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Geology and Petrographic Studies of Rocks in Anka Sheet 52, Northwestern, Nigeria

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Abstract
Over the years, models of evolution of the schist belts of Nigeria was proposed and classified under ensialic and ensimatic processes of formation. The study area (Anka Sheet 52) lies between latitudes 12º00′N and 12°30′N and longitudes 5°30′ E and 6°00′E and covers an area of about 3,086.76 km² (Anka Sheet 52). Field mapping and laboratory studies was considered for this study by taking every detail in the field necessary such as geologic boundaries, structures, physical appearances of rocks and orientation noted in field notebook. Structural characteristics on outcrop was also recorded with the help of photographs and sketches along with text description. Representative rock samples mostly granitoids were prepared into thin for microstructural observations to reconstruct the deformation features and mineralogical assemblages under polarized light microscope. The study area comprises of gneiss of sedimentary protolith and is the oldest rock unit forming a massive sheared and elongated ridge trending north-south for about 1800m with a porphyroblastic texture of gradual lineation of quartz and feldspar in places. Metasediments comprises of quartzite, quartz schist, pellitic schist, phyllite, hornfels and metaconglomerate accounting for more than 35 percent of the study area. Pan-African granites intruded both the gneiss and metasediments and comprises of coarse grained granites, porphyritic granites, diorite and rhyolite to accounts for about 20 percent of the study area. Field and petrological evidences indicates that the Pan-African reworking may have led to the recrystallization of the protolith rocks to form gneiss (paragneiss) resulting from partial melting signifying that metamorphism possibly reach lower amphibolite facies in part of the study area. These rocks were overlain by sedimentary rocks of Cretaceous age.
Keywords: Granitoids, Protolith, Metamorphism, Porphyroblastic, Paragneiss
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1. Introduction

The study area (Anka Sheet 52) in part of Anka schist belt includes a post-orogenic element of Pan-African age; the unmetamorphosed volcanic and sedimentary rocks of the Maradun and Kiserni areas which rest unconformably on the schists and granites and are dated provisionally at 516 ± 20 Ma (McCurry, 1976). The Anka schist belt lies west of Maru schist belt (Figure 1), the two being separated by the Pan-African Maiinchi granodiorite and by a probably older gabbro-granite- Anka pegmatite complex (APC) (McCurry, 1971). The rocks contrast with those of the Maru schist belt and include metaconglomerates, sandstones, slates, phyllites and acid volcanic rocks (Holt, 1982). Metaconglomerates formed several units with thicknesses reaching 150-250m, but which die out laterally and are interbedded with altered metasandstones. They contain rounded to angular boulders and pebbles composed of granite, quartzite, quartz, phyllite and volcanic rocks. The study area lies between latitudes 12º00′N and 12°30′N and longitudes 5°30′ E and 6°00′E and covers an area of about 3,086.76 km². Accessibility to the study area is fair in the south- southwestern than northern part, the use of roads like Anka-Abare-Derita in the southeast, Dan-Garamfa road off Anka - Nasarawa road, Nasarawa - Tunga Rogo - Kwali road, Kwali - Ruwan Gora - Ruwan Jema road, Anka - Wanu - Dakko – Kurua road and Anka - Ruwan Gora roads in the eastern part was very helpful to connect minor roads leading to villages, footpaths and cattle tracts. Accessibility especially during the dry season is fair and better compare to the raining season which is hampered due to rejuvenation of shrubs and trees.

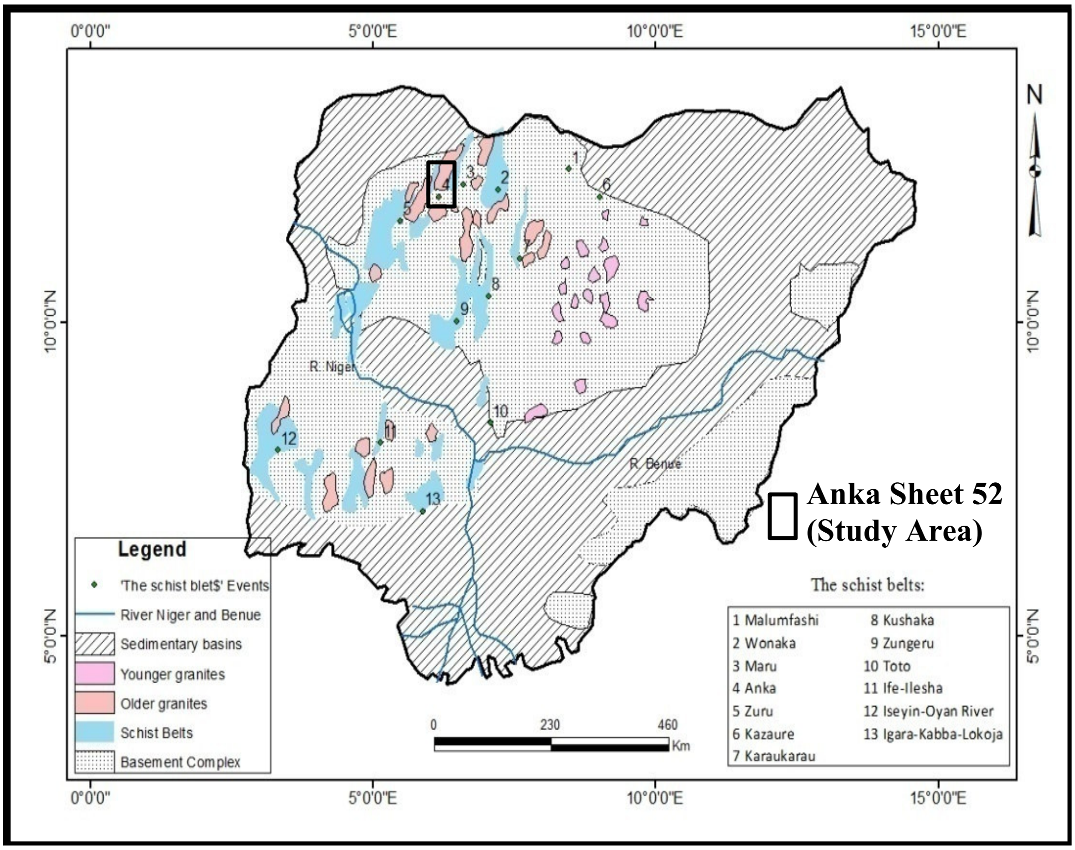


Figure 1: Schist belts localities within the context of the geology of Nigeria (After Woakes *et. al.,* 1987).

2. Geological Setting

The Nigerian basement complex is one of the three major litho-petrological components that make up the geology of Nigeria (1. Basement Complex which is Pan-African and older (Precambrian) ≥ ± 600 million years, 2. Younger Granites which is Jurassic 200–145 million years and 3. Sedimentary Basins which is Cretaceous to Recent ≤145 million years). Black (1980) stated that the Nigerian basement complex form part of the Pan-African mobile belt and lies between the West African and Congo Cratons, then south of the Tuareg Shield (Figure 2). The rocks are intruded by the Mesozoic calc-alkaline ring complexes (Younger Granites) of the Jos Plateau and unconformably overlain by Cretaceous and younger sediments.

Rahaman, (1988) in "Recent advances to the study of the Nigeria Basement Complex" subdivides the basement complex rocks into six major groups. They are;

i) Migmatite – gneiss – quartzite complex
ii) Slightly migmatised to non-migmatised metasediment and meta-igneous rocks. (The Schists)
iii) Chanockitic, gabbroic and dioritic rocks
iv) Members of the older granite suites
v) Metamorphosed to unmetamorphosed calc-alkaline volcanics and hypabyssal rocks.
vi) Unmetamorphosed dolerite dykes, basic dyke and syenite dyke.

According to (Dada, 2006) the Nigerian basement rocks was affected by the 600Ma Pan-African orogeny and it occupies the reactivated region which resulted from plate collision between the passive continental margin of the West African craton and the active Pharusian continental margin.

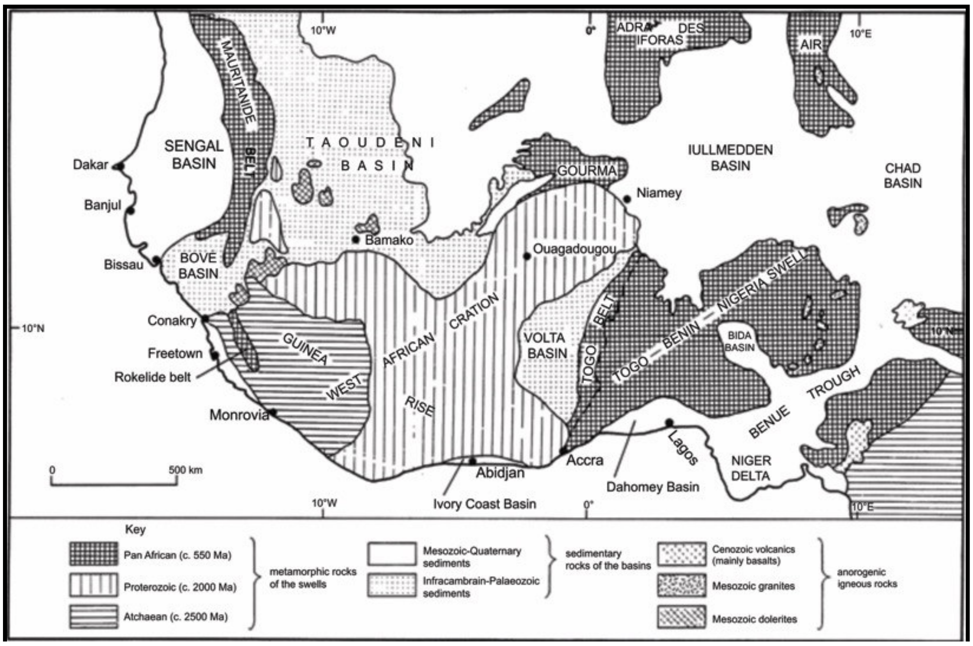


Figure 2: Generalized geological map of Nigeria within the framework of the geology of West Africa (Wright, 1985).

3. Methods

3.1. Field Mapping

Field mapping is an important approach for this study by taking every detail in the field deem necessary. Different places for the geological study were selected and location determined from maps produced from desk studies. Observations such as geologic boundaries, structures, physical appearances rocks and orientation with details were noted in field notebook. The different rock types at various locations and their properties were noted and marked in the map while samples obtained were properly numbered. All the available information such as the changes in rock type or structural characteristics on outcrop was also recorded with the help of photographs and sketches along with text description. Instruments used in the course of field mapping are; Hammer, Compass clinometer. Others includes; field vehicle, motorbike, measuring tape, field sampling bags, marker, bar magnet, dilute hydrochloric acid, digital camera and GPS.

3.2. Sample collection

Rock samples were collected from the exposed rocks. Seventy-six (76) rock samples were collected from the field regionally and labelled (A1-A76) see Table 1.

3.3. Petrographic Studies

Representative rock samples were prepared into thin section at Department of Geology, Ahmadu Bello University, Zaria. Standard Olympus BX51 transmitted light microscopy (magnification range between 4x to 50x) was used to study individual minerals in the rocks under plane and cross polarised light for microstructural observations to reconstruct the deformation features and mineralogical assemblages. The slides were also examined with a polarized light microscope at the regional office of the Nigeria Geological Survey Agency (NGSA) Abuja. An external digital camera, connected to the microscope eye piece and a laptop with the use of (AmScope software) aided clear and better view compare to eye strain through the eye piece of the microscope.

4. Results

Field sample points and coordinates for the study area are shown in (Table 1) and the physical study of the rocks during field mapping comprises the colour, texture, mineralogy, rock type and field relationships.
Four major rock types make up the geology of the study area (Anka Sheet 52) (Figure 3), they are;

i) **Gneiss** (grey and porphyroblastic in places)
ii) **Metasediments**, comprising of quartzite, quartz schist, pellitic schist, phyllite, hornfels and metaconglomerate.
iii) **Pan-African Granites**, comprising of coarse grained granites, porphyritic granites, granodiorite and rhyolite
iv) **Cretaceous Sedimentary Rocks**, comprising of basal conglomerate and sandstone.

Table 1: Sample points and coordinates for the study area

Sample Points	Latitude	Longitude	Sample Points	Latitude	Longitude
A1	12◦ 07' 14.1"	5◦ 57' 19.8"	A39	12◦ 09' 10.9"	5◦ 32' 54.2"
A2	12◦ 07' 50.2"	5◦ 57' 19.1"	A40	12◦ 03' 14.8"	5◦ 57' 14.9"
A3	12◦ 07' 11.3"	5◦ 54' 54.7"	A41	12◦ 11' 34.6"	5◦ 34' 08.9"
A4	12◦ 08' 09.7"	5◦ 53' 17.8"	A42	12◦ 03' 14.8"	5◦ 57' 14.9"
A5	12◦ 11' 26.7"	5◦ 50' 40.9"	A43	12◦ 01' 17.1"	5◦ 57' 24.1"
A6	12◦ 12' 33.4"	5◦ 50' 08.7"	A44	12◦ 09' 18.6"	5◦ 56' 22.3"
A7	12◦ 13' 25.3"	5◦ 49' 13.8"	A45	12◦ 10' 40.4"	5◦ 56' 30.4"
A8	12◦ 13' 47.7"	5◦ 48' 36.0"	A46	12◦ 11' 44.0"	5◦ 57' 02.9"
A9	12◦ 13' 49.6"	5◦ 48' 20.8"	A47	12◦ 12' 07.6"	5◦ 57' 26.6"
A10	12◦ 13' 55.4"	5◦ 47' 02.1"	A48	12◦ 12' 35.4"	5◦ 57' 06.7"
A11	12◦ 13' 54.4"	5◦ 46' 39.7"	A49	12◦ 13' 44.0"	5◦ 56' 35.5"
A12	12◦ 14' 31.4"	5◦ 46' 47.8"	A50	12◦ 14' 14.6"	5◦ 58' 27.7"
A13	12◦ 15' 48.9"	5◦ 46' 33.8"	A51	12◦ 13' 24.0"	5◦ 58' 58.8"
A14	12◦ 16' 44.5"	5◦ 47' 58.6"	A52	12◦ 14' 23.3"	5◦ 59' 38.9"
A15	12◦ 17' 02.0"	5◦ 46' 13.2"	A53	12◦ 16' 10.1"	6◦ 00' 00"
A16	12◦ 17' 30.8"	5◦ 44' 58.9"	A54	12◦ 17' 30.3"	5◦ 59' 06.1"
A17	12◦ 16' 37.4"	5◦ 44' 34.3"	A55	12◦ 17' 50.7"	5◦ 58' 58.1"
A18	12◦ 15' 35.3"	5◦ 41' 54.8"	A56	12◦ 19' 12.9"	5◦ 58' 21.6"
A19	12◦ 14' 52.3"	5◦ 41' 38.6"	A57	12◦ 20' 45.2"	5◦ 55' 36.4"
A20	12◦ 15' 44.6"	5◦ 43' 15.8"	A58	12◦ 11' 11.0"	5◦ 53' 37.9"
A21	12◦ 15' 07.5"	5◦ 38' 53.0"	A59	12◦ 20' 14.3"	5◦ 52' 04.0"
A22	12◦ 14' 21.7"	5◦ 38' 35.1"	A60	12◦ 20' 42.3"	5◦ 49' 08.8"
A23	12◦ 13' 20.9"	5◦ 39' 25.5"	A61	12◦ 12' 14.1"	5◦ 46' 29.4"
A24	12◦ 11' 12.4"	5◦ 40' 15.1"	A62	12◦ 12' 55.3"	5◦ 49' 40.5"
A25	12◦ 08' 55.0"	5◦ 40' 02.7"	A63	12◦ 12' 26.2"	5◦ 52' 21.6"
A26	12◦ 08' 33.0"	5◦ 40' 01.2"	A64	12◦ 12' 06.3"	5◦ 52' 10.7"
A27	12◦ 07' 13.8"	5◦ 41' 05.7"	A65	12◦ 11' 50.0"	5◦ 52' 11.9"
A28	12◦ 04' 51.2"	5◦ 42' 10.8"	A66	12◦ 11' 44.0"	5◦ 52' 28.5"
A29	11◦ 59' 45.7"	5◦ 47' 28.9"	A67	12◦ 11'40.6"	5◦ 53' 10.9"
A30	12◦ 00' 32.6"	5◦ 39' 45.4"	A68	12◦ 11' 30.2"	5◦ 53' 34.6"
A31	12◦ 00' 44.1"	5◦ 39' 39.1"	A69	12◦ 11' 15.8"	5◦ 53' 31.3"
A32	12◦ 01' 19.2"	5◦ 33' 01.8"	A70	12◦ 10' 49.5"	5◦ 53' 09.6"
A33	12◦ 02' 16.2"	5◦ 32' 41.6"	A71	12◦ 11' 10.7"	5◦ 52' 40.4"
A34	12◦ 04' 28.6"	5◦ 33' 18.0"	A72	12◦ 11' 08.3"	5◦ 52' 01.3"
A35	12◦ 04' 44.1"	5◦ 32' 10.2"	A73	12◦ 11' 20.2"	5◦ 52' 06.0"
A36	12◦ 04' 38.2"	5◦ 33' 37.5"	A74	12◦ 12' 06.3"	5◦ 52' 52.9"
A37	12◦ 05' 58.6"	5◦ 32' 07.4"	A75	12◦ 12' 01.1"	5◦ 53' 13.3"
A38	12◦ 06' 58.6"	5◦ 31' 58.8"	A76	12◦ 12' 09.1"	5◦ 53' 36.1"

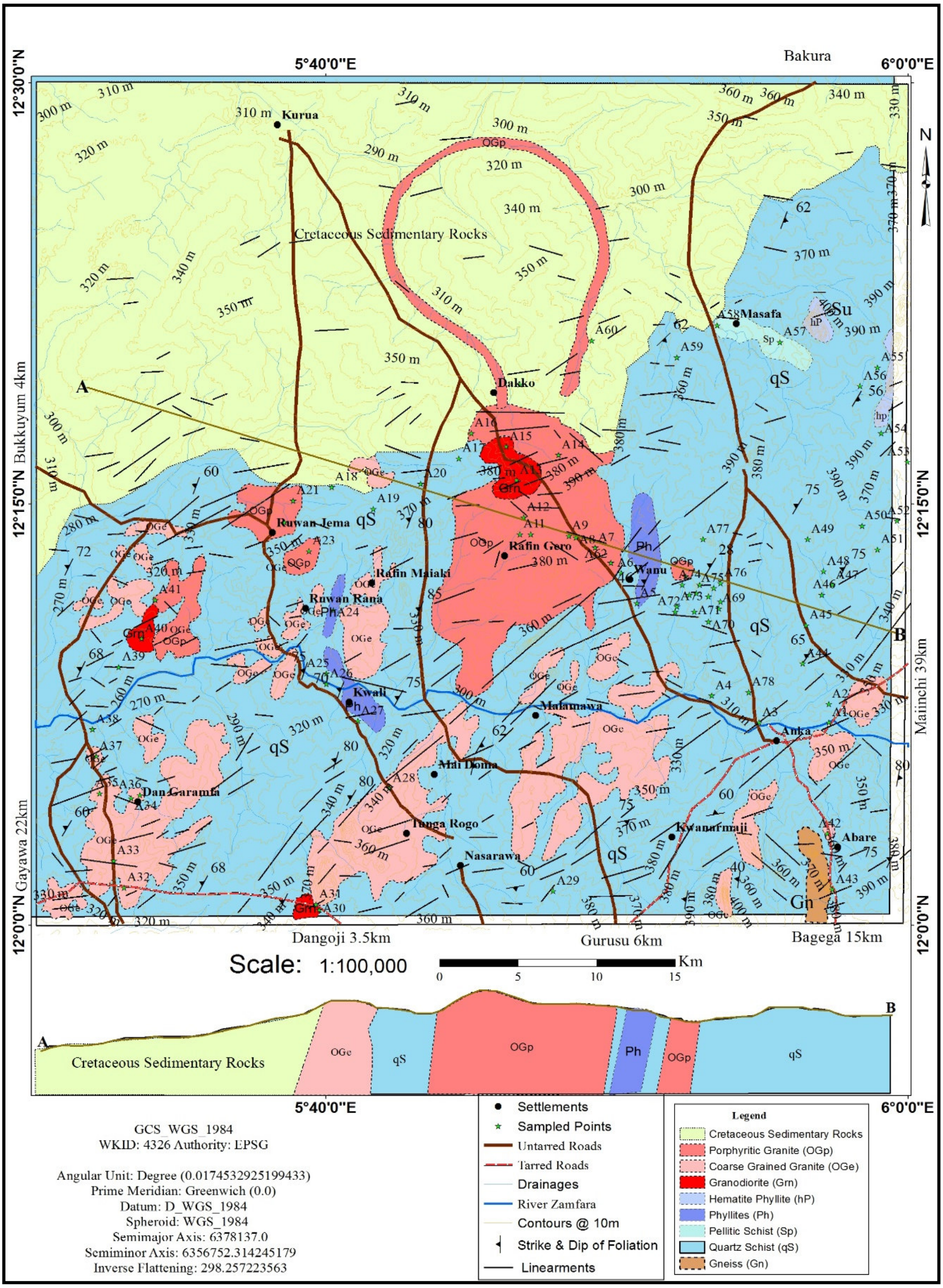


Figure 3: Geological sketch map of the study area (Anka Sheet 52)

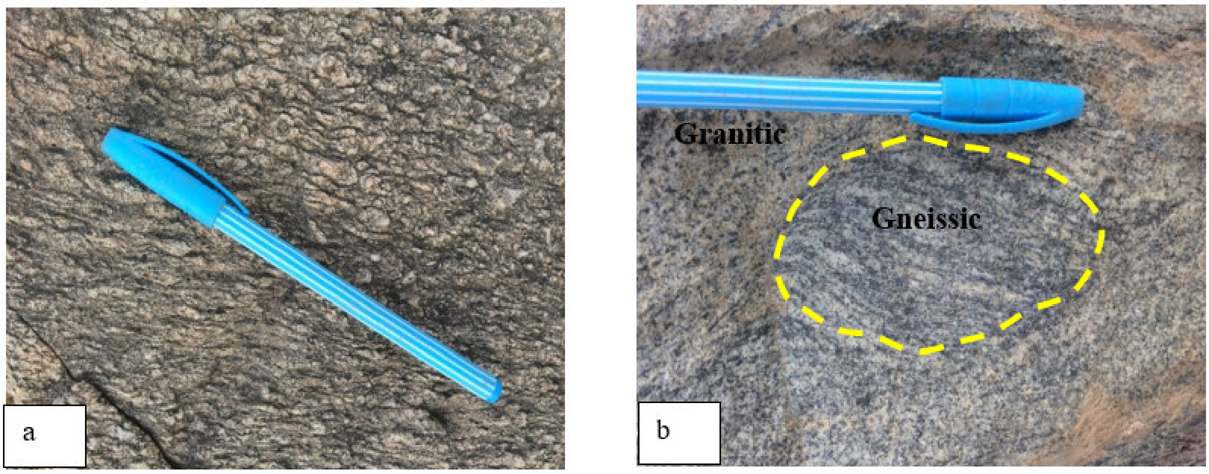


Figure 4: **(a)** Outcrop photograph of porphyroblastic gneiss along Abare-Dereta road with gradual lineation of quartz and feldspar in a preferred orientation. **(b)** Outcrop photograph of sheared gneiss road showing a xenolith of gneiss within granitic textures as an evidence of variation in temperature-pressure.

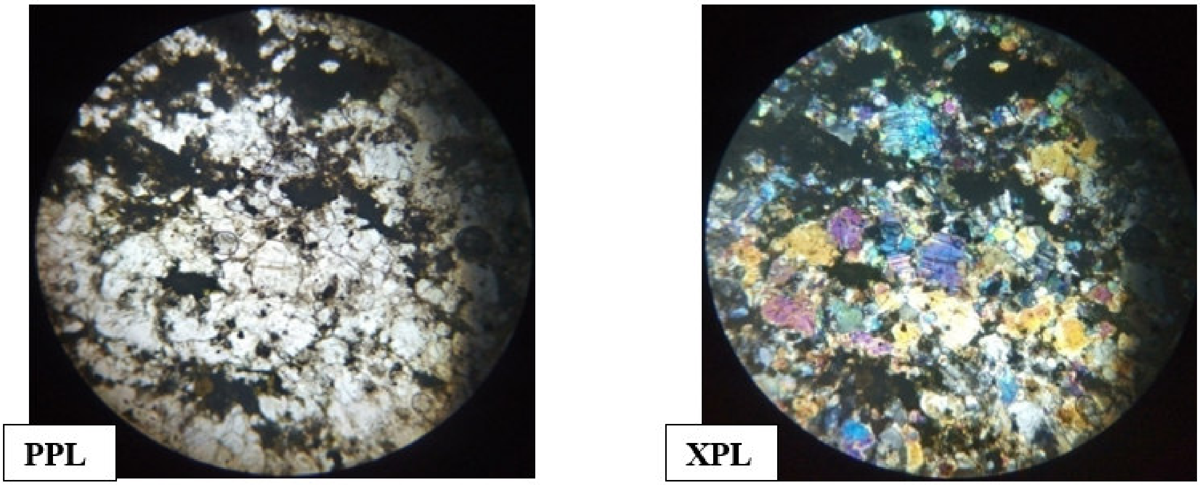


Figure 5: Photomicrographs of gneiss sample (A43) showing K-feldspar porphyroblasts of the metasome pushing idiomorphic biotite flakes aside thereby enriching this mineral at the growing edge.

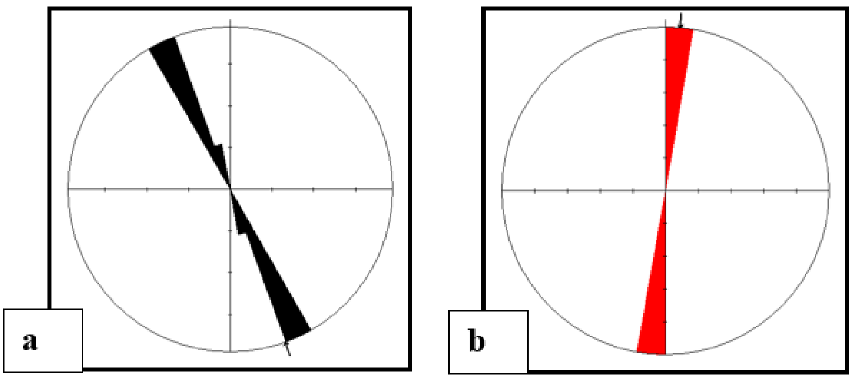


Figure 6: Rose plot of **(a)** primary (NNW-SSE) and **(b)** secondary (NNE-SSW) joints on Abare-Derita gneiss.

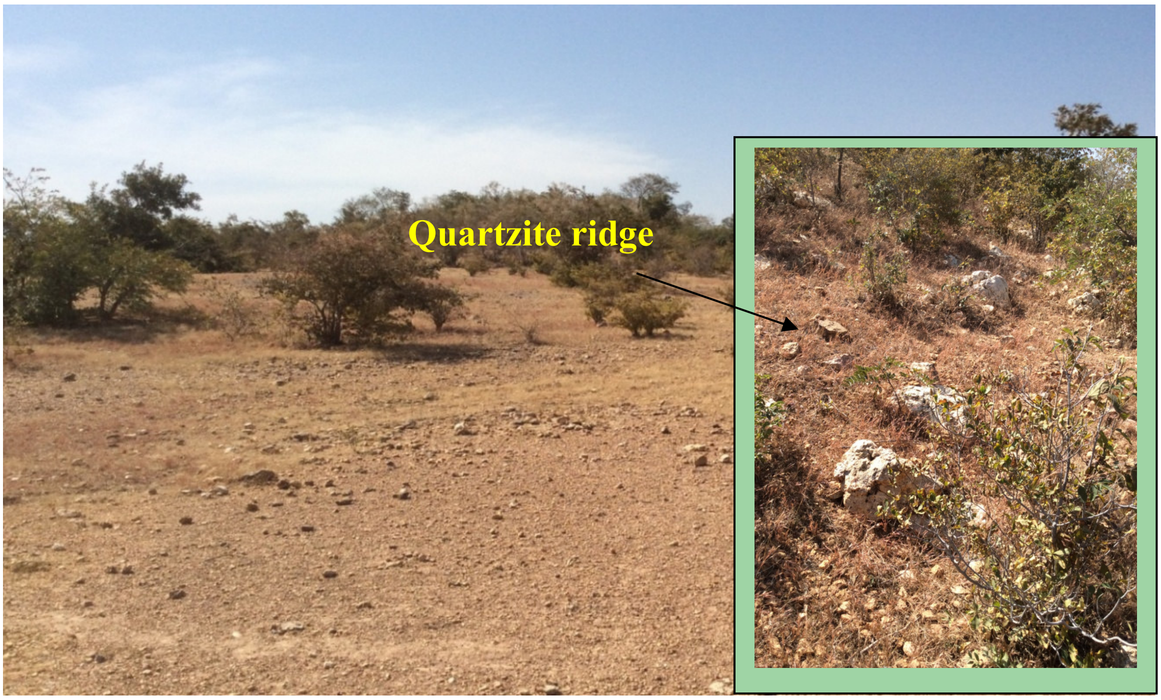


Figure 7: Outcrop photograph of a quartzite ridge trending in 058°. (Insert; a closer view of the quartzite from the ridge). Lat. 12° 14′ 14.6″, Long. 5° 58′ 27.7″

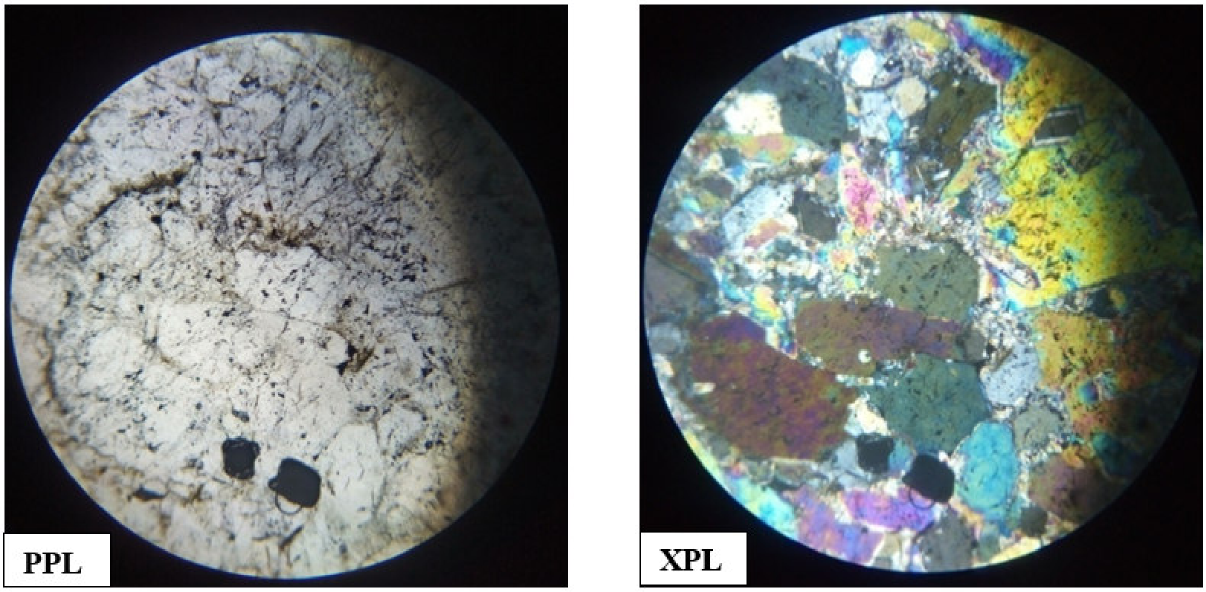
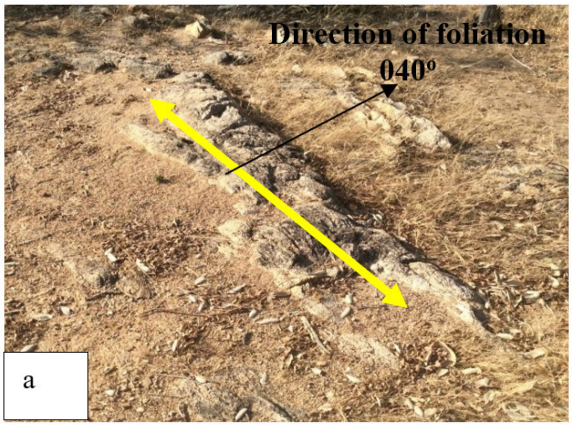


Figure 8: Photomicrographs of quartzite sample (A5) consisting of predominantly quartz as major constituents with biotite and muscovite as accessory minerals.



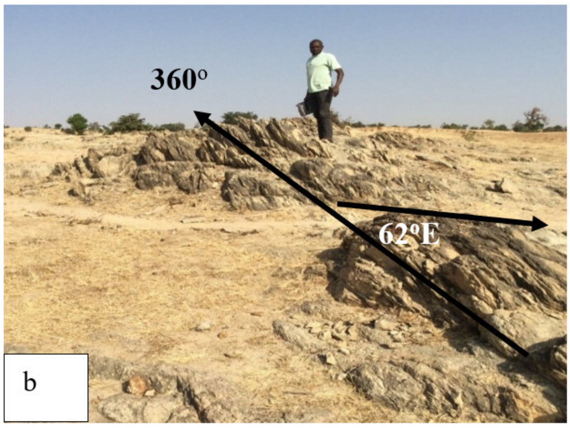


Figure 9: **(a)** Outcrop photograph of weathered flat-lying quartz schist (A3) trending 040°, Lat. 12 ° 07′ 11.3″, Long. 5° 54′ 54.7″ and **(b)** weathered low-lying quartz schist (A4) trending 360° and dipping 62°E, Lat. 12 ° 08′ 09.7″, Long. 5° 53′ 17.8″.

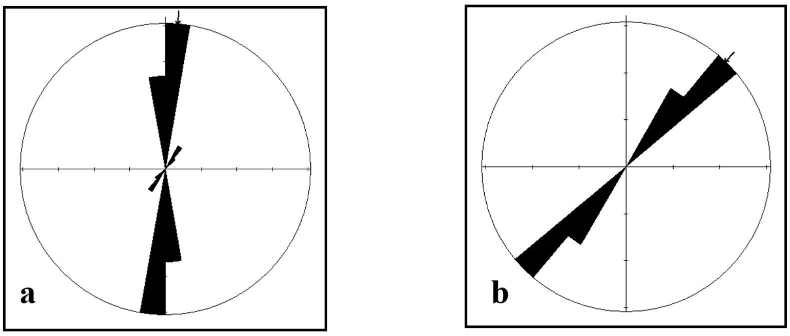


Figure 10: Rose plot of **(a)** N-S foliation trend and **(b)** NE-SW joints orientation in quartz schist.

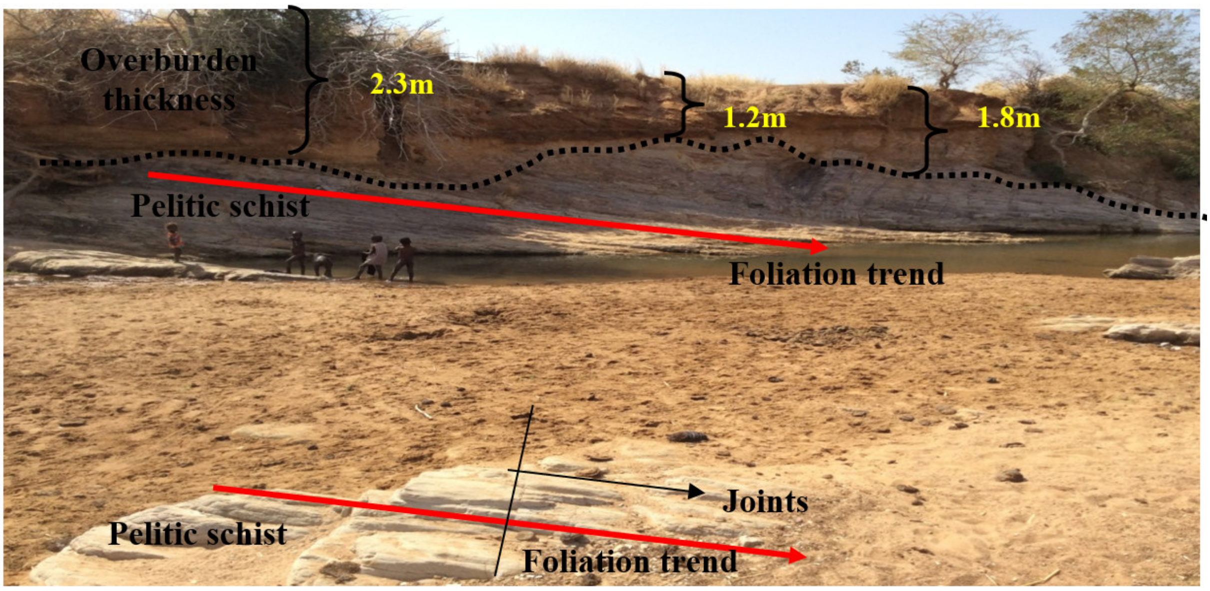


Figure 11: Outcrop photograph pelitic schist (A58a) trending 010° and dipping at 20° to the west. Lat. 12° 11′ 11.0″, Long. 5° 53′ 37.9″.

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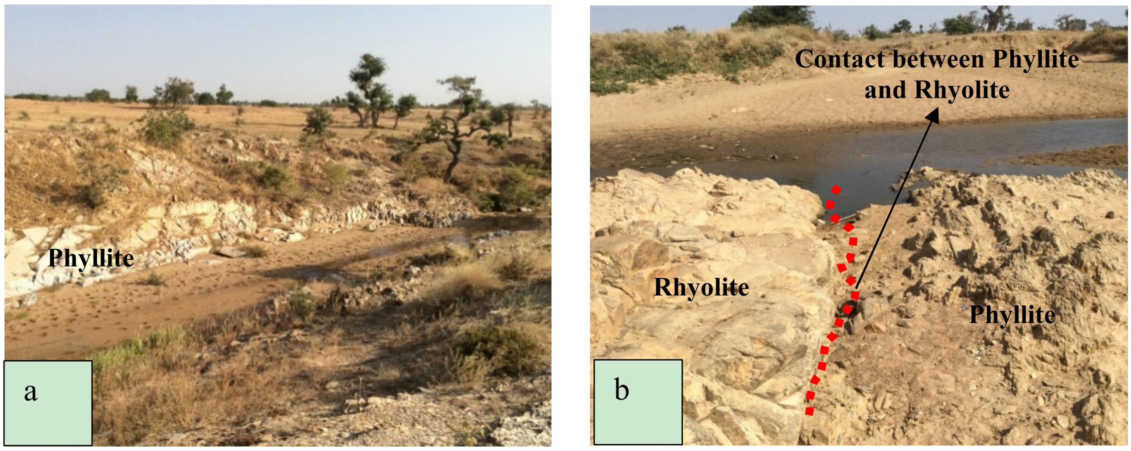

Figure 12: **(a)** Outcrop photograph of phyllite (A24) exposed along a river channel and trends at 180° with a dip of 60° to the west. **(b)** Outcrop photograph of phyllite intruded by rhyolite (A6). Lat. 12 ° 11′ 33.4″, Long. 5° 50′ 08.7″

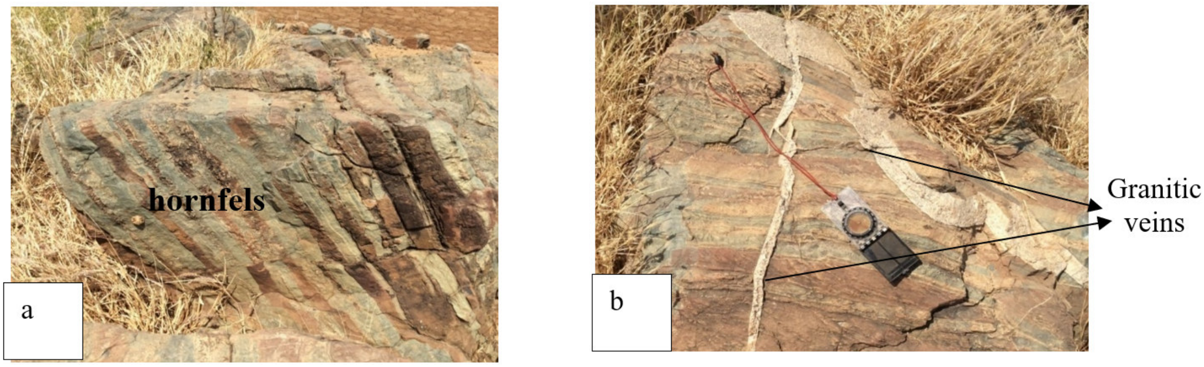

Figure 13: (**a**) Outcrop photograph of banded hornfels (A9a) (**b**) Outcrop photograph of hornfels (A9b) formed by contact metamorphism of sandstones and shale of the Metasediments by Pan-African granite intrusions. Lat. 12° 13′ 49.6″, Long. 5° 48′ 20.8″.

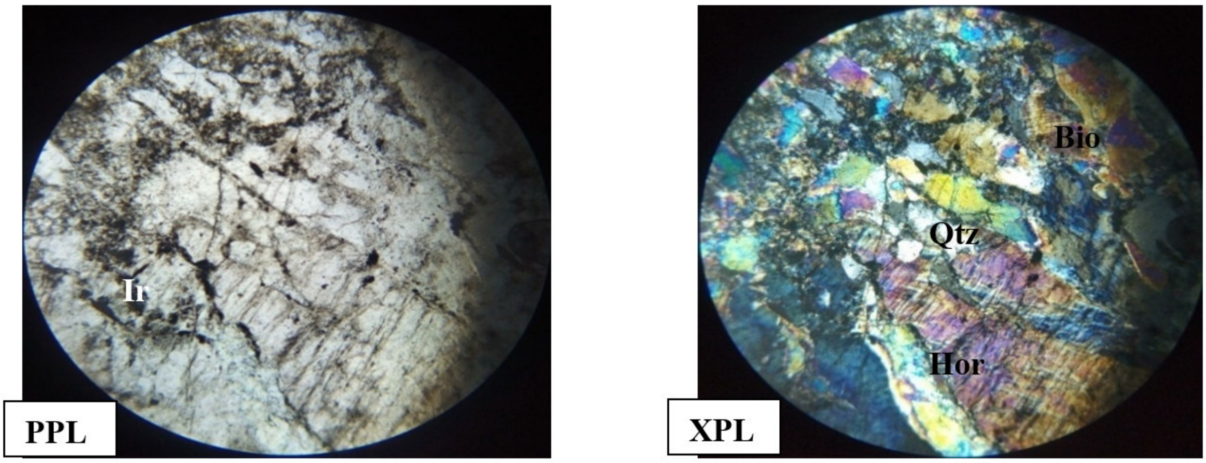

Figure 14: Photomicrographs of biotite (Bio) grading into actinolite/hornblende (Hor) (thread-like) in hornfels sample (A9). In plane plane-polarized light, variation is visible at the rims between the biotite and hornblende with iron concentration along the cleavage. Quartz (Qtz) and Iron (Ir).

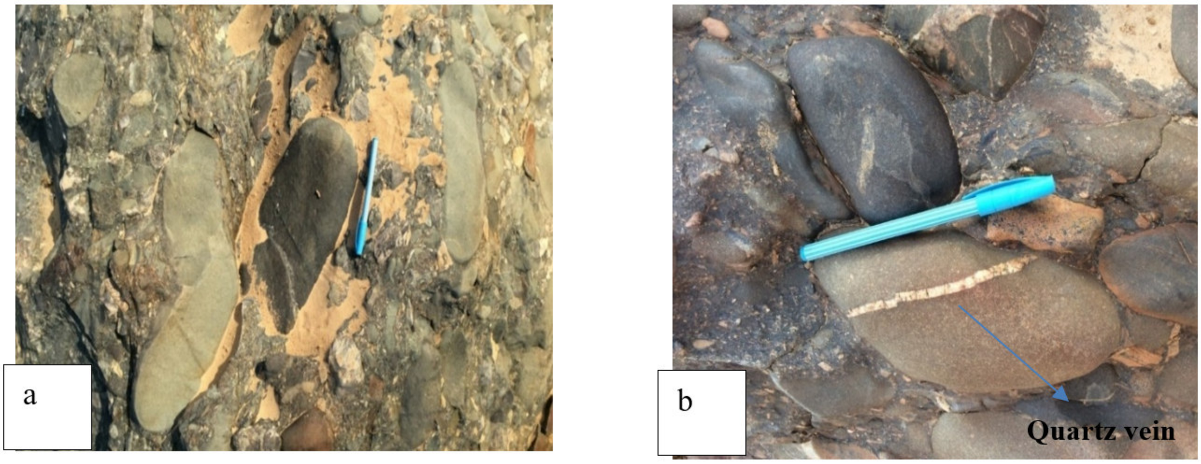

Figure 15: **(a)** Outcrop photograph of meta-conglomerate at Bunkasau showing a slippers shaped large clasts within matrix of smaller clasts and (**b**) showing an inherited quartz vein in the clasts before metamorphism. Lat. 12° 08′ 33.0″, Long. 5° 40′ 01.2″.

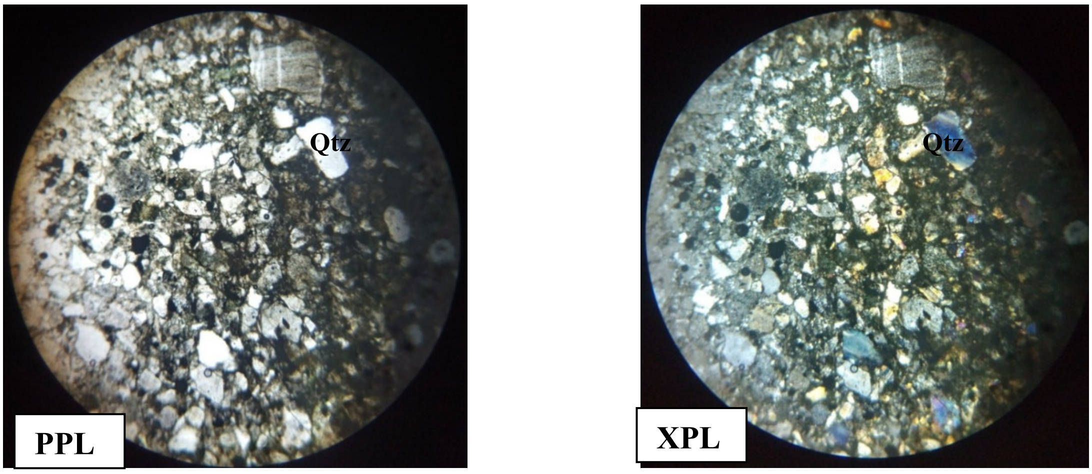

Figure 16: Photomicrographs of granitic rock extract from meta-conglomerate sample showing quartz, biotite and hornblende as major mineral component and minor mafic minerals.

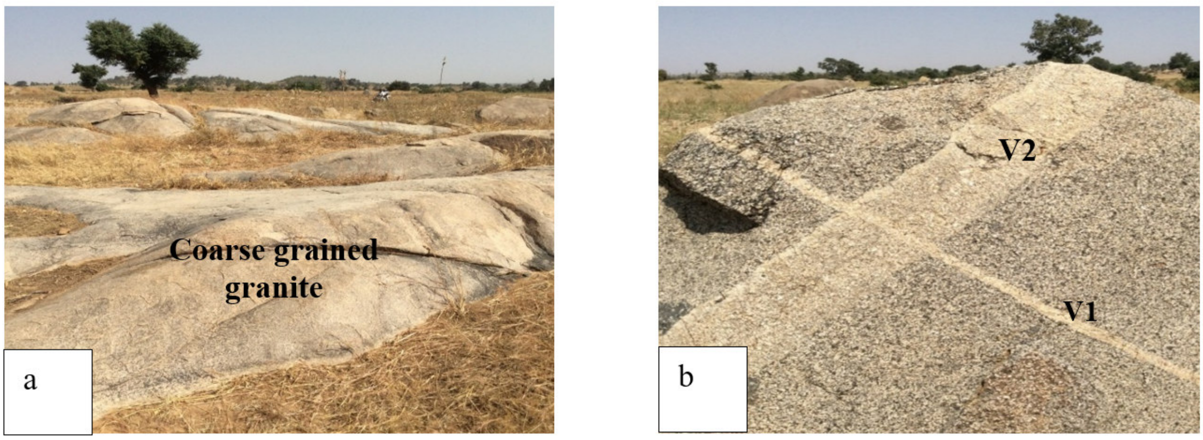

Figure 17 **(a)** Outcrop photograph of coarse grained granite (A8) showing No visible contact with host rock while **(b)** an outcrop photograph of coarse grained granite (A14) showing two (2) generation of granitic veins noted as primary (V1) and secondary (V2). Lat. 12° 16′ 44.5″, Long. 5° 47′ 58.6″.

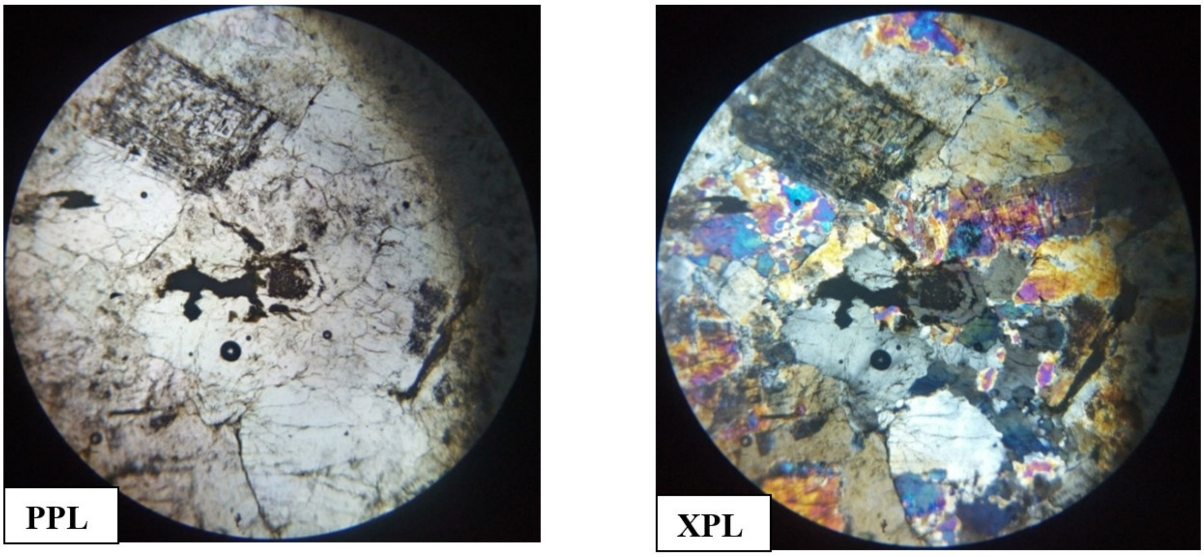

Figure 18: Photomicrographs of quartz and zoned plagioclase feldspar (albite) with stains of biotite in coarse grained granite sample (A8).

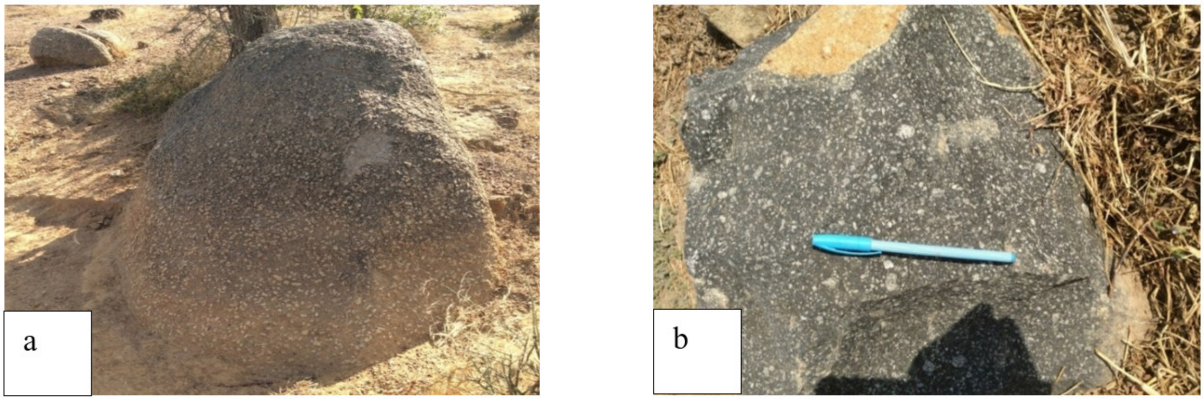

Figure 19 **(a)** Outcrop photograph of porphyritic granite (A21) at Ruwan Jema and **(b)** outcrop photograph of diorite (A29) exposed along Anka -Bukuyyum road.

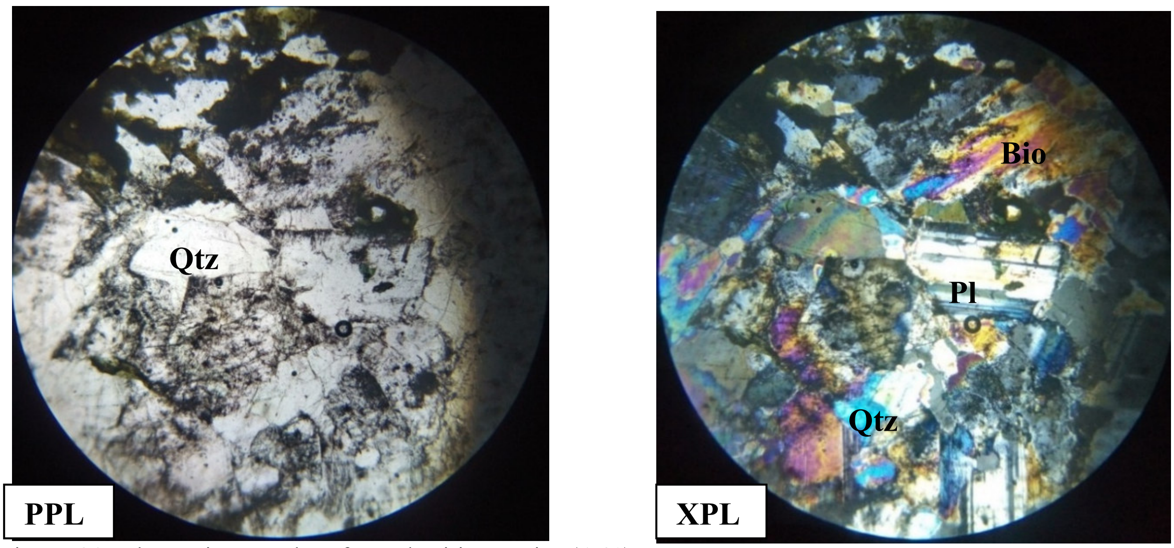

Figure 20: Photomicrographs of porphyritic granite (A41)
showing interlocking crystal of minerals identified as quartz (Qtz), *plagioclase (Pl)*, *biotite (Bio)*, small amounts of hornblende (Hor) and iron.

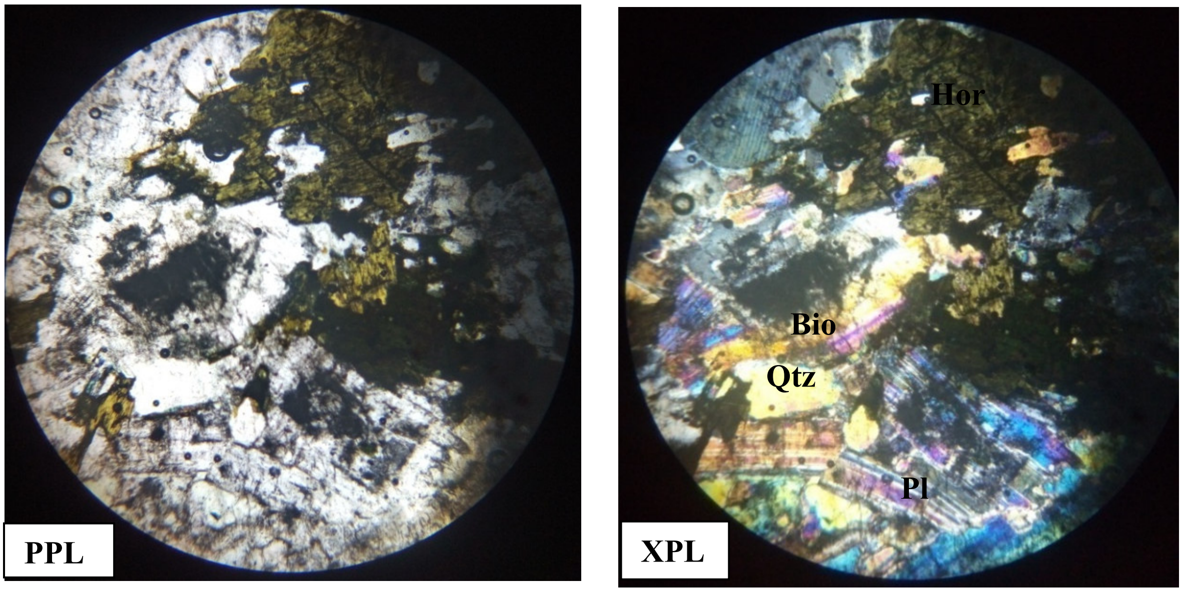

Figure 21: Photomicrographs of hornblende (Hor) plagioclase (Pl), Biotite (Bio) and quartz (Qtz) in diorite sample (A29).

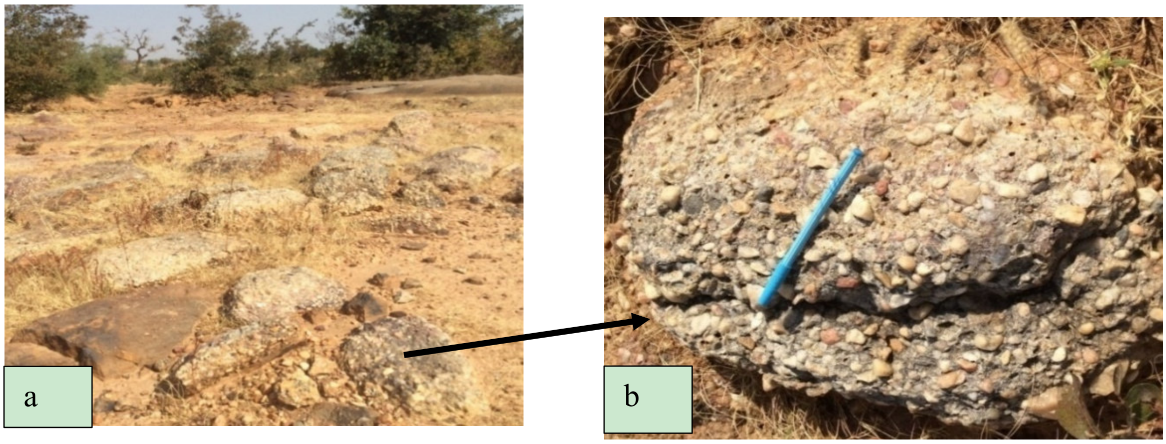

Figure 22: Outcrop photograph of weathered basal conglomerate (A18). Lat. 12° 15′ 35.3″, Long. 5° 41′ 54.8″.

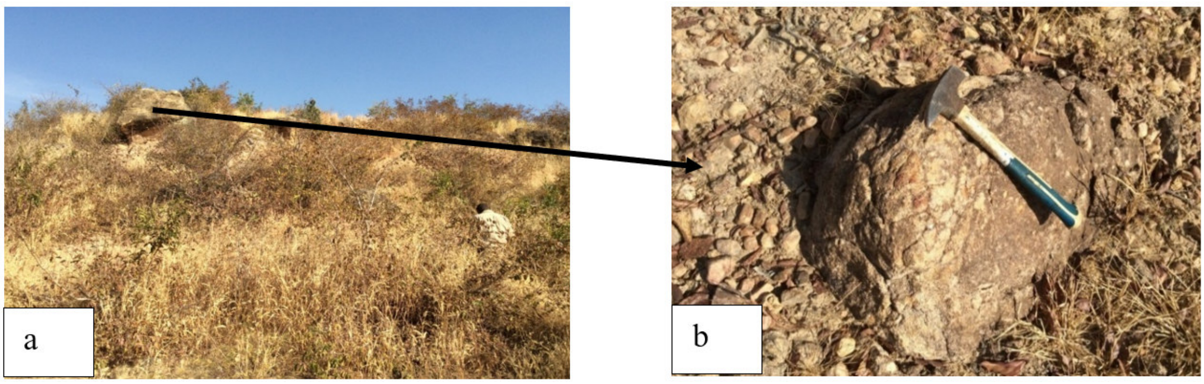

Figure 23: **(a)** Outcrop photograph of sandstone (A61) with **(b)** closer view of the sandstone.

5. Discussion

An outcrop of porphyroblastic gneiss along Abare-Dereta road with gradual lineation of quartz and feldspar in a preferred orientation is shown in (Figure 4a) and also mapped on the outcrop is a sheared gneiss showing a xenolith of gneiss within granitic textures as an evidence of variation in temperature-pressure (Figure 4b). Petrographic studies on the gneiss revealed K-feldspar porphyroblasts of the metasome pushing idiomorphic biotite flakes aside thereby enriching this mineral at the growing edge (Figure 5). Primary (NNW-SSE) and **(b)** secondary (NNE-SSW) joints were studied on the Abare-Derita gneiss (Figure 6). Figure 7 is an outcrop photograph of a quartzite ridge trending in 058^o and petrographic studies on the quartzite revealed quartz as major constituent mineral with minor biotite and muscovite. The quartz schist (Figure 9a) has medium to large, flat, sheet-like grains in a preferred orientation (between 040^o- 360^o in places), dips to the west and to the east in places (Figure 9b). Foliation on the quartz schist were studied in the field and data plotted as shown in rose plot (Figure 10a) and joints orienting (NE-SW) 048^o (Figure 10b). The pelitic schist trends in 010^o and dipping at 20^o to the west (Figure 11). It has multiple and parallel joints in an average of 088^o. At Masafa village it trends 170^o and dips at 60^o to the west with multiple and parallel joints in an average of 072^o. Phyllite occurred as low-lying outcrop and mostly exposed along a river channel, it trends at 180^o with a dip of 60^o to the west (Figure 12a) and at 150^o with a dip of 020^o in places. In another location the phyllite is intruded by sugary textured rhyolite (Figure 12b). Hornfels (Figure 13a) were mapped arround Rafin Gero village with a granitic textured rock as veins. Petrographic studies of the hornfels show that biotite grades into hornblende (Figure 14) with variation visible at the rims between the biotite and hornblende with iron concentration along the cleavage. The meta-conglomerate was mapped extensively along river Zamfara around Bunkasau village. Figure 15a shows a slippers shaped clasts of medium grained granite which inherited quartz vein before metamorphism (Figure 15b). Recovery of gold along the river channel by Artisans was encountered during mapping. Petrographic studies on granitic rock extract from the meta-conglomerate (Figure 16) revealed a medium to fine grained textures crystals of predominant quartz and biotite with minor hornblende in addition to mafic minerals. The granites within the study area comprises of coarse grained granites, porphyritic granites, diorite and rhyolite. These rocks accounts for about 20 percent of the total area mapped. The coarse grained granite forms the basic constituents of the granite suites in the study area and are more widespread (Figure 17a). The rock is weathered and shattered at Rafin Gero with NO visible field contact with host rock and also occurred as inselberg. Two (2) generation of granitic veins were noted as primary (V1) and secondary (V2) on the coarse grained granite mapped at location A14 (Figure 17b). Petrographic studies revealed quartz and zoned plagioclase with stains of biotite in coarse grained granite sample studied at location A8 (Figure 18). A grey coloured porphyritic granite within the study area occurs mostly as flat-lying and as small enclaves around Ruwan Jema (Figure 19a) and at Sabon Geri Sesawa. Diorite is less widespread in the study area and are only mapped as low to flat-lying outcrop along Anka- Bukkuyum road (Figure 19b) and are too small to be represented on the regional map. In the porphyritic granite sample, petrographic studies revealed hornblende, plagioclase, biotite and quartz as the major mineral constituent and the plagioclase occurred as phenocryst with lamellar twining (Figure 20) while in the hornblende, plagioclase, biotite and quartz are the major mineral constituent (Figure 21).

6. Conclusion

The Precambrian to Pan-African basement rocks which occur in northwestern Nigeria and cretaceous sedimentary rocks of Sokoto basin are duplicated in the study area. These rocks are gneiss (greyish and porphyroblastic in places) representing the migmatite-gneiss group of sedimentary protolith, quartzite, quartz schist, pellitic schist, phyllite, hornfels and meta-conglomerate representing the metasediments; coarse grained granites, porphyritic granites, diorite and rhyolite represents the Pan-African granites while basal conglomerate and sandstone represents the sedimentary group. The gneiss is the oldest rock unit forming a massive sheared and elongated ridge trending north-south for about 1800m with a porphyroblastic texture of gradual lineation of quartz and feldspar in places. Two cross-cutting joints of primary (NNW-SSE) 160^o and secondary (NNE-SSW) 008^o developed on the gneiss such that the later which obliterate the earlier suggests evidence of post tectonic deformation after the initial tectonism that form the primary joints inherited in the rock before displacement and post metamorphic tectonic deformation on the rock. Other structures observed on the grey gneiss include mylonitic textures resulting from a rather ductile fault shear zone signifying modification of the regional textures characterized by plastic flow predominantly due to dynamic recrystallization. The well-defined foliation bands of micas and felsic minerals studied as a common feature on the grey gneiss probably indicate that metamorphism in this area possibly reach a higher green schist facies. Rocks in the study area is composed chiefly of very poorly exposed, commonly homogeneous quiet-water argillites are in line with this studies as coarse clastic units and the magmatic rocks both yielded information concerning palaeo-environments and geotectonics evolution of the belt respectively. The Pan-African granites intruded both the gneiss and metasediments and the coarse grained granite forms the major constituents of the granite suites and are more widespread. It is light-coloured with grains of quartz and feldspar with minor amounts of mica which may have resulted from slow crystallization of magma below Earth's surface. Basal conglomerate and sandstone form the cretaceous sedimentary rocks unconformably overlying the basement complex rocks in close contact. In quintessence, the study area comprises of low grade metasedimentary rocks of Proterozoic time and intruded by a sedimentary sourced granitic plutons active during Pan African time. Field and petrological studies indicates that the Pan-African reworking may have led to the recrystallization of the protolith rocks to form gneiss (paragneiss) resulting from partial melting signifying that metamorphism possibly reach lower amphibolite facies in part of the study area. These rocks were overlain by sedimentary rocks of Cretaceous age.

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