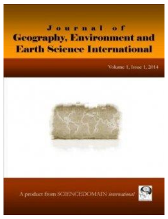

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Lithologic and Structural Mapping Using Aeromagnetic and Ground Radiometric Data in Song Area, N. E. Nigeria

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Authors' contributions

This work was carried out in collaboration between authors NEB and JB. Author NEB designed the study and conducted earlier surface geostructural and radiometric mapping. While author JB wrote the first draft of the manuscript. Data analysis and management of literature searches were jointly done. Both authors read and approved the final manuscript.

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ABSTRACT

This work analyses jointly aeromagnetic and ground radiometric data over Song region of Hawal Basement Complex. The area is marginally located with respect to the Yola Rift, an arm of the Benue Trough. The area comprises of gneiss, migmatite, granitoids and basalt as the main lithologies. Residual magnetic map was produced from the total intensity data using statistical analysis. Both magnetic and radiometric data were contoured using *surfer 9* surface mapping software. The tectonic setting of the study area is manifested in complex lithologies and structures which have been observed in the field and reflected in magnetic and radiometric anomalies. *NW, NE, E-W, and N-S* lineaments have been identified on the magnetic and radiometric maps. These are interpreted in terms of lithological emplacements, fracture and foliation directions in the basement. The magnetic and radiometric data have revealed some features not observed in the field. It is suggested that mapped lineaments would serve as guide in sustaining local quarrying industry in the area.

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1. INTRODUCTION

Magnetic surveying is used in the investigation of the subsurface geology of an area. This is achieved by detecting magnetic anomalies within the earth's magnetic field which are normally caused by magnetic susceptibility changes of the underlying rocks. Most rock forming minerals are non-magnetic but a few that contain sufficient amount of magnetic grains in them can impact magnetism to their host rock thus, producing detectable magnetic anomalies. Therefore, anomalies generated from rocks that contain magnetic grains in them may yield valuable information about the natural remanent magnetization (NRM) of the different rock units in an area and this information could be tied together to distinguish between two or more petrologically similar rock groups if they have different magnetic properties or histories.

The application of ground radiometric surveying is useful in geologic mapping because of its ability to detect radioactivity emanating from the natural decay of elements such as uranium, thorium and potassium from the earth material. The product of this decay results in the emission of alpha, beta and gamma radiations which can be detected on the surface using radioactive element detectors. The depth of penetration is however limited as the radiations are easily absorbed by earth material. To make up for this, this work combines radiometry and magnetometry. Magnetic and radiometric data have been conjunctively used in the study of lithologies and structures in Yola area, Nigeria by [1], in Ashanti gold belt of Ghana by [2]. Radiometric exploration for uranium in N.E. Nigeria has been done by several workers such as [3-7].

The use of rock for building and road constructions has necessitated local quarrying activities in the study area and this has provided employment opportunities for people across different age brackets. Because of lack of mechanized quarrying equipment, people in this area have resorted to exploiting this construction material by local means (example, burning of rock surface to weaken and to generate superfluity of fractures on the rock and later breaking the boulders in to smaller pieces using chisel and hammer).

In this work the two techniques are used to investigate the geology of Song and environs which are part of a relatively less studied north-eastern Basement Complex of Nigeria. The geology and structure have been mapped by authors such as [8-11]. The present work attempts to jointly analyse data from aeromagnetic and ground radiometric sources over the area for the first time. Hence information from both aeromagnetic and ground radiometric data can be well correlated with ground information. The outcome of this research will not just culminate at correlating ground information with that interpreted from aeromagnetic and ground radiometric data but the mapped lineaments would serve as a guide to local miners in siting or expansion of existing quarries.

1.1 Geology and Tectonic Setting of the Study Area

The study area Song and environs has an areal extent of about 118.7 km^2 and is situated along Yola-Gombi Road in north-eastern Nigeria. The area is defined by longitude 12°35' E – 12°40' E and latitude 9°45'N – 9°52'N (Fig. 1). [8-9] described the area as comprising Basement Complex rocks namely: Metamorphic rocks (gneisses and migmatite), granitoids (aplite, pegmatite, granodiorite and granite) and basalt which mainly outcropped as hillocks, scattered boulders and in some areas overlain by Tertiary alluvium. The latter are largely restricted to stream channels. Based on field relationship and petrological studies, the authors identified gneiss as the pre-dominant rock in the study area intruded by series of granite, pegmatite, aplite and basic rocks. The Basement Complex rocks are exposed in the northeast, northwest and central part of the study area.

Structural and tectonic studies carried out in the area by [9,10] revealed that, the most conspicuous structural features in the study area are pegmatite to aplite dykes and veins whose width varies from 2 cm to 80 cm and trend dominantly in the N-S to NE-SW directions. Other minor trends are NW-SE and E-W directions. Joints are also common in this area most of which are vertically dipping or nearly so and seem to have been, initiated by rock shearing. Their dominant trend is in the N-S to NW-SE directions. Other significant directions of the joints are in the NE-SW directions. Field studies also revealed that, rocks in the study area exhibit varying degrees of foliation trends dominated by the NW-SE trends and dips between (20°- 40°). Shear deformation which produced fracture planes and slickenside on the rocks are among other structures observed in the field. Three shear deformational directions were established in the study area in the N-S to NE-SW, NW-SE and E-W and from field observations. The NW-SE trend predominates over the N-S to NE-SW trends. Faults recognized in the study area are mostly normal and strike-slip faults. The normal faults are mostly minor and involve displacement of few centimeters to several meters and are all steeply dipping (60°-80°) and trends in the E-W direction while the strike-slip fault trends dominantly in the NW-SE direction; other significant trends are the NE-SW directions.

2. MATERIALS AND METHODS

2.1 Aeromagnetic and Radiometric Data

The aeromagnetic data set used in this study was acquired by the Geological Survey of Nigeria (GSN) in 1975, which is available as aeromagnetic map with sheet number 176 on a scale of 1:100,000. During the acquisition of data the following flight parameters were used for the survey; nominal flight altitude was 500 feet (150 m) above terrain, flight lines direction followed NW-SE (150°/330°) and nominal flight line spacing was 2 km. The flight tie was in the NE-SW (60°/240°) direction and nominal tie line spacing was 20 km. The geomagnetic gradient was removed from the data set using the International Geomagnetic Reference Field Formula (IGRF) of 1st January, 1974.

The total magnetic intensity (TMI) data over the study area were manually digitized at the corners of a regular grid at 1 km interval along the N-S and E-W directions. The digitized data (10 x 14 data points) were contoured at a contour interval of 10 nT using *Surfer* 9.0 software. From the digitized TMI data, the residual anomaly was separated from the observed data using statistical analysis. The mean for the data was first computed and then subtracted from the original data set to obtain the residual data. The residual values were then contoured at an interval of 10 nT.

Gamma-scout® instrument (tuned to Geiger counter mode) was used for the acquisition of radiometric data over the study area. Details of data acquisition and precautionary field measures have been presented by [11]. These authors used *surfer 8* contouring software for their work. However, in this work the radiometric data have been re-contoured using an upgraded version of *Surfer (Surfer 9)*. This has produced additional (not found on the earlier work by [11]) features with geologic significance. Hence in this work, the interpretation of the radiometric map is based on this re-contoured version.

3. RESULTS AND DISCUSSION

To the southern part of Fig. 2 is an E-W anomaly marked **A** with maximum amplitude of 32,920 nT (i.e. 7920 + 25,000 nT). This anomaly is well correlated with the easterly trend of the Yola Rift (Fig. 1). Its high amplitude is attributed to basalt a rock with high magnetic susceptibility. It has long been recognized that light coloured igneous rocks such as granites are usually more radioactive than dark coloured igneous rocks [12]. On the central part of the study area (Fig. 2) is another easterly anomaly (B) with magnetic low amplitude of 32,710 nT. This anomaly is generally over gneiss with few acidic intrusions to the west of Wuro Yakubu (Fig. 1). Anomaly C is essentially E-W trending with maximum amplitude of 32,890 nT. This high amplitude is attributed to the unexposed or unmapped basalt south of Murkuchi. This by implication is an extension of basalt found in the north-east. Anomaly D is a magnetic low with lowest amplitude of 32,740 nT. Its north-easterly trend is due to the north-east trending strike-slip fault found north of Murkuchi whose tectonic trend continues to the west of Song Town. Anomaly E is a magnetic high coincident with basalt in the area, while anomaly F (with a low amplitude) to the north-west is coincident with granite of Tappare.

Fig. 3 shows a lineament map derived from the residual magnetic map based on elongation direction of anomalies. In comparison with the radiometric lineament map (Fig. 4) produced on similar basis the following can be observed. E-W lineaments labelled 1 are observed on both maps. They are largely restricted southwards and consistent in trend with/attributed to the E-W Yola Rift (Fig. 1). NE-SW lineaments (labelled 2) on the residual magnetic map are also found on the radiometric map to the south, central, north portions of the area. Some of these lineaments have been observed and mapped as faults, dykes by [10,11]. They are considered as fracture zones/foliation directions of the Pan African Orogeny whose trend in the Nigerian Basement Complex is dominantly NE-SW and N-S. NW-SE lineaments (labelled 3) are found at the northwest margin of the magnetic lineament map, at the northeast and in the central part of the map. On the radiometric map, the north-west lineaments are found also at the northwest, the northeast, the west and to the south.

The NW lineaments at the north-west corner are attributed to mapped shear zones (Fig. 1). Those at the north-east are spatially related/or coincident with the emplacements of granite gneiss and basalt in Murkuchi area <<respectively>>.

The NW trending lineaments to the west in Fig. 4 is well correlated with the emplacement direction of the granite outcrops found between Jabbure and Wuro Yakubu in Fig. 1. Its trend is also consistent with and correlates well with the shear zone and strike slip fault found between Wuro Yakubu and Argurvila. This shear/fault zone has been geophysically proven to extend through Wuro Yakubu to the south east by [13]. By implication the two NW lineaments found to the south in Fig. 4 is an extension of these shear/fault zone.

N-S lineaments (labelled 4) are not found on the magnetic map but on the radiometric map. Its presence in the northwest is interpreted as the emplacement direction of basalt northwest of Song Town. The two other N-S lineaments found to the east are well correlated with the general flow direction of Mayo Song and the emplacement direction of the granite pluton at Wuro Yalde.

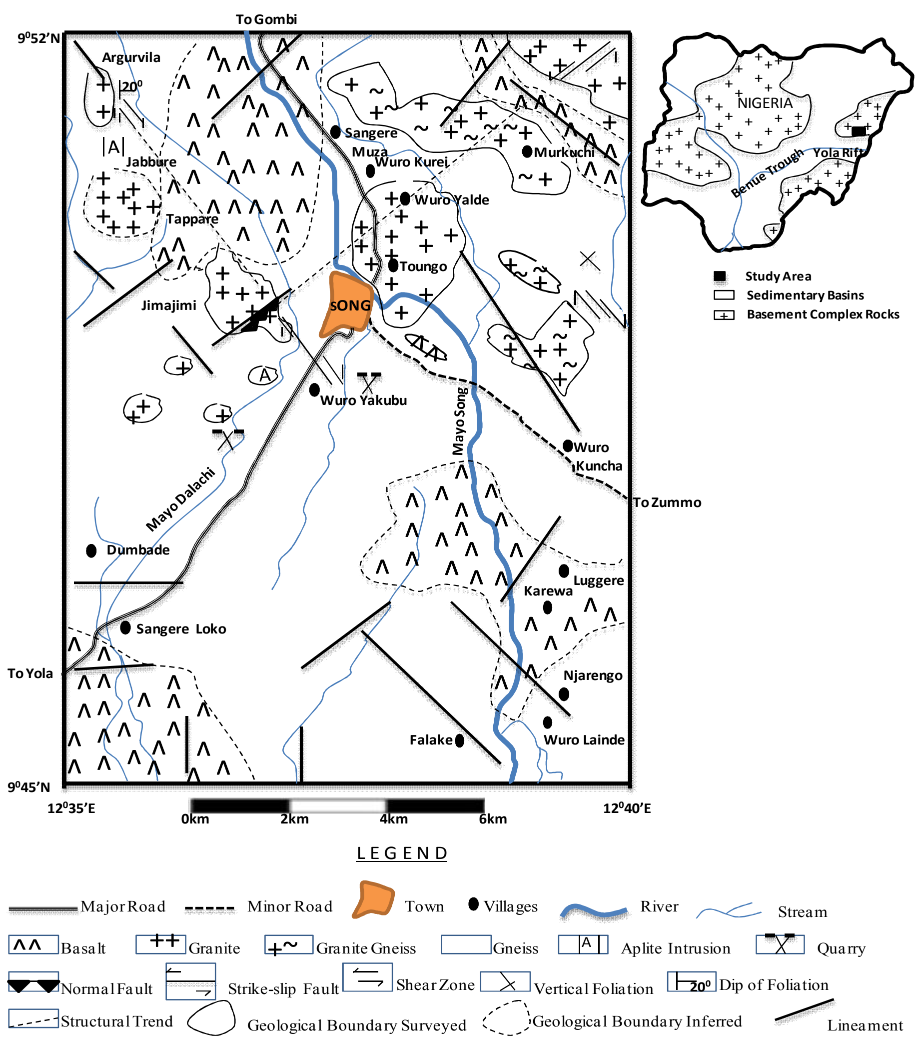

Fig. 1. Geological and structural map of song and environs [after 11]

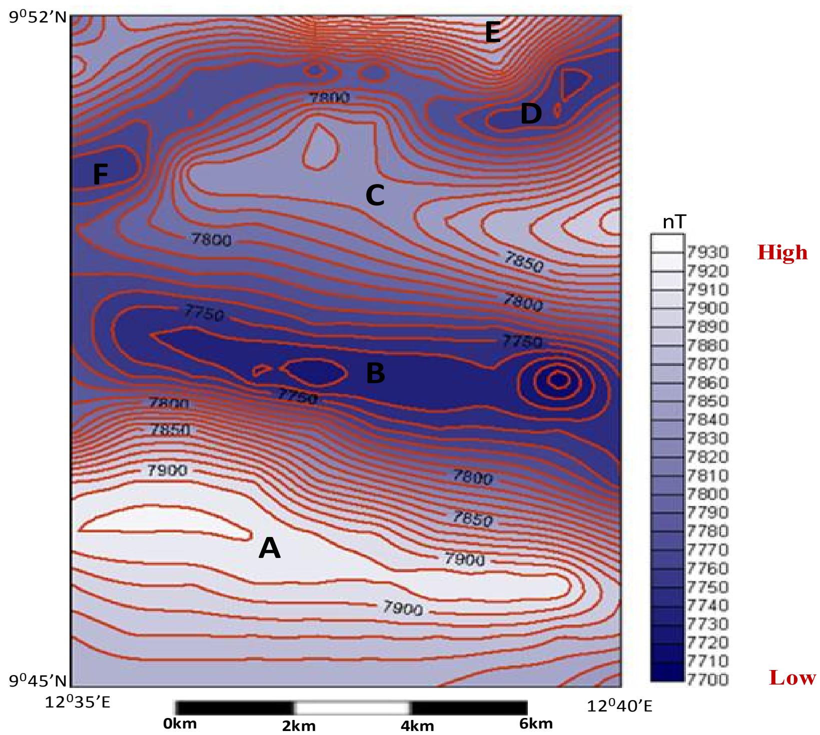

Fig. 2. Total magnetic intensity map over song and environs (CI=10 nT) [Add 25,000 nT to obtain the actual contour values]

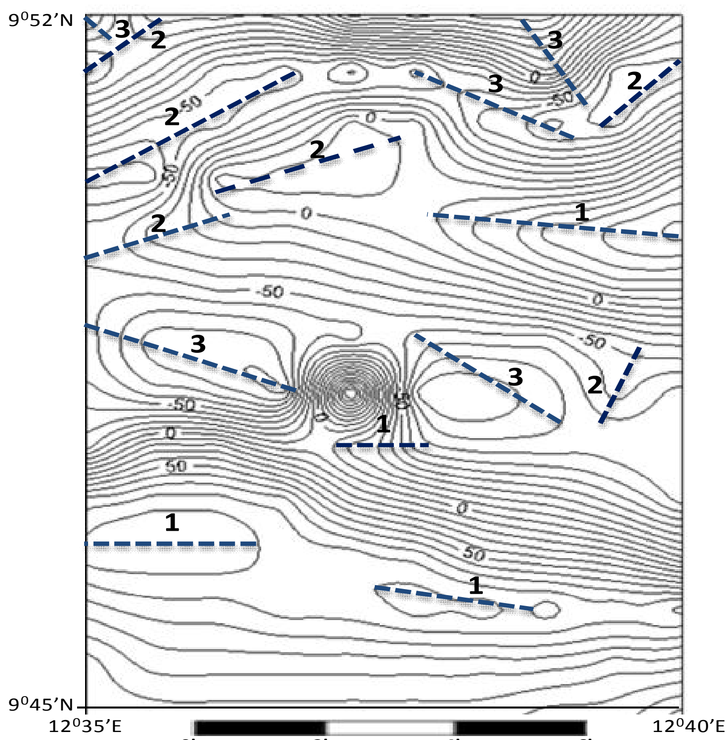

Fig. 3. Residual map over song and environs showing trends of lineament (CI=10 nT)

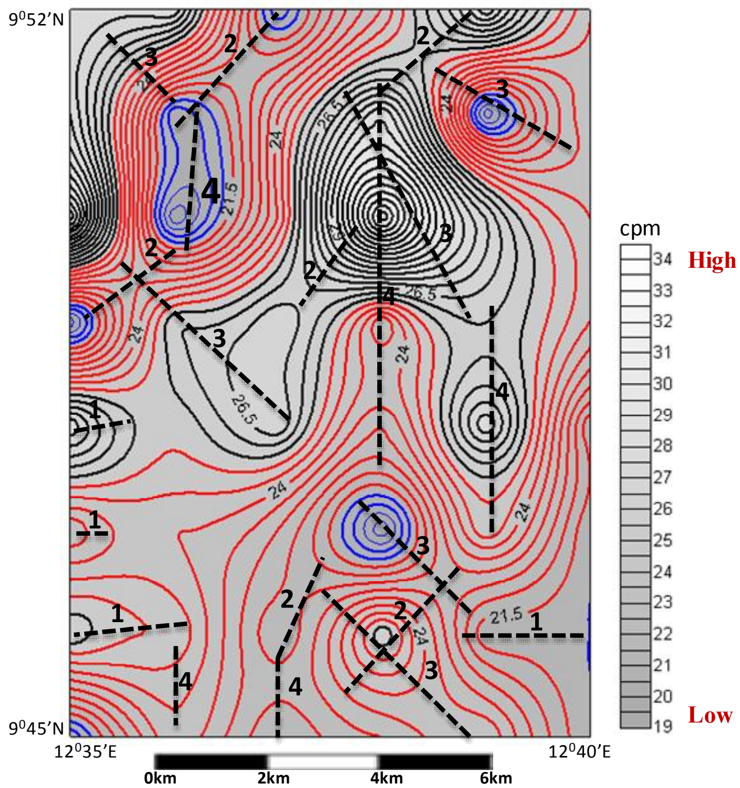

Fig. 4. Radiometric map over song and environs showing trends of lineament (CI=0.5 cpm)

4. CONCLUSION

This paper has demonstrated the usefulness of magnetic and radiometric data interpretation in the context of lithologic and structural mapping in the area. Song area has experienced metamorphism and plutonism during the Pan African thermotectonic event (750 +/- 150 Ma). Tertiary magmatism produced basalt in the area. Intense tectonism resulted in faults, shear zones, foliation and folds. The mapped anomalies and their derivative lineaments reflect lithological and structural disposition of the area. Rock quarrying for building and road construction is a common occupation of the indigenes of Song area. The quarrying operations are facilitated by the superfluity of fractures in the area. The lineaments mapped in this study would serve as guide in siting or expansion of existing quarries. Some features not observed in early geological work in the area are captured in this study.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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