Characterisation of Lithology
A case study of The Precambrian Basement Complex

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Abstract

Some parts of the Precambrian basement complex of North Central Nigeria was analysed using aeromagnetic data in order to characterise the various rock types. Having subjected the data to filtering algorithm and enhancement procedures such as shaded relief enhancement, elemental concentration enhancement using Geosoft Oasis Montaj Software, Golden Software Surfer was then used to characterise the revealed lithological units. Three different types of lithologies were delineated; the granitoids, the metasediments and the metavolcanics. The high magnetic intensity areas within the metavolcanic formation could be as a result of the presence of magnetic minerals such as magnetite and pyrrhotite and the granitoids are seen to record high magnetic values. The metasediments are seen in the central portion in the area with relatively low magnetic values. The inferences in this study have shown that lithological mapping of an area is feasible even without the actual visitation to the area.

Keywords: Aeromagnetic Data, Precambrian basement complex, Lithological Units, Metasediments, Metavolcanics, Igneous Granitoid

INTRODUCTION

The earth may be divided into three parts i.e. crust, mantle and core. The core of the earth may also be divided into two parts that is the molten outer core and the solid inner core. The core of the earth is the main provider of heat energy in the earth (Kent, 2011). Reeve (2010) indicated that the movement of the charged electric particles within the molten core produces a magnetic field around the earth. Inglis (1955) pointed out that it is impossible at present to determine the types of convectional motion in the molten core. The flow of these electrical charges successfully creates a huge electromagnet (Clark and Emerson, 1991). This magnetic field can be detected by sensitive equipments on the earth surface. Besides the presence of a magnetic mineral in a rock unit that would result in a magnetic anomaly, other features such as dykes, faults, folds or truncated sills and lava flow, massive basic intrusions and metamorphic basement rocks also give rise to magnetic anomalies (Keary *et al*., 2002). Very little or no magnetic influence is experienced or detected within the Precambrian meta-sedimentary sequences. Igneous and plutonic rocks demonstrate a broad range of magnetic features. On the other hand, meta-volcanic formations, gabbros and several Intrusive formations can generate strong magnetic anomalies (Harrison, 1987).

In general, the magnetite content and hence, the susceptibility of rocks is variable and there can be considerable overlap between different lithologies. It is not usually possible to identify with certainty the causative lithology of any anomaly from magnetic information alone, it is reasonable to classify the magnetic behaviour of rocks according to their overall magnetite content.

Table 1: Rock types and associated susceptibility range (Reynolds, 2011)

Rock Type	Susceptibility (x 10^6 rationalized SI units)
Sedimentary (Average)	0 to 360
Metamorphic (Average)	0 to 73,000
Igneous	
(Average for acidic igneous)	40 to 82,000
(Average for basic igneous)	550 to 122,00

Rahaman (1988) noted that the south western basement complex of Nigeria lies within the rest of the Precambrian rocks in Nigeria, he grouped the rocks in this region as migmatite – gneiss complex comprising largely of sedimentary series with associated minor igneous rock intrusions which have been altered by metamorphic, migmatitic and granitic processes. Odeyemi (1999) suggested that almost all the foliation exhibited by rocks of southwestern Nigeria excluding the intrusives are tectonic in origin, because pre-existing primary structures have been obliterated by-subsequent deformation. Anifowose (2004) also noted that joints ranging from minor to major ones are found in all the rock types, some of which are filled with quartz, feldspars or a combination of both which lie generally in the NE-SW direction, while Boesse and ocan (1992) reported that the south western basement complex of Nigeria has been affected by two phases of deformation namely D1, D2, the first phase (D1) produced tight to isoclinals folds while the second phase (D2) is characterized by more open folds of variable style and large vertical NNE-SSW trending fault. Oluyide (1988), gave evidence that within the basement complex, tectonic deformation has completely obliterated primary structures except in a few places where they survived deformation (Okonkwo, 1992).

The main objective of this study is to employ the use of areomagnetic data interpretation to characterize the individual litology that must have been brought about as a result of magnetic susceptibility differences in various rock types.

Study Area

The study area is located within the Precambrian basement complex of North Central Nigeria having a total area of 3,080.25 km^2 specifically $8^0$00’00’’N to $8^0$30’00’’N and $5^0$30’00’’E to $6^0$00’00’’E (Isanlu Sheet 225). The study area falls within the meta-sedimentary and meta-volcanic portion of the basement complex also known as the Schist belt. Rocks in this group constitute the Schist belts of Nigeria. They show lithologic similarities to Schist belts in other part of the world which are known to harbor important mineral deposits (Anhausseuer *et al.*, 1969). Lithologically, the Schists belts of the basement complex of Nigeria are composed predominantly of mafic to ultramafic igneous rocks. Mafic to ultramafic rocks, commonly referred to as the amphibolite complex, constitute important components of some of the Schist belts. The Precambrian Basement rocks of North-Central Nigeria consist of low grade meta-sedimentary and meta-volcanic Schists, intruded by Pan-African granites (Oyawoye, 1972). The migmatites and gneissic meta-sediments are often intruded by pegmatite veins and dykes (Oluyide *et al.*, 1998).

METHODOLOGY

The major software used to process and enhance the data is the Geosoft (Oasis Montaj). Other geophysical softwares were used to enhance the data in a variety of formats such as Golden

Software Surfer 10. Two colours are used in airborne magnetic maps to indicate the amount of magnetic minerals (magnetite, pyrrhotite) in different rock formations. Red colour is used to indicate areas with high content of magnetic minerals and deep blue colour indicates areas with low content of magnetic minerals. MAGMAP filtering utilities were then applied to the magnetic grids to enhance the data for easy interpretation. The filters in MAGMAP are a range of linear and nonlinear mathematical algorithm which selectively enhances the anomalies due to one group of geological source relative to anomalies due to other group of geological source (Milligan and Gunn, 1997). The mathematical enhancement techniques are complemented by a range of imaging routines such as the step by step procedure in MAGMAP which can be specified to visually enhance the effects of selected geological sources.

RESULTS AND DISCUSSION

Analytical Signal of the Vertical Integral

The mineral deposits with high concentrations of magnetic minerals always show high analytical signal amplitudes. This shows that analytical signal amplitude depends on the magnetizing amplitude of the causative body (Nabighian, 1972; Roest and Pilkington, 1993).The vector nature of magnetic field at low magnetic latitudes places like Nigeria and particularly the sub Saharan Africa makes the magnetic field (anomalies) developed by magnetized rocks complex and difficult to interpret. A very good method for positioning anomalies vertically over the bodies is to apply analytical signal to vertical integral of the magnetic field. With this method a maximum anomaly is always produced over the magnetic body regardless of the direction of magnetisation of the body (Macleod *et al.*, 1993). Analytic signal transformation is a kind of reduction to the pole from low magnetic latitude. It has an advantage over reduction to the pole in that; it is completely independent of the direction of magnetisation and the direction of the Earth's field (Milligan and Gun, 1997). Vertical integration is a particularly useful transformation for reducing the effects of noise and increasing the coherency of solutions from model-independent special functions (Phillips, Hansen and Blakely, 2007). Figure 1 is a map of the analytical signal on the vertical integral; from this map regions of low and high magnetic intensity are clearly seen.

Features are seen clearly in the analytical signal map because the source positions of the anomalies are defined vertically over the source. In addition, maximum anomaly has been produced over the magnetic body regardless of the direction of magnetisation with regards to analytical signal.

From the analytic signal map, it is seen that the formation MS recorded the lowest magnetic intensity, low magnetic intensity is generally associated with sediments. This suggests that the formation labelled MS which is indicated by deep blue is made of meta-sediments. The average magnetic signatures registered at some parts of the MV suggest that, these formations are composed of green Schist facies of mafic to ultra-mafic rocks in the greenstone belt. The high magnetic intensity observed in the mafic-ultra mafic volcanic regions are granulite facies (Igneous Granitoid) of mafic formation, since it is very magnetic and is located within the greenstone belt, its strong magnetism arise because of the great production of secondary magnetite related to amphibole and pyroxene growth during prograde reactions (Ohioma *et al.* 2017A). The analytical signal amplitude was very helpful in mapping the edges of the individual lithologies.

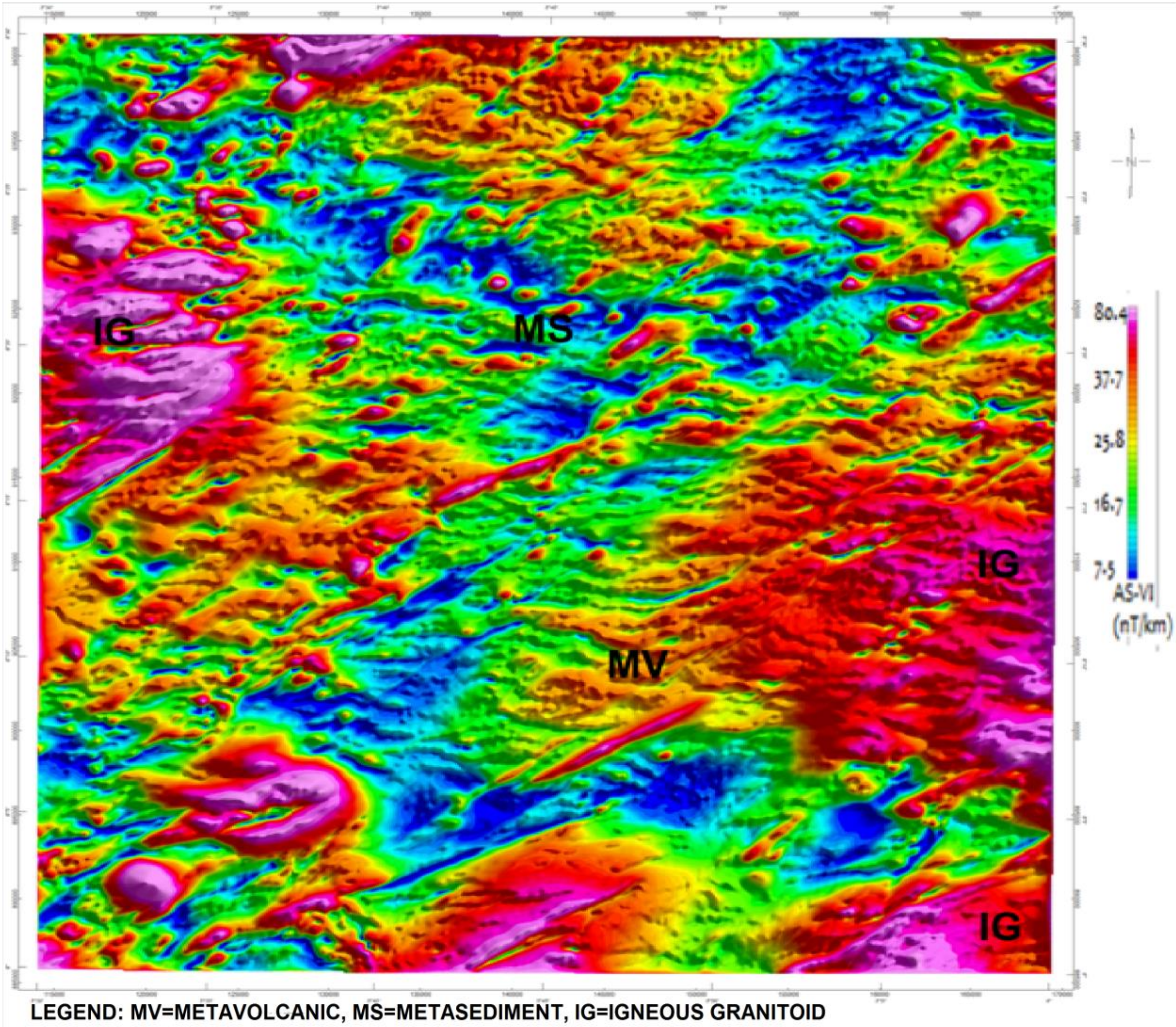

Figure 1: Map of analytical signal applied to vertical integral of Isanlu sheet 225

Interpreted Lithological Map From Magnetic Data

Figure 2 shows the interpreted lithological map of the surveyed area from the airborne magnetic data. Three main geological formations namely the meta-sediments, meta-volcanic and the granitoids are present in the study area. The areas with low magnetic intensity within the meta-volcanic and granitoids are most likely to be shear zones (Ohioma *et al.,* 2019) that serve as conduit for the hydrothermal fluid (Ohioma *et al.,* 2017B). Linear magnetic lows within country rocks of moderate or high magnetic relief are usually zones where surface weathering or hydrothermal alteration has oxidized magnetite to hematite or limonite.

The high magnetic values having a linear feature recorded within the meta-volcanic are likely to be as a result of the intrusion of mafic volcanic units (dyke) and the high magnetic intensity areas within the meta-volcanic formation could be as a result of the presence of magnetic minerals such as magnetite and pyrrhotite.

Another folding caused by the intrusion of the igneous grantoid (IG) was also identified around the north western part of the map. Intensively faulted and fractured zones associated with folded magnetic signatures are described as shear zone. This is a possible volcanic crater that might be associated with the meta-volcanic belt.

The mineralisation of gold is strongly characterized with the series of quartz stockwork mostly sourced in granitoids like IG (Griffis, 1998).

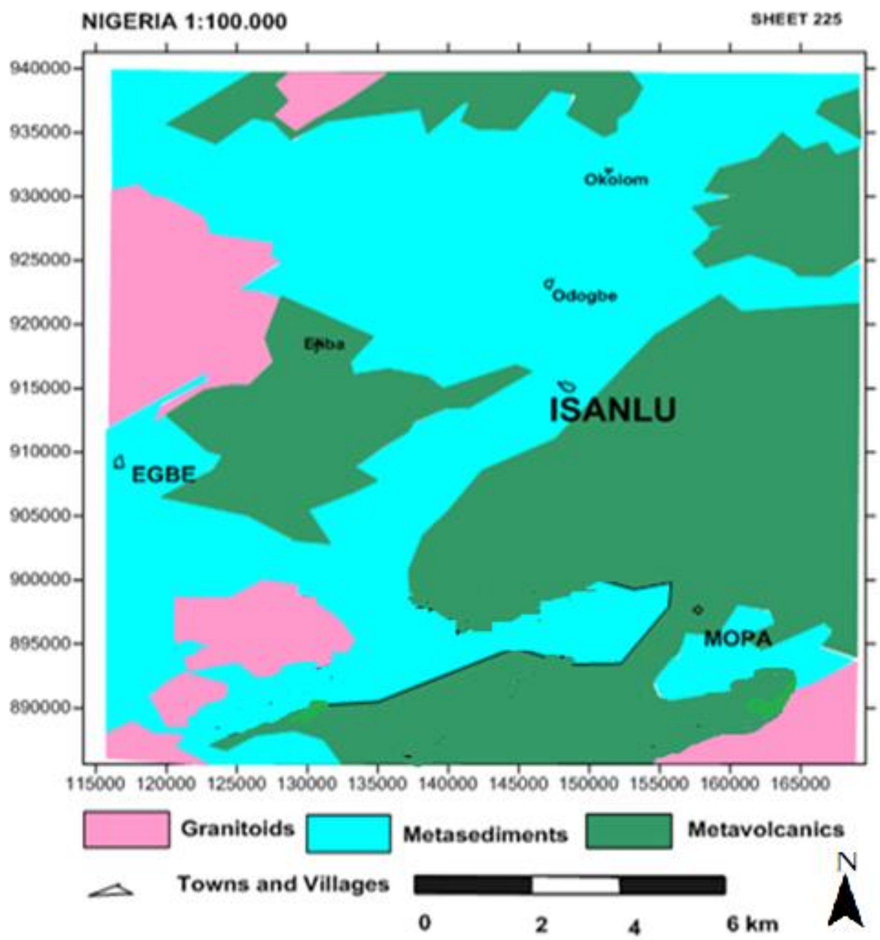

Figure 2: Interpreted geological map from the aero-magnetic data of Isanlu sheet 225

CONCLUSION AND RECOMMENDATIONS

Characterisation of the various litologies accentuated three different types; these are the metasedimentst (having around 25 nT/Km), the metavolcanic (having around 8 nT/Km), the igneous granitoids (having around 80 nT/Km) as can be deduced from Figure 1. The igneous granitoids units are seen to record very high magnetic activity followed by the metavolcanic then least is the metasedimentary. Reynolds (1997) indicates that most sedimentary rocks contain negligible quantities of magnetic minerals and are therefore non-magnetic. Most basic igneous rocks (meta-volcanics), on the other hand, have high magnetic susceptibilities, while acid igneous rocks and metamorphic rocks can have susceptibilities ranging from negligible to extremely high.

Results obtained in this research study have shown that the lithological mapping of an area is feasible even without the actual visitation to the area. The research suggests that this method of lithological identification may compliment the traditional geological mapping of an area. Moreover, due to the non-invasive nature of the method, large areas of space may be mapped within a limited time.

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