Analysis Of High Resolution Aeromagnetic Data And Satellite Imagery For Mineral Potential Over Parts Of Nasarawa And Environs, North-Central Nigeria.

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Abstract: The investigations involve the analyses of high resolution aeromagnetic data and satellite imagery over parts of Nasarawa and environs. Airborne magnetic data and satellite imagery were interpreted to delineate structures and lineament pattern of the study area as potential for minerals occurrence. Field work was undertaken in the study area to relate the effect of the structures in field to result obtained from the interpretation of the high resolution aeromagnetic data. The lineaments identified on both aeromagnetic map and satellite imagery are in agreement with the main structural trend of the Benue Trough. Results from the interpretations indicate anomaly trends in the NE-SW, NW-SE, E-W, and NNE-SSW directions. The rose diagrams obtained from the magnetic residual map and the satellite imagery suggest predominantly NE-SW, NW-SE directions, the consistency in the alignment of lineaments suggests a possible genetic association of these anomalies. The occurrences of lineaments which include pegmatites, fractures, faults joints veins and fold as revealed in the quantitative analysis of the magnetic residual contour map, satellite imagery and field work exercise show the interplay of tectonic activities due to multiple deformational episodes, this study highlight magnetic lineaments as key indicators to mineral occurrence.

Keywords: Mineral potentials satellite imagery Nasarawa and Environs

1. Introduction

The search for mineral deposits and hydrocarbon (oil and gas) have been in Nigeria for some time now, since the pre-colonial era to date for economic reasons. From the early seventies Nigeria’s economy has been depending on the export of crude oil (hydrocarbon), while the solid mineral sector has received less impact, even though it has been frustrated because of the poor knowledge of their geology. About ninety percent (90%) of the country’s revenue (earnings) comes from export and domestic sales of the oil and gas upon which about 180 million growing population depend on. Recently the prices of crude oil has dropped drastically because of the global economic meltdown and major buyers like USA and China have gotten crude oil in commercial quantity in their Shale rock and other major suppliers respectively. Due to the dwindling oil price and youth restiveness in the Niger Delta region which has almost crippled the economy and power supply in the nation, attention also needs to be shifted to other sectors of the economy like the Mineral sector and Agriculture. This study will be very useful on a reconnaissance basis for mineral prospecting in the area. In recent years, combined airborne magnetic and satellite imagery surveys have been used as geological mapping tools. Airborne magnetic data and satellite imagery can be manipulated in a variety of ways, to minimize noise, enhance particular aspects of the data and integrate with other geosciences and geographic data, to provide reasonable and accurate depiction of geology. This study focus on the use of the high resolution aeromagnetic data and satellite imagery to re-evaluate the study area to appraise its mineral potentials using a robust software the Oasis Montaj. This will build up a subsurface picture of basement configuration and possible structural trends as pathfinders that will promote mineral exploration. The study area is located between longitudes 8° 00’E and 10° 00’E and latitudes 7° 30’N and 9° 30’N in north central Nigeria (Fig. 1). The area is part of the Middle Benue Trough that is noted for hosting economic minerals, it covers an approximate area of 48,400 km², and covers farmlands, villages, towns, game reserves, natural reserves etc. Topographically, the study area is hilly at the northern fringes and drained mainly by river Benue and its tributaries in the southern part, it is characterized by moderate relief with high granitic hills generally extending several kilometers, having the NE – SW direction and forms several peaks of relatively higher elevation than the surrounding rocks. The area is in general undulating, despite the hilly nature of some part of the study area, there are still good road networks, foot-paths and tracks in the area. Major roads found in this area provide access road to the southeastern part of Nigeria and some other communities in the study area such as Akwanga, Nasarawa-Eggon, Lafia, Keana, Awe, Domas, Shendam, Pankshin to mention few. There are other minor roads that provide access to smaller settlements, farms, rivers and streams.

Figure 1. Topographic Map of the Study Area (After United State Geological Survey.2012)

2. Geology of the study area

The study area is located within the Basement complex of North-central Nigeria and the Cretaceous sediment of the Middle Benue Trough. It consists of various rock units which
have been reported to occur in this area (figure.2). It is underlain by Precambrian basement rocks, remobilised by the Pan African episode (600-500 ma) and uplifted relative to the surrounding areas (nnange et al 2001). These include the Precambrian basement complex rocks, mainly granulitic gneisses, migmatite, older granite, younger granite, porphyries and rhyolites which outcrop in the northern portion of the study area.

The cretaceous rock units include;
(a) Asu River Group: Consist of a mixture of lava-flows, dykes and sills representing the first middle Albian episode into the Benue Trough. This group, which is believed to be about 3000 m thick, lies unconformably on an older basement complex. Rock units belonging to the Asu River Group outcrop along axis of the Keana (Offodile, 1976).  
(b) Awe Formation, which consists of flaggy, whitish, medium to coarse – grained sandstones interbedded with carbonaceous shales or clays from which brine springs issue continuously (Ford, 1981; Offodile, 1980). The Awe Formation marks the beginning of the regressive phase of the Albian Sea.  
(c) Keana Formation consists of continental fluviatile sand and shale.  
(d) Ezeaku formation comprises essentially of calcareous shale, micaceous fine to medium – grained friable sandstones, with occasional beds of limestone.  
(e) ConicianAgwu formation consists mainly of black shale, sandstones and local coal seams.  
(f) Lafia Formation is the youngest formation reported in the Middle Benue Trough and consists of coarse-grain ferruginous sandstones, red loose sand, flaggy mudstones and clays (Offodile, 1976b).

The Tertiary– Recent volcanic rocks consist of the Basalts, Trachyte, Rhyolite, and newer basalts of Sura volcanic line also occur in the area.

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**Figure 2.** Geological map of the study area (Adapted from the Geologic Map of 2006).

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3. Materials and Method

The high resolution aeromagnetic data (HRAM) used for this present work was obtained from the Nigerian Geologic survey agency Abuja, which had acquired digital data for the entire country between in 2009. The airborne survey was carried out for the Nigerian Geologic Survey Agency by Fugro airways services, the surveys was flown at 500m line spacing and at an average flight elevation of 80 m along NW – SE direction, and published in form of grid (digital form) on 30° by 30° sheets. The IGRF of 2005 has been removed from the data. Sixteen sheets were assembled for this work with each square block representing a map in the scale of 1:100,000. Each square block is about 55 x 55 km² covering an area of 3,025 km² hence the total area studied is about 48,400 km², the digital data was acquired as merged unified block. The Airborne satellite data was obtained from the National Centre for Remote Sensing (NCRS) Jos, which had acquired satellite images from the internet that was flown by the United States (U.S.) National Aeronautics and Space Administration (NASA). The data obtained is SPOT 5 and was launched on May 4, 2002; it is polar, circular, sun-synchronous and phased. In magnetic data interpretation, it is often useful to compare structure or geologic bodies delineated from the derivatives with surface geology. Satellite imagery can give us a picture of the surface where outcrops and features such as fractures, faults and dykes can be observed. SPOT 5 data with a resolution of 5 m was used for this study. The high resolution satellite imagery acquired for this study covers most parts of the Middle Benue Trough and other adjoining sheets so as to understand the trend of the structures well beyond the area of interest. This area coverage which is between latitude 7° 30 N – 9° 30 N and longitude 8° 00 E – 10° 00 E and area coverage of 48,400 km² formed the basis on which other data sets were subset to be exactly the same dimension. To remove the regional magnetic field, which is the anomalies associated with low frequency components, a plane surface was fitted to the digital data by polynomial fitting least square analysis. In this method, the matching of regional by a polynomial surface of low order exposed the residual features as a random error, the treatment is based on statistical theory. The observed data are used to compute, usually by least squares, the mathematically describable surface giving the closest fit to the magnetic field that can be obtained within a specified degree of detail (Skeels, 1967; Johnson, 1969 and Dobrin, 1988). This surface is considered to be the regional and the residual is the difference between the magnetic field value as actually mapped and the regional field value, thus determined (Udensi, 2000).

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**Figure 4.** Residual Magnetic Intensity Grid Map of the Study Area.
The residual map shows striking similarity to the total magnetic intensity map with exception of few features, suggesting that the residual map is overwhelmingly sourced from the basement. The map shows colour ranges like the total magnetic intensity anomaly grid map, with red as high and blue as low and steep gradients which are distributed throughout the area, the maximum intensity value of 70 nT is observed in the northeastern region while the minimum value of -92 nT is recorded at the southeastern part the study area. The general trending fabric of the residual magnetic intensity anomalies is the NE-SW direction. The long wavelength anomalies which are certainly due to deep seated basement, dominate the central and southern part of the study area, while the short wavelength anomalies dominate the northern fringes. The contour pattern of the residual intensity gridded map is shown in fig. 6 and it represents the same thing.

3.1 Structural Analysis of Magnetic Data and Satellite Imagery

The structural analysis of the magnetic data and satellite imagery of the study area were carried out to relate the surface and subsurface structures. This process involved comparing the lineaments obtained from the magnetic residual map with the lineaments from Satellite imagery generated in a GIS environment and making inference to structures and geology. To carry out the analysis, lines were drawn parallel to elongations of the magnetic anomalies on the magnetic residual contour map which is the reflection of the geology of the area and in areas of contrast on the satellite imagery, these lines represent lineaments/fractures their length depend on the direction and the length of the anomalies. Lineaments were analyzed in order to extract further information on the spatial distribution and nature of the tectonic activities in the area, for this purpose a conventional technique called rose diagram was applied, to display graphically different tendencies for structures like joints or fault planes representing the angular relationships of the geologic map data.

Figure 5. Lineaments obtained from the Residual magnetic intensity contour map of the study area.

Figure 6. Rose Diagram of Lineaments obtained from the Residual magnetic Intensity Map of the Study Area

The interpretation of satellite imagery is been based on the spatial and directional attributes of their assemblages rather than on the evaluation of individual features. A purely statistical approach has been adopted and realistic inferences made on the mineralogical implication of the available data. Furthermore no attempts have been made to classify the lineaments as faults, joints, fractures and fissures etc. The development of satellite technology, otherwise known as remote sensing technology has been a worldwide acceptance and application particularly in the areas of groundwater exploration, geological mapping, mineral exploration, tectonic studies, climate and weather studies (Peterson 1976).

Figure 7. Satellite Imagery of the Study Area
3.2 Field work
A field work exercise was carried out in the study area to relate the effect of the structures in field to result obtained from the analysis of the high resolution aeromagnetic data, the process involved selecting an area of interest and identifying the geological features. The field work revealed some geological features and formations. These features include; fractures, joints, dykes, pegmatites and mineralization. The selected areas include Kerang, Wamba, Nasarawa-Eggon, Akiri and Awe. Furthermore, rose diagrams (Figures 10 and 11) were used to display graphically different tendencies for structures like joints, veins, faults and fractures, representing the angular relationships of structures during field mapping.
Plate I. Quartz vein in medium grained Granite at Wamba area

Plate II. Pegmatite vein in Medium grained Granites at Wamba area.

Plate III. Barite Veins at Akiri Area in Awe L.G.A. with NNE – SSW and NNW – SSE conjugate sets also well – developed.

Plate VI. Deformed beds of Awe Formation due to tectonic activities at Akiri area

Plate IV. Beddings of Awe Formation trending NE-SW

Fig. 12 Lineament Density Map of the Area
how good correlation

This shows that the major fracture
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W, NNW
diagram suggests predominantly NE
SE; 10% E
and it revealed that 60% trend NE
SE to NNW-SSE striking faults. These pegmatites are mainly quartz-feldspar-muscovite pegmatites rich in Nb-Ta-Sn-B-Li-W. Important pegmatite deposits are found in the Akwanga, Wamba and Kogum River region of Nasarawa and Kaduna States. Active magmatisms have been reported in the Benue Trough with Ofoegbu and Odigii, (1989) confirming the close associations between magmatisms, mineralizations and fractures in the area. Fatoye, et al (2014), observed that the lead-zinc-barytes mineralization in the Middle Benue Trough, occur as epigenetic fracture-controlled vein deposits restricted to Albian–Cenomanian sediments of Asu River Group, Awe and Kean Formation. These fractures occur as single linear structures or as series of irregular fractures interconnected and spaced over a considerable width and distance, the lithologies in the area were cut by E-W and NW-SE trending mineralized veins. At Akiri area, the mineralization is associated with the gangue minerals of quartz, feldspar, hematite, calcite, and copper. (Obaje et al, 2006) observed that Quartzite, Pegmatites and quartz veins carrying different type of solid mineral lodes are prominent features in rocks of the Basement Complex of Nasarawa State. The exploration of minerals resources can be categorized into four stages and this include regional reconnaissance, surface and subsurface mapping, ground geophysical surveys and actual drilling Ananaba and Ajakaiye (1987). This study depends on the first two steps, to achieve better target of the resource being sought for, a reasonable knowledge of possible factors that may indicate this resource has become necessary. Ananaba and Ajakaiye (1987) have, shown the relationship between lineament densities and primary mineral occurrences in Nigeria. A mosaic of the interpretation from the various scenes was used to prepare a lineament map of the study area, the lineament density map compared with the primary mineral occurrences maps of Nigeria adapted from the mineral map of Nigeria. The result show good correlation with areas of most primary minerals such as cassiterite, columbite etc. (fig 13). The study showed that information interpreted from remotely sensed imagery combined with magnetic method

Fig. 13 Mineral map of the study area (Adapted from the Mineral Map of 2006).

4. Discussion of Results

Result of the analysis of magnetic residual contour map revealed magnetic anomalies trend in the NE-SW, NNE-SSW, ENE-WSW, NW-SE, NW- SSE, WNW- ESE, and E-W directions and are presented in terms of azimuth. The lineaments deduced from magnetic residual map revealed that 58% trend NE-SW; 22% NW-SE; 10% E-W and 10% NNE-SSW (Fig. 6). This shows that the major fracture directions in the study area are NE-SW, NW-SE with minor as E-W and NNE-SSW, from the lineaments extracted, it is obvious that the rocks of the Nigerian Basement Complex have responded differently to many episodes of folding, faulting, fracturing, granitic emplacement, and remobilization along the linear zones. These various upheavals are still being investigated, perhaps the oldest fractures are the localized E-W trends which appear to have been healed by quartzo-feldspatic in-fillings, thus permitting only limited recognition in the study. Other structural trends include the NE – SW and NW – SE conjugate sets which are distinguishable from the NNE – SSW and NW – SSE sets, these are prominent around around Giza-Keana area and could be the tectonic episode responsible for the folding that produce Keana antline and Giza syncline, and possibly the faulting that produce the Giza and Awe warm springs. Some of the important features also occur around Mongun, Kogum River and Pankshin at the northern part of the study area, they are believed to be produced by transcurrent movements along the axis of the Benue trough. These fractures are probably marked by considerable shearing and brecciation, features attributable to brittle deformation. Also, attempts have been made to map the identifiable lineaments on a mosaic, Spot 5 satellite imagery for a better overview of the various features that may be of interest to the exploration geologist. The structural systems on the satellite imagery were statistically analyzed and plotted in the form of rose diagram and it revealed that 60% trend NE-SW; 25% NW-SE; 10% E-W and 5% N-S as illustrated in (Fig.9). The rose diagram suggests predominantly NE-SW tectonic trend which is the predominant trend of the Benue Trough but relics of E-W, NNW- SSE and NNE-SSW structures are also preserved (Bassey et al., 2000, 2000b), these lineaments could be fractures, faults, fissures, joints, shear etc. preserved on the surface rocks that occur in the study area. They also appear to be more varied on the basement complex rocks than the sedimentary rocks and range in length from 600m to 1000m. It is obvious, however, that the lineaments obtained from the satellite imagery are the surface expression of the lineaments from the magnetic residual contour map. These correspond to Pan-African and Pre-Pan-African deformational episodes. Lastly lineaments obtained from the field work exercise were also analyzed and the results of structures on rock outcrops at Wamba area revealed that 52% trend NE-SW; 33% NW-SE; 11% NNE-SSW and 4% E-W (fig. 10) and that 54% trend NE-SW; 36% NW-SE; 10% NNE-SSW and 5% E-W on rock outcrops at Nasaarawa Eggon (fig 11). The occurrences of lineaments which include pegmatites, fractures, faults, joints, veins and fold as revealed in the quantitative analysis of the residual magnetic intensity contour map, satellite imagery and field work exercise show the interplay of tectonic activities due to multiple deformational episodes, this study highlight magnetic lineaments as key indicators to mineral occurrence. There are good relationships between known mineral deposits and certain types of trends (O’Leary and Simpson, 1977). Kuster (1990) proved that the mineralized pegmatites exhibit the same geochemical behaviour with the late Pan African granites and are fracture controlled. They are also mylonitized along a conjugate set of NE-SW and NW-SE to NNW-SSE striking faults. These pegmatites are mainly quartz-feldspar-muscovite pegmatites rich in Nb-Ta-Sn-B-Li-W. Important pegmatite deposits are found in the Akwanga, Wamba and Kogum River region of Nasarawa and Kaduna States. Active magmatisms have been reported in the Benue Trough with Ofoegbu and Odigii, (1989) confirming the close associations between magmatisms, mineralizations and fractures in the area. Fatoye, et al (2014), observed that the lead-zinc-barytes mineralization in the Middle Benue Trough, occur as epigenetic fracture-controlled vein deposits restricted to Albian–Cenomanian sediments of Asu River Group, Awe and Kean Formation. These fractures occur as single linear structures or as series of irregular fractures interconnected and spaced over a considerable width and distance, the lithologies in the area were cut by E-W and NW-SE trending mineralized veins. 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5. Conclusion

The residual magnetic data and satellite imagery were analyzed quantitatively, the results are in close relationship in terms of structural pattern with the structures obtained in the field, and this observation suggests a possible genetic association of these anomalies. It is known that the study area host a lot of mineral deposits, this could be the result of multiple deformational episodes/tectonic activities that occurred in the area, which is characterized by several sets of fractures faults dykes joints and veins as observed in the field. In the recent past a lot of mineral deposits have been mined in the area, which included beryl, topaz, baryte, aquamarine, cassiterite, columbite, zircon, tourmaline, ruby, wolfromite, tantalite, gold, lead-zinc etc. however, there was no systematic and scientific approach to the exploration and mining of these mineral deposits. The pegmatites mined were only those accidentally discovered on the surface which were exhausted over time. It is for this reason that a study was carried out in the area to explore for hidden structures like faults, fractures, veins and dykes that could host mineralization in the area. This study have shown intense fracturing of the basement in this zone, some of these trends and lineaments could be pegmatite that host mineralization. The areas of high mineral occurrence as revealed by field work in the study fall along the NE – SW, NW - SE, and NNE-SSW tectonic trends in the area. Hence;

- The sections of the study area where lineaments are dense in the study are recommended for further detailed mineral exploration.
- Groundtruthing is highly recommended to confirm the delineated structure and lithology around Kogum River, Akwanga, Wamba and Nasarawa Eggon areas.
- Surface and downhole locational surveys should be undertaken around the potential zones delineated from this interpretation.
- Litho-geochemical survey should be undertaken around the prospect zones.
- Detailed ground magnetic survey, be carried out at the Nasarawa Eggon, Wamba and Akiri areas suggested as having magnetic mineralization, so as to determine their economic potential.

Exploration for Mineral deposits in Nigerian is worth given a push as this will provide employment opportunities for our teeming youths and increase the Country's revenue base, these will have economic and strategic benefits for the country.

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