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Delineation of Magnetic Zones of Tambuwal Basin, Northwestern Nigeria, Using Aeromagnetic Data

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ABSTRACT

Magnetic method is one of the best geophysical technics used for determining depth to magnetic source bodies, possible sediment thickness and delineating subsurface structures. An aeromagnetic intensity contour map sheet 50 of Tambuwal Sokoto state basin was acquired, digitized and analyzed using Oasis-Montaj v8.4. The study aimed to digitize the aeromagnetic map, produce the total magnetic intensity map (TMI) and performs upward continuation of the TMI at 2km, 5km, 10km, 15km and 20km.The map was acquired from Nigerian Geological Survey Agency (NGSA) and visual interpolation method was used to digitize the map. Data obtained was used to produce the Total Magnetic Intensity (TMI) and the Residual Maps which were used in finding out the clear picture of the surface area in terms of TMI values. The Residual Magnetic Map was subjected to upward continuation techniques which are applied at 2km, 5km, 10km 15km and 20km. The result of the study area revealed tha,t the northern part of the area has higher sedimentation. The areas with relatively thicker sediments are identified as probable sites for prospect of hydrocarbon accumulation in the area. Therefore, exploration of this areas of study is a worth given and a push to economic development, there is therefore need to take advantage of modern geophysical methods in the exploration of areas of this nature within the country.

Keywords: Aeromagnetic Map, Magnetic zones, Delineation, Total Magnetic Intensity Map and Residual Map.

1.0 INTRODUCTION

Geophysics is the study which involves the application of physical principles and quantitative physical measurements in order to study the earth's interior. The analysis of these measurements can reveal how the earth interior varies both vertically and laterally, and the interpretation of which can reveal meaningful information on the geological structures beneath (Hassanein and Soliman 2019).

The constituents of the earth and its concentration have been of concern to human, many years ago man has tried to find out the origin and content of the earth through various geophysical methods Dobrin (2016). The subsurface of the earth has been of particular concern to geoscientists, because, they seek to investigate it using diverse means, some for the purpose of research or knowledge, while others do it for exploration of economic resources such as minerals etc. Singh (2013). With the development in technology and the need to have clear features of the earth subsurface and its contents, the earth scientists have deemed it necessary to utilize the properties associated with earth's interior. By working at different scales, geophysical methods may be applied to a wide range of investigations from studies of the entire earth to exploration of a localized region of the upper crust for engineering (Kearey *et al*., 2004). A wide range of geophysical methods exist for each of which there is an operative physical property to which the method is sensitive. The type of physical property to which a method responds clearly determines its range of application. Thus, for instance, magnetic method is very suitable for locating buried magnetic ore bodies because of their magnetic susceptibility. Similarly, seismic and electrical methods are suitable for locating water table, because saturated rock may be distinguished from dry rock by its higher seismic velocity and higher electrical conductivity (Kearey *et al.*, 2004). In exploration for subsurface resources, the geophysical methods are capable of detecting and delineating local features of potential interest. Geophysical methods for detecting discontinuities, faults, joints and other basement structures, include the following: magnetic, seismic, resistivity, electrical, potential field, well logging, gravity, radiometric, thermal etc. Grauch (2018). Some geophysical methods such as gamma- ray spectrometry and remote sensing measure surface attributes; others, such as thermal and some electrical methods are limited to detecting relatively shallow subsurface geological features. Geophysical modeling provides generalized and no-unique solution to questions concerning the concerning the geometry of the subsurface geologic structures (Reeves, 2005). Rock material properties are measurable or describable lithologic properties of rock material that can be evaluated in hand specimens or tested in the laboratory. Geohydrologic properties are attributes of a rock unit that affect the mode of occurrence, location, distribution, and flow characteristics of subsurface water within the unit. Geohydrologic properties include material and mass properties, but also account for the interaction and behavior of subsurface water within the rock mass. Field tests are typically used to evaluate geohydrologic properties of the rock mass, including secondary porosity, hydraulic conductivity, transmissivity, and other hydraulic parameters. According to Telford and Geldart (2019), Laboratory tests are used to evaluate geohydrologic properties of the rock material, such as primary porosity and permeability. Typical classification elements include: primary porosity (use data collected for rock material properties), secondary porosity (use data collected for rock mass properties), hydraulic conductivity (pump tests, published information) transmissivity (pump tests, published information), storativity/specific yield (pump tests, published information), soluble rock (occurrence of limestone, gypsum, or dolomite; see data collected for rock material properties), water table/potentiometric surface (measured in field, published data, date of measurement), aquifer type (unconfined, confined, leaky artesian, perched), electrical conductivity or resistivity (geophysical Rock material properties are related to the physical properties of the rock-forming minerals and the type of mineral bonding. Properties are determined from hand specimens, core sections, drill cuttings, outcroppings, and disturbed samples using qualitative procedures, simple classification tests, or laboratory tests. Singh (2013) pointed out that, the results are applicable to hand specimens and representative samples of intact rock material. They do not account for the influence of discontinuities or boundary conditions of the rock. Typical classification elements include: principal rock type, mineralogy (estimate percentage of principal and accessory minerals; note type of cement and presence of alterable minerals), primary porosity (free draining or not), hardness and unconfined compressive strength categories unit weight (dry), unit weight (dry), color, discrete rock particle size (use D50 or cube root of the product of its three dimensions), Dry density: Information provided by the accessory minerals in the name of a rock can provide clues to properties that have engineering significance. For example, a mica schist might indicate potentially weak rock because the sheet silicates (the micas and chlorite) impart low shear strength to the rock mass (210–VI–NEH, Amend. 55, January 2012) Most economic minerals, oil, gas, and groundwater lie concealed beneath the earth surface, thus hidden from direct view. The presence and magnitude of these resources can only be ascertained by geophysical investigations of the subsurface geologic structures in the area.

In this study, aeromagnetic data of tambuwal sheet 50, was used to produce total magnetic intensity map and The residual map of tambuwal was also subjected to Upward continuation techniques; which was applied at 2km, 5km, 10km 15km and 20km to delineate areas of higher sedimentation which might favor accumulation of hydrocarbon.

1.1 Study Area

Tambuwal is a Local Government Area in Sokoto State, Nigeria. with headquarter in the town of Tambuwal, at approximately 12°24′00″N 4°40′00″E In sokoto state north western part of Nigeria, It also has a total area of 1,717 km^2 (663 sq mi) square kilometer and is bordered in the east with Alleiro Local government area of Kebbi state (Singh, 2013 in Dharmendra, 2017).

Fig 1.1: Map of Nigeria Indicating the Study Area

1.2 Topography

The Tambuwal local Government area which is dominated by massive flood plains of the in- land river valley system. Thus, it typically has a flat but undulating elevation of about 150 m in the flood plains. The alluvial sediment in the flood plains ranges from gravel level to clay level. It is this sediment which gets saturated during the rains, to store water in the sands for dry season use. The geology of Tambuwal local government is characterized by thick sedimentary deposited of the Sokoto-Rima basin and it also under lay by Precambrian Basement Complex rocks (Singh, 2013 in Dharmendra, 2017).

1.3 Climatic Condition

Tambuwal local government area which enjoys a tropical type climatic condition, generally characterize by wet and dry season. The rainfall begins in April with the heaviest rainfall recorded in the month of July and August. The cold harmattan periods characterized by dust laden wind prevails in the month of November to January while the month of February and March are extremely hot. The mean annual temperature vary considerably but usually stand at 42°_. The mean annual rainfall is 500 mm (Singh, 2013 in Dharmendra, 2017).

1.4 Aim and objectives of the Paper

The aim of this paper is to determine the Geology of Tambuwal while the objectives include the following:

i. To digitize the aeromagnetic map
ii. To produce the total magnetic intensity map (TMI)
iii. To performs upward continuation of the TMI to 2km, 5km, 10km, 15km and 20km.

MATERIALS AND METHODS

2.0 Data Acquisition

The study consists of aeromagnetic data of sheet number (50) of Tambuwal. This map is obtained from the Nigerian Geological Survey Agency [NGSA]. The Agency carried out an airborne magnetic survey of substantial part of Nigeria between 1974 and 1980. The magnetic information consists of flight lines plotted on a continuous strip chart or tape records. The data were collected at a nominal flight altitude of 19.02ft along N-S flight lines spaced approximately 2km apart. The magnetic data collected were published in the form ½ degree aeromagnetic maps on a scale of 1:100,000. The magnetic values were plotted at 10Nt (Nano Tesla) interval. The maps are numbered, and names of places and coordinates (longitude and latitudes) written for easy reference and identification. The actual magnetic values were reduced by 25,000 gammas before plotting the contour map. This implies that the value 25,000 gamma is to be added to the contour values so as to obtain the actual magnetic field at a given point. A correction based on the International Geomagnetic Reference Field, (IGRF,) and epoch date January 1, 1974 was included in all the maps. The visual interpolation method that is the method of digitizing on Grid Layout was used to obtain the data from field intensity aeromagnetic maps covering the study area. The data from each digitized map is recorded in a 19 by 19 coding sheet which contains the longitude, latitude and the name of the town flown and the sheets number. The unified composite dataset for the study area was produced after removing the edge effect. Oasis-montaj was used to import the dataset. The dataset consists of three columns (longitude, latitude and magnetic values). The composite map was produced using Oasis Montaj version v8.2. A program was used to derive the residual magnetic values by subtracting values of regional field from the total magnetic field values to produce the residual magnetic map and the regional map. (Kamba et al, 2016).

2.1 Regional-Residual Separation

Magnetic data observed in geophysical surveys comprises of the sum of all magnetic fields produced by all underground sources. The composite map produced using such data, therefore contains two important disturbances, which are different in order of sizes and generally super-imposed. The large features generally show up as trends, which continue smoothly over a considerable distance. These trends are known as regional trends. Super-imposed on the regional field, but frequently camouflaged by these, is the smaller, local disturbances which are secondary in size but primary in importance. These are the residual anomalies. They may provide direct evidence of the existence of the reservoir type structures or mineral ore bodies (Kamba et al, 2016).

2.2 Production of Regional and Residual Maps
The residual magnetic field of the study area was produced by subtracting the regional field from the total magnetic field using the Polynomial fitting method. The computer program Aerosupermap was used to generate the coordinates of the total intensity field data values. This super data file, for all the magnetic values was used for production of composite aeromagnetic map of the study area using Oasis Montaj software version 7.2 A program was used to derive the residual magnetic values by subtracting values of regional field from the total magnetic field values to produce the residual magnetic map and the regional maps. (Kamba *et al*, 2016).

2.3 Upward Continuation: Upward continuation is used in order to simplify the appearance of regional magnetic maps by suppressing the effects due to local features. The proliferation of local magnetic anomalies often obscures the regional features with an overabundance of detail. Upward continuation thus smoothed out these disturbances without impairing the main regional features. The main purpose of upward continuation is to view the magnetic field intensity at a height above flight level so as to eliminate short wavelength anomalies by emphasizing longer ones reflecting regional features. The total magnetic field of the earth obeys coulomb's inverse square law, which is simplified.

$$\frac{\text{TMI}\alpha\ 1}{\text{r\^{}2}} \qquad 2.1$$

It falls off rapidly with height i r. A potential field measured on a given observation plane at a constant height can be calculated as though the observations were made on different plane, either higher (upward continuation) or lower (downward continuation). The equation of the wave number domain filter to produce upward continuation is simply**:**

$$F = e - hw \qquad 2.2$$

Where (h) is the continuation height. (Kamba *et al*, 2016).
This function decays steadily with increasing wave number, attenuating the height wave numbers more severely, thus producing a map in which more regional features predominate. Similarly the equation of the wave number domain filter to produce downward continuation is:

$$F = ehw \qquad 2.3$$

This is a curve, which is zero at wave number and increases exponentially at higher wave number, thus emphasizing the effect of shallow sources and noise. Noise removal is therefore an essential first step before downward continuation is applied,and continuation depths should not exceed real source depths. Some careful experimentation is usually necessary to obtain acceptable result (Kamba *et al*, 2016).

3.0 RESULTS AND DISCUSSION
The total magnetic intensity map (TMI) of the Tambuwal produced from this study using Oasis Montaj is as shown in Figure 3.1.

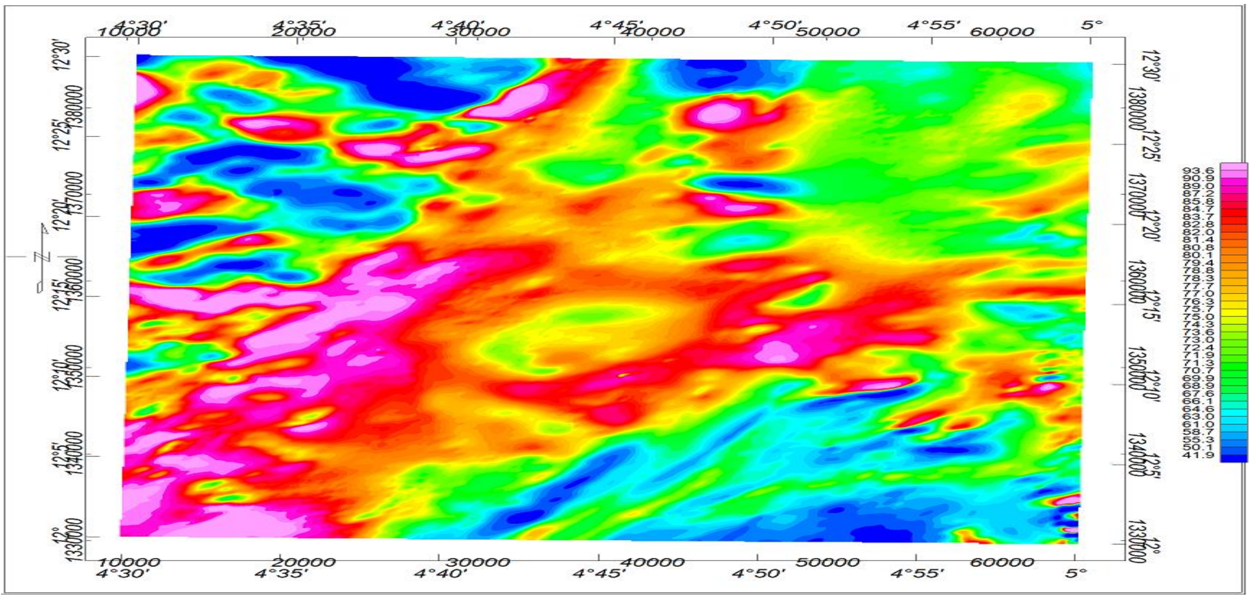

Figure 3.1 the total magnetic intensity map (TMI) of Tambuwal

3.1 The TMI Upward Continuation for 2km, 5km, 10km, 15km and 20km of Tambuwal

The TMI map of Tambuwal can be divided into main three sections, though minor depressions exist scattered all over area. The northern part of the Tambuwal is characterized by low magnetic intensity values represented by dark-green-blue color. Whereas the southern part is dominated by high magnetic intensity values indicated by red color. The two sections are separated by a zone characterized by medium magnetic intensity values area depicted by yellow-orange color. These high magnetic intensity values, which dominate the southern part of the tambuwal are caused probably by near surface igneous rocks of high values of magnetic susceptibilities. The low amplitudes are most likely due to sedimentary rocks and other non-magnetic sources. In general, high magnetic values arise from igneous and crystalline basement rocks. Whereas low magnetic values are usually from sedimentary rocks or altered basement rocks. The sedimentary thickness of the tambuwal in general, appears to increases from south to north. This collaborates well with earlier findings of 2D Seismic surveys conducted by ELF and Mobil Companies carried out in 1979.Inspection of the total magnetic intensity map (TMI) of the study area (Figure 3.1) does not show any general or particular trend. However, northeast- southwest trend is observed in the north central part of the total magnetic intensity map of the study area. Ananaba (2018) based on lineament of LANDSAT images, identified predominate tectonic trends in the NE –SW, NW-SE directions over the entire basin and in particular over parts of the country rejuvenated during tectonic phase of the pan Africa Oregency. Ananaba (2018), in a study of aeromagnetic field over the tambuwal, identified the existence of NE-SW trending anomalies as the predominant magnetic features in the area.

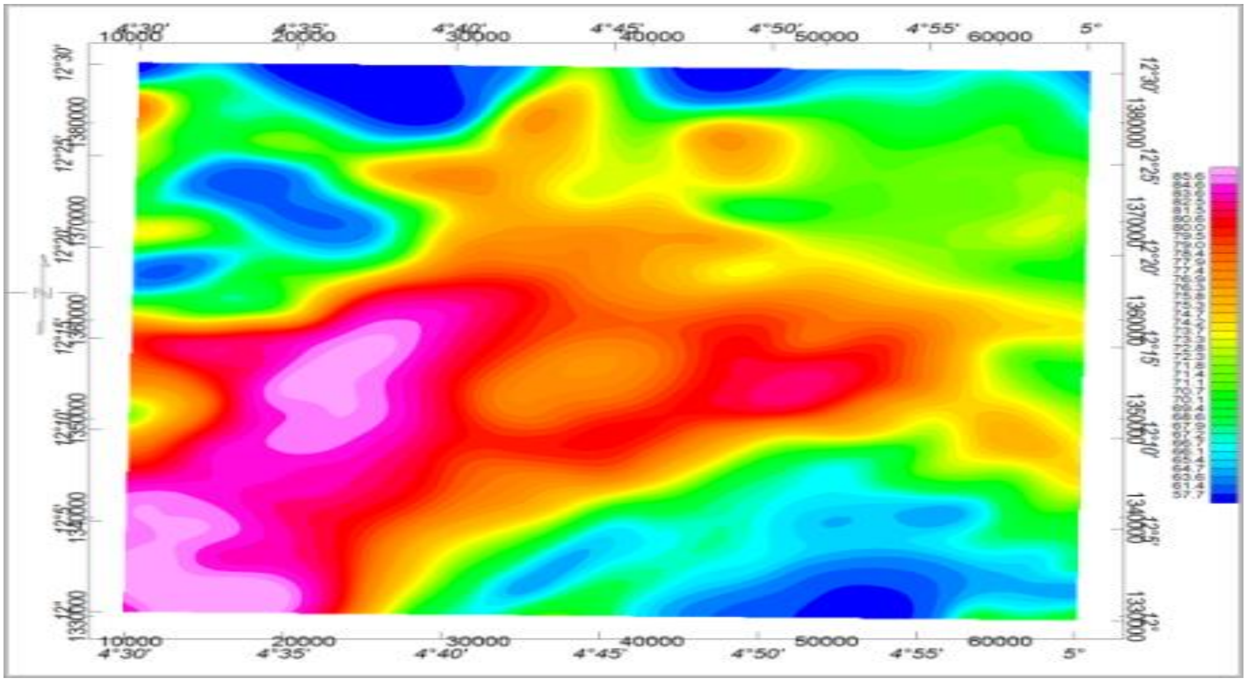

Figure 3.3 TMI at 2km

3.1.1 TMI Upward continued at 2km

the total magnetic intensity map of the study area was upward continued at 2 km to produce Figure 3.3 at the height of 2 km, the shorter wavelength anomalies are visible, though slightly refined than the total magnetic intensity map. Four sections can be observed. At the bottom side of the map (latitude 12° 00'N to 12° 15'N and longitude 4°30'E to 5° 00″E), is predominantly red color with few traces of pink, green and blue colors. A light red color is observed in the middle of this portion. Within the range of longitude 4° 35″E to 4° 50″E and latitude 12° 10″N to 12° 20″N is a section characterized by red color with few traces of green and blue pigments. The third section is the area defined by latitude 12° 00″N to 12° 30″N and longitude 4°30″E to 5° 00″E. Dark blue color dominates this portion of the map. At the extreme northern part of the map, approximately the ranges of longitude 4° 30″N to 5° 00″E and latitude 12°.00″N to 12° 30″N, blue and dark- blue colors are prevalent in this area. This is the section of the study area having the highest sedimentary thickness.

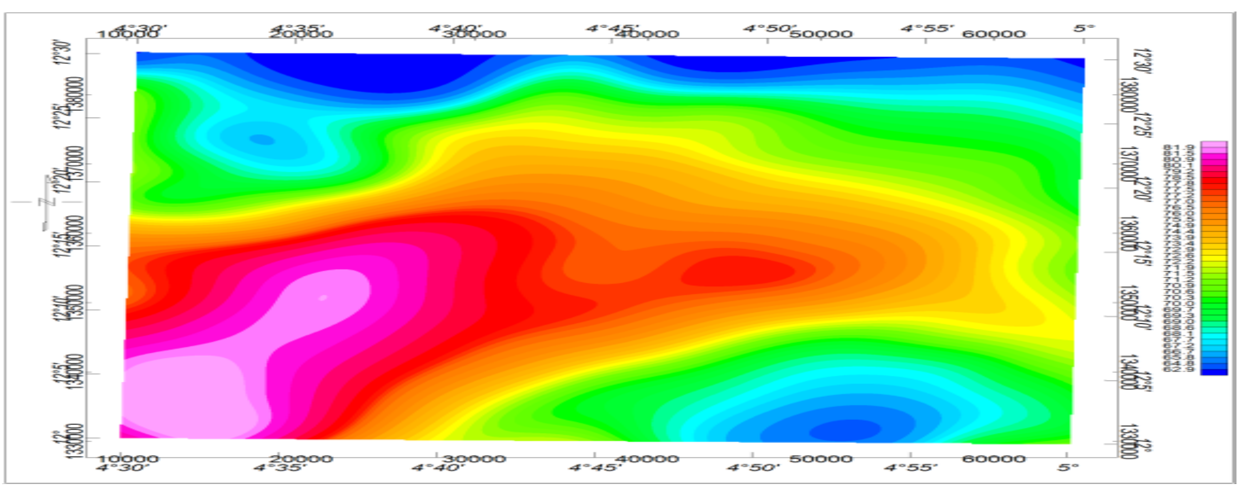

Figure 3.4 TMI at 5km

3.1.2 TMI Upward continued at 5km

The upward continuation of the total magnetic field map at 5 km is shown in Figure 3.4 The map shows that basement features are standing out at the detriment of sedimentary features. Basement structures and the lineaments in the study area are here well defined because erratic signals are filtered. Fault boundaries between basement and sedimentary areas can be clearly seen. At the bottom side of the map (latitude 12° 00″N to 12° 30″N and longitude 4° 30″E to 5° 00″E), is predominantly green and red color with few traces of pink and blue colors. A dark red color is observed in the middle of this portion. Within the range of longitude 4° 35″E to 4° 55″E and latitude 12°50″N to 12°20″N is a section characterized by red color with few traces of pink pigments. The third section is the area defined by latitude 12° 00″N to 12° 30″N and longitude 4° 30″E to 5° 00″E. Green color dominates this portion of the map. Areas around bounded by longitude 4° 30″E to 5° 00″E and latitude 12°.00″N to 12°30″N, blue and dark- blue colors are prevalent in this area. This section indicated high intensity sediment thickness in the area.

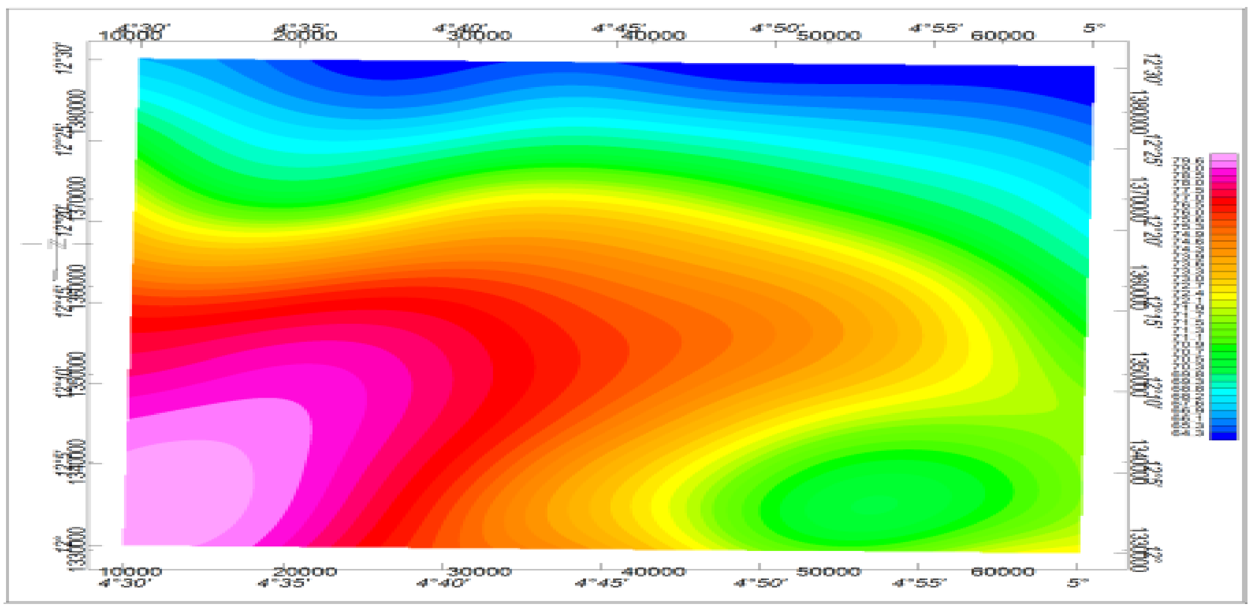

Figure 3.5 TMI at 10km

3.1.3 TMI Upward continued at 10 km

The map of the upward continuation at 10 km height above flight level is show in fig 3.5. At this height, basement structures appeared quite distinct from the sedimentary areas. Areas of lowest magnetic values, (i.e areas of thicker deposits of sediments) found to be at northeast part of the study area. The forth section of this map, particularly the area defined by longitude 4°30″E to 5° 00″E and latitude12° 00″N to12°30″N is a portion of dark blue color; clearly an indication of the area having the highest sedimentary thickness in the study area. At the bottom side of the map (latitude 12°00″N to 12°30″N and longitude 4°30″E to 5°00″E), is predominantly red and green color with few traces of pink colors. A light yellow color is observed in the middle of this portion. The third section is the area defined by latitude 12°00″N to 12°30″N and longitude 4°30″E to 5°00″E. Green color dominates this portion of the map. At the extreme northern part of the map, approximately the ranges of longitude 4° 30″E to 5°00″E and latitude 12°25″N to 12°30″N, blue and dark- blue colors are prevalent in this area. This is the section having the highest sedimentary thickness in the study area.

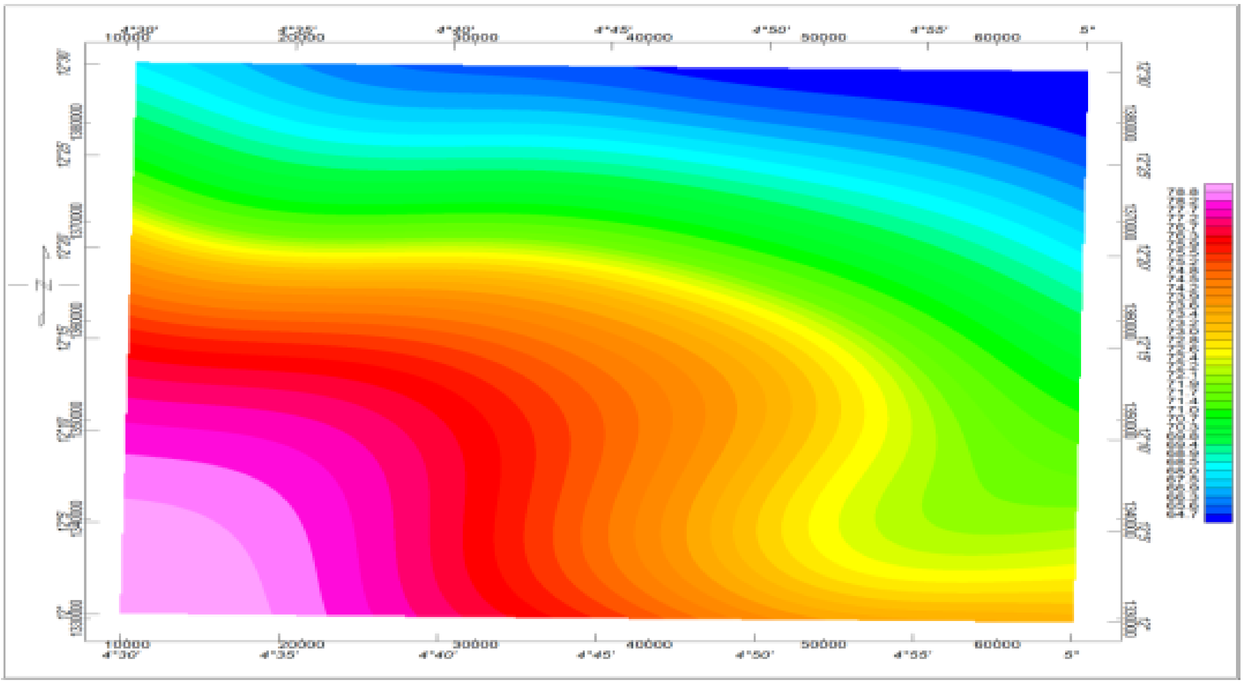

Figure 3.6 TMI at 15km

3.1.4 TMI Upward continued at 15km

The map of the upward continuation at 15 km height above flight level is shown in Figure 3.6. At this height, basement structures appeared quite distinct from the sedimentary areas. Areas of lowest magnetic values, (i.e areas of thicker deposits of sediments) found to be at northeast part of the study area. The forth section of this map, particularly the area defined by longitude 4° 35″E to 4° 55″E and latitude12° 25″N to12° 30″N is large portion of dark blue color; clearly an indication of the area having the highest sedimentary thickness in the study area.

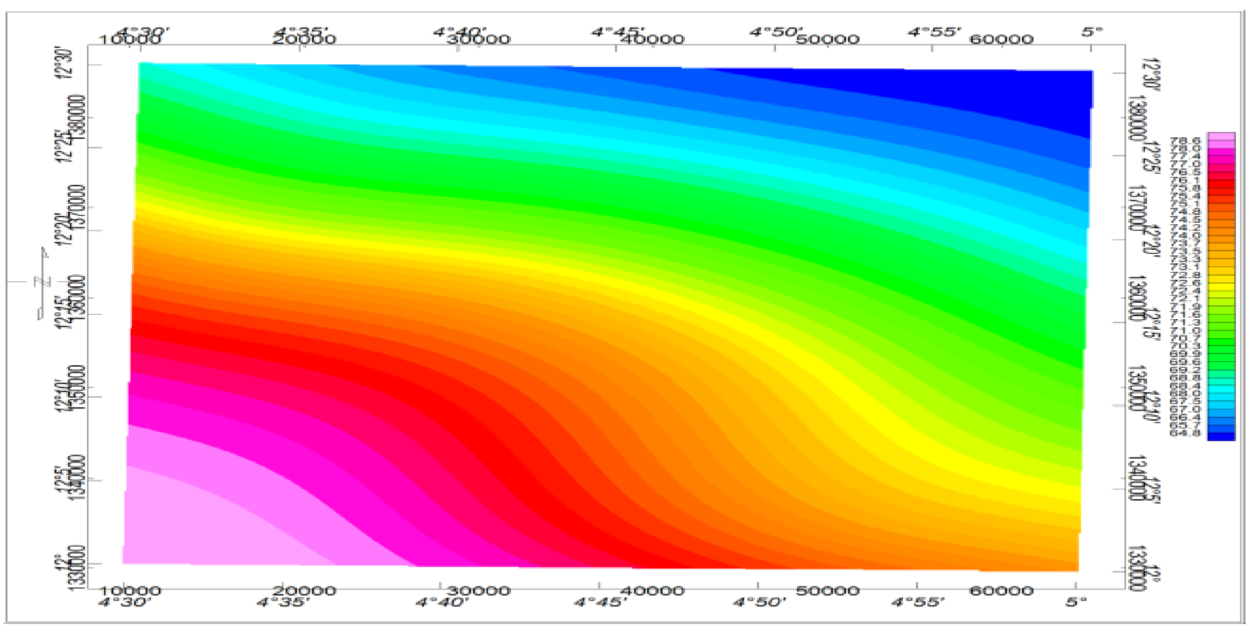

Figure 3.6 TMI at 20km

3.1.5 TMI Upward continued at 20km

The map of the upward continuation at 20 km height above flight level is shown in figure 3.7. At this height, basement structures appeared quite distinct from the sedimentary areas. Areas of lowest magnetic values, (i.e areas of thicker deposits of sediments) found to be at northeast part of the study area. The forth section of this map, particularly the area defined by longitude 4°30″E to 5° 00″E and latitude12° 00″N to12°30″N is a portion of dark blue color; clearly an indication of the area having the highest sedimentary thickness in the study area. At the bottom side of the map (latitude 12°20″N to 12°30″N and longitude 4°30″E to 5°00″E), is predominantly blue and dark blue color with few traces of green color. A light yellow color is observed in the middle of this portion. The third section is the area defined by latitude 12°00″N to 12°30″N and longitude 4°30″E to 5°00″E. Red color dominates this portion of the map. At the extreme northern part of the map, approximately the ranges of longitude 4°30″E to 5°00″E and latitude 12°25″N to 12°30″N, blue, green and dark-blue colors are prevalent in this area. This is the section having the highest sedimentary thickness in the study area.

4.0 CONCLUSION AND RECOMMENDATIONS

The analysis of the total magnetic intensity map (TMI), the residual map, the upward continuation maps at 2km, 5km, 10km, 15km and 20km of Tambuwal basin, all indicate that the basin is shallower in the south and thicker in the north, this result is in line with work of (Bonde et al., 2014) and this all depends on the geological setting of the area. Therefore, exploration of the Nigerian inland basins is worth given a push. Hydrocarbons if discovered and harnessed findings will increase the country's reserve and boost productivity. All these will have economic and strategic benefits for the country. There is therefore the need to take advantage of modern geophysical methods in the exploration of Nigerian inland basins.

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