IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 9, Issue 5 Ser. I (Sep. – Oct. 2021), PP 19-33
www.iosrjournals.org

Hornblende-bearingS-type Porphyritic Granite from the Basement complex terrain of Southwestern Nigeria.

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Aabstract
This study reports Petrology and petrochemistry of porphyritic granite in the Precambrian Basement complex of Idanre, southwestern Nigeria. Systematic geological mapping revealed Idanre area is underlain by gneisses, Pan-African granite and charnockite. The granitoid occur as intrusive bodies now exposed as plutons within the host migmatite country rock. The migmatite occur as low-lying units,the granite form prominent inselbergs while charnockite occur at the core of the porphyritic granite as small rounded bodies.Optical investigation indicates that the granite is containquartz, feldspar, biotite and hornblende.Analytical result reveals silica content in the granite ranges between 63-72% (ca. 65.43%) while alumina content falls between 11.95-15.8% (ca. 14.59%). Mean Fe_2O_3, K_2O and Na_2O are 5.54%, 5.44% and 3.06% respectively. Trace element geochemistry reflects pronounced enrichment in Rb (165.7-304.8) ppm, Sr (109.3-414.8) ppm, Zr (155.0-712.2) ppm and Ba (435.5-1737.9) ppm. Rare Earths Element (REE) geochemistry shows dominance of LREE over HREE. La/Sm versus La variation plot reveals the silicate melt for the granitoid originatefrom partial melting of a sedimentary protolith. Na_2O versus K_2O, and Al/CNK versus SiO_2 plots classifies the granite as S-type granitoid while Al/NK versus Al/CNK indicates the granite has peraluminous geochemistry. Tectonic discrimination diagram revealed the granite is within plate setting type.

Keywords:_Idanre; Pan-African granite; porphyritic; S-type granitoid; peraluminous_

Date of Submission: 06-09-2021 Date of Acceptance: 20-09-2021

I. Introduction

The global concept of granite classification now extends into domains of tectonic setting, isotope geochemistry, structural geology, mineralogy, and geochemistry. Granite falls into one of the classes: orogenic, transitional or anorogenic (Pitcher, 1983, 1993; Babarin1990; Winter, 2001). The first could be located in oceanic island arc, continental arc, or domains of continental collision. The transitional types occur dominantly as post-orogenic uplift/collapse. The anorogenic type may fall within domains of continental rifting, hot spots or even mid-ocean ridge and ocean islands. After the work of Chappell and White, (1974) describing two contrasting granite types in the Lachlan fold belt, the I- and S-type nomenclature has become popular and are often used for many granite terrains. I- type is typical of granite produced from igneous protolith, while the S-type has been considered product of anatexis of rocks of sedimentary origin. The expansion of granite class to include M- type, and A- type has followed afterward. The concept of I- and S-type has been subsequently emphasized after the initial work of Chappell and White (1974) in a series of papers (e. g. Chappell, 1999, 2004; Chappell and White, 1984, 1992, 2001; Chappell and Stephens, 1998; White and Chappell,1988; Chappell and Wyborn, 2012; Chappell *et al.* 2012). Even though, the I- and S-type granites could be distinguished based on geochemical and isotopic characteristics, the occurrence of hornblende and sphene has been used as the basis for mineralogical distinction of the I-type, while S-type is typified by muscovite and garnet. However, cases have been reported where this broad classification does not generally hold for granite from some regions, this is true particularly when the granite exhibit transitional features of both I- and S- types (Azman, 2000;Ghani *et al.* 2013). Granites of Pan-African age extend across the entire African continent along a N-S trending orogenic belt called the Trans-Saharan belt (Adetunji*et al.* 2016) (Figure 1). During late Precambrian, Nigeria like many other parts of Africa witnessed widespread magmatic activities which culminated in the emplacement of granites of batholitic dimensions popularly referred to as Older Granite (600±150 Ma) in Nigeria. The origin of these rocks is attributed to activities at relatively deep levels in the earth's crust under orogenic conditions (Ogunleye et al. 2005).After the pioneering work of (Falconer, 1911), detailed works on the Older Granites of Nigeria sprang up e.g. (Truswell, 1960; Truswell and Cope, 1963; Oyawoye, 1964) and are subsequently followed by more recent works (e.g.,Black and Liégeois, 1993; Bonin, 2004; Kuster and Harns, 1998; Liégeois*et al.* 1998; Goodenough et al. 2014) most of which pointed to these granite plutons as typically potassic and their parental magmas derived from mixed mantle and crustal sources. Fitches *et al.* (1985) had earlier asserted that Older Granite of western Nigeria were I-type granitoids.Hornblende-biotite granites from the western Nigeria terrane falls within 630-580 Ma age bracket and are like those of eastern Nigeria (Key *et al.* 2012).This study report thegeochemical and petrological features of the porphyritic granite from Idanre area to confirm the appropriateness of I-, S-type affiliations or both.

II. Geological Setting

Regional geology

Nigeria is bounded by Latitudes 4^{o}N and 15^{o}N and Longitudes 3^{o}E and 14^{o}E. It lies within the Pan-African mobile belt, specifically, towards east of the West African craton and northwest of the Congo-Gabon craton (Clifford, 1970; Black *et al.* 1979). Evidence from eastern and northern margins of West African craton indicates that the Pan-African belt evolved by plate tectonic processes which involved collision of the passive continental margin of West-African craton and the active margin of Pharusian belt (Tuareg shield), about 600 Ma (Black *et al.* 1979; Burke and Dewy, 1972; Leblanc, 1981; Caby*et al.* 1981).The presence of ophiolites, accretionary prisms, island-arc magmatic suites and high-pressure metamorphic assemblages makes this one of the best documented Pan-African belts revealing ocean opening followed by a subduction- and collision-related evolution between 900 and 520 Ma [Kroner and Stern, 2005).Rahaman*et al.* (1988) supports a model involving overlapping Wilson Cycle with ocean opening and closing as suggested by Burke *et al.* (1976). Because of the presence of tholeiitic basalts in some schist belts of southwestern Nigeria, some researchers (e.g., Rahaman*et al.* 1988; Ajayi, 1981; Bafor, 1988) considered the belt to have evolved by ensimatic process involving micro continental subduction and collision. However, Elueze, (1981) believes it originated by ensialic process with a subduction related tectonogenesis. Initial crustal extension and continental rifting at the West African craton's margin about 1000 Ma resulted in formation of graben-like structures in western part of Nigeria and the subsequent deposition of the rocks of the Schist belts(Kroner and Stern, 2005).Closure of the ocean at the cratonic margin, about 600 Ma and crustal thickening in the Dahomeyan resulted in deformation of the sediments, reactivation of the pre-existing rocks and emplacement of Pan-African granites (McCurry, 1976).

Geology of Idanre area.

The study areaforms part of basement complex of southwestern Nigeria, it is located between latitudes 7^{o}0'00"N to 7^{o}14'00"N and longitudes 5^{o}0'00"E to 5^{o}14'00"E. Idanre lies within southern part of Akure, the Ondo State Capital. The area is underlain by migmatite, granites and charnockite (Figure 2). The migmatite basement(mainly biotite-hornblende gneiss and migmatite)forms the country rock, and are altogether intruded by granite. The migmatite gneiss show prominent foliation with conspicuous alternating bands of melanocratic and leucocratic minerals. The dark bands comprise of biotite and hornblende while the light-coloured bands are dominated by quartz and feldspars. Fold patterns in migmatite vary from place to placeand range in geometry from simple harmonic to disharmonic and contorted similar folds. Tight isoclinal folds with characteristic thin limbs are also common. The migmatite sometimes show gradational change in colour in some localities. Porphyritic granite in the study area is remarkable as it forms spectacular topographic feature of the terrain outcropping prominently as inselbergs in and around Idanre town. Three major petrographic types of granite occur in Idanre, they are (1)- fine to medium grained biotite and biotite-muscovite granite (OGf), (2)- coarse porphyritic biotite and biotite-hornblende granite (OGp) and (3)- undifferentiated Older granite variably granitized with porphyroblastic gneiss and some migmatite. The fine to medium grained biotite and biotite muscovite granite is of restricted occurrence and are only limited to smaller plutons on eastern part of the study area. It is a fine-grained two-mica granite with well-distributed feldspar crystals that are enmeshed in quartz grains. The porphyritic biotite and biotite-hornblende granite, among the three petrographic types is the most widespread with its characteristic feldspar phenocrysts. Notable among the hills formed by the porphyritic granite are the towering inselbergs in the heart of Idanre town (Fig. 3a). The size of orthoclase feldspars range between 1 cm to 2cm in length in western part of the complex to those measuring up to 5cm in length around central part of the intrusive body in an observable gradual eastward coarsening (Figures 3b, 3c and 3d).The undifferentiated Older granite member is easy to recognize among othersuites by feldspar megacrysts which impact a seemingly weak alignment into the rock and a characteristic greyish color. The granite forms an envelope around porphyritic granite in the northern part and outcrops with high-elevation along Alade-Idanre road. The granite outcrops form extensive and massive exposures that are isolated from the main body towardsOpa area. Charnockite is restricted to the core of porphyritic granite. It is a medium-grained rock with a characteristic greyish green color.

III. Materials And Method

Ten fresh granite samples are analyzed in this study. Samples weighing about 0.5 to 1 kg were trimmed to remove any altered or weathered surface. This method was adopted to obtain the cleanest samples. Hydraulic cutting machine fitted with diamond blade was used to obtain 1 cm cube of each sample which were later dried at room temperature overnight. The samples were reduced by the jaw crusher and subsequently pulverized in a Tema mill. Glass fusion discs were used in the analysis of major elements. Each disc was prepared by a mixture of approximately 0.5 g of 153-micron rock powder and 3.3 g of lithium borate flux in ratio 5.4321:1 flux: rock at 1150^{o}C and the melt casted on to 4 cm diameter aluminum plates. The resultant glass disc was then mounted on a backing disc for analysis. Powder pellets used in trace elements analysis were prepared by mixing 7 g of 53µ(micron) powder with 12 to 15 drops of binder solution (4 g Moviol added to 10 ml ethanol and 50 ml distilled water). The resultant mixture was pressed into a 4cm disc under 5 tons pressure and dried before analysis following Ghani *et al.* (2013) on XRF. Ttrace and Rare Earth Elements (REEs) composition were carried out on the selected samplesusing Inductively Coupled Plasma Mass Spectrophotometer (ICP-MS) onResonatcs 193NM Excimer Laser (Agilent 7700) and He-Ablation gas at 0.3L/min with a Carrier gas of 1L/min Ar+ 0.003L/min Nitrogen. X-Ray Fluorescence (XRF) using Rh Tubewas adopted for the major elements analysis. All geochemical analyses were undertaken at the University of Western Cape, South Africa.Major elements (SiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, MnO, Na_2O, K_2O, TiO_2 and P_2O_5) and trace elements (Ba,Ce, La, Nd, Nb, Pb, Rb, Sr, Th, Y and Zr) were analysed. The powder of the samples was then shaken and dried at 110^{o}C for 12 hours. For the REE concentration, 0.25 g of powdered rock was weighed accurately into a graphite crucible and 2 g of Na_2O_2 was added. The mixture was then heated at 700^{o}C for about an hour and then extracted and leached with water. The precipitation of hydrated oxide was dissolved with HNO_3 and analysed using ICP-MS.

IV. Results And Discussion

Petrography

The mineral assemblage in Idanre porphyritic granite is K-feldspar + plagioclase + biotite + quartz + hornblende ± microcline. Accessory minerals are apatite and opaque magnetite. Biotite is randomly distributed, and the few hornblende grains are scattered (Figure 4a), few samples show large plates of microcline (Figure 4b), isolated grains of albite and interstitial quartz occurring in association with stretched biotite blades (Figure 4c). The common amphibole type in the granitic rock is mainly hornblende which occurs as discrete blocky minerals (Figure 4d). Figures 4e and 4f represent same rocks under cross Nicol and plane polarized lights respectively. The albite-twinned K-feldspar phenocrysts show micro perthiticcrystals with patchy texture. Inclusions of plagioclase, biotite and quartz may indicate growth of K-feldspar took place during magma crystallization. Plagioclase phenocrysts showing zoning are also common. Quartz occurs as small euhedral crystals that are well distributed in all the samples. However, some quartz grains are randomly arranged while it is in clusters in few samples. Quartz is next in abundance to feldspar, while biotite occurs as clusters of bladed aggregates, small pyroxene relics are common in amphibole. The dominant feldspar is albite distinguished by its characteristic Carlsbad twinning; hornblende appears as few blocky euhedral mineralsexhibiting acicular and lath-like habits. The result of the optical characteristics of the granite is shown (Table 1).

Geochemistry

Geochemical result (Table 2) and normative mineralogy (Table 3) are presented. For table 3, Ab + An represents (Plagioclase), Q (quartz), Or (Orthoclase), Ab (Albite), An (Anorthite), Hy (hyphersthene), Il (Ilminite), Hm (hornblende), Ru (Rutile), Ap (Apatite), and Pl (Plagioclase). Generally, Idanre porphyritic granite has SiO_2 values ranging from 61.5% to 74.56% with an average value of 65.43%. SiO_2 content ofporphyritic granite in Idanre varies within a wide limit and are comparable to 63.84-75.09% range recorded in Soli Hills, eastern Nigeria (Ferré*et al.* 1998), 65.59-67.87% in Rahama amphibole-biotite granite, northern Nigeria (Olarewaju and Rahaman, 1982), 62.92-67.79% in monzonite from northcentral Nigeria (Dada et al. 1995) and 65.86-69.18% in Toro Complex, Northern Nigeria (Deleris*et al.* 1996). Al_2O_3 content in the Idanre porphyritic granite which range between 11.95-15.8% (mean 14.59%) is comparable to alumina contents which range between 11.86-14.08%, 14.49-14.53%, 12.93-15.72% and 13.78-14.32% respectively in granite rocks from these areas. Average Fe_2O_3 and K_2O value of Idanre porphyritic granite is 5.55% and 5.44% respectively, these values are comparable to granitic rocks from other parts of Nigeria. Harker variation diagrams of major elements against SiO_2 (Figure 5a) show an overall negative correlation in all the samples. Generally, the Idanre porphyritic granite show enrichment in Ba, Sr, Zr and Rb with average values Ba (1111.5 ppm), Sr (304.9 ppm), Zr (551 ppm) and Rb (191.2 ppm); and certain rare earths like La (146.55 ppm), Ce (279.78 ppm) and Nd (102.7 ppm). While Ba values range between 450-1160ppm in granite from Soli Hills, and 950-1400 ppm in Rahama Amphibole-biotite granite (Olarewaju, 1987) of Northern Nigeria, Sr values range between 91-298 ppm in Soli Hills (Ferre et al., 1998) and 950-1400 ppm in Rahama amphibole-biotite granite. While Idanre porphyritic granite show all major elements (except K_2O show a negative trend with increasing SiO_2 (Figure 5a) and trace elements Ba, Sr and Zr shows negative correlation with SiO_2, Rb, U and Th. Harker diagram show positive relationship with increasing SiO_2 contents (Figure 5b).

Classification of plutonic rocks using the parameters R1 and R2 (De la Roche *et al.* 1980) calculated from milli-cation proportions. R1=4Si-11(Na+K)-2(Fe+Ti); R2 = 6Ca +2Mg+Al indicates the rock plots within close boundaries between quartz monzonite and tonalite (Figure 5d). The plutonic rock is further revealed ontriangular QAPF diagram (Figure 6a) of classification of igneous rocks, where the rock plotted within the field of monzo-granite and spreading into quartz monzonite field confirming (De la Roche *et al.* 1980) classification.In TiO_2 versus Zr plot (Figure 6b), mineral vectors indicate path evolved liquids for 15% of mineral precipitating with zircon, hornblende and sphene are the major precipitating phase in the granitic rock. The plot directly shows a single crystallization trend for the porphyritic rock. General trend of the granitic rock is controlled by combination of crystallization of hornblende and zircon. K_2O versus SiO_2 diagram (Figure 6c) which include the low-, medium- and high-K suite boundaries (Le Maitre, 1989) and the high-K-shoshonitic suite boundary (Pecerillo and Taylor, 1976), the Idanre porphyritic granite plot within shoshonite series. The plot shows consistently high K_2O in the granite with positive correlation between SiO_2 and K_2O values. Roberts and Clemens, (1993) showed that if a parent magma with given K_2O and SiO_2 contents evolve within a field in K_2O versus SiO_2 diagram and magma evolve into an adjacent field, this will indicate process other than crystal-liquid separation has been in operation, so, it clearly indicates that the granitic rock must have originated from same source. Fourteen REE elements (La-Lu) were analysed for the granite sample. REE data for the granitic rock is shown (Table 1). REE concentrations for the chondrite (Masuda *et al.* 1973)were used for normalization. The granite rock has an average total REE 250-810; with a mean value of 530 ppm. In general, total REE in the granitic rock does not show any discernible relationship with either increasing or decreasing SiO_2. All samples are generally enriched in light rare earth elements (LREE) and depleted in heavy rare earth elements (HREE). However, it is observed that the granite profile has similar distribution for both ranges of HREE and LREE. The granite displayed striking uniformity in their REE pattern shapes and Eu anomalies. However, two of the analysed samples pushed the granite profile to have a wider range of rock chondrite (Figure 6d). LREE in the granite typically have 300 to 950 times chondrite levels, whereas HREE have 4 to 30 times chondrite levels, and all samples show a negative Eu anomaly. The granite show concave shape profile (REE pattern) which may be the result of minerals such as clinopyroxene and amphibole having remained residual in their source (Williamson *et al.* 1992). Evidence of magma crystallization for the granite was further established on the La/Sm versus La plot (Figure 7a). The importance of sphene, zircon, allanite, apatite and monazite is shown in $(La/Yb)_N$versus La diagram (Figure 7b). Also shown is the vector diagram representing the net change in composition of the liquid after 15% Rayleigh fractionation by removing sphene, zircon, allanite, apatite or monazite. The rock samples show a rather scattered trend which makes it difficult to predict their mineral crystallization option.

Rock classification

Generally, the mineralogy of granitic rock can decipher whether it is “I’ or “S’ type. On the plot of A/CNK (Al_2O_3/CaO+ Na_2O+K_2O) values where all the granitic samples analysed are well above ACNK 1.0 (Figure 7c) and have a stable ACNK values higher than 1 with increasing SiO_2. Figure 7d further show the granite samples plotting in the S- type field implying that the magma source is sedimentary suggesting that the magma which crystallize to form the granite originate from anatexis of a sedimentary protolith (Shand, 1943; Chappell and White, 1992). It has been established also that contrasting mineralogy and geochemistry could be used to decipher whether the Idanre Granite falls within the I- or S-type classification scheme of Chappell and White, (1974). In this system, I- and S-type granitoids are geochemically discriminated primarily by their aluminium saturation index (A/CNK) which comes from the abbreviation $Al_2O_3/[(CaO-1.67P_2O_5) + Na_2O+K_2O])$. The division is drawn where A/CNK=1.1 (Figure 7e) such that I-type granitoids are essentially metaluminous and generally become weakly peraluminous with increasing silica contents, while S-type granitoids are typically peraluminous (Chappell and White, 1974, 1992; Ghani *et al.* 2013). The Al/NK versus Al/CNK plot (Mania and Piccoli, 1989) typically indicates the peraluminous nature of the Idanre granite. Peraluminous granites are produced from the anatexis of sedimentary rocks mainly during continent collision. AFM diagram (Figure 7f) (Carmichael *et al.* 1974) show that the granite has a calc-alkaline affinity. Both Peacock, (1931) alkali-lime index and Shand, (1943) subdivision into 'peraluminous', 'metaluminous' and 'peralkaline' are still used as indicators of the major element characteristics of granites and have led to the assumptions that peraluminous granites result from the anatexis of sedimentary rocks, mainly during continental collision.

Tectonic implication

Trace element discrimination diagrams have been in use for some time as a means of fingerprinting the tectonic setting of basic volcanic rocks (Pearce and Cann, 1973; Floyd and Winchester, 1975; Pearce, 1975; Wood *et al.* 1979; Winchester and Floyd, 1977; Shervais, 1982). In areas where the only accessible products of tectonic activities are plutonic rocks like granite, (Pearce *et al.* 1984) proposed that granites may be subdivided according to their intrusive settings into four main groups-ocean ridge granites (ORG), volcanic arc granites (VAG), within plate granites (WPG) and collision granites (COLG). Discrimination of ORG, VAG, WPG and syn-COLG can be established effectively on trace element Rb-Y-Nb and Rb-Yb-Ta space, particularly on projections of Y-Nb plots. Tectonic discrimination diagram of Nb versus Y (Figure 8a) (Pearce *et al.* 1984) indicates Idanre porphyritic granite plots on Within Plate Granite (WPG). Furthermore, Rb versus Y tectonic discrimination diagram (Figure 8b) shows the Idanre porphyritic granite plot in WPG (*Within Plate Granite*) field. Rb versus Y+Nb discrimination diagram (Figure 8c) indicates that the Idanre porphyritic granite plots within Syn-Collisional granitoid of the S- type. Pearce *et al.* 1984 indicates that the binary diagram of Rb against (Y+Nb) carry the most effective discriminating power of these three elements and that it retains the advantage of easier petrogenetic interpretation.De la Roche et al. (1980) proposed a classification scheme for volcanic and plutonic rocks based on their cationic proportions of major elements, expressed in milli-cations. The diagram is an X-Y bivariate graph using the plotting parameters R1 and R2 where R1= 4Si-11(Na+K) - 2(Fe+Ti) while R2= (Al+2Mg+6Ca). Batchelor and Bowden, (1985) showed that the diagram can discriminate five granitic groups related to the tectono-magmatic divisions proposed by (Pitcher, 1979, 1983). The Idanre porphyritic granite plot in Syn-collision field (Figure 8d). This result agrees with the unequivocal age of Pan-African and the convergence of opinion that the Older Granites represents the terminal plutonic phase of Pan-African Orogeny (Grant, 1970; Rahaman, 1973; Odeyemi, 1981) and the classification models erected by several authors reflect this position.

V. Summary And Conclusions

Being a tourist destination, Idanre area is the most popular of its kind in southwestern Nigeria due to occurrence of granite. The rock is made of three textural subunits which are Older granite (undifferentiated), porphyritic granite and fine-grained granite. The porphyritic granite forms the most extensive member. The granite shows an eastward coarsening and form spectacular inselbergs within Idanre town. Petrographic examination indicates it has mineralogy dominated by quartz, feldspar, biotite and hornblende. Geochemical features indicate that the porphyritic granite has silica content ranging between 61.5-74.56% and resulted from melting of sedimentary crustal rocks. The granite is S-type granitoid and falls within peraluminous group. Tectonic discrimination diagram characterizes the granite as WPG (*Within Plate Granite*) with calc-alkaline affinity.

Acknowledgements

The authors wish to acknowledgethestudents who assisted during field mapping and data acquisition. Worth mentioning is Tope Aderibigbe who stayed on all through the fieldwork to be imparted. The Head, and all the technical staff of theMineral Resources Engineering Department, Federal Polytechnics, Ado-Ekiti, Nigeria are appreciated for permission to accesstheir laboratory facilities. Dr. S. A. Akinyemi and Dr R.A. Obasi of the Department of Geology, Ekiti State University are focal to logistics and for facilitating the analytical process at the University of Western Cape, South Africa.

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Table 1: *Mineralogical composition of Idanre porphyritic granite*

Mineral	Slide A	Slide B	Slide C	Range	Average
K-Feldspar	45	41	47	41-47	44.3
Orthoclase	11	14	15	11-15	13.3
Microcline	-	2	-	0-2	0.7
Quartz	24	18	18	18-24	20
Biotite	7	10	11	7-11	9.3
Hornblende	8	8	5	5-8	7
Pyroxene	2	5	2	1-5	3
Opaque	3	2	2	2-3	2.3
Total	100	100	100		99.9

Table 2: *Major and trace and REEs composition of Idanre porphyritic granite*

SN	PG 1	PG 2	PG 3	PG 4	PG 5	PG 6	PG 7	PG 8	PG 9	PG 10
SiO_2	74.56	63.40	63.05	66.45	63.89	62.99	63.34	61.50	72.05	63.11
Al_2O_3	11.95	14.84	14.90	13.98	14.91	15.01	15.17	15.39	13.93	15.80
Fe_2O_3	2.49	6.34	6.81	5.69	6.31	6.44	6.12	7.22	1.98	6.03
CaO	1.13	3.13	3.26	2.51	3.04	3.03	2.82	3.60	1.05	3.15
MgO	0.25	1.16	1.22	0.82	1.72	1.17	1.16	1.41	0.23	1.06
Na_2O	2.45	3.16	3.20	2.99	3.22	3.08	3.04	3.18	2.76	3.51
K_2O	5.59	5.14	5.04	5.38	5.03	5.68	5.89	4.87	6.55	5.21
MnO	0.03	0.07	0.08	0.07	0.08	0.08	0.07	0.09	0.03	0.07
TiO_2	0.27	1.02	1.09	0.80	1.80	1.04	1.00	1.33	0.21	0.93
P_2O_5	0.05	0.34	0.36	0.22	0.32	0.32	0.32	0.43	0.06	0.28
LOI	0.48	0.59	0.35	0.61	0.26	0.49	0.42	0.36	0.21	0.35
Sum	99.22	99.22	99.37	99.53	99.31	99.28	99.35	99.38	99.06	99.50
Trace Elements										
Ba	435.5	1451.7	1475.8	1078.7	1433.9	1660.7	1737.9	1620.9	654.1	1453.1
Cs	0.5	0.3	0.4	0.3	0.4	0.3	0.4	0.2	0.6	0.3
Hf	6.9	13.4	14.2	16.5	14.0	13.7	12.8	17.2	4.5	16.4
Nb	18.0	37.2	42.0	45.1	40.1	41.8	37.2	43.5	18.1	39.7
Rb	239.7	165.7	169.8	181.4	171.0	174.5	179.4	153.0	304.8	172.5
Sr	109.3	347.0	343.6	250.7	347.2	364.2	378.2	414.8	144.8	349.1
Ta	0.6	1.3	1.6	1.5	1.5	1.4	1.3	1.8	0.6	1.3
Zr	253.9	572.3	600.2	706.1	608.3	582.6	547.1	772.0	155	712.2
Y	21.6	41.5	46.1	46.6	41.6	40.5	37.9	43.4	12.2	41.53
Th	42.5	18.2	16.5	41.4	27.3	18.7	18.5	22.2	33.7	20.8
U	8.1	1.3	1.4	1.4	1.3	1.2	1.2	0.6	2.4	1.6
Pb	27.9	21.6	22.9	25.2	22.5	23.5	23.9	22.2	32.3	23.7
REE Elements										
La	133.5	143.5	126.7	195.8	184.3	149.5	144.4	182.8	56.0	149.5
Ce	246.9	276.4	257.0	368.5	343.0	286.5	275.4	348.5	106.8	288.8
Pr	24.7	30.0	29.1	38.7	35.9	30.6	29.5	37.3	11.2	31.7
Nd	75.87	108.1	106.0	129.6	120.5	108.6	102.8	127.0	36.8	111.8
Sm	10.9	17.7	18.1	20.2	17.4	16.4	16.0	20.2	6.4	17.5
Eu	1.1	2.7	2.7	2.4	2.7	2.7	2.8	3.0	0.9	2.9
Gd	7.0	12.2	14.0	14.3	13.3	13.1	11.6	13.7	4.4	12.9
Tb	0.9	1.7	1.8	1.9	1.6	1.6	1.5	1.7	0.5	1.7
Dy	4.9	8.6	9.8	10.2	8.8	8.3	7.9	8.9	2.9	8.6
Ho	0.8	1.5	1.8	1.8	1.6	1.5	1.4	1.6	0.5	1.5
Er	2.3	4.1	4.6	4.5	4.2	3.8	3.7	4.3	1.2	4.0
Tm	0.3	0.6	0.6	0.6	0.6	0.5	0.5	0.5	0.2	0.5
Yb	1.9	3.2	4.0	3.4	3.6	3.2	3.2	3.4	0.8	3.3
Lu	0.3	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.1	0.4

Table 3: CIPW Norm of Idanre Porphyritic Granite.

	Q	Or	Ab	An	Hy	Il	Hm	Tn	Ru	Ap	Pl	Sum
PG1	36.31	33.04	20.73	5.10	0.62	0.06	2.49	0.13	0.18	0.12	25.83	98.78
PG2	18.35	30.38	26.74	11.13	2.89	0.15	6.34	1.54	0.33	0.81	37.87	98.63
PG3	17.89	29.78	27.08	11.41	3.04	0.17	6.81	1.70	0.31	0.85	38.48	99.04
PG4	22.97	31.79	25.30	8.83	2.04	0.15	5.69	1.54	0.10	0.52	34.13	98.93
PG5	18.09	29.73	27.25	11.37	4.28	0.17	6.31	1.14	1.25	0.76	38.62	100.35
PG6	16.57	33.57	26.06	10.35	2.91	0.17	6.44	1.82	0.21	0.76	36.42	98.87
PG7	16.59	34.81	25.72	10.35	2.89	0.15	6.12	1.09	0.48	0.77	36.07	98.96
PG8	16.14	28.78	26.91	13.33	3.51	0.19	7.22	1.21	0.74	1.02	40.24	99.05
PG9	28.51	38.71	23.35	4.82	0.57	0.06	1.98	0	0.18	0.14	28.17	98.86
PG10	15.62	30.79	29.70	11.97	2.64	0.15	6.03	1.29	0.33	0.66	41.67	99.17

Figure Captions

Figure 1. Geological map of the Trans Saharan (Pan-African) Belt showing the location of the study area (modified afterFerré et al., 1998; Haruna, 2014).

Figure 2. Geological map of the study area modified after Geological Survey Nigeria (1966).

Figure 3. (a) Panoramic view of Idanre town located on a pediment surrounded by inselbergs of porphyritic granite; (b), (c) and (d) show variation in sizes of the feldspar phenocrysts along West-East direction.

Figure 4. Photomicrographs of Idanre porphyritic granite in transmitted light (cross polars) showing (a) randomly arranged biotite blades; (b) large blocky microcline crystals; (c) isolated albite crystals, subhedral quartz, and stretched biotite; (d) hornblende, biotite and few quartz grains(e) abundant quartz grains in interstices of biotite blades and hornblende crystals; (f) plane polarized

Figure 5. (a) Harker plot for major elements; (b) Harker diagram for trace elements composition (c) Binary plot of R1 against R2 for classification of plutonic rocks for the porphyritic granite (after De la Roche et al., 1980)

Figure 6. (a) QAPF diagram of Idanre porphyritic granite. (b)TiO_2 vs Zr plot, Pl (plagioclase); Kf (K-feldspar); Qz (quartz); Mt (magnetite); Sp (sphene); Hbl (hornblende); Zr (zircon); (c) K_2O versus SiO_2 diagram; (d) Spider plot for REE distribution in the Idanre porphyritic granite.

Figure 7. (a) La/Sm versus La plot: (b) La versus (La/Yb) N binary plot, Zr = zircon; Sp = sphene; Allan = allanite; Ap = apatite; Mon = monazite; (c) Molecular Al_2O_3/ $CaO+Na_2O+K_2O$ versus SiO_2(Al/CNK vs SiO_2) plot and (d) Na_2O versus K_2O classification plot for the porphyritic granite; (e)$Al_2O_3/(CaO+Na_2O+K_2O)$ versus Al_2O_3/Na_2O+K_2O (Al/CNK vs Al/NK) plot; (f) AFM ternary variation diagram showing the chemical trends of the Idanre porphyritic granite. Continuous line is the cascade trend of Carmichael et al., 1974 discriminating between Tholeiitic series and cal-alkaline series.

Figure 8. (a) Nb versus Y discrimination diagram
(b) Rb versus Y Tectonic discrimination diagram after Pearce et al., 1984.
(c) Rb versus Y+Nb discrimination plot of the porphyritic granite of the study area
(d) R1-R2 diagram (De la Roche et al., 1980) showing major tectonic associations of the Idanre porphyritic granite. R1 = (4Si − 11(Na + K) −2(Fe + Ti)), R2 = (Al + 2Mg + 6Ca)

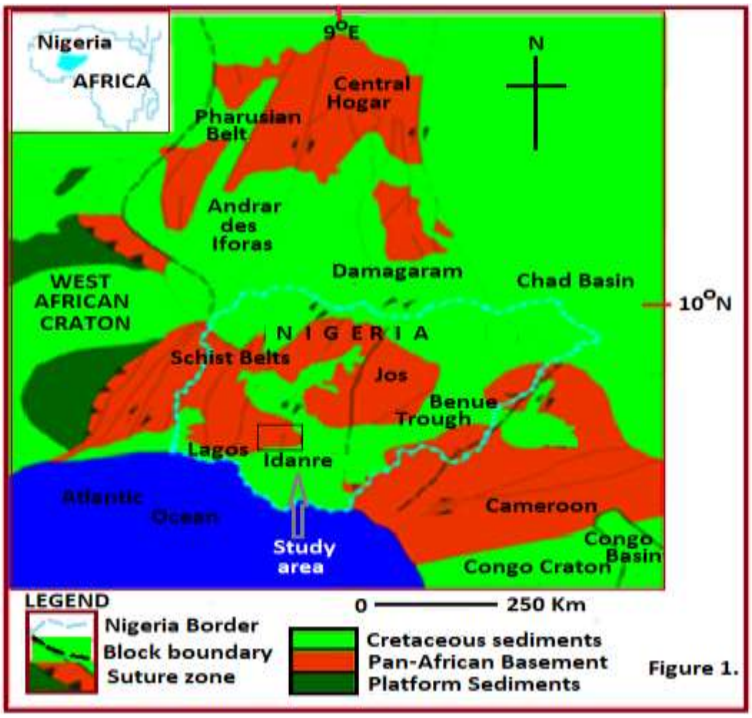

Figure 1.

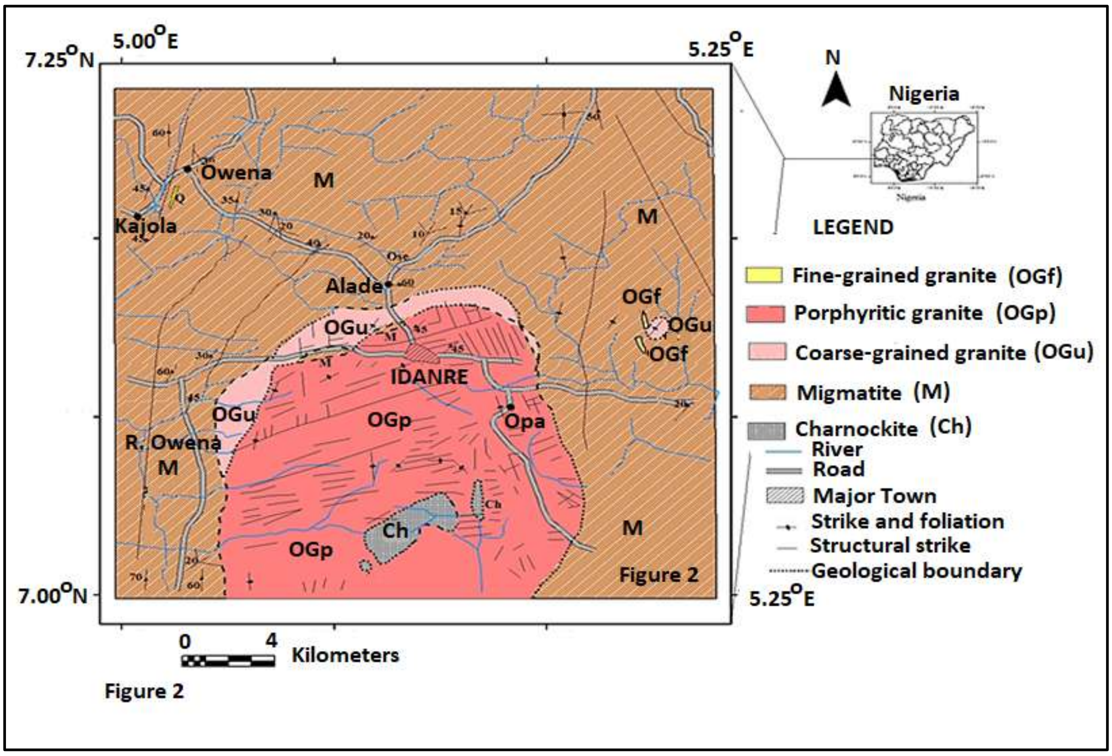

Figure 2.

Figure 3.

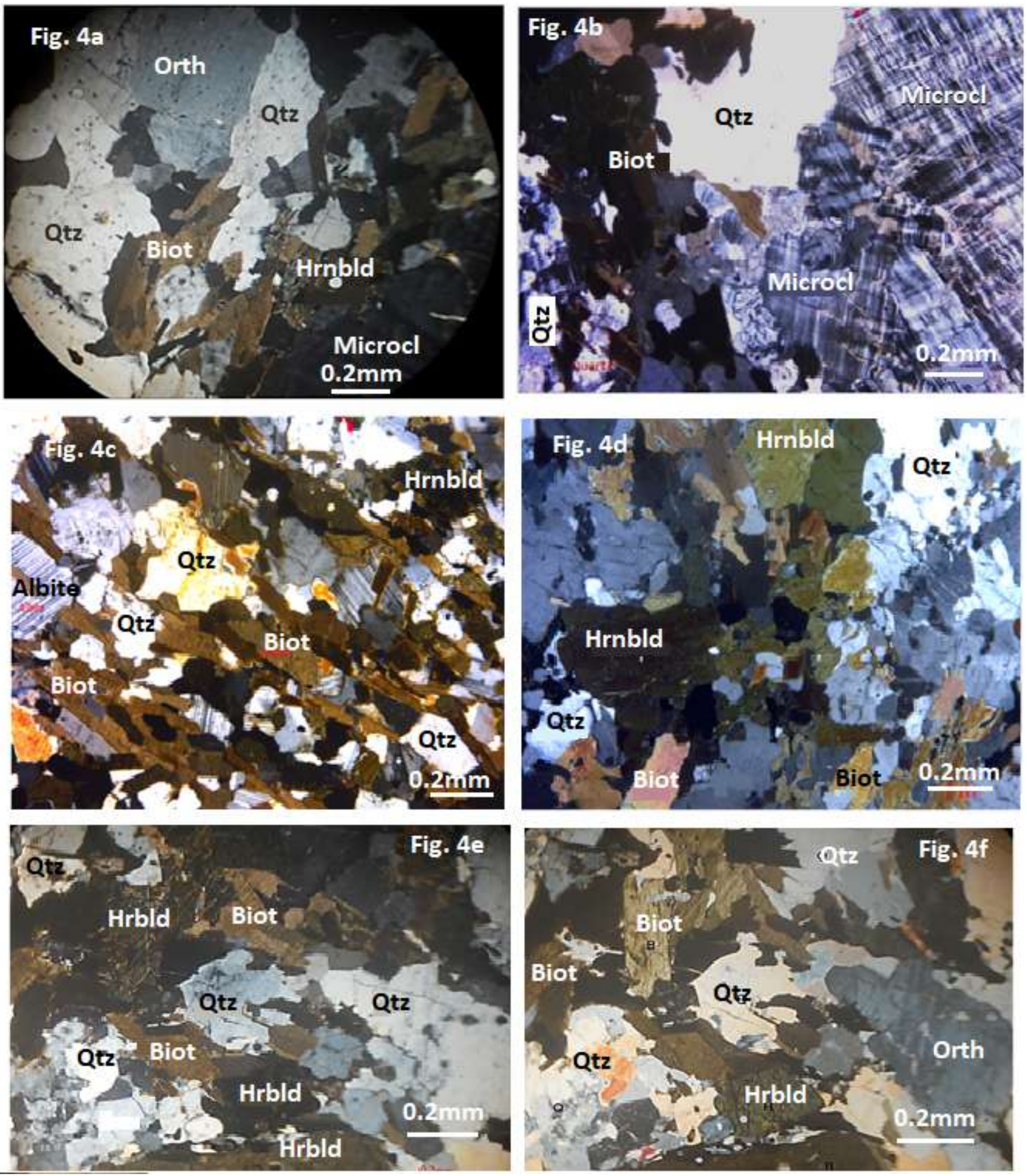
Fig. 4a
Orth
Qtz
Qtz
Biot
Hrnbld
Microcl
0.2mm
Fig. 4b
Qtz
Microcl
Biot
Microcl
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Fig. 4c
Hrnbld
Qtz
Albite
Qtz
Biot
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Fig. 4d
Hrnbld
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Hrnbld
Qtz
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Fig. 4e
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Fig. 4f
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Figure 4.

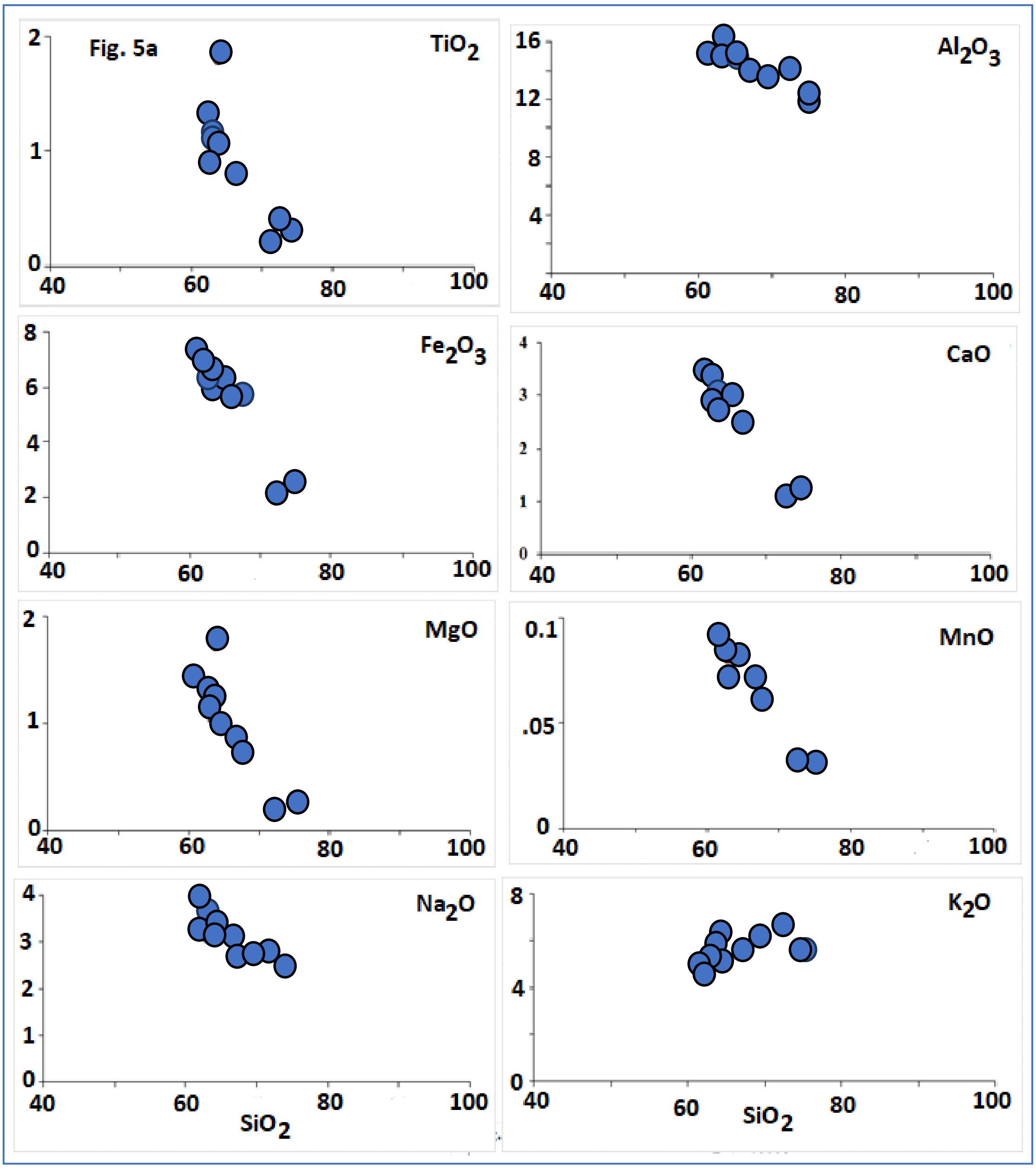


Fig. 5a
TiO2
Al2O3
Fe2O3
CaO
MgO
MnO
Na2O
K2O
SiO2
SiO2

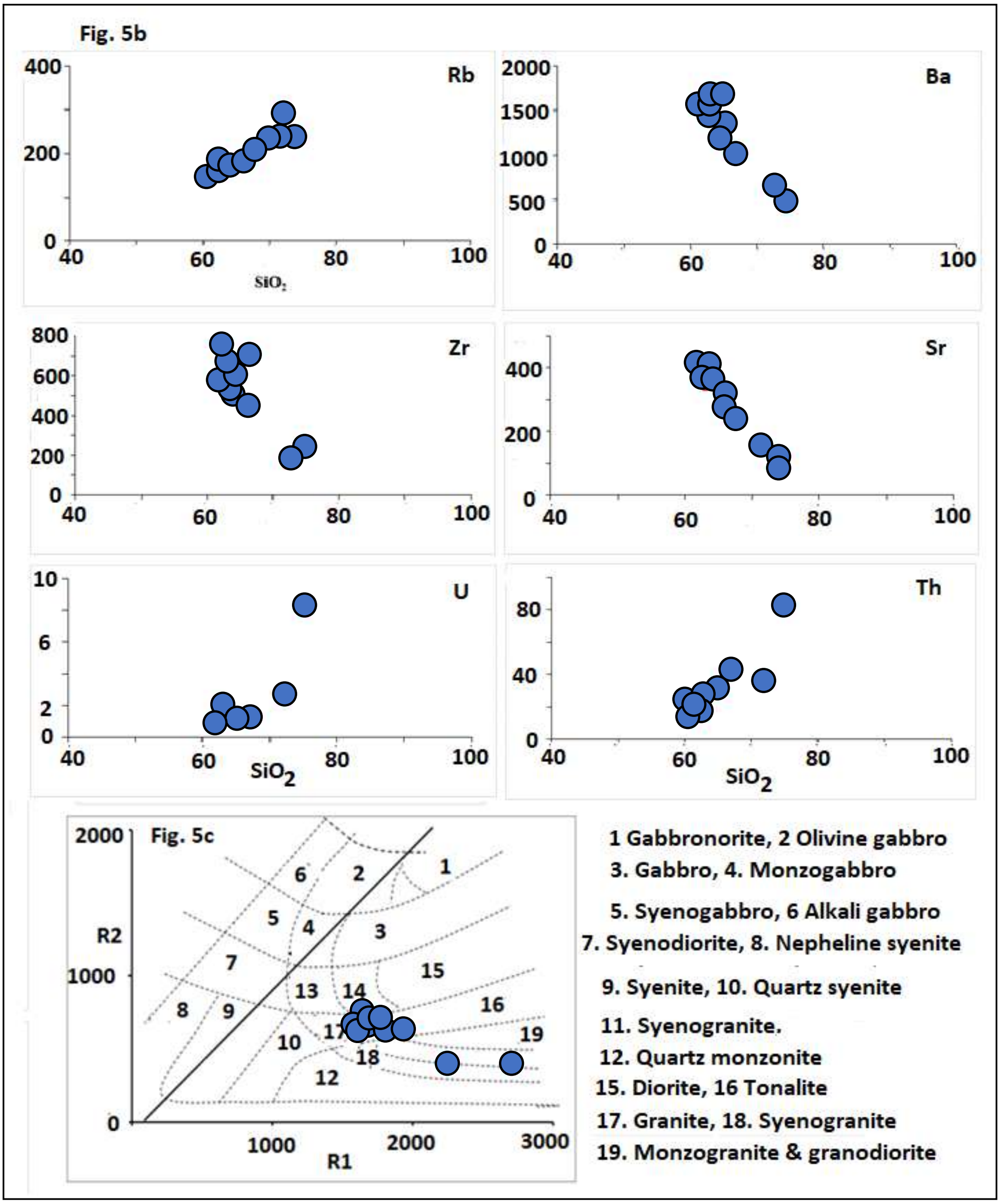


Fig. 5b
Rb
Ba
Zr
Sr
U
Th
SiO2
Fig. 5c
R2
R1
1 Gabbronorite, 2 Olivine gabbro
3. Gabbro, 4. Monzogabbro
5. Syenogabbro, 6 Alkali gabbro
7. Syenodiorite, 8. Nepheline syenite
9. Syenite, 10. Quartz syenite
11. Syenogranite.
12. Quartz monzonite
15. Diorite, 16 Tonalite
17. Granite, 18. Syenogranite
19. Monzogranite & granodiorite

Figure 5.

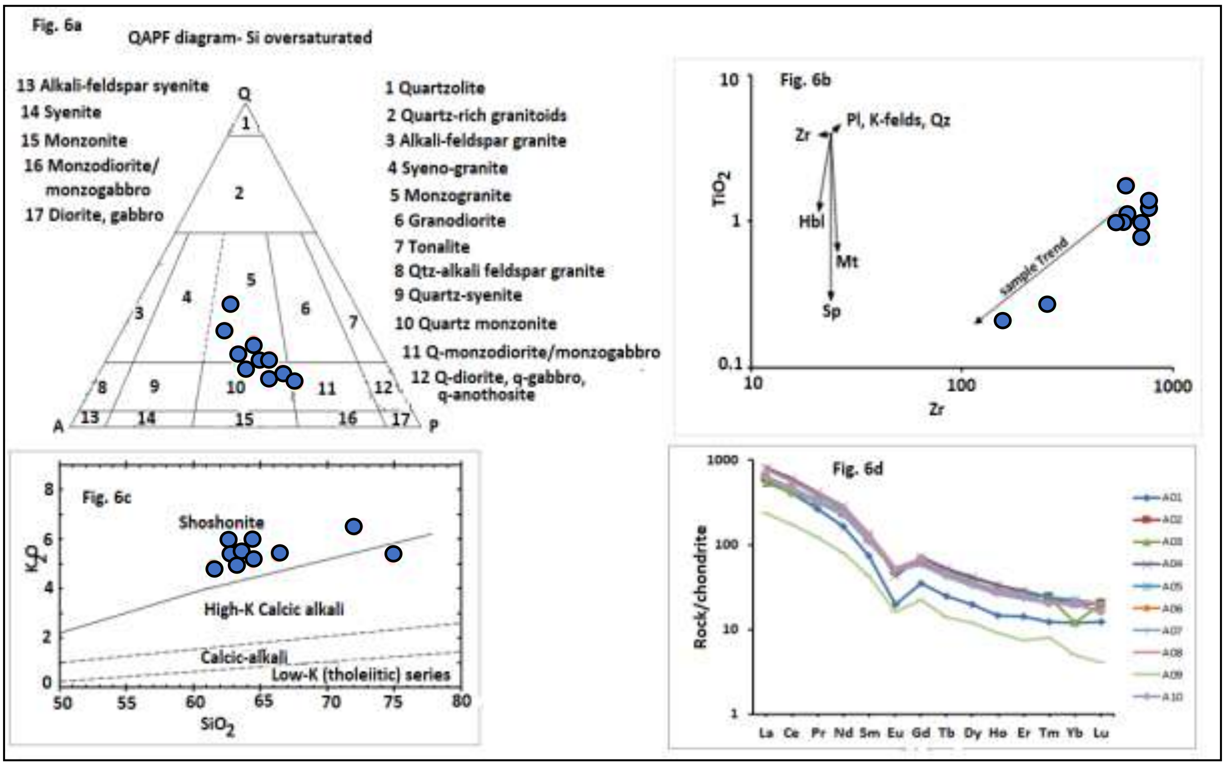


Figure 8.

Figure 6.

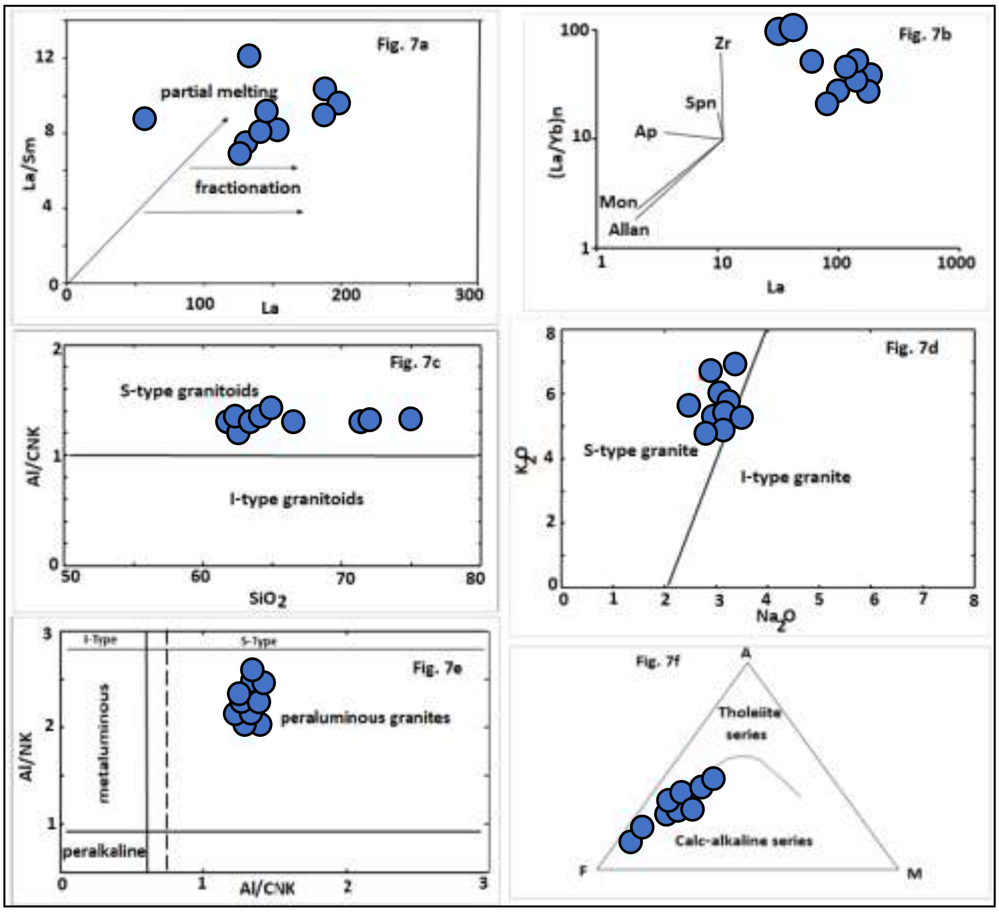
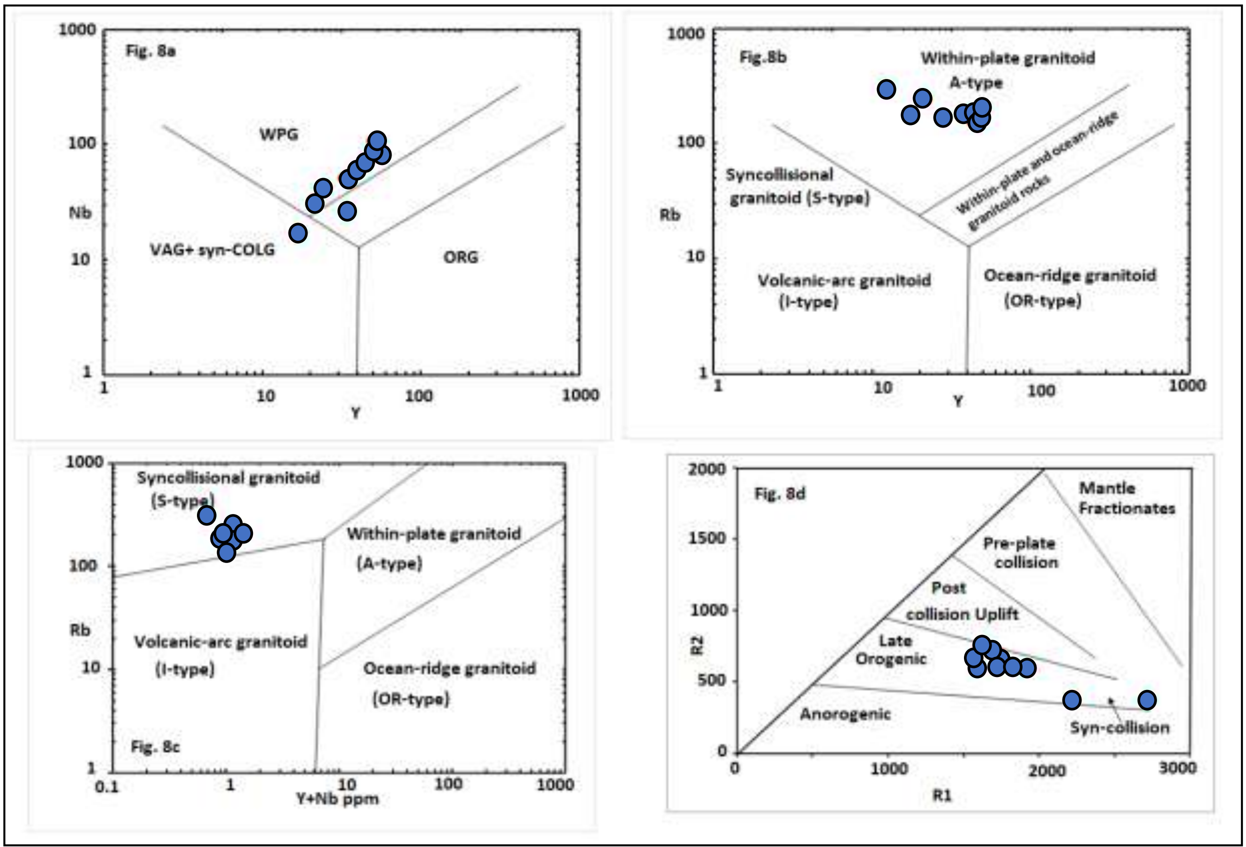


Figure 7.



Akinola, O. O, et. al. "Hornblende-bearingS-type Porphyritic Granite from the Basement complex terrain of Southwestern Nigeria." *IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)*, 9(5), (2021): pp 19-33.