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DEPTH ANALYSIS AND ITS IMPLICATIONS ON HYDROCARBON PROSPECTIVITY IN PART OF THE LOWER BENUE TROUGH OF NIGERIA USING HIGH RESOLUTION AEROMAGNETIC DATA

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ABSTRACT.

High resolution aeromagnetic map of Ugep in the Lower Benue Trough of Nigeria was analyzed with the intention of determining its potentials in terms of hydrocarbon prospectivity. The vaarious transformations were carried out by plotting the TMI, upward continuation, SPI and Euler deconvolution maps using Oasis Montaj software, version 6.4.2. The results showed a magnetic high due to a shallow crystalline magnetic basement in the entire western and the far northern region of the study area with magnetic intensity ranging from 88.5nT and 107.9nT. The areas with thick sediment deposits was noted to be the eastern, the south-eastern as well as some parts of the south-south region wit magnetic intensity of between -14.4nT and 27.3nT. The shallow basement regions when analyzed quantitatively, reveal a depth to basement of about 280m, hence the recommendation for a further investigation to determine the potentials for mineral exploration. On the other hand, the sedimentary regions have depth of between 2477m and 3386m. The presence of hydrocarbon was not ruled out here since the sediment thickness is reasonable.

Keywords: Anomalies, Basement, Benue Trough, deep, hydrocarbon, intrusives, magnetic intensity, regional, shallow.

INTRODUCTION

An aeromagnetic survey is a geophysical survey which is carried out using a magnetometer onboard or towed behind an aircraft. The principle is not different from that of a magnetic survey carried out with a hand-held magnetometer, though, an aeromagnetic survey allows much larger area of the earth's surface to be covered quickly for regional reconnaissance. Geophysical methods provide fast, efficient and non-destructive reconnaissance techniques often required by archeologists (Oyeyemi et. al, 2014).

In order to search for the presence of buried magnetic materials and to determine the probable depth to basement, magnetic method has been very useful.

Magnetic method can also be used in the location of shallow magnetic materials such as buried metallic containers and metallic pipes.

Aeromagnetic method has its distinctive advantages which distinguishes it compared with other geophysical methods such that it exhibits a rapid rate of coverage and low cost per unit area covered.

The main purpose of any magnetic survey is to detect minerals or rocks in the subsurface that possess unusual magnetic properties which reveal themselves by imposing some anomalies in the observed magnetic intensity of the earth.

Aeromagnetic surveys are used in mapping the above mentioned anomalies in the earth's magnetic field which is then correlated with the underground geological structure of the study area. The presence of faults are usually identified by abrupt changes or close spacing in orientation of the contours as revealed by the magnetic anomalies. Also, for hydrocarbon exploration, residual magnetic anomaly maps are useful since they identify the presence of intrusives, lava flows, or igneous plugs which are areas to be avoided in hydrocarbon exploration.

Aeromagnetic surveys are widely used to aid in the production of geologic maps and are also commonly used during mineral exploration (Taufiq et. al, 2014).

Aeromagnetic data were employed in hydrocarbon exploration for regional reconnaissance survey because a large area can be covered quickly and is useful for providing first-hand information about the basement (Oladele et. al, 2013). Also, during oil and gas exploration, the mapping of magnetic basement within sedimentary layered rocks is very important.

The bedrock in Nigeria has been the source of solid minerals in the country as well as the lucrative hydrocarbon which has really prospered the oil sector. This is due to its high profitability as over 80 percent of the country's revenue comes from export and domestic sales of the oil and gas upon which about 200 million population depends on. As the hydrocarbon potential of the prolific Niger delta becomes depleted or in the near future may be exhausted due to continuous exploitation, attention needs to be shifted to other sedimentary basins (K. A. Salako, 2014).

The aeromagnetic survey is the oldest potential field method used for hydrocarbon exploration (Onuba et. al, 2011).

There are some publications showing that work has been done to estimate the depths to basements/magnetic source bodies over several areas in the Lower Benue Trough in which Ugep and environs are located.

As a prerequisite, the thickness of sediment required for the generation or production of hydrocarbon is not generally constant as it varies from place to place.

Generally, the minimum overburden thickness of sediment required for oil to form ranges from 2 to 4 km, while for gas to form the minimum thickness required is between 3 to 7 km (Onuba et al, 2011).

LOCATION AND GEOLOGY OF THE STUDY AREA

The study area is Ugep which is located in Cross River State of Nigeria in the southern Benue Trough and on the African continent with coordinates as follows; 5°48'30.74"N, 8°4'53.72E.

The Benue Trough was formed as a result of series of tectonics and repetitive sedimentation in the Cretaceous time when South American continent separated from Africa and the opening of the South Atlantic Ocean (Anyanwu & Mamah, 2013).

The Benue Trough is filled with sediments of Cretaceous (Albian–Maastrichtian) age and the sediments are made up of sandstones, shales and limestone and underlain by Precambrian basement (granites and gneisses) and the earlier (Albian–Santonian) sediments in the trough are mainly marine in character and their deposition was terminated by the episode of deformation in the Santonian (Okiwelu et.al, 2015).

The oldest rocks within the study area comprise of Precambrian basement rocks of Oban massif (Granite gneisses, banded gneisses, biotite garnet schist, quartz diorite, and porphyritic granites), and these rocks are unconformably overlain by the Asu river group (Albian) which comprise of Sandstones, Shales, and Limestones (Obi & Obeten, 2017). The above mentioned units are overlain by the Eze-Aku Shale unit which in turn is overlain by the Agwu Shale, Nkporo Shale and Imo Shale. All these unit are then overlain by the Mamu Formation which comprise of coal units.

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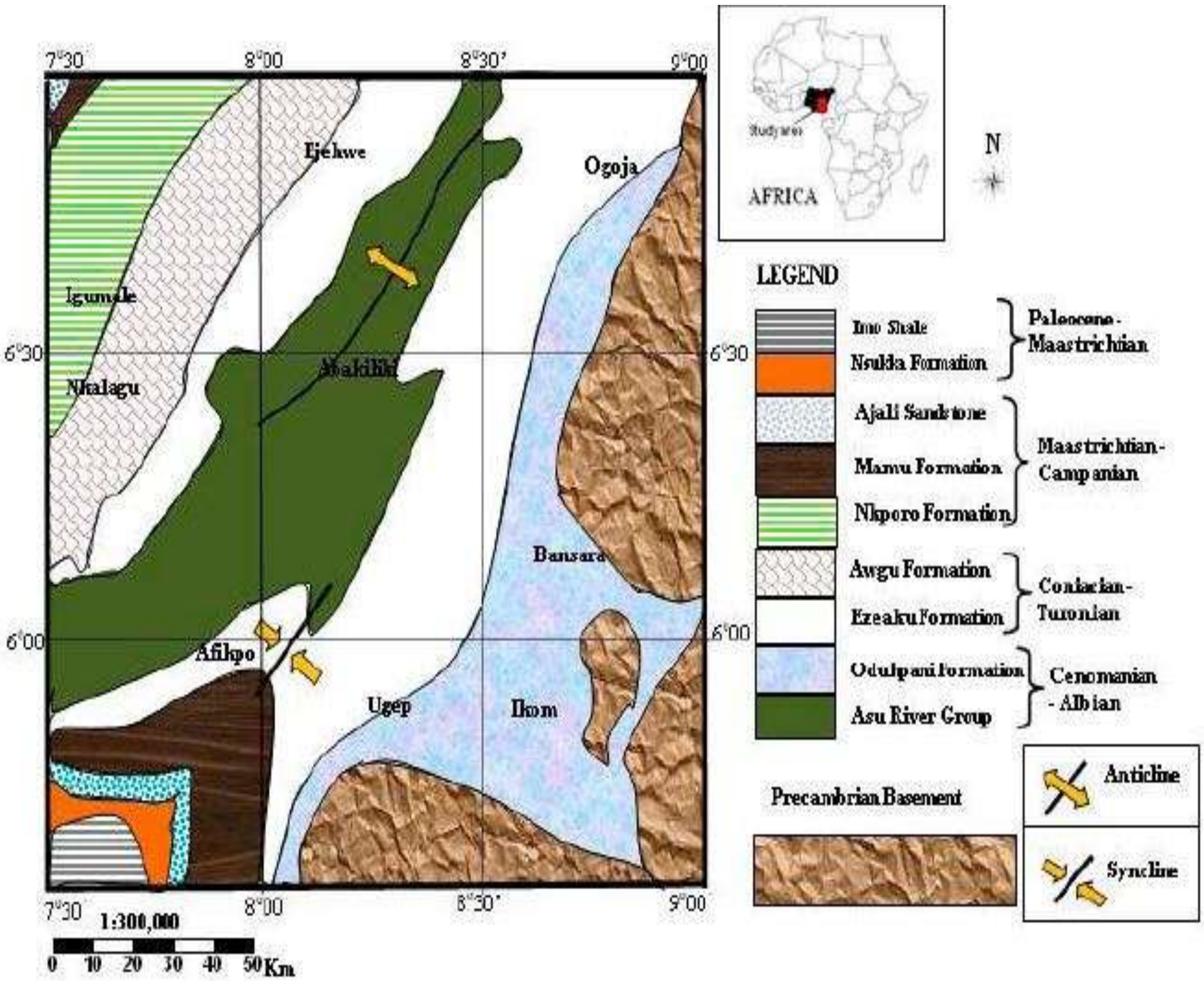


Fig. 1. Geologic map of parts of southern Benue trough showing the study area. (Onuba et.at, 2013).

Sedimentation in the Lower Benue Trough commenced with the marine Neocomian – Albian Asu River Group, although some pyroclastics of Aptian – Early Albian age have been scantly reported (Fatoye and Gideon, 2013). These sediments in the Lower Benue Trough comprise mainly of shales with localized sandstones, siltstones and limestones. There are also extrusives and intrusives which can be found in the Abakaliki Formation in the Abakaliki as well as the Mfamosing Limestone in the Calabar Flank.

MATERIALS AND METHOD

The aeromagnetic survey over the Lower Benue Trough covering the study area (Ugep) was part of the nationwide aeromagnetic survey of Nigeria which was completed 1975.

The airborne magnetic data used for this work was supplied by the Geological Survey of Nigeria.

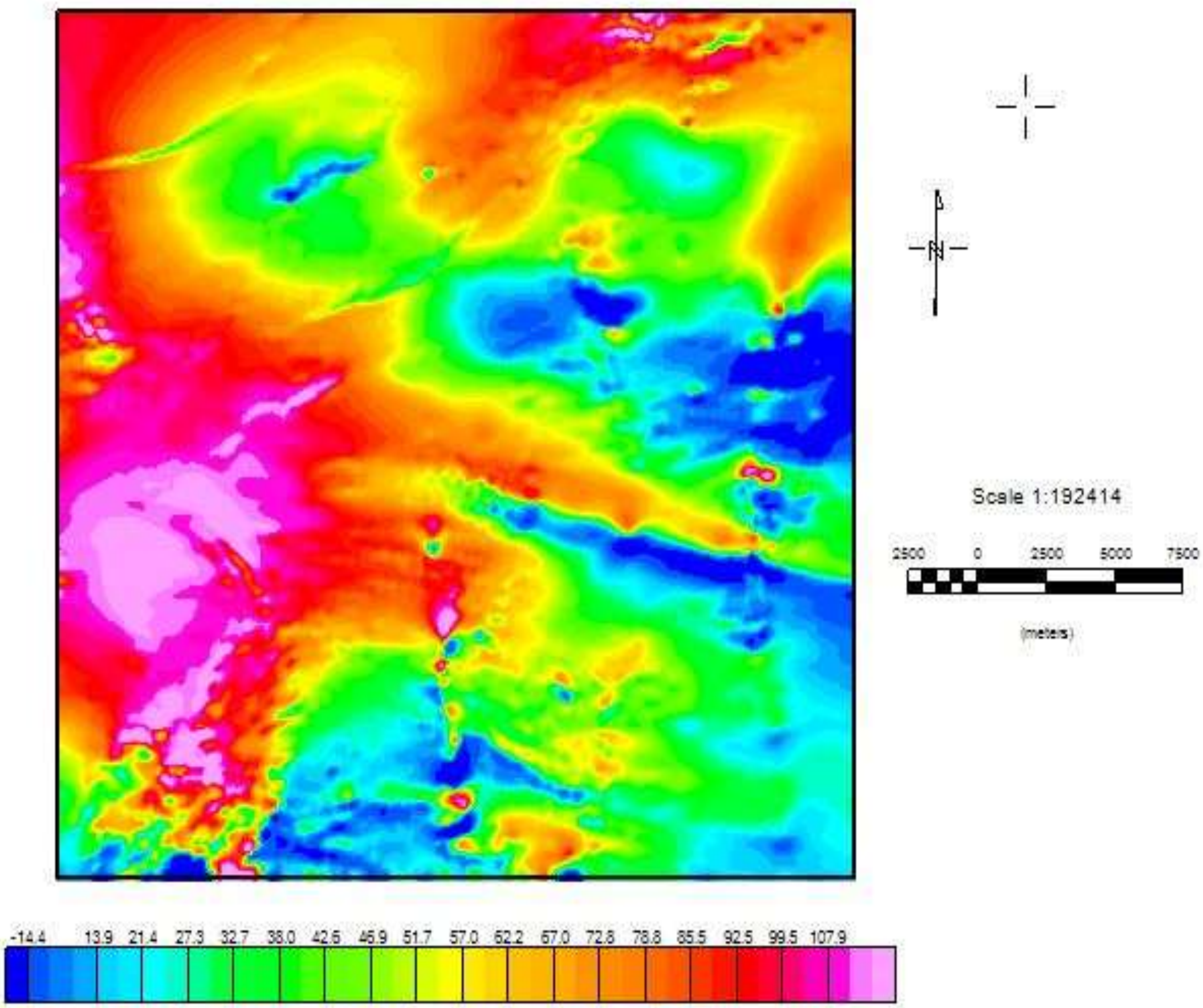
The basic problem in the analysis of magnetic data is the isolation of weak magnetic anomalies caused by low concentrations of magnetic minerals (Alagbe & Sunmonu, 2014).

Much stronger magnetic anomalies caused by underlying magnetic rock/or by rocks in the sedimentary basin often mask these weak anomalies.

In order to isolate or remove these weak anomalies, various transformation and enhancement techniques can be applied to the magnetic data such as; reduction to pole, upward and downward continuation, derivatives-based filters, analytic signal, Log power spectrum, horizontal gradient method, TMI,etc.

For the purpose of this research work, in order to determine the depth to magnetic source as well as overburden thickness, certain filtering processes were employed using Oasis Montaj software version 6.4.2. The results are as seen below.

Fig. 2 **TMI**



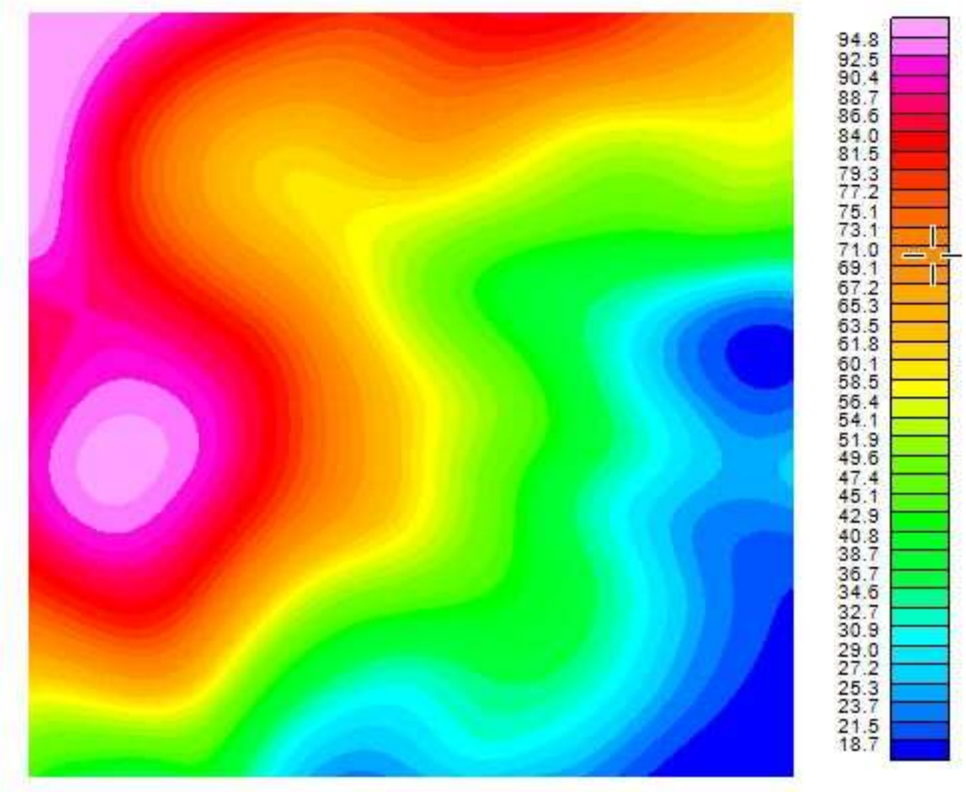
The total magnetic intensity map (TMI) (fig. 2) shows the variation in the magnetizing field of the bodies buried under the ground. The TMI map is the representation of high and low frequencies of geological structures corresponding to regional and residual anomalies.

To achieve a good correlation between these anomalies and geological sources, it is however necessary to separate these two components i.e. to separate the regional from the residual anomalies.

The above is achieved using the upward continuation filtering process (fig. 3) which is an analytical method used to separate regional anomalies resulting from deep sources from residual anomalies arising from shallow sources.

The upward continuation with increasing heights highlights the magnetic effect of deep body sources because the transformation attenuates high frequency signal components associated with shallow magnetic sources and tends to underline deep regional-scale magnetic anomalies (Basseka et al, 2018).

Fig. 3 **UPWARD CONT. AT 20KM**



Upward continuation is the transformation of potential data measured on one surface to some higher surface and it helps in the interpretation of magnetic anomaly fields over an area.

It is however a mathematical technique that projects data taken at one elevation to a higher elevation in order to enhance high wavelength and low frequency anomalies.

Potential fields obey Laplace's equation and thus permits us to determine the field over an arbitrary surface if the field is known completely over another surface and no masses are located between the two surfaces (Eze et al, 2017).

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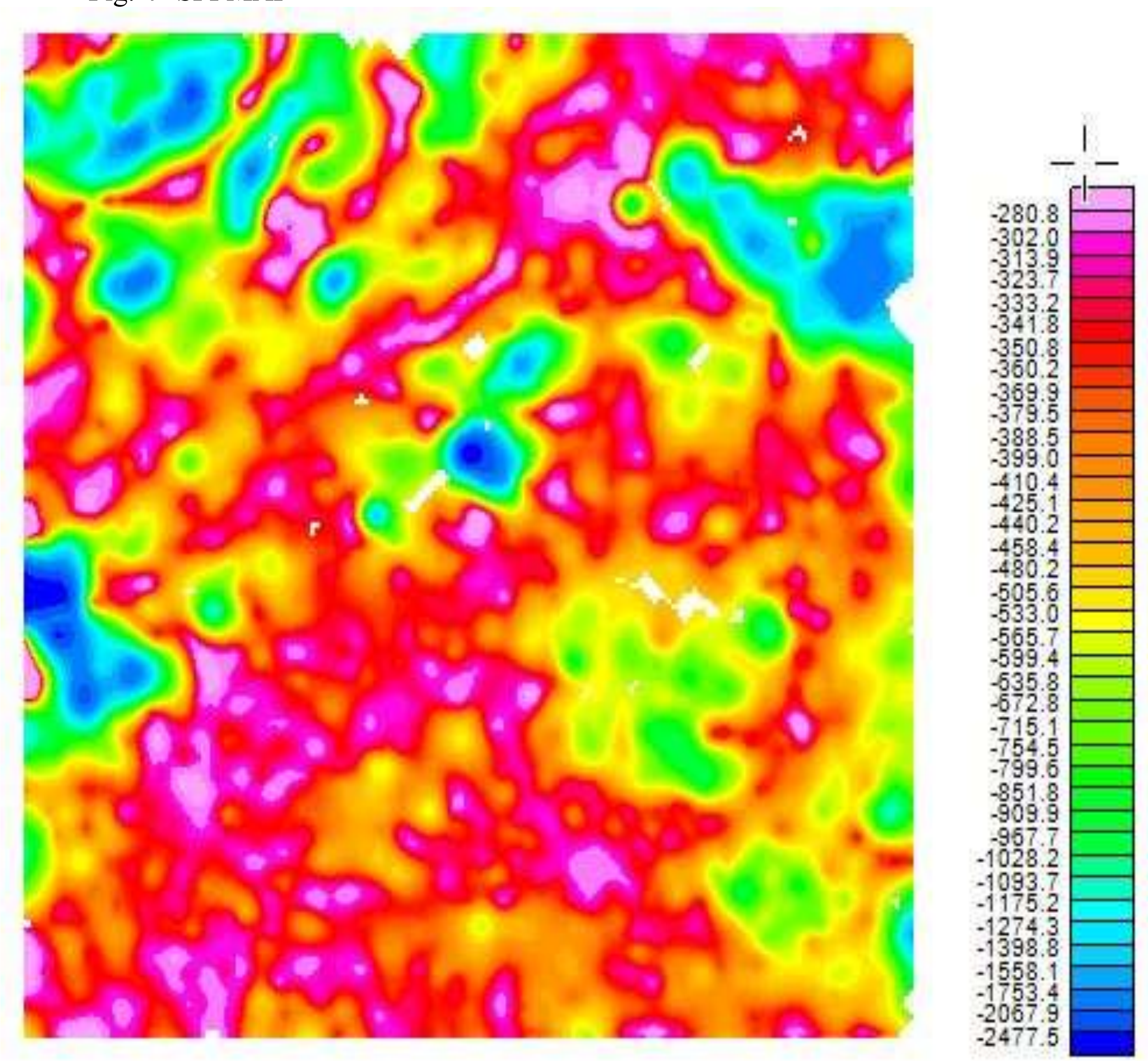
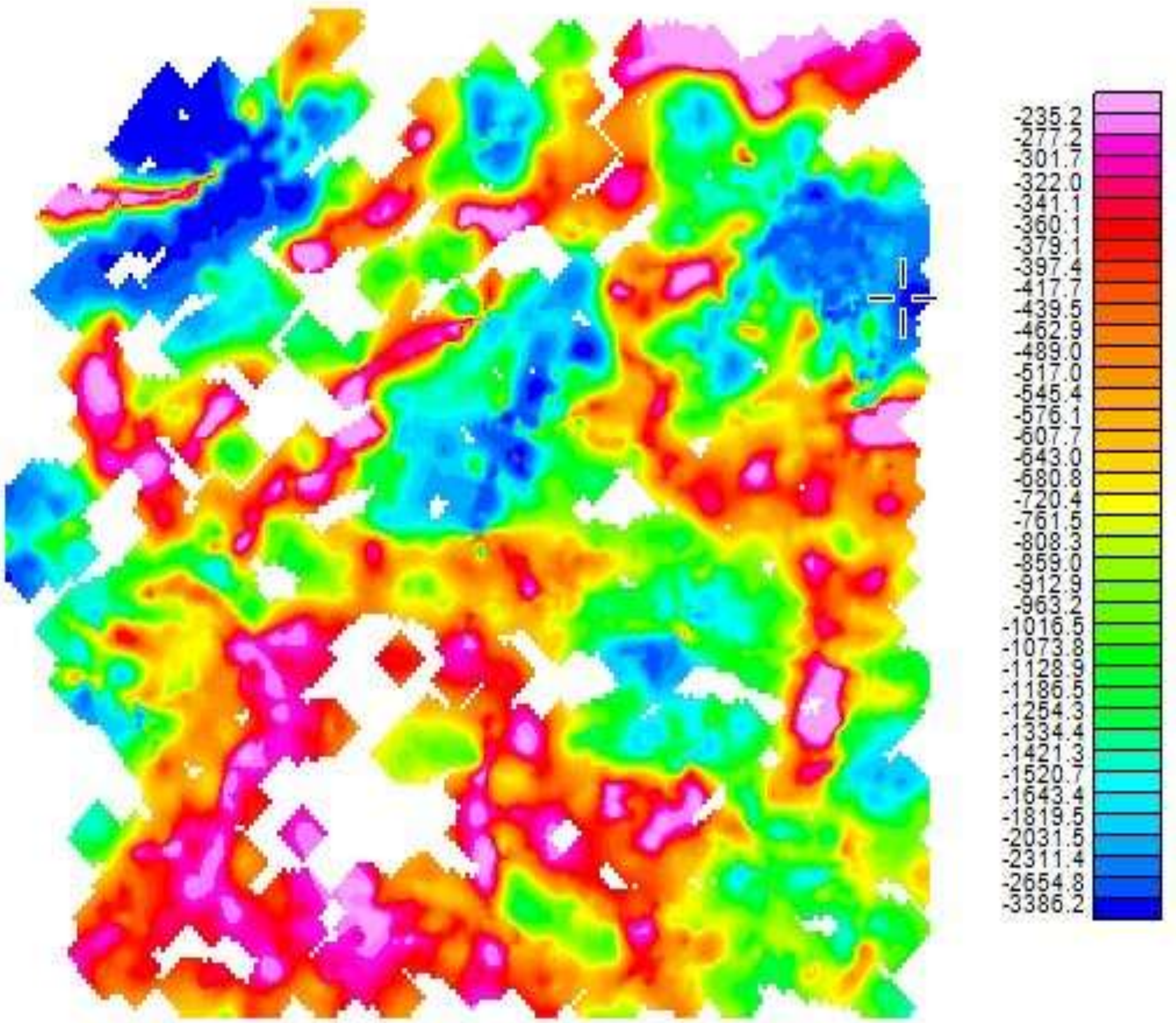
Fig. 4 SPI MAP



The Source Parameter Imaging function (fig 4) is a quick, easy, and powerful method of quantitative interpretation used for estimating the depth to magnetic sources. Its accuracy has been shown to be +/- 20% in tests on real data sets with drill hole control and this accuracy is similar to that of Euler deconvolution, however SPI has the advantage of producing a more complete set of coherent solution points and it is easier to use (K. A. Salako, 2014).

Fig. 5 EULER 3D, S.I =0.5



The Standard 3-D Euler method (fig. 5) is based on the fact that the potential field produced by many simple sources obeys Euler's homogeneity equation (Onyewuchi & Ugwu, 2017).

The structural index describes the rate at which the field decays as a function of source geometry, though source locations and depth estimation may be marred by interferences due to

Noise. The 3D euler method makes use of a structural index and has the potential to calculate depth and determine the geological structures such as: faults, magnetic contacts, dykes, sills etc.

DISCUSSION OF RESULTS

The TMI map (fig 2) shows a variation in the magnetic intensities of the bodies causing the anomalies. These intensity values vary between -14.4nT and 107.9nT. The entire western portion and the far north of the study area with pink and purple colour and intensity ranging between 88.5nT and 107.9nT indicate the presence of magnetic high which may be as a result of crystalline basement rocks which have intruded into the sediments.

On the contrary, some parts of the study area with deep blue and sky blue colors mostly in the eastern and south eastern parts as well as some parts of the south-south region, all have the least value of magnetic intensity (-14.4 nT and 27.3nT. These are pure indications of magnetic low, implying the presence of sediments devoid of the presence of intrusions.

The portions with high magnetic intensities can be investigated for the presence of magnetic minerals since the presence of basement intrusives imply high temperatures which may not be conducive for hydrocarbon.

From the upward continuation map at 5km, the effects of high frequency anomalies have been smoothened out, hence highlighting regional features. The entire far north, western and north weastern regions all show a magnetic basement with some elements of folding and trending in the north east / south west direction. Also, it can be seen that the eastern down to the south eastern region with blue to sky blue colour also show a less magnetic basement. This shows that the less magnetic components noticed here on the TMI map were actually more of regional features.

The SPI map shows the variation of depth representing different regions of the study area. The depth ranges from 280m to 2477.5m all below the surface. The negative values indicate that the basement intrusives which intruded into the sediments to constitute the residual anomalies are still within the sediments as there are no outcrops. The regions with the magnetic highs (pink and purple) have the least depth showing that the anomalies therein are from shallow basement sources which are basically basement rocks indicating that the basement at this regions are shallow. On the other hand, the regions dominated by sediments (blue and sky blue colours) have the highest depths to source with the deep blue having the highest depth of about 2400m. Again, this information shows that the sedimentary regions have the highest depth to basement.

From the Euler 3D map, the depth to source/the depth distribution shows the most magnetic regions with the shallow depth, while the deepest portions are the sedimentary regions with the least magnetization just as seen on the SPI map. The depth ranges from 235.2m to 3386.2 meters below the surface.

A comparison between the SPI and 3D euler map shows that both maps depict about similar depths for the shallow magnetic sources while there is a variation for the deep seated sources. This variation confirms that several human factors may have come to play during processing, hence the need to confirm depths using others techniques instead of relying on just one or two techniques of depth estimation.

However, the depths from the euler deconvolution and the SPI map both confirm that the sedimentary regions is above 2400m and this value is reasonable for hydrocarbon accumulation.

CONCLUSION

It can be concluded that the study area is divided into two major sections; the regions of magnetic high due to igneous intrusions and the sedimentary regions with thick sediments. If the TMI and upward continuation maps were both divided by a line from the north east down to the south west, it clearly shows that the magnetic high regions with shallow basement are on the left of the map with the pink and purple colours while the right part with deep blue to sky blue colours depict the sedimentary regions with high sediment cover.

Due to the low depth to source as recorded on the magnetic high regions, the region is recommended for further investigations in order to ascertain the presence of magnetic minerals since hydrocarbon has been ruled out there due to the presence of basement intrusives and shallow depths. Also, the sedimentary regions (deep blue and sky blue) are recommended for further studies because of the hydrocarbon prospects since the depth of sediments is over 2400m and the region is mainly sedimentary. Again, the fold noticed on the upward continuation map also points to the fact there might be some grabens with hydrocarbon accumulation.

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