Petrology and Structural Features of Tsiga and its Environs Northwestern Nigeria.

ABSTRACT

The major rock types mapped in the area include gneisses and granites associated with minor rocks such as xenoliths and some structural features including foliation, joints, faults and veins (quartz and pegmatite).The mineralogy includes feldspar (orthoclase and plagioclase), quartz, biotite and some accessory minerals. These rock types and the associated structural features have their trends in N-S direction. The structural analysis of joints on the granites of the study area shows that the joints have a trend of NNE-SSW. The joints on the gneisses have a trend of NE-SW. In terms of age relationships of the rocks, gneisses are older than the granites based on deformed features. The gneisses probably originated from sediments, para-gneisses. The granites must have resulted from magma intrusion. The structures in the study area suggests the imprint of the Pan-African Orogeny, as indicated by the structural analysis of fractures. The major rivers in the study area include Yali and Moryaji with their tributaries which formed a dendritic drainage pattern, and are structurally controlled. Surface water occurs during the raining season and underground water are available in the area, occurring in shallow pit dug along the stream and river channels, and the fractured crystalline aquifer. The economic potentials in the area includes; rock aggregates, lateritic soil and alluvium deposits which are used for different purposes and include building houses and construction of roads and bridges.

Keywords: Rock Types, Deformation, Structural Features, Pan-African, Magmatism, Tsiga NW, Nigeria.

1. Introduction

Tsiga area is part of Malumfashi sheet 79 SW. It lies within Latitude 11^{0}35'21.0"N to 11^{0}39'21.0"N and longitude 007^{0}30'00.0"E to 007^{0}32'30.0"E. The area covers about 40km². Prominent towns in the area includes; Ungwan Koli in the northwest, Ugwan Gero to the north, and Zagezegi and Ungwan Maitokibi in the eastern part. The area is accessible through a network of foot paths, minor and major roads that transverse from Bakori across the study area towards Funtua. In addition, the area has a fairly through network of dry streams and river channels. The area occurs within the Northern part of the Nigerian Basement Complex and [1]. [2] carried out a reconnaissance survey and mapped a part of sheet 79 geological map of Nigeria on a scale of 1:100,000 based mainly on photo-geological interpretation. She postulated that the rocks in the area belongs to the Nigerian Basement Complex and are of Precambrian to early Paleozoic age. [3] classified the rocks into three groups, viz: A crystalline complex of gneisses, migmatites and remnants of an ancient metasedimetary sequence (feldspathic, quartzites) constituting the oldest rocks and considered to be underlying the whole area. A late Proterozoic sequence of sediment folded and metamorphosed into syclinoral belt within the crystalline complex and metamorphosed to phyllites, quartzites, pelitic and psammitic schist and calcareous rocks of low to medium metamorphic grade (Greenschists

Facies). Intrusive rocks of Proterozoic to Cambrian age, including syn-orogenic to late-orogenic (Older Granites) Pan-African Granites , minor basic and ultrabasic dykes, pegmatite and aplite dykes. This research aim to map and identify the rocks in the study area on a scale of 1:25,000 and access their economic potentials.

2. Geological Setting

Tsiga constitutes part of the Nigerian Basement Complex, it forms part of the Pan-African mobile belt, which is situated between the West African Craton WAC, to the West and Gabon-Congo Cration GCC to the Southeast Turner, [4]. The Tuareg shield and the Togo-Benin-Nigerian shield units are separated by extensive Phanerozoic sediment [5]. Evidence from the eastern margin of the WAC indicates that the Pan-African belt evolved by plate tectonic processes, which involves the collision between the passive continental margin of the WAC and the active continental margin of the Taureg shield about (600Ma) [6]. The collision of the plate margin is believed to have led to the reactivation of the internal region of the belt in which the Nigerian Basement Complex lies. Figure 1.

is the geological map of the area showing the rock types.

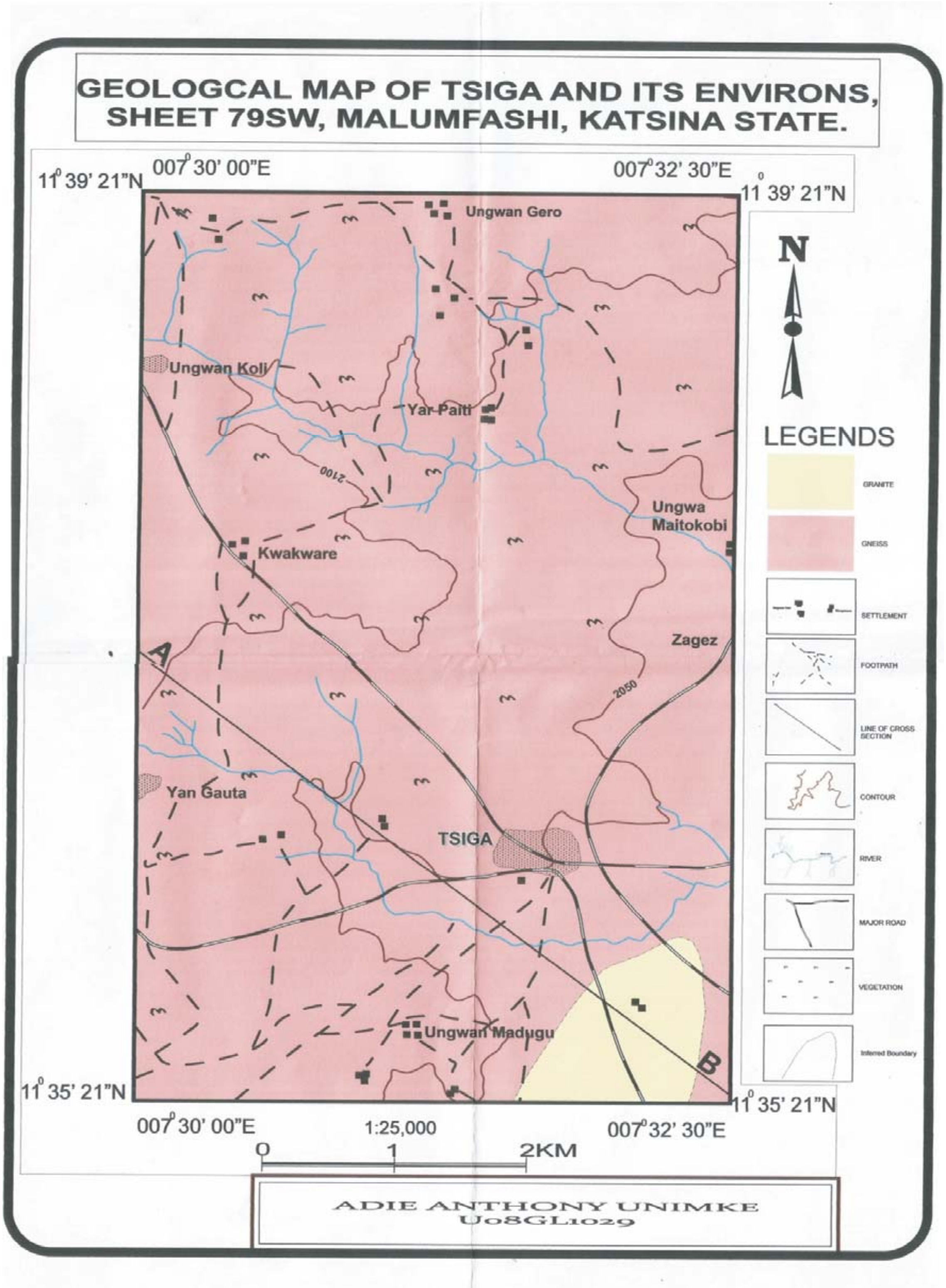

Figure 1

3. Methodology

Field mapping was carried out in the Tsiga area on topographic map of scale 1:25, 000, gneiss occupied about 95% of the mapped area and its exposures were encountered almost in the entire area except in the southeastern part of the study area. Most of the outcrops are low-lying, occurring sparingly on the surface hence, most of the observed occurrences are found along stream and river channels where the overburden lateritic materials have been eroded out. Their outlines are mostly circular with a general, trend in NE-SW direction. Some of the exposures in the field have their elevation between 0.5-2m above the surrounding areas, having a sharp or gradational contact with adjacent rocks. The surface in the study area includes the major seasonal rivers, as well as their ephemeral tributaries which were all dry during the period of mapping exercise.

4. Results and Discussion

Petrological and Structural Analysis

The major rock types mapped in the area include gneisses and granites associated with minor rocks such as xenoliths and some structural features including foliation, joints, faults and veins (quartz and pegmatite). The mineralogy includes feldspar (orthoclase and plagioclase), quartz, biotite and some accessory minerals. These rock types and the associated structural features have their trends in N-S direction, which suggest the imprint of the Pan-African Orogeny. The structural analysis of joints on the granites of the area shows that the joints have a trend of NNE-SSW. The joints on the gneisses have a trend of NE-SW direction. In terms of age relationships of the rocks, gneisses are older than the granites. Plates 1, 2 and 3, are field photographs showing foliation in gneisses and xenoliths in porphyritic granite. In Igarra region southwestern Nigerian Basement Complex the granites which are syn-tectonic also contains joints and mineral veins [7].

Plate 1: Field photograph showing gneissosity foliation on gneiss exposure with the coordinates; $11^0 38'$ 22.7"N and 007^0 32' 02.1'E'

Plate 2: Field photograph of a highly foliated weathered gneiss along a river channel with coordinates; latitude $11^0 36'$26.5"N, and longitude $007^0 31'$13.8"E

Petrographic analysis

The gneiss display a light-dark colour (grey); it has an alternation of felsic and ferromagnesian minerals aligned in a preferred N-S direction. The texture is generally medium to coarse-grained; the grain size is between 0.1cm and 0.3cm. Feldspar crystals form the porphyroblast grain while biotite constitutes dominantly in the groundmass with some amount of quartz. The rock is well foliated and composed of feldspars, biotite and quartz in the order of abundance. The major minerals include orthoclase, plagioclase, biotite, quartz and microcline with some accessory minerals.

Plate 3: Field photograph of Xenolith observed on a porphyritic granite due to incomplete obliteration of the country rock at location with the coordinates; latitude $11^{0}35'$ 27.2"N, and longitude $007^{0}32'$ 07.8"E

The presence of the minor xenoliths mapped in the area, demonstrated that the protoliths or the country rock as postulated by some geologist, from different locations within the basement complex were not completely obliterated during the metamorphism, remobilization, reactivation of the Pan-African orogenic events. The granite have dome shape structure and exfoliation structures as result of weathering Plates 4 and 5 while pegmatite intrusion as dyke was observed on Plate 6.

Plate 4: Field Photograph showing the field occurrence of granite in the study area with coordinates; latitude $11^{0}37'40.2''$N, and longitude $007^{0}32'22.8''$E

The outcrops occur in pockets, having a well back shape, and some in form of boulders with irregular outline, trending in N-S direction (Pan African orogeny) with gradational contact with its host rock. The granite exposures have average elevation between 1.5 and 3.5m above the ground level. The texture of the rock is porphyritic. Xenoliths and structures like joints and veins (quartz and pegmatite) were observed on the exposures. Both mechanical and biological weathering (exfoliation and roots penetration through fractures) were observed on the exposures.

Plate 5: Field Photograph of a specimen of granite obtained at a location with the coordinates; latitude $11^0$35’46.5”N, and longitude $007^0$32’ 14.8”E.

Plate 6: Field Photograph of a pegmatite dyke observed in a weathered gneiss with coordinates; latitude $11^0$37’46.5”N, and longitude $007^0$32’05.8”E

The fresh sample obtained is light in color (greyish), porphyritic in texture with feldspar forming the phynocryst ranging from 0.5-1.5cm in size. The pinkish coloration observed on the phynocryst is as a result of alteration. Biotite, feldspar and quartz constitute the major minerals and also predominates in the groundmass. Visual estimates of minerals in the rock using hand lens shows that the milky-pinkish color mineral predominate (that is, feldspar) followed by the dark (biotite) and then the glassy (quartz) minerals in the order abundant, i.e., feldspars constitute about 48%, biotite 25%, quartz 20 and other necessary minerals constituting about 79%.

The rock is poyhyritic, none foliated, and the minerals are mostly euhedral to subhedral in shape. The rock is composed of orthorclase feldspar, biotite, quartz and plagioclase feldspar in the order of abundant. The Photomicrograph of the thin sections of the minerals are shown on Plates 7 – 10.

Orthoclase

It is colourless to cloudy at the edges of the crystals due to incipient alteration in plane polarized light (PPL) and cross polarized light (XPL) and shows a weakly two directional cleavage with a Carlsbad twinning. It is subhedral in shape, with some crystal displaying myrmekitic texture (an intergrowth of quartz in orthorclase crystal) with white-gray interference colors, low relief and constitutes about 23% of mineralogical composition of the rock.

Plagioclase

Plagioclase occurs as colorless crystals in plane polarized light and milky white when observed under crossed polarized light. The crystals are subhedral in shape and exhibit polysynthetic twinning, low relief and low extinction angle. The mode percentage composition is about 17%.

Biotite

Biotite appers pale green to reddish brown crystals in PPL and XPL (Plane polarized light and cross polarized light respectively), and strongly pleochroic. The crystals are subhedral with a needle form with moderate relief. It constitutes about 12% of the rock.

Quartz

The mineral occur as colorless crystals, medium in grain size and anhedral in shape. It occurs as ground mass, without cleavage but exhibits undulatory extinction, fractured with moderate relief. It has a percentage composition of about 35%.

Microcline

The mineral is colorless and milky white plane and cross polarized light respectively. It occurs as anhedral crystal, exhibiting lenticular cross-hatched twins and constitutes about 8%.

Accessory Minerals

These account for about 5% of the total rock composition and include the opaque minerals which appeared dark both in plane and cross polarized light.

Orthoclase

It occurs as phenocryst. It is colorless to cloudy due to incipient alteration in plane and cross polarized light and shows a weakly two directional cleavage with a Carlsbad twining. The mineral is zoned. It is euhedral in shape, and shows white-gray interference colors, low relief and constitutes about 25% of the rock.

Biotite

It appears yellowish brown in plane polarized and cross polarized light and strongly pleochroic. The crystals are subhedral-anhedral in shape with a moderate relief. It constitutes about 24% of the rock.

Quartz

The mineral is colorless, medium in grain size and anhedral in shape. It occurs as ground mass, without cleavage but exhibits undulatory extinction, fractured with moderate relief. It has a percentage composition of about 26%.

Plagioclase

It is colorless in plane polarized light and milky white in crossed polar. Subhedral to Anhedral in shape, it exhibits a polysynthetic twining, low relief and low extinction angle. The percentage composition is about 12%.

Accessory Minerals

These include zircon has a high relief occurring as colorless prismatic and rounded grain matrix. The proportion of the mineral is about 8%.

Opaque Minerals

The opaque minerals are isotropic, occurring as black minerals under both the plane polarized and crossed polarized light composition 4%.

Table 1. Average modal composition of minerals of some rocks in Tsiga area

Minerals	**Gneiss**	**Granite**
Qaurtz	35	26
Orthoclase	23	25
Microcline	8	-
Plagioclase	17	12
Biotite	12	24
Muscovite	-	-
Pyrozenes	-	-
Olivines	-	-
Accessory minerals	5	8
Opaque minerals	3	4

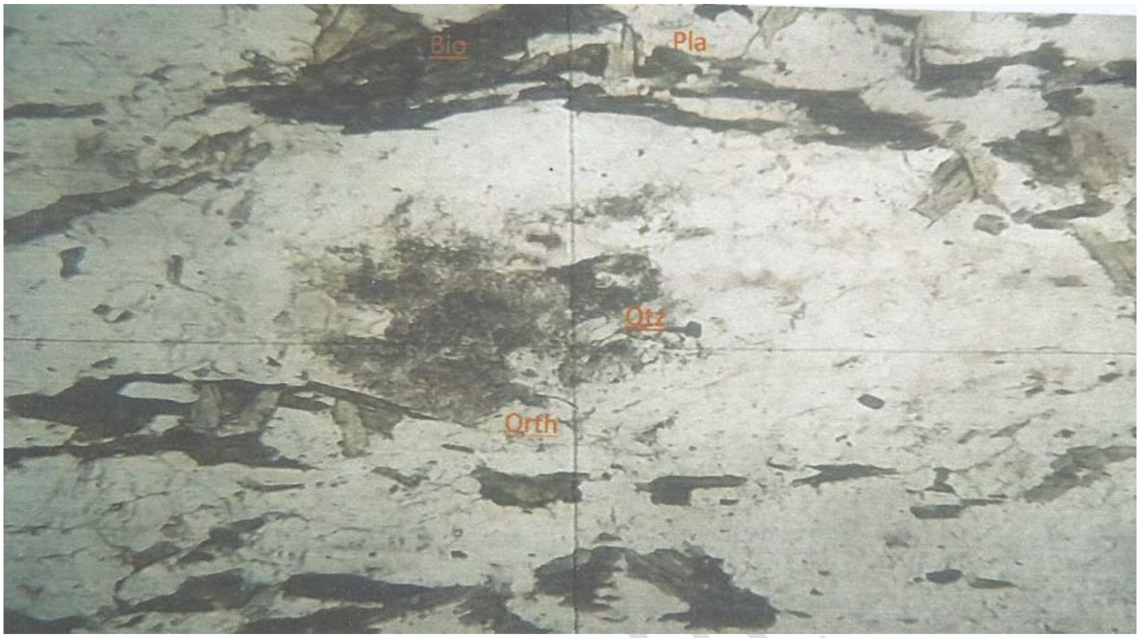

Plate 7: Phtomicrograph of gneiss, shows crystals of orthoclase, biotite and groundmass aligned in a preferred direction. (Orth-orthoclase, Bio-biotite, Pla-plagioclase, Qtz-quartz) applicable to all photomicrographs. (PPL view, Ma. X40).

Plate 8: Photomicrograph of gneiss, showing myrimekitic intergrowth texture of orthoclase crystal at the cross wires as shown by the arrow. (XPL view, Mag. X40)

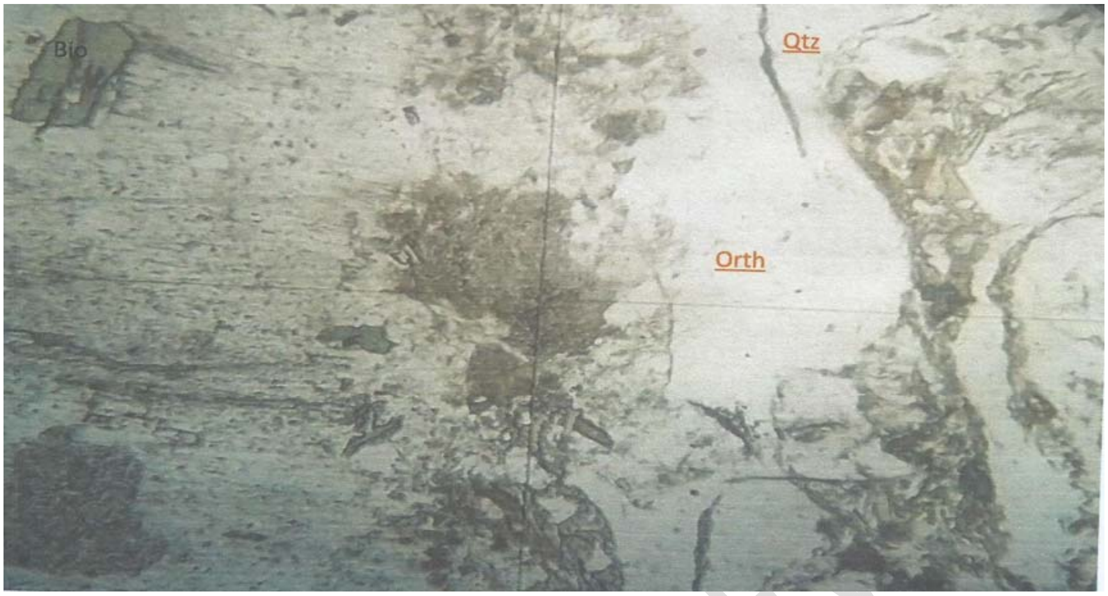

Plate 9: PPL (X40) Photomicrograph of granite, showing euhedral crystals of orthoclase feldspar and some biotite embedded in the groundmass. (Orth-orthoclase, Bio-biotite and Qtz-quartz)

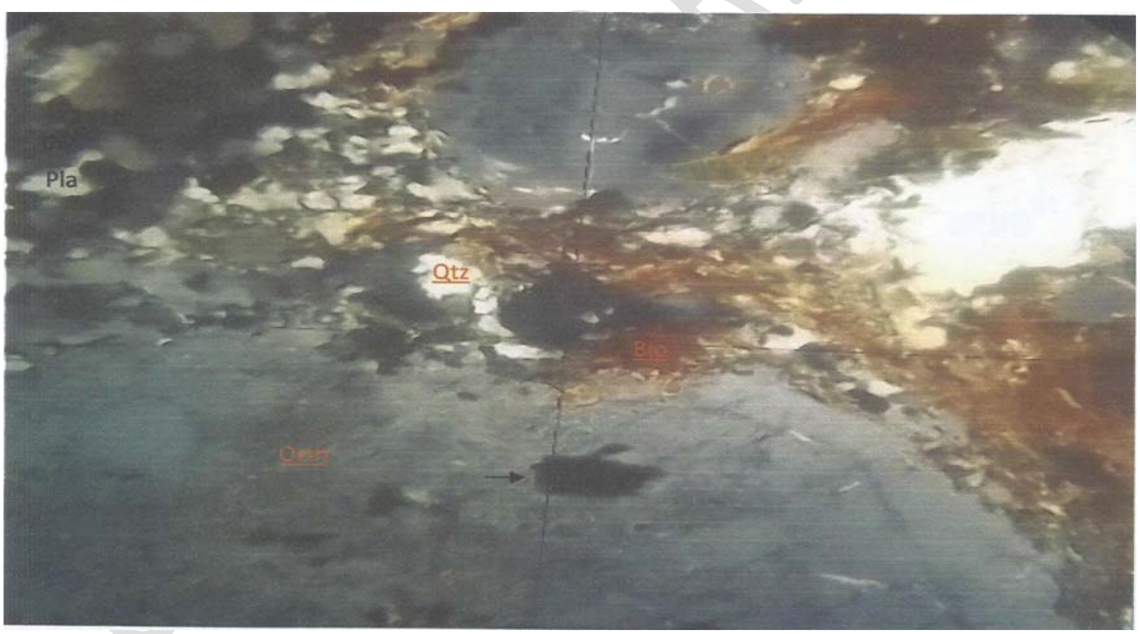

Plate 10: Photomicrograph of granite, showing phynocryst of orthoclase feldspar displaying zoning as shown by the arrow and the groundmass. (XPL view, Mag. X 40)

Evidence from field and petrographic studies indicates that rocks in the mapped area had been affected by regional metamorphism that occurs as a result of the orogenic event that affected the Nigerian Basement Complex. All structural features observed in the field such as foliation, faults,

joints, veins and other intrinsic ones strike in N-S direction. This indicates Pan-African Orogeny that almost cancels out all imprints of the earlier orogenic events.
The rocks the study area were affected by regional metamorphism as clearly demonstrated by gneiss foliation observed on the gneiss exposures.

Foliation is a common feature to rocks affected by regional metamorphism or metamorphic compression typical of regional belt. Gneissosity is an indication of a high grade regional type of metamorphism which affected about 90-95% of the rocks in the study area. structure was observed on gneiss exposures (gneissosity) where an alteration of felsic and mafic minerals were observed aligned in preferred direction. Most of the foliation observed have their trend in N-S direction which shows the effects of metamorphism and tectonic processes during the formation of the rocks. Gneissosity observed in the study area is highly penetrative though rock type (gneiss) is highly weathered. The evidence of alteration of the rocks is the present of secondary mineral kaolin formed from the weathering of feldspar.

In the field, many micro faults were observed mostly with sinistral form of displacement of few centimeters on some outcrops in the study area with average displacement of 15-25cm. a major sinistral fault was observed along river Moryaji at a location with the coordinates; latitudes $11^0$35” 55.7”N and longitude 007^0 32’ 04.5” on a pegmatite dyke with a displacement of 1.30m, length of exposure of the dyke is 24.30m with a thickness of 0.54m striking at 020^0 and dipping 68^0W. A number of structural elements were observed in the mapped area which is considered to have been formed as a result of different tectonic processes that had affected the rocks in the study area. The rocks in the area have geological history that has resulted into variable structural features e.g. the regional display of N-S trending of rocks, which is the representation of the final imprint of Pan-African orogeny.

Based on the difference in genetic properties of the various rocks, their response to different stress and strain conditions varies. Using field observation and data collected on the field, it has been possible to describe the main structural pattern of the area. The observed structures can be described under two groups: Syn-tectonic structures and Post-tectonic structures, which are structures that were formed at the same time of formation or after emplacement of rocks. These include linear and planar features, foliation and fold etc. In the study area, the common syn-tectonic structure observed, identified and mapped is foliation. Joints are fractures normally found in rocks along which has no observable relative movement or displacement had occurred. Most of the outcrops observed in the study area are jointed but the intensity of joints varies with different rock types. Majority of the joints identified and measured makes in N-S and NE-SW direction. Some joints are parallel to one another thus forming or defining a joint set, some of the joints on the outcrops are barren while others are commonly filled with crystals of minerals such as quartz, feldspar and biotite forming pegmatite. (Pegmatite veins less than 0.30m and dykes greater than 0.30m). Field observation indicates that gneiss exposures have high intensity of jointing than the granite exposures as a result of series of episodes Pan-African activities. The two rose diagrams below shows the dominant trends of the joints and the direction of the forces (stress) that produced them Figures 2 and 3.

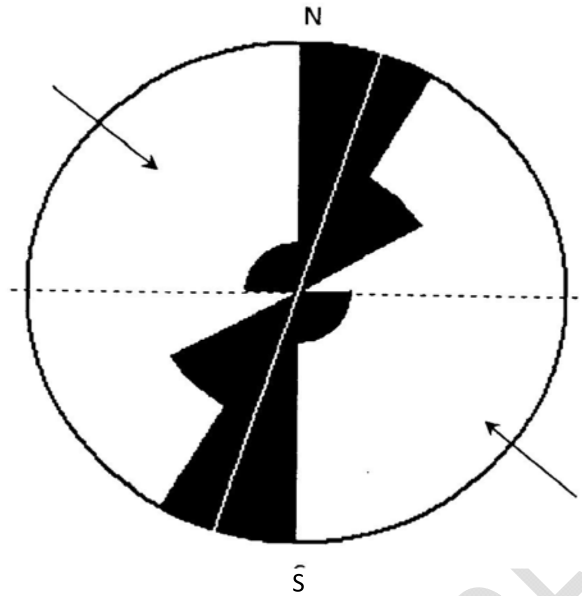

Figure 2: Above shows a rose diagram indicating the dominant trend of joints on granite exposures.

Veins are tabular or sheet-like bodies which have intruded into the main lithological unit through joints and fissures of various lengths and thickness. Veins observed in the study include quartz and pegmatite veins Plate 11.

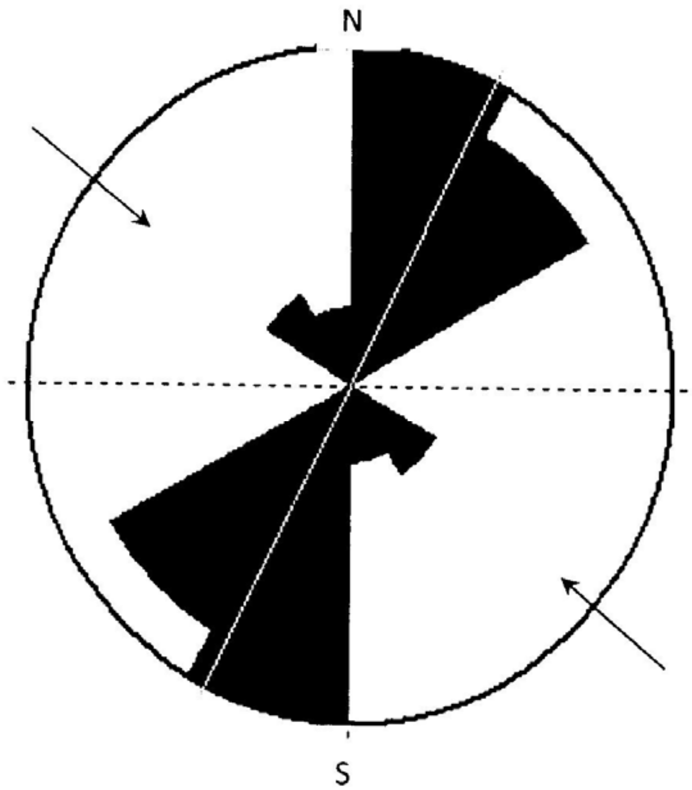

Figure 3: Above shows a rose diagram indicating the dominant direction of stress on gneiss exposures

Plate 11: Field Photograph showing series of quartz veins emplaced along the foliation direction with coordinates; latitude $11^0$37’ 36.9” and longitude 007^0 32’ 27.0”N

Discussion

The geology of Tsiga area consists mainly of metamorphic rocks. The late to post Pan-African intrusives mainly occur in a small proportions. The ganitoids were emplaced into the metamorphic basement complex of the area probably at the later phase and mark the terminal end of the Pan African event [8]. The Pan-African orogeny seems to have left its structural imprints on the rocks of this area as observed in the field. [9] correlated structural orientations in the NW-SE direction to an older Pan African deformation in northern Cameroon. Opinion is however divided on the occurrence of these structural imprints in the basement rocks in Nigeria. [3] and [10] are of the view that the last Pan-African tectonothermal event was so pervasive that it erased earlier structures. Other researchers are of the opinion that though pervasive, the Pan-African event did not completely homogenize the rocks in the basement as traces of earlier structures remains [11; 12; 13; 14; 15; and 16]. The geology is strongly defined by weathered to highly foliated gneiss, which form lowlands as observed from the Northern part around Ungwan Koli towards Ungwan Gero. Weathering effects decreases towards the central part of the area and fresh samples were collected around Yan Gauta and Zegazi. The granitoids intrusions occupied or dominated the southeastern part of the area with xenoliths forming a gradational boundary between the gneisses and the intrusives which shows that the effect of the Pan-African imprint did not completely obliterate the older rocks before its occurrence [17]. The evidence of incomplete obliteration mapped as xenoliths demonstrated a support on the earlier geoscientists who proposed that the Pan-Africa orogenic event was strong but not sufficient enough to completely wipe out the older features [18].

There is observed shortage of water in the study area which resulted primarily by the high rate of evaporation during the long period of dry season and high permeability of the overburden. The alternative source of water available to the inhabitants for their domestic activities is found by digging shallow pits along the stream and river channels which form small pools of stagnant water, thus making it easier to fetch. These pools of water are usually turbid as observed during the field investigation. However, the inhabitants of Tsiga town in the study area depend largely on water from boreholes with majority of the boreholes powered by solar system and few other ones operated manually. The depth to water table is typically greater in region with low rainfall than region with high rainfall. Water table varies greatly to its highest or maximum depth during the rainy season and to its lowest or minimum depth during the dry season. Though the depth of water table in the study area was not determined due to the absent of open wells (hand dug wells) in the area. But the depth of water table is typically greater deeper in region with low rainfall than in region with high rainfall. Though the two aquifer mentioned are interconnected but the former (overburden) is very common in the study area where shallow pits are dug along the river channels in search for underground water. These aquifers are recharged mainly during the rainy season. But the rate of recharge is less than the rate of discharge because of the high rate of evaporation, high permeability of the soft overburden aquifer (which is mainly gritty clays, the product of weathering of the underlying rock) and the high demand of water by the inhabitants.

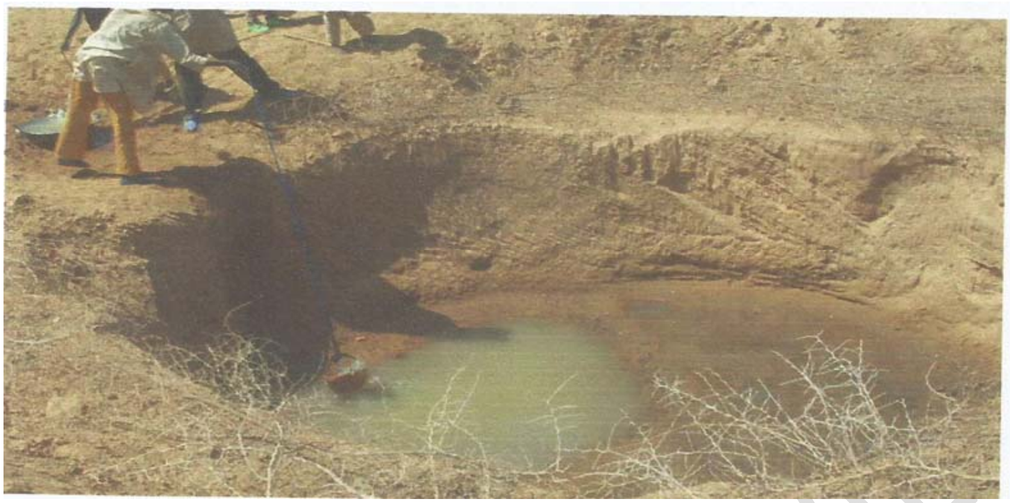

Plate 12; Field Photography of a hand dug pit along river Yali close to Ungwan Maitokobi with the coordinates; latitude 11^{0}37’ 40.02”N and longitude 007^{0} 32’22.07”E, elevation of 616m and a depth of 1.4m.

The area is accessible through network of foot paths along dry stream and river channels, minor and major roads. The vegetation is dominantly shrubs, while the soil is sandy, reddish brown to dark brown in colour with a dendritic, coarse drainage pattern. The study area consist of different rock types which include gneiss and granite as the major lithology, associated with structures like; foliation, faults, joints, quartz veins and some minor rocks to include pegmatites and aplite dykes. The gneisses occupied about 95% of the area while granite covers about 5%. These rocks are characterized by structures such as foliation, joints, faults and most of these rocks and structures have their trends in N-S direction. Economic mineral deposits in the area include; rock aggregates, feldspar, quartz, laterite and lateritic sand which are used for various purposes. The hydrogeology of the area has both surface and underground water, the surface water is normally found in a pit hole along river and stream channels, while the underground water is mainly boreholes.

5. Conclusion

The field and laboratory descriptions, petrographic studies and structural elements, the different rock types gneisses and granites were identified and it is our view that the evolution of the

Basement Complex rock of the area can be traced to an ancient circle of sedimentation followed by deformation, metamorphism and magmatism. Remobilization and reactivation of gneisses during the Pan-Africa Orogeny was accomplished by intrusion, uplift and further metamorphism into granite gneisses. Based on field relations and deformed features observations, the gneiss is probably the oldest rock in the study area and was intruded by the Pan-African Granite which represents the latest rock to be emplaced. In terms of structures, joints represents the oldest structural features which have different generations, some generations of the joints are were later filled with quartz and pegmatite veins. Later tectonic episode resulted in the displacement of the veins into faults, which represent the latest structural features in the area.

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