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Structure and tectonics of Hong Hills in Hawal Precambrian Basement Complex, North East Nigeria

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The tectonics and impact of the Pan-African orogeny on the Hong Hills area of North Eastern Nigeria has been unraveled. This work basically used structural identification and tectonic inference to decipher the deformation episodes in this region. The results show that this area was subjected to multiple episodes of deformation and there were evidence of reworking of older structures by younger ones. Foliation, folds and dykes/vein data suggests that the metamorphic rocks in this area experienced a predominant E - W compression during the Pan - African Orogeny. Structural evidence and the presence of dominant ductile shear zones also confirm that the deformation in this region is predominantly ductile. The relatively younger granite intrusions show structural trends which are consistent with the closing periods of the Pan-African Orogeny. Evidences show the emplacement of these plutons followed regional structural direction defined by major fold trends and rock foliation. Salient isolated features suggest the occurrence of pre Pan-African orogenic structures but there aren't enough data or evidences to buttress this claim. From this work, we can safely say that the Hong Hills region is a complex Pan-African zone with two major episodes of deformation.

Key words: Basement complex, geological structures, pan-African deformation, pluton emplacement.

INTRODUCTION

The Hong Hills are part of the Pre-Cambrian basement complex in North Eastern Nigeria. This complex is a section of the 3000 km long Trans-Saharan belt which formed in the Neoproterozoic (between 750 and 500 Ma) by a continental collision between the converging West African, Congo and East Saharan blocks (Ferre et al., 2002). The Pan-African mobile belt, within which the Hong Hills lies, contains high-grade metamorphic assemblages which expose middle to lower crustal rocks (Kalsbeek et al. 2012, Ekwueme and Kroner 1997). There is also a host of igneous intrusive some of which are of Pan-African orogeny (750±150), while the dykes are much younger (Udinmwen, 2017). The exact origin, environment of formation, tectonics and structural evolution of these Pre-Cambrian rocks are quite difficult to reconstruct and this is why we use observed structures in this region to try and present the deformation episodes that took place in this region.

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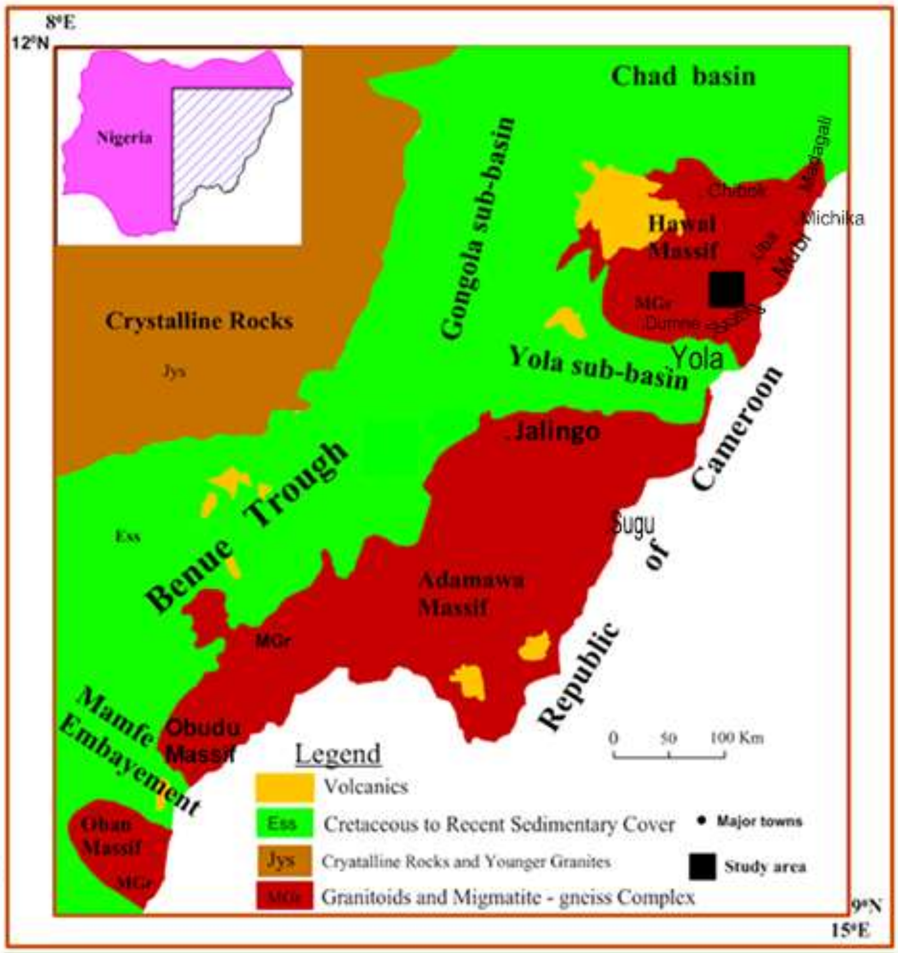

Figure 1. Regional geological map of Nigeria's eastern Basement Complex Massifs showing location of study area.
Source: Adapted from Haruna et al. (2011).

There are numerous structural evidences in this region which gives a fair idea of the regional deformation that operated in the Pan-African era. Although these structures have been well documented in the literatures, they have not been used to discuss the possible tectonic situation that occurred in the region. This work seeks to add this knowledge to the existing information on this region. It must be noted that the use of structures alone to determine the deformation episodes in an area is speculative to a large extent. This is because structures and the forces that produce them are not always concordant. Two rocks with different composition may deform differently even when the same stresses act on them. Also, a rock that which is subjected to a coaxial deformation may generate a structural geometry different from another rock deformed by non-coaxial deformation. Both deformation patterns (coaxial and non-coaxial) can be activated by the same principal stresses in a region (Udinmwen, 2017). These can easily mislead a researcher to think that structures with slightly different geometries belong to different phase of deformation. However, the use of structures to infer deformation pattern is always the first step or foundation studies in determining the tectonics of a region. Thus the findings in this study lay a good foundation which will serve as a pivot to the use of a more deterministic approach in unraveling the tectonics of the Hong Hills.

Location and geologic settings of the study area

The area mapped is located in Northeastern Nigeria (Figure 1). It lies between longitudes 12° 54" and 13° 00" E, and latitudes 10° 07" and 10° 17"N (Figure 2). It is about 43 km^2 in areal extent and lies south central in the Hawal massif. This massif is bounded westward and southward by the two arms of the Cretaceous Benue rift namely Gongola Basin and the Yola Trough (Figure 1).

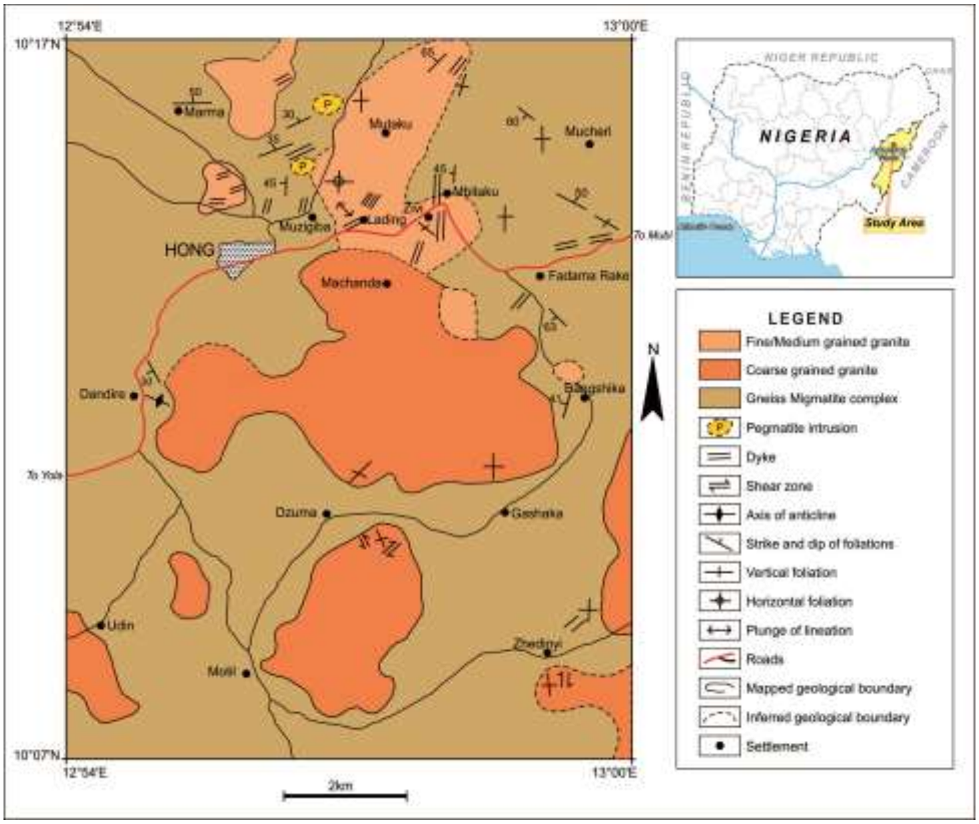

Figure 2. Geological map of Hong.

Northwards it is bounded by the Chad Quaternary Basin. The major geomorphologic features in the study area are the Mandara hills (which form the highest elevation in the area at more than 850 m above sea level). The hills extend into the Republic of Cameroon. Previous works in the Hawal Basement Complex include Bassey (2006a,b), Unachukwu (2014), Kwache and Ntekim (2014), Abdulahi et al. (2016) and several others. These authors worked in different capacities but each of them reported the occurrence of gneisses, migmatites, Older granites and Tertiary Basalt within the region. Of these rocks the Pre-Cambrian gneisses are dominant. This area has some mineralizations, Kwache and Ntekim (2016), Mohammed and Mohammed (2017) reported the occurrence of barites at Dumne and uranium at Michika respectively. This authors among other things observed that the mineral deposits are structurally controlled in many instances. Thus a detailed structural studies of this region is quite important in order to properly understand the structural environment of the mineralizations.

METHODOLOGY

The method of investigation was the conventional geological mapping of outcrops, recording and analysis of structural data. The procedure involved location and examination of outcrops for lithological and structural details, recording and plotting of data on field notebook and base map respectively.The field tools used include silva compass-clinometer, chiesel, geological hammer, field camera etc. Field mapping techniques of Moseley (1981) were followed.

RESULTS

Lithologies

Gneiss and migmatite

These rocks are the most widespread in occurrence (Figure 2) and their field relationship is very intimate that boundary between the two is difficult to establish in places. The gneiss is however distinguished by their alternating light and dark coloured bands which contain mostly feldspar, quartz, biotite and hornblende which were observable macroscopically. The bands are commonly contorted and folded presenting a convoluted look. These bands impart a lepidoblastic texture to the rock. In some instances, the gneisses are strongly foliated, fine grained and contain dominantly mafic mineralogy. A good example is at north east of Muzigiba. The contact between the gneiss and granite is transitional as observed northeast of Mutaku hill. The migmatite appears as bands of light and dark coloured material.

Granite gneiss

At Marma in the NW axis of the study area, there is a huge occurrence of coarse grained light coloured granite gneisses. The feldspar and quartz crystals occur as deformed ellipsoids, with a preferred orientation imparting foliation to the rock. Foliation on the rock is strong where there is concentration by metamorphic segregation of the mafic minerals and the grain size of quartz and feldspar are reduced.

Pegmatite/Aplite

Pegmatite intrusions are abundant especially in the northern end of the study area existing as irregular bodies, dykes or veins within the migmatite - gneiss suites, and in the marginal parts of the granitic rocks. From observation they are coarse grained and contain quartz, feldspar, garnet and minor quantities of biotite and muscovite. These were observable using a hand lens. This mineral composition shows they are granitic pegmatites. There is clear zonation of the minerals with quartz at the core and feldspar at the borders. The pegmatite dykes are intensely sheared. Minor occurrences of complex pegmatites are found at Zivi hill area exposed as ridges.

Granites

These occur as elliptical bodies oriented in the N-S direction which is consistent with what is observable in other Pan-African sectors in Nigeria (Udinmwen, 2017; Udinmwen and Oden, 2016; Udinmwen et al., 2016). Texturally, the granites are mainly pegmatitic and coarse grained (grain size of minerals >2 cm). Similar type has been observed and reported in Mubi area (Bassey, 2006c) and Sugu Hills in Adamawa Massif. The largest of the granite plutons is found at the central part of the area with N-S dimension of about 3 km and E-W dimension of about 2 km. Exposed contact of gneiss and granite is sharp. The main minerals of the rock are quartz, pink feldspar, and biotite using a hand lens. Fine and medium-grained granites are found in the north of the area.

Structural features

Foliation/cleavage

The migmatite – gneiss country rock in the area is strongly foliated. Foliation directions vary from N-S with vertical dip in the northeast of the study area to NW-SE with a dip of 50° NE. At Zivi near Mbitaku, axial planar foliation is found in the gneiss. Mineral alignment on the plutonic rock (granites) is found and the directions vary from NE-SW, N – S, to NW – SE. At Muzigba hill which is a gneiss dominated hill near Hong town, foliation defines the lithological layering of the hill. This was reported by Bassey and Audu (2003). The structural map of structure of Muzigba hill is presented in Figure 3. Toward the northern boundary at Mutaku hill (Figure 2), wrapping of foliation around sigmoid shaped mafic (amphibolite) xenoliths was observed (Figure 4a). The wrapping of foliation over the xenolith produces a pressure shadow structure at mesoscopic scale. Northwest of Lading (Figure 2) outcrops of highly weathered gneiss are found, this rock has horizontal foliation striking at 160°. Within this area too, outcrops of foliated weathered granite (with attitude: 90°, 20°S), with elliptical xenoliths of probably amphibolites are found. The xenoliths have their major axes measuring between 10-25 cm and minor axes 5-9 cm. The major axes are oriented parallel to foliation direction of the granite. Fracture cleavage is found on some pegmatite dyke intrusive to gneiss at Muzigiba hill. This cleavage strikes N – S. The cleavage is interpreted as SF tectonite produced by brittle fracture and characterized by slickensided mesoscopic parallel fractures (Figure 4c). From foliation, cleavage and mineral orientation studies, the major observable trend is N – S. In a co-axial deformation, this trend will be formed by an E – W operating maximum principal stress. From these, the foliated rocks were most likely subjected to an E – W compression during the Pan-African orogeny and this episode of compression is well known to be the most dominant in the Pan African Mobile Belt (Udinmwen, 2017).

Folds

During the field mapping exercise, the southernmost exposure of folded rock was found at Zhedinyi in the southeast close to the foot of the granitic hills (Figure 2). Exposures are abundant in the north especially northeast. In the northwest, there is paucity of folded rock possibly because those formed earlier were destroyed by intrusive rocks. Folds in Hong basement area occur as symmetric, asymmetric, simple or complex folds (Figures 5 and 6). At Zhedinyi folds of axial orientations between 0°-10° (N-S), 30°-60° (NE-SW), 160°-175° (NNW-SSE) are found. Some are open with wavelengths measuring up to 53 cm. In Mucheri, there are complex folds with axial trend between 160^{o} –180^{o}. Some folds are resolved in Figure 5 into three episodes F_1, F_2 and F_3 in deformational order. Sheath folds or tubular folds are found at the northeast of Mutaku; they are the result of the flattening and attenuation of earlier folds. At Mbitaku the fold axial plane dips parallel to rock foliation and trends at 170°. Upright sheath folding of mafic bands of

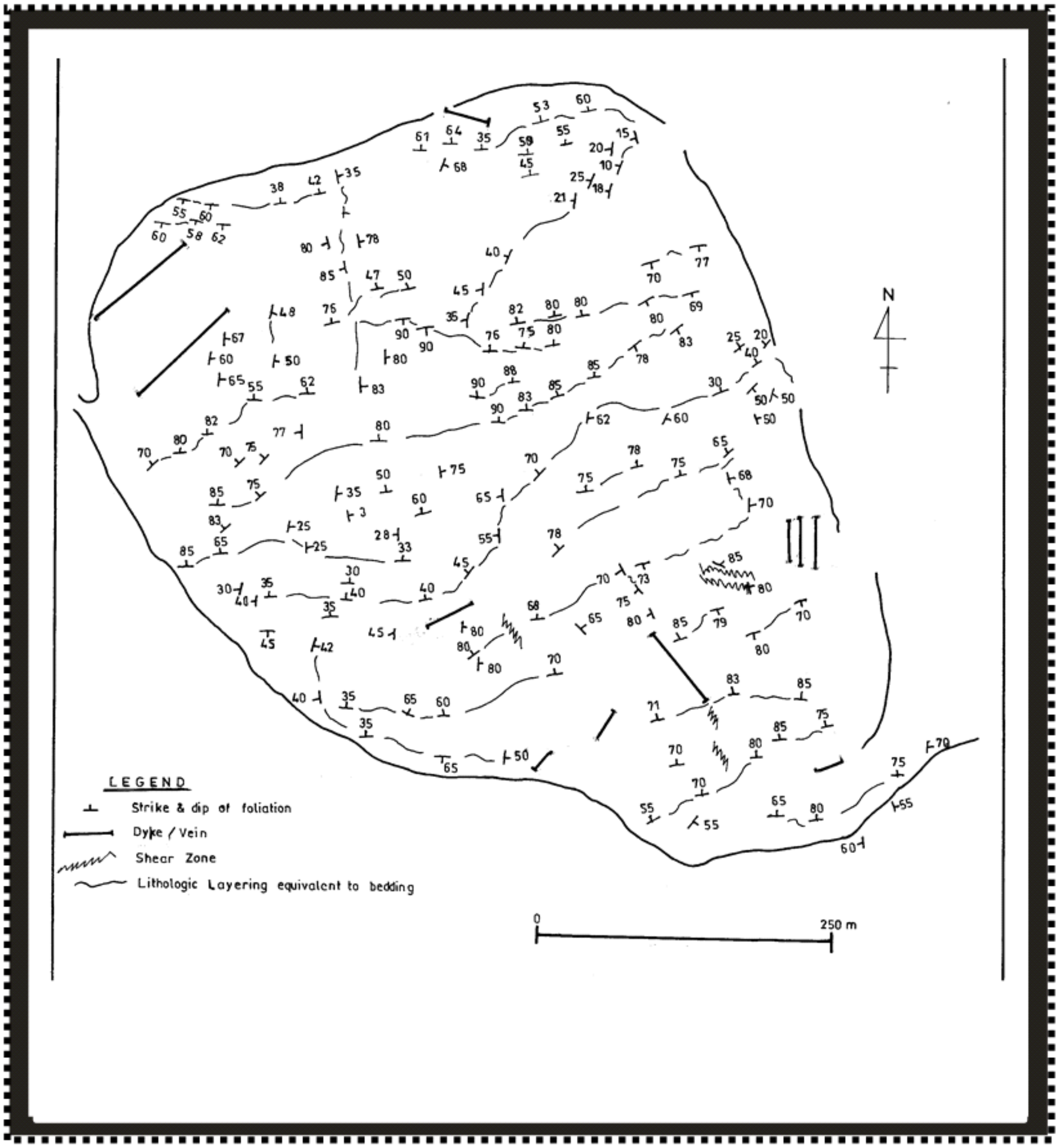

Figure 3. Structural map of Muzigiba Hill, Hong. Foliation defines the lithological layering.
Source: Bassey and Audu (2003).

rock is observed here too. Near Dandire along Yola – Hong Road (opposite Wandanda Gasoline station), a complex fold on gneiss is found. It has numerous minor folds on either limb. The core of the fold has a lens of amphibolite with feldspar megacryst. An S-pole diagram of the complex fold is shown in Figure 6b, with its axial trend as 150°; the dip of the axial plane is 45° SW, and it is an anticline. A rosette of axes of fold in Hong area is presented in Figure 6c. The dominant trends are NNW-SSE and N-S. The occurrence of NNW-SSE and N-S corroborates with the presence of E – W compression in this region as fold axes tend to form perpendicular to the direction of the maximum principal stress (σ_1) (Udinmwen, 2017; Udinmwen and Oden 2016). However, we cannot ignore the presence of NE – SW trending folds which suggests the presence of another deformation episode.

Dykes and veins

Dykes of granite, pegmatite, aplite and dolerite lithologies are found in the Hong area. They display diverse orientations reflective of the tectonic episodes that controlled their emplacement. Most of the mapped dykes are found in the northern part of the study area where

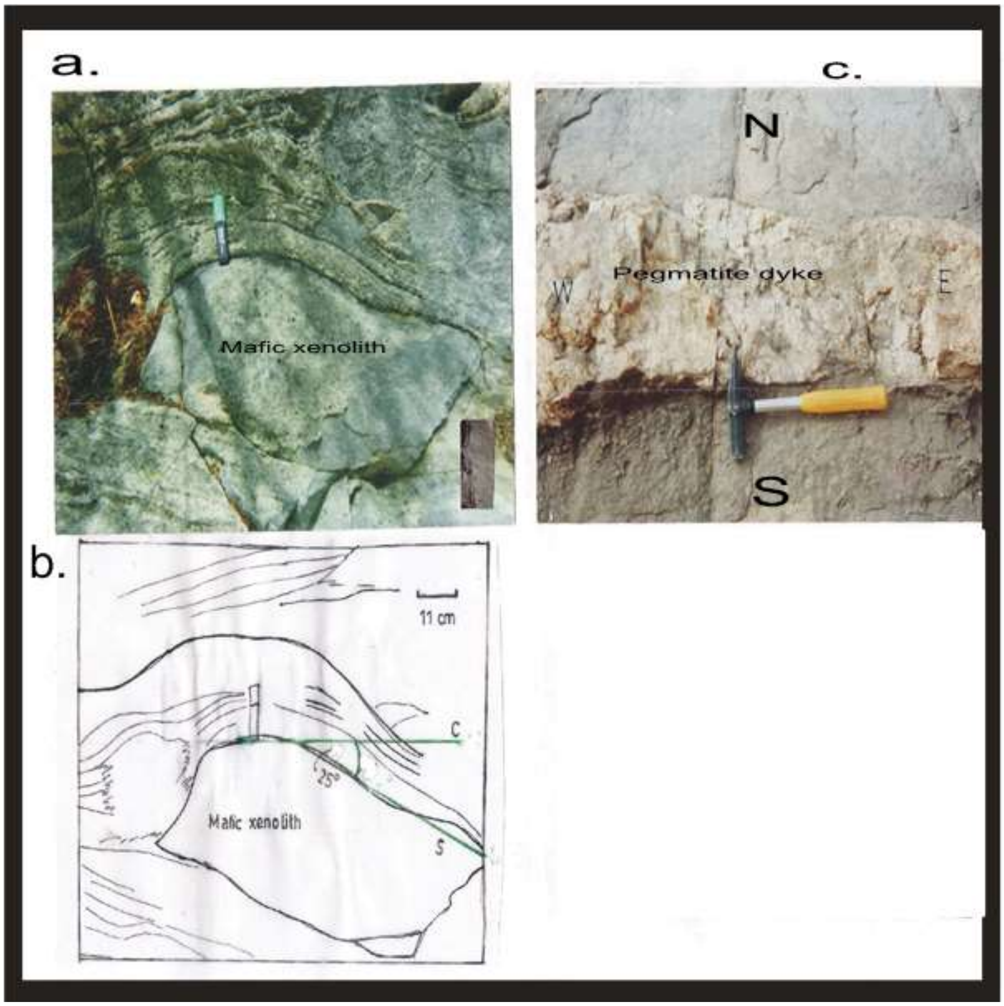

Figure 4. (a) Wrapping of foliation around mafic xenoliths at Mutaku hill, Hong. (b): Line drawing of (a). (c):N-S fracture cleavage produced by brittle fracture on pegmatite dyke at Muzigiba hill.

rocks are well exposed. At Fadama Reke, a fine-grained granitic dyke striking 20 and with an exposed width of about 37 cm and dip of 550 W intrudes the gneissic rock there. The dyke possible crosses Hong –Mubi road (Figure 2). The foliation in the gneiss is 1500. To the east of Fadama Reke a quartzo- feldpartic dyke with exposed length of 100 m, width about 2 m and strike 90o is vertically dipping; eastward a similar dyke possibly a continuation of the former with similar lithological and structural character is found and extends for 7 m. A good majority of the observable pegmatite dykes and Aplite veins strike from N – S.

At Mbitaku near the road bend at Zivi, two parallel 20 striking, medium grained equigranular granitic dykes, of pink colour with width 3-4 m are found. A NNE-SSW (20°) dyke is found 30 m from the parallel dykes. The latter is pegmatitic and is quarried for construction work. On the east slope of the gneissic hill at Muzigiba (Figure 3) is a swarm of parallel N-S dykes of granitic composition. They are more resistant to erosion than host rock. Some of these dykes are foliated in the N-S direction. Partial melt veins were observed on the slopes of Muzigiba hill. Along Muzigiba - Mutaku road near Daga a 250 striking dyke which dips 250 E with a width of 30 cm, and length 70 m is found. About 8 m east of this dyke, a quartzo- feldpatic dyke strikes at 200. Further east quartz -feldpatic dyke of pegmatite texture strikes at 200. Along the plain east of Muzigiba, fine- grained granitic dyke strikes at 1200 intruding the coarse grained granite. This dyke is displaced by a 1450 shear zone. Some of these dykes are difficult to map. Southwards at Zhedinyi, a 400 dyke of length 22 m and width 1 m intrudes the gneiss. At the northwest near Marma granite gneiss is intruded by a dolerite dyke. The width of the dyke is about 10 cm, striking at 700 and dipping vertically. A rosette diagram of dykes observed is presented in Figure 6d. Some quartz veins occur following anastomosing pattern in the gneissic rocks at Muzigiba Hill.

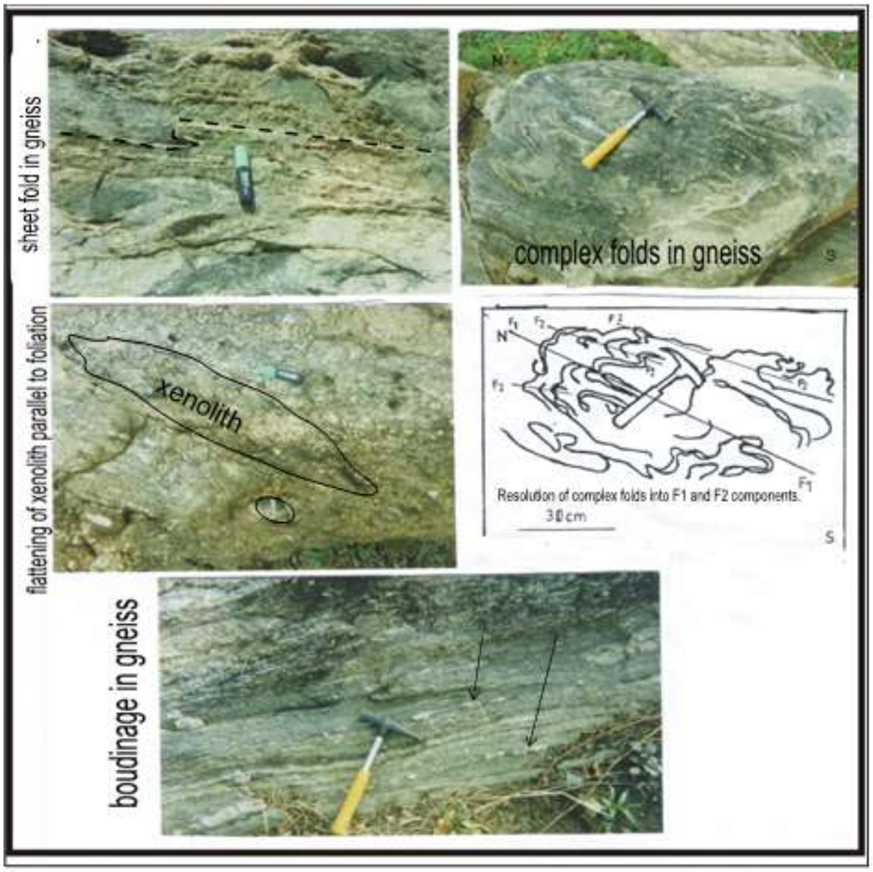

Figure 5. Folds, xenoliths, boudinage with pinch and swell structures in Hong.

The conspicuous absence of fractures in the study area and the dominance of folding and foliation strongly suggest that the Hong Hill region experienced a predominant ductile deformation. The structural geometry of the dykes and veins also supports this. Generally, mineral veins and dykes tend to prefer ac-extension fractures parallel to the maximium compressive stress and perpendicular to the fold axis (Udinmwen et al., 2016). However, in the absence of ac-extension fractures, these veins and dykes will use either the foliation plane or the bc-tensile fractures which forms parallel to the axis of the folds as a result of tension along the fold axis (Udinmwen et al., 2016). In the Hong Hill region, the fold axis and the dykes/veins are parallel which means that the ac-extension fractures are absent and the veins/dykes here used the bc-tensile fractures. This generally suggests that the study area is a dominantly ductile region.

Linear structures

Northwest of Mucheri, we found boudins of quartz in the gneisses (Figure 5). The boudins strike at 140° which also the foliation direction of the gneiss. The boudins are quartz minerals in biotite groundmass, some occurring as bead-like strings. The foliation in the gneiss is axial planer to the folds as the rock has developed folds with axes striking also 1400. At Marma in the northwest boudins, pinch and swell quartzitic material is found in a 700 striking dolerite dyke, the dyke is emplaced in granite gneiss.

Shear zones

Shear deformations in the area are diverse in orientations affecting different rock types. Possibly this diversity is reflective of the different periods of geological history that shearing took place. At the slope of the granitic hill south of Dzuma the rock shears along 1500 direction. N –S shearing also affects the granite south of Zhedinyi. The gneissic rocks of Muzigiba and the granite at Arndu are sheared severally. A NW – SE ductile shear zone about 3 cm wide affect the rock which also has a foliation along same direction as shear zone. Similarly, in the same area a NW –SE shear zone displaces an ENE – WSW dyke by dextral shear with a magnitude of slip 4 cm. Also, a NW –

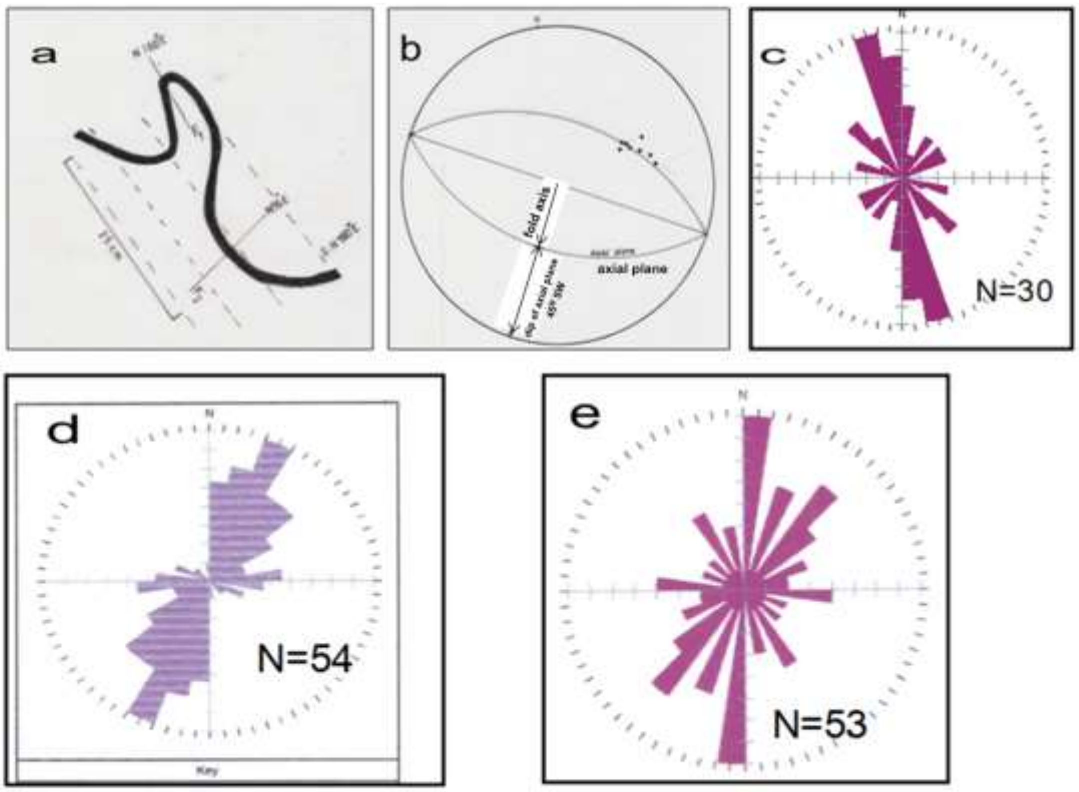

Figure 6. (a) Field sketch of refolded fold at Zivi; F1: first generation fold, F2: second generation. Foliation S is axial planar to F1. (b) S-pole stereogram of anticline at Dandire, axial plane of fold=115^o.dip of fold axis=45° SW. (c) Rose diagram plot of fold axes in study area. (d) Rose diagram plot of trends of dykes and veins. (e) Rose diagram plot of shear zones.

SE shear zone displaces a foliated microgranite dyke in the plain west of Mutaku. Minor shear directions are N - S, E - W. At Mbitawi village (close to Mbitaku) N-S, NNE-SSW granite dykes are sheared along 750 - 950, and 1650. A rose diagram of the distribution and orientation of shear zones is shown in Figure 6e. The presence of these ductile shear zones shows further that the study area is predominantly ductile.

DISCUSSION

From field observations the crustal history of the Hong basement complex probably followed the stages presented below:

(i) The earliest crustal materials are obviously the mafic xenoliths and amphibolites fragments in gneiss and migmatite.

(ii) Intense predominantly ductile deformation which led to the development of folds, foliation and numerous ductile shear zones

(iii) Emplacement of granite plutons in the core of deep seated folds of the metamorphic rocks. Acidic and basic intrusions of dykes and veins were also formed at this stage.

(iv) Some granite plutons were also deformed but at the ductile stage, this resulted in the preferred alignments of the phenocrysts in the granite gneiss.

(v) Uplift and erosion leading to exposure of the rocks at the surface.

In the northern part of the study area, we have the preponderance of small intrusive bodies (dykes, veins and irregular pegmatite bodies) and these seem to be aligned in the N – S direction. The emplacement of these plutons most-likely took advantage of pre-existing fractures and they ultimately sealed most of the fracturing which is why the fractures are not observable today. The small angle (25^o) between the c and s surfaces of Figure 4b shows that the region was subjected to high strain rate according to Gleizes (1994) who said that such small angles mark high strain rate on rocks.

The Pan-African orogeny affected the gneisses and migmatite in that some pre – existing folds were refolded along NE – SW or N – S directions, accompanied by the development of axial planar foliation. At least two generations or episodes of folding can be recognized at Zivi. The most dominant orientation is N – S which is the main fold direction of the Pan-African orogeny. The NE – SW (55^o axes - Figure 6a) trending folds are younger

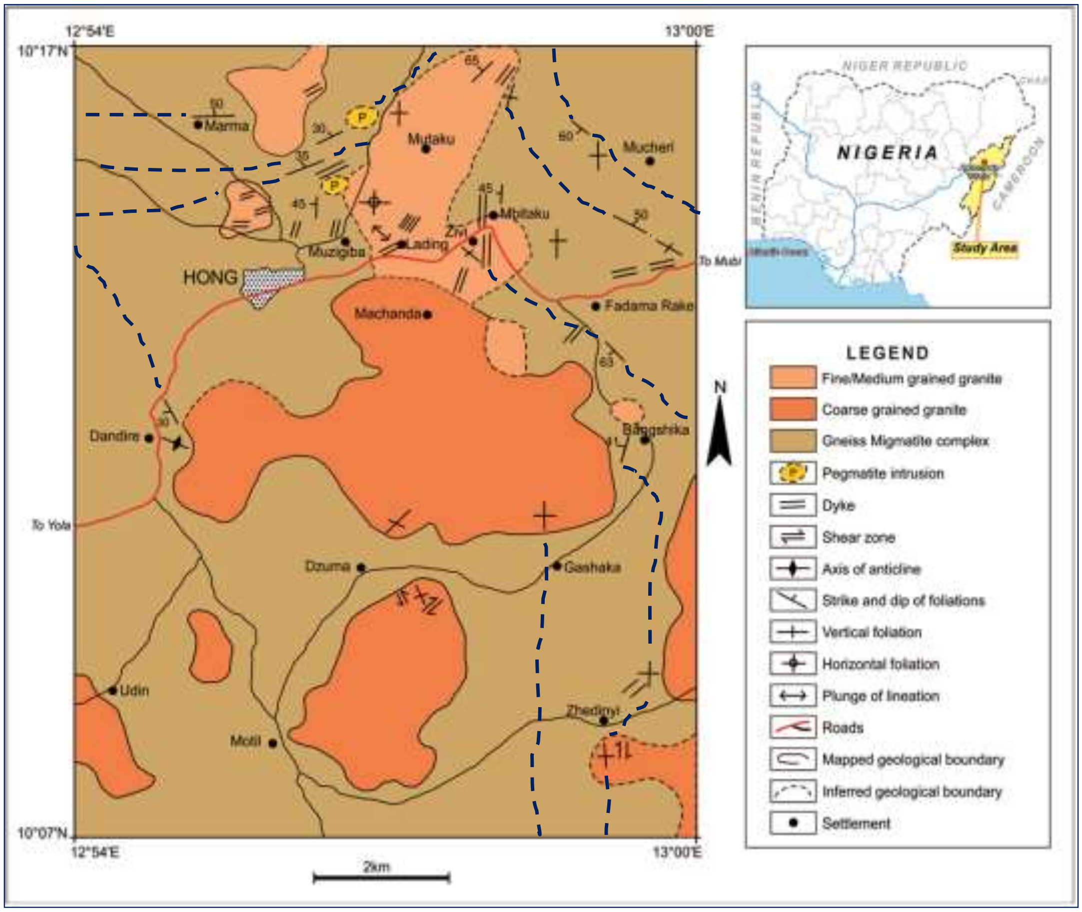

Figure 7. Foliation trajectories (thick broken lines) in study area generated from mapped data.

and probably formed at the closing stages of the Pan-African orogeny. These folds are younger because they re-folded the pre-existing N – S trending folds.

The coarse grained nature of the granites in the area shows their deep seated origin. Their present level is due to isostastic uplift related to the formation of the Yola and Chad Basins (Bassey, 2006c). The smaller igneous bodies in the area are probably stocks that are connected to larger batholiths at depth. According to Blyth and de Freitas (1979), batholiths are found in regions of folded rocks, especially in the cores of mountain fold belts, and dominantly acid (granitic) in composition. According to these authors, the North American Cordillera contains very large batholiths, elongated parallel to the length of the folds. Another example provided by these authors is the coastal batholith of Peru, emplaced in the Andean folds of South America. The migmatite-gneisses of Hong area have well developed folds. These rocks constitute host to the granite plutons. The similarity in tectonic setting of the American Cordillera batholiths and the Hong plutons qualifies the latter as batholith though their sizes differ. However, it should be noted that the study area is part of the larger Massif which has several other plutons.

Clark (1992) presented criteria for pre-tectonic, syn-tectonic and post-tectonic granitoid pluton emplacements. According to him, plutons emplaced prior to deformation are likely to behave as resistant bodies during deformation and perhaps deformed only at their margins. Those intruded during deformation are likely to be stretched out by tectonic stresses. Plutons intruded after deformation may follow the regional structural patterns in host rock or be largely oblivious to its existence. The dominant direction of fold axes in the metamorphic rocks of Figure 6c (essentially N-S) accords with the direction of emplacement of the plutons. This is indicative that the emplacement of the plutons was controlled by pre-existing structure. Figure 7 further illustrates the influence of foliation directions of the host rocks (gneiss/migmatite) on emplacement of granite plutons. Obviously the plutons are structurally concordant to host rocks.

Some criteria listed by Castrol (1987) for concordant plutonism include but not limited to: (a) ovoid shaped geometry in horizontal sections, (b) regular and sharp contact with host rock, (c) accomodation of pre-existing regional structures to the pluton geometry. These

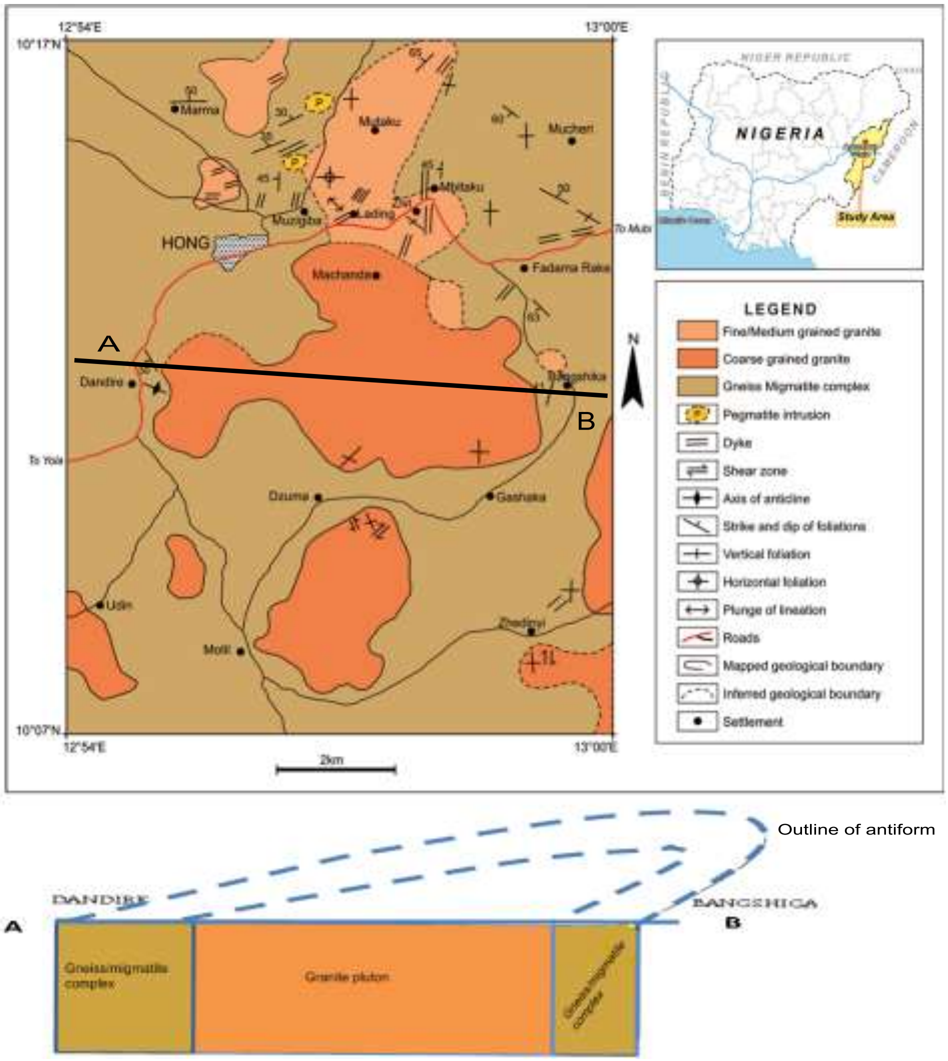

Figure 8. Geological map of study area with cross section A to B showing emplacement model of the central granite pluton within core of an overturned antiform.

features are obvious in Figure 7. Based on a reconstruction of the host/country rock envelope to the central pluton (Figure 8), it is suggested that the emplacement of this pluton and probably others was by diapiric injection. The pluton was forcefully injected into the core of an overturned antiform. A similar observation was made by Pons et al. (1991) on the Saraya granite pluton in Senegal, West Africa.

Conclusion

Information from the geology and structures of the Hong Hills, an area lying in the south central part of Hawal Massif have given us a fair idea of the stresses that acted during the Pan – African orogeny.

(i) There was dominant E – W compression: evidence from the preferred stretching of minerals in the N – S direction and the foliations and fold axes also preferred the N - S direction.

(ii) The deformation was predominantly ductile: evidence from the conspicuous absence of fractures which have probably been healed by intruding dykes and mineral veins. Also, the presence of numerous ductile shear zone lend credence to this conclusion.

(iii) Besides the E – W compression, there is at least one other episode of deformation which probably took place towards the closing stages of the Pan – African orogeny

(iv) The earliest crustal materials are amphibolites which are found as xenoliths in the metamorphic rocks.

(v) The youngest crustal rocks are the granites and some minor intrusives (dykes and veins) which were emplaced in the pre-existing metamorphic rock.

(vi) The mechanism of emplacement of the central granite pluton was by diapiric injection.

(vii) Some granites were emplaced when deformation was still active. This is the best explanation for the preferential alignment of the phenocrysts. The existing stress forced the phenocrysts to grow in a particular direction.
(viii) Isostatic uplift and erosion have exposed the granitic plutons which were formed in the cores of deep antiforms possibly by diapiric injection. From the foliation trajectories generated from field data the pluton are interpreted as post tectonic and concordant to regional structural pattern.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdulahi IM, Yelwa NA, Abdulmumin A, Nabage NA (2016). Ground water exploration in the Basement Complex around Chibok area, N E Nigeria using vertical electrical sounding method. Nigerian Journal of Basic and Applied Science 24(2):37-44.

Bassey NE (2006a). Structure of Madagall Hills NE Nigeria from Airborne Magnetic and Satellite data. Global Journal of Geological Science 4(1):47-54.

Bassey NE 2006b. Structural Geological Mapping and Landsat and Aeromagnetic Data Interpretation Over Parts of Hawal Basement Complex, Northeast Nigeria. Doctoral Thesis, Abubakar Tafawa Balewa University, Bauchi (Unpublished).

Bassey NE, Audu Y (2003). Structural elements of Muzigiba hill in the Basement Complex terrain of northeastern Nigeria. In: Abstracts Volume of the Nigerian Mining and Geosciences Society Annual Conference, Itakpe 2nd - 8th March 2003.

Blyth FGH, de Freitas MH (1979). A geology for engineers. 6th edition, ELBS and Edward Arnold Ltd., London, 556p.

Castrol A (1987). On granitoid emplacement and related structures, A. review. Geologische Rundshcau 76(1):101-124.

Clarke DB (1992). Granitoid Rocks. Chapman and Hall. London, 283p.

Ekwueme BN (1994). Basaltic magmatism related to the early stages of rifting along the Benue Trough: the Obudu dolerite of southeastern Nigeria. Geology Journal 29:269-276.

Ekwueme BN, Kroner R (1997). Zircon evaporation ages and chemical composition of a migmatitic schist in the Obudu plateau: evidence for Palaeoproterozoic component in the basement complex of southeastern Nigeria. Journal of Mining and Geology 33(2):81-88.

Ferre E, Gleizes G, Caby R (2002). Obliquely convergent tectonics and granite emplacement in the Trans-Saharan belt of Eastern Nigeria: a synthesis. Precambrian Research 114:199-219.

Gleizes G (1994). Structural studies in metamorphic and igneous terrains: aims, methods and technical aspects**.** Seminar paper presented at the Applied Geological Mapping Project, Geology and Mining Department, University of Jos, Nigeria, 18th Feb., 1994.

Grant NK (1978). Structural distinction between a meta- sedimentary cover and an underlying basement in 600 M.Y. old Pan African domain of northwestern Nigeria, West Africa. Geological Society of America Bulletin 89(1):50-58.

Haruna IV, Orazulike DM, Ofolme AB (2011). Some petrological and mineralogical constraints on source and processes for uranium mineralization of granitoids of Zing- Monking area Adamawa Massif. Global Journal of Geological Science 9:23-34.

Hatcher RD (1995). Structural geology, principles concepts and problems (2nd ed.) Prentice Hall. 525p.

Kalsbeek F, Affaton P, Ekwueme B, Frei R, Thrane K (2012). Geochronology of granitoid and metasedimentary rocks from Togo and Benin, West Africa: Comparison with NE Brazil. Precambrian Research 197:218-233.

Kwache JB, Ntekim EE (2015). Geology of Dumne area in Southeastern Hawal massif, Northeastern Nigeria. International Journal of Science and Research 4(11):2477-2482.

Kwache JB, Ntekim EE (2016). Occurrence, geochemistry and industrial quality of Dumne barite deposit SE Hawal massif NE Nigeria. Journal of Applied Geology and Geophysics 4(3):73-77.

Mohammed SI, Mohammed MD (2017). Geology and radiometric survey of Ghumchi (Michika) part of Hawal Basement Complex. Journal of Applied Geology and Geophysics 5(2):06-16.

Moseley F (1981) Methods in field geology.Published by W. H. Freeman and Co., Oxford and San Francisco, 211p.

Pons J, Debat P, Oudin C, Valero J (1991). Emplacement kinematics of the syntectonic Saraya granite (Sénégal, West Africa). Bulletin de la Société géologique de France 162(6):1075-1082.

Udinmwen E (2017). Palaeostress configuration of Pan-African orogeny: evidence from the Igarra schist belt, SW Nigeria. Iranian Journal of Earth Sciences 9(2):85-93.

Udinmwen E, Oden MI, Ayuba R, Asinya EA (2016). Structural Control on Mineral Vein Geometry in the Igarra Schist Belt, Southwestern Nigeria. Journal of Earth and Atmospheric Sciences 1(1):10-21.

Udinmwen E, Oden MI (2016). Strain analysis and tectonite classification using polymictic metaconglomerates in the Igarra schist belt, southwestern Nigeria. Arabian Journal of Geosciences 9(8):1-11.

Unachukwu H 2014. Ground radiometric survey of Hong and its environs in the Hawah Basement Complex N E Nigeria. M.Sc. Thesis (unpubl.), Modibbo Adama University of Technology, Yola, Nigeria. 59p.