Petrographic Study and Rock Quality Assessment of Some Selected Granitoids of the Kongo area, Upper East Region-Ghana

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Abstract

The suitability of rocks as both construction materials and as sites for construction are heavily dependent on their geological and geotechnical characteristics. Though the Kongo area in Northeastern Ghana is enriched with rocks that can be utilized for engineering activities, details of the qualities of the various distinctive granitic rocks still require further evaluation. This study focused mainly on the petrographic mapping of the area coupled with an examination of the geotechnical characteristics of these rocks to ascertain the suitable engineering applications of the rocks. Sixteen rock samples were collected from the area for petrographic analysis. These samples were then tested for density, abrasive resistance, and porosity. The Pycnometer and Los Angeles Abrasion test methods were adopted to respectively estimate rock density and abrasive resistance. Porosity was measured as a percentage of the ratio of the difference in the soaked and dry weight to the dry weight, whereas wearing percentage was estimated as the abrasive value. The identified granitoids included porphyritic granitoid, Tonalitic rocks, Muscovite-Biotite granitoid and quartz-plagioclase porphyry, as they were studied to be granodioritic in character rather than true granite. The study revealed that, the granitoids were well fractured with joints and faults. Some of the granitoids had low porosity and abrasion resistance, making them suitable for certain engineering works. However, these were restricted in quality by their low densities.

Keywords — *Birimian, Bole-Nangodi, Kongo, Pycnometer, Los Angeles Abrasion Test*

I. INTRODUCTION

The Birimian or Baoulé Mossi domain is the Paleoproterozoic nucleus which was shaped between 2250 to 1980 Ma and is circumscribed to the Archean domain at the north and eastern parts. According to Feybesse et al. [1], the major underlying rocks within the Paleoproterozoic Baoulé Mossi domain are of volcanic, volcano-sedimentary and sedimentary sequences parted by tonalite-trondhjemite-granodiorite (TTG) and granite provinces. These are characterized by typical Archean-like greenstone granitoid assemblages [2].

The Kongo area falls within the Bole-Nangodi belt which is part of the Birimian supracrustal rocks of Ghana. These terranes are composed mainly of metavolcanic and metasedimentary rocks intruded by granitoids of varying ages in Ghana [3]. These rocks are more commonly associated with gold mining activities which are carried out in these areas. However, a significant portion of these areas are covered byintrusive granitic rocks. Granitic rocks can be of varied use in the construction sector. It may be used as building stones or for road construction. Before this is done, there is a requirement to evaluate the engineering characteristics of these rocks. Though there is a wide outcrop of granitoids in the Kongo area, these resources have been given very little attention in their utilization as constructional materials. Exceptfor a few small-sized quarries, the potentialsof these rocks remain untapped. Also, the construction sector is growing rapidly and there is the need for quality and innovative materials to enhance the longevity, strength, and durability of constructs [4]. This work, therefore, seeks to evaluate the engineering characteristic of the rocks within the area to determine their suitability for constructional purposes.

II. METHODOLOGY

A. Profile of the Area of Study

The study area is located within the Nabdam area which lies within latitude 10^o 47'N and longitude 00^o 51'W, along the north-eastern part of the Upper East Region, Ghana. It has Zebilla as its administrative capital and covers a total landmass of about 1275km^2. The study area lies about a kilometer from the district capital. It is bordered to the north with Burkina Faso, and the south,west,and east with the Talensi, Bawku west districts, and Bolgatanga municipalityrespectively. The topography of the area is generally dominated by relatively undulating lowlands, gentle slopes with some isolated rock outcrops and upland slopes, with some extending up to 12m above sea level. The climate of the area is tropical with two distinct seasons (dry and wet seasons). The study area has a generally high temperature ranging between 33°C and 42°C [5].

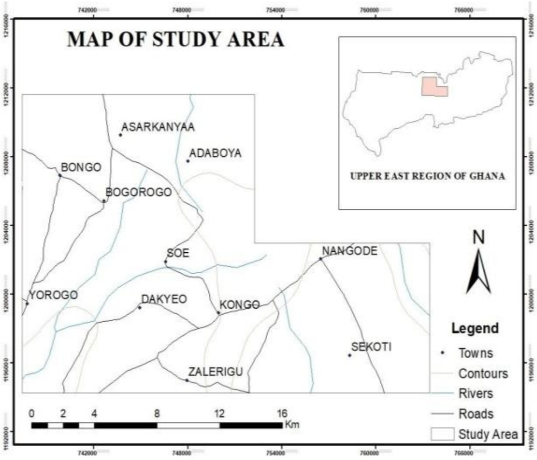

Figure 1. Map of the Study Area

B. Local Geology

The Kongo area is located inthe north-eastern part of the Paleoproterozoic Bole-Nangodi greenstone belt. According to Murray [6], the rocks in the area comprise of metabasalts, phyllites, granodiorites, muscovite-biotite granite, biotite gneiss, chlorite schist, chlorite epidote schist, and porphyritic granite, hornblende granodiorite, tonalite, and granodiorite gneisses, dioritic and granodioritic gneisses. Most of these rocks show either schistose or gneissic fabric and appear sheared [7]. The Independent Geologists' group [8], detailed that the Bole-Nangodi belt is intensely folded with at least two phases of deformation (D1 and D2), which are regarded as a series of refolded folds. The fold axis of D1 trend NNE-SSW and practices a series of tight isoclinal folds with the D2 fold axis trending WNW-ESE. This can be seen in outcropping cherty sediments within the belt as clear pencil cleavage formed by an intersection of two cleavage planes which have been mapped as refolded folds at the western flanks of the belt.

C. Resources and Methods Used

a). Petrography Test and Modal Percentages

Thin sections were prepared from the rock specimens to permit the identification of constituent minerals, microstructural features, and textures of the fabric elements using an optical cross-polarizing microscope. Modal percentages of the minerals under thin sections were also estimated using the point count method. To assess the quality of the rock samples, the Los Angeles Abrasion Test using the Los Angeles machine was adopted.

b). Rock Porosity, Apparent Density, and Weighed Average Apparent Density

Rock Porosity, and Apparent Density (AD) were respectively determined using the Direct Saturation Weight Method as recommended by Brun et al. [9] and the PycnometerMethod. Apparent Density was calculated using the relation:

$$AD = [g * c]/[(e-a)-(d-b)] \text{..........}(1)$$

Meanwhile, Weighted Average Apparent Density (WAAD) was measured using the equation:

$$WAAD = [\sum c * h]/\sum c \text{.............}(2)$$

Where a=mass of Pycnometer + lid (in grams), b=mass of Pycnometer + lid + dry crushed sample (in grams), c=mass of dry crushed sample (b-a), d=mass of Pycnometer + lid + dry crushed sample +water (in grams), e=mass of Pycnometer + lid + water (in grams), g=density of water at test temperature (in kg/m^3) and h=Apparent density.

III. RESULTS AND DISCUSSION

A. Petrographical Mapping

The study revealed that rocks within the study area fell within the Birimian group of rocks in Ghana. These rocks are meta-volcanics and meta-sediments which are intruded by granitic rocks of various generations. Mapping these granitoids showed alterations and jointing which were generally massive, compact and appeared to be weakly weathered, as slight foliations at mesoscale and weak deformations were observed. Quartz and pegmatite veins were evident in some outcrops with an average thickness of about 4cm. Fig. 2 shows the various granitoids in the study area at an outcrop scale.

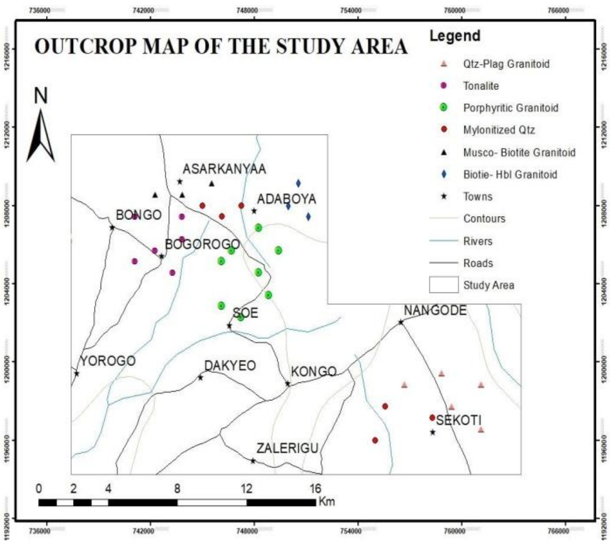

Figure 2.Outcrop Map

a). *Porphyritic Granitoid*

The porphyritic granitoids were identified mainly within the Adaboya Township. These bordered to the north-east with the Bongo-Soe Muscovite-Biotite granitoid and extended towards the western and southern parts of the Adaboya community. Towards the NNW, some thinly-foliated phyllites (striking NESW) contacted these granitoids at Kanaba community. These were generally light to pink colored, slightly deformed and showed quartz stretches. The porphyritic granitoids were linked to the main fault running through the area, where they intersected the rocks at Adaboya and Asarkanyaa to the east. The porphyritic granitoids were studied to be compact and jointed with undeveloped pegmatite veining of an average thickness of 3cm (Fig. 3).

Two sets of orthogonal systematic joints and three sets of conjugate systematic joints were developed in most of the outcrops with general trends of 305^o, 4^o, and 140^o, 302^o, 160^o respectively. The joints trended mostly in the NW-SE direction with subordinate trends similar to the general NE-SW direction of rocks in the terrane (Fig. 4). The majority of the outcrops showed rectangular phenocrysts of plagioclase with apparent irregular edges, with some being rounded (Fig. 5). The phenocrysts were dominantly K-feldspar which measured up to 2cm by 3.2cm. Towards the SSN direction, the phenocrysts of the plagioclase appeared to be larger with developed joints. In hand sample, quartz, plagioclase, and biotite were visible.

The granitoids bordered to the north with the Asarkanyaa Biotite-Hornblende granitoids which were studied to be coarse-grained and mainly jointed systematically. Three joint sets were observed. These were orthogonal with trends extending up to 325^o, 245^o and 60^o with quartz and developedpegmatite veins. In some exposures, the rocks showed dextral faulting trending towards 248^oSW. Foliations were also visible within some outcrops. Biotite and Hornblende were aligned mostly with dip 78^o and trend 220^o. From the north of Adaboya, before the Biotite-Hornblende granitoids were observed at Asarkanyaa, deformed and massive mylonitic quartz with joints (trend NW) were detected.

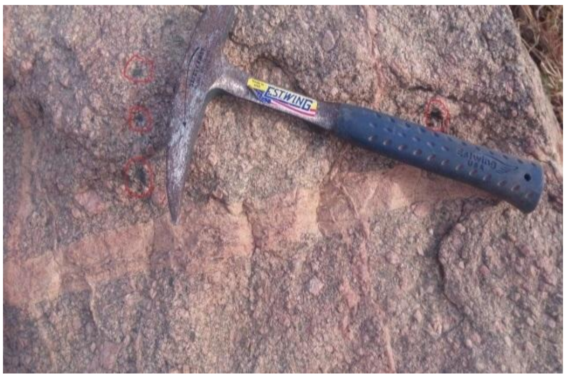

Figure 3.Porphyritic Granitoid of a Pegmatite Vein and Mafic inclusion

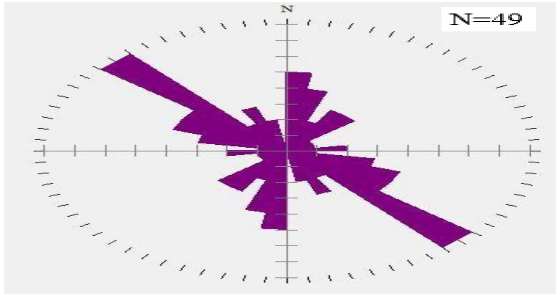

Figure 4.Rose Diagram of Joints Developed in the Outcrops

Figure 5.Outcrop of Porphyritic Granitoid

The porphyritic granitoids were petrographically made up of Biotite (1%), Quartz (35%), Microcline (30%), Muscovite (15%), Plagioclase (18%) and an Opaque mineral (1%). The rocks were dominantly quartz and microcline with minor biotite altered to a moderate percentage of muscovite (Table 1). Microcline and plagioclase were also subhedral. The micas were subhedral to anhedral and quartzes were generally anhedral. The quartzesweregenerally competent, relatively-minimally deformed and showed interlocking grains, whereas the microcline showed intergrowths. Some of the plagioclase were zoned and twinned, whiles the quartzes were sheared minimally and stretched. Most of the quartzes were also sutured, polycrystalline and showed undulated extinction and appeared to be finer than the feldspars but relatively coarser than the micas whereas the biotite had large grains with irregular edges. Grain boundary migration of quartz, with the inclusions of micas in plagioclase, occurred in the rock (Fig. 6). Linear alignment of the micas (specifically the biotite) and sericitization of plagioclase were also observed.

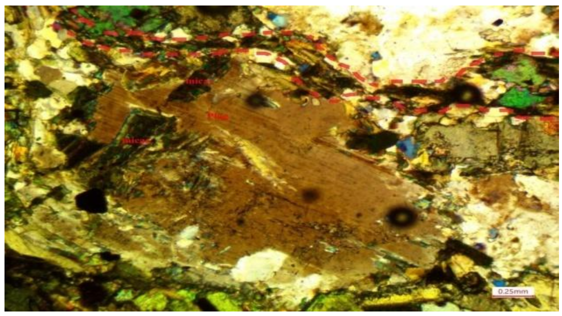

Figure 6.Photomicrograph of Mica inclusion in Plagioclase, Quartz suturing and Linear Alignment of the Micas

b). Tonalitic Rock

The tonalitic rocks were observed as coarse-grained, light-colored to dark-grey and appeared to be exposed moderately, slightly sheared and moderately deformed. They bordered to the west with the Adaboya porphyritic granitoid and comprised of quartz, plagioclase, minor biotite, and muscovite. The quartz was blocky and showed interlocking grains, had well developed joint sets that were systematic and orthogonal in the outcrops (Fig. 7). At least, three (3) sets of joints appeared in most of the outcrops with trends 282^{o} and 163^{o}. The conjugate joints were inclined on average at 55^{o} and 76^{o} to the other (Fig. 8). The average joint spacing throughout the exposures measured as 12cm, 6cm, 4cm, 3cm, 9cm, and 2cm. A dark-grey, deformed and fine-textured mafic dike intruded the rock, with a substantial extent (Fig. 9). At the SSE area, massive basaltic intrusions were also observed.

Petrographically, the tonalitic rock comprised of Biotite (5%), Quartz (30%), Muscovite (20%), Microcline (15%) and Plagioclase (40%) as shown in Table 1. The rock showed recrystallization of quartz in cross-polar giving the quartz a polycrystalline nature. Plagioclase sericitization was also evident whiles some of the microcline occurred as inclusions in the plagioclase feldspar (Fig. 10).

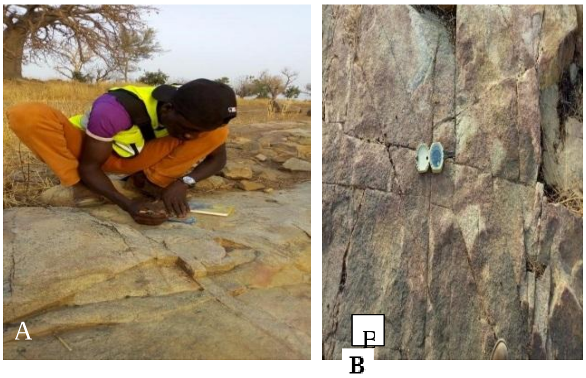

Figure 7.Tonalitic Rocks (A) Systematic Conjugate Joints and (B) both Conjugate and Orthogonal Joint sets

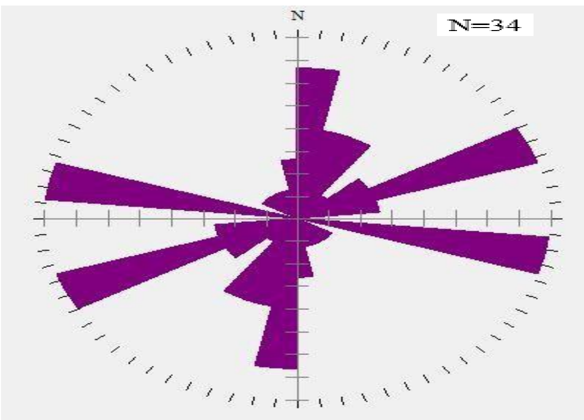

Figure 8.The Trend of Joints evident in the Tonalitic Rocks

Figure 9.Tonalitic Rock Intruded by a Massive Mafic Dike

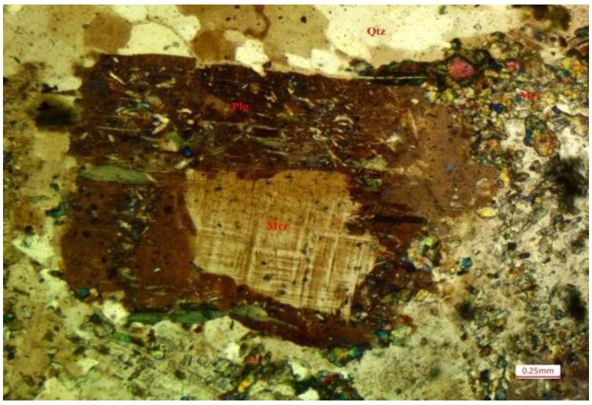

Figure 10.Quartz Recrystallization, Plagioclase Sericitization and Microcline inclusion in Plagioclase in Cross-polars

c). Muscovite-Biotite Granitoid

The Muscovite-Biotite granitoid outcrops were generally light-grey, massive and medium to coarse-grained (Fig. 11). They were dominantly exposed at the Asarkanyaa community. They appeared to be dominantly biotite and quartz with subordinate muscovite and plagioclase. The outcropped mesoscale showed slight deformations, stretches, and more whitish quartz veins. They showed increasing deformationswhich were low to a medium grade of metamorphism at mesoscale toward the NE direction. In some exposures, the rocks were uprightly oriented with few developed joints, which were systematic and were not numerous at all outcrop scales (Fig. 12).

Figure 11.Outcrop of Muscovite-Biotite Granitoid

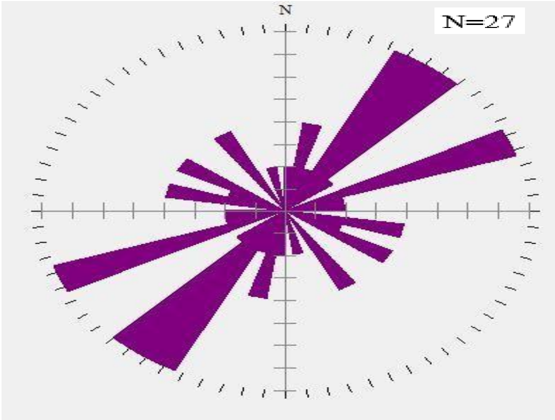

Figure 12.The Trend of Joints Developed in the Muscovite-Biotite Granitoid Outcrop

Petrographically,the rock comprised of quartz (30%), micas (24%), k-feldspar (10%) and altered plagioclase (35%) as shown in Table 1. The muscovite-biotite granitoid generally appeared to be sheared, recrystallized and showed a mylonitic texture (Fig. 13). Quartz showed a polycrystalline nature, while most of the plagioclase feldspars were altered to sericite. Micas formed the groundmass and very few opaque minerals were present. In cross Nicols, a secondary mineral (likely a metamorphic mineral) with high relief, low interference colors, one (1) good cleavage and brownish appeared to be Kyanite within 1% of the rock sample was identified.

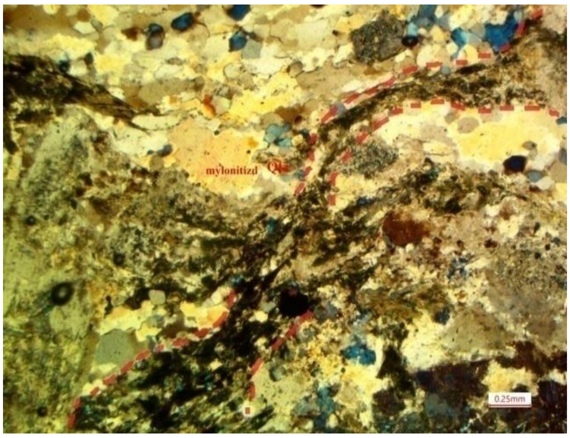

Figure 13.Plagioclase Sericitisation, Quartz Recrystallization, Shearing and Mylonitic Nature

d). Quartz-plagioclase (feldspar) porphyry

The quartz-plagioclase porphyry showed a light-grey colored, massive and coarse-grained nature that outcropped at Nkunzesi-Okanagan to the south of the Nangodi Greenstones but predominantly at Sekoti. The quartzes were well developed with less muscovite and predominantly plagioclase feldspars with green minerals. Quartz and plagioclase appeared as grey rectangular phenocrysts measuring up to 1.2cm by 0.9cm in a fine dark grey matrix. Little signs of deformation both on an outcrop and microscopic scales were observed. Discrete shears were also identified in some of the outcrops trending 12^{o}NE. Quartz veins were also evident (about 2cm thick) trending 276^{o}NW and 287^{o}NW in most of the outcrops (Fig. 14). The granitoids extended to the NE and NW and bordered with the Nangodi greenstones at the NNW direction. The greenstones were fine-grained, slightly jointed and deformed and strike towards NW. Biotite, hornblende, and epidote were also observed. Massive quartz (about 1km NW of the granitoids) separated the greenstones from the granitoids. In some exposures towards the NS direction, there were marked quartz stretches (1km to Sekoti community) and the displacement of pegmatite veins by joints in the quartz-plagioclase granitoid (Fig. 15). Developed quartz veins in the outcrops were thickened and became more whitish along the NS direction. Some other exposures showed thin veins of quartz with trends 274^{o}NW. Generally, there were well developed systematic joints in most of the outcrops with some orthogonal and conjugate sets (Fig. 16).

The quartz-plagioclase were petrographically made up of K-feldspar (8%), plagioclase (45%), quartz (35%) and biotite (10%). Feldspar alterations were present with the K-feldspars subordinating in the plagioclase (Table 1). A secondary mineral was observed with medium relief. Pleochroism was very pale-to-green with grey-to-brown colors like amphiboles (with about 2% volume of the entire sample volume percentage) with few opaque minerals. The quartz occurred as phenocryst and anhedral in shape. Euhedral phenocrysts of plagioclase were also observed, which were partially replaced by sericite in some cases as presented in Fig. 17.

Figure 14. Quartz Vein Developed in an Outcrop of Quartz-Plagioclase Porphyry

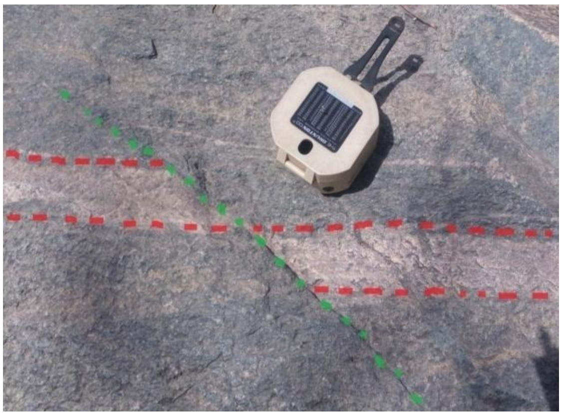

Figure 15. Pegmatite Vein displaced by an NW-SE Trending Joint

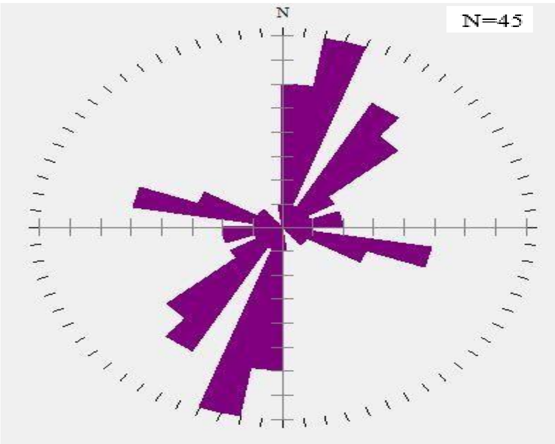

Figure 16.Joints Trends in the Outcrops of Quartz-Plagioclase Porphyry

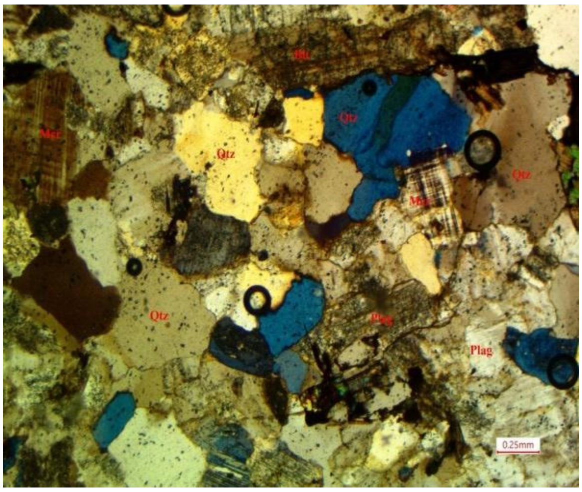

Figure 17. Quartz and Plagioclase Phenocryst in Quartz-Plagioclase Porphyry

Table 1. Modal composition of the different rock types

Sample	Porphyritic Granitoid	Muscovit-Biotite Granitoid	Quartz-Plagioclase Porphyry	Tonalitic rock
N	4	4	4	4
Biotite	<2	10-14	10	5
Muscovite	15	6-10	-	20
Secondary mineral	-	-	2	-
Quartz	30-35	30	30-35	30
Plagioclase	15-18	35	40-45	35-40
K-feldspar	-	8-10	8	-
Microcline	30		-	15
Opaque	<2	<2	-	-

N=Number of samples

e). Joint, Veins and Fractures

Joints in the study area were well developed, evenly spaced and had both orthogonal and conjugate relationships with the conjugate system dominating. It was observed that the area had undergone two main jointing planes with the majority of them having strikes of SEE-NNW or NWW-SEE. The parallel joints were mainly perpendicular or oblique to the dominant foliation surface in the area and had a mean strike of 038° and dip 73° towards the SE. However, the discordant joints displayed a mean strike of 325° and dip 60° towards the NE. From the stereo net plots, the orientation cluster became evident showing three (3) main directions, SEE-NWW, NE-SW, and NNE-SSW in ascending order.

Both filling fractures and fault surfaces were observed. The veins which comprised of quartz and carbonates and a width which measured from 0.2cm to 9cm were associated with the granitic rocks(especially the pegmatitic kinds). The veins acted as very useful kinematic indicators to decipher trends of deformations. Two main trends can be observed from the rose diagram plot (Fig. 18) on the veins in the study area. These are SEE-NWW and NEE-SWW. The majority of the veins trended towards the SEE-NWW direction.

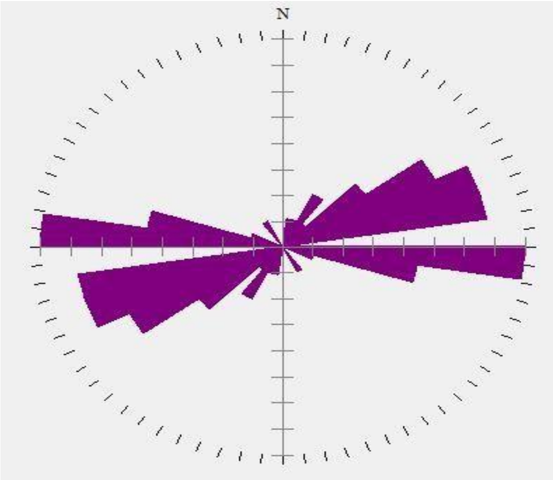

Figure 18.Rose Diagram showing the Plot of Veins

B. Rock Quality Assessments

a). Abrasive Resistance

Table 2 presents the results of abrasive resistance. Quartz-plagioclase (feldspar) porphyry, porphyritic granitoid, Tonalitic rock and Muscovite-Biotite granitoid recorded abrasion values of 31.66%, 27.76%, 25.0%, and 21.94% respectively. Thus, porphyritic granitoid, Tonalitic rock and Muscovite-Biotite granitoid showed susceptibility to rub actions to about 28%.

Table 2. Abrasion Test of Granitoids

Rock type	Total mass (g)	L.A value (%)	Remarks
Porphyritic granitoid	500	27.76	Acceptable value for paving work
Tonalitic rock	500	25.0	Tough, resistant to abrasions and disintegration
Muscovite-Biotite granitoid	500	21.94	Tough and resistant to rubbing. Passed for lining works
Quartz-plagioclase porphyry	500	31.66	Vulnerable to crushing up to about 68.34%

b). The Apparent density of the graded crushed stones

Table 3 presents the apparent densities of the mapped granitoids. The obtained density values of the porphyritic granitoid, Tonalitic rock, Muscovite-Biotite granitoid and Quartz-plagioclase (feldspar) porphyry were 2156.94Kg, 2156.15Kg, 2211.84Kg, and 1236.37Kg respectively.

Table 3. Apparent density test of Rocks

Rock type	Apparent density
Porphyritic granitoid	2156.94
Tonalitic rock	2156.15
Muscovite-Biotite granitoid	2211.84
Quartz-plagioclase porphyry	1236.37

c). Porosity

The laboratory results of porosity are presented in Table 4. Porphyritic granitoid recorded a porosity value of 0.9%, whereas Quartz-plagioclase (feldspar) porphyry, MuscoviteBiotite granitoid and Tonalitic rock respectively recorded 0.54%, 0.18%, and 0.49% porosity values.

Table 4.The Porosity of Granitoids

SAMPLE ID	DRY MASS (g)	SOAKED MASS (g)	POROSITY (%)	REMARKS
Porphyritic granitoid	3284.5	3314.0	0.90	Apparently show loose grain packing
Tonalitic rock	2338.5	2350.0	0.49	Closely packed mineral grains
Muscovite-Biotite granitoid	1645.0	1648.0	0.18	Evidence of interlocking crystals
Quartz plagioclase porphyry	3969.5	3991.0	0.54	Closely packed mineral grains

C. Petrographic and Geological Assessments

Generally, the mappedgranitoids showed gneissic-mylonitic textures in thin sections and shears. The high proportions of plagioclase feldspar indicated granodioritic characteristics instead of true granite. Pegmatite intruded all the granitoids and the presence of large quartz bodies indicatedlate-stage intrusiveness within the granitoids. The porphyritic granitoids were generally less deformed except in the fault and shear zones where faulting and alteration which included foliations (northward towards Asarkanyaa) were displayed. The subhedral to anhedral crystal shapes of the quartz observed under thin section indicated a mutual interference that impededcrystal development. Also, the tonalitic rock shows intense brittle and ductile deformation both in outcrop and thin-section scale with plagioclase often fractured and recrystallized quartz. These units formed close to the metabasalts and showed features of low-grade metamorphism under thin-section. The K-rich granitic rocks, although massive and relatively less deformed, also indicated some degree of deformation and metamorphism. The study revealed that muscovite-biotite granitoid had also undergone progressive deformation, evident in grain size reduction moving from Asarkanyaa towards the forest reserve into the shear zone. Finally, the development of foliations in the quartz-plagioclase granitoids with dips between sub-vertical to sub-horizontal reveal discrete shears.

D. Rock quality evaluation

a). Abrasive resistance

According to the American Society for Testing and Materials(ASTM) (C295-08), for building stone to be suitable for engineering works, it must have an abrasion value of less than 30%. Therefore, the high resistance to abrasion shown by the porphyritic granitoid indicates a higher proportion of quartz (considerably harder mineral) in its composition and a moderate percentage of mica alterations in its thin-section. Likewise, the Tonalitic rock and the Muscovite-Biotite granitoid are generally strong due to lesser evidence of deformation from the petrographic results. This makes the aforementioned rocks suitable materials for engineering purposes (building stones). However, the Quartz-plagioclase porphyry recorded a high value (beyond 30.0%) making it unsuitable for engineering works such as the construction of roads and pavements which require materials with more resistance to degradation impacts. This is confirmed by the development of discrete shears in the outcrop and microscopic scale which showed alterations, and are an indication of the presence of altered and weathered mineral grains. This result conversely is empirical and may not represent field performance, as the Civil Engineering Dictionary states that, field observations generally do not show a good relationship between L.A abrasion values and field performance. Thus, L.A abrasion loss may be unable to predict field performance.

b). Porosity

Porosity, as an engineering property of a rock, accounts for the absorption value of materials purposed for constructional activities. According to Scott and Nielson [11], higher porosities make rocks less dense, and the lesser the compressive strength of a rock material to serve as an engineering material. The tested granitoids for density fell below standards. According to ASTM [11], for a typical common granitic rock to serve engineering purposes, it should be very low in porosity. The combined field results with the outcome of the thin-section of the rocks showed that, apart from the porphyritic granitoid which showed loose grains, the other rocks are suitable engineering materials due to their very low porosities,which indicate closely packed grains and/or less alteration. Porphyritic granitoid had open grain spacing and micro-openings between the crystals hence yielding a higher porosity, while the Muscovite-Biotite granitoid generally appeared stronger and blocky in hand sample. Also, the thin-section results confirmed its interlocking crystal nature, and thus, a very low porosity. Also, the Tonalitic and Quartz-plagioclase (feldspar) porphyry showed closely packed grains in thin-section which contributed to their low porosity values.

c). Joints and faults

Joints are always considered as planes of weakness within rocks since they serve as pathways for the seepage of water and other fluids (which may dissolve or react with the minerals) in rocks. These two properties of joints terminate the inherent strength of rocks to a great magnitude. The granitoids mapped in the area generally have well pervasive, vertical to sub-vertical and systematic joints. This indicates the possibility of easily looseningrock materialsin humid conditions. Similarly, the existence of faults in some of the rocks, as well as the evidence of directional deformations,could affect their quality for engineering projects especially for foundations or as roofing materials, as faulting causes shearing and crushing in rocks which weaken them, andincreasepermeability and unstableness. Other structural features such as folds, foliations, and veins developed slightly in some of the rocks couldalso adversely affect the strength of the rocks.

E. Significance of the Results

The studied rocks were assessed for their quality from field observations and descriptions, microscopy, and porosity, density, and resistance to abrasion tests. They proved to be economically significant for engineering purposes to a considerable extent. The Porphyritic granitoid, though showed open grain packing (with an indication of high fluid absorption) and not worthy of load-bearing for their less dense nature, showed acceptable crushing strength for constructional purposes such as pavements along roads and linings in tunnels due to their high abrasion resistance and appealing color.

Notably, the selection of highly porous varieties of rocks for use in building construction (especially in moist situations) would be inappropriate [11] since water found within those pores does not only decrease the strength of the rock but makes it vulnerable to frost actions. In this regard, the Muscovite-Biotite granitoid which showed very low porosity would be suitable for constructional works in cold humid climatic conditions combined with its quality of toughness and resistance to rubbing actions. The Tonalitic rock is generally not worthy of load-bearing as a constructional stone due to its less dense property. Conversely, this rock can retain its usefulness of toughness and resistance to abrasions and disintegrations to about 75% under continued strain (grinding or impact activities). These make it suitable to be used as 'facing stones' in buildings in arid regions where strong sand-laden winds are not an exception, flooring in buildings and pavements along roads. The considerable porosity of the Quartz-plagioclase (feldspar) porphyry makes it suitable for constructional use in moist conditions but would be limited in applications involving compaction, compression and load impositions due to its vulnerability to grinding and impacts activities.

IV. CONCLUSIONS

The rocks in the study area were identified as granodioritic and form part of the Birimian granitic intrusions and were proven to be economically significant to some extent based on the various investigations conducted on their suitability for engineering purposes. The considerable porosity of the Quartz-plagioclase (feldspar) porphyry can be suitable for construction in moist conditions. Whiles Tonalitic can be used for flooring, pavements along roads and as ‘facing stones’. The Porphyritic granitoids will be suitable for lining tunnels and pavements along roads due to its appealing colorwhich may add quality hue for such uses. Muscovite-Biotite granitoid which showed very low porosity will be suitable for constructional works in cold humid climatic conditions combined with its quality of toughness and resistance to rubbing actions.

V. RECOMMENDATIONS

It is recommended that both geophysical and geochemistry data sets should be combined to ascertainthe bearing capacities of the rocks. This would be essential to evaluateother possible usage and engineering properties such as crushing strength, Absorption value, and frost resistanceto comprehensively authenticate the economic uses of these rocks.

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