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Original Research Article

Geophysical Investigation for Mineral Prospecting of Some Parts of Eastern Sokoto Sedimentary Basin Nigeria

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Abstract

An appraisal of aeromagnetic data lying between latitude 12^0N to 13^0N and longitude $4^0$30"E to$5^0$30"E comprising Argungu, Dange Tanbuwal and Gumi was carried out with a view to understanding the structural trends of interest for mineral exploration. A set of aeromagnetic data obtained from the Nigerian geological survey Agency was gridded to produce the total magnetic intensity (TMI) map of the study area, followed with a polynomial fitting to remove the regional anomaly from the total magnetic intensity so as to obtain the residual anomaly. The analysis was preceded by production of Shaded relief map depicting the profile of contact solution, shaded relief map of the profile dyke solution as well as magnetic susceptibility values of structures in each profile was analyzed. The result obtained from the profile contact and profile dyke solution showed an abnormal trend behavior which swept from southwest (SW) towards the center and the Northwest (NW) of the study area. The contacts and dyke solutions can be seen as arranged on the profiles, some portions being highly concentrated than other portions as they were arranged on their respective profiles indicating the possibility of much structural bodies or host for potential minerals. This is evident as the case maybe from the depth values obtained in Werner depth analysis performed with corresponding depth values for both Shallow and deeper bodies indicating the presence of geologic contacts and weak zones highlighting dyke-like bodies which might serve as host to the minerally controlled fluid around the area. Likewise results obtained from the magnetic susceptibility values in all the three profiles of the study area showed a number of structures possessing high and low magnetic susceptibility values indicating different types of minerals at different distance along the area at different depths. Minerals such as schist and limestone are likely to be present.

Keywords: Aeromagnetic, Structural trend, magnetic susceptibility, Profile contact, Profile dyke.

1.1 INTRODUCTION

Although over the years researchers have laid much emphasis on the exploration of the Sokoto sedimentary basin for oil and gas, kearey and Brookes (2002), less or little consideration is given to other aspect, especially the sub surface structures for solid minerals, the solid minerals industry plays a vital role in boosting the economy of Nigeria. Field methods and modern interpretation techniques of geophysics resulting from the emergence of large digital computers and their application have been put in use in various International and National organizations to probe the earth for valuable economic minerals, radioactive elements and hydrocarbons Stephen and Iduma (2018), (Uwa 1984).

It is certain that the feature of applied geophysics in particular and the earth science in general appears enviably bright in any case of the synthetic and the substitute material, although the dissatisfying demands for basic needs will surely continue to accelerate, but the best use of these geophysical methods in exploring the earth for mineralization if well manage, will course a drastic positive change to the development of a country (Udensi 2013).

1.2 Location of the study area

The study area under investigation is situated in the northeastern part of the Sokoto Basin, it comprises of Argungu, Dange Tanbuwal and Gummi, covered by aeromagnetic sheets number 28, 29, 50 and 51 respectively, which were merged together into a single composite block. The study area lies between longitude 4º30´to 5º30^{0}E and latitude of 12^0 to 13^0N.

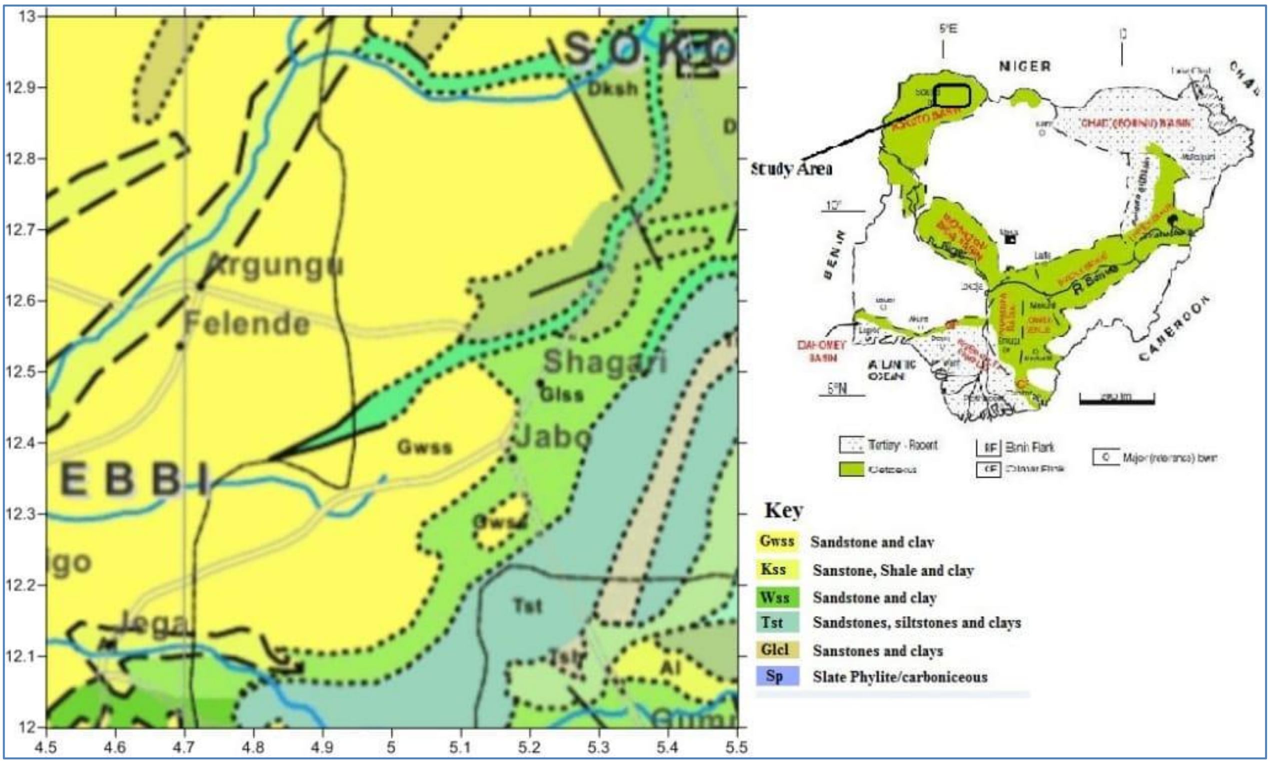

Fig-1.1: Map showing the location of the study area (modified after NGSA 2016)

2.1 MATERIALS AND METHOD

The aeromagnetic map of the study area was obtained on a scale of 1: 100000 from the Nigerian Geological Survey Agency (NGSA). The data acquired from NGSA, by Fugro airborne survey limited in 2008 using proton precession magnetometer at a flight altitude of 80m above the ground surface. The nominal flight lines spacing was 500m while the tie line spacing was 2 km apart. The flight line direction was NE to SW. and then the data was digitized. The trend surface equation was obtained using surfer software. Thus the equation:

$$Z(X, Z) = A00 + A01Y + A01Y + A10X \qquad (2.1)$$

Where Z(X, Y) is the regional field, X and Y are the geographical coordinates of the map, A00, A01 and A10 are the polynomial regression coefficients. The regional field values obtained from equation (2.1) above was then subtracted from the corresponding total field values and residual field is obtained. The residual field is the component of the magnetic field which represents the effect of the near surface bodies. The value of the residual field together with the geographical coordinates where then mapped.

The equation of the total magnetic field for a thin dyke with infinite strike length and depth extend can then be written in the form:

$$F(x) = \frac{A(x-x_o)_{+BZ}}{(x-x_0)^2 + z^2} \qquad (2.2)$$

Where x_0 is the surface point directly above the center of the top of a dyke, x is point of measurement and x-axis is normal to the strike and z is the depth to the top. A & B are the functions of the dyke geometry and mineralization.

$X^2f = -Ax_0 + Bz + Ax + 2x_0 XF - x_0^2F - Fz^2$

If $a_0 = -Ax_0 + Bz$, $a_1 = Ax$, $b_0 = -x_0^2 - z^2$ and $b_1 = 2x_0$ so that equation (2)

Becomes. $X^2F(x) = a_0 + a_1x + b_0f(x) + b_1xf(x)$ (2.3)

The depth (Z) and the surface point directly above the center of the top of the dike (x) can be determine from the solution of equation (2.3) using the relation $x_0 = ½ b1$ and Z is The susceptibility and dip can be obtained from the function A and B while admitting the possibilities of interference and assume that the interference can be represented by a polynomial of some degree, we can then add the interference polynomial to equation (2.2).

$$F(x) = A\frac{(x-x_0) + BZ}{(x-x_0)^2 + z^2} + C_0 + C_1X + \ldots\ldots\ldots C_n x_n \qquad (2.4)$$

Where n is the order of interference polynomial and c is the coefficient.

2.2 Data compilation

The major steps in the entire process between measurement and interpretation involve a routine activity but can be automated using a lot of techniques, programs have been developed and are been applied for a gamut of mathematical filtration procedures such as polynomial surface fitting, correlation, derivative continuation, frequency analysis, power spectrum etc. With these achievements this method has become firmly established to the point that can easily be employed in most geophysical works, up till these days, the magnetic method accounts for a major portion of the mining geophysical effects kearey and Brookes (2002).

The four digitized aeromagnetic data sheet of Argungu (sheet No 28), Dange (sheet No 29), Tambuwal, (sheet No 50) and Gummi (sheet No 51) were first merged into a single composite block which formed the study area using oasis montaj software. The regional geomagnetic gradients were then removed from the data using International Geomagnetic Reference Field (IGRF) .The merged data was then gridded into 18 equally spaced cells using oasis montaj. This was used to obtain the total magnetic intensity map followed by polynomial fitting for Regional-residual separation, other software include Geosoft, oasis montaj software version 6.4, surfer and grapher software were also used in the analysis of the gridded data obtained.

2.3 DATA PROCESSING

The data was gridded to produce the total magnetic intensity (TMI) map of the study area (fig 3.1). A grid cell size of 250m was used in order to avoid under sampling based on the sampling distance of the two data, this was then followed with the polynomial fitting to remove the regional anomalies from the total magnetic intensity, to obtain the residual anomaly (fig 3.2). First order polynomial fitting was applied on the data.

The qualitative interpretation of magnetic anomaly maps begin with a visual inspection of the shapes and the trends of the major anomaly, delineation of the structural trend, closer examination of the characteristics features of each individual anomaly etc, This features majorly dwell on the relative location and the amplitude of the positive contour parts of the anomaly (high magnetization), and the negative part of the anomaly (low magnetization), Shama, (1976). The process used in this work dwell in the production and the interpretation of the composite anomaly map of the area, the regional map, the residual map, the contact solution maps, the dyke solution maps, the Werner depth maps and the magnetic susceptibility maps of the study area.

2.4 Production of the Total magnetic map (TMI)

The unified total magnetic data set of the study area was made up of three columns, the longitude, the latitude and the magnetic values represented by x, y and z respectively, these values were fed into the computer using Oaisis Montaj software to produce the composite TMI map of the study area, followed by the Regional-Residual separation. Here the Total magnetic intensity (TMI) map comprises of two important disturbance superimposed but different in size include the Regional trends which are large features that generally show up as trends, and continued smoothly over a considerable distance. The second was the residual anomaly superimposed on the regional field and contained smaller and local disturbance, secondary in size but primary in importance. These fields may actually provide information of the existence of a reservoir, type of structure or mineral ore.

In order to interpret potential field data, the residual field anomaly must be separated from the regional, Stavrev and Gerouska (2000) this was done using some procedures which remove the unwanted field components so as to come up with the desired field anomaly which is of interest. Although there are many methods used in this operation but the often ones used are the graphical smoothening and analytical.

3.1 RESULTS AND INTERPRETATION

The Total magnetic intensity map of the study area is shown in fig (3.1) the map was divided into three main sections, though minor depressions are scattered all over the area. The high magnetic intensity values dominates the southwest towards the North east part of the study area and are represented by red to pink color, whereas the south eastern part and some parts along the Northwest indicated by blue and green color represents the low and moderate magnetic values. These high magnetic values which dominate the Northern part of the study area are caused probably by near surface igneous rocks of high magnetic susceptibility. The low amplitude TMI values are probably caused by the sedimentary rocks of low magnetic susceptibility or altered basement rocks while the high magnetic values were caused by the igneous and crystalline basement rocks.

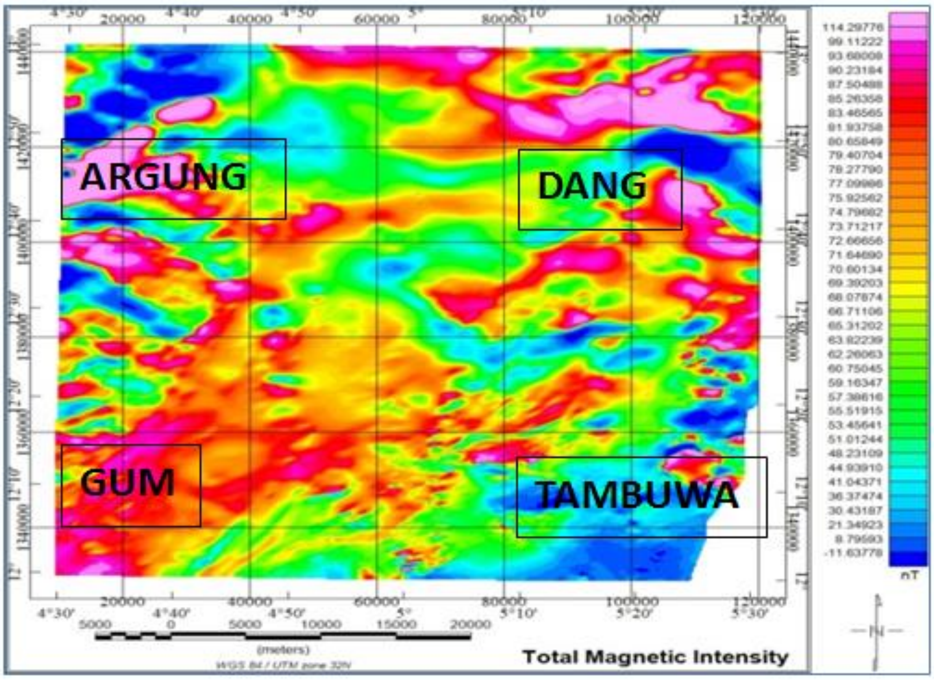

Fig-(3.1): The Total magnetic intensity of the study area

The fig (3.2) showed the color shaded residual magnetic intensity map of the study area, the residual map is characterized by positive and negative magnetic values. As shown in the map, the pink and red colors represents high and moderate values, the yellow colors represents high positive values, whereas the green and blue colors represents the moderate high and low negative values respectively. The thick pink color dominates the Northwestern part with some small shaded blue colored, the Northeastern (NE) part is dominated by the blue and red color while the yellow color dominates the central parts from the southwestern (SW) towards the Northeastern (NE) parts of the study area. The residual magnetic intensity values ranges from -75.862 nT to 51.31917 nT the trend of the residual field anomalies were observed to be along Southwest towards Northeast (SW to NE) and Northwest Southeast direction (NW to SE).

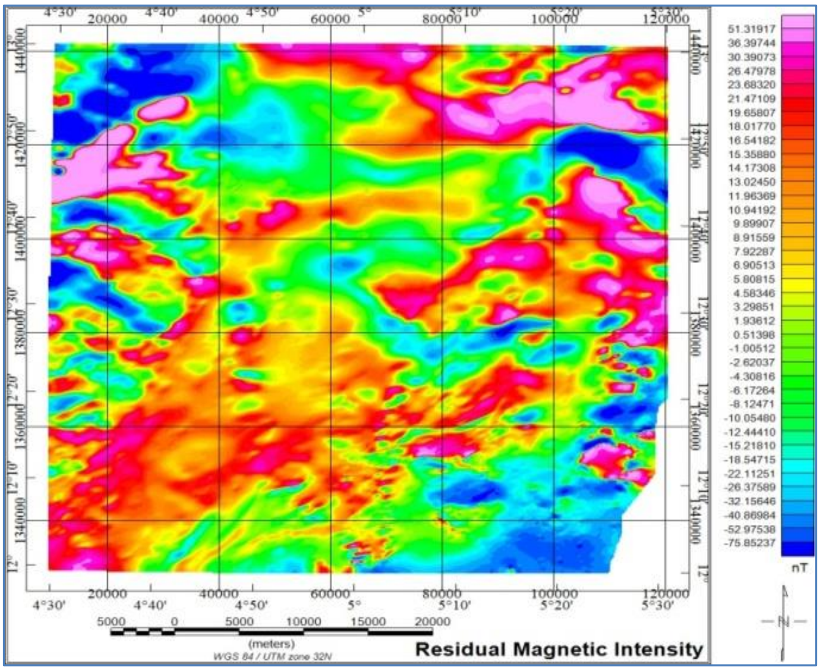

Fig-(3.2): Residual magnetic intensity map

The shaded relief map of the contact solution in the study area is indicated by a profile line which cut across the study area in NW-SE direction figure (3.3). The entire map showed an abnormal behavior which swept from the south-west towards the central and to the north-west of the map. Another abnormal behavior can also be seen at the western and southeastern part of the map, this possibly indicated some anomalous behavior of different structures in the study area.

In profile one (P1), the contact solution can be seen to be arranged on the profile indicated by a line drawn from the mid of the western part towards the southeastern part of the map and concentration of the contact solution is at the southeastern portion and midpoint of the western part of the map.

Likewise in profile 3 (P3), which almost have the same concentration and arrangement of contact solution with profile 1 (P1). But in profile 2 (P2), the contacts here tends to have been concentrated at the mid portion of the profile.

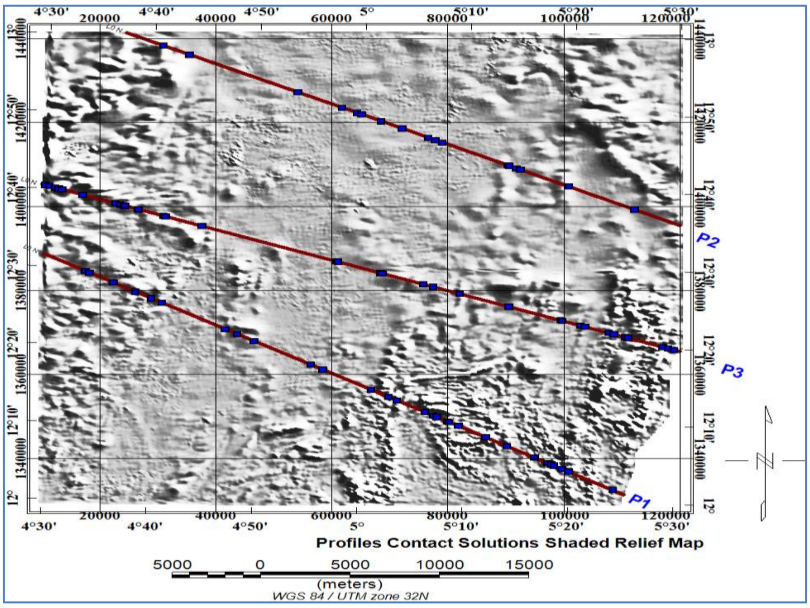

Fig-(3.3): Shaded relief map of the profile contact solution

In the case of the dyke solutions, just like the contact solution, the map showed almost the same behavior at profile 1 (P1), where dykes are massively concentrated at the south-eastern portion and western part of the study area, profile 3 (P3), lies along the north-eastern part of the study area and showed no dyke, this may possibly be as a result of deep sedimentation. In these results, portions with deep sedimentation showed no dyke solutions which are indication for the presence of low magnetic minerals. These correlation can be seen clearly at varying depths as shown in figure (3.5, 3.6 and 3.7) respectively.

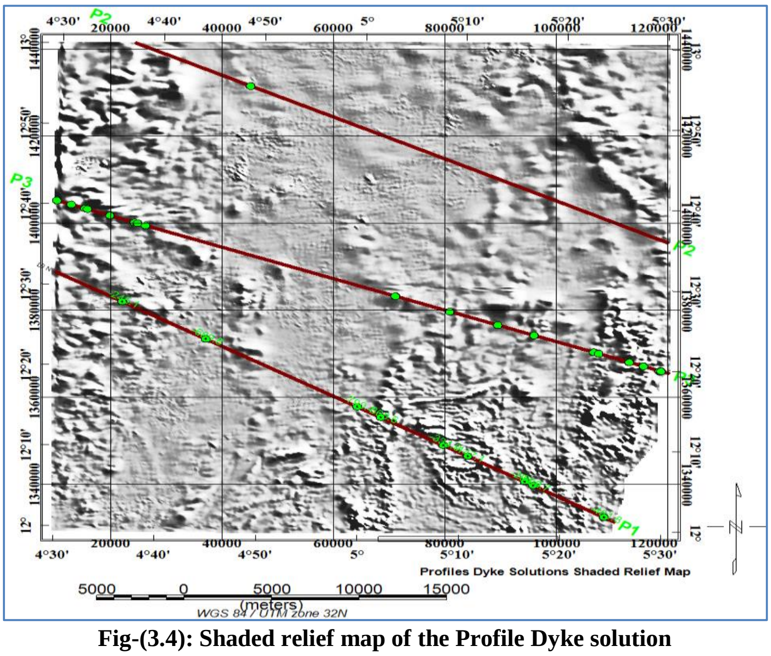

Fig-(3.4): Shaded relief map of the Profile Dyke solution

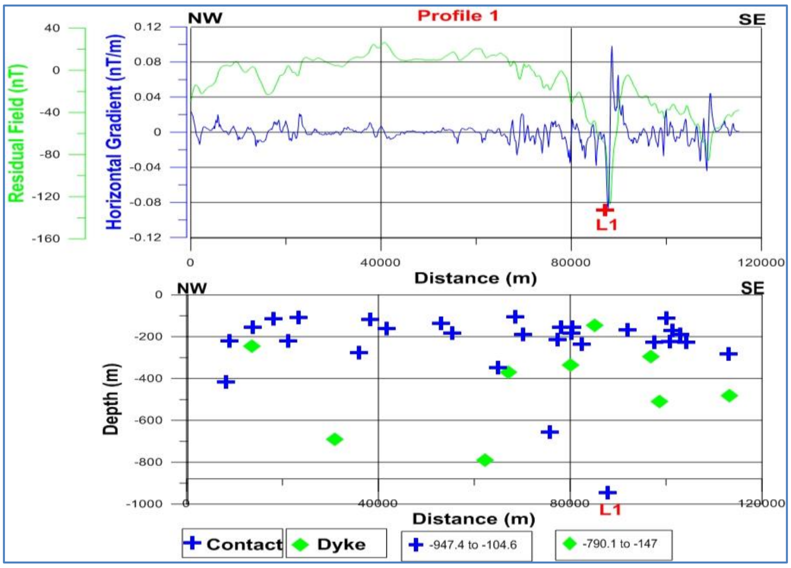

Fig-(3.5): The depth and distance in (m) of the dyke and contact solutions of profile 1

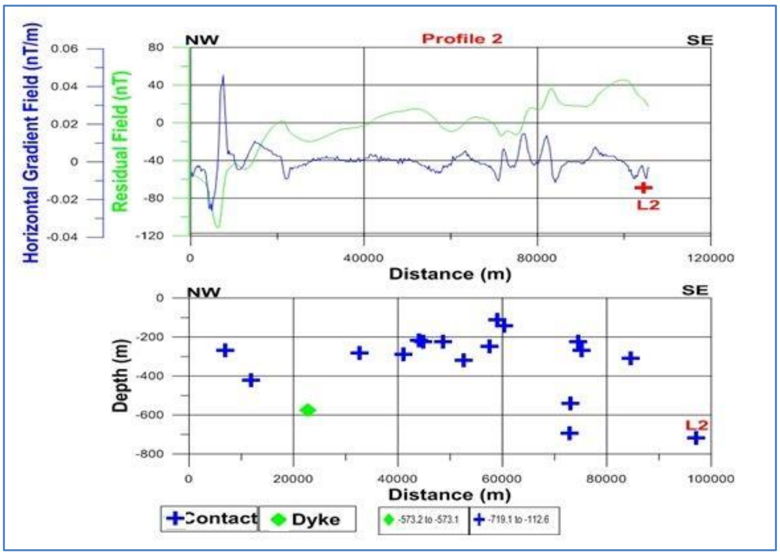

Fig-(3.6): The depth and distance (m) of contact and dyke solution for profile (2)

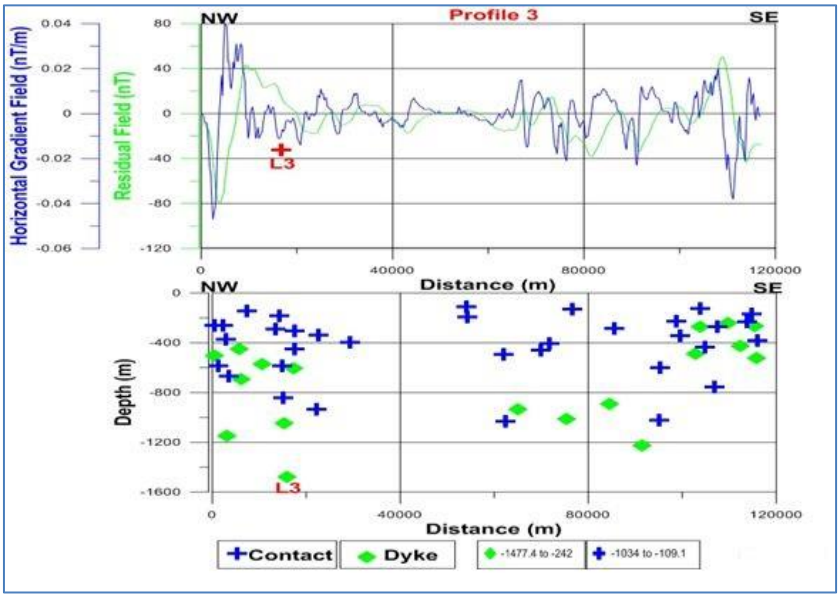

Fig-(3.7): The depth and distance in (m) of the dyke and contact solution of profile (3)

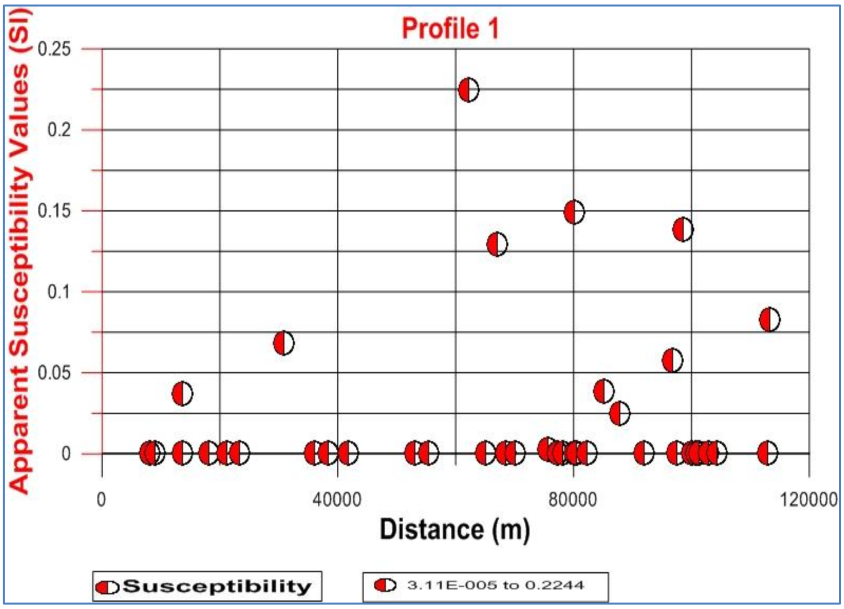

Fig-(3.8): Susceptibility values of solutions in profile (1)

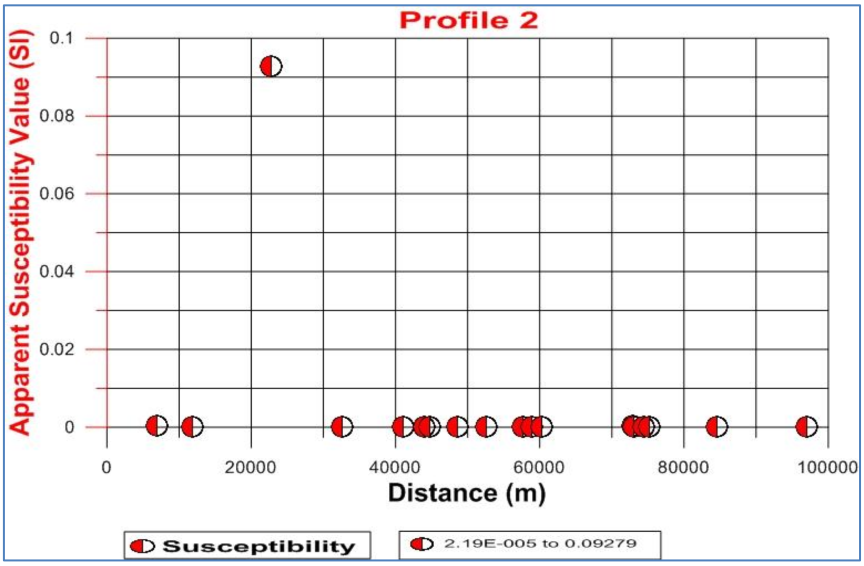

Fig-(3.9): Susceptibility values of solutions in profile (2)

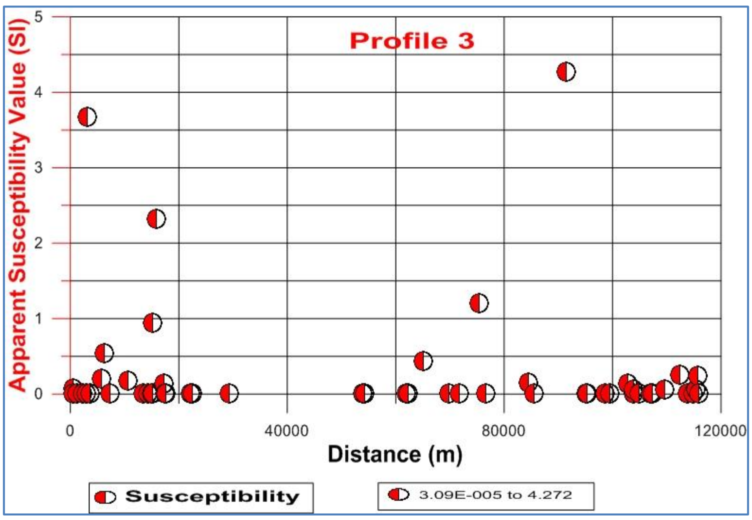

Fig-(3.10): Susceptibility values of solutions in profile (3)

Table-3.1: The Magnetic susceptibility value of some rocks and minerals

Minerals	Susceptibility value in $*10^{-3}$
Air	About 0
Quartz	-0.011
Rock salt	-0.01
Calcite	0.001-0.01
Sphaalerite	0.4
Pyrite	0.05-5
Hematite	0.5-35
Illminite	3003500
Magnetite	1200-19200
Limestone	0-3
Sandstone	0-20
Shales	0.01-15
Schist	0.3-3
Gneiss	0.125
Slate	0-35
Granite	0-50
Gabbros	1-90
Basal	0.2-175
Peridotite	90-200

DISCUSSION

The Total magnetic intensity (TMI) map was interpreted to contained minor depressions scattered all over the three main section of the study area with high and low values of 33051 nT and 33068 nT of magnetic intensity. This result agreed with work of Stephen and Iduma (2018). Structural investigation of Northeastern Sokoto basin, in their research, three section of structural deformation were observed from the lineament map, it shows the Northeastern part of the study area highly deformed, the trend followed along the Northwest down the Southeast with minor or low magnetic intensity, indicating low magnetic structures.

The residual map of the study area was formed after separating the regional from the residual anomaly, from the residual map, the area reveal high magnetic intensity value of 51.31917 nT indicated by pink color and a low magnetic value of -75.85237 nT indicated by blue color which may be coursed by high frequency shallow anomalies.

The result so far obtained from the analysis performed for structurally controlled deposits in the Sokoto basin is a fact that will encourage the Nigerian government to also emphasize the need for mineral exploration in the study area in other to boost its economy rather than highly dependent on oil and gas. Using contact and dyke solution to analyze the structural inbuilt of the study area, The result from the shaded relief map of the contact solution, showed areas that are highly or densely concentrated with contact solutions, areas in the southern part of Argungu and Tambuwal, but little contact solutions at Dange, with a unique interest for a contact at a depth of-895m southwest of the study area fig (3.3), 700m depth southeast of (Tambuwal). This showed that there is high possibility of intrusion of high magnetic susceptibility within this zone of contacts solutions. The dyke solution is a type of sheet intrusion referring to any geological body that cuts discordantly across a form of minor intrusion injected into the crust during its subjection to tension. Areas noticeable by the concentration of geological dykes are areas marked with high structural deformation with possibility and high expectation of traps which are cavities or host for geological minerals. In this study Tambuwal and southern part of Argungu were areas that showed high possibilities of geological structures because of the number of dyke solutions and with a special occurrence of a dyke of interest at a depth of 1500m at a distance of 20000m southwest of the study area (Gumi), fig (3.4). This dyke of interest may probably serve as a host for an important mineral of interest. This fact is in agreement with the work of Ibe and Iduma (2018) structural interpretation of northern Sokoto basin using airborne magnetic data. In structural analysis of sub-surface structures using aeromagnetic method.

The magnetic susceptibility of structures plays vital role in the delineation and location of magnetic bodies. The maps in Fig (3.8, 3.9 and 3.10) above showed the magnetic susceptibility of different bodies on different profiles in the study area. The study area was divided into profiles in other to study the susceptibility values of the solutions. Each profile covered a distance which was used to trace structures possessing different susceptibility values. In profile one Fig (3.8), structures with magnetic susceptibility values of 0.05 and 3-10 were observed and according to table (3.1), the structural magnetic values may probably be as a result of a structural body hosting pyrite and hematite which are forms of iron, the profile also indicated the possibility of gneiss, granite, gabbros, basalt and schist. Likewise in profile (3) Fig (3.10), a structure of high magnetic susceptibility value of 4.4 is located at a distance of 85000m which may contain limestone and sandstone, according to susceptibility range value in table (3.1).

Profile two, which proved to be unique as earlier mentioned lied within the zone of high sedimentary thickness at the Northern part of the study area and contained less magnetic anomalies in the form of shale and sphalerite, this result therefore is an indication that within the zone of high sedimentary thickness of the Northeastern part of the study area, valuable structures for economic minerals especially such with high magnetic susceptibility can hardly be found and this result agreed with the past work of Steven and Iduma (2018), for structural complexity using first vertical and horizontal gradient on aeromagnetic data in the eastern part of the Sokoto basin, also Uwah (1984), although the accentuated high magnetic structures of uranium and Ironstone could not reach the concentration level needed or regarded for economic importance.

CONCLUSION

From the analysis performed structurally controlled deposits over the eastern part of Sokoto sedimentary basin using aeromagnetic data, the result from the werner analysis performed agreed with the results obtained by Bonde *et al*., (2014), Adetona *et al.*, (2007) that the area is of highly sediment around Dange and Argungu with low sedimentary thickness in areas around Tambuwal and Gumi. Using the profile contact solution, the profile dyke solution, magnetic susceptibility maps and the Werner analysis map. The study area reveals much concentration of dykes and contacts along Gumi and Tambuwal with little of these dykes and contacts sparsly distributed along Dange and Argungu. Highly magnetic susceptibility solutions were also revealed along the less sedimentary thick areas. With this, it may be concluded that structures for mineralization can probably be found along Tambuwal and Gumi, meaning that the expected structures for economic growth may not be found in deep sedimentary areas of the Sokoto basin, but can be seen in areas with less sedimentation, although may not contain minerals with high magnetic values, yet, some minerals with low magnetic values can also be good economic booster for the country.

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