INTERPRETATION OF HIGH RESOLUTION AEROMAGNETIC AND LAND SATELLITE IMAGE OVER PART OF THE NORTH-CENTRAL BASEMENT COMPLEX: IMPLICATION FOR GROUNDWATER EXPLORATION

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ABSTRACT

Considering the significance of groundwater to population growth, this study interprets high resolution aeromagnetic and land satellite imagery data to explore prospective areas for groundwater occurrence in part of the north-central Basement Complex of Nigeria. The study area lies between longitudes $5^030'$ – $7^000'$ E and latitudes $9^030'$ – $10^030'$ N. To achieve this objective, high resolution aeromagnetic data covering the study area was subjected to magnetic residual separation and analytical signal using Oasis Montaj version 8.4. The Land satellite imagery data was also subjected to false colour composite analysis using ILWIS version 3.3 software. Combination of this analysis aided in mapping of lineaments within the study area. Result of lineaments mapping from analytical signal and land satellite images shows high density lineaments around Wushishi, Zungeru, Tegina Kagara, Pandogari, Alawa, Gurmana and low density lineaments around Bobi, Kuta, Guni, Minna, Tenenge. These lineaments having a dominant trend in the NE-SW and NW-SE, E-W minor directions were interpreted as joints, veins, faults, foliations and lineation of outcrops. Field studies in Tegina, Zungeru and Wushishi falling within areas with high lineament density revealed good groundwater yield from motorized pumps, hand pumps and hand dug wells. This is contrary to what was observed in Gidan Gwari an area attributed to low lineament density where only one hand bore hole out of the seven drilled boreholes was productive.

Key words: North-Central Basement Complex, High resolution Aeromagnetic, Satellite image, Lineaments mapping, Groundwater prospecting.

INTRODUCTION

Ground water is a precious and the most widely distributed resource of the earth, unlike mineral resource that are invariable non-renewable. Groundwater is annually replenishment through infiltration of meteoric water. It is the largest source of fresh water on the planet excluding the polar icecaps and glaciers. (Anji-Reddy, 2008). Groundwater prospects of an area depend mainly on lithologic units (rock types) occurring in an area. However, within each lithologic unit, the ground water conditions vary significantly depending upon the geomorphology, structure, slope, soil thickness, depth and nature of weathered material, presence of fractures, lineaments, surface water bodies, canals, irrigated areas, etc (Anji-Reddy, 2008). Therefore, groundwater exploration means to identify and to locate zone(s) of occurrence and recharge of groundwater in a particular basement or sedimentary terrain.

In crystalline terrains groundwater occurrence depends on the depth and extent of weathered materials overlying a fresh basement complex rock. It also depends on the size, extent, pattern, intensity, orientation, continuity, variance from macro to mega level and inter-connection of joints, fractures, foliation, and faults in these rocks.

Geologic mapping of outcrops and weathered zones, as well as delineation of fault- fractures systems in hard rock terrains

for groundwater exploration can be greatly aided by image interpretation using conventional aerial photographs such as satellite imagery (Mogaji et al. 2011). Major faults, fracture zones, weaker planes acts as collection point as well as movement and infiltration of surface water in to the subsurface. These structures are known to yield considerable quantities of groundwater; hence they are good targets for groundwater exploration and exploitation. In the same manner, the open and close characters of these structures on the surface and at depth affect and controls water movement and storage.

In view of the fact that groundwater is one of the major sources of water supply in urban and semi urban areas. To augment the daily water needs of the populace in the study area considering the rate of population growth, this research was carried out to explore potential areas for groundwater occurrence. This objective was achieved through mapping of lineaments from interpretation of high resolution aeromagnetic and land satellite imagery data.

Regional Geology of the Study Area

The study area is located in the north-central part of Nigeria and the geology is dominated by the Precambrian Basement Complex rocks (Figure 1). The crystalline basements rocks in the study area have been subjected to deformational episodes of different intensities throughout thegeological period. Consequently, N-S, NE-SW, NW-SE, and to a less extent, E-W faults, dykes and fractures have developed (Obaje, 2009). The Precambrian Basement rock consists of the Migmatite-Gneiss complex and is generally considered as the basement complex sensu stricto (Rahaman, 1988; Dada, 2006). It is the most widely spread units in the Nigerian basement and makes up about 60% of the surface area of the Nigerian basement rock (Rahaman and Ocan, 1978). The Basement Complex rocks in the study area has aheterogeneous assemblage comprising migmatites, orthogneises, paragneisses, and a series of basic and ultrabasic metamorphosed rocks. The Migmatite – Gneiss Complex has ages ranging from Pan-African to Eburnean.Other units include the NE-SW trending schist belts mostly developed in the western half of the country. The prominent schist belt within the study area is the Zungeru-Birnin Gwari schist belt. The Zungeru-Birnin Gwari Schist Belt is a simple N–S syncline, 150 km long, with the northern part displaced dextrally by a NE–SW transcurrent fault (Obaje, 2009). Intruding both the Migmatite-Gneiss Complex and the Schist belt is the granitoid plutons of the Older Granite suite dated Late Proterozoic to early Phanerozoic (Obaje, 2009).

MATERIALS AND METHODS

Materials

Nine half degree high resolution total magnetic intensity (TMI) aeromagnetic data provided in grid and data based format each on a scale of 1:100,000 and land satellite imagery with a spatial ground resolution of 22 m x 22 m on a scale of 1: 100,000 were utilized for this analysis. The high resolution total magnetic intensity aeromagnetic data was purchased from the Nigerian Geological Survey Agency in Abuja while the satellite image data was purchased from the National Centre for Remote Sensing in Jos as a single grid from spectral bands 1 – 7.

Methods

The regional residual separation filter within the Oasis Montaj software was applied to the total magnetic intensity (TMI) field data to obtain the magnetic residual data utilized for this work. Nabighian (1984) developed the concept of analytical signal (A) of magnetic anomalies which was a better alternative for positioning anomalies vertically over the bodies calculated by taking the square root of the sum of squares of the data derivatives in the x, y, and z directions of magnetic field (T) as follows:

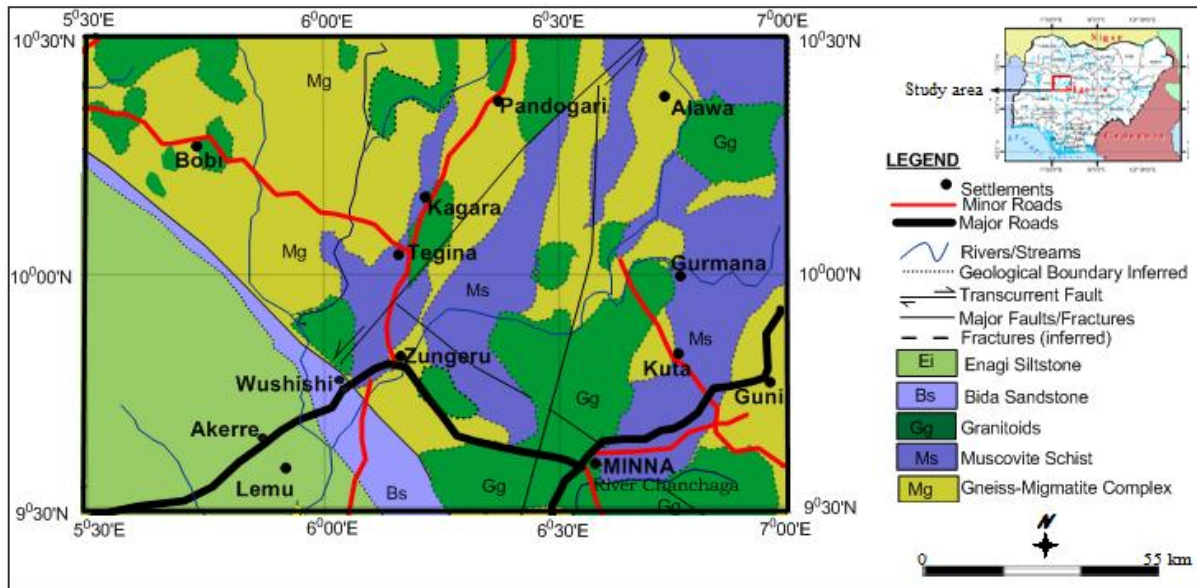$$|A(x,y)| = ((dT/dx)^2 + (dT/(dy)^2 + (dT/dz)^2)^{1/2}$$

Figure 1: Geological Map of Part of North-Central Basement Complex (Modified from Barka, 2020)

The analytical signal was useful in this work in locating the edges of a magnetic source and for lineaments mapping.

Land satellite image was analysed for surface structural mapping. This research work utilized the multi-band images which uses three or more bands combined in continuous colour of red-green-blue (RGB) images to extract structural trends from the satellite imagery map. The land satellite data was subjected to various digital image processing techniques in the Ilwis version 3.3 environments among which is the colour composite image processing which is a technique that enhances geologic features such as lineaments, linear/edge enhancement.

Analysis on the land satellite imagery was carried out by visual inspection where non-geologic features such as roads; footpaths were excluded from the lineament extraction with the aid of the topographic map of the study area. Lineaments were delineated by visual interpretation of false colour composite (FCC) image which was obtained by fussing together of band 1 (Blue band of the visible spectrum), band 4 (Red band) and band 7 (Near infrared).

The idea of various band combinations that gave rise to the false colour composite (FCC) image was borrowed from the findings of researchers such as Juhari and Ibrahim (1997); Pradeep et al. (2000); Syed and Saied (2004); Mogaji et al. (2011) for lineaments interpretation. In this research work, band combination of 147 gave a good resolution for lineaments extraction and linear features seen on the false colour composite (FCC) image considered to represent a deformational zone were digitized as polylines. Result so obtained was used to produce lineament density/lineament intersection map of the study area.

RESULTS

Figure 2 is the total magnetic intensity (TMI) map of the study area and it ranges from 32,908.11 nT to 33,098.9 nT. This range of magnetic intensities implies that the study area is characterised by high to low frequency of magnetic intensities. The

residual magnetic map over the study area (Figure 3) was obtained by subjecting the TMI data to regional residual separation. Also scattered in different parts of the map are attributes of positive and negative anomalies. The anomalies ranges from –104.2 nT to 57.1 nT.
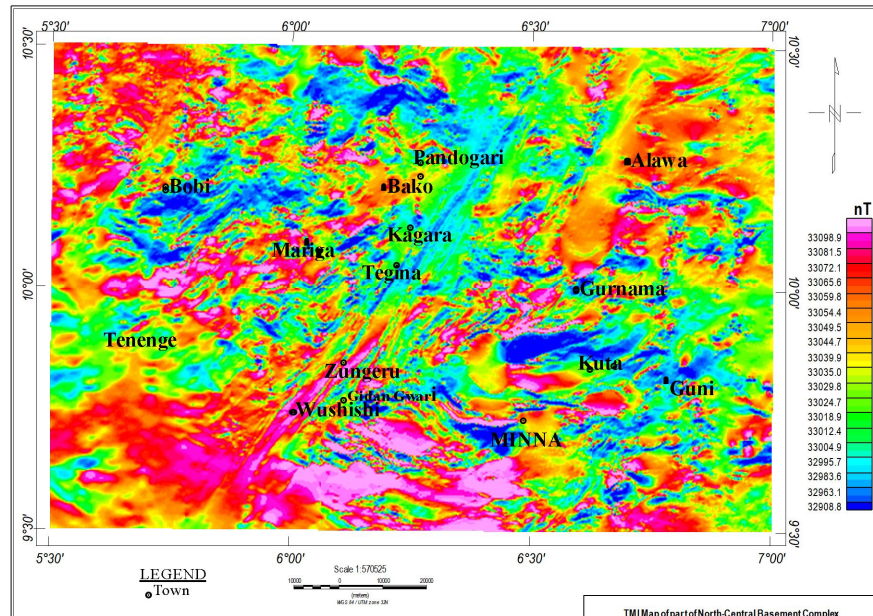

Figure 2: Total Magnetic Intensity (TMI) Map of Part of North-Central Basement Complex
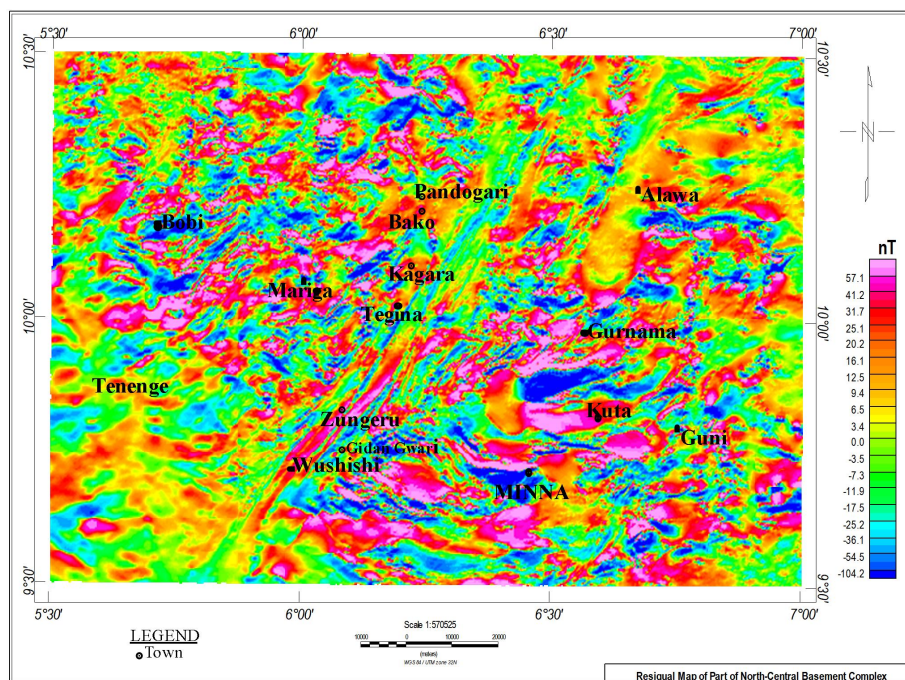

Figure 3: Residual Magnetic Map of Part of North-Central Basement Complex

Figure 4 revealed lineaments extracted from analytical signal map. From figure4, a NNE-SSW to NE-SW lineament trends are noticeable over Wushishi, Zungeru, Tegina, Kagara Pandogari Alawa and Gurmana, other lineaments delineated are in the NW-SE and E-W directions.
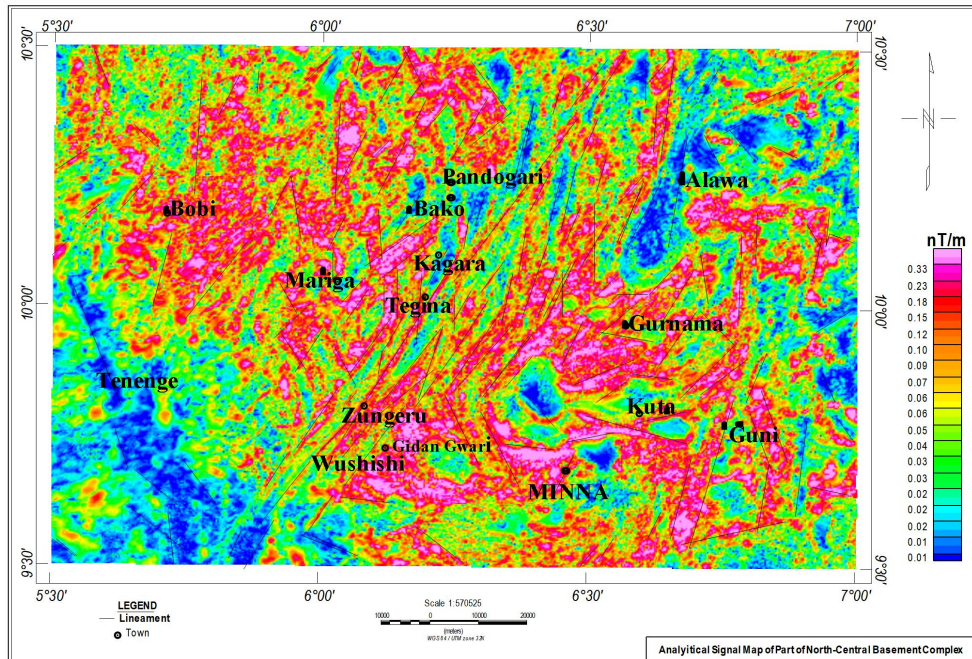
Figure 4: Lineaments superimpose on the Analytical Signal Map of Part of North-Central Basement Complex

The false colour composite (FCC) image (Figure 5) obtained from fussing together of bands 1, 4 and 7was used for the lineament extraction. The lineaments density map (Figure 6) shows high lineament density in areas around Wushishi, Zungeru, Tegina Kagara, Pandogari, Alawa and Gurmana. All these areas lie within the Basement Complex terrains.
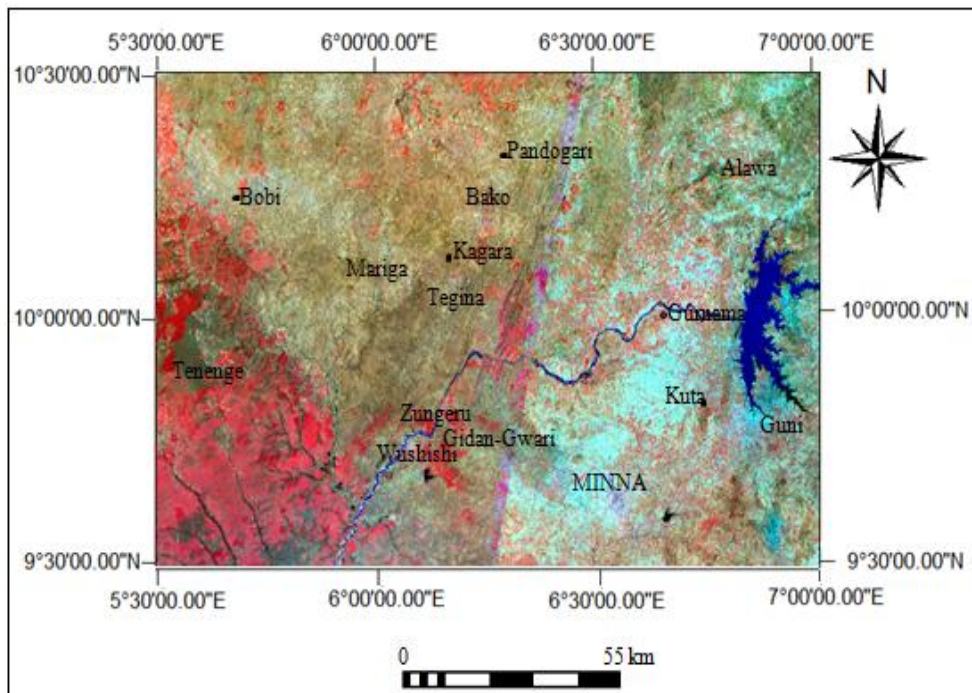

Figure 5: False Colour Composite Land Satellite Image (Bands 1,4,7) of Part of North-Central Basement Complex
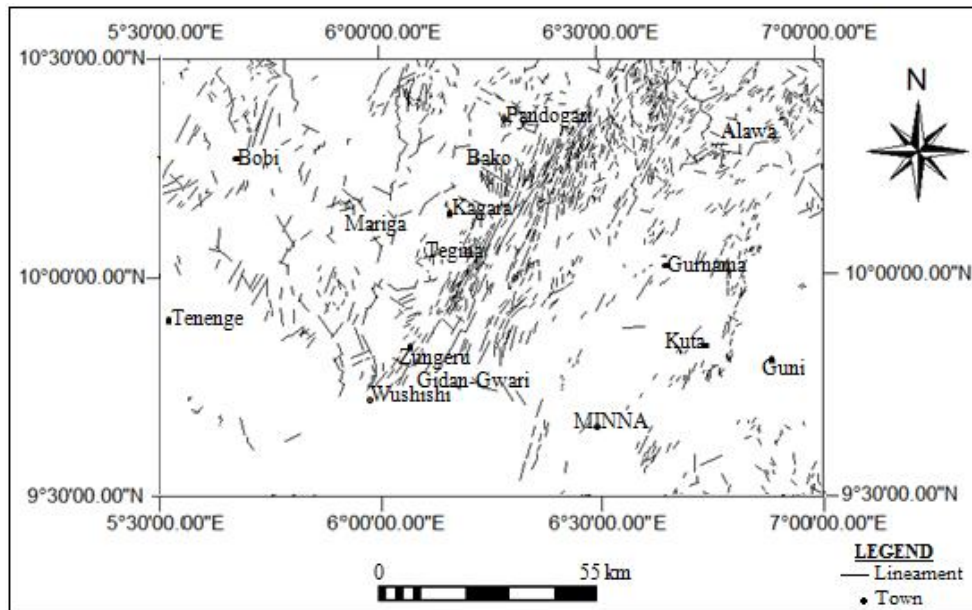
Figure 6: Lineament Density Map extracted from FCC Land satellite Image of Part of North-Central Basement Complex

Rose plot of linear structures from analytical signal map shows trends in the NE-SW, NW-SE and E-W directions (Figure 7) the dominant structural trends are in the NE-SW direction and minor directions are in the NW-SE and E-W. These structures run from about 1 km to 85 km in length. The rose plot of structural trends as interpreted from the lineament density map shows a dominant lineament trend in the NE-SW direction while minor trends are in the NW-SE and E-W directions (Figure 8). These structures run from about 0.5 km to 72 km in length.

No. of Data = 140
Length = 1 – 85 km
Sector angle = 15°
Scale: tick interval = 10% [14.0 data]
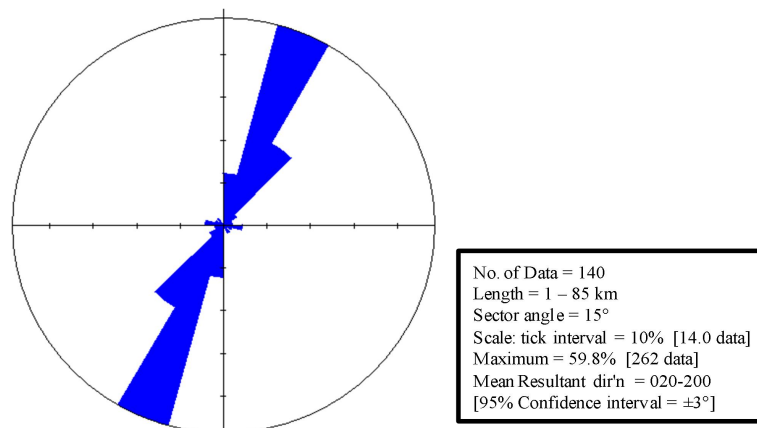Maximum = 59.8% [262 data]
Mean Resultant dir'n = 020-200
[95% Confidence interval = ±3°]

Figure 7: Rose Diagram of Linear Structures from Analytical Signal Map of Part of North-Central Basement Complex

No. of Data = 1045
Length = 0.5- 72 km
Sector angle = 15°
Scale: tick interval = 10% [104.5 data]
Maximum = 45.4% [474 data]
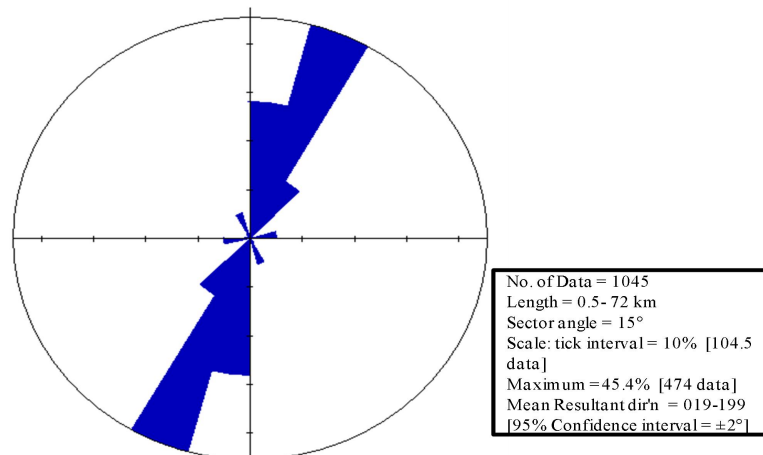Mean Resultant dir'n = 019-199 [95% Confidence interval = ±2°]

Figure 8: Rose Diagram of Linear Structures from Lineament Density Map of Part of North-Central Basement Complex

DISCUSSION

Lineaments are geological features noticeable at the earth surface and are reflection of discontinuities on the earth caused by geologic or geomorphic processes (Waikar and Nilawar, 2014). Geologic features that are generally referred to as lineaments include faults, shear zones, fractures, dykes and veins as well as bedding planes and lithologic contacts (Waikar and Nilawar, 2014). In their contribution, the authors further state that lineament density of an area has direct influence on groundwater potential hence it can be used to infer high secondary porosity.

From this study high lineaments density with intersections were observed over, Wushishi, Zungeru, Tegina Kagara, Pandogari, Alawa and Gurmana all within the Basement Complex terrains. Low lineaments densities were observed in areas around Bobi, Kuta, Guni, Minna. These lineaments were interpreted as faults, shear zones, linear arrangement of rocks, dykes, veins, fractures and other lithologic contacts.

The rosette plot of these structures shows a dominant trend in the NE-SW direction and minor trends in the NW-SE and E-W directions. It will be of interest to note that the linear features delineated from both Analytical and false colour composite (FCC) image shows a dominant trend in the NE-SW direction this implies that some of the structures observed on the surface as delineated from the false colour composite (FCC) are deep seated because they were also delineated on the analytical signal map.

Field observations and personal communication with the natives from Tegina, Zungeru and Wushishi revealed that dwellers in these communities have little or no difficulty in accessing ground water. For instance, in Tegina and Zungeru towns boreholes are drilled in almost all parts of the community and all the boreholes drilled are productive except for some mechanical problems. This is attributed to the high lineaments density over these regions resulting to high percolation of surface water in to the subsurface, thereby recharging the secondary aquifers. This by extension should be observed in areas around Kagara, Pandogari, Alawa and Gurman because of the record of high lineaments density over these regions.

Study carried out in Gidan- Gwari a settlement about 2 km to Wushishi from Zungeru lying on the basement sedimentary contact shows that the natives have difficulty in accessing ground water. Out of about seven bore holes drilled in this community only one is productive as at the time of this field work (June, 2017). This

was attributed to the absence or near absence of linear structures or fractures, which could act as infiltration medium for surface water in to the subsurface thereby recharging the secondary aquifers. The implication is that all areas lying on the Basement Complex terrain with low lineament density or near absence of lineament like Bobi, Kuta, Guni, Minna, Tenenge have to rely on alternative source of water supply. This could be streams, rivers and dam construction even though the probability of getting ground water in these areas cannot be completely ruled out.

CONCLUSION

The interpreted lineaments from analytical signal and land satellite image showed a dominant trend of lineaments in the NE-SW direction while NW-SE and E-W are the minor directions. Zones of high lineaments densities and lineaments intersections were considered as potential zones for groundwater exploration and exploitation. This phenomenon was observed over Wushishi, Zungeru, Tegina Kagara, Pandogari, Alawa and Gurmana. Low lineaments densities were observed in areas around Bobi, Kuta, Guni, Minna and Tenenge. Field observation in Tegina, Zungeru and Wushishsi towns shows that areas with high lineaments densities have high percolation of surface water in to the subsurface, therefore recharging the secondary aquifers hence high groundwater potentials. Field observation in Gidan-Gwari lying within low density lineaments revealed low percolation of surface water over such areas visa-vis poor groundwater potentials. This observable field fact from Gidan-Gwari can also be extended to areas with low density lineaments in the study area.

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