ISSN 2229-5518

Geochemical characteristics of the basin-type granitoids in the Atia and its surrounding areas of Kumasi basin of Ghana.

Tandoh Kingsley Kwaah, Morgan Anthony, Seckley Albert Worlanyo, Brako Blestmond Afrifa

Abstract— Representative rocks of the metasediment suite granitoids (basin-type granitoids) were selected from the Atia area in the Ashanti part of Ghana for geochemical analyses. The rocks contained quartz, plagioclase, microcline, biotite, muscovite, and garnet as the main mineral phase. The CIPW normative mineral shows that the rocks are syeno-granite, monzogranite, granodiorite and quartz-monzonite. The geochemical classification of the basin type granitoids based on the Fe-Number, the modified alkali-lime index and the aluminium saturation index, defined the rocks as mainly magnesian, alkali, alkali-calcic to calc-alkali and peraluminous respectively. The rocks also show calc-alkaline affinity. The aluminous character by the molar ratio Al/ (Na+ K+ Ca/2) show mainly S-type characteristic of the rocks, which is a characteristic of basin type granitoids.The major element composition of the whole rock revealed that the basin- type granitoids are from metapelitic and or metagreywackes, with little or no metabasaltic to metatonalitic, and calc-alkaline to peraluminous source.

Index Terms— Basin-type, Birimian, Geochemical Characteristic, Granitoid, Kumasi Basin, Major Elements Metasediment, S-type

1 INTRODUCTION

Most part of Ghana falls within the West African Craton. The main rock units underlying the country are the early Proterozoic BirimianSupergroup and Tarkwaian group of the main West African Craton occupying the west and northern parts; the Pan African province covering the Dahomeyan, Togo and Buem formations in the southeast and eastern parts; and Infracambrian/Palaeozoic sedimentary basin situated in the central and eastern parts of the country (Junner 1935; Kesse, 1985).

The Birimian terrain of Ghana is characterized by narrow sedimentary basins and linear volcanic belts (Fig 1.1), and both the basins and the belts are intruded by extensive granitoids of Proterozoic age (Kesse, 1985). The sedimentary basins are composed mainly of daciticvolcaniclastics, wackes and argillites. The metavolcanic rocks consist mainly of tholeiitic basalts (basaltic lava flows, mafic dolerites, gabbros, etc) and minor calc-alkaline rocks (andesites, dacites, rhyolites, pyroclastites). These Birimian rocks are associated with and overlain by the clasticTarkwaian formation, derived from them (Junner, 1940; Kesse, 1985; Leube et al., 1990; Davis et al., 1994).

Intruded into the Birimian rocks are Winneba, Cape Coast, Dixcove and Bongo granitoids (Junner 1935; Kesse, 1985). The latter three have been recently termed “Basin”, “Belt” and “K-rich” granitoids by Luebe et al. (1990). These plutons range from foliated to massive, and concordant to discordant types, which from field relations are mostly syn- to post tectonic in emplacement. The basin and belt type intruded the sedimentary basin and volcanic belt respectively. The Birimian sedimentary basins in Ghana include the Cape Coast, Kumasi, Sunyani and Maluwe Basins (Hirdes et al., 1992). On the basis of U-Pb zircon and monazite dating, Hirdes et al. (1992) determined the age of the Belt-type granitoids in the Ashanti belt to be about 2175 Ma and the age of the Kumasi Basin-type granitoids at about 2116 Ma.

The granitoids display different geochemical characteristics, with the belt-type and the basin-type granitoids showing I-type and S-type characteristics, respectively (Leube et al., 1990). However, recent studies conducted on granitoids from the Konongo area, the north-eastern part of the Ashanti volcanic belt (Dampare et al., 2005) have revealed that some of the belt-type granitoids show S-type characteristics, which might have a different tectonic setting or origin from the others. The basin-type granitoids in the Winneba area of Ghana also show I-type characteristics (Nyarko et al., 2012).

This work seeks to present XRF data on the major elements of the whole rock to examine the current geochemical nature and source of the basin-type granitoids in the Atia and its surrounding areas of Kumasi basin.

2 GEOLOGY OF THE STUDY AREA

The rocks in Atia area belong to the Kumasi metasedimentary group which corresponds to the Lower Birimian series of Junner (1940) and Milési et al. (1992). The metasidementary rocks in the area are intruded basin-type granitoids. The metasedimentary rocks comprises volcaniclastic rocks, turbidite-related wackes, argillitic rocks, and chemical sediments now metamorphosed into meta-greywackes, phyllites, schists, and shales. They are intruded by felsic and mafic dykes. Shear and fault zones are found in all the metasedimentary units but more pronounced in the soft rocks adjacent to the intrusive

ISSN 2229-5518

units (Leube et al., 1990).The basin-type granitoids mainly display S-type characteristics (Loh et al., 1999). They are less mafic than the belt-type granitoids and display granodioritic and granitic compositions. The youngest intrusions are sometimes K-rich. Mauer (1990) proposed two formation models: (1) a formation in situ by partial melting of surrounding metasedimentary rocks, or (2) a formation by melting of metamafic rocks with significant contamination by the upper crustal metasediments.

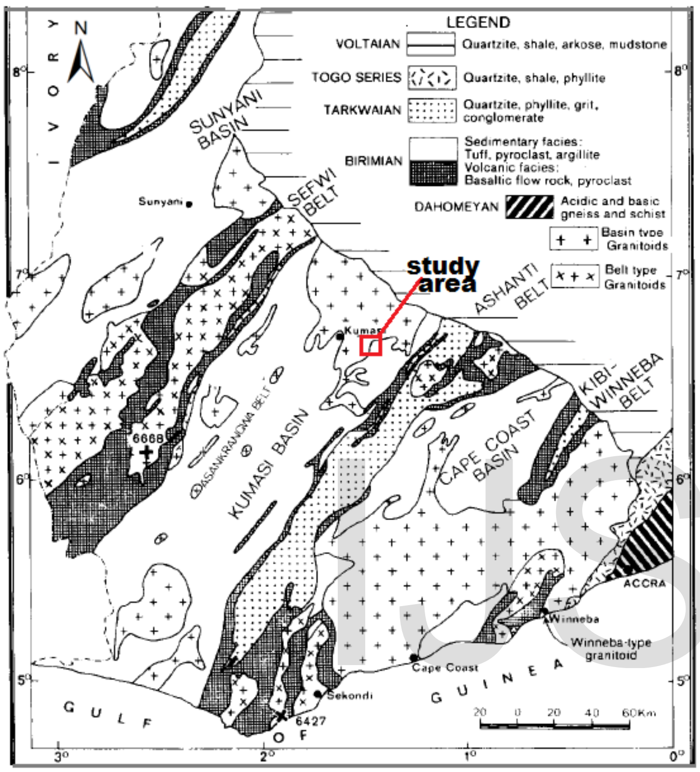

Fig.1 Regional geological map of part of southern Ghana showing the rock units and the study area (after Leube et al., 1990)

3 MATERIALS AND METHODS

Representative samples of the granitoids were collected. The samples were given sample identities (I.D.) and then placed in sample bags marked with name corresponding to the sample I.D. Fifty-nine oriented rock samples were collected; 25 of these samples were cut to make thin sections and twenty selected for whole rock geochemistry, XRF at Ghana Geological Survey Department.Thin sections of the representative rock samples were prepared for the mineral composition analysis at the Department of Earth Science petrological laboratory, University of Ghana, Legon-Accra.

3.1Thin sections preparations

Small sections of the rock samples were cut using a diamond saw. The softer rocks were impregnated with Canada balsam to make them hard for cutting. Sequentially, the sections were then grounded flat and smoothed on one surface using Silicon-Carbide powder. The smoothed surfaces were mounted on glass slides using Canada balsam. The other surfaces were then ground down with silicon carbide powder grade 80 until the rocks became very thin. Advancingly, finer abrasives were used as the section became thinner, and finishing was done with 600-grade of silicon carbide powder until the thickness of the rocks was about 30 microns. The thickness was deduced by observing the interference colours of common minerals such as quartz and feldspar under the petrographical microscope.From the hand specimen and modal analyses, appropriate rock names were assigned to the various rocks observed and sampled in the field.

3.2 X-Ray fluorescence Rock saw with a diamond blade was used to cut the rocks into rectangular blocks which are about 9 centimetres in length, 6.5 centimetres in breath, with a thickness of about 5 centimetres.The samples were crushed into powdered particles by using jaw crusher. The samples were sieved with 125 μm aperture to obtain grain sizes less than 125 μm. Samples were stored in transparent containers that were labelled with appropriate sample I.D.The pellet-making process started with weighing 4.0 g of rock samples added to 0.9 g of cereox wax on the Adventurer Pro AV264 electronic balance. The weighed mixture was transferred into a sample cup, covered which was then fix into a Petsch MM 30 Homogenizer. The homogenizer machine was used to mix the content of the cup to obtain a homogenous powder. Pressing the powder with the aid of a die produced the pellets. The sample cup and die were cleaned with acetone before the process was repeated for the next rock sample in order to avoid contamination.

The rock samples were analysed by XRF for 12 major elements, reported as oxides (SiO_2, TiO_2, Al_2O_3, Fe_2O_3,MnO, MgO, CaO, Na_2O, K_2O, P_2O_5, SO_3, Cl) and 18 minor elements (V, Cr, Co, Ni, Cu, Zn, Ga, Rb, Sr, Y, Zr, Nb, Ba, La, Ce, Pb, Th, and U). The major elements were stated in wt% while the minor elements were in ppm. The XRF spectrometer model, Spectro X-Lab 2000 was used for the tests. Data accuracy was enhanced by taken three measurements for each sample. In order to evaluate the precision of the results, known standards were tested prior to the analysis.

4 RESULTS AND DISCUSSION

4.1Geochemical Characteristics

The major element composition (in wt oxide) of the representative basin-type granitoids from the Atia Suite and their CIPW normative mineral assemblages are in table 1.and 2. All the analyzed granitoid samples from the Atia and its surrounding area have SiO2 content of 59.23-72.92%; TiO2 of 0.02-0.66%; Al2O3 of 14.49-23.48%; total iron as Fe2O3 of 0.59-6.04%; MnO of 0.02-2.0%; MgO of 0.94-6.93%; CaO of 0.01-4.46%; (Na2O+K2O) content of 3.90-9.88% and Na2O/K2O ratios from

ISSN 2229-5518

0.67 to 24.69 and P2O5 of 0.10-2.30%. The Mg# of the rocks ranges from 28.11 to 79.42.

The major element composition does not reveal an evolutionary trend as evidenced in Fig.4.5.2, showing roughly scattered pattern. All the major element composition apparently decreased with increasing SiO2.

The Cross-Iddings-Pirsson-Washington (CIPW) norm calculations were performed using ferric-ferrous iron ratio of 0.15 to nullify any effect that might have resulted from post-emplacement oxidation processes. Table 4.3 represent the normative mineral assemblage for the granitoids in the study area. The rocks are quartz normative and contain normative hypersthene in the range of 2.34-17.26 wt. %. Normative albite occurs in all the rocks. Interestingly, K-68 is the only sample which contains normative corundum (0.00%) and all the samples contain normative.

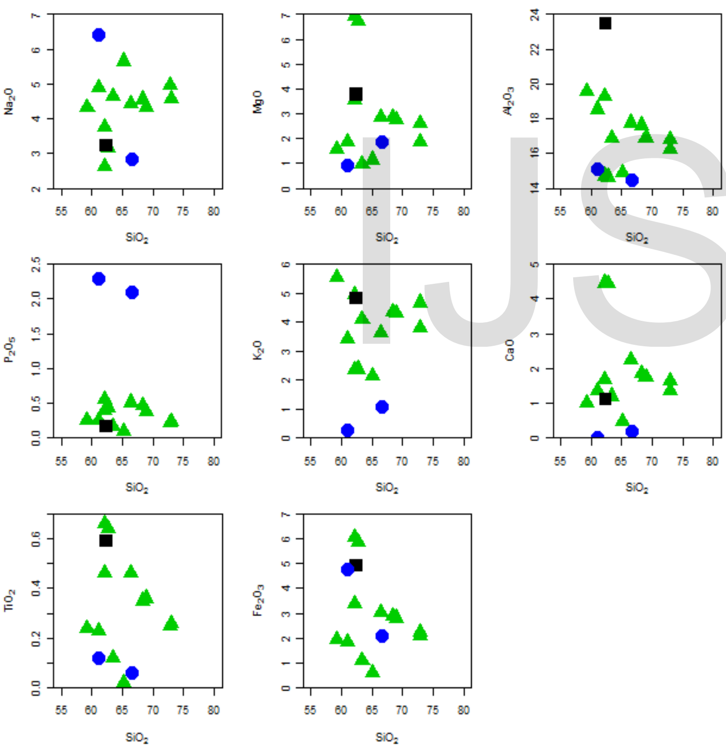

Fig.2 Harker diagrams showing variations of major element oxides with silica for the Atia area basin-type granitoids. Symbols same as Figure 4.5.1

Table 1 Major element abundances in the representative

samples from the Atia area granitoid suite.

Locality Wt%	K-13	K-14	K51A	K-31	K-38	K-40	K-51B	K-63	K-65	K-67	K-70B	K-70A	K-01A	K-01B	K-68
Na_2O	4.57	4.43	4.95	4.55	4.32	4.9	5.65	3.77	4.33	4.65	2.61	3.23	6.42	2.84	3.15
MgO	2.624	2.84	1.86	2.87	2.76	1.88	1.15	3.57	1.55	0.98	6.93	3.77	0.94	1.86	6.71
Al_2O_3	16.24	17.77	16.79	17.62	16.91	18.54	14.91	19.26	19.56	16.86	14.71	23.48	15.1	14.49	14.65
SiO_2	72.92	66.4	72.84	68.28	68.91	61.03	65.1	62.12	59.23	63.38	52.12	62.37	61.05	66.58	62.71
P_2O_5	0.23	0.51	0.22	0.47	0.38	0.26	0.09	0.40	0.26	0.16	0.56	0.17	0.04	0.16	0.44
K_2O	3.81	3.64	4.67	4.36	4.31	3.41	2.15	4.96	5.55	4.10	2.34	4.81	2.30	2.10	2.37
CaO	1.65	2.24	1.35	1.85	1.76	1.36	0.45	1.67	0.99	1.28	4.46	1.11	0.26	1.06	4.45
TiO_2	0.26	0.46	0.25	0.35	0.36	0.23	0.02	0.46	0.24	0.12	0.66	0.59	0.01	0.19	0.64
MnO	0.03	0.03	0.04	0.03	0.03	0.04	0.03	0.03	0.03	0.02	0.08	0.04	0.12	0.06	0.09
Fe_2O_3	2.24	3.01	2.09	2.88	2.80	1.85	0.59	3.39	1.93	1.11	6.04	4.92	0.61	2.00	5.86
Total	104.5	101.3	105.0	103.2	102.5	99.5	90.1	99.6	99.6	92.5	100.5	104.5	86.9	91.4	101.0
Mg#	69.85	65.14	63.80	66.37	66.13	66.81	79.42	67.59	61.39	63.62	69.44	60.27	28.11	63.58	69.39
A/CNK	1.11	1.16	1.07	1.13	1.13	1.30	1.53	1.312	1.31	1.18	0.98	1.87	1.37	1.42	0.92

Table 2 CIPW normative mineral assemblages in the representative samples from the Atia areas granitoid suite.

Sample	K-13	K-14	K-51A	K-31	K-38	K-40	K-51B	K-063	K-65	K-67	K-68	K-70B	K-70A	K-01A	K-01B
Q	24.96	19.11	21.13	18.21	20.47	14.49	21.59	13.44	9.08	17.06	17.10	19.68	17.65	21.31	43.23
C	2.15	3.69	1.66	3.18	2.85	4.94	2.69	5.61	5.23	2.97	0.00	1.12	11.35	4.26	8.67
Or	22.52	21.51	27.60	25.77	25.47	20.15	12.71	29.31	32.80	24.23	1401	13.83	28.43	1.54	6.26
Ab	38.67	37.49	41.89	38.50	36.56	41.46	47.81	31.90	36.64	39.35	26.65	22.09	27.33	54.32	24.03
An	6.68	7.78	5.26	6.11	6.25	5.05	1.63	5.67	3.26	4.91	18.83	18.47	4.39	0.00	0.00
Hy	6.53	7.07	4.63	7.15	6.86	4.68	2.86	8.89	3.86	2.44	16.71	17.26	9.39	2.34	4.63
Mt	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
Il	0.00	0.02	0.06	0.05	0.04	0.13	0.04	0.04	0.03	0.04	0.17	0.13	0.059	0.00	0.11
Hm	2.24	3.01	2.09	2.88	2.80	1.85	0.59	3.39	1.93	1.11	5.86	6.04	4.92	4.76	2.07
Tn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.00	0.00	0.00	0.00
Ru	0.26	0.45	0.23	0.33	0.34	0.16	0.00	0.44	0.22	0.10	0.45	0.56	0.56	0.12	0.00
Ap	0.55	1.21	0.52	1.11	0.90	0.62	0.24	0.94	0.62	0.38	1.04	1.33	0.40	0.02	0.34
Pr	0.05	0.03	0.02	0.03	0.02	0.02	0.02	0.02	0.02	0.00	0.02	0.03	0.02	1.03	3.27
Sum	104.6	101.3	105.0	102.5	102.5	93.5	90.2	99.7	93.7	92.6	101.1	100.5	104.5	89.7	92.7

4.2 Petrography

The principal phase assemblage of the Basin type granitoids studied composes of Quartz, plagioclase, microcline, biotite, muscovite, and garnet. Accessory minerals are chlorite, and opaque minerals. The rock composition based on the normative modal abundance showed mainlysyeno-granite and monzo-granite with three samples plotting in granodiorite field, with some in quartz-syenite (fig 3A)and in the normative Ab-

An-Or classification diagram of O'Connor (1965) plotted in the field of granitic and granodioritic (Fig. 3B). Also based on the normative Q'/ANOR (Fig.3C) classification of rocks, the rock still showedsyeno-granite, monzo-granite, granodiorite field , and quartz-syenite.

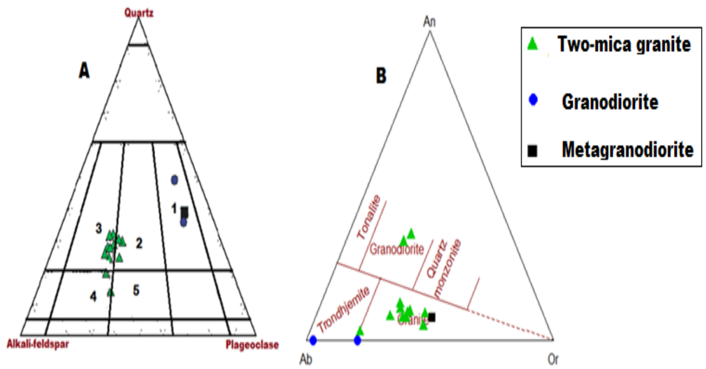

Fig.3 (A) Mesonormative QAP diagram (after Le Maitre, 1989) showing granodioritic composition for the rocks in the study. Fields: 1-granodiorite, 2 – monzo-granite, 3 – syeno-granite, 4 - quartz syenite. 5-quartz-monzonite and (B) Ab-An-Or diagram (O'Connor, 1965; Barker, 1979)

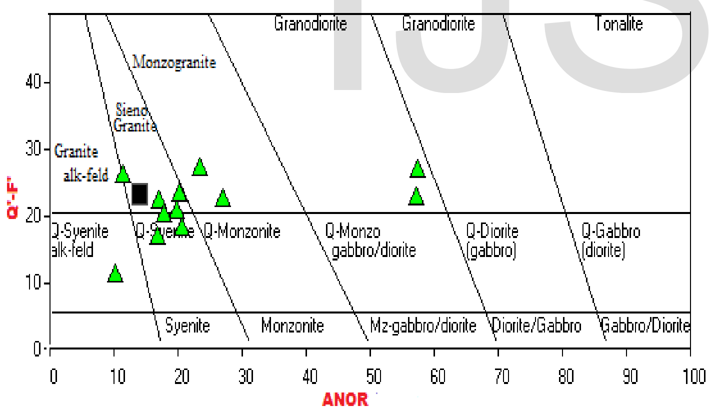

Fig.4 Molar norm compositions in the Q' -ANOR diagram of Streckeisen and Le Maitre (1979).

4.3 Classification

Various schemes, which involve parameters such as presumed origin of granitoids, mineralogy, geochemistry, and tectonic environment, have been proposed for the classification of granitoids. In this study, the rocks under investigation have been classified in 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). Debon and Le Fort (1983) developed several major element-based chemical-mineralogical plots which are useful in providing information about plutonic rocks.On the A-B diagram (Fig. 4.5.6), the rocks demonstrate peraluminous character and also plot in field I, II, III with two samples graded into the IV.

The peraluminous character of the rocks is corroborated by their lack of normative corundum and the position in the A/CNK-A/NK diagram of Maniar and Piccoli (1989), which further indicates that the rocks are of S-type character with slight I-type character (Fig. 4.5.7).

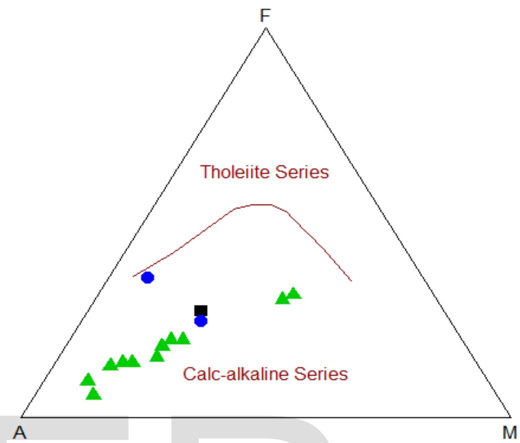

Fig.5 AFM of Irvine and Barager (1971).

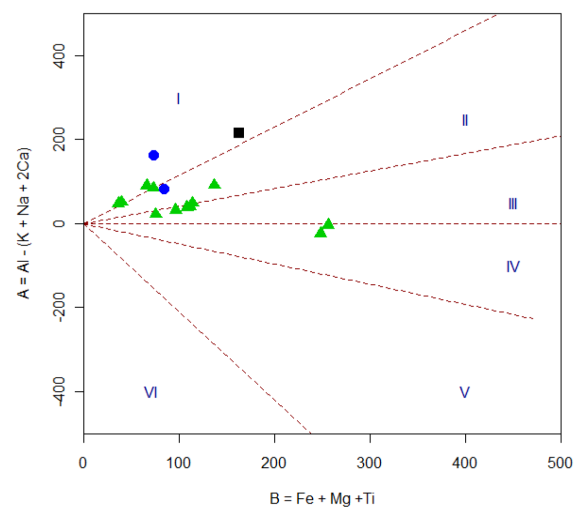

Fig.6 A-B diagram (Debon and Le Fort, 1983) plotted for granitoid in present. Each of its six sectors, numbered from I to VI, corresponds to a specific mineral assemblage.I, II and III are peraluminous sectors, where I: muscovite>biotite (by volume); II: biotite>muscovite; III: biotite (usually alone, at times with a few amphiboles); IV, V and VI are metaluminous sectors, where IV: biotite+amphibole±pyroxene;V:clinopyroxene±amphibole±biotite;

VI: unusual rocks (e.g., carbonatites) . Samples mostly plot in the I, II, III with some graded into the IV

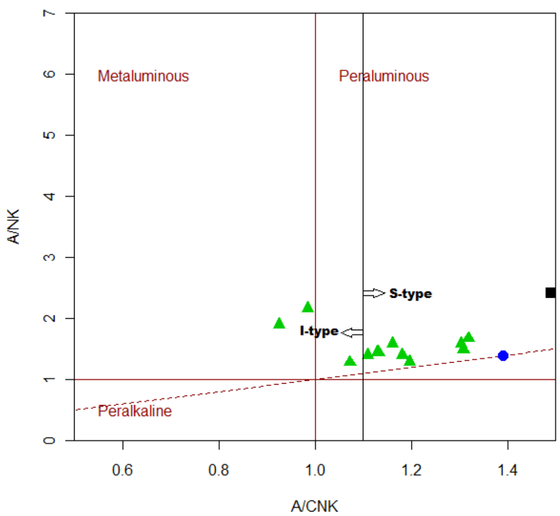

Fig.7 Shand's molar parameters A/NK = Al2O3/(Na2O+K2O) vs. A/CNK = Al2O3/(CaO+Na2O+K2O) of the granitoids (fields after Maniar and Piccoli, 1989). Dashed line represents boundary between I- and S- type granites (Chappell and White, 1992).

When the data are plotted in the K2O versus SiO2 diagram (Le Maitre,1989) (Fig.8), the rocks mainly indicate a high-K , some medium-K with two grading into low-K affinities.

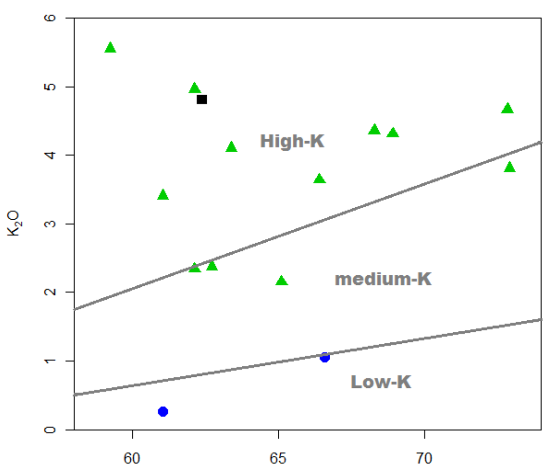

Fig.8 K2O versus SiO2 diagram (Le Maitre, 1989)

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* [FeOtot/(FeOtot+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 (Na2O+K2O-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 granitoid in the Atia areas is Magnesian, and mainly peraluminous. The MALI of the studied granitoids slightly increases with increasing SiO2 (wt. %) as showed in Figures 4.5.11.and 4.5.12. Their high total alkalis (Na2O + K2O = 0.33–8.91 wt. %) content compared to -lime concentration (CaO = 0.46–4.46 wt. %) classifies the granitoids into to the alkalic, alkali-calcic and calc-alkalic series fields.

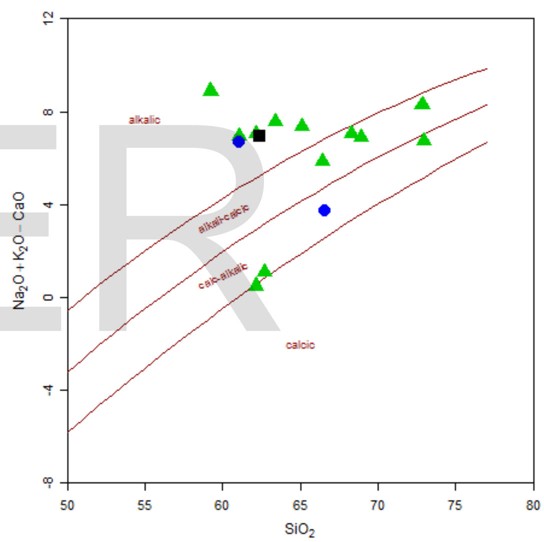

Fig.9 The MALI – SiO2 diagram indicating a crossing trend of alkali, alkali-calcic to calc-alkalic characteristics of the rock

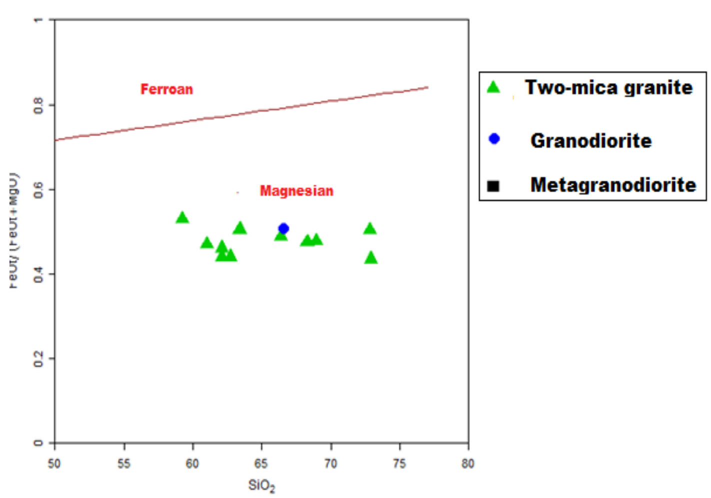

Fig.10 Chemical classification of the basin granitoids in the Atia suite based on the iron number or Fe*, modified alkali-lime index (MALI), and aluminum saturation index (ASI). (a) Fe*-SiO2 diagram showing a magnesian affinity.

4.4 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).

The Ti/K and Si/K cationic ratios computed for the rocks do not show similar values, ranging from 0.005 to 0.272 and 8.35 to 184.05, respectively. On the Ti/K and Si/K cationic plot (Fig.4.5.13), the rocks do not define a continuous trend, deviating from the trend of differentiation. The differences in their values including their calc-alkaline, peraluminous to slightly metaluminous and magnesian affinity suggest that the rocks were probably generated by different processes and sources. This is supported by their curvilinear trend in the Al2O3/TiO2 vs. TiO2 plot (Fig.4.5.14).

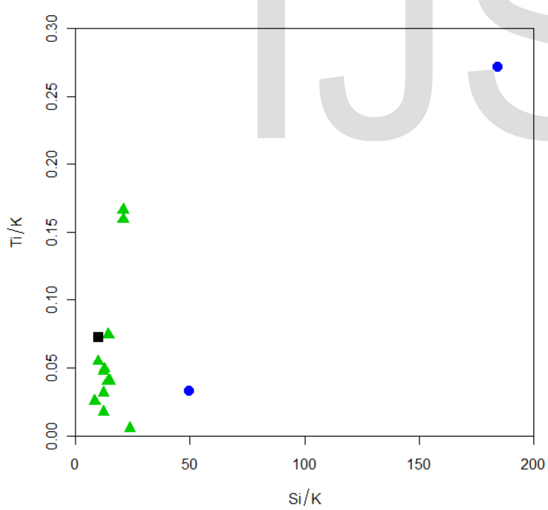

Fig.11 The Si/K verses Ti/K element ratio plot for the Atia areas' granitoids, depicting a nearly continuous trend characteristic of rocks developed from a common source.

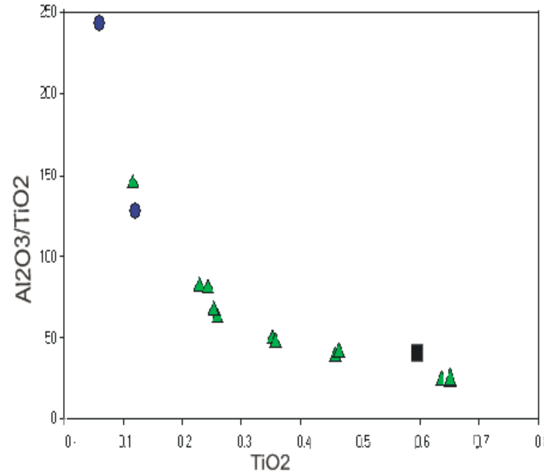

Fig.12 Al2O3/TiO2 verses. TiO2 diagram for the Etia areas' granitoids showing a curvilinear trend characteristic of plutonic rocks developed through magmatic differentiation.

The nature of the igneous rocks can be constrained using the geochemical and isotopic signatures of the plutonic rocks. 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). 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. (Roberts and Sundvoll, 2000)Compositional differences in melts generated by partial melting of different source rocks, such as amphibolites, tonaliticgneises, metapelites and metagreywackes, under variable melting conditions can be visualized in terms of molar CaO/(MgO+FeOtot) vs. molar Al2O3/(MgO+FeOtot) of the major element composition of the whole rock (Altherr et al., 2000; Fig. 4.5.15). Fig. 4.5.15 indicates that the basin type granite in the Atia and its surrounding areas in the Kumasi basin was derived from partial melting of metagreywackes and metapelites with somewhat 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, their peraluminious character could also result from large-scale contamination of the ascending granitoid magma by first-cycle assimilated intermediates to acid Volcaniclastic basin sediments. (Leube et al 1990). Also the plot of some samples into the I-type domain might be cause by the geochemical primitiveness of the early Proterozoic Birimian Sediments.

ISSN 2229-5518

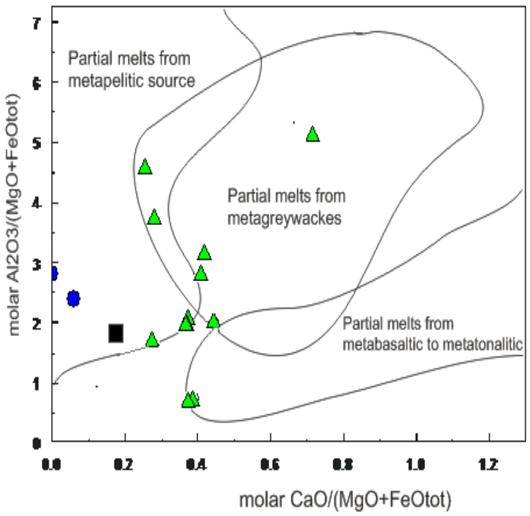

Fig.13 Chemical composition of the Atia granitoids in the molar Al2O3/ (MgO + FeOtot) – CaO/ (MgO +FeOtot) of Altherr et al (2000). Composition field of partial melts were obtained by various source rocks (Wolf and Willie, 1994).

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The basin-type granitoids in the study area are predominantly peraluminous, calc-alkaline, magnesian, and S-type. They are medium to high K-rich. The granitoids were largely derived from partial melting from metapelitic and metagreywackes, with little or no contribution from partial melting of metabasaltic and or metatonalitic source. The basin-type granitoid in the Atia area has different geochemical characteristics from the Winneba basin-type and belt-type granitoids. The dominant source for material for this granitoid is the Birimian metasedimentary rocks and magnesian. This is in contrast to both the Winneba- and belt- types' granitoids.

5.2 Recommendation

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.

Acknowledgment

The authors wish to express their profound gratitude to Prof. Prosper M. Nude and Mr. Richard K. Afenu of Earth Science Department, University of Ghana for their excellent guidance and support.

References

[1] Altherr, R., Holl, A., Hegner, E., Langer, C. And Kreuzer, H., ''High potassium, cal-alkaline I- type plutonism in the European Variscdes: northern Vosges (France) and northern Schwarzwald (Germany)'', Lithos, 50, 51-73, 2000

[2] Barker, F., ''Trondhjemite Definition, Environment and Hypotheses of Origin. In: Trondhjemites, Dacitesand Related Rocks (Barker F, Ed)'', Developments in Petrology 6. Amsterdam Elsevier, pp. 1-12. 1979

[3] Chappell, B.W. and White, A.J.R., ''I- and S-type granites in the Lachlan Fold Belt, Tran. Roy. Soc. Edinburg,'' vol. 83, pp. 1–26, 1992

[4] Condie, K.C., Latysh, N., Van Schmus, W.R., Kozuch, M. and Selverstone, J., '' Geochemistry, Nd and Sr isotopes, and U/Pb zircon ages of granitoid and sedimentary xenoliths from Navajo Volcanic Field, Four Corners area, Southwestern United States'', Chem. Geol., 156, 95-133, 1999

[5] Dampare, S., Shibata, T., Asiedu, D.,Osae, S., ''Major-Element Geochemistry Of Proterozoic Prince's Town Granitoid From The Southern Ashanti Volcanic Belt, Ghana'', Okayama University Earth Science Reports, Vol. 12, No. 1, 15-30, 2005

[6] Davis, D.W., Hirdes, W., Schaltegger, U., Nunoo, E.A., ''U-Pb age constraints on deposition and provenance of Birimian and gold-bearing Tarkwaian sediments in Ghana, West Africa'', *Precambrian Research*, 67, pp. 89-107, 1994

[7] Debon,F. and Le Fort, P., 'A chemical–mineralogical classification of common plutonic rocks and associations'', Transactions of the Royal Society of Edinburgh, Earth Sciences 73, pp. 135–149, 1983

[8] Frost, R.R., Baroes, C.G, Collins, W.J., Arculus, R.J., Ellis, D.J. and Frost, C.D., '.A chemical classification for granitic rocks'', J. Petrol., 42, pp. 2035-2048, 2001

[9] Gardien, V., Thompson, A.R., Grujic, D., Ulmer, P., 'Experimental melting of biotite+plagiocl ase+quartz+muscov ite assemblages and implications for crustal melting'', J. Geophys. Res., 100, 15581-15591, 1995

[10] Hirdes W., Davis D. W., and Eisenlohr B. N., ''Reassessment of Proterozoic granitoid ages in Ghana on the basis of U/Pb zircon and monazite dating'', Precambrian Research, vol. 56, pp. 89–96, 1992

[11] Irvine, T. N., Baragar, W. R. A., ''A guide to the chemical classification of the common volcanic rocks'', *Canadian Journal of Earth Sciences*, 8, 523-548, 1971

[12] Junner, N.R. ''Gold in the Gold Coast. Gold Coast '', Geological Survey Memoir No. 4, Accra, 67 pp, 1935

[13] Junner, N.R., ''Geology of the Gold Coast and Western Togoland'', Gold Coast Geological Survey Bulletin No. 11, Accra, 40 pp, 1940

[14] Kesse, G.O., ''The Mineral and Rock Resources of Ghana'', A. A. Balkema, Rotterdam, 610pp, 1985

[15] Le Maitre R.W., ''A Classification of Igneous Rocks and Glossary of Terms'', Blackwell, Oxford, pp. 193, 1989

[16] Leube, A., Hirdes, W., Mauer, R., and Kesse, G., ''The Early Proterozoic Birimian Supergroup of Ghana and some aspects of its associated gold mineralization'', *Precambrian Research*, vol. 46, pp. 139-165, 1990

[17] Loh, G., Hirdes, W., Anani, C., Davis, D.W., Vetter, U., '' Explanatory Notes for the Geological Map of Southwest Ghana 1 : 100,000'', Geologisches Jahrbuch, Reihe B, Heft 93, 150 p, 1999

[18] Maniar, P.D. and Piccoli, P.M., ''Tectonic discrimination of Granitoids'', Geol. Soc. Amer. Bull., v. 101, pp. 635–643, 1989

[19] Mauer, R., ''Petrographische und geochemische Untersuchungen der prakambrischen (Birimian) Granitoide Ghanas: Disertation, Techn. Univ., Berlin'', 202 pp, 1990

[20] Milési, J.P., Ledru, P., Feybesse, J.L., Dommanget, A., Marcoux, E., ''Early Proterozoic ore deposits and tectonics of the Birimian orogenic belt'', West Africa.*Precambrian Research,* 58, 305-344, 1992

[21] Nyarko, S.E., Asiedu, D.K., Dampare, S., Zakaria, N., Hanson, J., Osei, J., Enti-Brown, S., Tulasi, D., ''Geochemical characteristics of the basin-type granitoids in the Winneba Area of Ghana'', Proceedings of the International Academy of Ecology and Environmental Sciences,2(3), 177-192, 2012

[22] O'Connor J.T., ''A classification of quartz-rich igneous rocks based on feldspar ratios'', USGeologicaL Survey Professional Paper, 525B: 79-84, 1965

[23] Pearce J.A., ''Source and setting of granitic rocks. Episode'', 19, 120-125, 1996

[24] Roberts, D., Sundvoll, B. ''Geochemistry and Rb-Sr isochron age of trondhjemite dykes from the Gula Complex, near Snøan, Central Norway''. Norges geologiske undersøkelse Bulletin, 437, 67-74, 2000

[25] Rollinson H.R., ''Using Geochemical Data: Evaluation, Presentation, Interpretation'', 1993

[26] Streckeisen, A., Le Maitre, R.WA ''chemical approximation to the modal QAPF classification of the igneous rocks'', Egypt Neues Jahrb Mineral Abh, 136,169-206, 1979

[27] Wolf, M.B., Wyllie, P.J., ''Dehydrationmelting of amphibolite at 10 kbar: the effects of temperature and time'', Contributions of Minerology and Petrology, 115, pp. 369-383, 1994

- ***Tandoh Kingsley Kwaah*** *holds a Master of Philosophy degree in Geology from University of Ghana, Legon, currently working at the Oil & Gas Engineering Department, All Nations University College, Koforidua, Ghana.*
  Email: *ktandoh@anuc.edu.gh*
- ***Morgan Anthony*** *is currently studying Master of Science degree in Petroleum Engineering at Aberdeen University, United Kingdom.*
  Email: *morgt@ymail.com*
- ***Seckley Albert Worlanyo*** *is is currently studying Master of Science degree in Reservoir Engineering at Aberdeen University, United Kingdom.*
  Email: *wallasalberto@yahoo.com*
- ***Brako Blestmond Afrifa*** *holds a Master of Philosophy degree in Geology from University of Ghana, Legon.*
  Email: *bblestmond@gmail.com*