

Classification, Tectonic Setting, and Mineralization Potential of Ayetoro and Sasaro Syenitic Plutons in Igarra Schist Belt, Southwestern Nigeria

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Abstract

Petrographic and geochemical studies of syenite-looking Ayetoro and Sasaro plutons within Igarra Schist Belt were carried out in order to classify them and determine their tectonic setting and mineralization potential. Petrographic study and geochemical classification revealed that while Ayetoro boss is microgranite constituting an aggregate of medium grained muscovite, quartz and biotite minerals, Sasaro stock is micromonzonite made up of medium grained albite, orthoclase, biotite, hornblende and pyroxene. Geotectonic setting showed the boss and stock are orogenic, probably derived from the same upper mantle magma as Igarra batholith that got contaminated by crustal materials responsible for their difference in lithology. Their mineralization potential showed that the massive Ayetoro microgranite with no appreciable trace-element contents cannot serve as host of any metallic deposit, and should be suitable for industrial applications. Whereas, the silicified, highly sheared Sasaro monzonite, with elevated level of some trace elements contents as Ag, Au and Cu, could harbor Ag-Au-Cu deposit.

Keywords

ICP-MS, Microgranite, Micromonzonite, Orogenic, Ag-Au-Cu Deposit, Igarra Schist Belt

1. Introduction

Igarra Schist Belt is one of the twelve main Schist Belts that have been recognized in the Basement Complex of Nigeria [1]. This Schist Belt is located in the southeastern margin of the Western Nigerian Basement Complex (**Figure 1**) [2].

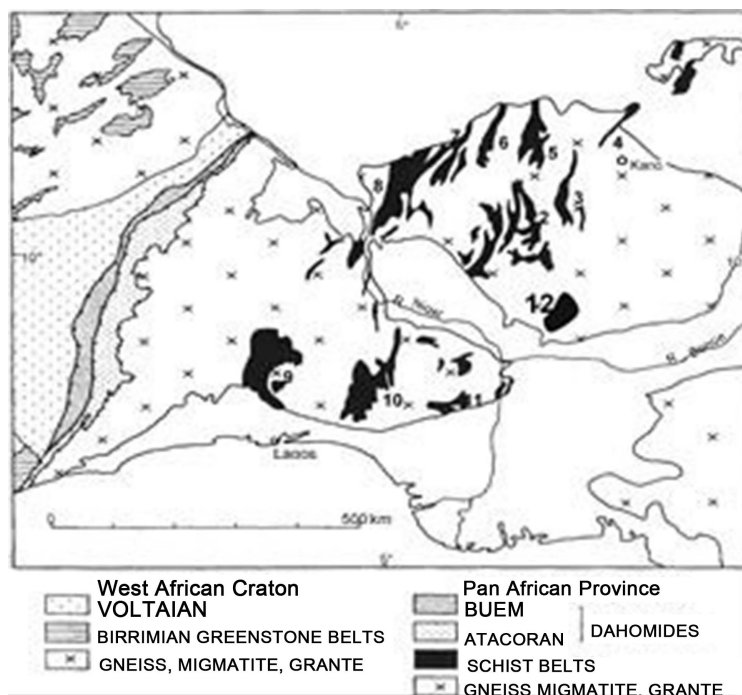


Figure 1. Nigerian Schist belt localities within the context of the regional geology of parts of West Africa after Wright [2]. 1. Zungeru-Birnin Gwari, 2. Kuseriki-Kushaka, 3. Karaukarau, 4. Kazaure, 5. Wonaka, 6. Maru, 7. Anka, 8. Zuru, 9. Iseyin-Oyan River, 10. Ilesha, 11. Igarra, and 12. Muro Hill.

The Nigerian Basement Complex forms the southern part of the Trans-Saharan mobile belt [3] of Neoproterozoic (750 - 500 Ma) age situated between the Archean-Paleoproterozoic blocks of the West African craton in the west, the Congo craton in the southeast, and the East Saharan block in the northeast (Figure 2). Igarra Schist Belt covers an area of roughly 750 km² [4], and is surrounded and underlain by the migmatite-gneiss-quartzite complex—a group of polycyclic crystalline rocks as migmatites, auto- and para-gneisses, and relict metasedimentary rocks. The Schist Belt comprises mainly of metasedimentary rocks, such as mica schist, quartz-biotite schist, quartz schist and quartzite, metaconglomerate, calc-silicate gneiss and marble [4]-[10]. The two aforementioned rock groups were intruded by members of the Older (Pan African) Granite Suite including batholiths, stocks and bosses of porphyritic granite, charnockite, syenite, and diorite. All these were cross-cut by some minor intrusives such as dykes and sills of microgranite, syenite, lamprophyre and dolerite [11] [12]. It follows, therefore, that syenite can occur in the Igarra Schist Belt as a member of Older Granite Suite and/or minor intrusive. Syenite, meanwhile, is a saturated, coarse-grained, igneous rock consisting of essential alkali feldspar and ferromagnesian minerals such as biotite, hornblende, arfvedsonite, aegirine-augite, and/or aegirine, and accessory apatite, zircon, and iron oxides. The feldspar constitutes more than 65% of the rock. The study of syenite is important not only because of scintillating knowledge its classification accord, but also because of the positive

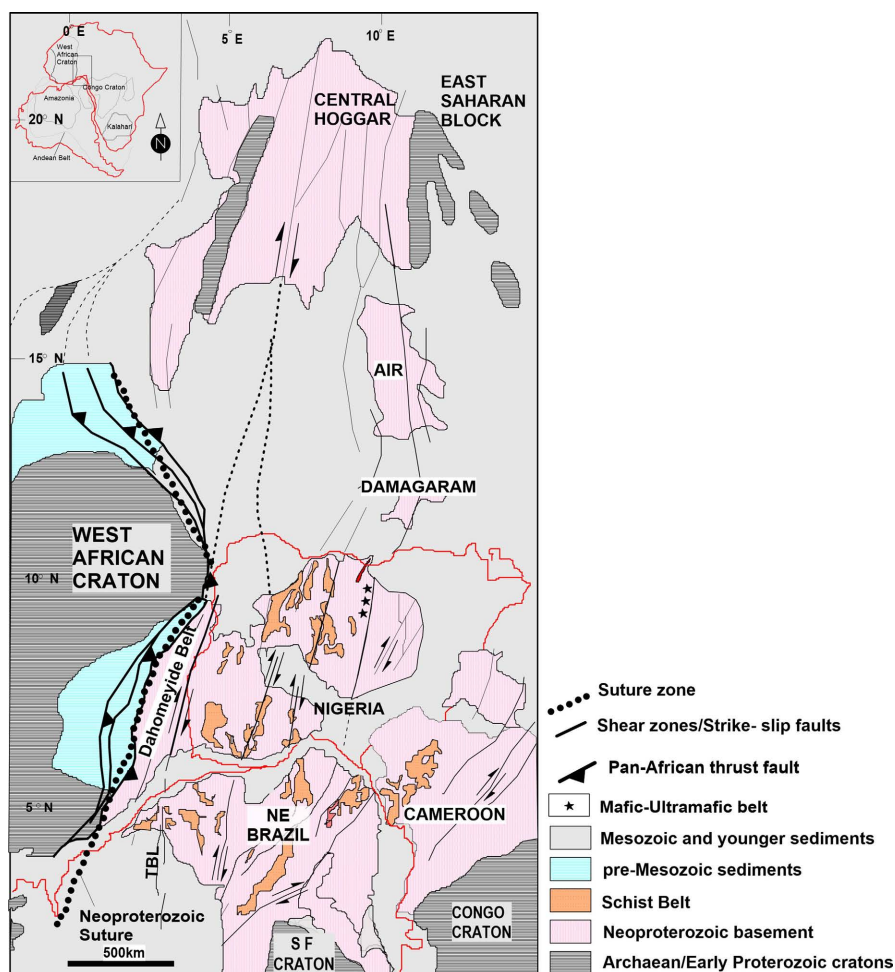


Figure 2. The Trans-Saharan Fold Belt, Nigerian Segment of the Pan-African Belt and the Brasiliano Belt in a Pre-Mesozoic Drift Reconstruction After Caby [3].

economic aspects it offers. Syenitic rocks, as used here, are syenite-like rocks, which may or may not be syenite upon further petrographic and/or geochemical inquest. The present study sets to carry out the petrographic and geochemical study of the syenitic rock bodies around Ayetoro and Sasaro within the Igarra Schist Belt, southwestern Nigeria. This is done with a view to classify the syenitic rocks, and determine their geotectonic settings and economic aspects.

2. Geological Setting

Ayetoro, Sasaro and Igarra towns are among the more densely-populated communities within the Igarra Schist Belt. Ayetoro is to the northwest and Sasaro to the southeast of Igarra town (**Figure 3**). **Figure 4** is a geological map of Igarra Schist Belt that shows the locations of Ayetoro and Sasaro plutons under study. Ayetoro granitoid intruded the quartz-biotite schist [4] [5] and occur at about 1.5 km west of Ayetoro town as a moderate platform outcrop covering an area of about 3 km². The intrusion occurs as *boss* with sub-circular outlook. It is uniformly medium grained in texture and grey in colour. It comprises essentially

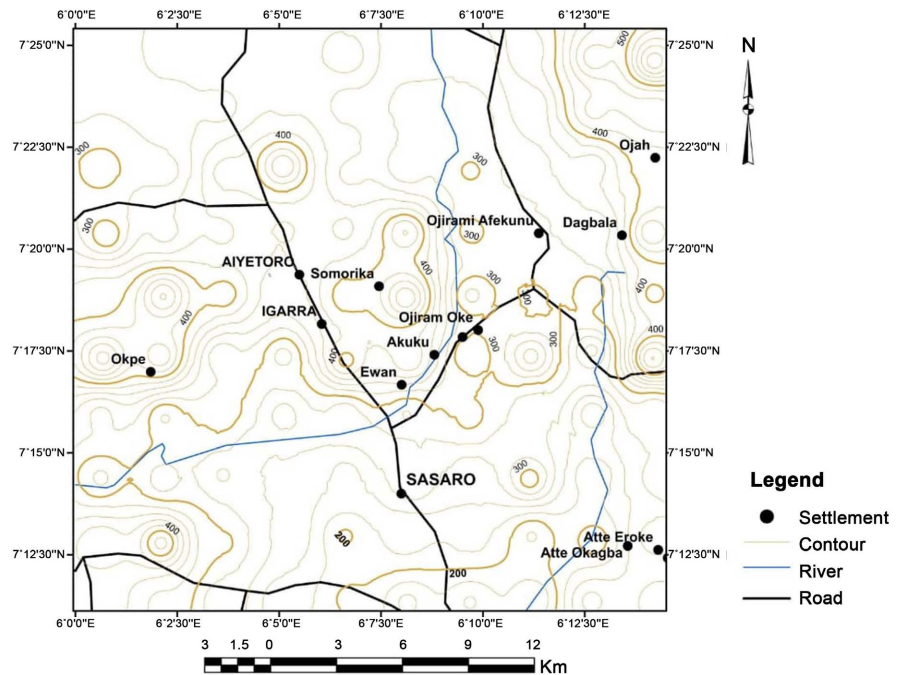


Figure 3. Topographic map of Igarra Schist Belt area.

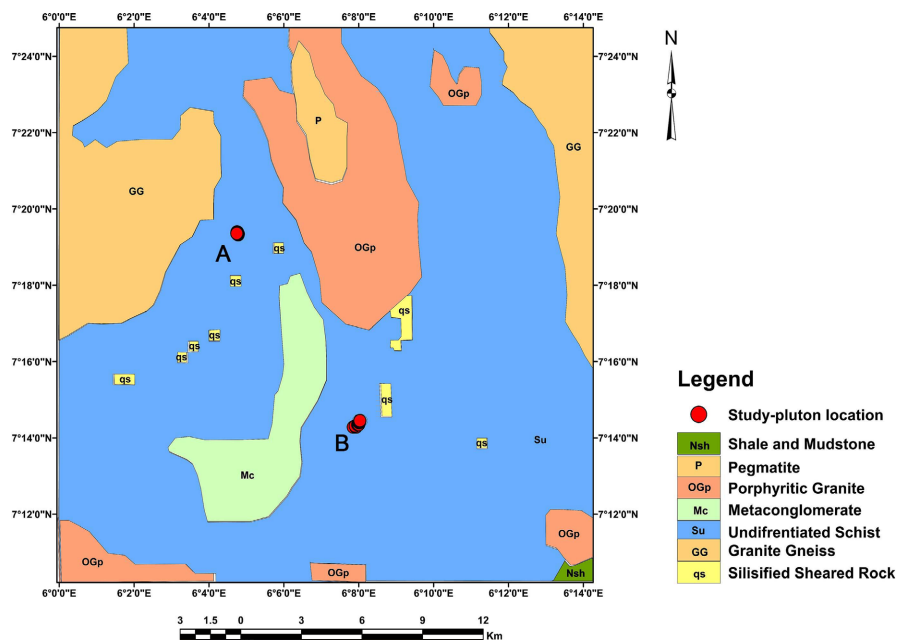


Figure 4. Geological map of Igarra Schist Belt showing the locations of Ayetoro (A) and Sasaro (B) plutons.

feldspars, and minor biotite, observable in hand specimen. The syenitic rock is massive, being devoid of foliation, folds, and fractures.

The granitoid at Sasaro intruded marble and quartz-biotite schist [4] [5] and is therefore bounded by them. The intrusion outcrop prominently as *stock* with a diameter of about 4.5 km north of Sasaro town. The stock has an adjoining dyke of the same rock that can be traced for about 1 km to the west. It is me-

dium grained, dark in colour with feldspars, amphibole and biotite as observable minerals. Sasaro syenitic rock is intensely sheared containing numerous fractures, breccias, and a few pegmatite and quartz veins.

3. Methodology

The methods employed for this study include those of geological mapping, petrographic and geochemical studies. Geological/field mapping entailed studying and sampling rock outcrops in the field. During the field mapping, the extensive rock outcrops encountered were studied for their lithology, and observable minerals, texture and structure for the purpose of determining the mode of occurrence of the plutons under study, prior to collection of samples. Petrographic study comprised preparation of thin sections of rock samples and the study of the thin sections under polarizing microscope for the purpose of classifying the rocks. Twenty thin sections made up of ten each from Ayetoro and Sasaro plutons were examined with Brunel and Meiji polarizing binocular microscopes to determine their constituent minerals. Also, textural relationships among the minerals were described, and photomicrographs of the thin sections showing microstructures/features of interest were taken. Geochemical survey entailed rock sample preparation and instrumental geochemical analysis of rocks for major, minor, and trace elements. For the preparation of rock samples for geochemical analysis, about 1 kg each of the twenty rock samples was crushed in a jaw crusher to reduce the rock sample to millimeter sizes. The crushed sample was subjected to Ball Swing pulverization in order to obtain about 200-mesh particle size. Comminution of the rock samples was carried out at the Metallurgical and Material Engineering laboratory, Federal University of Technology, Akure, Nigeria. The powdered rock sample was subjected to coning and quartering to collect representative samples of about eight grams each of 10 samples, 5 each from Ayetoro and Sasaro granitoids, which were packaged and sent to Geochemistry Laboratory of *Bureau Veritas Commodity Limited Vancouver, Canada*. At Bureau Veritas, 0.2 g each of the pulverized samples was subjected to lithium borate ($\text{LiBO}_2/\text{Li}_2\text{B}_4\text{O}_7$) fusion prior to ICP-ES analysis for major oxides and some trace elements used to further classify and unravel the tectonic setting of the rocks, while 0.5 g each subjected to modified aqua regia (1:1:1 HNO_3 , HCl , distilled H_2O) digestion before using ICP-MS to analyze for trace elements employed for the determination of their mineralization potential. Geochemical data processing employed a software package, GCD Kit in R programming language. In plotting the data, half the instrumental detection limit was substituted for any element that contains censored data below it at any site.

4. Results and Discussion

4.1. Mode of Occurrence and Petrography

As said earlier, the syenitic rock around Ayetoro occurs as a 'boss' 1.5 km west of the town, that intrudes mainly quart-biotite schist. The rock is massive, being

devoid of structures as folds and fractures; light grey in colour and dull in appearance (**Plate 1(A)**), which gave the impression that it either lacks quartz or contains it sparingly. It is medium-grained in texture and looks syenitic being thought to compose mainly feldspars and minor biotite. Under the microscope, Ayetoro granitoid comprises 70% felsic minerals and 30% ferromagnesian minerals as observed by their low and high relief, respectively, with plane polarized light (**Plate 2(A)**). With the polars crossed, the felsic minerals were found to be feldspars and quartz; while the ferromagnesian minerals constitutes predominantly biotite (**Plate 2(B)**). The feldspars are alkali with microcline, identified by grid twinning, being the most abundant (**Plate 2(B)**). Quartz was identified by undulose extinction and lack of cleavage (**Plate 2(A)** & **Plate 2(B)**), and seems to occur in the same proportion as microcline. Biotite was recognized by brown to green colour, and strong pleochroism (**Plate 2(B)**). This mineralogy of mainly microcline, quartz and biotite as well as the texture of the rock indicate that the syenite-looking granitoid of Ayetoro area is actually *microgranite*.

Sasaro granitoid occurs as 'stock' near the town where it intrudes marble and quart-biotite schist in the Igarra Schist Belt [4] [5]. The rock is dark grey in colour and highly dim in appearance (**Plate 1(B)**) indicating that it lacks in quartz. The rock shows an extensive brecciation and quartz-veining, which indicate that it is highly sheared. In hand specimen, the rock is medium-grained and contains feldspar, biotite and pyroxene. In thin section, Sasaro granitoid consists of almost 65% felsic and 35% ferromagnesian minerals as observed under the plane polarized light (**Plate 3(A)**). Under cross nicols, the felsic minerals are, essentially, feldspars, which are Na-rich plagioclase (*i.e.* albite—identified by pericline twinning) and alkali feldspar, mostly orthoclase—identified by Carlsbad twinning (**Plate 3(B)**). The ferromagnesian minerals are biotite; hornblende, which is pleochroic in shades of yellow-green to green to blue-green; and pyroxene, identified by prismatic habit and presence of at least two orthogonal set of perfect prismatic cleavage planes (**Plate 3(B)**). The texture and mineralogy of the syenitic rock in Sasaro area suggest that it is *micromonzonite*.

4.2. Geochemical Classification

Chemical bulk rock analysis has been used to further classify the syenitic rocks at Ayetoro and Sasaro as well as to unravel their tectonic settings. Concentrations of main metal oxides (*i.e.* SiO₂, Al₂O₃, Fe₂O₃, MgO, CaO, Na₂O, K₂O, TiO₂, P₂O₅, MnO and Cr₂O₃), in % and some trace elements (*i.e.*, Ba, Ni, Sr, Zr, Y, Nb, and Sc), in ppm, obtained from the bulk rock analysis are given on **Table 1** for the syenitic rock at Ayetoro. The SiO₂ content of Ayetoro granitoid ranges from 69.73% to 70.19% with an average of 69.89%, which classifies as acidic rock (**Table 1**). Also, a comparison of (Na₂O + K₂O) content, which ranges from 9.11% to 9.55% with an average of 9.33% and Al₂O₃ content that ranges from 14.31 to 14.77% with an average of 14.54% shows that for Ayetoro syenitic rock the (Na₂O + K₂O) content is generally less than the Al₂O₃ content (**Table 1**). This has further classified it to subalkaline rock with (Na₂O + K₂O) < Al₂O₃. This

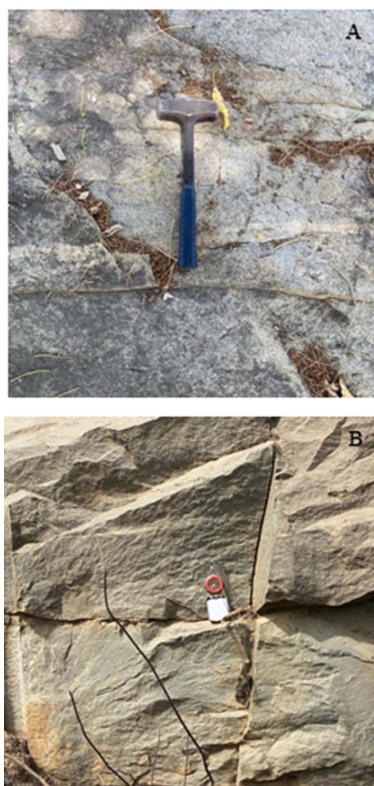


Plate 1. Outcrops of (A) Ayetoro and (B) Sasaro Granitoids within Igarra Schist Belt.

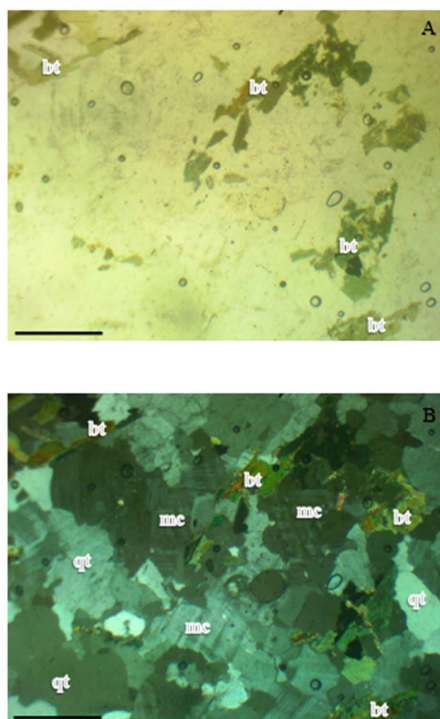


Plate 2. Photomicrograph of Ayetoro Granitoid Comprising Microcline (mc), Quartz (qt) and Biotite (bt). Bar Scale: 2 μ m (A ppl, B xpl).

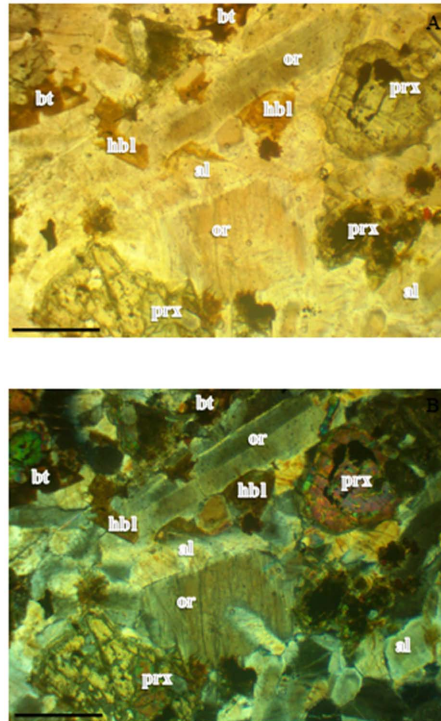


Plate 3. Photomicrograph of Sasaro Granitoid Comprising Orthoclase (or), Albite (al), Biotite (bt), hornblende (hbl), and Pyroxene (prx). Bar Scale: 2 μm (A ppl, B xpl).

Table 1. Concentrations of Major-element oxides and some minor elements in Ayetoro Granitoids.

	ATR1	ATR2	ATR3	ATR4	ATR5	AVERAGE
SiO ₂ (%)	69.73	70.19	69.75	70.05	69.73	69.89
Al ₂ O ₃ (%)	14.71	14.77	14.53	14.31	14.39	14.54
Fe ₂ O ₃ (%)	2.44	2.42	2.65	3.14	3.34	2080
MgO (%)	0.90	0.84	0.93	0.75	0.83	0.85
CaO (%)	1.51	1.47	1.68	1.43	1.50	1.52
Na ₂ O (%)	3.91	4.03	3.91	3.99	3.98	3.96
K ₂ O (%)	5.64	5.37	5.43	5.27	5.13	5.37
TiO ₂ (%)	0.22	0.19	0.20	0.19	0.19	0.20
P ₂ O ₅ (%)	0.14	0.13	0.14	0.13	0.14	0.14
MnO (%)	0.05	0.05	0.05	0.05	0.05	0.05
Cr ₂ O ₃ (%)	0.009	0.12	0.11	0.006	0.005	0.05
LOI (%)	0.4	0.2	0.4	0.4	0.4	0.4
TOTAL	99.89	99.90	99.95	99.93	99.93	99.92
Ba (ppm)	1550	1364	1515	1376	1342	1429
Ni (ppm)	<20	<20	<20	<20	<20	-

Continued

Sr (ppm)	589	533	612	565	542	568
Zr (ppm)	149	156	152	145	141	147
Y (ppm)	17	13	13	12	11	13
Nb (ppm)	13	10	16	11	14	13
Sc (ppm)	4	4	4	4	4	4

subalkaline magma series can be further subdivided to K-rich (high K-type) calc-alkaline magma series considering the fact that K₂O content, which ranges from 5.13% to 5.64% with an average of 5.37% is higher than Na₂O content, which ranges from 3.91% to 4.03% with an average of 3.96% (Table 1). The TAS (total alkali versus silica) diagram of plutonic rocks after Middlemost [13] is a diagram routinely used to classify such plutonic rocks and has been employed here (Figure 5). The diagram reveals that all the five samples from Ayetoro granitoids plot in the field of granite. This has confirmed the classification from petrography, which indicated that Ayetoro granitoid is medium-grained granite (microgranite).

Table 2 gives the bulk contents of main oxides in % and some trace elements in ppm, for Sasaro syenitic rock. In its own case, SiO₂ content, which ranges from 53.95% to 55.71% with an average of 54.76 (Table 2), classifies the rock as intermediate. Also, when compared the (Na₂O + K₂O) content, which ranges from 8.37% to 9.34% with an average of 8.93% with Al₂O₃ content that ranges from 11.89% to 12.53% with an average of 12.31%, the (Na₂O + K₂O) content of Sasaro granitoid is also less than its Al₂O₃ content (Table 2). This further classifies the rock as subalkaline magmatic rock, which can be further subdivided to K-rich (high K-type) calc-alkaline magma series. This being that the K₂O content of the rock, which ranges from 6.16% to 6.95% with an average of 6.66% is higher than Na₂O content, which ranges from 2.20% to 2.39% with an average of 2.27% (Table 2). The TAS diagram of Middlemost [13] shows all the five samples from Sasaro rock plot in the field of Monzonite (Figure 6). This result from geochemical classification of the Sasaro plutonic rock has further buttressed that of the petrographic classification, which showed it to be monzonite (micromonzonite).

4.3. Geotectonic Setting

Major- and trace-element discrimination plots have been used to infer the tectonic conditions present at the locations of Ayetoro granite and Sasaro monzonite. That is, whether the places are near a tectonic plate boundary or in a more interior position on the plate.

The R1, *i.e.* $[4\text{Si} - 11(\text{Na} + \text{K}) - 2(\text{Fe} + \text{Ti})]$, versus R2, *i.e.* $[6\text{Ca} + 2\text{Mg} + \text{Al}]$, plot of Batchelor and Bowden [14] for Ayetoro granite (Figure 7(A)) shows it to be orogenic granite as all its samples plot in the field of late orogenic granites. The trace element geotectonic discrimination Y versus Nb diagram (Figure 7(B))

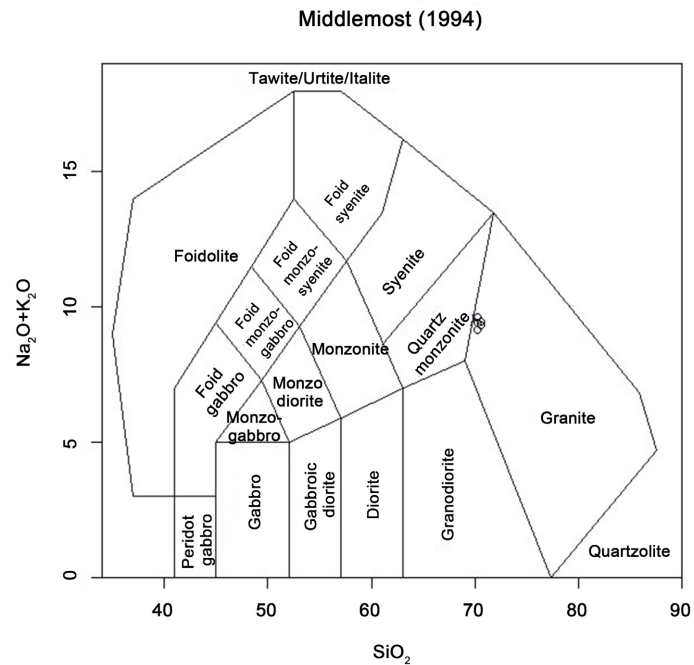


Figure 5. TAS (total alkali versus silica) diagram according to Middlemost [13] for Ayetoro plutonic rock.

Table 2. Concentrations of major-element oxides and some minor elements in Sasaro Granitoids.

	SSR1	SSR2	SSR3	SSR4	SSR5	AVERAGE
SiO ₂ (%)	53.95	55.71	54.60	55.03	54.53	54.76
Al ₂ O ₃ (%)	11.89	12.50	12.44	12.53	12.17	12.31
Fe ₂ O ₃ (%)	9.02	7.50	8.68	7.76	7.97	8.19
MgO (%)	6.83	6.22	5.80	6.26	6.93	6.41
CaO (%)	6.47	5.53	5.29	5.91	6.32	5.90
Na ₂ O (%)	2.21	2.29	2.39	2.25	2.20	2.27
K ₂ O (%)	6.16	6.62	6.95	6.78	6.78	6.66
TiO ₂ (%)	0.70	0.78	0.77	0.73	0.72	0.74
P ₂ O ₅ (%)	1.21	1.18	1.06	1.14	1.24	1.17
MnO (%)	0.13	0.11	0.12	0.12	0.13	0.12
Cr ₂ O ₃ (%)	0.027	0.034	0.027	0.025	0.031	0.029
Ba (ppm)	2912	3124	2711	2893	3201	2968
Ni (ppm)	53	54	47	49	57	52
Sr (ppm)	923	971	755	927	935	902
Zr (ppm)	163	161	194	174	101	159
Y (ppm)	20	18	18	20	20	19
Nb (ppm)	12	11	13	10	20	13
Sc (ppm)	22	18	19	20	21	20
LOI (%)	0.7	0.9	1.2	0.8	0.3	0.8
TOTAL	99.81	99.82	99.78	99.78	99.79	99.80

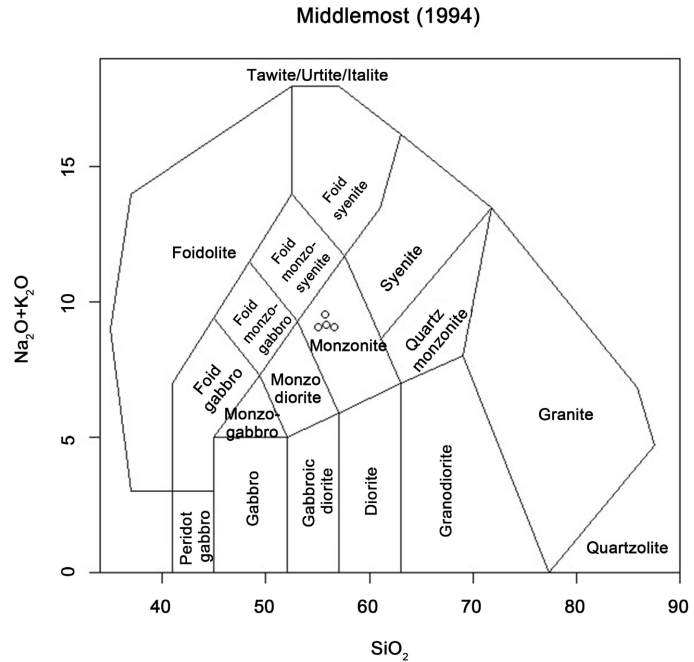


Figure 6. TAS (total alkali versus silica) diagram according to Middlemost [13] for Sasaro plutonic rock.

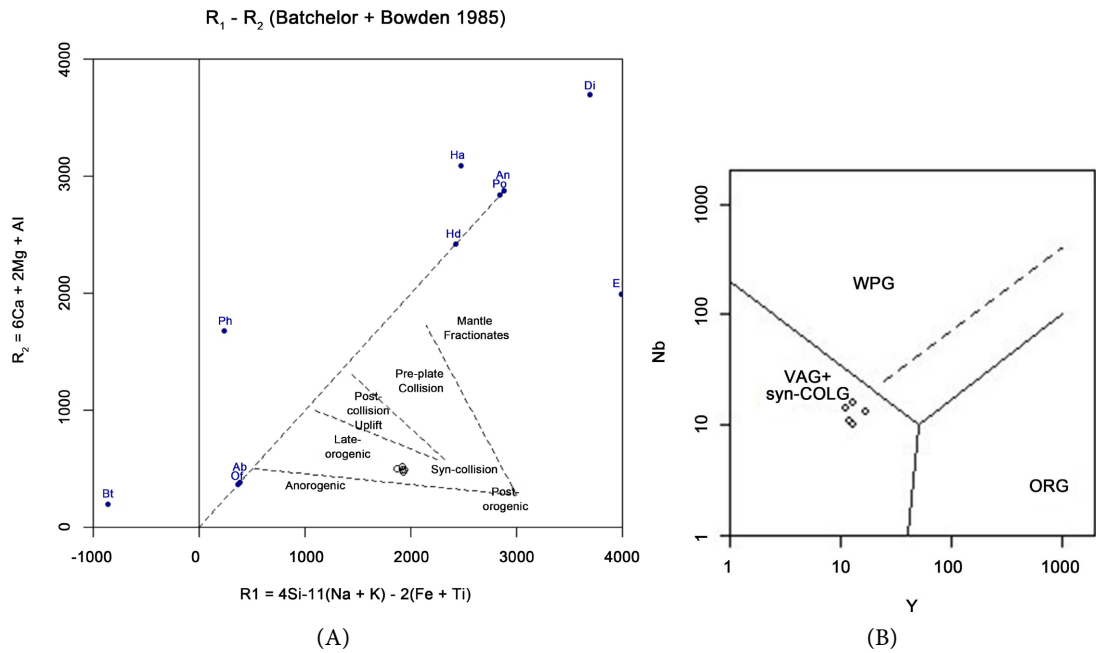


Figure 7. (A) Geotectonic discrimination R_1 - R_2 plot after Batchelor and Bowden, (1985) for Ayetoro granite. (B) Trace element geotectonic discrimination Y-Nb plot after Pearce *et al.* (1977), Nb versus Y. (Symbols: ORG, ocean ridge granitoids; VAG, volcanic arc granitoids; Syn-COLG, syn-collisional granitoids; WPG, within-plate granitoids; post-COLG, the post-collisional granitoids).

after Pearce *et al.* [15] revealed the Ayetoro granite to be volcanic arc or syn-collisional. The major elements granite tectonic discrimination plots of Maniar and Piccoli [16] are given in Figure 8 for Ayetoro granite. The SiO_2 versus FeOt

/(FeOt + MgO) plot (**Figure 8(A)**), M/AFM, *i.e.* $[\text{MgO}/(\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 + \text{MgO})]$, versus F/AFM, *i.e.* $[\text{Fe}_2\text{O}_3/(\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 + \text{MgO})]$, plot (**Figure 8(B)**) and C/ACF, *i.e.* $[\text{CaO}/(\text{Al}_2\text{O}_3 + \text{CaO} + \text{Fe}_2\text{O}_3)]$, versus F/ACF, *i.e.* $[\text{Fe}_2\text{O}_3/(\text{Al}_2\text{O}_3 + \text{CaO} + \text{Fe}_2\text{O}_3)]$, plot (**Figure 8(C)**) show that Ayetoro granite formed from post orogenic granitoid magma, which intruded the sedimentary succession of Igarra Schist Belt in an island arc, continental arc, or continental collision environment. The A/NK, *i.e.* $[\text{Al}_2\text{O}_3/(\text{Na}_2\text{O} + \text{K}_2\text{O})]$, versus A/CNK, *i.e.* $[\text{Al}_2\text{O}_3/(\text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O})]$, plot (**Figure 8(D)**) shows that Ayetoro granite is a metaluminous igneous rock.

The F/ACF, *i.e.* $[\text{Fe}_2\text{O}_3/(\text{Al}_2\text{O}_3 + \text{CaO} + \text{Fe}_2\text{O}_3)]$, versus C/ACF, *i.e.* $[\text{CaO}/(\text{Al}_2\text{O}_3 + \text{CaO} + \text{Fe}_2\text{O}_3)]$, plot of Maniar and Piccoli [16] for Sasaro monzonite (**Figure 9(A)**) shows it to be orogenic as they mostly plot in post orogenic magma zone. The M/AFM, *i.e.* $[\text{MgO}/(\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 + \text{MgO})]$, versus C/AFM, *i.e.* $[\text{CaO}/(\text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3 + \text{MgO})]$, plot, also of Maniar and Piccoli [16] shows that Sasaro monzonite formed in either an island arc, continental arc or continental collision environment (**Figure 9(B)**). Also, the A/NK, *i.e.* $[\text{Al}_2\text{O}_3/(\text{Na}_2\text{O} + \text{K}_2\text{O})]$, versus A/CNK, *i.e.* $[\text{Al}_2\text{O}_3/(\text{CaO} + \text{Na}_2\text{O} + \text{K}_2\text{O})]$, plot of Maniar and Piccoli [16] for Sasaro monzonite (**Figure 9(C)**) shows it to be metaluminous igneous rock like Ayetoto granite. The FeO_t -MgO- Al_2O_3 ternary plot of Pearce *et al.* [15] restricts Sasaro monzonite to an island arc environment as all its samples plot in the field of oceanic ridge or floor (**Figure 9(D)**), which is in agreement with the presence of marble among the metasedimentary successions intruded by Sasaro monzonite.

The main take from this geotectonic study is that Ayetoro boss and Sasaro stock are orogenic quite like Igarra batholith, which is believed to be equally pre-, syn- and post-tectonic rocks [11] [17]; and could have been formed by the same magma. The difference in composition among the varieties of Older Granite suites on one hand, and between Ayetoro microgranite and Sasaro monzonite, on the other, could be in the type of crustal rock digested. While Ayetoro microgranite intruded mainly biotite schist, Sasaro monzonite intruded marble mainly and, probably, could have been altered by it.

4.4. Mineralization Potential

The mineralization potential of the plutonic rocks at Ayetoro and Sasaro have been discussed on the bases of their structural disposition and trace element contents, in ppm, from the partial rock analysis. The structural disposition enables the knowledge of whether features and structures that enhance the permeability of the rocks for hydrothermal-fluid flow are present or not. Whereas, the trace-element contents of the rocks give an indication of whether there has been some initial metal mineralization in them.

Ayetoro granite is massive and seems devoid of features and structures that can serve as passageways for hydrothermal fluids and loci to precipitate metallic minerals from them. Concentrations of partially extracted trace elements using aqua regia digestion in Ayetoro microgranite (**Table 3**) shows that Au, Bi, Cd

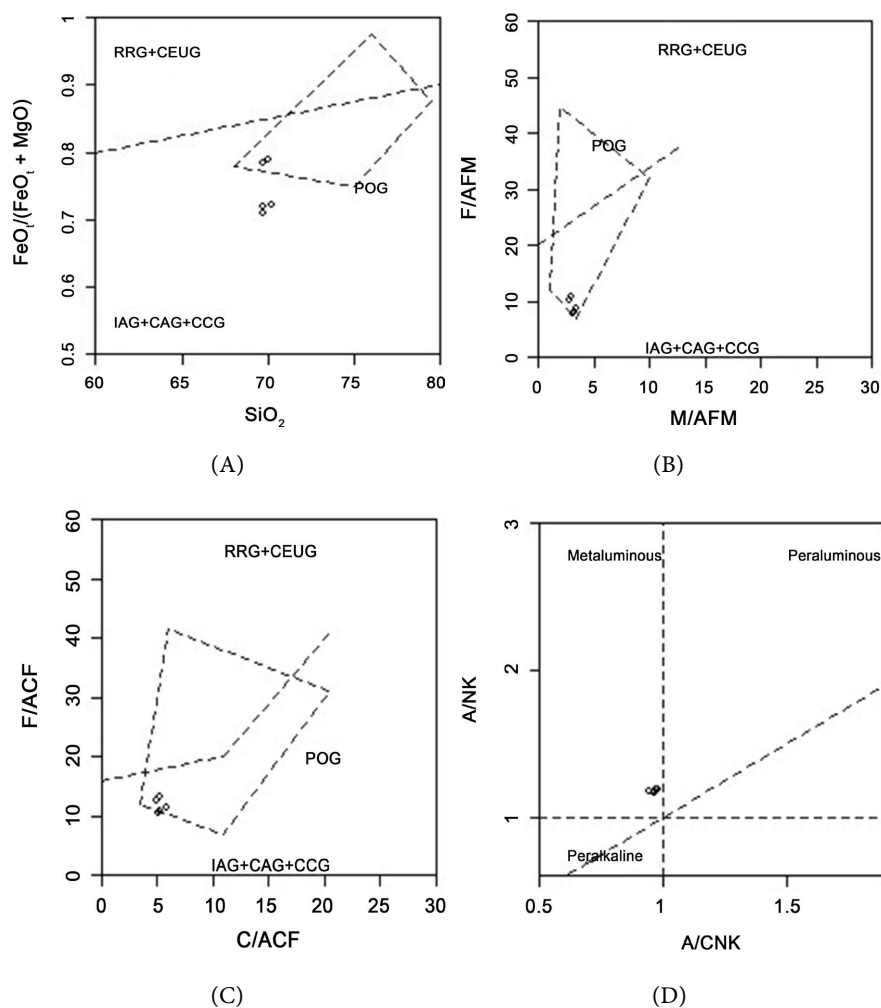


Figure 8. Major element tectonic discrimination plots for Ayetoro granite after Maniar and Piccolli [16]. A. SiO_2 versus $\text{FeO}/(\text{FeO} + \text{MgO})$, (B) M/AFM versus F/AFM , (C) C/ACF versus F/ACF , (D) A/ANK versus A/CNK . (Symbols: IAG— island arc granites, CAG—continental arc granites, CCG—continental collision granites, POG—post-orogenic granites, CEUG—continent-epirogenic uplift granite, RRG—rift related granites).

and W are sparsely distributed, being mostly present below their detection limits in analytical equipment employed. Whereas, others like Ag, As, Co, Cu, Mo, Pb, Ba, Sb, Sr, Th, Tl, U, V, and Zn have low distribution because their average concentrations in Ayetoro microgranite (*i.e.* 20, 0.7, 3.5, 10.69, 1.17, 23.89, 49.6, 0.10, 19.8, 11, 0.24, 2.1, 17 and 22.2, respectively) are less than or comparable to their average abundance in felsic rock (Table 3) after Taylor [18]. These sparse and low distribution of trace elements do not amount to anything in terms of mineralization of Ayetoro granite. The economic aspect of this massive microgranite body, with no sign of mineralization of any metal, is that it can be employed as an industrial rock. There is therefore a need to determine its strength for application in construction industry.

On the other hand, Sasaro monzonite is highly sheared, heavily brecciated, and contains a few quartz and quartzo-feldspathic veins. This plutonic body,

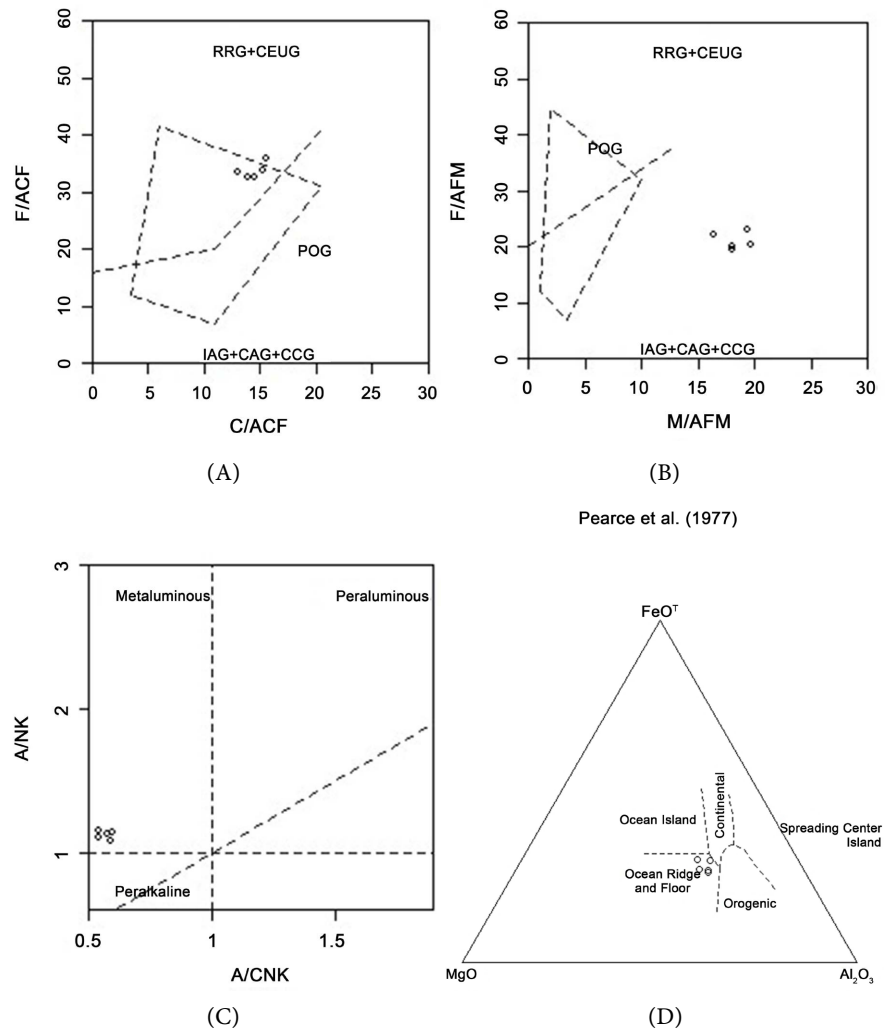


Figure 9. (A, B, C) Major element tectonic discrimination plots after Manir and Picolli [16], [(A) C/ACF versus F/ACF, (B) M/AFM versus F/AFM, (C) A/CNK versus ANK. (Symbols: IAG— island arc granites, CAG—continental arc granites, CCG—continental collision granites, POG—post-orogenic granites, CEUG—continent-epirogenic uplift granite, RRG—rift related granites)]; and (D) Ternary FeO-T-MgO-Al₂O₃ plot after Pearce *et al.*, [15] for Sasaro monzonite.

therefore, does not only contain required spaces suitable to serve as passageways and loci for hydrothermal fluids to traverse and deposit its metal load, but also evidences that hydrothermal fluids have traversed it. All the 18 partially extracted trace elements, *i.e.* Ag, As, Au, Bi, Cd, Co, Cu, Mo, Pb, Ba, Sb, Sr, Th, Tl, U, V, W and Zn, considered for this study are widely distributed in Sasaro monzonite because they are present at detectable levels, above the minimum detection limits of the ICP-MS (Table 4). The average concentrations of Mo, Cu, Ag, Co, Au, Bi and Tl are much higher at 1.62, 87.17, 63, 16.5, 1.5, 0.26 and 0.6 ppm, respectively in the rock as compared to their average abundances in intermediate rocks, which are respectively 0.9, 35, 7, 10, 0.5, 80, and 0.5 [18]. This indicates possible mineralization of Ag, Au, Cu and Mo in Sasaro Syenite. The

Table 3. Concentrations of Trace elements in Ayetoro Granitoids.

	ATR1	ATR2	ATR3	ATR4	ATR5	AVERAGE	AV FSR
Mo	0.89	1.12	2.06	0.95	0.82	1.17	1.0
Cu	8.02	8.15	11.67	17.00	8.61	10.69	20
Pb	23.00	23.81	24.38	27.16	21.09	23.89	20
Zn	23.8	17.4	20.0	26.4	23.3	22.2	60
Ag	6	13	37	25	19	20	0.05
Co	3.5	2.7	3.6	3.9	3.6	3.5	5
As	0.4	0.3	0.6	1.7	0.6	0.7	1.5
Au	<0.2	<0.2	<0.2	<0.2	<0.2	-	5
U	2.6	1.4	2.2	2.3	2.0	2.1	3.5
Th	13.7	9.7	12.5	8.8	10.4	11.0	1.8
Sr	9.6	7.5	18.1	37.5	26.4	19.8	300
Cd	<0.01	<0.01	0.01	<0.01	<0.01	-	0.1
Sb	0.05	0.06	0.10	0.25	0.05	0.10	0.26
Bi	<0.02	<0.02	0.03	0.08	0.02	-	0.01
V	17	13	16	20	19	17	40
Ba	29.1	17.3	23.3	112.3	66.2	49.6	830
W	<0.1	<0.1	0.1	0.1	0.2	-	1.5
Tl	0.28	0.16	0.19	0.28	0.28	0.24	1.5

Element Concentration in ppm. Ag & Au in ppb.

Table 4. Concentrations of Trace elements in Sasaro Granitoids.

	SSR1	SSR2	SSR3	SSR4	SSR5	AVERAGE	AV IMR
Mo	1.69	1.72	2.18	0.92	1.61	1.62	0.9
Cu	55.08	97.83	122.45	43.22	117.26	87.17	35
Pb	5.44	1.68	15.08	2.70	2.93	5.57	15
Zn	43.6	45.8	45.1	32.0	35.9	40.5	72
Ag	45	103	62	29	77	63	7
Co	18.2	19.1	16.1	12.4	16.6	16.5	10
As	0.8	0.8	1.4	1.6	1.1	1.1	2.4
Au	1.3	2.4	2.0	0.5	1.3	1.5	0.5
U	0.7	0.7	0.8	0.7	0.6	0.7	1.8
Th	2.0	2.3	3.9	3.6	2.1	2.8	7.0
Sr	68.7	76.9	150.6	49.2	70.6	83.2	800
Cd	0.03	0.01	0.02	0.01	0.03	0.02	0.09
Sb	0.05	0.06	0.06	0.05	0.07	0.06	0.2
Bi	0.04	0.11	0.06	0.03	1.04	0.26	0.01

Continued

V	82	97	85	72	87	85	100
Ba	317.4	387.5	268.9	67.5	385.1	285.3	650
W	0.5	0.3	0.3	0.2	0.2	0.3	1.0
Tl	0.65	0.68	0.64	0.55	0.55	0.61	0.5

Element Concentration in ppm. Ag & Au in ppb.

average contents of other trace elements as As, Cd, Pb, Ba, Sb, Sr, Th, U, V, W and Zn in Sasaro monzonite is far less than their average abundance in intermediate rocks after Taylor [18]. Consequently, the economic aspects of Sasaro monzonite is possible presence of Au, Ag, Cu, etc. minerals in it, which warrants more detail exploration study.

5. Summary and Conclusions

Ayetoro boss and Sasaro stock intruded Igarra Schist Belt some distance away from the batholith of the Older Granite popularly referred to as the Igarra porphyritic granite. They were thought to be syenitic because of lack of observable quart mineral in them from field observation.

Detail petrographic study revealed the Ayetoro granitoid is microgranite for being medium-grained and consisted mainly of microcline and quartz with minor biotite. Sasaro syenitic rock is also medium-grained and was found to be monzonite (syenodiorite) being made up of orthoclase, albite, pyroxene, hornblende and biotite. The geochemical classification model used confirmed this as it classified Ayetoro and Sasaro granitoids as granite and monzonite, respectively. It was established from the geotectonic setting that the two could have been formed from the same magma that formed the Older Granite at Igarra and that the difference in lithology observed might be due to the type of the crustal rock digested. On the basis of mineralization potential, it was seen that the massive Ayetoro boss is devoid of features and structures that can make it amenable to metallic mineralization and that its trace element contents do not show any sign of the presence of economic metallic minerals in it. On the other hand, the Sasaro stock is highly sheared with quartz and quarto-felspathic veins and also comprises elevated levels of trace elements contents that suggest it could harbor Ag-Au-Cu minerals

Further work is, therefore, needed to determine the industrial application that the Ayetoro microgranite can be best suited, and unravel whether the Sasaro monzonite can constitute Ag-Au-Cu deposits.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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