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Geochemical Classification and Geotectonic Setting of Granitic Gneisses from Southeastern Margin of Western Nigeria Basement

Mohammed Olatoye Adepoju* Yinusa Ayodele Asiwaju-Bello

Department of Applied Geology, The Federal University of Technology, Akure, Nigeria

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ABSTRACT

Chemical whole-rock major oxides and some trace element analyses were done on granitic-gneiss rocks from Dagbala-Atte District, located on the southeastern margin of western Nigeria Basement Complex. This was meant to classify the rocks and to understand the tectonic setting in order to evaluate their crustal evolution. The chemical analyses were done using inductively-coupled plasma mass spectrometer. From the results obtained, these rocks classified into calc-alkaline to shoshonite series with metaluminous to peraluminous varieties. They are I-type granitoids of ferroan composition. The granitic gneisses formed from metamorphism of granite and granodiorite. Tectonically, most of the rock samples plotted in the field of island arc, continental arc and continental-collisional granitoids, which indicated that the protolith granite and granodiorite are orogenic and are arc related inferring arc tectonic setting.

1. Introduction

The Proterozoic Eon is marked by the voluminous addition of granitic plutons along the continental arcs and the study of their genesis holds the key to our understanding of the evolution of continental crust^[1-3]. The migmatite-gneiss-quartzite complex (MGQC) in western Nigeria Basement, like in all other parts of the Basement Complex of Nigeria, has experienced many episodes of felsic magmatism during the Paleo-Proterozoic^[4]. This is evident from a variety of Paleo-Proterozoic felsic rocks exposed in different parts of MGQC terrain in the form of granitic gneisses. Apart from the granitic gneiss, other rock types that constitute the MGQC are migmatites, all kinds of para- and ortho-gneisses, and lenses of quartzites. The MGQC rocks are the oldest rock group in the Base-

ment Complex of Nigeria and have been dated Paleo-Proterozoic by a number of geological works^[5-8]. In this paper, a new whole-rock major and trace elemental data for granitic gneisses from Dagbala-Atte District that lies within Latitudes 7°10' and 7°21' N and Longitudes 6°09' and 6°17' E at the south eastern margin of the western Nigeria Basement Complex (Figure 1) are presented. The dataset allows us to characterise these granitoids and put constraints on their tectonic settings.

2. Geological Background

The MGQC of the southeastern margin of western Nigeria Basement (Figure 1) is studied at Dagbala-Atte District that lies within Latitudes 7° 10' and 7° 21' N and Longitudes 6° 09' and 6° 17' E. The district is spread over

*Corresponding Author:

Mohammed Olatoye Adepoju,

Department of Applied Geology, The Federal University of Technology, Akure, Nigeria;

Email: moadepoju@futa.edu.ng

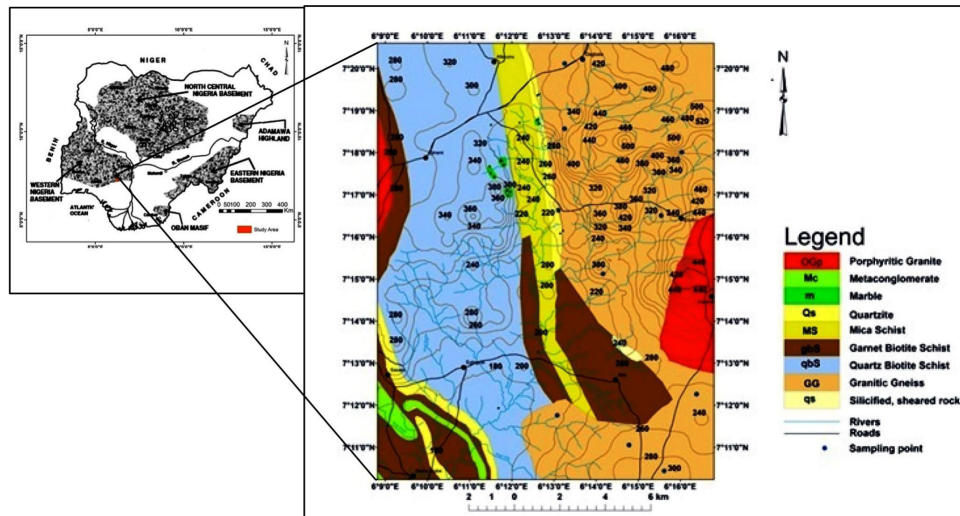


Figure 1. Geological map of the study area (adapted from ^[9, 10]). Inset: Map of Nigeria showing the distribution of Basement Complex and the Study area.

an area of about 285 km² (Figure 1). The eastern part of this district is dominated by MGQC that is essentially granitic gneiss ^[4] and the western part is composed mainly of metasediments of Igarra Schist Belt (Figure 1). These two contrasting lithologies are separated by a narrow zone of silicified, sheared rock ^[9]. The metasedimentary assemblage consists of quartz-biotite, garnet-biotite and mica schists with minor constituents of metaconglomerate, quartzite and marble ^[11, 12]. Both the metasediments and granitic gneiss are intruded by porphyritic granite (i.e. the Pan-African granite). All the three aforementioned groups of rocks, i.e., the MGQC, the metasediments and the Pan-African granite were intruded by the minor intrusive rocks comprising lamprophyre, dolerite, pegmatite, aplite, quartzo-feldspathic- and quartz- veins.

3. Methodology

This study entailed sampling of the granitic-gneiss rock as well as geochemical study of the rock samples. Field sampling entailed cutting about 1-kg mass of the rock using geologic hammer and chisel at all locations where it was studied, taking coordinates of the locations, recording the texture, mineral composition and noting the important geologic features found. Altogether, ten samples of the granitic-gneiss rock were taken. Figure 1 shows the sampling points of these 10 samples. Geochemical study consisted of crushing, splitting and pulverization of 250 g rock sieved with 200 mesh after which 0.2 g of the pulverized sample was digested by lithium borate fusion. Whole rock major, minor and some trace element analysis was done using inductively coupled plasma-mass spectrometer (ICP-MS) at the ACME laboratory, Vancouver, Canada. A

software package GCD kit 4.1 in r programming language was used to plot all the classification and geotectonic setting diagrams employed for this study. In plotting the results, any element that contains censored data (i.e. values below the analytical detection limit, DL) at any site (recorded in the table of chemical composition as < DLs), value equals to 50 % of the element's lower DL is substituted at that site.

4. Results

4.1 Geochemistry

Chemical whole rock major and minor oxides (in %) and some trace elements (in ppm) analyses of 10 rock samples (Table 1) have been used to classify the granitic-gneiss rocks and to understand the geotectonic setting in order to evaluate the crustal evolution in the southeastern margin of Western Nigeria Basement Complex. The Dagbala-Atte granitic gneiss has a composition with the range of 66.2-78.49 % for SiO₂, 11.22-15.95 % for Al₂O₃, 2.84-6.33 % for Fe₂O₃, 1.75-3.29 % for CaO, 2.78-4.68 % for Na₂O, 0.74-6.3 % for K₂O, 0.04-0.08 % for MnO, 66-1238 ppm for Ba, 114-453 ppm for Sr, 74-428 ppm for Zr, and 2-10 ppm for Sc.

4.2 Geochemical Classification

According to the classification of Middlemost ^[13] and De la Roche et al. ^[14] most granitic gneisses plot in the field of granites and granodiorites (Figures 2a and 2b). They are consequently mostly granite gneiss and granodiorite gneiss. On the molar Na₂O+Al₂O₃+K₂O plot (Figure 2c) the granitic gneiss falls in the sodic and potassic metalu-

Table 1. Chemical compositions of the granitic gneiss of Dagbala-Atte District (major and minor oxides in %, trace elements in ppm)

Element	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
SiO ₂	66.98	68.73	70.58	69.13	78.49	67	69.79	66.2	66.2	70.75
Al ₂ O ₃	14.61	14.76	14.69	15.78	11.22	14.6	15.71	15.95	15.18	14.31
Fe ₂ O ₃	4.67	3.66	3.23	3.36	2.84	6.33	3.5	4.19	5.36	3.02
MgO	1.12	0.67	0.45	0.48	0.37	1.04	0.71	1.22	1.26	0.41
CaO	3.29	1.84	2.17	2.52	2.56	3.06	2.8	2.45	3.12	1.75
Na ₂ O	3.22	2.78	3.94	4.68	3.1	3.36	4.64	3.01	3.45	3.31
K ₂ O	4.46	6.3	4.03	3.2	0.74	2.67	2.01	5.87	4.29	5.45
TiO ₂	0.42	0.42	0.24	0.27	0.25	0.91	0.29	0.35	0.47	0.27
P ₂ O ₅	0.14	0.1	0.05	0.06	<0.01	0.33	0.09	0.2	0.16	0.07
MnO	0.07	0.04	0.04	0.05	0.04	0.08	0.06	0.06	0.08	0.04
Cr ₂ O ₃	0.002	0.002	0.002	0.002	<0.002	<0.002	<0.002	0.002	0.002	<0.002
LOI	0.8	0.4	0.4	0.3	0.3	0.4	0.3	0.3	0.2	0.4
Total	99.98	99.93	99.99	99.99	100.02	99.95	100.01	99.98	99.97	99.99
Ba	903	1238	822	634	66	666	340	1179	857	1043
Ni	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
Sr	453	286	285	297	114	311	365	417	430	276
Zr	190	335	184	231	412	428	111	74	199	234
Y	18	21	14	13	<3	25	10	9	23	17
Nb	9	22	11	11	8	20	6	<5	9	15
Sc	6	2	3	4	2	10	5	5	7	3

minous-peraluminous field. Their aluminium saturation index, according to B-A plot of Villaseca et al. ^[15], varies between metaluminous and low to moderately peraluminous (Figure 3a). On the K₂O versus SiO₂ diagram (Figure 3b) after Peccerillo and Taylor ^[16], the granitic gneisses plotted in the calc alkaline-high K calc alkaline-shoshonitic fields. Also on the A/CNK versus SiO₂ plot after White

and Chappell ^[17] the granitic gneiss plot largely in the field of I-type granitoids, which is below 1.10 value on Al₂O₃/Cao+Na₂O+K₂O (A/CNK) axis (Figure 3c). Also, on the plot of Fetotal/(Fetotal+MgO) against SiO₂ (Figure 3d) after Frost et al. ^[18], the granitic gneiss samples plotted mainly in the field of ferroan rocks.

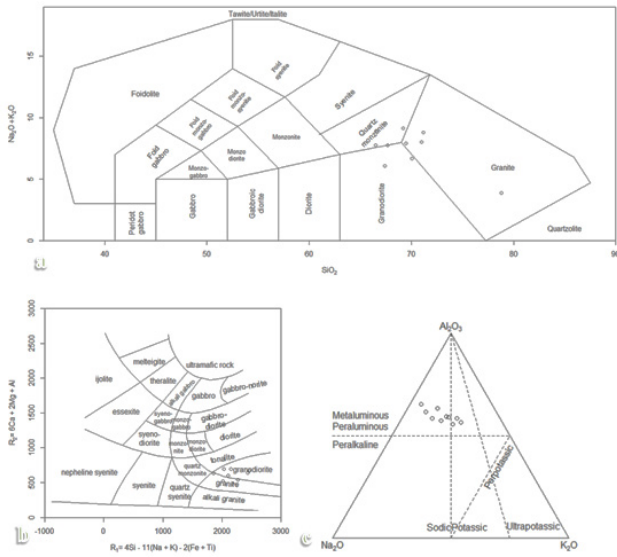


Figure 2. Classification diagrams for the granitic gneiss. (a) (Na_2O+K_2O) vs. SiO_2 (TAS) diagram of Middlemost^[13], (b) R1 $(4Si+11(Na+K)+2(Fe+Ti))$ vs. R2 $(6Ca+2Mg+Al)$ plot of De la Roche et al.^[14], (c) Molar $Na_2O+Al_2O_3+K_2O$ plot.

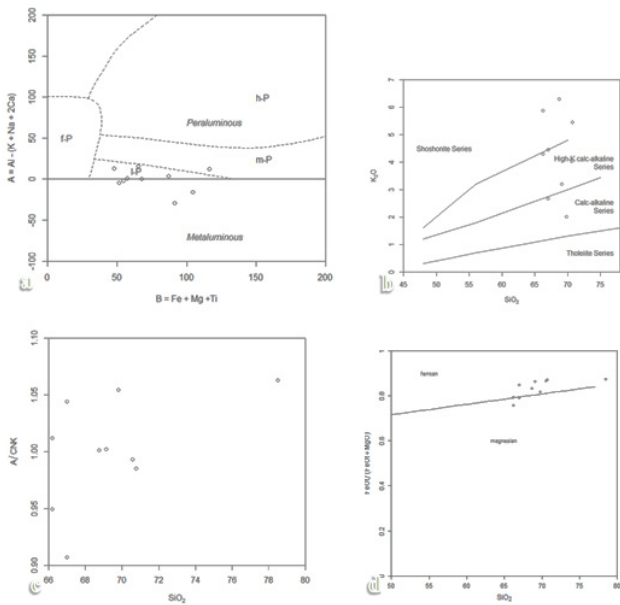


Figure 3. Classification diagrams for the granitic gneiss. (a) the aluminium saturation index B-A plot of Villaseca et al.^[15] (symbols: h-P = highly peraluminous; m-P = moderately peraluminous; l-P = low peraluminous; f-P = felsic peraluminous). (b) K_2O versus SiO_2 plot after Peccerillo and Taylor^[16], (c) Molecular $Al_2O_3/Ca+Na_2O+K_2O$ (A/CNK) versus SiO_2 diagram showing the rocks all plots in the field of I-type granitoids below 1.10 value on A/CNK, (d) $FeOt/(FeOt+MgO)$ versus SiO_2 diagram after Frost et al.^[18] showing the distribution of the granitic rocks with respect to the ferroan and

magnesian fields.

4.3 Geotectonic Setting

The R1-R2 plot (Figure 4a) of Batchelor and Bowden^[19] showed the granitic gneiss formed from metamorphism of Orogenic granitoids. Figure 4b showed that the formation of the rock varied from late orogenic tectonic to post-collision and pre-plate collision to syn-collision uplifts. On the Nb versus Y diagram (Figure 4b) after Pearce et al.^[20] the granitic gneiss plotted largely in the fields of volcanic arc and syn-collisional granites with few plotting in the within-plate granites. The granite geotectonic discrimination plots of Maniar and Piccoli^[21] revealed that the granitic gneiss formed from island arc-, continental arc-, continental collision-, continent-epirogenic uplift-, post-orogenic- and rift related granitoids (Figure 5a). However, majority of the samples of Dagbala-Atte district plot in the fields (Figure 5b – 5d) of Island arc- (IAG), continental arc- (CAG) and continental collisional granitoids (CCG). These characteristic features indicate that the protolith granite and granodiorite of these granitic gneiss rocks are arc related and thus inferred arc tectonic setting.

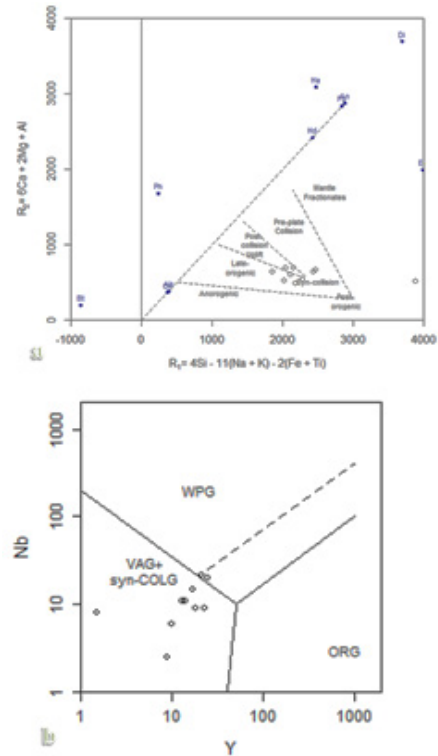


Figure 4. Geotectonic Discrimination Diagrams. (a) R1-R2 Plot of Batchelor and Bowden^[19], (b) Trace element geotectonic discrimination diagrams of Pearce et al.^[20], Nb versus Y. (Symbols: ORG, ocean ridge granitoids; VAG, volcanic arc granitoids; Syn-COLG, syn-collisional granitoids; WPG, within-plate granitoids; post-COLG, the post-collisional granitoids).

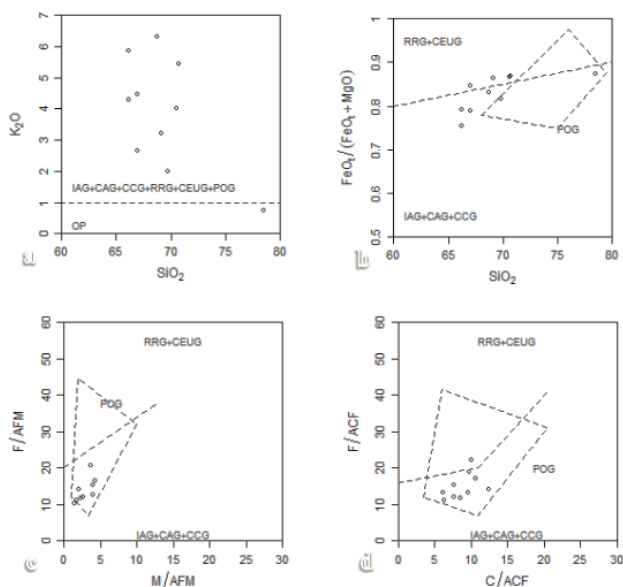


Figure 5. Major element geotectonic discrimination diagrams of Maniar and Piccoli^[21]. (a) K_2O versus SiO_2 , (b) $FeO_{tot}/(FeO_{tot} + MgO)$ versus SiO_2 , (c) F/AFM versus M/AFM , (d) F/ACF versus C/ACF diagrams. (Symbols: IAG- island arc granites, CAG- continental arc granites, CCG- continental collision granites, POG- post-orogenic granites, CEUG- continent-epirogenic uplift granite, RRG- rift related granites).

5. Discussion

The granitic gneiss in the Southeastern margin of western Nigeria basement complex around Dagbala-Atte District (Figure 1) formed as a result of medium- to high-grade metamorphism of granites and granodiorites (Figure 2a and 2b) that are metaluminous to low peraluminous (Figures 2c and 3a) in composition. The protolith granite and granodiorite belong to calc-alkaline magmatic series that ranges from high K calc alkaline- to shoshonite- series (Figure 3b). The granite and granodiorite are I-type rocks (Figure 3c) of ferroan composition (Figure 3d). Ferroan (Fe-enriched) granites are closely associated with conditions of limited availability of H_2O and low oxygen fugacity during partial melting of their source rocks^[18] as well as the crystallization of anhydrous silicates. The granitic gneisses are *sensu stricto* granite gneiss and granodiorite gneiss. This observation is similar to those of other workers on the granitic gneisses in various parts of the basement complex of Nigeria^[4, 22-27].

The protoliths granite and granodiorite of the granitic gneisses of this area are orogenic in nature (Figure 4a). They therefore resemble the Pan African (Older) granites of Nigeria instead of the Jurassic Younger Granite of Nigeria that is anorogenic^[28]. They plotted largely in the fields of Volcanic Arc and Syn-collisional with only few in

within-plate granites (Figure 4b). The granite geotectonic discrimination plots (Figure 5) of Maniar and Piccoli^[21] reveals that the granitic gneiss formed from Island arc-, continental arc- and continental collisional-granitic rocks. All these suggested they form like volcanic-arc magmas, from the LIL-enriched mantle wedge above subducted oceanic lithosphere which have probably been contaminated with melts from the lower crust^[27]. The crustal melts may have resulted from thermal relaxation in the lower crust and the mantle-derived magmas by adiabatic decompression in the upper mantle^[29].

6. Conclusions

The granitic gneisses of Dagbala-Atte District in the southeastern margin of the western Nigeria Basement Complex terrain showed, from their overall geochemical features, that they were most likely derived from metamorphism of I-type granites and granodiorites. These protoliths were formed from mantle magma mixed with partial melting of crustal materials in an arc related orogenic (syn-collisional) tectonic setting.

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