MAGNETIC ANOMALIES AND STRUCTURES IN SONG, HAWAL BASEMENT COMPLEX NORTHEASTERN NIGERIA

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ABSTRACT

Digitized data obtained from the aeromagnetic map covering Song and environs ranges from 32640 to 33000 gammas and the amplitude of residual magnetic anomaly ranges from a minimum of -63 to a maximum of 90 gammas. Areas of positive residual magnetic anomalies were interpreted in terms of intrusive/extrusive marfic rocks owing to the geological evidence of basaltic rocks in the area while negative residual magnetic anomalies were interpreted in terms of the presence of gneisses, granites, migmatite and non-magnetic sedimentary rocks of the Tertiary age. Qualitative interpretation of the magnetic anomaly map covering the study area revealed a regional trends of N-S to NE-SW, NW-SE and E-W, this character of magnetic field support the results obtained from the structural geologic mapping of the area and could be genetically related to trends of magnetic grains within structures such as faults, foliations, joints, shear deformation, dykes and veins encountered within the area during a follow-up ground truthting.

Keywords: Song, Hawal, Basement Complex, Magnetic Anomalies and Structures

INTRODUCTION

The study area is located in the southern fringe of the Hawal Basement Complex of northeastern Nigeria. The area is covered by the Nigerian Geological Survey Agency (NGSA) aeromagnetic map sheet 176 Zummo (1975) and is located in the northwestern part of this map and the sheet is on a scale of 1:100,000. The study area extend from Longitude $12^{0}30'$E – $12^{0}45'$E and Latitude $9^{0}45'$N – $10^{0}00'$N (Fig.1), geological map of Song and environs which is within the study area with total land area of about 119 km^2 showed area covered by ground truthting (Fig.2).

Song area has a rugged topography consisting of series of northwesterly regional trend of hills this in most cases underwent brittle deformation which resulted from either tectonism or exfoliation and are separated by low lands at the northwestern, northeastern and central portion and a flat topography covered by Tertiary sediments towards the southern part. Elevation of the area varies from 800 m to about 1650 m above sea level. The area is drained principally by river Song and other distributaries and their courses are principally controlled by geologic structures.

Climate in the area is typical of northern Nigeria with two main climatic seasons (dry and wet). The dry hot (with a short duration of low temperature or harmattan period) and dusty season commences from November to April. The rainy season with moderate to high intensity precipitation commences from April to October with July

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to September being the peak period of the raining season. The area is sparsely vegetated with trees and verdant grassland especially in the rainy season.

This paper attempts to interpret the aeromagnetic map covering Zummo NW, as well as conducting a follow-up ground truthting of surface structural features and trends within an area (Song and environs) subset from the regional aeromagnetic map of the area; so as to correlate interpretation from the aeromagnetic map with ground evidence.

Regional Tectonic Setting and Geology of the Study Area

The Hawal Basement Complex is bounded to the north by the Chad Basin, to its west and south lays the Cretaceous northerly trending Gongola arm and easterly trending Yola arm of the Upper Benue Trough respectively. The crystalline basement rocks bordering the Benue Trough are composed mainly of Precambrian gneisses and migmatite (Rahaman, 1976). These rocks were intruded by granites and their related rock types during the major thermo tectonic event of Pan-African age (Ekwueme, 1994). The major structural trends in the Basement Complex are N-S, NE-SW, E-W, and NW-SE (Ekwueme, 1994). Some of these trends correspond to the general trends of the Cretaceous Benue rift and this implies that the orientation of the rift were strongly influence by the preexisting structures (Wright, 1976; Benkhelli, 1989).

The geology of Song and environs as presented by Adekeye and Ntekim (2004) comprises of gneisses, migmatite and granite as the dominant rock groups which were intruded by series of granitic, pegmatitic and basic rocks. The gneissic rocks according to Adekeye and Ntekim (2004) are the pre-dominant rocks in the area and consist of different groups predominantly of granite composition and exhibit variable colours due to the nature and proportion of the feldspars and marfic minerals. Older granite in this area intruded the predominant gneissic rocks and in some locations occurs in close association with the migmatite and occurred mainly as sizeable plutons showing lithologic variations to include granodiorite, aplite and amphibolites. According to these authors, migmatite rocks occurring in the area are of two types; the veins and the agmatite which were probably formed by late injection of quartzo-feldspathic rich acid materials into the gneissic and granite host rocks. Basalt occurrence in the area occurs as volcanic basaltic rocks exhibiting some vesicular and sometimes amygdaloidal textures.

MATERIALS AND METHOD

Aeromagnetic Data Acquisition and Treatment

The data used in the study was obtained from the Nigerian Geological Survey Agency (NGSA) as aeromagnetic map sheet 176 Zummo on a scale of 1:100,000, compilation of this aeromagnetic map was completed in January, 1975. Data used for the compilation of this map were acquired at a nominal flight altitude of 500 feet above terrain, along a flight lines direction of $150^0/330^0$ and the nominal flight line spacing is 2 km apart. The flight tie direction was $60^0/240^0$ at a nominal tie line spacing of 20 km; regional correction for the data was based on I.G.R.F of January, 1974.

The map was manually digitized at the corners of a regular grid of 1 cm interval along the N-S and E-W directions, with each 1 cm representing 1 km on ground. The choice of digitization at the corner of grids was guided by the facts that it will as much as possible retain the significant geologic structures on the map, in this manner sheet 176 (Zummo NW) was digitized to obtain a 28 x 28 data points. The resulting digitized magnetic data was contoured at a contour interval of 15 nT using the Golden software surface mapping system (SURFER 8.0).

From the digitized data, the regional background anomaly was separated from the observed data to obtain the residual data by applying a 2-points average filter a method adopted from Sherriff (1989). In this method, the residual data was obtained by multiplying each of the surrounding values by -¼ and the central station value by +1 and then summing the results. The 2-points average filter was considered satisfactory as higher point averaging filters will cause loss of significant details on the magnetic map. The residual values were then re-contoured at an interval of 5 nT using SURFER 8.0 software to obtain the residual map and its 3-D version

Ground Truthting

This aspect of the research work was carried out as a follow-up to aeromagnetic data interpretation and it involved identifying, describing and classifying the different types of structures occurring on the Basement Complex rocks in the study area and measurement of structural trends (strikes) and dips as well as their thickness and lengths. Recognition of structures such fault, shear zones, foliations was done following some criteria as described by Billings (1972), Barnes (1981) and (George and Stephen, 1996). The data obtained from the field measurements (strikes) were inputted into computer software (GEOrient version 9.4.4) for statistical analysis where rose diagrams were plotted to show the predominant structural trends in the study area.

RESULTS AND INTERPRETATION

Aeromagnetic Map Interpretation

The re-contoured version of the original aeromagnetic map of Zummo NW sheet 176 as presented in Fig.3 showed that, the area is characterized by short, medium and long wavelength magnetic anomalies. The relative smooth magnetic anomalies of gentle magnetic gradient (long wavelength) flank the southern part of the map and this could be attributed to the relative thick sequence of Tertiary sedimentary rock in the southern portion of the study area. Smooth magnetic anomalies of short wave length are seen on the central, northeastern and northwestern parts of the study area and are probably caused by either the presence of magnetic basement rocks and small near surface intrusive bodies.

From the residual magnetic anomaly map and its 3-D version (Fig.4), the area is characterized by both positive and negative magnetic anomalies. Amplitude of the residual magnetic anomaly ranges from a minimum of - 63 nT to a maximum of 90 nT. The areas of positive magnetic anomalies occur in the northeastern, northwestern and the central parts of the map. The large positive magnetic anomaly extending northwesterly alone the central part of the map which is also covered by ground structural mapping, can be interpreted in terms of intrusive/extrusive marfic rocks owing to the geological evidence of basaltic rocks in the area which mostly outcrop as hillocks and scattered boulders along the stream channels. Fitton (1980) relates these rocks to the volcanic rocks of the northern arm of the Cameroon volcanic lines. The areas of negative residual magnetic anomalies as seen in the central and southern part of the area are interpreted in terms of the presence of gneisses, granites, migmatite and non magnetic sedimentary rocks of the Tertiary age.

The lineament map of the study area (Fig.5) was derived from the residual magnetic map by drawing parallel lines passing through the centers of elongation of elliptical closures to indicate their trends as presented by Odia (1989). From the lineament map, N-S to NE-SW, NW-SE and E-W trends of magnetic anomaly was recognized. These trends as seen from the residual map were elongated mainly in the directions corresponding to the strike of the regional tectonic structures in the study area as observed from the trends of structures during the geologic mapping.

Structural Geology of the Area

Structures recognized in the field are dykes / veins, joints, shear zones, foliation / contact, and faults.

a) Dykes and Veins

Dykes and veins are the most common structural features in the area. At the southern slope of the Bongwo hill (three sisters hill), the coarse grained granite rocks was intruded by Sugary textured pegmatite to aplite dykes and veins, whose width varies from 2 cm to 80 cm. The dykes and veins structures at the slope of the Bongwo hill (three sisters hill) which dominantly trends in the N-S to NE-SW directions were seen to offset a less penetrative NW-SE and E-W trending veins (plate 1). To the north of the Bongwo hill (three sisters hill), a granite-gneiss rock is intruded by a N-S to NE-SW trending quartzo-feldspathic dykes and pegmatite to aplite veins of about few centimeters to 50 cm in width were seen to offsets the NW-SE trending veins. Pegmatite to aplite dykes and veins criss-crossing each other (plate 2) are found in places such as the new and old quarry mines at Mangwarom hill south of Bongwo hill (three sisters hill), Wuro Yakubu old quarry mine, foot of Vinde Sawim hill, Tappare hill and on most granite-gneiss rocks mapped in the area. About one hundred and fourteen measurements of strike of dykes and veins in the area were statistically analyzed. From the rose plot of trends of dykes and veins (Fig. 6) the dominant trend is in the N-S to NE-SW directions, other trends are NW-SE and E-W directions.

b) Joints

Joints in the study area occur commonly on all the granite-gneiss rocks mapped. At the Bongwo hill, Mochipore hill Vinde Sawin and other rocks outcropping in the area, joints are second most omnipresent structure in the area, the joint attitudes in a rose diagram (Fig. 7) shows that, the dominant trend is in and N-S to NW-SE directions. Most of the joints are vertically dipping or nearly so and seems to have been, initiated by rock shearing. Other significant directions of the joints are in the NE-SW directions. The basaltic hillocks in the study area showed evidence of columnar jointing even though, not well expose on the surface.

c) Foliation and Contacts

Foliation on older granite has been interpreted by some workers as igneous laminations (Ekwueme, 1994). Foliations on the granite-gneiss rock in the area are also expressed by parallelism or layering of some directional property of the mineral grains exhibiting banding and a clear contacts (plate 3). From the field studies, the rocks exhibit varying degrees of foliation trends and dips between (20^0- 40^0). Fourty-Eight foliation trends measured in the field was statistically analyzed and from the rose plot (Fig.8), the NW-SE trend dominates and this is in line with the regional trend of rocks in the area.

d) Shear Deformation

Shear deformation on the granite-gneiss rocks is common at the northern part of the Bongwo hill, Tapppare hill and foot of Vinde sawin hill. The shearing has produced fracture planes and slickenside on the rocks. About thirty shear zones were observed in the field and their strikes measured. From the rose plot of shear deformation (Fig.9) three deformational directions were found in the study area the N-S to NE-SW, NW-SE and E-W. From field observations, the NW-SE and E-W shear deformations are the oldest; this is because they were offset by the N-S to NE-SW shear deformations in some places. Bassey (2007) reported the occurrence of shearing and faulting in this area as intimately related because some of the faults were initiated by shear deformation. Statistical analysis of shear deformation in the area showed that, the NW-SE trends predominates over the N-S to NE-SW (Fig.9)

e) Faults

Faults recognized in the study area are mostly normal and strike-slip faults. About sixteen (16) faults were observed during the mapping exercise. The normal fault in the study area are mostly minor and involves displacement of few centimeters to about several meters and are all steeply dipping (60^0-80^0) and trends in the E-W direction (Plate 4). Other faults observed are the strike-slip fault, one of such strike-slip fault occurred along Yola- Gombi road at Wuro Yakubu with a dextral sense of movement. Trends of the strike-slip fault were dominant in the WNW-ESE direction; other significant trends are the NE-SW directions.

DISCUSSION

The major structural lineament as interpreted from the aeromagnetic anomaly map covering the study area revealed a regional trends of N-S to NE-SW, NW-SE and E-W, this character of magnetic field support the results obtained from the structural geologic mapping of the area and could be genetically related to trends of magnetic grains within structures such as faults, foliations, joints, shear deformation, dykes and veins encountered within the area. It is obvious from the account of the tectonic trends of N-S to NE-SW, NW-SW and E-W in Song area, that the basement complex rock in this area was affected by orogenic episodes just like its counterpart basement complexes in the north central, northwest and southwestern Nigeria. From field study and statistical analysis, the dominant structural trend in the area is the N-S to NE-SW direction and structures which trends dominantly in this direction include dyke, veins and joints other structure such as shear zone and foliation trends dominantly in the NW-SE, directions. The N-S to NE-SW structures were penetrative and were seen to offset the NW-SE and E-W trending structures. Ekwueme (1994) attributes the N-S to NE-SW trending structures to the Pan-African orogeny and are widespread in the Nigeria basement complex rocks. The NW-SE and E-W trending structures have been interpreted as products of pre-Pan-African deformation (Ekwueme, 1994). Contrary to the opinion of some authors that, the last thermo-tectonic event (Pan-Africa) was so perverse that it obliterated earlier structures. This study revealed that the Pan-African event did not completely homogenize the rock in the basement complex hence, traces of earlier structures still remain as seen in the field where less penetrative NW-SE and E-W trending structures were offset by a penetrative and dominant N-S to NE-SW trending structures.

The field study revealed occurrences of E-W to WNW-ESE trending normal faults and strike-slip faults, this could not be far from the facts that the study area adjoined the Benue trough. These faults probably might have occurred during the major thermo-tectonic event of Pan-African which was accompanied by faulting, fracturing, and magmatic intrusion which later led to the formation of the Benue rift. The fault scarp on Bongwo hill and a granite hill north of Bongwo hill and the strike-slip fault at Wuro Yakubu trending in the same E-W direction as the Yola Rift of the Benue trough or nearly so, were indications that, the formation of the Benue rift is strongly influence by these structures. It is also evident from the field study that almost all the streams and rivers observed flows either in the N-S, NE-SW and NW-SE directions; this is in line with Bassey (2007) who observed that the course of major streams and rivers in the study area, are largely controlled by geologic structures.

CONCLUSION

Qualitative interpretation of the aeromagnetic map covering Song and environs revealed a N-S to NE-SW, NW-SW and E-W trending structures and this was interpreted in terms of the trends of structures such as faults, foliations, joints, dykes and veins as evidenced from the ground truthting exercise. Cross-cutting relationship of structures from the field study revealed that the last thermo-tectonic event (Pan-Africa) did not obliterate completely early structures. It is also obvious from the field study that orientation of some of these structures i.e. E-W and WNW-ESE structural trends plays an important role in the formation of the Yola rift of the Upper Benue Trough since the study area adjoined the Benue Trough.

ACKNOWLEDGEMENT

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Figures and Plates

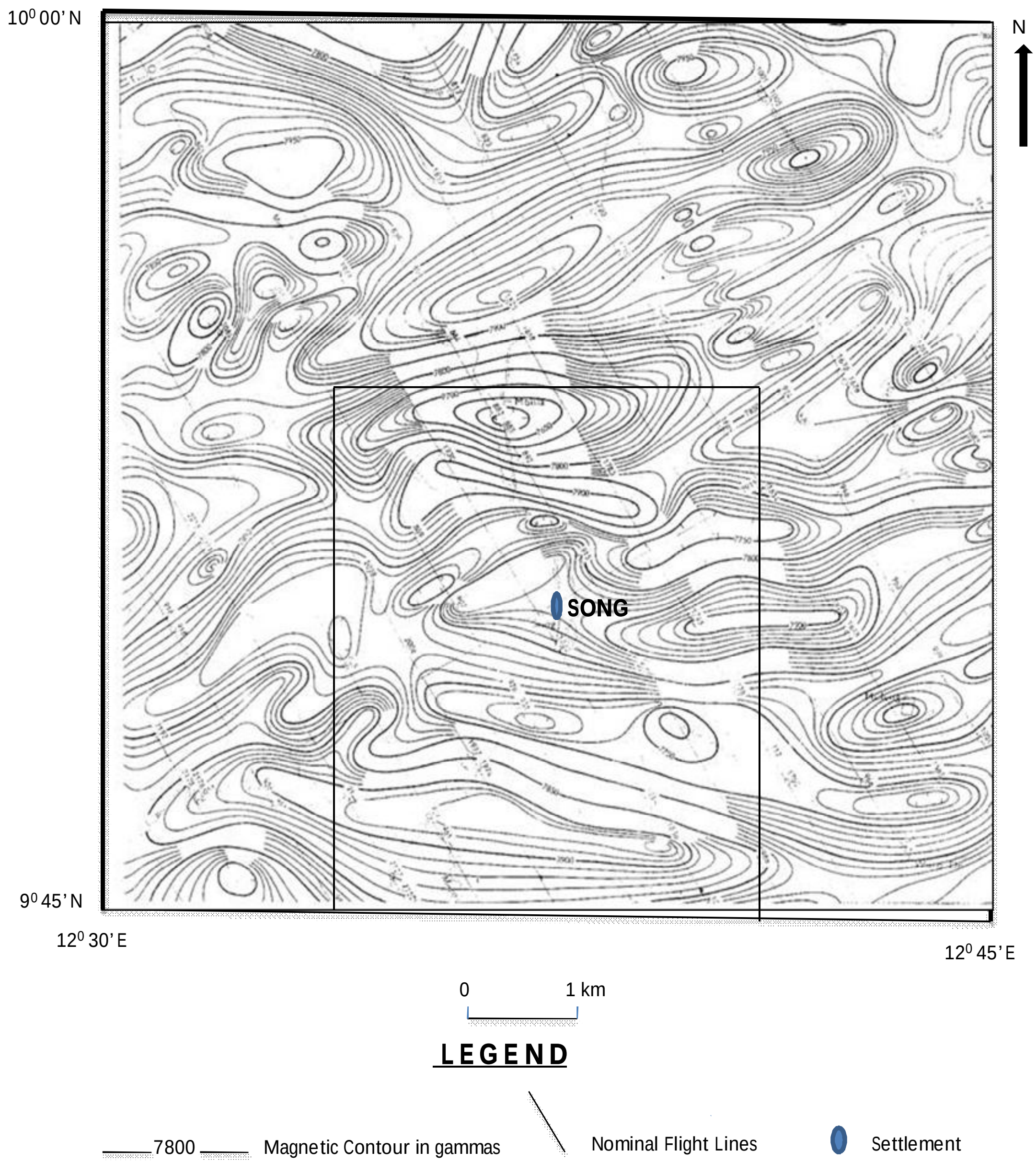

Fig. 1: Aeromagnetic Map of Zummo NW Covering the Study Area . (After GNS 1975)
[inset: Shows Area covered by Fig.2]

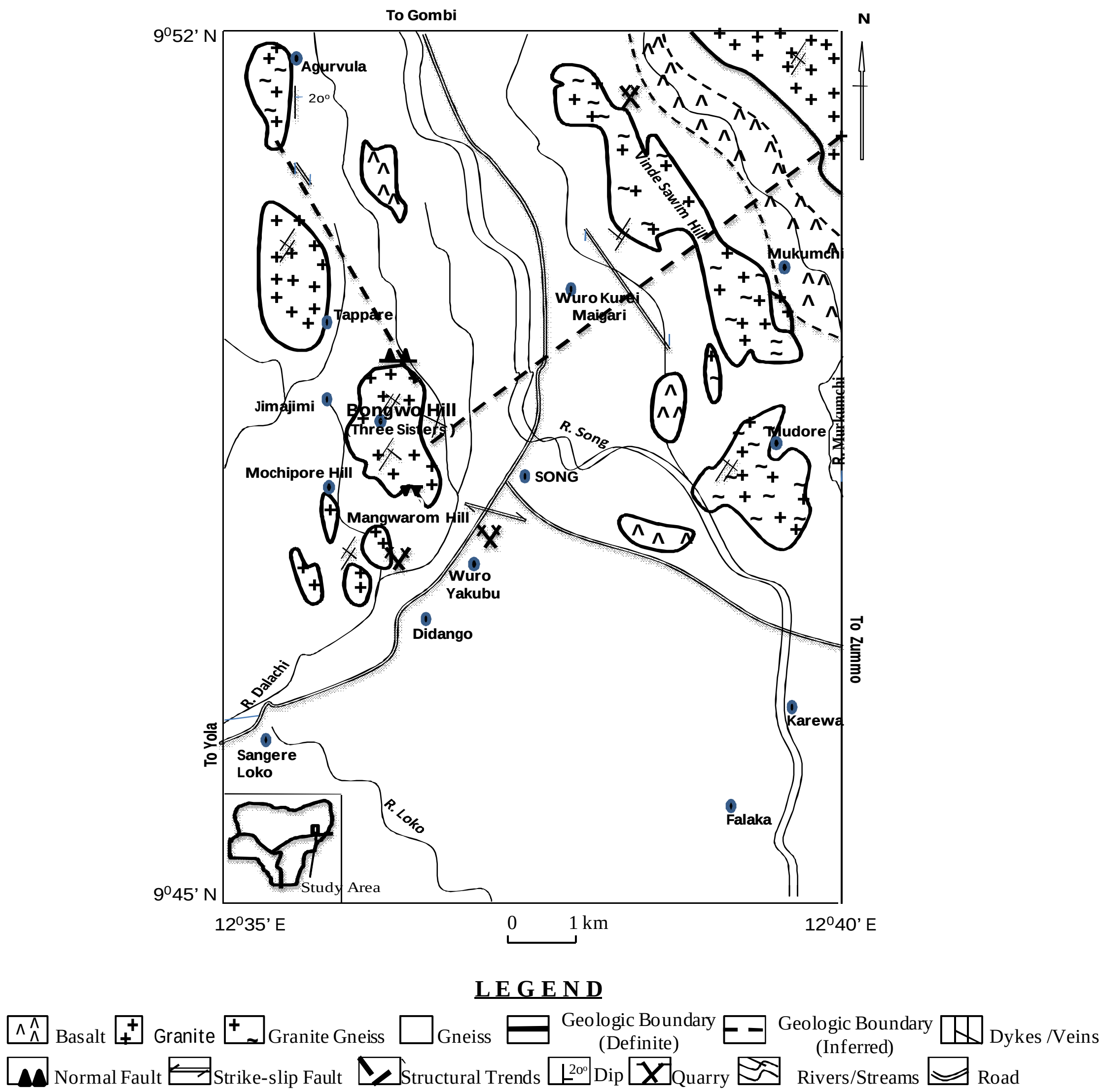

Fig. 2: Geological and Structural Map of Song Area. Modified from Bassey (2007)
[Inset : Map of Nigeria showing the study area]

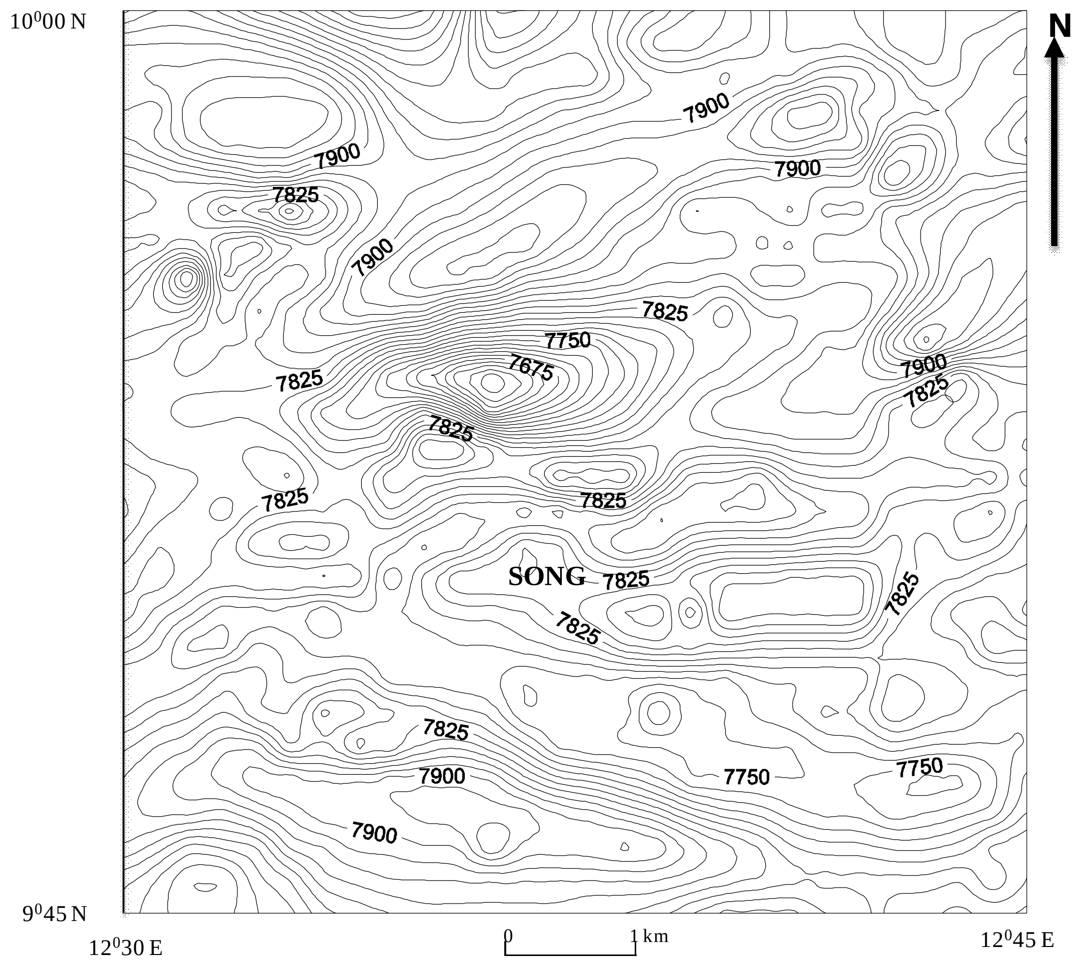

Fig.. 3: Re-contoured Total Magnetic Intensity Map of Zummo NW (C.I. = 15 nT)
[Add 25,000 gammas to contour values to obtain the actual total magnetic field values]

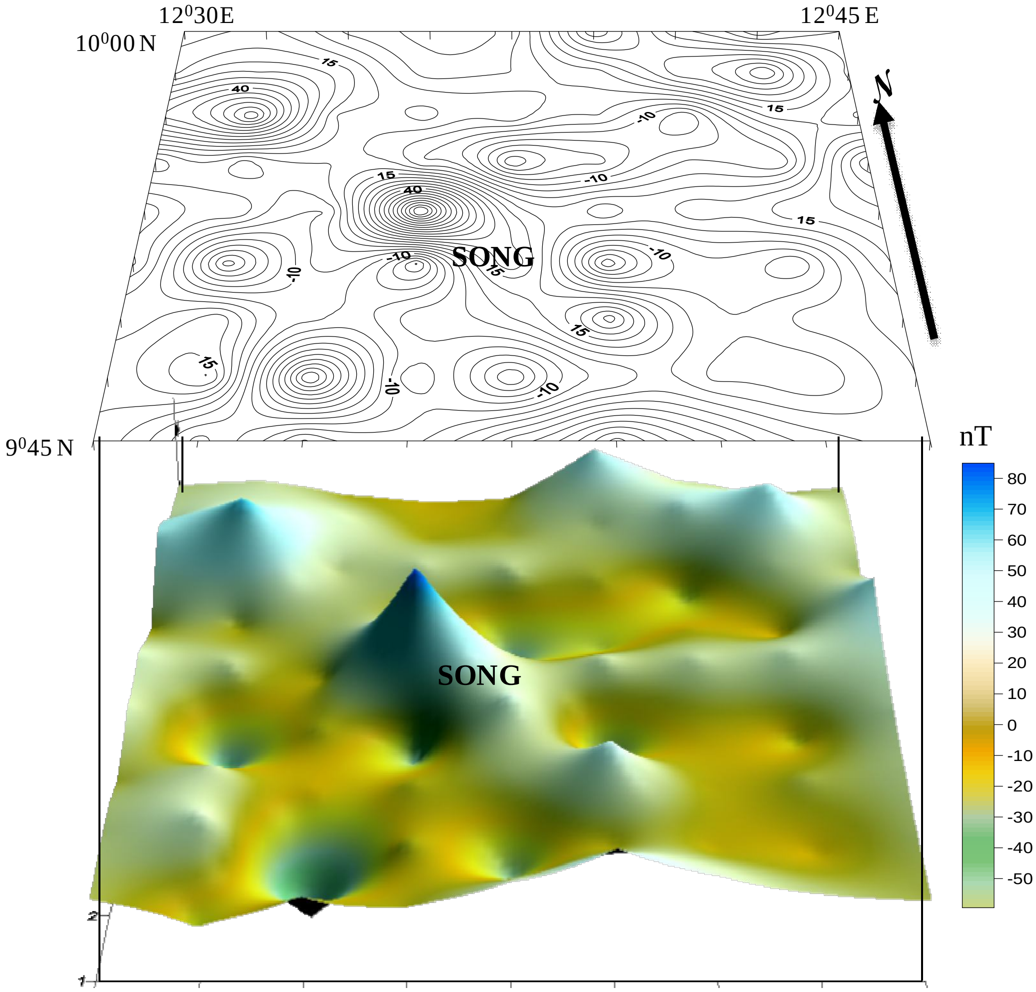

Fig.. 4: Overlay of Residual Contour Map of Zummo NW over its 3D- Surface Map (C.I. = 5 nT)

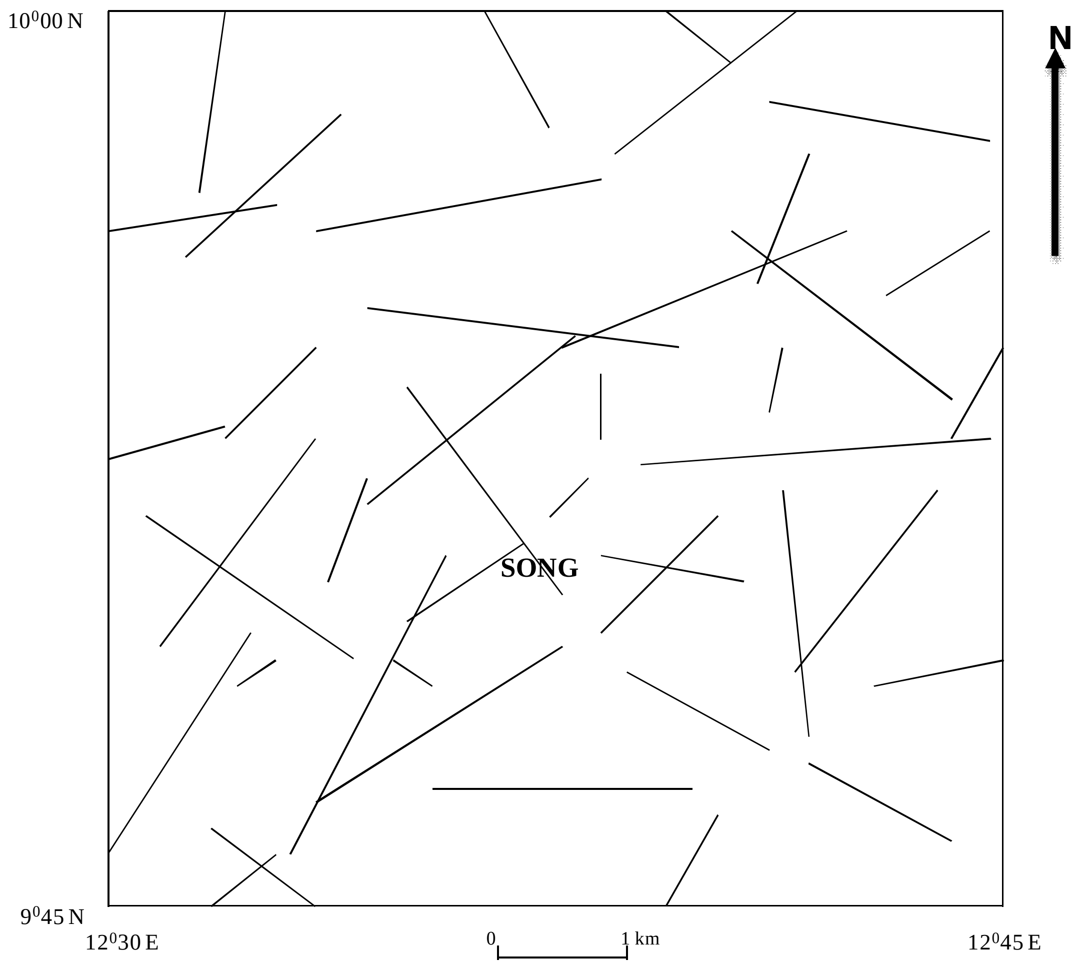

Fig.. 5:Linearment Map of Zummo NW Inferred from the Residual Map

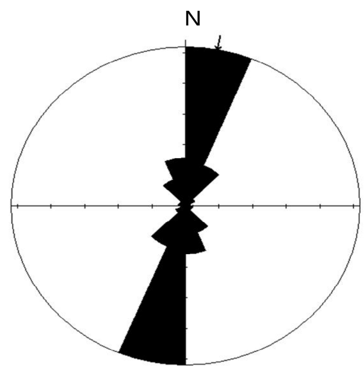

Fig. 6: Rose diagram plot for dykes and veins in Song area (n = 114)

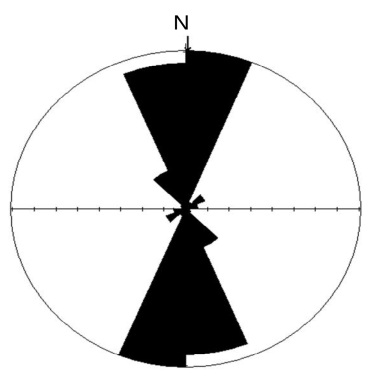

Fig. 7: Rose diagram plot for Joints in Song area (n = 274)

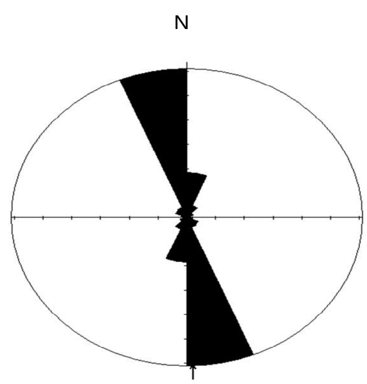

Fig. 8: Rose diagram plot for Foliation in Song area (n = 48)

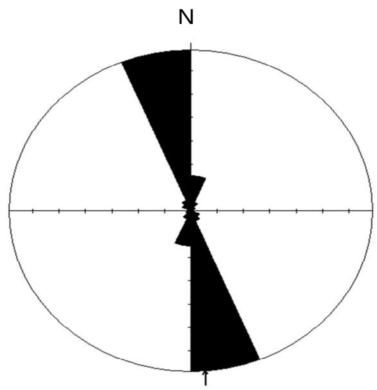

Fig. 9: Rose diagram plot of shear zones in Song area (n = 30)

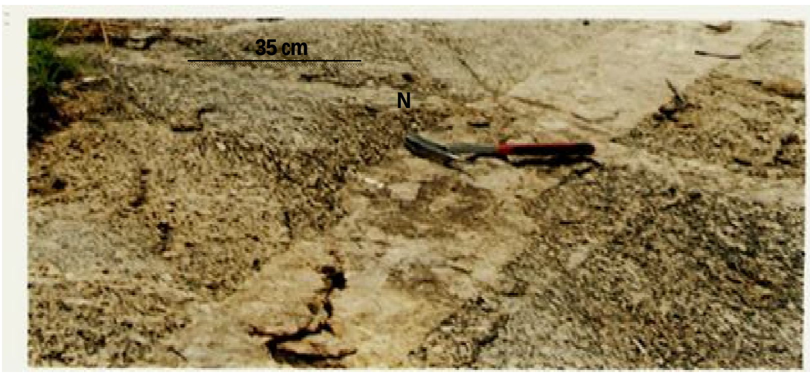

Plate 1:A NE-SW Trending Quartzo-feldspathic Dyke seen to Offset a NW-SE Trending Pegmatite to Aplite Veins at the Slope of Bongwo Hill

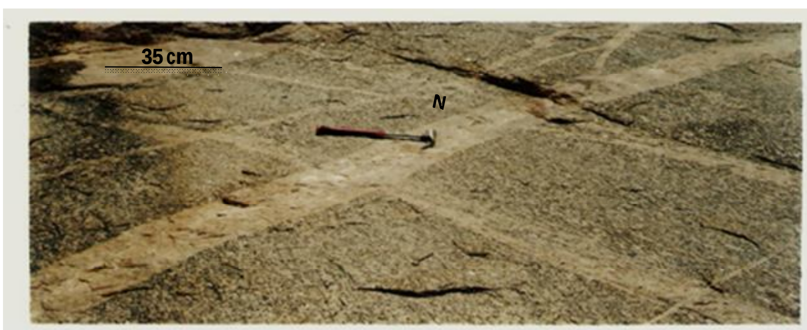

Plate 2: Pegmatite to Aplite Dykes and Vein seen to cross-cut each other on one of the Granite -Gneiss Rocks in the Study Area.

Plate 3: Banding Exhibiting a Sharp Contact on one of the Granite-gneiss Rock

Plate 4: Fault Scarp on one Face of the Bongwo Hill (Three Sisters Hill)