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Structural Interpretation of the area around Obajana using Satellite Imagery and High Resolution Aeromagnetic data

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ABSTRACT: The area covered around Obajana is located on Kabba Sheet 146 and Aiyegunle 226 and falls within Kogi State, Nigeria. The rock types in the area are mainly migmatites and porphroblastic gneiss. The purpose of this work is to interpret subsurface and subsurface structures that may serve as conduits for possible polluted effluents from the Obajana cement factory using high resolution aeromagnetic data and satellite imagery. A reduction-to-the-equator (RTE) operation was carried out on the data after which several data transforms/derivatives such as horizontal derivative, analytical signal, and tilt derivative were calculated to highlight subsurface boundaries and the major structures within the area. Several digital image enhancement techniques such as general contrast stretching and edge enhancement were applied to the SPOT 5 image in ERDAS IMAGINE 9.2 after which structures from the interpreted magnetic data and the image were mapped out on-screen using ArcMap 10. The results show that the RTE produced a more reasonable geological picture of the area. The structural analysis of the area revealed that SPOT 5 image is suitable in detecting surface/geological structures. Lineaments in the area could serve as potential conduits for possible pollutant to the surrounding environment.

Keywords: Aeromagnetic Data Interpretation, Structural Mapping, Lineaments.

1. INTRODUCTION

The study area is located in Kogi State, North-Central Nigeria. It is bounded by the following coordinates; Obajana lies within longitude 6°24'E to 6°27'E and latitude 7°54'N to 7°56'N (Fig.2). The Area is Accessible by a major road linking Abuja, Okene and Lagos (Fig. 2) with a complex system of minor roads and footpaths linking the various communities together. The climate is characterized by two distinct seasons; rainy and dry seasons. The rainy season starts in April and end September. The peak of the rainfall is in July/August. Temperatures vary between 30°C and 35°C. The coldest temperatures are experienced during the harmattan periods when temperatures drop as low as 18°C. During the harmattan, the winds are cold, dry, dusty and strong. The hot season starts in March and ends in May. The area is made up of typical Sudan savannah vegetation characterized by short stunted trees with communities of grasses. What remains of the natural vegetation today are mainly economic trees such as sheer butter, locust bean. Another major characteristic of the vegetation in the area is the derived vegetation as a result of re-growth on fallow farmlands.

2. GEOLOGY OF THE AREA AROUND OBAJANA

The study area lies within the Benin-Nigeria shield (Fig. 4), situated in the Pan-African mobile zone extending between the ancient Basements of West African and Congo Cratons in the region of Late Precambrian to Early Palaeozoic orogenies (Rahaman, 1976; Hockey et al., 1986; Odigi, 1993 and Ekwueme, 2003). The Precambrian Basement rocks of Obajana area, South-western Nigeria comprise of schists and gneisses which have been subjected to major supracrustal tectonic events such as the Dahomeyan (3000± 200Ma), Eburnean (1850 ± 250Ma), Kibaran (1000± 100Ma), and Pan-African (550± 100Ma). (Ezepue and Odigi, 1993; Rahaman, 1976). The Obajana gneisses comprise of three types of rocks designated as quartz-biotite gneiss; quartz-biotite-hornblende-pyroxene gneiss and quartz- biotite-garnet gneiss (Odigi and Ezepue, 1993; Ezepue and Odigi, 1994; Odigi, 2002). According to these authors, igneous rocks of this area occur as small, circular to oval outcrops and include members of the older granite suite mainly Granites, Granodiorites and Syenites while associated Schists in the area are: Quartz-biotite Schist, Amphibolite Schist, Muscovite schist and Quartzitic. Also, the geologic structures around Obajana represent NE-SW, NW trend (Ejueyitsi et al., 2015).

3.0 MATERIALS AND METHODS

a) **Magnetic data** -The aeromagnetic data for the area covered by Kabba sheet 146 and Aiyegunle 226 (figure 4) was acquired at a flight line spacing of 500 meters and a terrain clearance of 80 meters. The data available for this study is in grid format only, without the flight line data.

b) **SRTM data-** SRTM stands for shuttle Radar Topography mission which was flown by NASA that obtained digital elevation models of the earth's surface. It is useful in surface mapping especially in areas where a detailed geological map is not available. The SRTM data of the study area is shown in fig 5.

c) **SPOT 5 Data-** 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 dykes can be observed. SPOT 5 data with a resolution of 5 meters was used for this study (fig 7).

3.1 Image Processing

Several digital image enhancement techniques such as general contrast stretching and edge enhancement were applied to the SPOT 5 images in ERDAS IMAGINE 9.2.

3.2 Reduction to the Pole/ Reduction to the Equator

In most aeromagnetic data interpretation, the total magnetic intensity data is usually reduced to the pole which assumes that the data was collected at the pole where the magnetic anomaly is vertical and therefore give interpretations that resemble the actual geology. For the interpretation of aeromagnetic data covering Kabba sheet 146 and Aiyegunle 226 which contains the area covered by Obajana, the reduction to the equator was carried out with the aid of geosofts magmap using a geomagnetic inclination of -9.940, declination of -2.620 (Derived from IGRF 11) and an amplitude correction of 10 degrees.

3.3 Total Horizontal Derivative of the RTE

The total horizontal derivative (THDR) was used for this study because this method was designed to image faults and contact features which makes it well suited for this study as we intend to delineate faults in the Pan-African and Older granites which may contain mineralized pegmatites/quartz veins as well as mineralized shear zones or alteration zones. Total horizontal derivative is a good edge detector because it computes the maxima over the edges of the structures.

3.4 Analytical Signal (AS)

The Analytical signal performs well at all magnetic latitudes because the direction of the ambient field does not affect it and the maxima define the edges of magnetic bodies. For locating contacts and sheet like structures, the Analytical method has been found to be an effective method irrespective of their angle of dip or the magnetic latitude.

3.5 Tilt Derivative of RTE

The tilt-derivative (TDR) was chosen because of its peculiar characteristics. It tends to equalize the amplitude output of TM anomalies across a grid. The TDR has also been shown to act as an effective signal discriminator in the presence of noise. The tilt method was applied to the RTE data of the study area using Geosoft's magmap.

3.6 Structural Mapping

The analysis and interpretation of remote sensing imagery are determined by the objective of the interpretation. The term lineaments were originally used by Hobbs (1904) in his paper titled "Lineaments of the Atlantic Border region." He defined lineaments as significant lines of landscape that reveal the hidden architecture of rock basement. However O'Leary et al (1976) defines lineament as a mappable, simple or composite linear feature of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differ from the pattern of adjacent features and presumably reflects some sub-surface phenomenon. The regional analysis of the lineaments/structures presented in this work has been based on the spatial and directional attributes of their assemblages. The ArcMap is a powerful GIS tool that that can be used to integrate different data sets that have the same spatial reference to extract information that may be common or different among the various data sets. The SRTM data is a digital elevation model which is used to study the terrain of the study area. The relief of the area can give us an impression of the surface geology. The SPOT 5 imagery also shows the geomorphology of the surface. Integrating all the data sets including the derivatives from the magnetic data makes mapping the structures easier than looking at the data sets separately. The structural mapping involved mapping out magnetic lineaments from the several derivatives.

To achieve this, all the various data sets were displayed in ArcMap and by studying one layer at a time and comparing with other layers in the GIS environment. The geological map was useful because it showed the location where the basement occurs as surface exposure. The SRTM data was able to show the outline of surface geological features that are also evident on the SPOT 5 data. One of the advantages of working in a GIS environment using several data sets is the opportunity to examine features that are spatially referenced. A feature that is less pronounced in one data set can be more pronounced in another data set and this can be better studied in a GIS environment. To start digitizing the magnetic lineaments, a feature class was created in ArcCatalog and it was set to the same coordinate and spatial reference as the other data sets. The digitizing tool was then used to map out the magnetic lineaments observed from the various derivatives.

3.7 Depth to Basement Inversion from Magnetic Data

3.7.1 Local wavenumber

This method developed by Thurston and Smith (1997) also known as the Source Parameter Imaging (SPI) technique is so called because all the parameters that make up the source which include depth, dip and susceptibility contrast are computed from the complex analytical signal. The technique assumes only induced magnetization and works well at all magnetic latitude which makes it a good choice for Nigeria that is at low magnetic latitude. Fairhead et al (2004) related the source depth to the local wavenumber (k) of the magnetic field which can be derived from the calculated total horizontal and vertical gradients of the RTE grid. The depth to the magnetic body is equal to n/k at the peaks in the local wavenumber field and *n* is a function of the model of the magnetic body (e.g. dike, contact, sill etc) similar to the structural index, *N* in Euler deconvolution .

Local wavenumber can be derived using methods described by Verduzco et al (2004) and Fairhead et al (2004).

Similar to the Analytical signal, the THDR_TDR is not in any way affected by the inclination of the magnetic field which makes it suitable for this research since the area is at low magnetic latitude. The Local wavenumber grid of the study area was derived using the method.

3.7.2 Overlay Analysis

An overlay analysis was done to relate features with similar locations in other to compare the relationship between them. The overlay done compares both surface and subsurface lineaments with geology, elemental concentration topography, water table contour and structural depth map. This is very important because since lineaments serve as conduits for contaminants hence if the location of contaminants corresponds to the location of major lineaments, contamination index will be higher.

4. RESULTS and DISCUSSIONS

4.1 Total Horizontal Derivative

THDR is a powerful method because it brings out the edges of the structures and they appear like rail lines. The output shows the NE-SW structures in the data clearly defined (figure 8).

4.2 Analytical Signal

The transformed Analytical signal grids (figure 9) show the maxima over some of the magnetic sources that were not enhanced in the other derivatives.

4.3 Tilt Derivative

The Tilt derivative grid (fig 10) clearly shows that this method is obviously very good at enhancing anomalies as the maxima of the anomalies peak over the magnetic sources.

4.4 Structural Mapping

The lineaments extracted from the magnetic data range in length from 700m to about 5 km (figure 11). The rose diagram suggests predominantly northeast-southwest tectonic trend. All the lineaments derived from the magnetic data are mainly subsurface. The lineaments derived from the SPOT 5 data revealed a major NE-SW trend and they range from 300 m to about 2.6 km in length (figure 12). From the structural relationship between surface and sub-surface structures within the study area (Fig. 13), in some locations such as around the mines, both subsurface and surface structures cut across each other. According to the geology of the area, the dam was constructed on the granite schist to minimize contamination of the dam. As shown from the map, the dam was constructed on a relatively stable location away from both surface and subsurface fractures, this will in turn limit contamination from the dam to nearby water bodies. Areas where fractures cut-cross each other could serve as possible areas for the construction of wells and boreholes in the study area.

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4.5 Structure-Depth Map

The depths to magnetic sources range from about 1022.2m and 54. 0479m respectively (figure 14) with the deepest parts being at the North-Eastern part of the area. However, most of the area shows depths of less than 100 meters to the magnetic sources.

4.6 Overlay Analysis

An overlay analysis was done to relate features with similar locations in other to compare the relationship between them. The overlay done compares both surface and subsurface lineaments with geology, elemental concentration topography, water table contour and structural depth map. This is very important because the lineaments serve as conduits for contaminants hence if the location of contaminants corresponds to the location of major lineaments, contamination index will be higher. Similarly, subsurface structures cutting through the underlined geology such as BIF, Marble, Quartz mica schist, Granite Schist, Porphyritic granite, Pegmatetes and phyllites could filter into the environment through capillary actions or during thereby causing anomalous concentration of trace elements in few locations (figures 15 and 16). Likewise, the overlay analysis of the sub-surface structures on the geochemical map was carried out to ascertain the correlation between the fractures and the anomalous concentration of trace elements such as Al, Ba, Cl, and Fe (figures 17 and 18).

5. CONCLUSIONS

The conclusions drawn from the interpretation of the high resolution magnetic data and satellite imagery of the area covered by Obajana are;-

1. The structural analysis of the area revealed that SPOT 5 image is suitable in detecting surface/geological structures while the Tilt derivative grid clearly shows that the method is good at enhancing anomalies as the maxima of the anomalies peak over the magnetic sources.
2. The major structural trend in the area is NE-SW
3. The lineaments extracted from the magnetic data range in length from 0.7km to about 5km.
4. All the lineaments extracted from the magnetic data are subsurface. These magnetic lineaments could be the contacts between two rock types of contrasting magnetic susceptibility or edges of structures that could be faults. Most of the magnetic lineaments are within a depth of a few meters to 100 meters.
5. The magnetic lineaments in the area overlaid on the surface lineaments showed some good correlation meaning that some of the surface structures cut deep into the subsurface around Jakura where some of the mines are located.
6. The Factory and Mine which are the possible source of contamination in the area seem to be feeding other aquifers in the study area directly and indirectly. These faults may act as conduits for polluted ground water into the surrounding environment.

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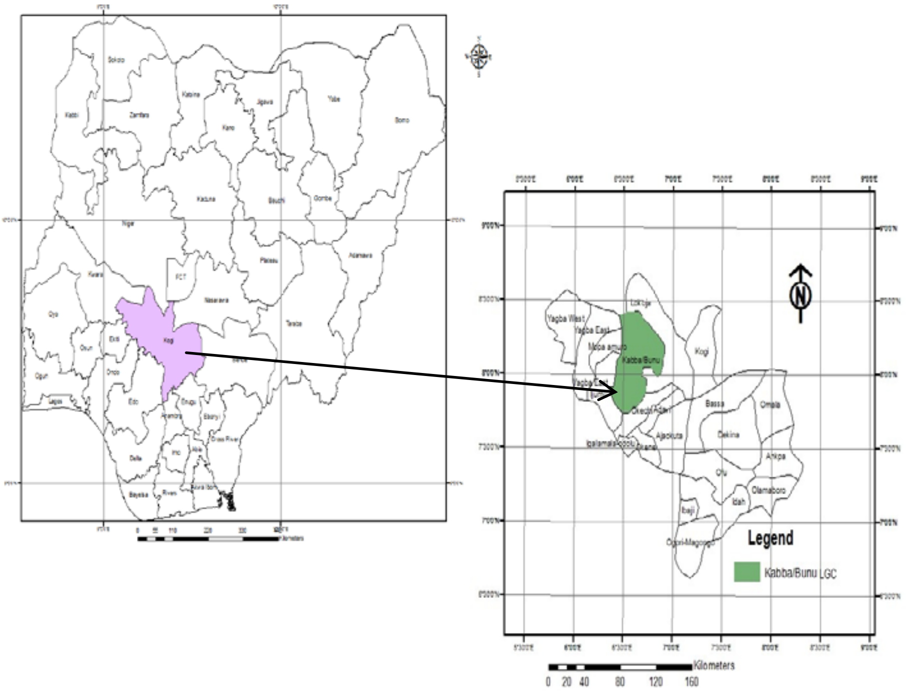

Figure 1: Map of Nigeria showing location of study area

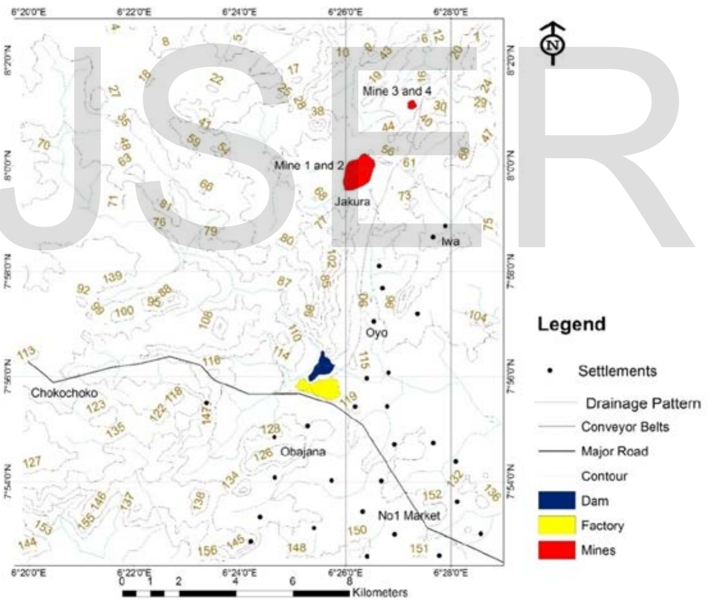

Figure 2. Topographic Map of Study Area Showing Major features Modified using ArcMap10.2.

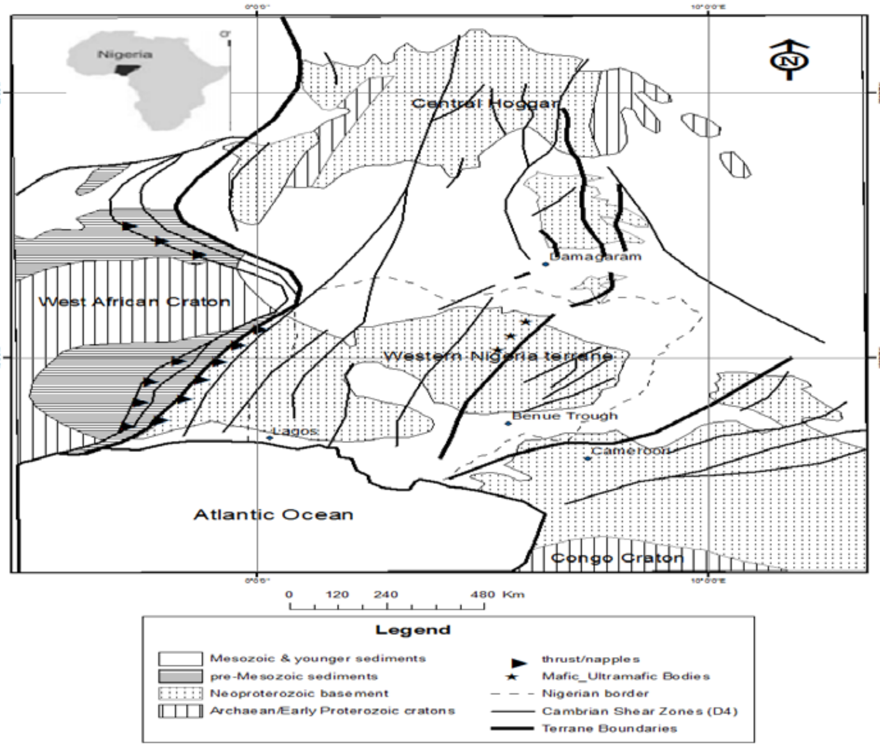

Figure 3: Geological map showing the Trans-Saharan belt resulting from terrance

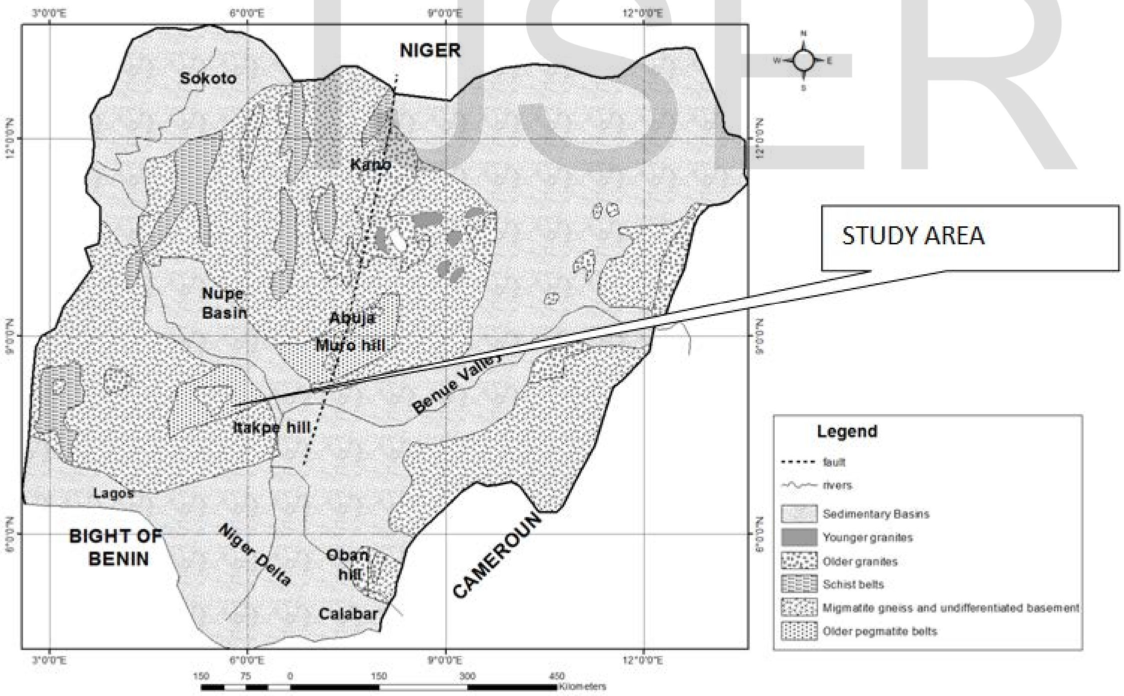

Figure 4. Geologic Map of Nigeria showing the location of Obajana

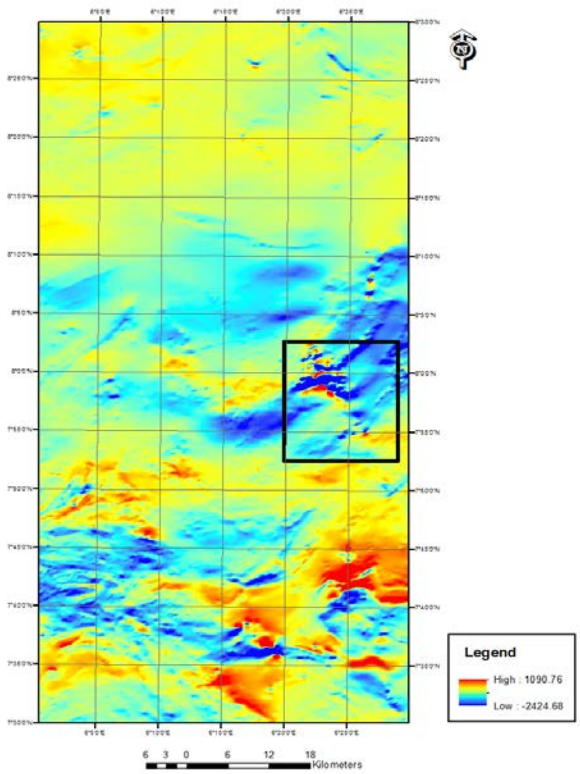

Figure 5. Aeromagnetic data of Kabba Sheet 146 and Aiyegunle 226 showing the area covered by Obajana and environs in black box

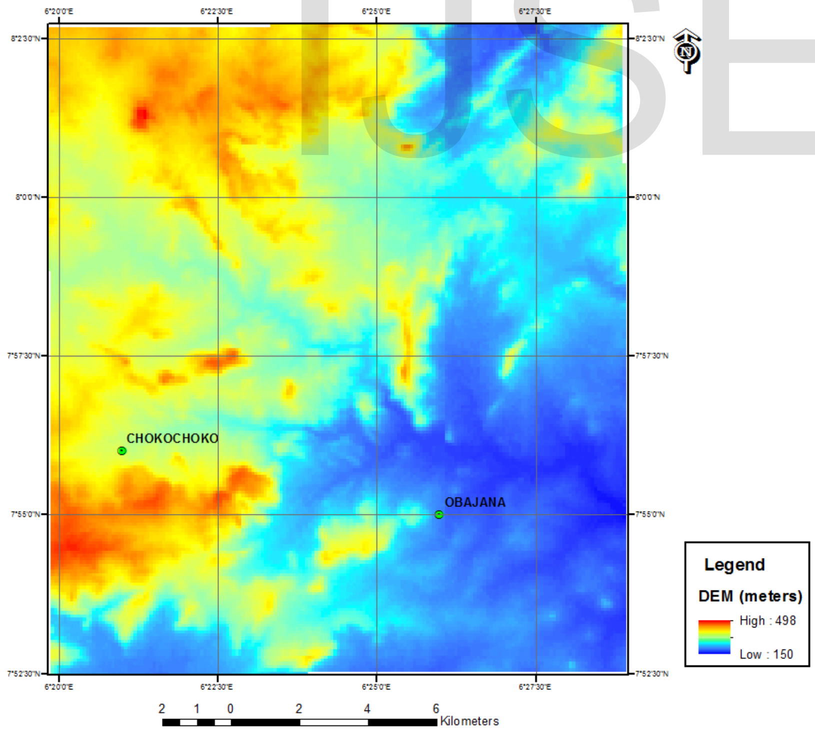

Figure 6 The SRTM data of Obajana and environs

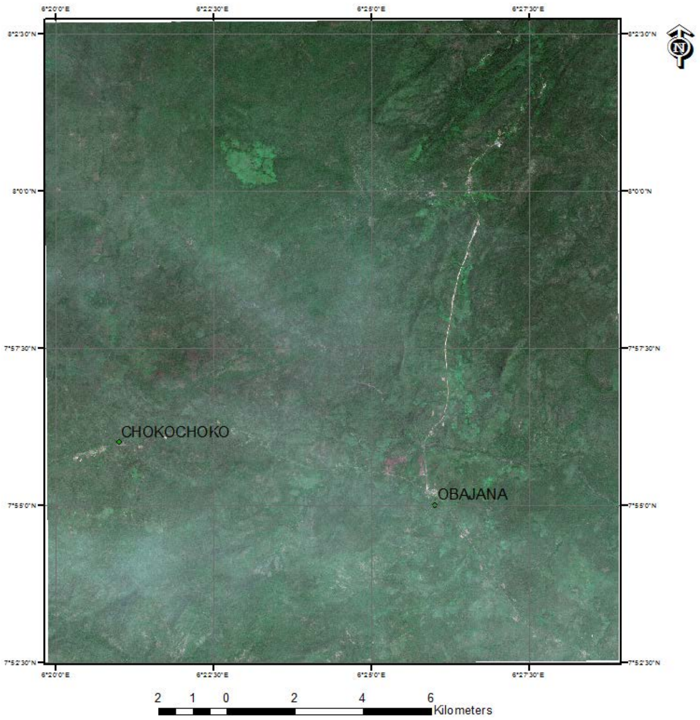

Figure 7. SPOT 5 satellite data of Obajana and environs

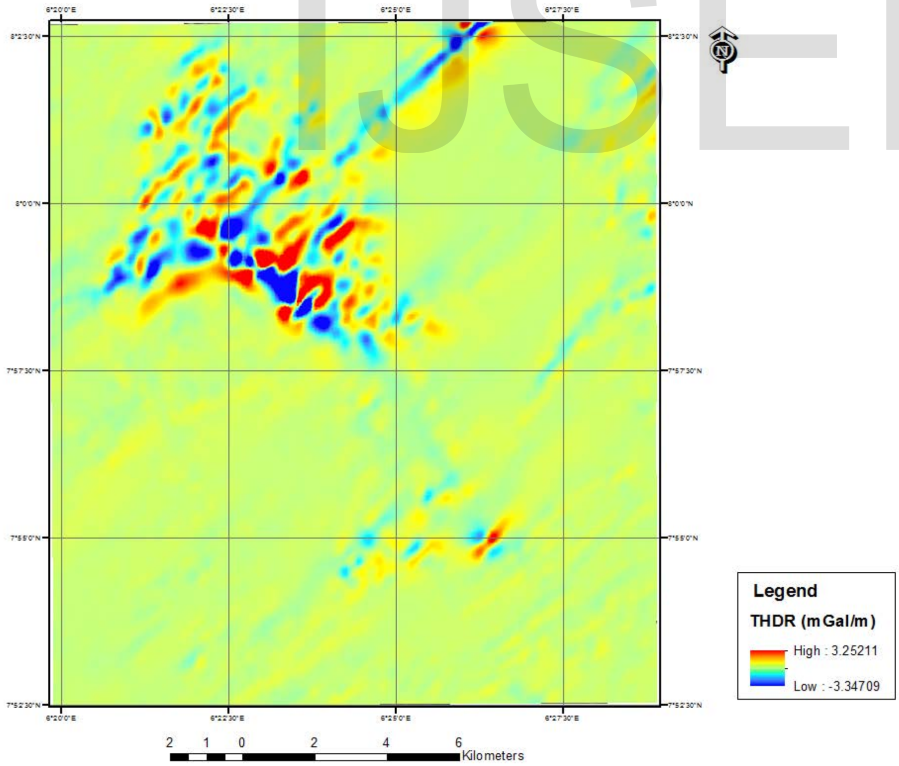

Figure 8. Total Horizontal Derivative grid of area covered by Obajana and environs

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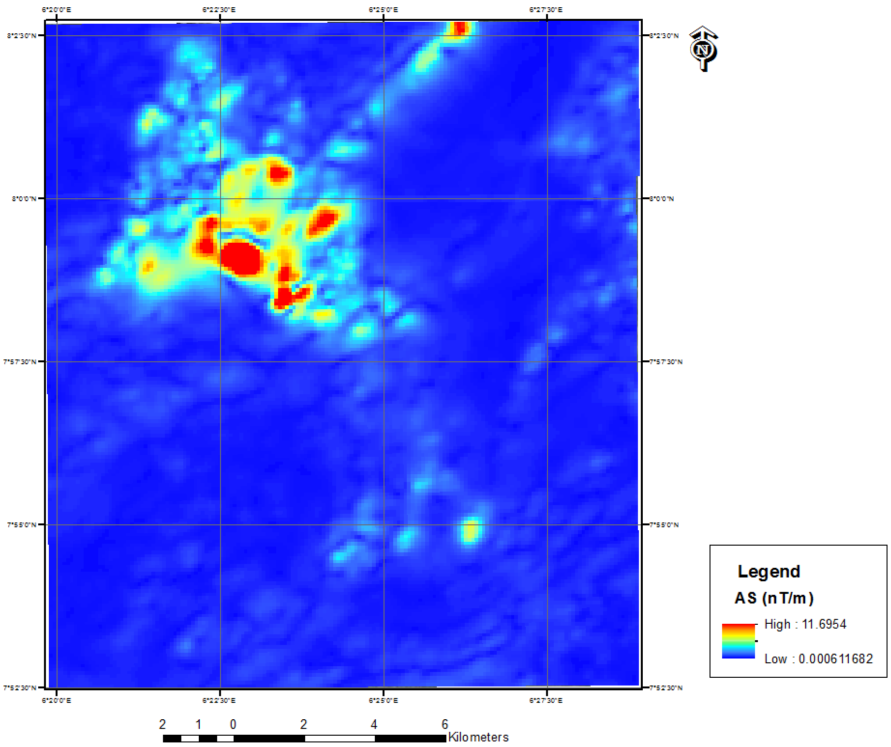

Figure 9. Analytical Signal Derivative grid of area covered by Obajana

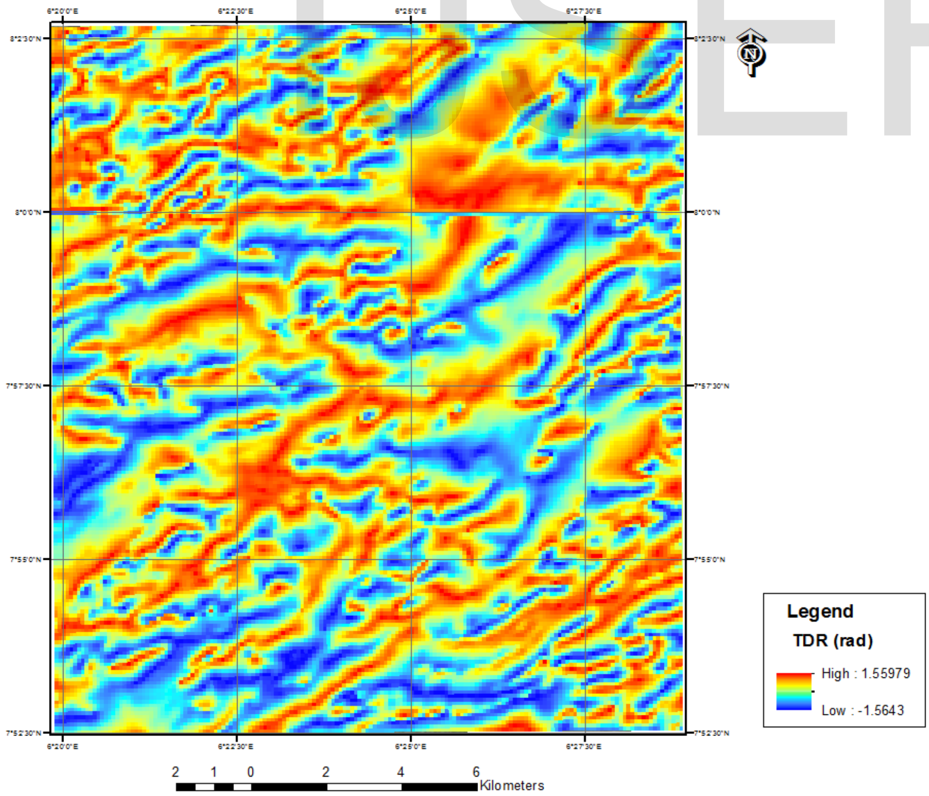

Figure 10. Tilt Derivative grid of area covered by Obajana and environs

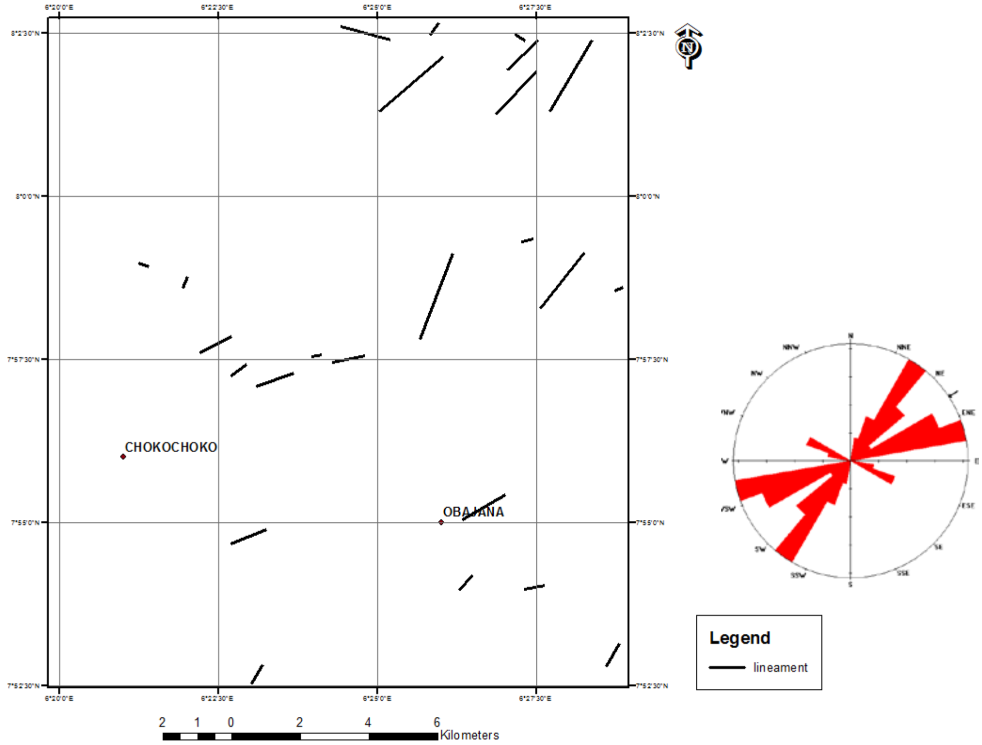

Figure 11. Surface lineaments

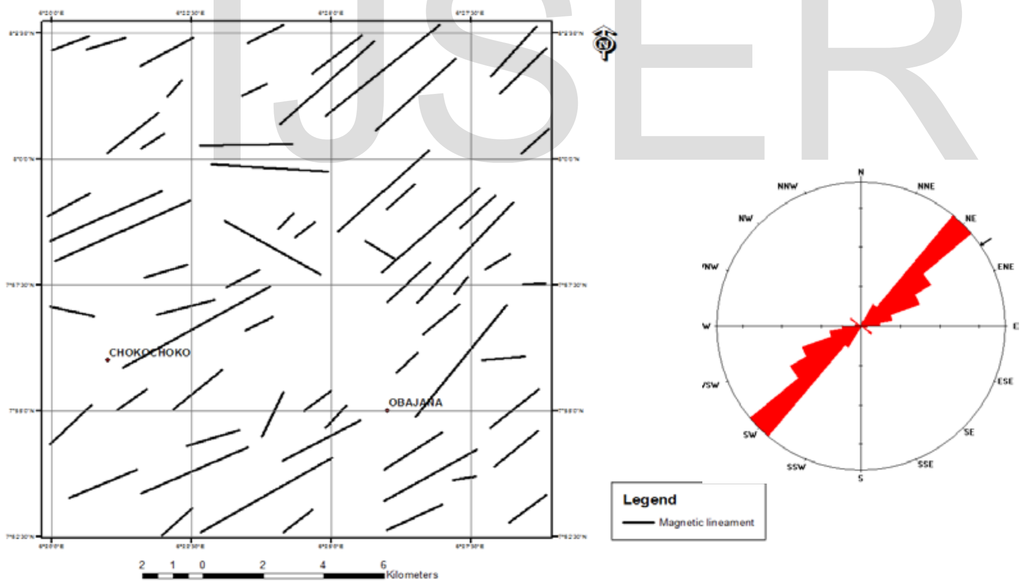

Figure 12.Subsurface structures

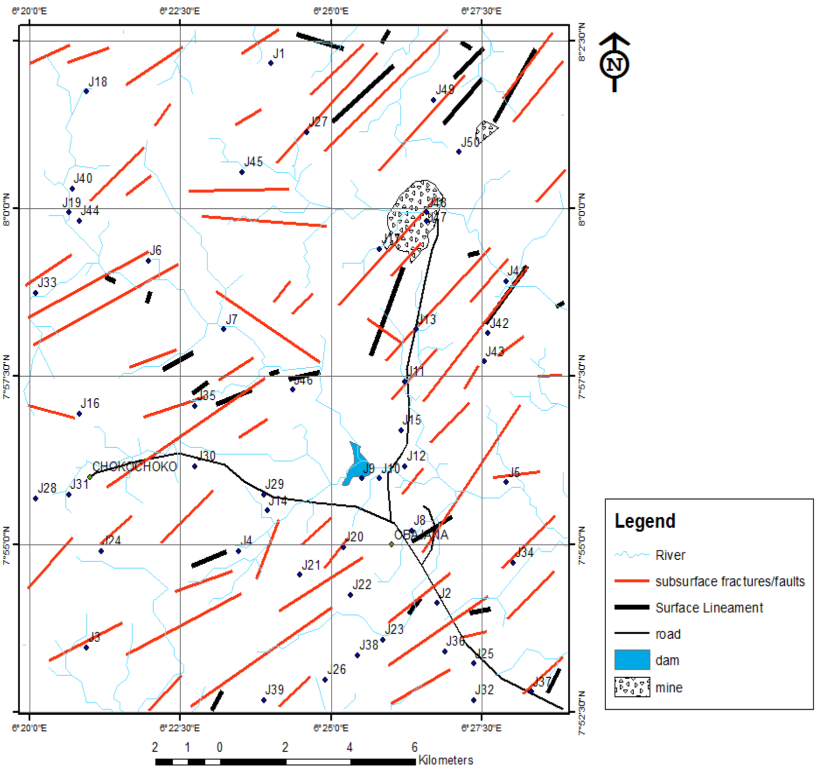

Figure 13.Overlay of Surface and subsurface lineaments on topographical map.

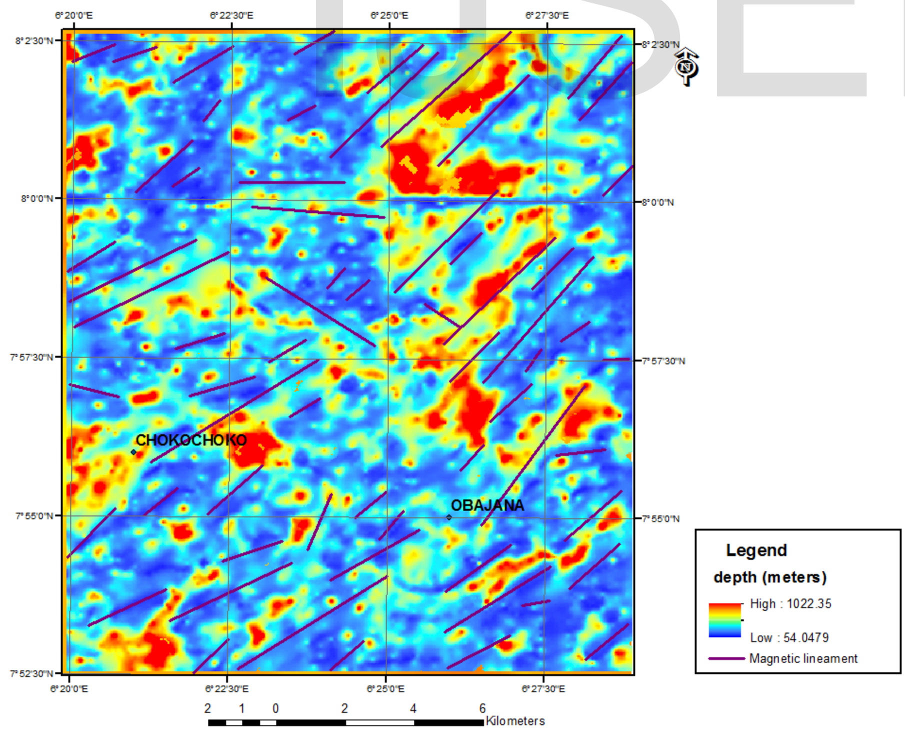

Figure 14. Structure-depth map of the area covered by Obajana and environs

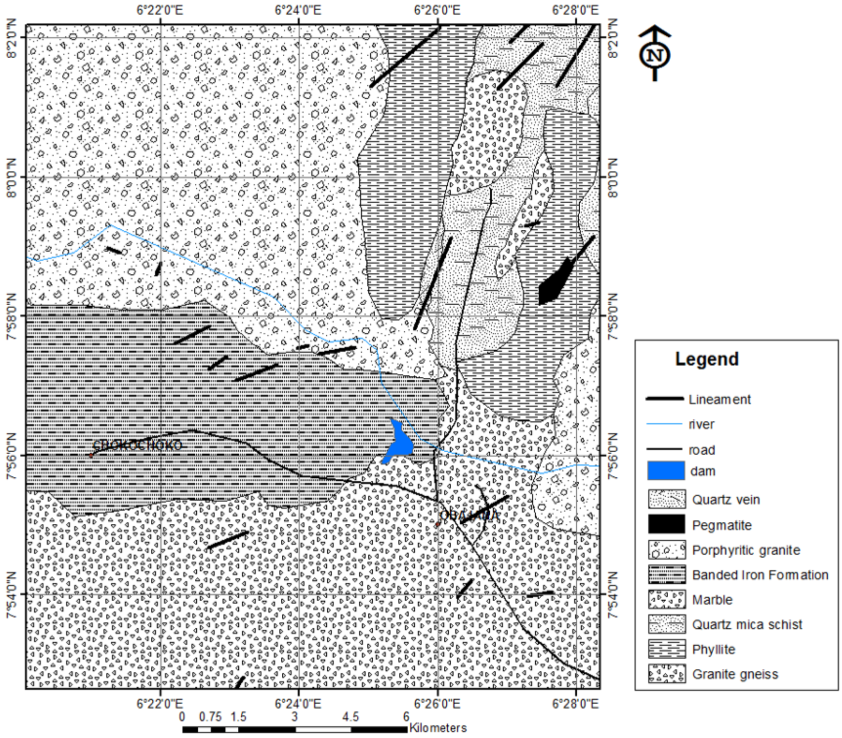

Figure 15. Overlay of surface and subsurface structures on geologic map.

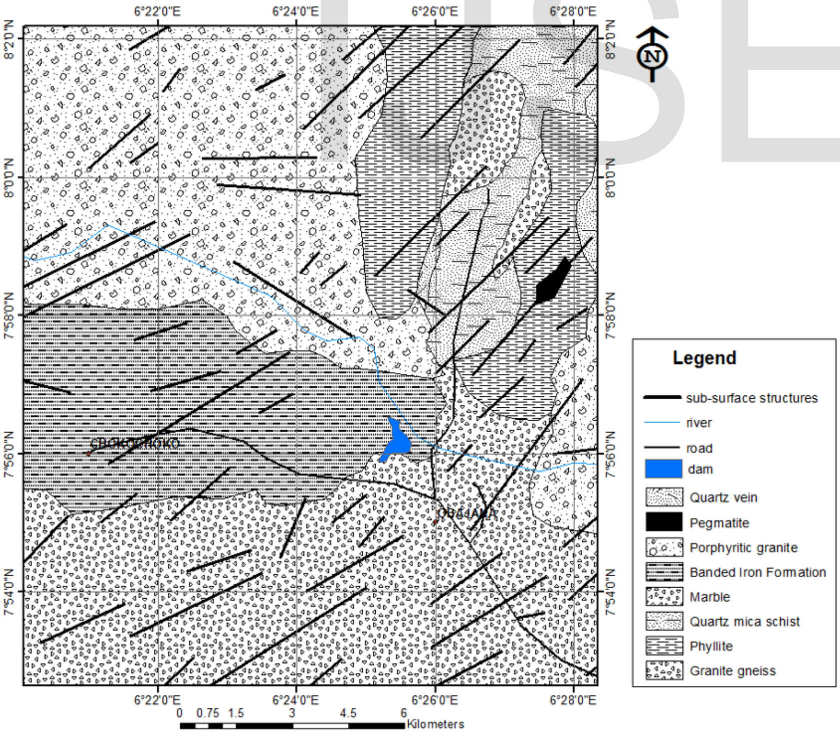

Figure 16. Overlay of surface and subsurface structures on geologic map.

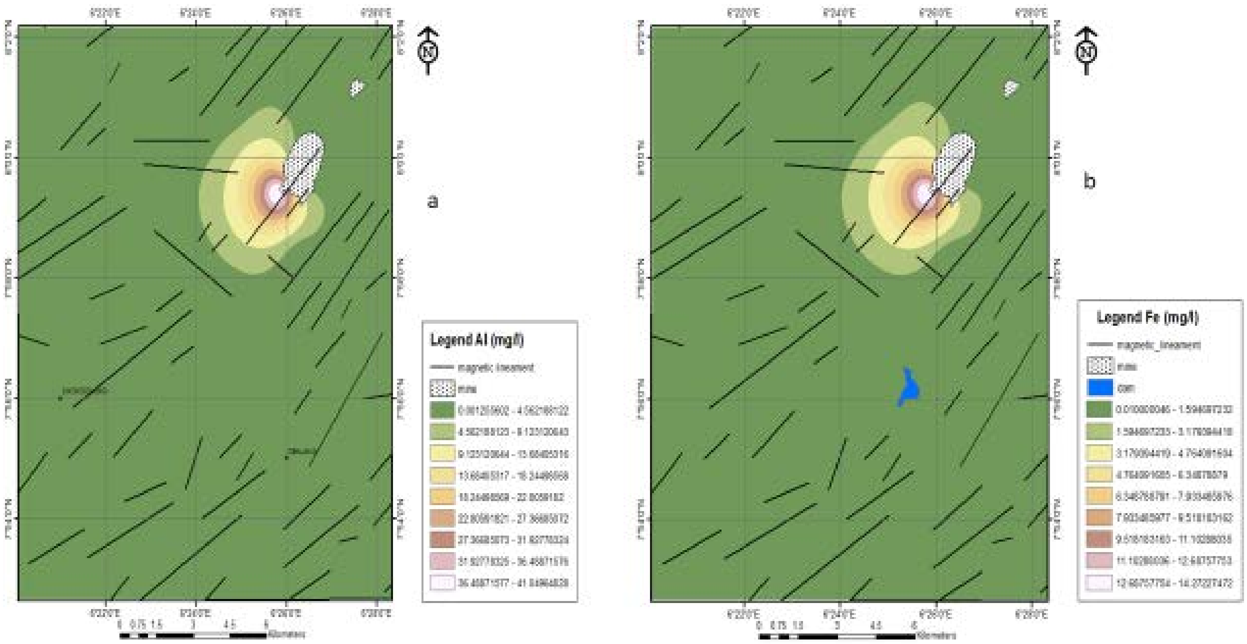

Figure 17.Overlay of sub surface structures on Al (a) and Fe (b) geochemical maps.

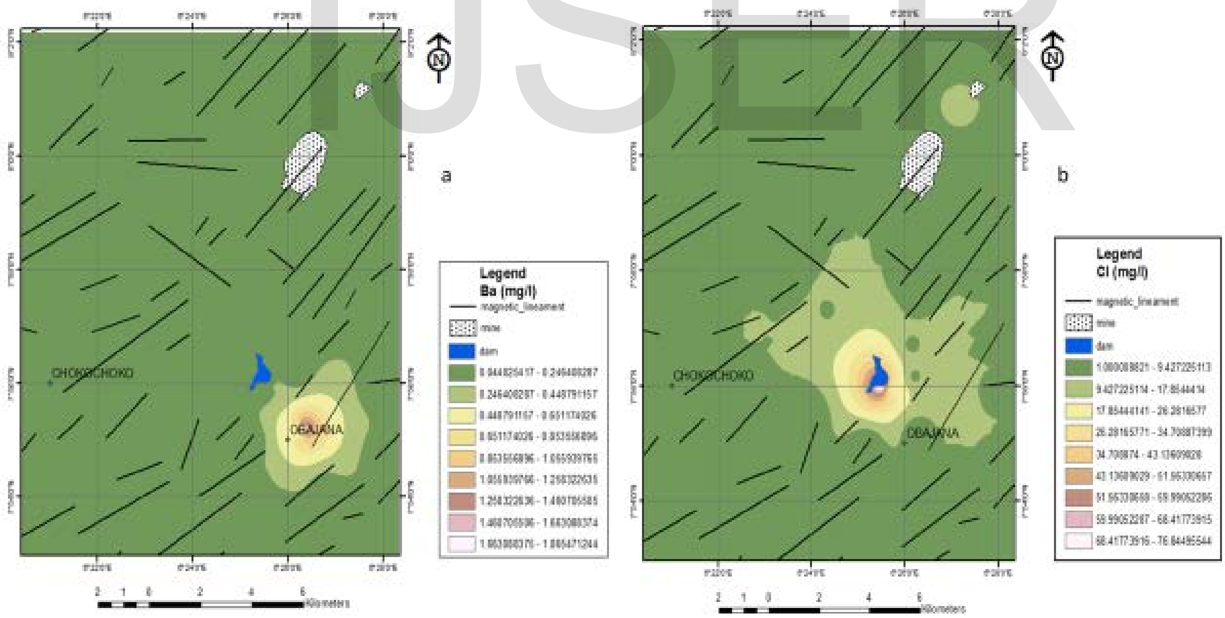

Figure 18: Overlay of sub surface structures on the Ba and Cl geochemical maps