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CLASSIFICATION, GEOTECTONIC SETTING, AND MINERALIZATION POTENTIAL OF THE MINOR INTRUSION IN THE EASTERN MARGIN OF IGARRA SCHIST BELT, SOUTHWESTERN NIGERIA

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ABSTRACT

Petrographic and geochemical studies of the minor intrusion that occurs as sill in the eastern boundary of the Igarra Schist Belt with the granite-gneiss of the migmatite-gneiss complex were undertaken to classify it and determine its tectonic setting and mineralization potential. Petrographic study and geochemical classification revealed that the sill is microgranitic in composition, comprising an aggregate of medium grained microcline and quartz, and accessory actinolite, possibly formed by the alteration of hornblende. The geotectonic setting showed that the sill is orogenic, probably derived from the same upper mantle magma that got contaminated by crustal materials as Igarra batholith. A study of its mineralization potential revealed the microgranite to be intensely sheared being heavily brecciated, and contains quarts, quartzo-feldspathic and pegmatite veins-features that predisposed it for mineralization. The average contents of Ag, As, Au, Bi, Cu and Fe are much higher than their average abundances in standard granites and could host iron oxide-copper -gold (IOCG) deposit with Ag, Au, Bi, Cu and Fe ore minerals.

Keywords: Microgranite, Orogenic, IOCG deposit, Igarra Schist Belt.

INTRODUCTION

Minor intrusion (MI) is an intrusion such as a dyke or sill rather than a major intrusion like a batholith or lopolith. Many MIs are emplaced at shallow depths, within a few kilometers of the surface, and very often reveal links between plutonic and volcanic activity. In the Nigerian Basement Complex (NBC), MIs consist of felsic and mafic rocks that occur as concordant and discordant sills, dykes, veins and irregular bodies of quartz rock, pegmatite, aplite, microgranite, dolerite, gabbro, pyroxenite, lamprophyre and serpentinite (Adekoya, 2012; Rahaman, 2003). They intruded all the pre-existing rocks, within the NBC, namely, in order of decreasing age, the migmatite-gneiss-quartzite Complex (MGQC), the Schist Belts (SB) and the Older Granites (OG). Thus, they are the youngest members of the NBC. The MGQC, the oldest, is the most widespread group of rocks, which occupies about 30% of the total surface area of Nigeria and constitutes more than 70% of the NBC (Rahaman, 2003). It is a heterogeneous rock group, which comprises largely gneisses and migmatites with minor amounts of basic schists and amphibolites, subordinate quartzites and infrequent marbles (Rahaman, 2003). The SB, the second oldest rock group in the NBC, consist of approximately N-S trending narrow zones of low to medium grade metamorphic rocks of mainly sedimentary and minor igneous origin. The protoliths of these rocks were presumably deposited on the pre-existing MGQC before they were deformed, metamorphosed and invaded by Pan African granites during the Pan African orogeny. Hence the rocks of the Schist Belts are considered as supracrustal cover rocks (Adekoya, 1991). The OGs, otherwise known as the Pan African granites, are the most obvious manifestation of the Pan African orogeny in this part of West Africa (Rahaman, 1988). They intruded on the MGQC and the SB. They are widely distributed in the country and occur in all the three main areas of the country where the Basement Complex rocks are exposed. These areas include the north central, the eastern and the western parts of Nigeria (Figure 1). The OG suite includes porphyritic and non-porphyritic granites, granodiorite, adamellite, tonalite, quartz diorite, syenite and charnockites (Rahaman, 2003, 1988; Adekoya, 1991; Olarewaju, 1988). As said earlier the MIs intrude the MGQC, the SB and the OG, however the MI under study occurs as *sill* along the boundary between the eastern margin of Igarra Schist Belt and the granite gneiss of the MGQC

(Figure 2). In this paper, petrographic and a new whole rock major, minor and trace element as well as partially extracted trace element data for this MI is presented to characterize it, put constraints on its tectonic setting and discuss its mineralization potential.

GEOLOGICAL SETTING

Igarra Schist Belt (ISB) extends over an area of roughly 750 km^2 (Hockey *et al*., 1986), and is surrounded by the older migmatite-gneiss-quartzite complex (MGQC), believed to be of Archean to Paleoproterozoic age (Dada, 1989; Hockey et al., 1986) that underlain it. The MGQC is a group of polycyclic crystalline rocks such as migmatites, auto- and para-gneisses, and relict metasedimentary rocks (Adekoya, et al. 2003, Rahaman, 2003). ISB consists mainly of metasedimentary rocks, such as mica schist, quartz-biotite schist, quartz schist and quartzite, calc-silicate gneiss and marble (Odeyemi, 1988; Omitogun *et al*., 1991; Egbuniwe and Ocan, 2003; Ocan, 2016; Adepoju, 2017; Adepoju *et al*., 2018). Metaconglomerate constitute a distinct rock unit infolded into the Igarra Schist Belt (Figure 2). Both the metasedimentary rocks, i.e. ISB, and the MGQC are intruded by the Pan African granites (also known as the Older Granites) represented by the lgarra batholith. Minor felsic and mafic intrusions, including dykes, sills, and veins of pegmatites, aplite, microgranitte, syenite, lamprophyre, dolerite, etc, known locally as minor intrusives (MI), crosscut the Pan African granites and the pre-existing rocks. The ISB and MGQC are separated by a narrow zone of a minor felsic intrusion mapped at the eastern margin of ISB (Adepoju, 2017). This narrow zone of felsic minor intrusion coincides with a shear zone depicted through Landsat-8 lineament analysis (Adepoju, 2017; Adepoju et al., 2021). The intrusion occurs as a sill with a tabular outlook, and is sandwiched between the mica schist of ISB and granite- and minor granodiorite-gneiss of MGQC (Adepoju, 2017; Adepoju and Asiwaju-Bello, 2021). The sill is medium grained, light in colour containing predominantly quartz and feldspar as observable minerals. It is blisteringly sheared having many fractures, breccias, and pegmatite and quartz veins.

METHODOLOGY

This study entailed field mapping and sampling of the massively sheared leucocratic MI rock bodies, as well as petrographic and geochemical analyses of the rock samples. The MI was mapped along the boundaries between MGQC and ISB, in its eastern margin. Field mapping involves studying the rock, their mineralogical composition, geologic structures, and textures were noted and recorded when found. A global positioning receiver was used to accurately locate the positions of the rock outcrop. 1.0 kg of the representative samples of the rock were collected using a geologic hammer and chisel at all the localities where the rock was studied. The petrographic study entailed the preparation of thin sections of rock samples and the study of the thin sections with a polarizing microscope. Preparation of thin sections were done for many of the rock samples collected in the field using standard procedure. A total of 15 thin sections were prepared from the sill-rock samples and the petrographic study was done using the MEIJI petrographic/polarizing microscope. The slides were properly described noting their textural, mineralogical differences, and mineral assemblages. Photomicrographs showing the fabrics and some particular microstructures/textural

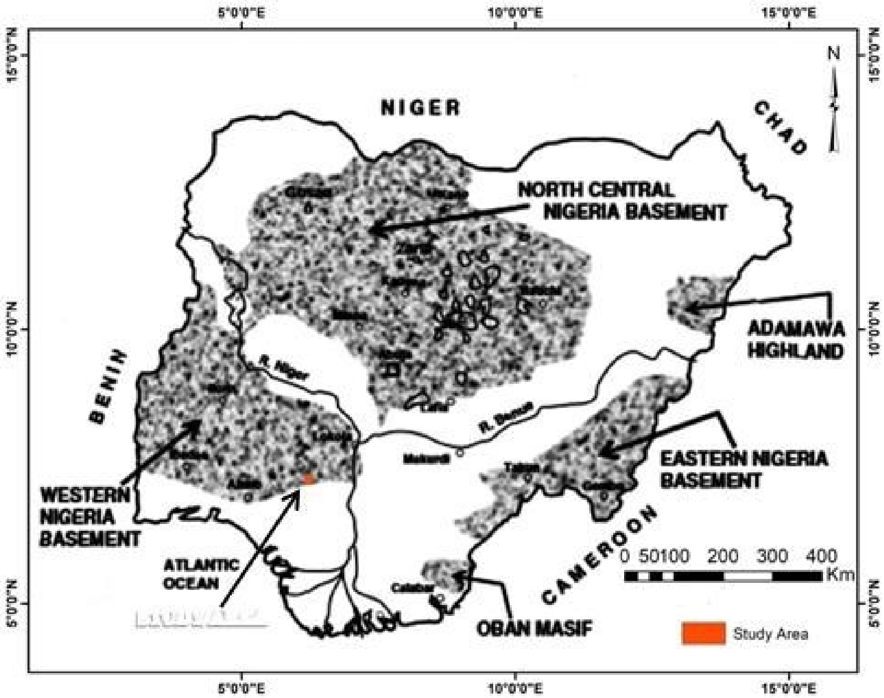


Figure 1: Map of Nigeria showing the distribution of Basement Complex and the Study area in the Southeastern Margin of Western Nigeria Basement (modified after Obaje, 2009).

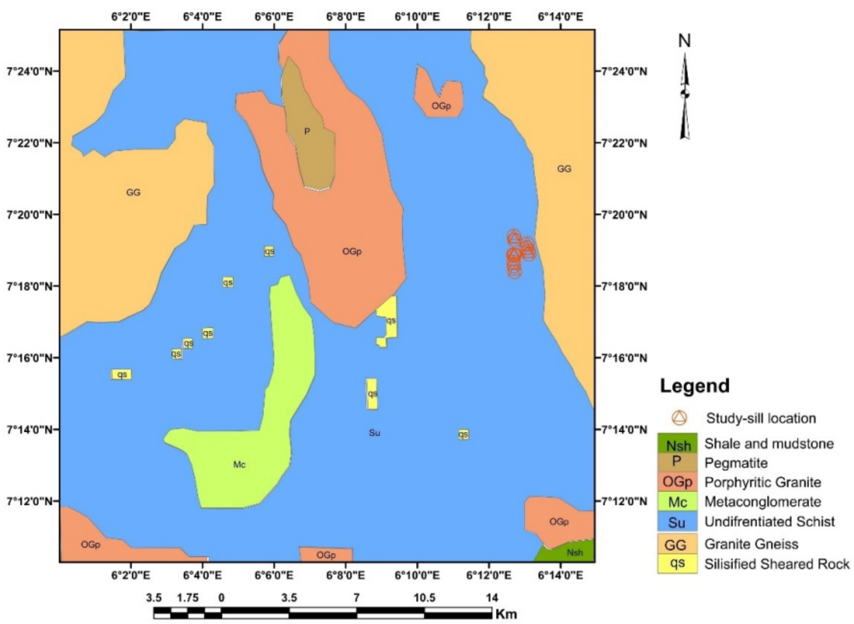


Figure 2: Geological map of a part of Igarra Schist Belt showing the location of the sill under study (modified after NGSA, 2006).

features were also taken. Geochemical study consisted of rock sample preparation and geochemical analyses. The rock sample preparation involves crushing, milling and pulverization of 250 g of each of the rock samples prior to sieving with 200 μm nylon mesh. For the geochemical analysis, about eight grams each of the pulverized samples was packaged for delivery to the Geochemistry Laboratory of *Bureau Veritas Commodity Limited Vancouver, Canada.* At Bureau Veritas, 0.2 g each of the samples was treated to lithium borate ($LiBO_2/Li_2B_4O_7$) fusion prior to ICP-ES analysis for major oxides and some trace elements to further classify and unravel the tectonic setting of the rocks. Furthermore, 0.5 g each was subjected to modified *aqua regia* (1:1:1 HNO_3, HCl, distilled H_2O) digestion prior using ICP-MS to analyze for trace elements used to determine the mineralization potential of this minor intrusion. Geochemical data processing uses a software package, GCD kit 4.1 in r programming language, to plot classification and geotectonic-setting diagrams. In plotting the results, any element that contains censored data below the analytical instrument's detection limit (DL) at any site, a value equals to 50% of the element's lower DL was substituted at that site.

RESULTS AND DISCUSSION

Mode of Occurrence and Petrography

The minor intrusion at the eastern margin of ISB occurs as a *sill*, concordant narrow body of about 8-12 m thick that intrudes the boundaries between its mica schist and granite gneiss of MGQC. Where exposed, it occurs as fragmented pavement outcrops with scattered boulders (Plate 1). It has dips that conform to those of the rocks it intrudes, i.e. dips away from the granite gneiss and towards the metasediment, which only indicates that the MGQC is older than the ISB. On the outcrop, the rock varies in colour from brown through brownish-grey to dark grey depending on the degree of weathering. However, the colour of the fresh surface of the rock varies from grey through light green to green. Fine grains of whitish, light yellow and yellow metallic minerals are conspicuous in hand specimens. The rock is generally medium grained and seems finely banded, although in most places it is massive. The rock displays extensive brecciation and quartz veining (Plate 2), evidence that the rock has been intensely sheared and silicified. Also, granitic and pegmatite dykes intrude the sheared rock in some places, displacing the quartz veins in a sinistral or dextral fashion (Plate 3). The silicate minerals in the rock are difficult to identify because it has been heavily altered, which made Adepoju (2017) refer to it as silicified sheared rock.

In thin sections, the rock reveals homeoblastic texture with the essential mineral constituents, quartz and feldspar, having approximately equal size (Plate 4). It contains slender prismatic actinolite crystals developed during recrystallization (Plate 4). There is extensive granulation with surviving porphyroclasts surrounded by granules. Evidence of recrystallization of the granules is revealed by polygonization of the grains and the development of overgrowth. This observation indicates that the rock is probably a cataclasite. The rock is composed mainly of quartz and alkali feldspar (Plate 4). Opaque minerals and amphibole occur as the minor minerals present in the rock (Plates 4 - 7). **Quartz** grains are essentially polygonal granular occurring in two contrasting grain sizes (Plate 7). The bigger grains are polygonal with essentially rectangular outlines. The small quartz grains occur as aggregates surrounding the bigger grains (Plate 4). This arrangement of larger mineral fragments set in a groundmass of crushed material derived from the same mineral crystal defines a mortar texture (Plate 7). The type of **alkali feldspar** identified in the thin section is microcline distinguished by its typical cross-hatched twining (Plate 4). However, there is possibility of occurrence of other feldspar types and more crystals of microcline than observed, unidentifiable owing to lack of twining. This reason also may make the finer-grained feldspar and quartz crystals indistinguishable. The size and texture of feldspar are similar to those of quartz (Plate 4), which gives the rock homeoblastic texture. **Opaque minerals** are fairly abundant in this silicified sheared minor intrusive rock at the boundary between the eastern margin of ISB and MGQC. They occur in varying sizes and shapes. The grain size of the opaque minerals is generally fine, but in thin section there are two contrasting sets of grain sizes. The first set comprises finer-grained euhedral opaque minerals associated with granules of quartz and feldspars of similar grain size (Plate 7). The second set consists of larger-grained opaque minerals of various shapes ranging from anhedral to subhedral (Plate 5). The opaque minerals of this set are essentially porphyroblastic with few of their crystals being poikiloblastic. **Amphibole** grains are also fairly abundant in the silicified sheared rock (Plate 6). The amphibole occurs essentially as large prismatic crystals whose colours vary from yellow-green to green to dark green/blue-green.

This indicates that the amphibole is most likely to be actinolite. The actinolite crystals in many cases occur as large grains embedded in the finer grain matrix of quartz and feldspar giving the rock a porphyroblastic texture. However, the long axes of the actinolite grains have a random orientation, suggesting that the amphibole formed post tectonically, probably by alteration. The preponderance of cataclasitic textures, such as homeoblastic, mortar, and porphyroblastic textures in the rock confirm it to be a cataclasite. The dominance of quartz and microline in the sheared rock as well as its texture, medium grained of such minor intrusion, makes microgranite a suspect for its progeny. The pervasiveness of quartz veins and the preponderance of opaque (i.e. metallic) minerals in this rock suggest that the rock is probably mineralized.

Plate 1: Outcrops of the minor intrusive rock under study.

Plate 2: Outcrop of the intensely sheared leucocratic minor intrusion under study displaying brecciation, quartz veining and spheroidal weathering.

Plate 3: Field Photograph of Silicified Sheared Rock Showing Quartzo-feldspartic Vein Cutting through Quartz Vein in Sinistral Version.

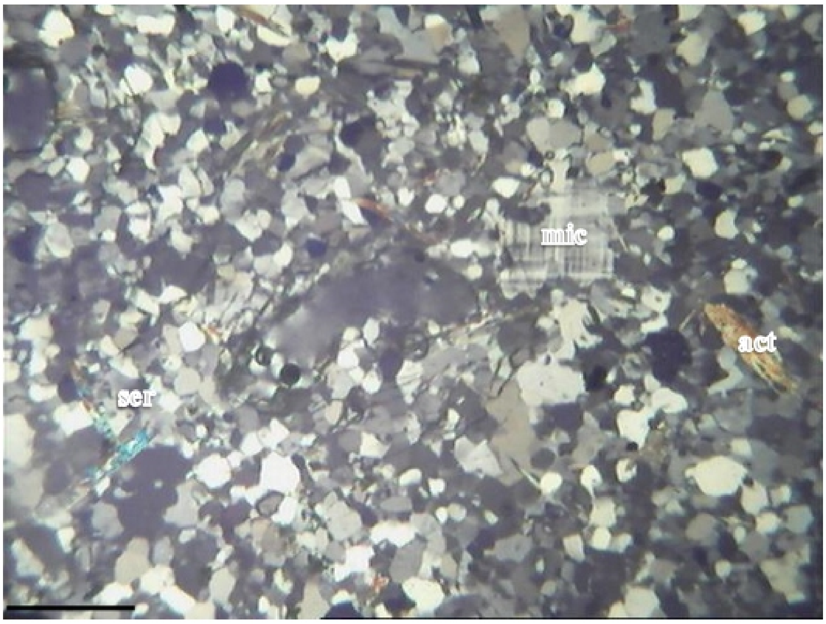


Plate 4: Photomicrograph of Silicified Sheared Rock Consisting of Quartz (qtz), Microcline (mic), Sericite (ser) and Actinolite (act). Bar Scale: 2 μm (xpl).

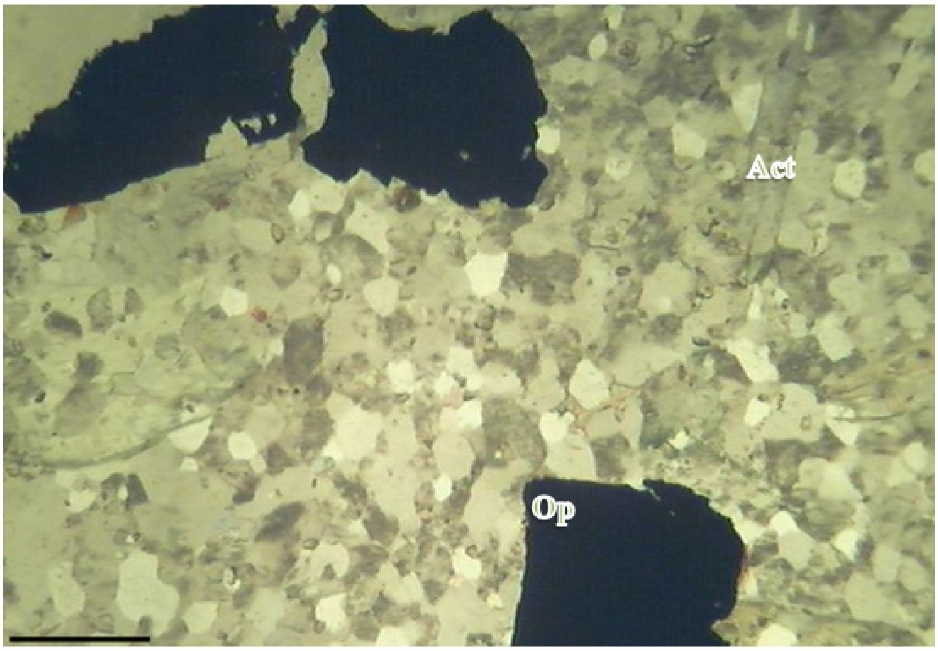


Plate 5: Photomicrograph of Silicified Sheared Rock Showing Some Crystals of Opaque (Metallic) Minerals. Bar Scale: 2 μm (ppl).

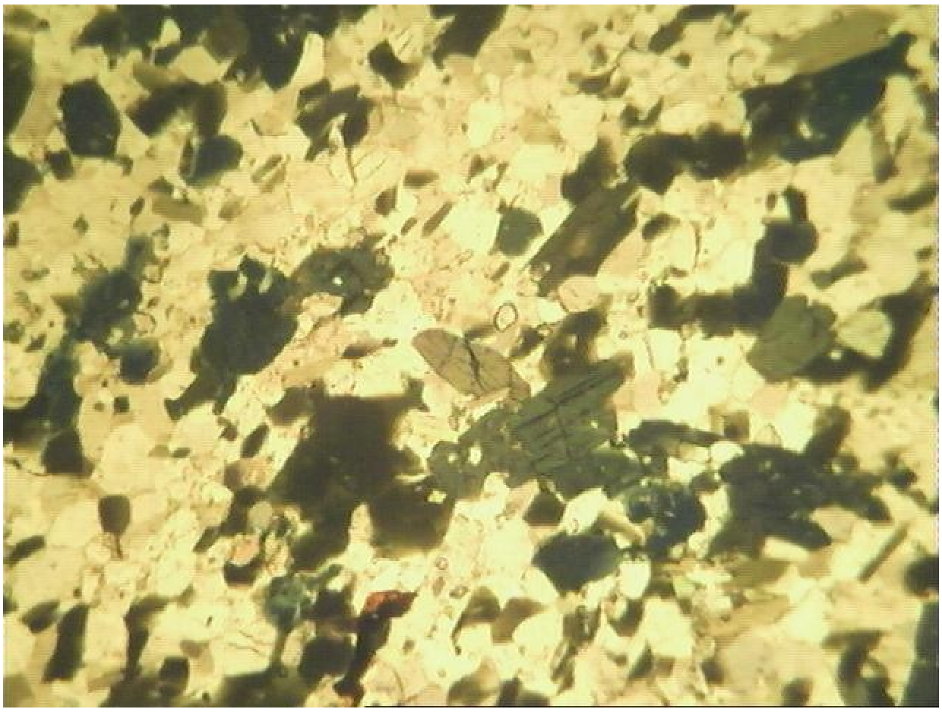


Plate 6: Photomicrograph of the Silicified Sheared Rock Showing a Few Dark-green Crystals of Amphibole (Actinolite). Bar Scale: 2 μm (ppl).

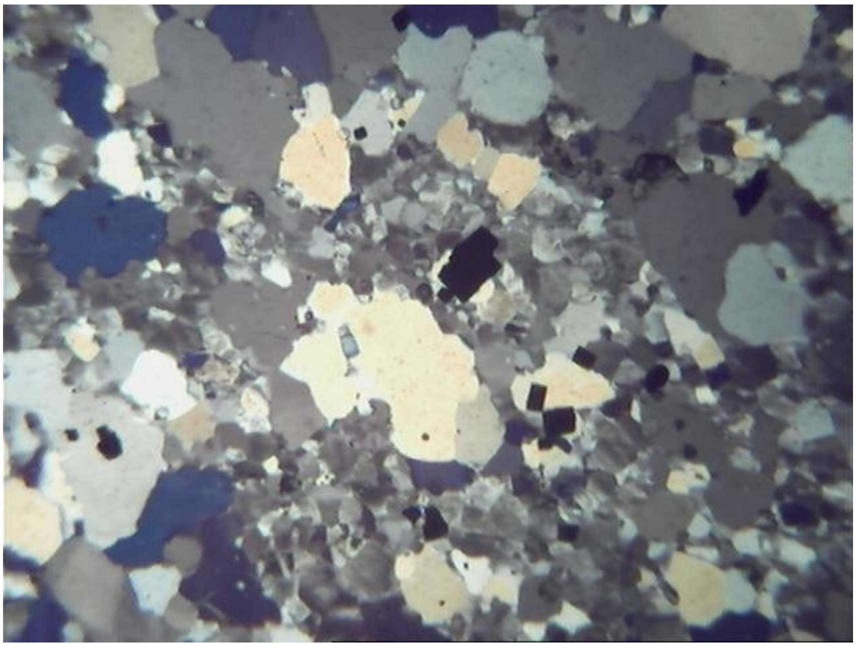


Plate 7: Photomicrograph of the Silicified Sheared Rock Showing the Contrasting Grain Sizes of Quartz (white) and Opaque minerals (black). Bar Scale: 2 μm (xpl).

Geochemical Classification

The results of the bulk chemical analysis of the rock were used to further classify the minor intrusion and they are presented in Table 1. This gives the concentrations of major oxides (i.e. SiO_2, Al_2O_3, Fe_2O_3, MgO, CaO, Na_2O, K_2O, TiO_2, P_2O_5, MnO and Cr_2O_3), in % and some trace elements (i.e, Ba, Ni, Sr, Zr, Y, Nb, and Sc), in ppm. The SiO_2 content of the rock varies from 70.27 to 82.26 % with an average of 72.99% and this reveals it to be acidic in composition having SiO_2 content greater than 63 wt. % (Le Maitre, 2002). Also, a collation of ($Na_2O + K_2O$) content, and Al_2O_3 content shows that for the minor intrusion, the former is somewhat less than the latter. The ($Na_2O + K_2O$) content varies from 6.77 to 8.98 % with an average of 8.29 %, while the Al_2O_3 content varies from 7.99 to 12.58 % with an average of 10.26 % (Table 1). This further classifies it as subalkaline rock. The subalkaline magma series can be in advance subdivided to K-rich (high K-type) calc-alkaline magma series when consider the fact that K_2O content is higher than Na_2O content. The former ranges from 1.60 to 8.49 % with an average of 7.35 %, and the latter ranges from 0.29 to 5.68 % with an average of 0.94 % (Table 1). The TAS (total alkali versus silica) plot of plutonic rocks (Middlemost, 1994) commonly used to classify such rocks (Figure 3) shows that all the 12 samples from the minor intrusive rock plot in the field of granite. This has certainly classified this rock as microgranite, a classification which was suspected from the petrography of the rock.

Table 1: Concentrations of major-element oxides and some minor elements in the rock of the sill.

	MI1	MI2	MI3	MI4	MI5	MI6	MI7	MI8	MI9	MI10	MI11	MI12	AV,
SiO_2 (%)	82.26	78.28	72.12	70.27	71.02	70.69	72.27	82.19	78.24	76.42	73.21	72.94	74.99
Al_2O_3 (%)	7.99	12.58	10.03	10.4	10.7	10.71	10.04	8.34	9.37	9.9	10.18	10.26	10.04
Fe_2O_3 (%)	2.16	1.18	3.84	4.27	3.87	3.55	3.74	1.6	1.94	2.44	3.22	3.24	2.92
MgO (%)	0.01	0.02	1.29	1.36	1.29	1.14	1.06	0.25	0.37	0.5	1.08	1.1	0.79
CaO (%)	0.05	0.47	2.5	3.28	2.35	2.34	1.89	0.33	0.74	0.94	1.72	1.73	1.53
Na_2O (%)	0.29	5.68	0.63	0.7	0.71	0.76	0.38	0.5	0.35	0.33	0.45	0.45	0.94
K_2O (%)	6.48	1.6	7.82	7.92	8.27	8.24	8.33	6.67	7.74	8.27	8.39	8.49	7.35
TiO_2 (%)	0.12	0.02	0.56	0.58	0.56	0.61	0.58	0.05	0.14	0.13	0.54	0.53	0.37
P_2O_5 (%)	0.11	<0.01	<0.01	0.02	<0..01	0.02	0.18	0.1	0.29	0.35	0.03	0.03	-
MnO (%)	<0.01	0.02	0.07	0.08	0.07	0.12	0.11	0.02	0.02	0.03	0.08	0.08	-
Cr_2O_3 (%)	0.003	<0.002	0.007	0.008	0.006	0.007	0.006	<0.002	<0.002	0.002	0.07	0.006	-
LOI (%)	0.4	0.1	1	0.9	0.9	1.7	1.2	-0.1	0.7	0.6	0.9	1	0.8
TOTAL	100.02	100	99.98	99.97	99.97	99.97	99.98	99.99	100.03	100.02	99.99	99.99	100
Ba (ppm)	806	55	834	875	898	355	471	554	405	401	724	722	592
Ni (ppm)	<20	<20	22	24	25	44	43	<20	<20	<20	30	31	-
Sr (ppm)	64	26	232	294	246	270	325	130	99	113	220	219	187
Zr (ppm)	76	12	236	256	220	212	242	44	63	72	245	205	157
Y (ppm)	6	21	10	10	8	10	34	14	23	29	16	15	16
Nb (ppm)	17	153	54	46	54	120	100	8	15	20	99	98	65
Sc (ppm)	2	18	4	6	5	2	3	<1	<1	<1	4	4	-

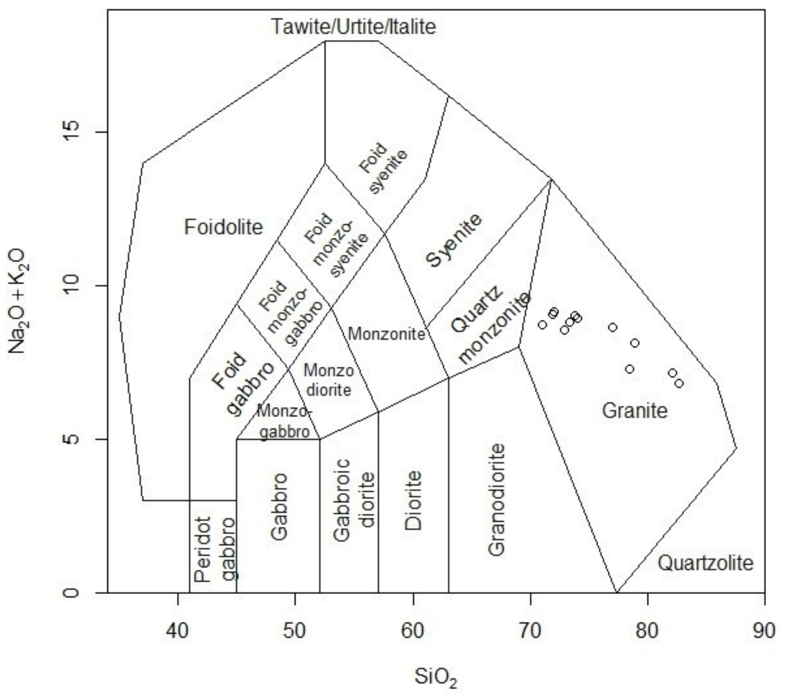


Figure 3: TAS (total alkali versus silica) diagram according to Middlemost (1994) for the minor intrusion in the eastern margin of Igarra Schist Belt.

Geotectonic Setting

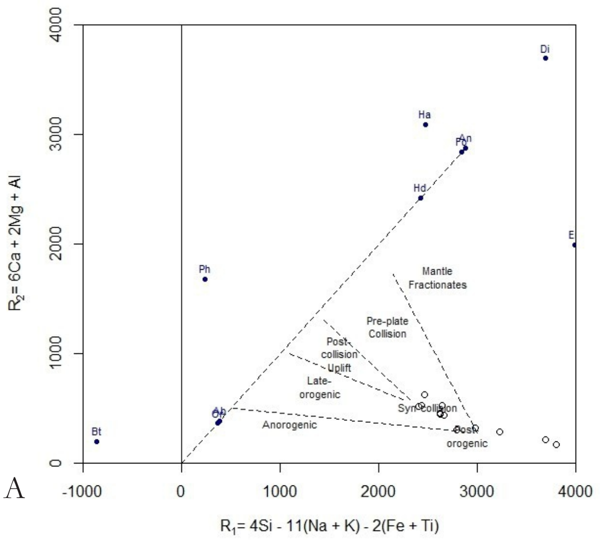
The tectonic conditions present at the locations of the contact between ISB and MGQC that the minor intrusion intruded have been inferred by total major- and trace-element discrimination plots.

The R1 versus R2 plot of Batchelor and Bowden (1985) for the granite (Figure 4A) reveals it is orogenic granite as all its samples plot between the fields of syn-collision and post orogenic granites. The trace element geotectonic discrimination Y versus Nb diagram (Figure 4B) after Pearce *et al.* (1977) shows the microgranite to be volcanic arc plus syn-collisional and within-plate granite. Major elements granite tectonic discrimination plots (Maniar and Piccoli, 1989) for this microgranite are given in Figure 5. The SiO_2 versus FeOt /(FeOt + MgO) plot (Figure 5A) shows the granite to be essentially post orogenic. The M/AFM versus F/AFM, i.e. $[MgO/(Al_2O_3+Fe_2O_3+MgO)]$ vs $[Fe_2O_3/(Al_2O_3+Fe_2O_3+MgO)]$, plot (Figure 5B) indicates it formed in either an island arc, continental arc or continental collision environment. The C/ACF versus F/ACF, i.e. $[CaO/(Al_2O_3+CaO+Fe_2O_3)]$ vs $[Fe_2O_3/(Al_2O_3+CaO+Fe_2O_3)]$, plot (Figure 5C) confirms that the microgranite formed from post orogenic granitoid magma, which intruded the boundaries of ISB and MGQC in either an island arc, continental arc or continental collision terrain. The A/NK versus A/CNK, i.e. $[Al_2O_3/(Na_2O+K_2O)]$ vs $[Al_2O_3/(CaO+Na_2O+K_2O)]$, plot (Figure 5D) shows that the microgranite is mostly metaluminous with only few peralumnous igneous rock. It can be deduced from this geotectonic study that the microgranite at this boundary is orogenic like Igarra batholith (Dada, 2006; Rahaman, 1988); and probably was formed by the same upper mantle magma that digested the crustal materials intruded.

Mineralization Potential

The mineralization potential of this sill that intruded the boundary between ISB at its eastern margin and MGQC has been discussed based on its structural disposition, and concentration of partially extracted trace elements. Based on its structural disposition, the sill has been intensely sheared as evidenced by the intense brecciation observed on it (Plate 2). This has corroborated the observation of a shear zone, which aligns with the location of the sill (Adepoju, 2017; Adepoju et al, 2021). Also many quartz, pegmatite and granitic veins were observed in the rock (Plate 3). All these suggest that the minor intrusion that intruded the contact of ISB at its eastern margin with MGQC does not only contain the required spaces suitable to serve as passageways and loci for hydrothermal fluids to traverse and deposit their metal load, but also evidences that hydrothermal fluids have traversed it.

In terms of concentrations of trace elements, all the 20 partially extracted trace elements, i.e. Ag, As, Au, Ba, Bi, Co, Cr, Cu, Fe, Ga, La, Mn, Mo, Pb, Sb, Sc, Sr, Th, U, and Zn used in this study are widely distributed in the sill as they are present at detectable levels, above the minimum detection limits of the analytical instrument, i.e. ICP-MS (Table 2). The average concentrations of Ag, As, Au, Bi, Cu, and Fe are 155, 2.8, 1.7, 6.7, 71.36, and 16,500, respectively, which are much higher than their corresponding average abundances of 50, 0.5, 0.4, 0.07, 13, and 13,700 in a standard granite (Taylor, 1964). This indicates possible mineralization of Ag, Au, Bi, Cu and Fe in the sheared microgranite of the sill at the contact between ISB and granite gneiss of the MGQC in the eastern margin of ISB. The average contents of other trace elements as Ba, Co, Cr, Ga La, Mn, Mo, Pb, Sb, Sc Sr, Th, U, and Zn in the sheared rock (Table 2) is far less than their average abundance in the standard granite of Taylor (1964). As a results, the economic aspect of the sheared microgranite is its possible host of iron oxide copper gold deposit (IOCG), which are polymetallic, usually composed of two or more of the elements copper, gold, silver, uranium, bismuth, cobalt, niobium, phosphorus, vanadium, REEs and iron. The suspected IOGC in this



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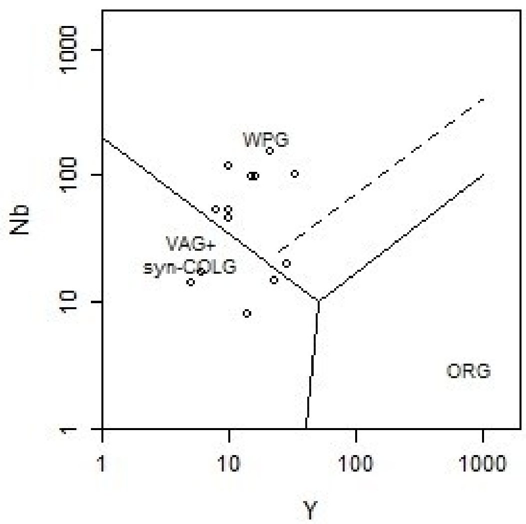

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Figure 4: (A) Geotectonic discrimination R1-R2 plot after Batchelor and Bowden, (1985) for the minor intrusion. (B) Trace element geotectonic discrimination Y-Nb plot after Pearce *et al.* (1977) for the micrmicrogranite. (Symbols: ORG, ocean ridge granitoids; VAG, volcanic arc granitoids; Syn-COLG, syn-collisional granitoids; WPG, within-plate granitoids; post-COLG, the post-collisional granitoids).

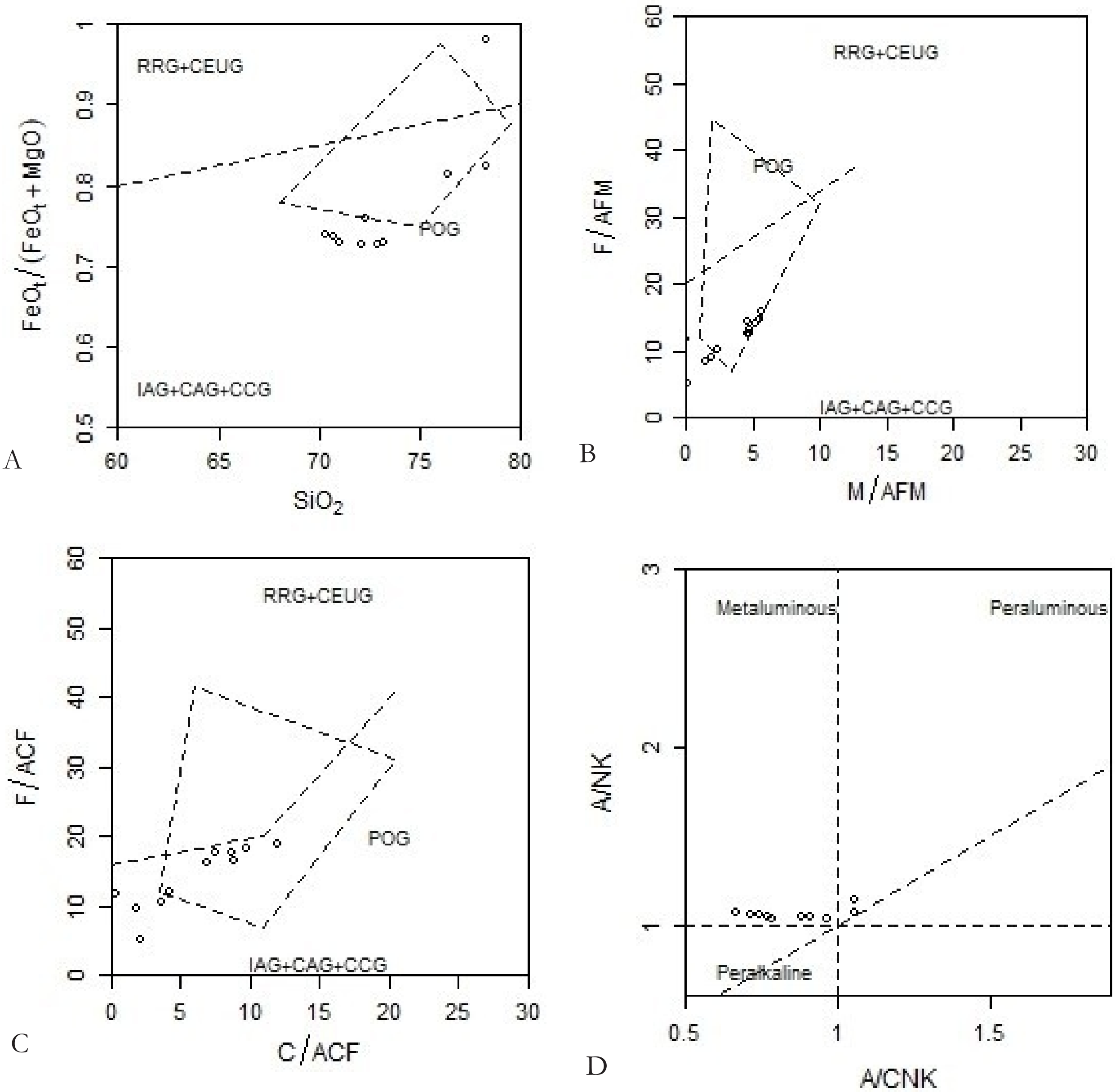

Figure 5: Major element tectonic discrimation plots for the microgranite after Maniar and Picolli (1989). A. SiO_2 versus FeOt /(FeOt + MgO), (B) M/AFM versus F/AFM, (C) C/ACF versus F/ACF, (D) A/CNK versus A/NK. (Symbols: IAG- island arc granites, CAG- continental arc granites, CCG- continental collision granites, POG- post-orogenic granites, CEUG- continent-epeirogenic uplift granite, RRG- rift related granites).

Table 2: Concentrations of trace elements in the microgranite.

Element	MI1	MI2	MI3	MI4	MI5	MI6	MI7	MI8	MI9	MI10	MI11	MI12	AV	AVGr
Ag	114	21	205	223	231	240	180	119	72	77	182	197	155	50
As	0.9	0.9	0.6	1.6	0.5	1.6	6.1	1	9.2	8	1.7	1.7	2.8	0.5
Au	2.1	1.5	1.4	2.8	5.1	1.5	1.2	1.5	0.5	0.4	1.6	0.5	1.7	0.4
Ba	50.7	11.6	23.5	37.7	22.6	11.9	15.5	13.9	6.8	2.2	56.8	55.4	25.7	1220
Bi	0.78	9.07	0.48	0.35	0.37	1.56	1.38	0.63	0.87	0.93	0.8	0.8	1.5	0.07
Co	2.3	0.7	7.4	7.7	8.3	14.4	12.1	0.9	3	3.4	10	10.7	6.7	2.4
Cr	11	7.1	12.5	18.5	11.3	12.9	11.2	11.3	8.1	4.1	8.8	9	10.5	20
Cu	46.86	16.62	142.91	157.98	126.34	159.37	68.74	17.4	12.81	10.52	48.47	48.35	71.36	13
Fe	1.42	0.71	2.11	2.36	1.98	2.12	2..16	1.02	1.21	1.16	1.74	1.79	16500	13700
Ga	0.3	1.1	0.8	1.2	0.7	1.9	0.6	0.5	0.4	0.2	0.3	0.4	0.7	20
La	7	4	9	15.2	10.2	2.5	4.4	3.4	9.1	8	18.4	18.3	9.1	101
Mn	71	70	139	175	133	127	89	74	50	26	46	46	87	95
Mo	1.35	1.13	2.22	3.59	1.47	1.48	1.19	1.31	0.9	0.41	0.92	0.8	1.4	6.5
Pb	16.75	9.79	16.14	16.07	16.79	23.78	11.71	16.17	10.34	9.97	7.01	7.27	13.48	48
Sb	0.11	0.14	0.12	0.16	0.09	0.13	0.17	0.12	0.06	0.04	0.18	0.17	0.12	0.31
Sc	0.8	2.9	0.4	0.7	0.4	0.2	0.3	0.2	0.3	0.2	0.3	0.3	0.6	2.9
Sr	8.5	2.8	19.2	72	14.2	7.4	34.9	11.2	9.2	8.3	7.4	7.3	16.9	250
Th	1.7	5.1	4.3	5.8	4.4	0.7	2.6	0.7	2.1	1.9	3.9	3.9	3.1	50
U	0.5	11.7	0.5	0.8	0.5	0.3	1.6	0.1	0.5	0.3	0.7	0.6	1.5	3.4
Zn	1.5	4.4	4.9	8.2	4.7	7.2	21.5	1.7	3.4	2.9	18.2	19.7	8.2	45

Element Concentration in ppm. Ag & Au in ppb.

microgranite probably comprises copper, gold, silver, bismuth and iron with respect to the present study.

CONCLUSION

The minor intrusion under study occurs as sill at the boundaries of the northeastern margin of ISB and granite gneiss of MGQC (Figure 2). The petrographic study showed that the rock that constitutes the sill is microgranite, being medium grained and consisting essentially of quartz and feldspar with minor opaque minerals and actinolite derived, probably, from alteration of hornblende. Geochemical classification also revealed the rock of the sill to be microgranite as all the twelve samples of it plotted in the granite field of Middlemost (1994). It was substantiated from the geotectonic setting that the microgranite is orogenic like Igarra batholith (Dada, 2006; Rahaman, 1988); and probably was formed by the same magma. A study of the mineralization potential showed the sill to be highly sheared by being intensely brecciated and also contain extensive quartz, quartzofeldspathic and granitic veins (Plates 2 and 3). These features do not only demonstrate the minor intrusion to be porous and permeable for hydrothermal fluids but also the evidence that such fluids have traversed it. The presence of the minor metallic minerals in the rock showed these features have also served as loci for the hydrothermal fluids to have precipitated their ore components. This highly sheared sill also contains much higher levels of some trace elements such as Ag, As, Au, Bi, Cu and Fe (Table 2) than their average abundances in standard granites (Taylor, 1964), and could host iron oxide-copper -gold (IOCG) deposit consisting of Ag, Au, Bi, Cu and Fe ore minerals. There is therefore a need to examine the detailed characteristics of this suspected IOCG deposit host by the minor intrusion at the eastern margin of the ISB, and to descry whether such minor intrusion occurs at all the margins of this rock.

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REFERENCES

Adekoya, J.A. (2012): Nigerian Geological frameworks. Lecture Material, Field Mapping Training Workshop, Federal University of Technology, Akure Nigeria, 32 p.

Adekoya, J. A. (1991): The geology of the banded iron-formations in the Precambrian Basement Complex of Northern Nigeria. Unpubl. Ph. D. Thesis. University of Ibadan, Nigeria.

Adekoya, J. A., Kehinde-Phillips, O. O. and Odukoya, A. M. (2003): Geological distribution of mineral resources in southwestern Nigeria. In: Prospects for investment in mineral resources of southwestern Nigeria, A. A. Elueze (ed), p. 1 – 13.

Adepoju, M. O. (2017) Geological and Geochemical Exploration Studies in Dagbala-Atte District in Igarra Schist Belt, Southwestern Nigeria. Ph.D. Dissertation, FUTA, Nigeria.

Adepoju, M. O., Adekoya, J. A. and Odeyemi, I. B. (2018): Statistical evaluation of soil geochemical data from Dagbala-Atte District in Igarra Schist Belt, Southwestern Nigeria. *Geoinformatics and Geostatistics: An Overview,* 6:4, 1 – 11. doi: 10.4172/2327-4581.1000189

Adepoju, M. O., Odeyemi, I. B. and Akinluyi, F. O. (2021): Landsat-8 lineament analysis for detection of egigenetic mineralization zones in parts of Igarra Schist Belt, southwestern Nigeria. Remote sensing in Earth System Science, 4, 76-86. doi: 10.1007/s41976-021-00046-1

Adepoju, M. O. and Asiwaju-Bello, Y. A. (2021): Geochemical classification and geotectonic setting of granitic gneisses from southeastern margin of western Nigeria Basement. *Journal of Geological Research*, 3(2), 1-6. doi: 10.30564/jgr.v3i2.2831

Batchelor, R.A. & Bowden, P. (1985): Petrologic interpretation of granitoid rocks series using multicationic criteria. Chemical Geology 48, 43-55. doi: 10.1016/0009-2541(85)90034-8

Dada, S. S. (1989): Evolution de la croute continentale au Nord Nigeria U-Pb et de traceurs isotopiques Sr, Nd et Pb. These diplome de Doctoral, Univ. der Sci. Tech. Lang. Montpellier. pp 200.

Dada S. S. (2006) Proterozoic evolution of Nigeria. In: Oshin, O (ed) The basement complex of Nigeria and its mineral resources (A Tribute to Prof. M. A. O. Rahaman). Akin Jinad & Co. Ibadan, pp 29–44.

Egbuniwe IG, Ocan OO (2003) Selection of Fieldwork Areas for Teaching/Training: Igarra Area as an Example. Proceedings of Field Mapping Standardization Workshop, Ibadan University Press, Ibadan, 79 95.

Hockey RD, Sacchi R, de Graaff WPFH, Muotoh EOG (1986) The Geology of Lokoja-Auchi Area: Explanation of 1:250,000 Sheet 62. Geol. Surv. Nigeria. Bull., No. 39, 71 p.

Le Maitre, R. W. (2002). *Igneous rocks – a classification and glossary of terms. Recommendations of the IUGS subcommission on the Systematics of Igneous Rocks*. Cambridge: Cambridge University Press. 2nd edn .

Maniar, P.D. & Piccoli, P.M. (1989). Tectonic discrimination of granitoids. *Geological Society of America Bulletin* 101, 635-643. doi: 10.1130/0016-7606(1989)101 <0635:TDOG>2.3.CO;2

Middlemost, E. A. K. 1994. Naming materials in the magma/ igneous system. *Earth-Science Reviews* 37, 215–224. doi: 10.1016/0012-8252(94)90029-9

NGSA (2006). Geological map of Edo State, Nigeria. Published map, Nigerian Geological Survey Agency, Abuja, 1 p.

Obaje, N.G. (2009). The Basement Complex. In: Geology and Mineral Resources of Nigeria. Lecture Notes in Earth Sciences, vol 120. Springer, Berlin, Heidelberg. doi: 10.1007/978-3-540-92685-6_2

Ocan, O. O. (2016): The structure and metamorphic evolution of the Igarra Schist Belt, Edo State, Nigeria. In Ladipo, K. (Editor), Season of Rahaman II, NMGS special publication, p. 107-117.

Odeyemi. I. B. (1988) Lithostratigraphy and Structural Relationships of the Upper Precambrian Metasediments in Igarra Area, Southwestern Nigeria. In: Oluyide PO, Mbonu WC, Ogezi AE, Egbuniwe IG, Ajibade AC, Umeji AC, Eds., Precambrian Geology of Nigeria, Publ. GSN, 111-125.

Olarewaju, V. O. (1988) Petrology and geochemistry of charnockitic and associated granitic rocks of Ado Ekiti–Akure, southwestern Nigeria. In Oluyide, P.O., Mbonu, W.C., Ogezi, A.E., Egbuniwe, I.G., Ajibade, A.C. and Umeji, A.C. (Eds.), *Precambrian Geology of Nigeria.* Geological Survey of Nigeria spec. pub., 231-239.

Omitogun, A. A., Caby, R., Debat, P. and Mercier, A. (1991). Le metamorphisme Pan African de la partie central la zone mobile du Nigeria ("Schist Belt" d'Igarra s. l.). C.R. *Acad. Sci. Paris*, t. 313, Serie II, 1417-1423.

Pearce, J. A., Harris, N. B. W. & Tindle, A. G. (1984): Trace element discrimination diagram for tectonic interpretation of granitic rocks. *Journal of Petrology* 25, 956-983.
doi: 10.1093/petrology/25.4.956

Rahaman, M. A. (2003): Geology of Nigeria. Opening Address by the President of Nigerian Mining and Geosciences Society (NMGS) at the 33rd Annual International Conference and Exhibition (AICE) of NMGS tagged Itakpe NMGS-AICE 2003.

Rahaman, M. A. (1988): Recent advances in the study of the Basement Complex of Nigeria. In: Oluyide, P. O., W. C. Mbonu, A. E. Ogezi, I. G. Egbuniwe, A. C. Ajibade, and A. C. Umeji (editors), Precambrian geology of Nigeria. Publ. GSN. 11 – 41.

Taylor, S. R. (1964): Abundance of chemical elements in the continental crust: a new table Geochtm. Cosrriochim. Acta 28, 1273-1285. A critical compilation and evaluation of the large amount of recent data on minor and trace elements in granites and basalts.
doi: 10.1016/0016-7037(64)90129-2