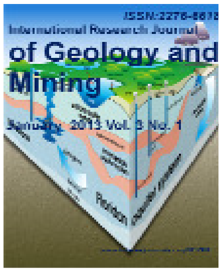

International Research Journal of Geology and Mining (IRJGM) (2276-6618) Vol. 3(1) pp. 19-30, January 2013
Available online http://www.interesjournals.org/irjgm

Full Length Research Paper

Geological mapping, petrological study and structural analysis of precambrian basement complex rocks in part of Ago-Iwoye Southwestern Nigeria

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Abstract

Geological map is a veritable planning tool for economic development of any nation. This map contains the distribution of various types of bedrock in the area. Geological map of Nigeria geographic landmass has been produced since 1964 with the recent update being in 2009. This map largely omits some local geology of interest, possibly owning to its large area coverage. Thus, local geologic mapping must be encouraged to bridge this lacuna; the focus of this study. Four different rocktypes were identified: porphyroblastic (augen) gneiss, hornblende-biotite gneiss, banded gneiss and quartz schist with mineralogical assemblages ranging from quartz, micas (biotite and muscovite), hornblende, feldspars (plagioclase and microcline) feldspars to accessory and opaque minerals (iron oxide). Deformational tectonic events that accompanied Pan African orogeny were mapped out in the area resulting to the development of structural elements such as mineral lineation, foliation, jointing and veins. Faulting and folding were absent which suggest possible low-intensity deformation. This was further corroborated in the development of sericite (porphyroblast) clast which is an intermediate clay mineral between micas and feldspar. Measured structural parameters were integrally statistically processed. The result reveals NW-SE trending of foliations and mineral lineation, which conforms with the direction of stream flow as an indication of the streams being structurally controlled.

Keywords: Geological mapping, geological map, rocktype, photomicrograph, joints, foliation, lineation, Rosset, Pan African orogeny.

INTRODUCTION

A geological map shows the distribution of various types of bedrock in an area. It usually consists of a topographic map (a map giving information about the topography and height data of the earth's surface) which is shaded, or coloured to show where different rock units occur at or just below the ground surface. The importance of geological maps cannot be over-emphasized. They are planning tools for the economic development of any nation. Thus, it becomes imperative to update geological map of an area to gain full knowledge of the area's geological 'treasures'. The available geological maps of Nigeria are those of Jones and Hockey (1964) until recently that Nigeria Geological Survey Agency (NGSA) collected geological data from various sources, authenticated the data through field check, to produce the latest map. In this new map, the Granite-Gneiss and the Schist complexes have been differentiated lithologically, an improvement over the old map. An attempt has also been made to distinguish "pure Quartzites" and "Quartz Schist" from sillicified "Sheared Rocks" or "Mylonites", thus setting ground for a new tectonic unit to be erected for the latter (NGSA, 2006). Even at the recent update of Nigeria geological map, information of some local geology was still largely omitted as the case of the area under study. Local geology reporting must thus be encouraged as this is more detailed than the general regional mapping and important

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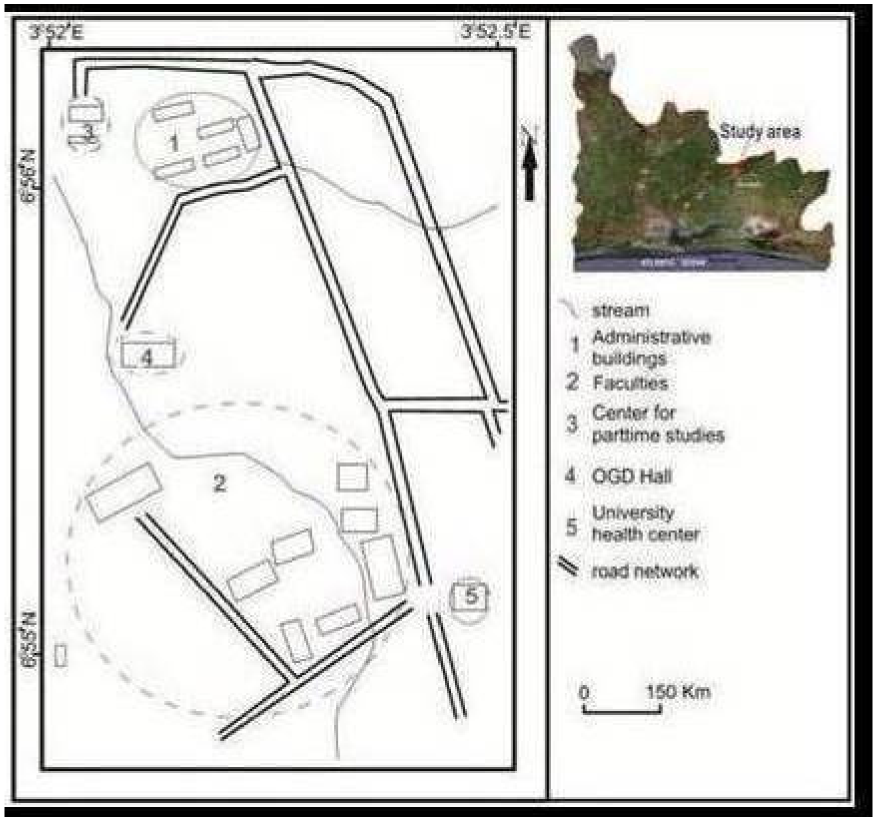

Figure 1. Map of the study area showing physical development and its relative position in the region (inset)

omission could be corrected in subsequent regional report. This is the focus of our study in this paper.

Olabisi Onabanjo University campus lies 3.5km to the southwestern part of Ago-Iwoye at longitudes 3^0 52' and 3^0 53' and latitudes 6^0 54.5' and 6^0 56' (Figure 1). The relief is gently rugged with an elevation gradient of about 30 m and a dendritic drainage pattern. Geology of Ago-Iwoye lies a few kilometers away from the contact between the basement complex and the sedimentary terrain as shown in Figure 2a. It is a part of the basement complex of Nigeria which forms one of the three major litho-petrologic units that make up the geology of Nigeria (Figure 2b). Earlier workers such as Annor and Freeth (1985), Rahaman (1989), Annor (1998), and Caby (1989), Caby and Boesse (2001) show four distinct basement lithologies in the basement complex of Nigeria. These lithologies are etrologic-gneiss complex, metasedimentary and metavolcanic rocks (The Schist Belts), the Pan-African granitoids (The Older Granites), and the undeformed Acid and Basic dykes, Rahaman (1989). (Figure 1)

The Migmatite–Gneiss Complex is a heterogeneous assemblage including migmatites, orthogneisses, paragneisses, and a series of basic and ultrabasic metamorphosed rocks (Rahaman, 1988) characterized by three etrological units making up about 60% of the surface area of the Nigerian basement (Rahaman and Ocan, 1978). The petro-units are: A grey foliated biotite and/or biotite-hornblende quartzo-feldspathic gneiss of tonalitic to granodioritic composition (Rahaman 1981); Mafic to ultramafic component often outcrops as concordant sheets of amphibolites and small amounts of biotite rich or biotite-hornblende-rich ultramafite; and Felsic component as a varied group of rocks consisting essentially of pegmatite, aplites quartz-oligoclase veins, fine-grained granites, granite gneiss, porphyritic granites etc (Rahaman 2006).

The Schist Belts also referred to as Metesedimentary and Metavolcanic Rocks comprise low grade, metasediment-dominated belts occupying N-S trending synformal troughs. They are infolded into the older Migmatite-Gneiss Complex. The important lithologies are aplites, semi-pelites, quartzites, marbles, banded iron formations, amphibolites, ultramafites and minor felsic to intermediate metavolcanics and greywackes (Rahaman, 2006). Some may include fragments of ocean floor material from small back-arc basins. The schist belts are mostly developed in the western part of Nigeria though; smaller occurrences are found in the eastern part too (Obaje, 2009). They have been extensively studied in the western half of the nation coming up with following groups: the Kusheriki Schist Group, the Karaukarau

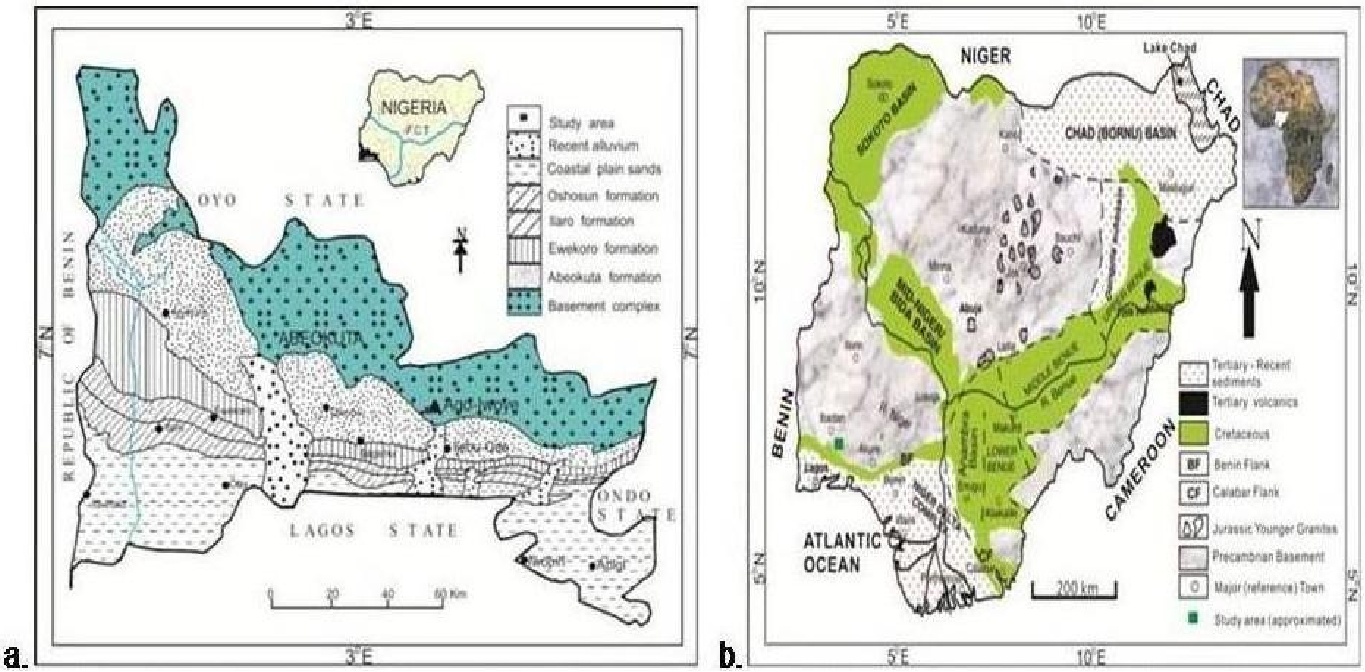

Figure 2. a). Updated and digitized geological map of Ogun State **b).** Geological map of Nigeria showing the three major litho-petrological units with African map inset (modified after Obaje, 2009)

Schist Belt, the Kazaure Schist Belt, the Maru Schist Belt, the Anka Schist Belt, the Zuru Schist Belt, the Iseyin-Oyan River Schist Belt, the Ilesha Schist Belt and the Igarra Schist Belt (Obaje, 2009). Some undifferentiated rock units (The Granite-Gneiss and the Schist complexes) by earlier workers were recently differentiated lithologically and a new tectonic unit erected by NGSA (2006).

The Older Granites, a term introduced by Falconer (1911), is now preferably called Pan-African granitoids because of its merit on age and the fact that it covers several important petrologic groups formed at the same time (Dada, 2006). The Pan African granitoids include biotite- and biotite-muscovite granites, syenite, charnockites, diorites, monzonites, serpentinites, anorthosites etc. (Rahaman, 2006). It is good to note that the Older Granites occur intricately in association with the Migmatite-Gneiss Complex and the Schist Belts into which they generally intruded. This means that the rocks occur in most places where rocks of the Migmatite-Gneiss Complex or of the Schist Belt occur (Obaje, 2009). The last unit is the Undeformed Acid and Basic Dykes which are late to post-tectonic Pan African crosscutting the three main rock units described above. They include felsic dykes that are associated with Pan-African granitoids on the terrain such as the muscovite, tourmaline and beryl-bearing pegmatites, micro-granites, aplites and syenite dykes (Dada, 2006); and Basic dykes (the youngest units) that are generally regarded as the less common basaltic, doleritic and lamprophyric dykes.

METHODOLOGY

Field geological mapping and structural measurement

Intensive geological mapping subsequently followed by thin section petrographic studies of fresh whole rock samples was carried out. Five rock samples were collected within the geographical landmass occupied by the University permanent site (Figure 3). Accessibility was quite easy especially in the developed part mainly at the center of the area surveyed. The boundary sides posed a little challenge because of the thick vegetation cover but were accessed by cutting to enhance thorough search for outcrop. At each location, rock outcrops were carefully examined and properly located on the base map for digitization using GARMIN global positioning system (GPS), Figure 4B. In situ measurements of strikes and dips were taken for structural study with compass clinometers (Figure 4A). This will later help to deduce the direction of the tectonic forces that produce some structural elements observed. Observations made include foliations, joints, mineral lineation, intrusions (e.g. vein) as shown in Figure 4C-F; faults and folds are rarely encountered in the outcrops. Based on the in situ observations, textural and compositional studies of the outcrop, tentative names were given to rock samples taken from the outcrop. Attempts were also made to determine the petrogenesis and geochronology to explain the sequence of events as it affect rocks in the area. At

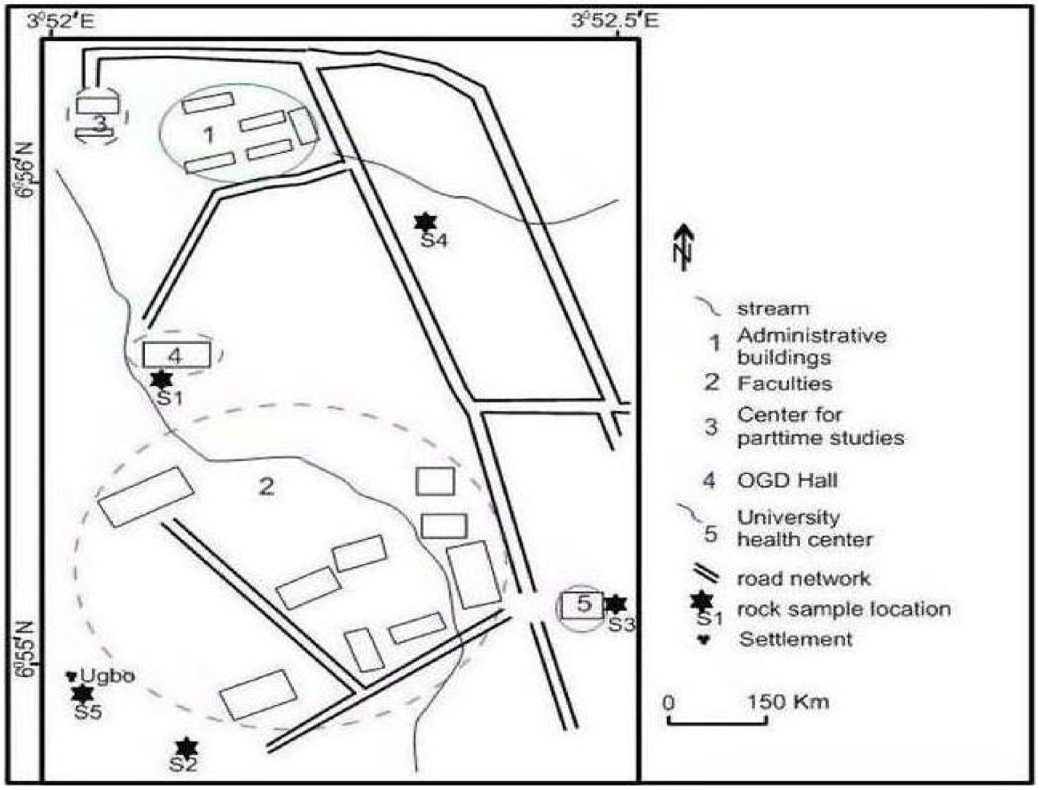

Figure 3. Rock sampling map

Figure 4. A) Compass Clinometers for measuring strike of structures and dip of outcrop **B)** GARMIN 76 Global Positioning System (GPS) for taking the outcrop coordinate used in map digitization **C)** foliation in this rock, a Quartz Schist, developed as a result of metamorphism **D)** veins on biotite gneiss **E)** joint on porphyroblastic gneiss **F)** porphyroblastic gneiss showing some porphyroblast

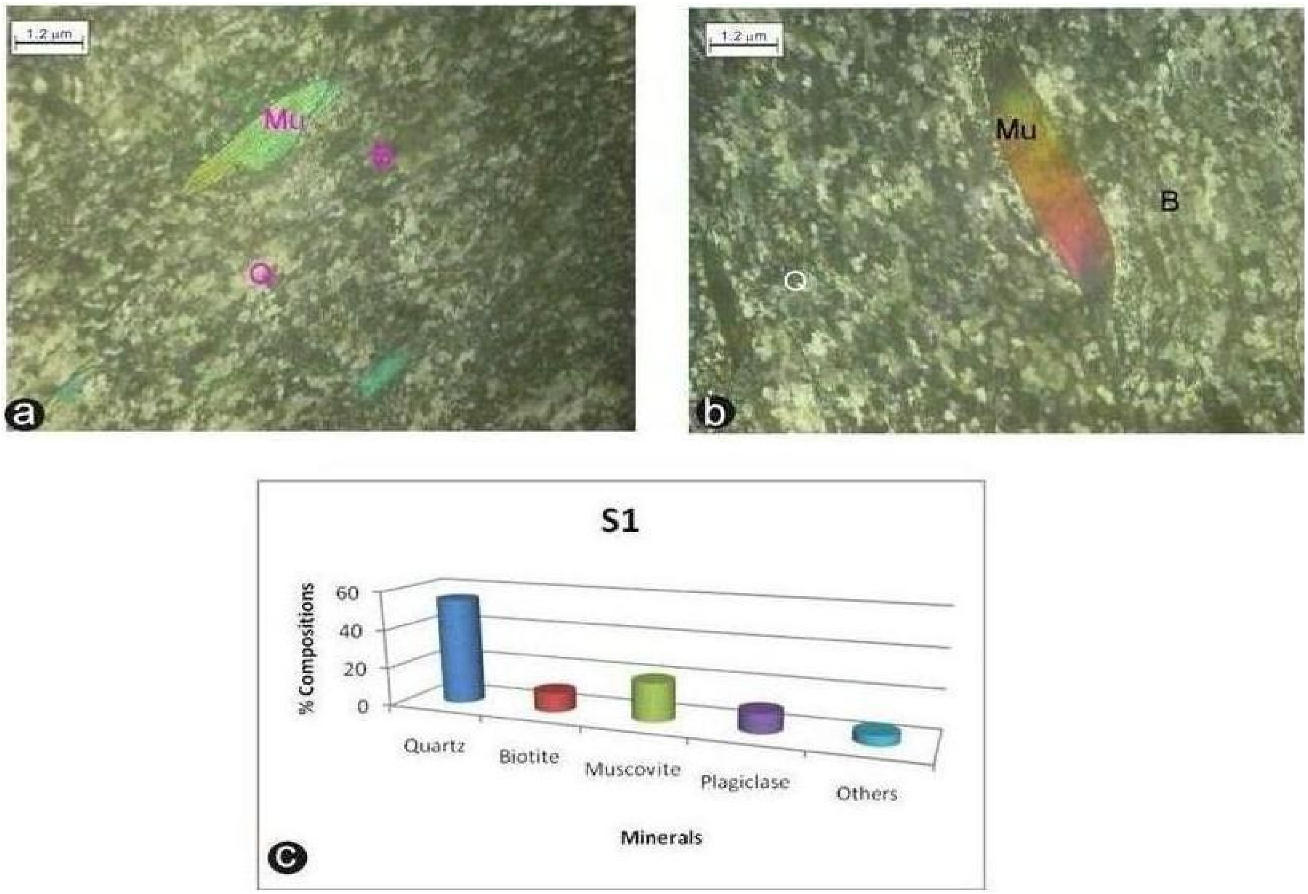

Figure 5. a and b) Photomicrographs of porphyroblastic augen gneiss X40 c) Bar chart of percentage mineral compositions for S1. Note the high percentage of quartz and the gneisicity/ alignment of both clasts and background minerals in a preferred orientation, hence the rock name.

the end of these exercises samples were taken with the aid of sledge hammer for petrographic preparation and analysis. (Figure 3)

Petrographic preparation of rock slide was done in a standard way at Geology Laboratory of Obafemi Awolowo University, Ile-Ife. The processes involve cutting the rock into small rectangular pellet of 3mm, mounted on glass slide using resin araldite. The mounted slide was lapped on a glass plate using medium-grain carborundum as abrasive to generate friction between the rock pellet and the glass, in the process reducing the slide thickness to a desirable thickness of 0.3mm. At this thickness, it has been established that rocks behave like a transparent medium allowing the passage of light (Kerr, 1977). Canada balsam was later used to seal the thinned rock using a glass cover lid. Hence, the study of optical properties of mineral components of the rock was enhanced.

Optical study

Rock slides were studied under microscope to determine the properties of minerals making up the rocks. Once we know the properties of minerals, we can use a few simple tests to identify them. Usually, it is not necessary to analyze a mineral chemically to discover its identity (Murck, 2001 p.34). Some properties are diagnostic features for some minerals. However, this approach may not be realistic when the minerals are aggregated to form rock. Additional studies like microscopic examination can shed more light on the identity of the mineral. This is the approach we adopted in this study. In general, physical and optical properties most often used to identify minerals are crystal form, habit, cleavage, hardness, luster, color, streak, specific gravity (density), plaeochroism, extinction (angle), birefringence, interference colour and twinning. Optical observations were realized in both plane polarized light and cross nicol.

RESULTS AND INTERPRETATIONS

Petrographic Studies

Petrographic studies reveal the mineral assemblages and

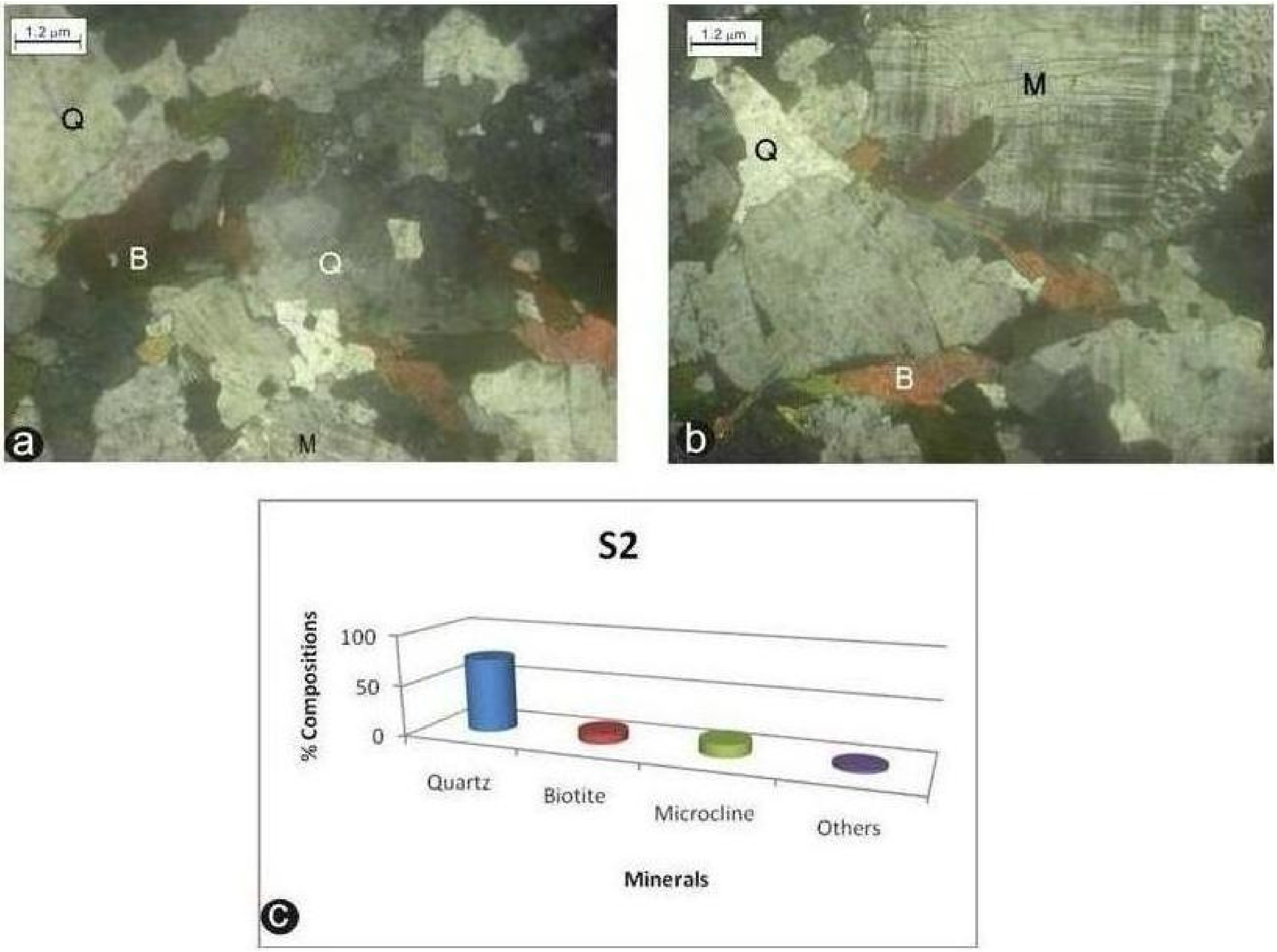

Figure 6. a and b). Photomicrographs of quartz schist From c) bar chart of percentage mineral compositions for S2 X40. Note the high percentage of quartz. In field observation Figure 4C, it is highly schistose, cleaved and brittle.

structural features that are used in the eventual naming of the rock. The mineral assemblages are analogous of metamorphosed granite, suggesting paleo-deformational effect of Pan-African orogeny reported in earlier basement studies in Nigeria (e.g Olayinka, 1992; Dada, 2006 and Obaje, 2009). Table 1 shows the summary of mineralogical compositions of rock based on optical study of the slide and field observations

The porphyroblastic (augen) gneiss (Slide S1)

Figure 5a. and b. represents photomicrograph of the rock slide. The mineralogical compositions comprise quartz, micas (biotite and muscovite), plagioclase feldspars and others (which include opaque minerals (iron oxide) and the accessories). The common accessory minerals in granite include tourmaline, zircon, sphene, *etc.* The percentage mineral compositions in the study area as determined from optical analysis of the thin section by grain counting is presented in Table 1 and Figure 5c. An eye-like structure (augen structure) was observed under the microscope which we included in naming the rock as porphyroblastic (augen) gneiss. Originally, augen gneiss is believed to contain relatively large feldspar clasts floating in a finer-grained matrix (Van der Pluijm and Marshak, 2004). However, the clasts in our study are muscovite almost grading to sericite (an intermediate clay mineral from partial alteration of mica, which further alteration will lead to feldspar). The partial alteration could be linked to low degree of the deformational force, having previously noted that there was no faulting and folding found on the rock outcrop.

The Quartz Schist Slide S2

The mineral compositions are quartz, biotite, microcline feldspar and some accessories (Figure 6a and b), having quartz as the dominant mineral (Figure 6c). NGSA (2006)

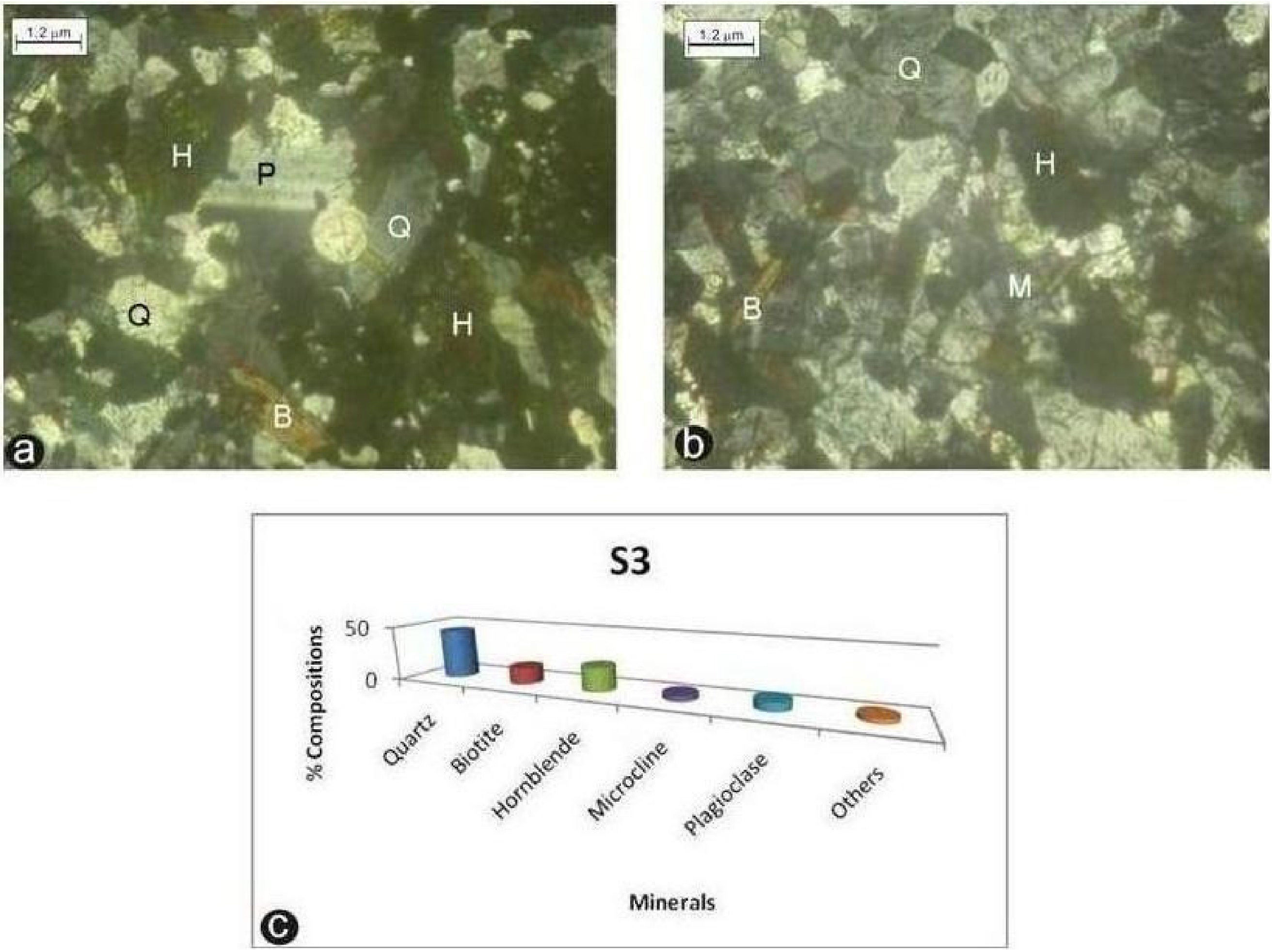

Figure 7. a and b) Photomicrographs of Banded Hornblende Gneiss From S3 X40, c) Bar chart of percentage mineral compositions. Note: the felsic and mafic mineral band was macroscopic hence it absence in the photomicrographs.

has however distinguished "pure quartzites" and "quartz schist from sillicified "sheared rocks" or "mylonites", thus a new tectonic unit is now erected for the latter. It is compositionally resemblance of Ilesha schist belt thought to be mainly in the amphibolite facies metamorphism in which in the Eastern side, quartzite is dominant, occurring together with quartz schist, quartzo-feldspathic gneiss and minor iron-rich schists and quartzites (Obaje, 2009).

Banded Hornblende Gneiss Slide S3

The compositional variations of minerals in the rock sample include quartz, biotite, plagioclase and microcline feldspar, hornblende and some unidentified accessories (Figure 7a. and b.), in varying proportions (Figure 7c). The high content of hornblende over biotite coupled with the alternation of mafic and felsic content was the factor that influences its name.

Biotite Hornblende Gneiss Slide S4 and S5

Mineralogical contents of the rock samples S4 and S5 show quartz, biotite, hornblende, and microcline and plagioclase feldspars in various percentages as depicted in Figure 8a-f. The name of the rock, biotite-hornblende gneiss was determined from both the field sample and optical analysis in which biotie content is more than hornblende in contrast to sample S3. It should be noted that all of these rock samples have accessory mineral even though not labeled or mentioned in the slides.

Statistical Treatment and Analysis of Structural Data

The study area is part of the Nigerian Basement Complex, a polycyclic terrain that has responded to various tectonic events within the Pan African Orogeny. The Pan African orogeny comes with deformation (Obaje, 2009), which imprint has been widely reported in Precambrian rocks of

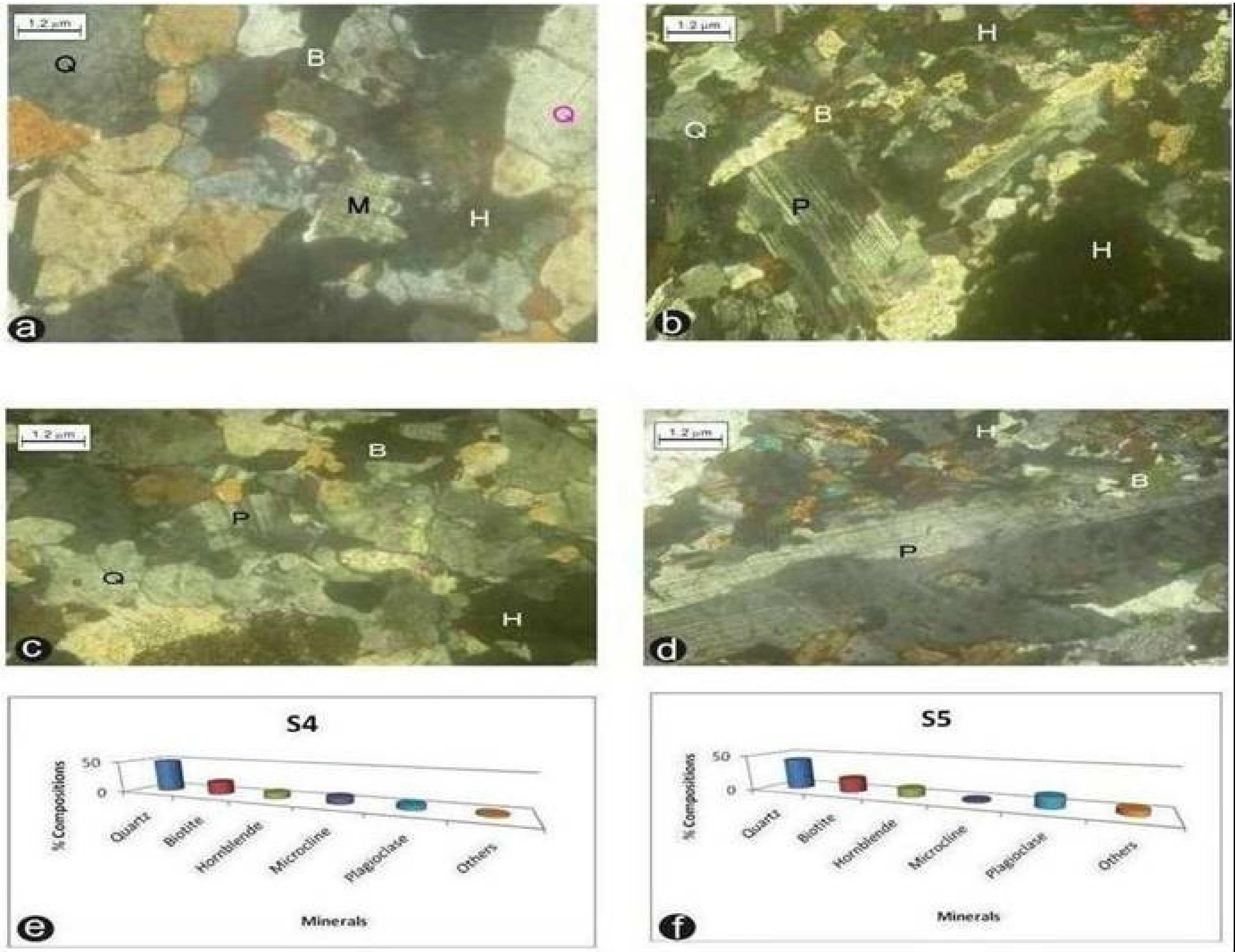

Figure 8. Photomicrographs of biotite hornblende gneiss a and b) from sample S4 X40 c&d) from sample S5 and bar chart of percentage mineral compositions e) for S4 f) for S5

Table 1. Summary of mineralogical compositions of rock based on optical observation and classification

Sample	Minerals	% Compositions	Name of Rock	Remarks
S1	Quartz (Q)	55	Porphyroblastic augen gneiss (Figure 1)	Contains porphyroblasts as evidence of its being metamorphosed from porphyritic granite. The augen clast is muscovite, grading into a sericite – a clay mineral which further change to a feldspar
	Biotite (B)	10		
	Muscovite (Mu)	20		
	Plagioclase (P)	10		
	Others (O)	5		
S2	Quartz (Q)	74	Quartz schist	Quartz Schist is highly schistose, fissile, well fractured, cleaved, weathered and brittle as could be seen in Figure .
	Biotite (B)	10		
	Microcline (M)	13		
	Others (O)	3		
S3	Quartz (Q)	45	Banded hornblende gneiss	Has higher percentage of hornblende than it has biotite. Even in hand specimen, the greenish colour of the hornblende predominates, hence its name. It is also banded with alternation of mafic and felsic mineral
	Biotite (B)	15		
	Hornblende (H)	22		
	Microcline (M)	5		

Table 1. Continue

	Plagioclase (P)	8		
	Others (O)	4		
S4	Quartz (Q)	50	Biotite hornblende gneiss	This rock contains higher proportion of bitotite compared to hornblende as determined by grains counting at different microscopic views and finding the average.
	Biotite (B)	20		
	Hornblende (H)	10		
	Microcline (M)	10		
	Plagioclase (P)	7		
	Others (O)	3		
S5	Quartz (Q)	43	Biotite hornblende gneiss	
	Biotite (B)	20		
	Hornblende (H)	12		
	Microcline (M)	3		
	Plagioclase (P)	15		
	Others (O)	7		Same as S4

Capital letters in bold indicate how the minerals are labeled in the figures.

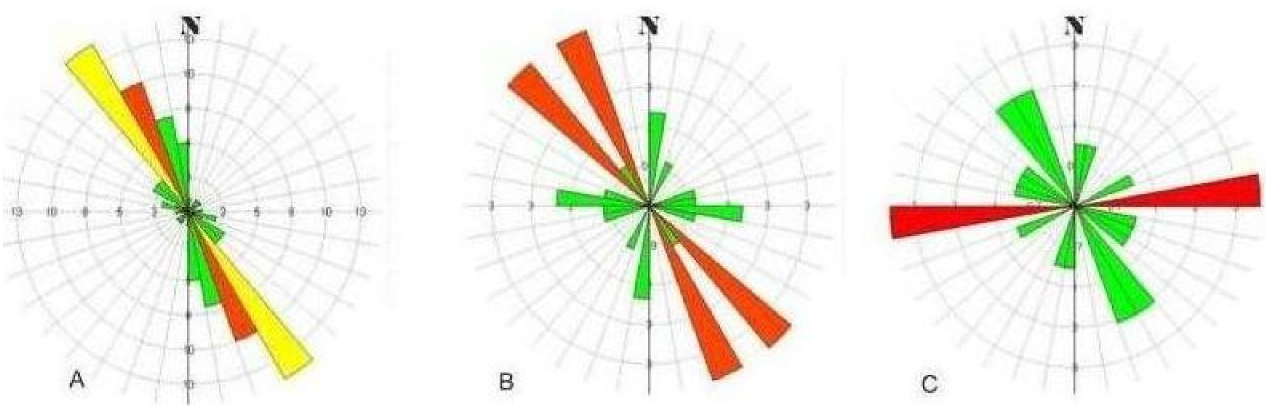

Figure 9. Rosette diagram of orientation of A) Foliation and B) Vein and C) Joint

Southwestern Nigeria (Rahaman, 1989). Regional metamorphism was one of these events that accompanied the Pan-African deformation (Abaa, 1983). This has resulted in the formation of structures such as faulting and fracturing (Olayinka, 1992), folding, jointing, veins, intrusions, foliation and mineral lineation. We attempted the description, spatial representation, and analysis of foliations, joints and veins structures measured on the field. Table 2 represents the statistical representations of the orientations of the structural features mapped and measured. The different ways of presenting such information are Rosette diagram, line diagram, point diagram and stereographic plotting. Rosette diagram is used here to evaluate the portion of the tectonic forces that affected rocks in the study area and characterize the extent of the deformation.

Foliations can be described as a planar arrangement or orientation of mafic minerals and felsic minerals into a distinct band. They usually occur in metamorphic rocks. They may have developed along a pre-existing cleavage. Shearing or flow movement may lead to the directional trending of the original minerals. Foliation of rocks is tectonically controlled, and was observed in most or almost all the outcrops within the study area (see Figure 4c). The rosette plotting of strikes of foliation values indicates a NW-SE trend the direction of dominant tectonic forces that affected rocks in the area (Figure 9A).

Intrusions are bodies of rock whose names are based on their size and shape, as well as their relationship to surrounding rocks. They are usually emplaced during or after the formation of the original host/country rock. In this study, the only forms of intrusion found are the veins. They are usually younger than the host rock and are either quartz/quartzite or quartzo-feldsparthic (as found in this study) in composition. The Rosette diagram of veins also indicates an orientation trending in a NW-SE direction (Figure 9B) in compliance with that of foliation in the area. The general interpretation is that the groundwater flow pattern is expected to be in NE-SW direction in line with the direction of joint. This could be understandable since basement aquifers are controlled mainly by fractured or weathered rock.

Table 2. Statistical table of strikes of foliations, joints and veins measured on the rock outcrops in the area.

Structural Elements		Foliation		Joints		Veins	
Azimuth (Degree)		number	%Frequency	number	%Frequency	number	%Frequency
0 – 10	181 – 190	1	2.17	1	7.69	2	11.76
11 – 20	191 – 200	-	-	1	7.69	-	-
21 – 30	201 – 210	-	-	-	-	1	5.88
31 – 40	211 – 220	1	2.17	-	-	-	-
41 – 50	221 – 230	1	2.17	-	-	-	-
51 – 60	231 – 240	1	2.17	-	-	-	-
61 – 70	241 – 250	-	-	1	7.69	-	-
71 – 80	251 – 260	-	-	-	-	1	5.88
81 – 90	261 – 270	1	2.17	3	23.08	1	5.88
91 – 100	271 – 280	-	-	-	-	2	11.76
101 – 110	281 – 290	2	4.35	1	7.69	1	5.88
111 – 120	291 – 300	1	2.17	1	7.69	-	-
121 – 130	301 – 310	3	6.52	1	7.69	-	-
131 – 140	311 – 320	3	6.52	-	-	4	23.53
141 – 150	321 – 330	13	28.26	2	15.38	1	5.88
151 – 160	331 – 340	8	17.39	2	15.38	4	23.53
161 – 170	341 – 350	7	15.22	-	-	-	-
171 – 180	351 – 360	4	8.70	-	-	-	
Total		46		13		17	

Joints are fractures or cracks in a rock along which no visible displacement has occurred. They are product of brittle behavior of rocks when acted upon by tectonic forces, along the areas of weakness in the rocks. Orientation data on jointing holds valuable information about the orientation of stress fields at the time of failure. Statistical diagrams that show attitudes of many different joints within a given region can help to identify dominant joint orientations in a region (Van der Pluijm and Marshak, 2004). All the rocks in the study area show joints and measurements taken are plotted on the Rose diagram shown in Figure 9C. It shows E-W directional response to the dominant tectonic stress that produced it.

DISCUSSION

The mineral assemblages and field observations of the rock as described above were good factors for the classification of the rock. Incorporating this with the strikes and dips measured, we produced the geological map of the area as presented in Figure 10. Juxtaposing our classification with earlier worker (for example Jones and Hockey, 1964; Rahaman, 1989, Caby and Boesse, 2001) reveals the extension of quartz schist to the area mapped, though omitted in the published geologic map of Nigeria. The quartz schists have high proportion of quartz mineral as found in quartzite but largely fissile, cleaved and weathered, in contrast to quartzite. The field evidence of this outcrop includes frequently display preserved sedimentary bedding. The augen gneiss (porphyroblastic gneiss) was also not reported in the earlier geologic map, probably due to the regional nature of the map. The structures on the outcrop aptly bear the imprint of evolution and/or paleotectonic activities. For example, on sample S1 (porphyroblastic augen gneiss in Figure 5aandb), microscopic mineral lineation of the background felsic and mafic minerals (biotite and felspar) in a prefer orientation suggests the readjustment of mineral compositions of the rock during metamorphism. Though folding and faulting are not prominently displayed on the rocks, the fact that the rocks were fractured (jointing) is an evidence of paleo-tectonic magmatic cycle associated with the Pan-African orogeny (Obaje, 2009).

On the structural measurements, the resultant orientation of foliations and vein shows a NW-SE trending analogous to the direction of tectonic event responsible for the metoamorphism and/or fracturing of rock in the region (Rahaman, 1989; Obaje, 2009). Foliation is defined by the planar alignment of micas which defines a syn-metamorphic mineral lineation (Caby and Boesse, 2001). Strike of joint were also studied which indicate W-E trending. Joints are studied for engineering or hydrologic applications. For example, in a region of systematic jointing that is oriented north–south, groundwater is also expected to flow faster and/or with

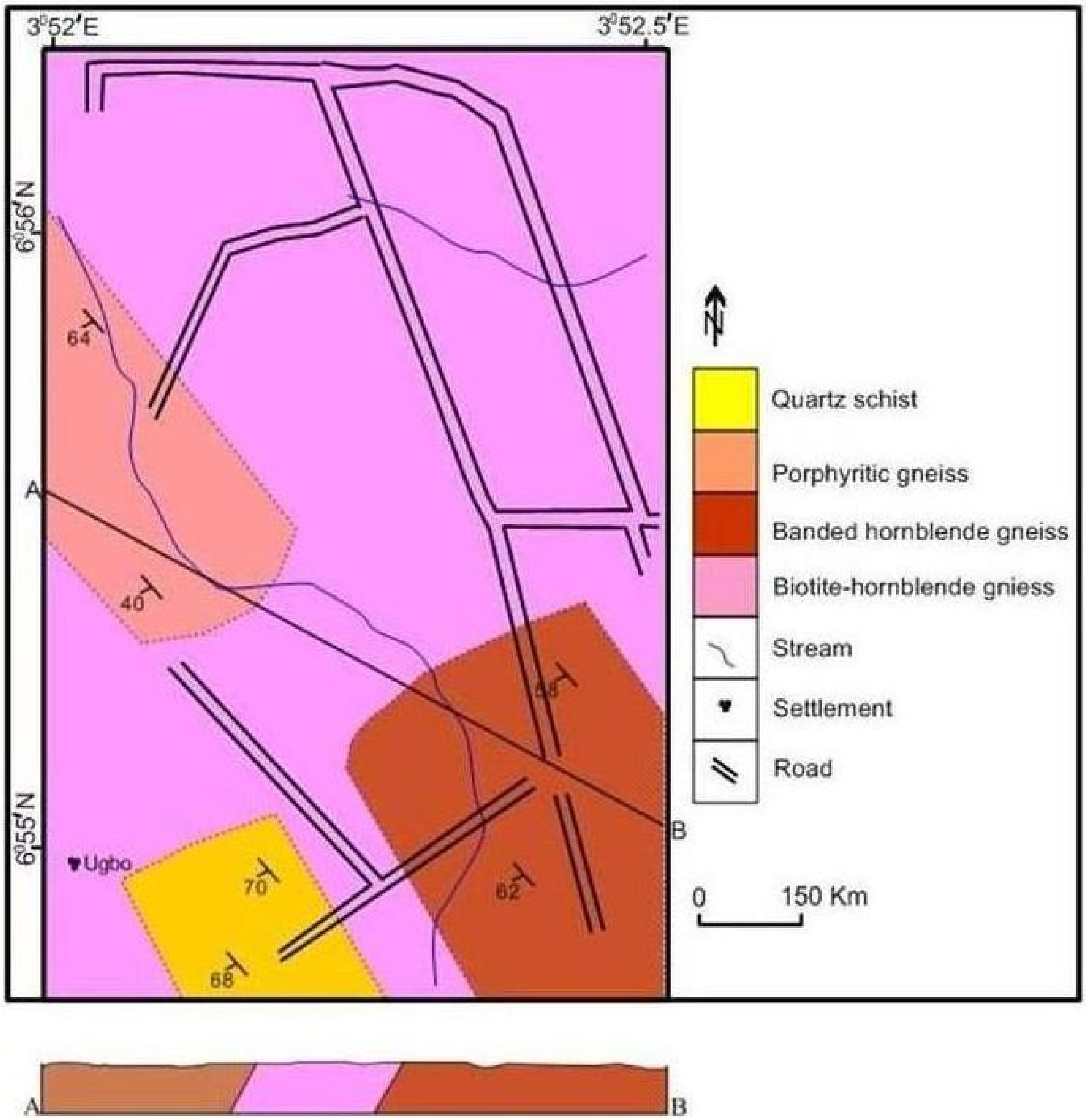

Figure 10. Geological map of the area

larger discharge in the north–south direction than in the east–west direction (Van der Pluijm and Marshak, 2004) because of enhanced porosity in the fractures. Since most veins occurred along existing fracture (joints), therefore, the implication of NW-SE trending of foliations and veins obtained in the area is that groundwater will flow in NW-SE direction. Incidentally, Folorunso (2009) reported that surface water (streams) in the area flow in NW-SE direction which also coincide with the direction of underground water flow.

CONCLUSION

Geological mapping of Olabisi Onabanjo University campus was carried out as a prototype geological mapping and reporting in a modern age. Optical study of the thin sections prepared from five rocks samples collected revealed four distinct rock units which are porphyroblastic (augen) gneiss, hornblende-biotite gneiss, banded gneiss and quartz schist. Porphyroblastic (augen) gneiss and quartz schist have not been reported in the area before. They were inadvertently omitted in the various published geological map of Nigeria. The rocktypes in this study are members of the schist belt of Nigeria. The mineralogical assemblages of these rocks are quartz, micas (biotite and muscovite), hornblende, feldspars (plagioclase and microcline) feldspars and others (opaque minerals (iron oxide) and the accessories). Most minerals components of the rocks show evidence of metamorphism. The imprint of deformational tectonic events that accompanied Pan

African orogeny was mapped out in the area resulting in the development of structural elements such as mineral lineation, foliation, jointing and veins. Statistical data of joints, foliation and veins were integrally processed. Rose diagram plotted from these data revealed a NW-SE trending (for the foliations and veins), similar to the Igarra schist belt that trend NNW. The same trending was observed for the streams in the area as an indication of the streams being structurally controlled.

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