray fluorescence

Major element oxides concentrations were determined on powdered samples by X-ray fluorescence (XRF) spectrometry at the Department of Earth Sciences, Okayama University. The preparation of glass beads for the analysis followed the procedure outlined below.

About 0.5g of heated rock powder was weighed, and mixed with a 5.0g lithium tetraborate flux to give a flux to rock ratio of 10:1.the mixture was then fused in an induction furnace for about six minutes, and the resulting melt was cooled to form a glass disc. The Whole rock major element analysis was performed on the fused disc by automated XRF spectrometer, Philips PW1480.the analytical equipment was calibrated using geochemical standards. The precision was better than 1% for all analyzed elements.

4 Result

4.1 Bulk –Rock geochemistry

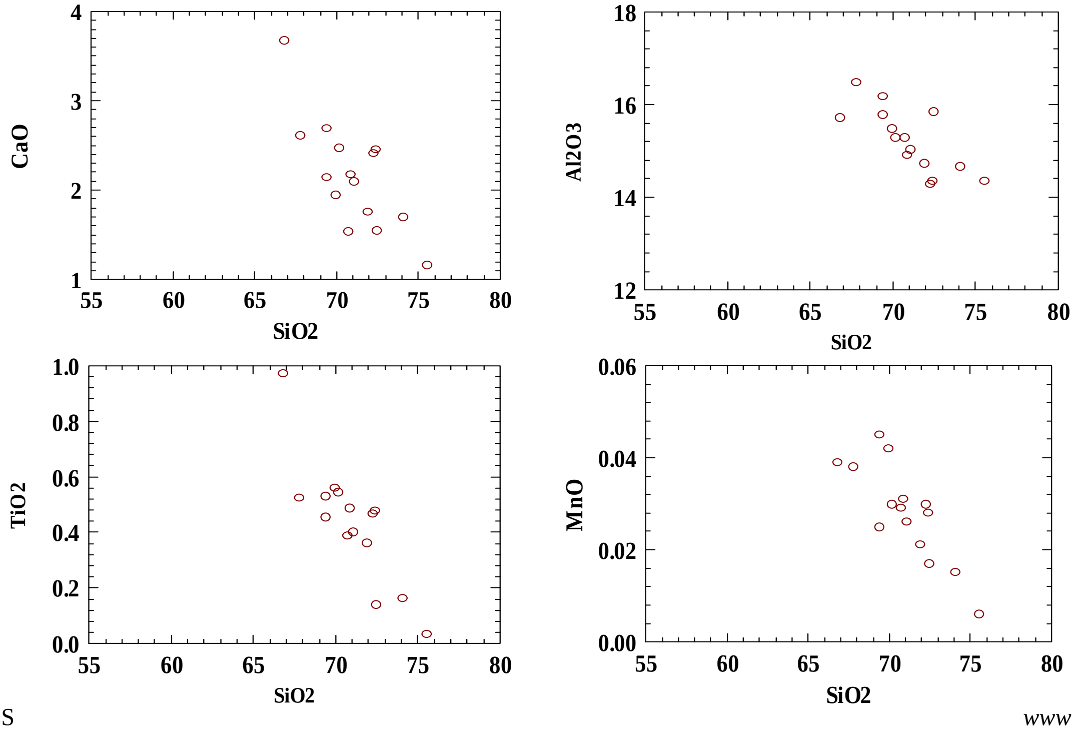
The result of the analyses of bulk rock geochemistry by XRF fusion method, XRF by pressed pellet method and the mineral chemistry is shown in Appendix I, II, III respectively.

4.1.1 Geochemical characteristics

The major element composition (in wt oxide) of the representative basin-type granitoids from the Winneba Suite and their CIPW normative mineral assemblages are in table 1. All the rocks samples analyzed have SiO_2 content ranging from75.5%-66.8%, Ti_2O from 0.95%-0.03, Al_2O_3 from 16.46-14.28%, total iron as FeO from 7.4-0.41%, MnO from 0.05-0.02%, MgO from 0.99-0.05%, CaO from 3.68-1.16%, (Na_2O +K_2O) content of 8.74-6.20, and Na_2O/ K_2O ratios from 1.79 to 0.64 and P2O5 from 0.21-0.01. The Mg# (Mg#=100*(MgO /40.32) /{(Fe2O3/79.85) +MgO/40.32)}) of the rocks ranges from 23.95-11.54 and the A/CNK (molecular Al_2O_3/(CaO+Na_2O+K_2O) ranges from 0.83 -0.78.

The major element composition revealed an evolutionary trend as evidenced in Fig. 2, showing a negative correlation with Si_2O expect Na_2O which showed roughly scattered pattern. All the major element composition apparently decreased with increasing Si_2O content and showed medium to high-K affinity (Fig. 2). The overall decreasing trend of FeO_{tot} and MgO suggest high fractionation of mafic minerals like biotite.

The Cross-Iddings –Pirsson –Washington (CIPW) norm calculations were done using Fe_2O_3 as 0.15 of total iron to mollify any effect that might have resulted from post-emplacement oxidation processes (Tate et al., 1999).The normative mineral assemblages (Table 1) revealed the rocks are quartz-normative and contain normative orthoclase, albite, anorthite, corundum and apatite among others. The CIPW norm was calculated using Fe^{3+}/Fe^{2+} ratio of 0.15 (Tete et al., 1999).



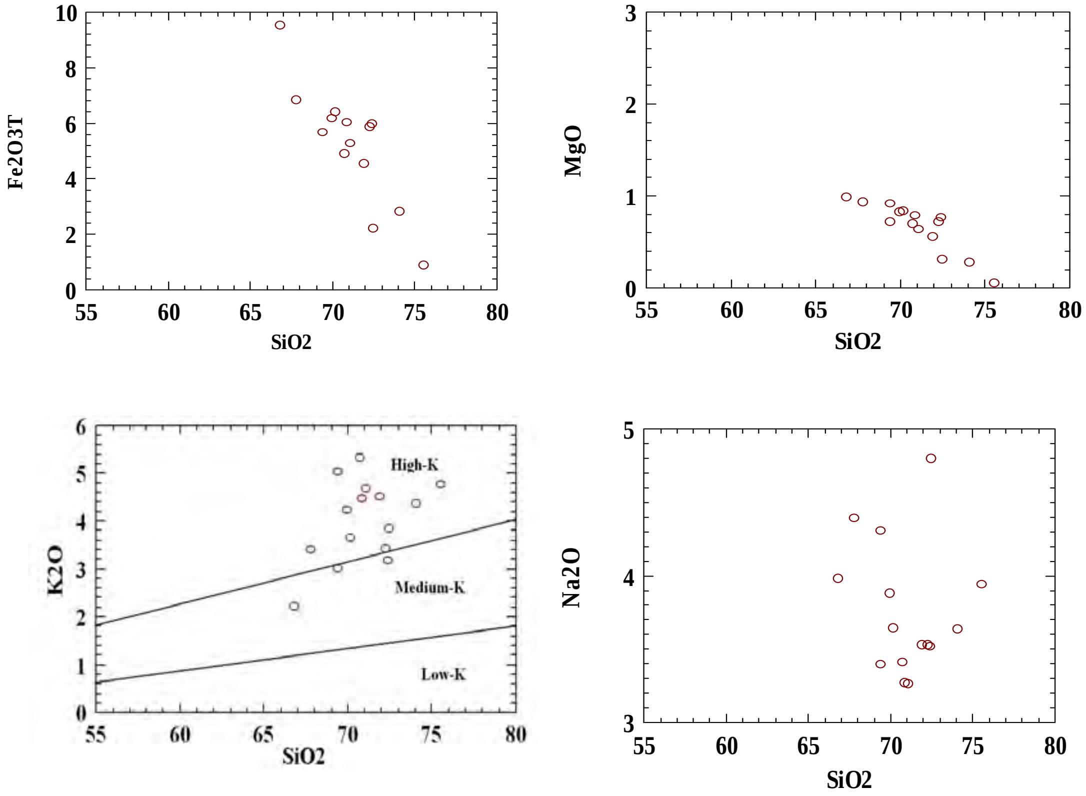


Fig. 2 Harker diagrams showing variations of major element oxides with silica for the Winneba area basin-type granitoids. The K_2O vs SiO_2 diagram after Le Meiter, (1989), indicates a medium to high- K affinity of the granitoids.

Table 1 (a) Major element abundances in representative sample from Winneba area

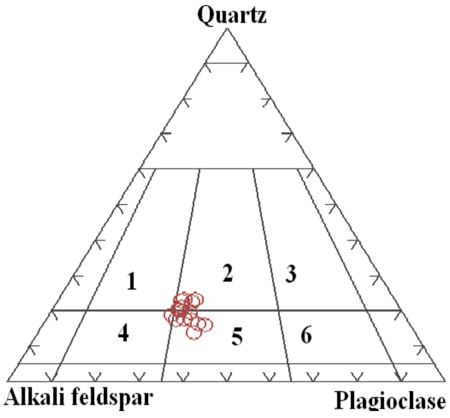
Co-ordinate	5^{O}20’24’’N	5^{O}20’24’’N	5^{O}20’24’’N	5^{O}20’26’’N	5^{O}20’12’’N	5^{O}20’12’’N	5^{O}20’12’’N
Sample No.	WG-01	WG-02	WG-03	WG-04	WG-06	WG-07	WG-08
SiO_2	66.811	75.528	70.151	71.06	70.728	69.912	71.904
TiO_2	0.971	0.033	0.545	0.402	0.388	0.559	0.364
Al_2O_3	15.714	14.337	15.295	15.026	15.295	15.492	14.731
Fe_2O_3	4.769	0.46	3.205	2.638	2.461	3.085	2.279
FeO_{tot}	8.58	0.82	5.77	4.75	4.43	5.55	4.10
MnO	0.039	0.006	0.03	0.026	0.029	0.042	0.021
MgO	0.995	0.054	0.837	0.64	0.697	0.824	0.556
CaO	3.676	1.164	2.469	2.098	1.534	1.942	1.75
Na_2O	3.983	3.936	3.649	3.263	3.413	3.879	3.531
K_2O	2.219	4.767	3.664	4.692	5.324	4.235	4.519
P_2O_5	0.207	0.012	0.149	0.115	0.092	0.156	0.091
Total %	99.387	100.298	99.994	99.959	99.96	100.127	99.746
Mg#	18.676	11.537	22.316	21.063	23.756	22.721	21.170
A/NCK	0.778	0.799	0.808	0.792	0.811	0.818	0.805

Table 1 (b) CIPW normative mineral assemblages in representative sample from Winneba area

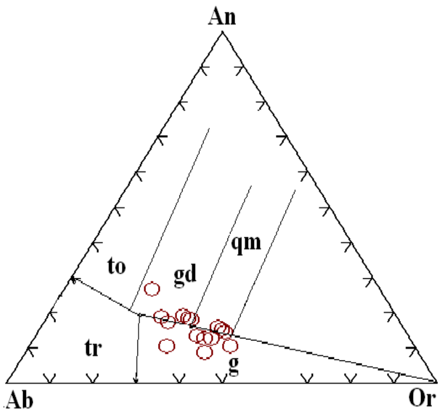
Co-ordinate	5^{O}20’24’’N 0^{O}37’05’’W	5^{O}20’24’’N 0^{O}37’05’’W	5^{O}20’24’’N 0^{O}37’05’’W	5^{O}20’26’’N 0^{O}37’05’’W	5^{O}20’12’’N 0^{O}37’06’’W	5^{O}20’12’’N 0^{O}37’06’’W	5^{O}20’12’’N 0^{O}37’06’’W
Sample No.	WG-01	WG-02	WG-03	WG-04	WG-06	WG-07	WG-08
Q	20.66	31.14	24.68	25.57	23.30	22.28	26.85
Or	12.70	28.01	21.12	27.17	30.88	24.40	26.30
Ab	32.58	33.05	30.05	27.00	28.29	31.93	29.37
An	16.50	5.67	11.09	9.54	6.94	8.50	8.02
C	0.48	0.59	1.11	0.97	1.28	1.28	1.01
Hy	13.02	1.27	9.4	7.73	7.46	9.06	6.69
Mt	1.82	0.17	1.23	1.01	0.95	1.18	0.88
Il	1.79	0.06	1.01	0.75	0.72	1.03	0.68
Ap	0.44	0.03	0.32	0.25	0.20	0.33	0.20

4.1.2 Petrography

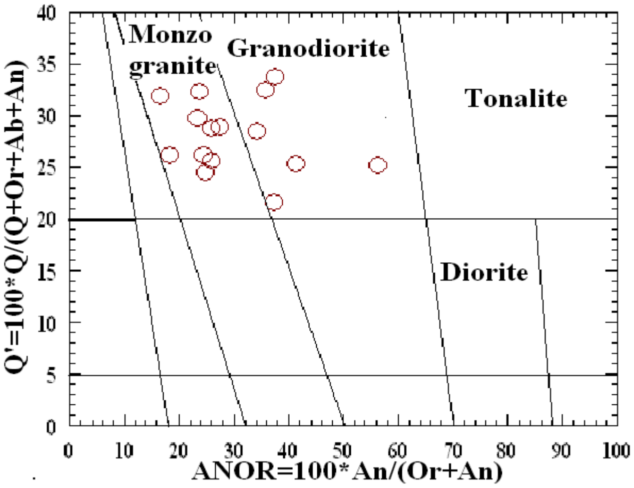
The principal phase assemblage of the Basin type granitoids studied composes of Quartz, Alkali feldspar, Biotite, and Amphibole. Accessory minerals are titanite, allanite, apatite, zircon and iron oxides. The rock composition based on the normative modal abundance showed monzogranite and quartzmonzonite composition (Fig. 3A) and in the normative Ab-An-Or classification diagram of O’Connor (1965) plotted in the field of granodorite, granite and quartzmonzonite (Fig. 3B). Also based on the normative Q’/ANOR (Fig. 3C) classification of rocks, the rock still showed monzogranite and granodiorite type.



(a)



(b)



(c)

Fig. 3 (a) Mesonormative QAP diagram (after Le Maitre, 1989).1-synogranite, 2-monzogranite, 3-granodorite, 4-quartzsyenite, 5-quartzmonzonite, 6-quartz monzodiorite. (b) Normative Ab-An-Or classification diagram (after O'Connor, 1965; Barker, 1979) showing the fields of the granitoids of the Winneba suite. gd-granodoirite, to-tonalite, qm-quartzmonzonite, g-granite. (c) Molar norm composition in the Q'ANOR diagram of the Streckeisen and Le Maitre (1979).mg-monzogranite, sg-syenogranite,gd-granoiorite,to- tonalite, qm- quartzmonzonite, g- granite and tr- trondhjemite

4.2 Mineral chemistry

Biotite has relatively high Al and moderate Fe contents (Djouka-Fonkwe et al., 2008) and SME analyses of the biotite from the basin type granitoids. Table 2 indicate compositions of meroxenes and lepidomelanes (Fig. 4), following the classification of Trőger (1982) with an intermediate Al content. The most important feature of biotites is that they are Mg-rich (Helmy et al., 2004). The range of molar Fe2/ (Fe2+Mg) of the biotite composition is high (57–64) and the alumina saturation index (ASI= Al/Ca+Na+K,) is moderate (1. 4– 2.5) and reflects some extend of alumina activity in the crystallizing magma (Zen, 1988).

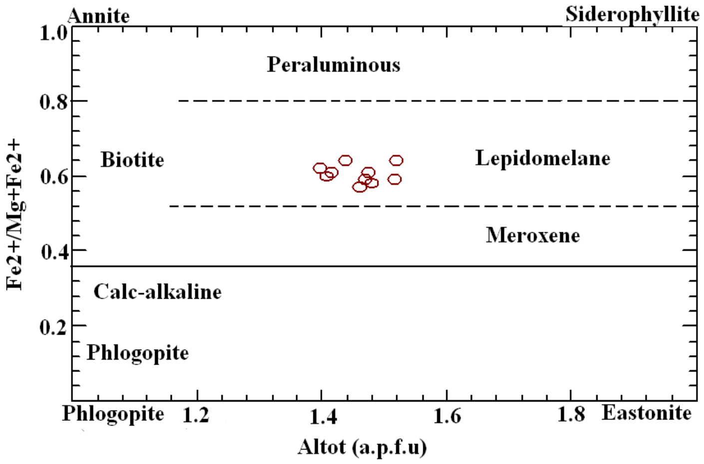


Fig. 4 Biotite chemistry plotted in the Al vs. Fe2+/ (Fe2+ + Mg) diagram of Trőger (1982).

The progressive increase of the total Al contents and the Fe^{2+}/ (Fe^{2+} + Mg) ratios in biotite (Fig. 4) are consistent with a compositional trend of Biotite in continental–collision related granites (Lalonde and Bernard, 1993). It indicates contribution of crustal material (metasediments) during the petrogenesis of the basin type granitoids magmas, either by assimilation or anatexis (Shabani and Lalonde, 2003). The biotite compositions systematically range from the calc-alkaline to the peraluminous granitic of the discriminative trend defined by Abdel-Rahman (1994) among the different granitoid suites.

Table 2 Representative electron microprobe Biotite mineral analyses from the studied Basin type granitoids

Wt %	W-1	W-2	W-3	W-4	W-5	W-6	W-7	W-8	W-9	W-10
SiO_2	38.6	39.33	38.36	41.87	40.58	36.21	39.34	39.15	39.91	39.49
TiO_2	1.27	2.3	2.21	2.44	2.16	1.88	4.01	1.78	1.96	2.1
Al_2O_3	17.67	16.4	16.76	17.11	16.51	17.71	16.27	17.2	17.03	17.24
Cr_2O_3	0	0.01	0	0.03	0	0	0	0.01	0	0
FeO*	25.72	22.3	24.42	19.89	22.33	27.2	21.65	22.99	21.2	21.65
MnO	0.15	0.24	0.14	0.25	0.19	0.27	0.31	0.21	0.21	0.16
MgO	9.89	8.38	7.69	7.61	7.84	8.63	7.57	8.37	8.96	8.83
CaO	0.36	0.33	0.29	0.68	0.35	0.96	2.01	0.27	0.27	0.19
Na_2O	0.18	0.29	0.26	1.2	0.56	0.31	0.11	0.26	0.23	0.24
K_2O	6.02	9.87	9.54	8.8	9.19	6.08	8.47	9.39	9.85	9.5
P_2O_5	0	0.32	0.16	0	0.04	0.36	0.15	0.24	0.16	0.31
Total	99.86	99.77	99.83	99.88	99.75	99.61	99.89	99.87	99.78	99.71
Number of ions on the basis of 11 Oxygens										
Si	2.810	2.863	2.792	3.048	2.954	2.636	2.863	2.850	2.905	2.874
Ti	0.070	0.126	0.121	0.134	0.118	0.103	0.219	0.097	0.107	0.115
Al	1.516	1.407	1.438	1.468	1.416	1.519	1.396	1.475	1.461	1.479
Cr	0.000	0.001	0.000	0.002	0.000	0.000	0.000	0.001	0.000	0.000
Fe	1.566	1.357	1.486	1.211	1.359	1.656	1.318	1.399	1.290	1.318
Mn	0.009	0.015	0.009	0.015	0.012	0.017	0.019	0.013	0.013	0.010
Mg	1.073	0.909	0.834	0.826	0.851	0.936	0.821	0.908	0.972	0.958
Ca	0.028	0.026	0.023	0.053	0.027	0.075	0.157	0.021	0.021	0.015
Na2	0.025	0.041	0.037	0.169	0.079	0.044	0.016	0.037	0.032	0.034
K2	0.559	0.916	0.886	0.817	0.853	0.565	0.786	0.872	0.915	0.882
P	0.000	0.020	0.010	0.000	0.002	0.022	0.009	0.015	0.010	0.019
Total	7.655	7.680	7.635	7.742	7.672	7.572	7.605	7.688	7.727	7.704
Fe/Mg+Fe	0.593	0.599	0.640	0.595	0.615	0.639	0.616	0.606	0.570	0.579
ASI	2.475	1.431	1.521	1.412	1.476	2.224	1.456	1.587	1.509	1.589

5 Discussion

5.1 Classification

Various schemes which involve parameters such as the presumed origin of granitoids, mineralogy, geochemistry and tectonic environment, have been proposed for the classification of granitoids. In this study, the basin type granitoids in the Winneba area have been classify in some selected geochemical schemes aside the mineralogical classification.

Generally, the rocks showed calc-alkaline affinity (Fig. 5) other than tholeiitic in the AFM diagram of Irvine and Barager (1971) and this characteristic is also seen in the Biotite mineral discrimination diagram (Figs 10 and 11) of Abdel-Rahman (1994).

The plot of alumina saturation vs alkalinity (after Maniar and Picooli, 1989) [Al_2O_3/ (Na_2O+K_2O) vs Al_2O_3/ (Na_2O+K_2O + Na_2O)] classify the rocks as peraluminous and plots in the I-type field of the Chappel and White granite classification diagram (Fig. 6). These are characteristic features of basin type granitiods in Ghana, thus peraluminous and I-type characteristic (Leube et al., 1990).

The characteristic mineral diagram (Fig. 7) which is a measure of Dark minerals [B=Fe+Mg+Ti+] and aluminous character [A= Al-(K+Na+2Ca)] also indicates a peraluminous nature of the rocks. The peralumious character demonstrated by the A-B diagram reflects the presence of boitite. Generally, granitiods plotting in the peraluminous domain have been derived from anatexis of granitiods magma by first- cycle assimilated intermediate to acid volcaniclastic basin sediments (Leube et al., 1990).

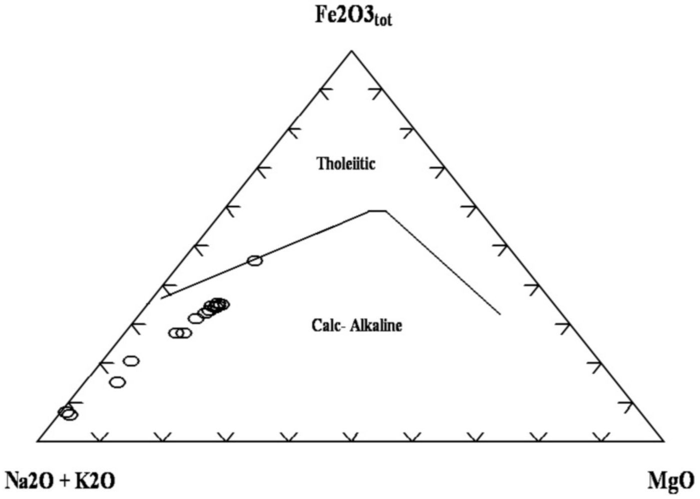


Fig. 5 AFM (A=Na_2O + K_2O), F=FeO_{tot}, M=MgO) diagram, showing a calc-alkaline affinity for the Cape Coast granite in the Winneba suite. The Calc-alkaline and tholelitic series differentiation line is from Irvine and Barager (1971).

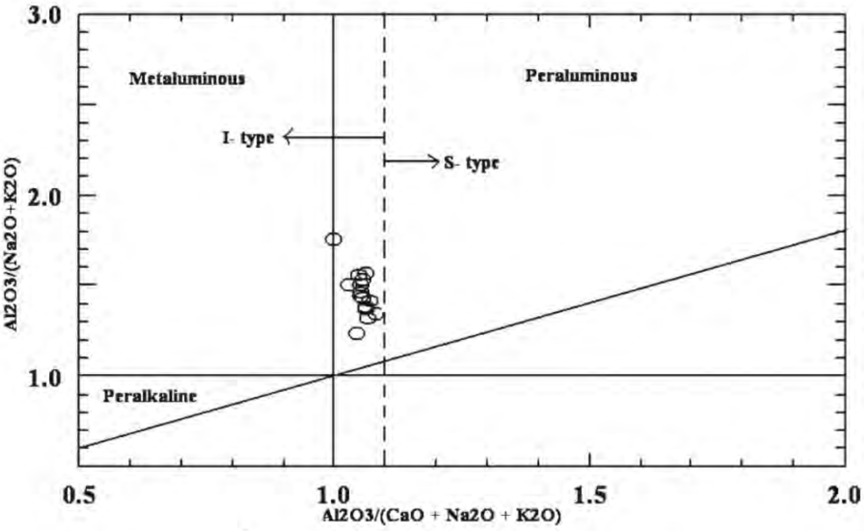


Fig. 6 Plot of alumina saturation vs alkalinity after Maniar and Picooli (1989) of the Cape coast granitiods in the Winneba suite. And also falling within the I-type granite field of Chappell and White (1974)

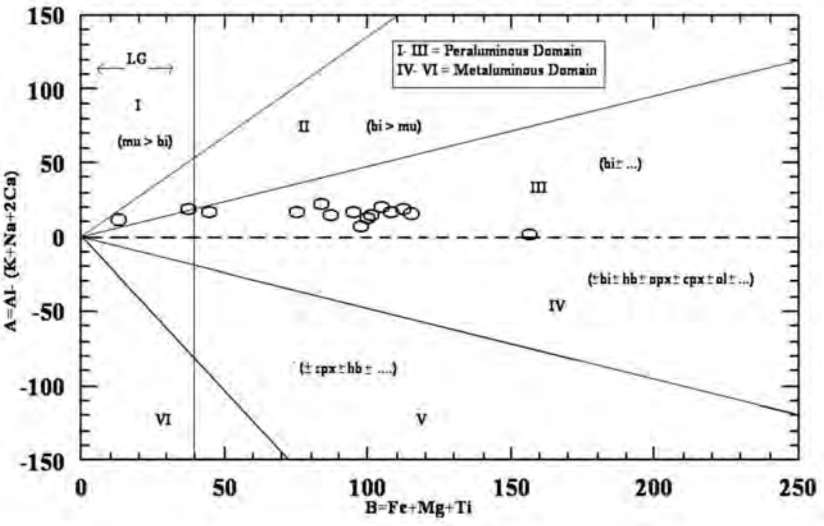


Fig. 7 Composition of the granitoids in the cationic classification scheme after Debon and Le Fort (1983). Indicating the characteristic mineral composition of the rocks

Frost et al. (2001) proposed a classification scheme based on major elements and using factors defined as the iron number or Fe*, modified alkali-lime index (MALI), and aluminum saturation index (ASI). The iron number [FeO/(FeO+MgO)] or Fe* [FeO_{tot}/(FeO_{tot}+MgO)] classifies samples as either ferroan or magnesian. The iron number or Fe* provides information about the differentiation history of a granitic magma. The MALI is defined by (Na_2O+K_2O-CaO) and divides samples into alkali, alkali-calcic, calcic-alkaliic and calcic affinities. MALI is used to interpret magma source. ASI is also defined by molecular Al/(Ca-1.67P+Na+K) and it differentiated peralkaline, metaluminous and peraluminous suites. Peraluminous suites have ASI>1.0, metaluminous suites have ASI<1.0 and (Na+K) <Al, and peralkaline suites have ASI<1.0 and (Na+K) >Al. the ASI index is a reflection of micas and accessory minerals in the rock, and is related to magma source and conditions of melting.

On the classification scheme of Frost et al. (2001), the analysed basin type granitoids in the Winneba area is ferroan, calcic and metaluminous Figs 6,7 and 8 respectively.

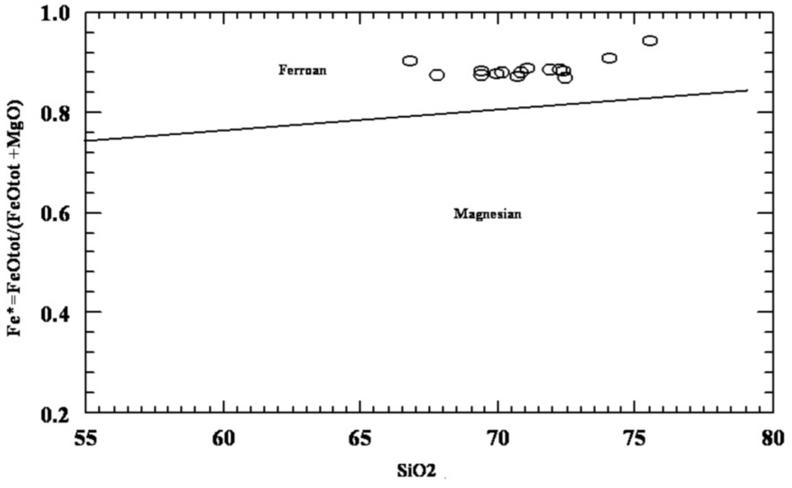


Fig. 8 Chemical classification of the cape coast granite in the winneba suite based on the iron number or Fe*, modified alkali-lime index (MALI), and aluminum saturation index (ASI). (a) Fe*-SiO_2 diagram showing a ferroan affinity.

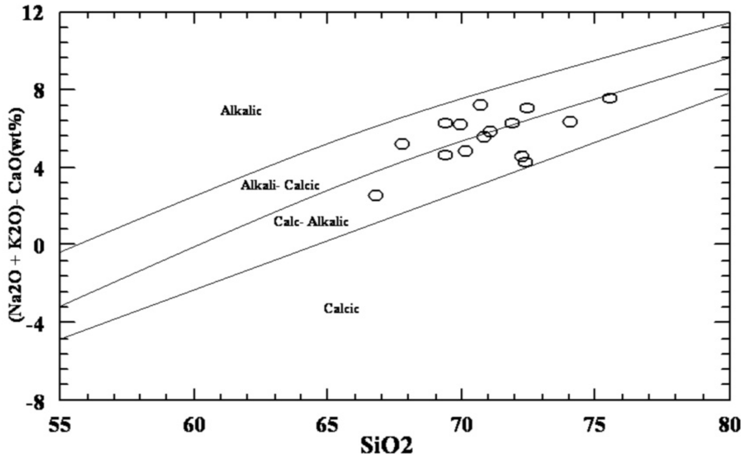


Fig. 9 The MALI – SiO_2 diagram indicating a crossing trend of alkali-calcic to calc-alkalic characteristics of the rock.

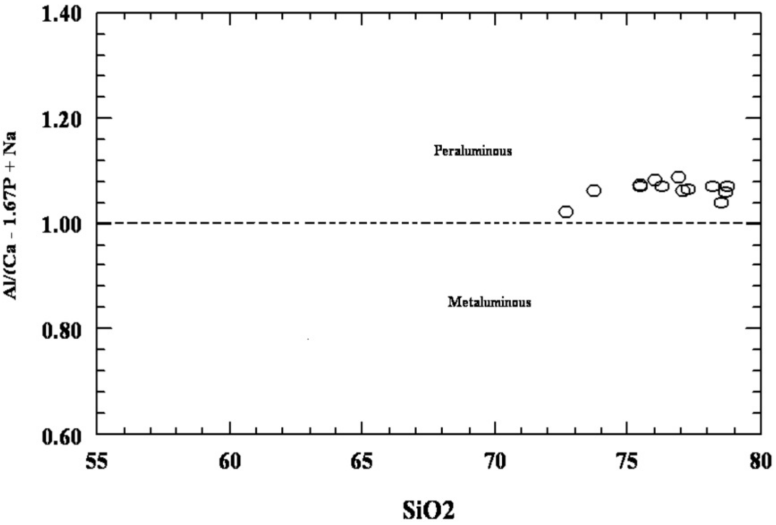


Fig. 10 Chemical classification of the cape coast granite in the winneba suite based on the iron number or Fe*, modified alkali-lime index (MALI), and aluminum saturation index (ASI) (c) The ASI-SiO_2 diagram showing a predominantly peraluminous character of the rocks.

5.2 Source rock characteristics and petrogenesis

Magmatic source of igneous rocks can be inferred using immobile to mobile ratios, which are commonly referred to as Pearce element ratio (after Pearce, 1996). Rocks from the same magmatic source have similar Pearce element ratios and plot along linear trends of magmatic differentiation. In granites, Ti, P, and Si are considered to be immobile elements, whereas K, Na, and Ca are mobile elements (Rollinson, 1993). Variables such as H_2O content, pressure, temperature and oxygen fugacity may be important during melting of source rock. As mentioned earlier, the belt type granitoids are typically dioritic to granidioritic in composition, I-type and metaluminous. On the other hand the basin- types (e.g., Cape Coast granite) are typically granodioritic in composition, I-type and peraluminous. The analyzed granitiods showed mineralogical and chemical characteristic of I-type which is derived from partial melting of igneous batholiths. This characteristic is notable of basin-type granitoids in Ghana (Leube et al., 1990; Hirdes et al., 1992; Loh and Hirdes, 1999). Their alkali-calcic to calc-alkali, medium to high –K and peraluminous nature indicate a source that is peraluminous and rich in potassium.

Partial melting experiments conducted at geologically realistic temperatures and pressures have indicated that granitoid magmas can be generated from a wide range of common crustal rocks (e.g., Wolf and Wyllie, 1994; Gardien et al., 1995; Patino Douce and Wyllie, 1996; Singh and Johannes, 1996). The geochemistry and mineralogy of the resulting granitic rocks are indicative of the nature of the source from which they were derived, as well as, the dynamic conditions under which magmas were formed, evolved and eventually solidified (Roberts and Sundvoll, 2000).

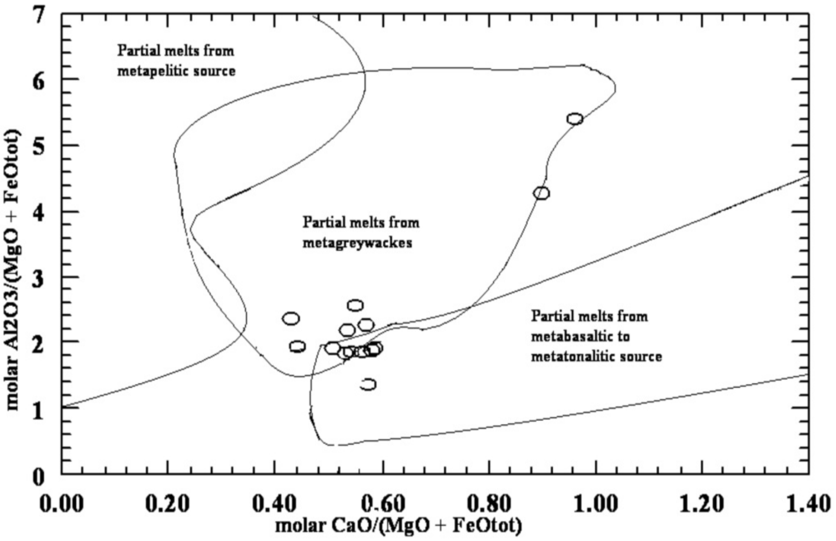


Fig. 11 Chemical composition of the Winneba suite granitoids in the molar Al2O3/ (MgO + FeOtot) – CaO/(MgO +FeOtot) of Altherr et al (2000). Composition field of partial melts were obtained by various source rocks (Wolf and Willie, 1994).

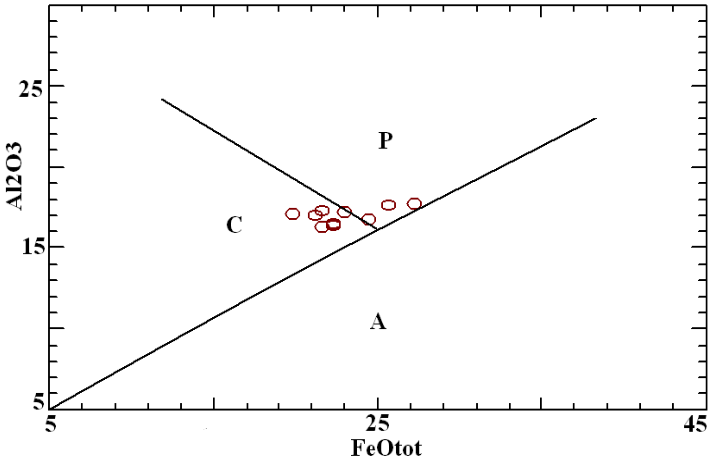


Fig. 12 Biotite composition diagram showing the classification of magmas after Abdel-Rahaman, (1994)

Compositional differences in melts generated by partial melting of different source rocks, such as amphibolites, tonalitic gneises, metapelites and metagreywackes, under variable melting conditions can be visualized in terms of molar $CaO/(MgO+FeO_{tot})$ vs. molar $Al_2O_3/(MgO+FeO_{tot})$ of the major element composition of the whole rock (Altherr et al., 2000; Fig. 9). Fig. 9 indicates that the basin type granite in the Winneba area was derived from partial melting of metagreywackes with contribution from metabalsaltic to metatonalitic source. Experimental and geochemical studies suggest that the major source of peraluminous and S-type granitods could be the partial melting of detrital metasediments, especially shales and greywackes (Condie et al., 1999; Frost et al., 2001). However, they may be also form by melting of biotite-bearing metaluminous felsic rocks (Miller and Thomas, 1985).

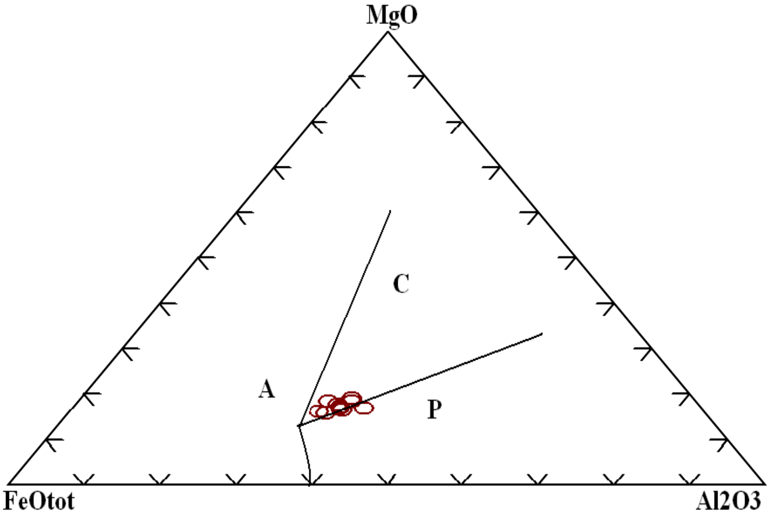


Fig. 13 Biotite composition diagram showing the classification of magmas after Abdel-Rahaman, (1994)

Biotite composition has also been used to describe the nature of granitic magma (Abdel-Rahman, 1994); Barriere and Cotton, 1979; Kabesh and Refaat, 1975; Moazamy, 2006). Abdel-Rahman (1994) suggested discrimination diagrams on the basis of major - elements (FeO, MgO, Al_2O_3) of biotites in igneous rocks 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 through peraluminous to alkaline suites (FeO*= total Fe).

The investigated biotites are found in field C to P (Fig.10 and 11). It means that based on chemistry of biotites, basin type granitoids formed from calc-alkaline to peraluminous magma. This conclusion is in line with the whole rock analysis that indicated peraluminous and calc alkaline nature of the rocks. 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 amphibole and iron oxides (typically magnetite), which in turn precludes the build-up of iron in calc-alkaline melts from which a moderately Mg-rich biotite crystallizes (Abdel-Rahman, 1994; Lalonde and Bernard, 1993; Shabbani and Lalonde, 2003).

The oxygen fugacity of magma is related to its source material, which in turn depends on tectonic setting. Sedimentary-derived granitic magmas are usually reduced, while I-type granities are relatively oxidized. It is difficult to estimate the original oxygen fugacity of primary magmas from the study of granitoids, as magnetite usually becomes Ti free during slow cooling and ilmenite undergoes one or more stages or oxidation and exsolution (Haggerty, 1976). However, some inferences on the oxidation state of magma can be made using the rock mineral assemblage and mineral chemistry. The occurrence of Mg-rich, pargasitic, magnesio-hornblende (Fig. 4a and b) and Fe^{2+} biotite in the rocks suggest relatively oxidized magma.

According to Wones (1989), the assemblages of titanite + magnetite + quartz in granitic rocks permit an estimation of relative oxygen fugacity. The $LogfO_2$ estimated bases on Wones (1989), equilibrium expression of $LogfO_2$= -30930/T+14.98+0.142 (P-1)/T (where, T is temperature in Kelvin and P is pressure in bars) gave $logfO_2$ in the limit between -17.6 to -25.9 which shows that the calc-alkaline, peraluminous, and K-rich magma crystallized in low oxygen fugacity (fO_2) .

6 Summary, Conclusion and Recommendation

Geochemically the basin-type granitoids are predominantly peraluminous, calc-alkaline, ferroan, and I-type, similar to the Cordilleran-type batholiths that are believed to be of magmatic arc origin (Pearce et al., 1984; Frost et al., 2001). They are medim to high k-rick and iron rich. The rocks were largely derived from partial melting from metagreywackes, with a probable contribution from partial melting of metabaslatic and or metatonalitic source, but excluded any contribution from metaplelitic rocks. The Birimian metasedimentary rocks, with which they are associated, provide the most likely source material of the basin granitoids. The mineral characteristic indicated that the rocks are from a cal-alkaline to peraluminous source.

From the geochemical characteristic of the basin-type granitoids, the granitoids are not juvenile as establish but indicated a contribution from an older rock or metasediment rocks.

More geochemical data, including trace element and isotopic data are required to confirm the petrogenic and tectonic setting deductions made from the major elements of the plutonic rocks.

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