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Review

Delineation of mineral potential zone using high resolution aeromagnetic data over part of Nasarawa State, North Central, Nigeria

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ABSTRACT

Qualitative analysis of aeromagnetic data of part of Nasarawa State had been carried out with the aim of delineating mineral potential zone. The study area is bounded by Longitude 8.0°E – 9.0°E and Latitude 8.0°N – 9.5°N with an estimated total area of 18,150 km^2. Different filters were used to enhance the short wavelength anomalies which could give preliminary information about the magnetic minerals present in the study area. The total magnetic intensity map shows variation of both highs and lows magnetic signature ranges from −51.2 nT to 110.4 nT after the removal of IGRF value of 33,000 nT; the highs which is basement dominates the north-eastern and north-western part of the study area which corresponds to Akwanga, Wamba and Nasarawa Eggon; these are areas with promising solid minerals of economic potentials like, gold at Wamba; Tin, Columbite and Tantalite at Akwanga while Granite rocks with possible radioactive elements are in abundance at Nasarawa Eggon. The low magnetic values on the other hand, which is made up of sediment deposition also dominates the southern part of the study area, this area corresponds to Lafia, Doma and Keana; Lafia and Doma host some industrial minerals like Clay, glass Sands and the Salt Brines at Keana. The major high magnetic signature trends east-west. The greenish part of the study area indicates alluvium deposition. The filters used are vertical derivatives, downward continuation and analytic signal. The first and second vertical derivatives; shows structures like lineament that could be the host to minerals present in the study area and it trends NE-SW. The downward continued at the depth of 50 m and 100 m shows the veins where magnetic minerals most especially gold are known to settle along igneous and metamorphic rocks. The analytic signal map shows that magnetic amplitude highs could be found at the northern end with most lineaments delineated also conform to other filter used. The tilt derivative map enhances short wavelength anomalies which could be used to mapped shallow basement structures and mineral exploration targets. The results of these filters agreed largely and since most magnetic minerals are structural controls, it is expected that those lineaments identified, most especially at the northern part, could play host to those minerals aforementioned.

Contents

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1. Introduction

This present study is aimed at delineating the mineral potential zones of part of Nasarawa State. Mineral are of importance to the economy of a nation if discovered and harnessed. As this will create a productive environment for business opportunities, boast the nation's economy and provide raw materials for industrial uses which might in turn reduce the level of unemployment thereby eradicating poverty in Nigeria. It is therefore of necessity to carry out research of this magnitude using high resolution aeromagnetic (HRAM) data set of part of Nasarawa State which is endowed with a lots of mineral resources of high economic potential.

Exploitation of mineral resources has assumed prime importance in several developing countries including Nigeria. Nigeria is endowed with abundant mineral resources, which have contributed immensely to the national wealth with associated socio-economic benefits. Mineral resources are of important source of wealth for a nation but before they are harnessed, they have to pass through the stages of exploration, mining and processing [1,2].

The study area comprises of part of Nasarawa State which is known as the home of solid minerals, part of Kaduna State which also pronounce to have considerable number of solid mineral resources and of commercial quantities. Therefore, delineation of more mineral zones in a regional form in this area is quite a laudable effort.

The magnetic method, which is the method adopted in this study, involves the measurement of the earth's magnetic field intensity. Measurements of the horizontal, vertical or horizontal gradient of the magnetic field may also be achieved. The aim of magnetic surveying is to investigate subsurface geology on the basis of anomalies in the earth's magnetic field resulting from the magnetic properties of the underlying rocks.

1.1. Geology and location of the study area

The study area which is part of Nasarawa State, North Central Nigeria is bounded by Longitude 8.0°E – 9.0°E and Latitude 8.0°N – 9.5°N with an estimated total area of 18,150 km^2. The State is accessed by road through Kaduna–Plateau State, Taraba–Benue States and Kogi State – Abuja road (Fig. 1). The State is blessed with abundant mineral resources and for this reason it is tagged, "The Home of Solid Minerals in Nigeria". Prominent among the mineral deposits of the State are coal, barytes, salt, limestone, clays, glass sand, tantalite, columbite, cassiterite, iron ore, lead, and zinc [3].

The area of study is located within the middle Benue Trough as the name infers the middle portion of the Nigerian Benue Trough (Fig. 2). The Benue Trough itself is a rift basin in Central West Africa that extends NNE–SSW for about 800 km in length and 150 km in width. The Trough contains up to 6000 M of Cretaceous Tertiary Sediment of which those pre-dating the mid-Santonian compressionally deformed [4]. The study area is covered with 60% Basement complex rocks while the remaining 40% is made up of sedimentary rocks of the Benue Trough. The Younger Granites intrude the Basement complex at Mada and Afu and therefore do not occupy any separate landmass of their own of the Basement complex The Migmatite-Gneiss intricately associated with the Older Granite occupy the areas of Karu, Gurku, Panda, Gitata to

Fig. 1. Map of Nasarawa State Showing the location of Study area. ☐ Study Area.

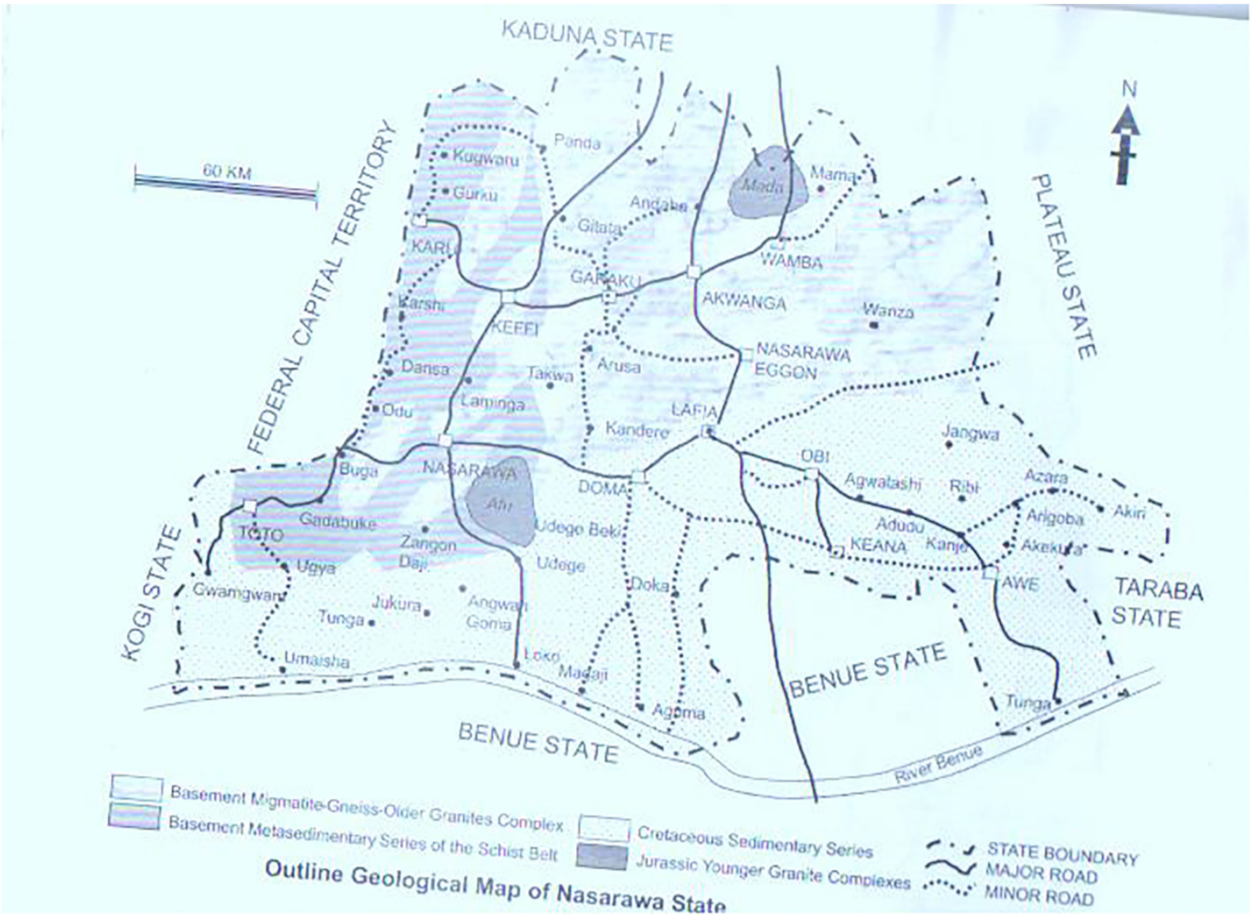

Fig. 2. Outline Geological map Nasarawa State showing the study area. (Adapted from [6]).

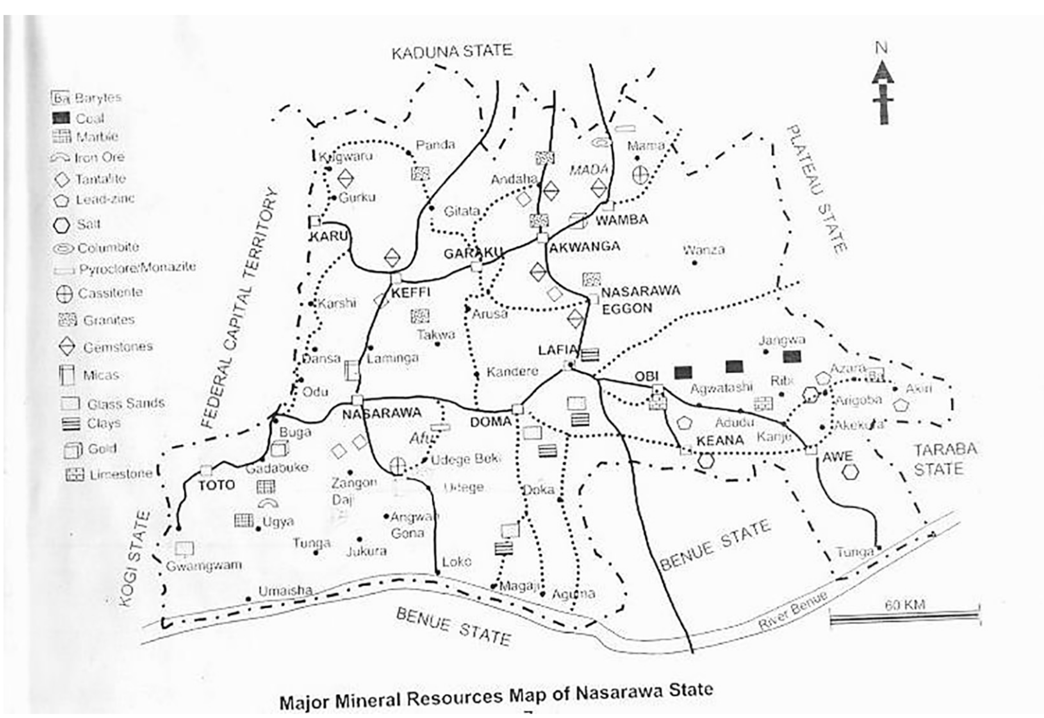

Fig. 3. Major Mineral Resources Map of Nasarawa State (Adapted from [6]).

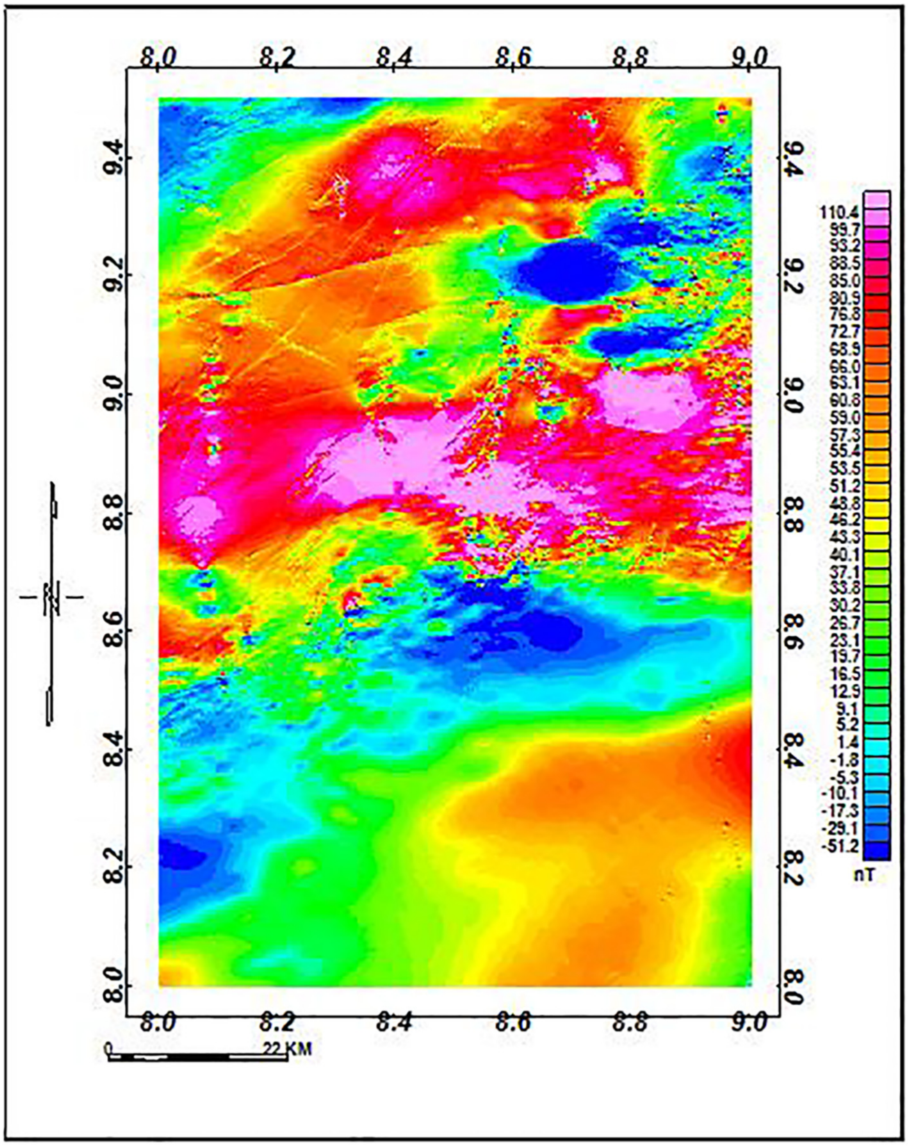

Fig. 4. Total Magnetic Intensity Field Map of the Study Area (A value 33,000 which remove from the magnetic field for handling must be added to it so as to get the actual value at every point).

the northwest, Keffi, Garaku Akwanga and Nasarawa Eggon to the north-central and Wamba, and environs to the northeast [5].

Sedimentary rocks of Cretaceous-Tertiary ages cover greater part of Nasarawa State in the South beginning from areas around Lafia, Doma through Obi, Jangwa, Awe and Keana. Part of the study area therefore lies within this sedimentary part of the state.

1.2. Major mineral Resource of Nasarawa State

Nasarawa state is known to be "Home of solid minerals" and the State is endowed with abundant mineral resources unlike other state in Nigeria. The three major geological components that makeup the geology of Nigeria, namely, Basement complex, younger Granites and Sedimentary rocks are all pronounced in the State. All known minerals that occur in the Nigerian geological environments have remineralized in Nasarawa State [6].

The rocks in Nasarawa State (Fig. 3) are the host to Gold in Wamba; Baryte at Azara, Wuse and Aloshi; Coals (of the highest rank in Nigeria) at Obi, Jangerigeri, Jangwa and Shankodi; Tantalite at Afu, Udege Beki, and Wamba; Gemstone in Keffi; Nasarawa Eggon and Kokona; Salt deposits in Ribi, Keana and Awe; Limestone deposits at Adudu, and Jangwa; at Keffi, Akwanga, Nasarawa Eggon, Tudu Uku, etc. [6].

2. Materials and methods

Six high resolution aeromagnetic maps (HRAM) over part of Nasarawa State were acquired, assembled and interpreted. These maps were obtained as part of the nationwide airborne survey carried out by Fugro and sponsored by the Nigerian Geological Survey Agency in the year 2009. The data were obtained at an altitude of 100 m along a flight line spacing of 500 m oriented in NW-SE and a tie line spacing of 2000 m. The maps are on a scale of 1:100,000 and half-degree sheets contoured mostly at 10 nT intervals. The geomagnetic gradient was removed from the data using the International geomagnetic Reference Field (IGRF). The total area covered was about 18,150 km^2. The actual magnetic intensity value of 33,000 nT which was reduced for handling must be added to the value of magnetic intensity at any point so as to get the actual value of the magnetic intensity. The first step taken was to

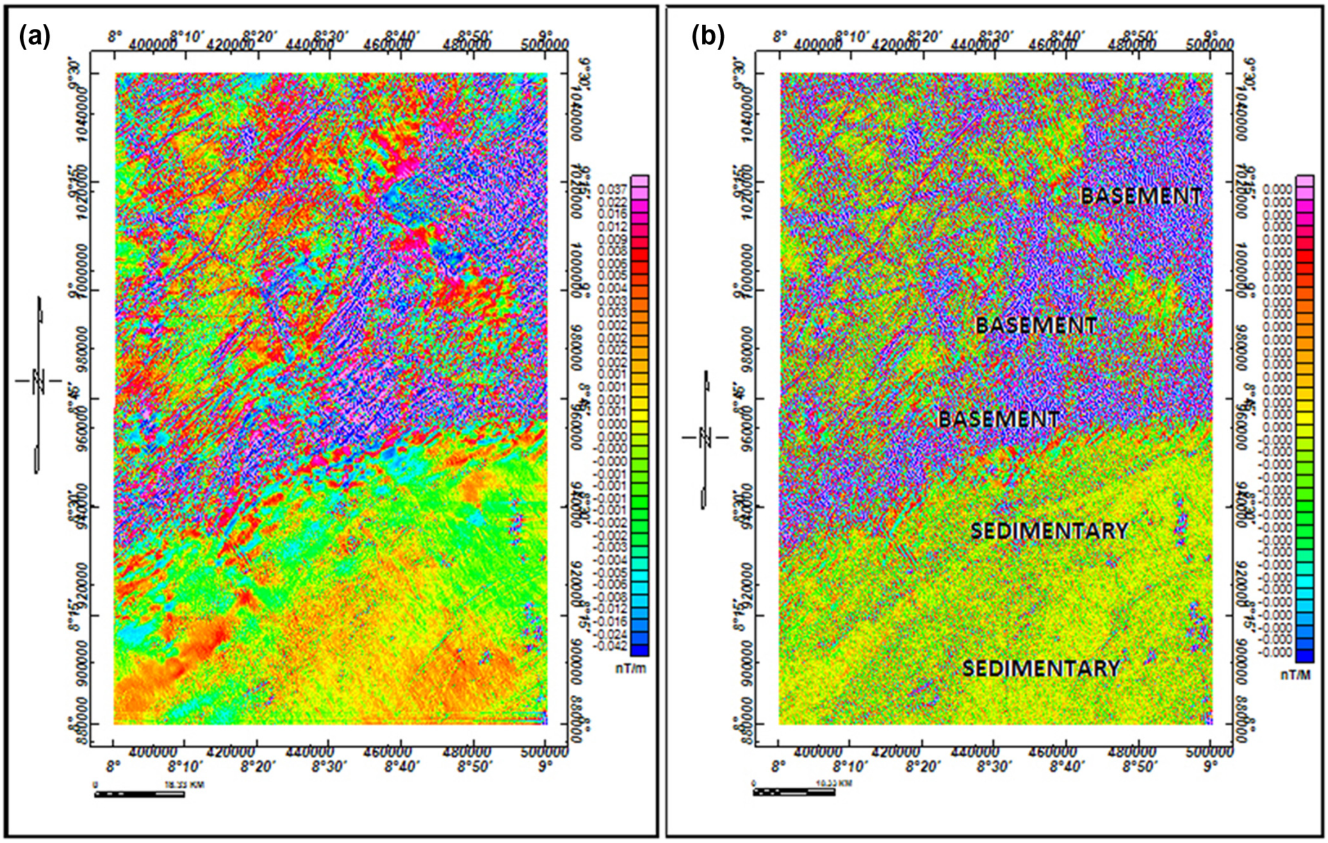

Fig. 5. a: First vertical Derivative Map. b: Second Vertical Derivative Map.

assemble the four maps covering the study area which was in different sheets and the next step was to re-gridded the maps using Oasis Montaj software to produce the total magnetic intensity map (TMI) of the study area (Fig. 4).

3. Methods

3.1. Vertical derivative filters

The vertical derivative is commonly applied to total magnetic field data to enhance the most shallow geological source and can be calculated either in space or frequency domain. The enhancement sharpens anomalies over bodies and tends to reduce anomaly complexity, allowing a clearer imaging of a causing structure. The transformation can be noisy since it will amplify short wavelength noise.

First vertical derivative data have become almost a basic necessity in magnetic interpretation projects. The second vertical derivatives has more resolving power than the first vertical derivatives [7].

$$L(r) = r^n \tag{1}$$

With: n = order of differentiation.

3.2. Downward continuation

Downward continuation is used to enhance features at a specified depth/elevation, lower than the acquisition level. This procedure accentuates near surface anomalies and can be used as an interpretation tool to determine the depth to a causative body. The filter can be applied to both gravity and magnetic data. Downward continuation is done using the expression [8]:

$$L(r) = \ell^{hr} \tag{2}$$

with h the distance in meters to be continued downward.

3.3. Analytic signal

This is a filter applied to magnetic data and is aimed at simplifying the fact that magnetic bodies usually have a positive and negative peak associated with it, which in many cases make it difficult to determine the exact location of the causative body.

Ref. [9] has shown that for two-dimensional bodies, a bell-shaped symmetrical function can be derived which maximises exactly over the top of the magnetic contact. The three-dimensional case was derived in 1984 also by [10]. This function is the amplitude of the analytical signal. The only assumptions made are uniform magnetization and that the cross section of all causative bodies can be represented by polygons of finite or infinite depth extent. This function and its derivatives are therefore independent of strike, dip, magnetic declination, inclination and remanent magnetism [11].

The 3-D analytical signal, A, of a potential field anomaly can be defined [10],

$$A(x,y) = \left(\frac{\partial M}{\partial x}\right)\hat{x} + \left(\frac{\partial M}{\partial y}\right)\hat{y} + \left(\frac{\partial M}{\partial z}\right)\hat{z} \tag{3}$$

as:

With:

M = Magnetic field.

The analytical signal amplitude can now be calculated [11] as:

$$|A(x,y)| = \sqrt{\left(\frac{\partial M}{\partial x}\right)^2 + \left(\frac{\partial M}{\partial y}\right)^2 + \left(\frac{\partial M}{\partial z}\right)^2} \tag{4}$$

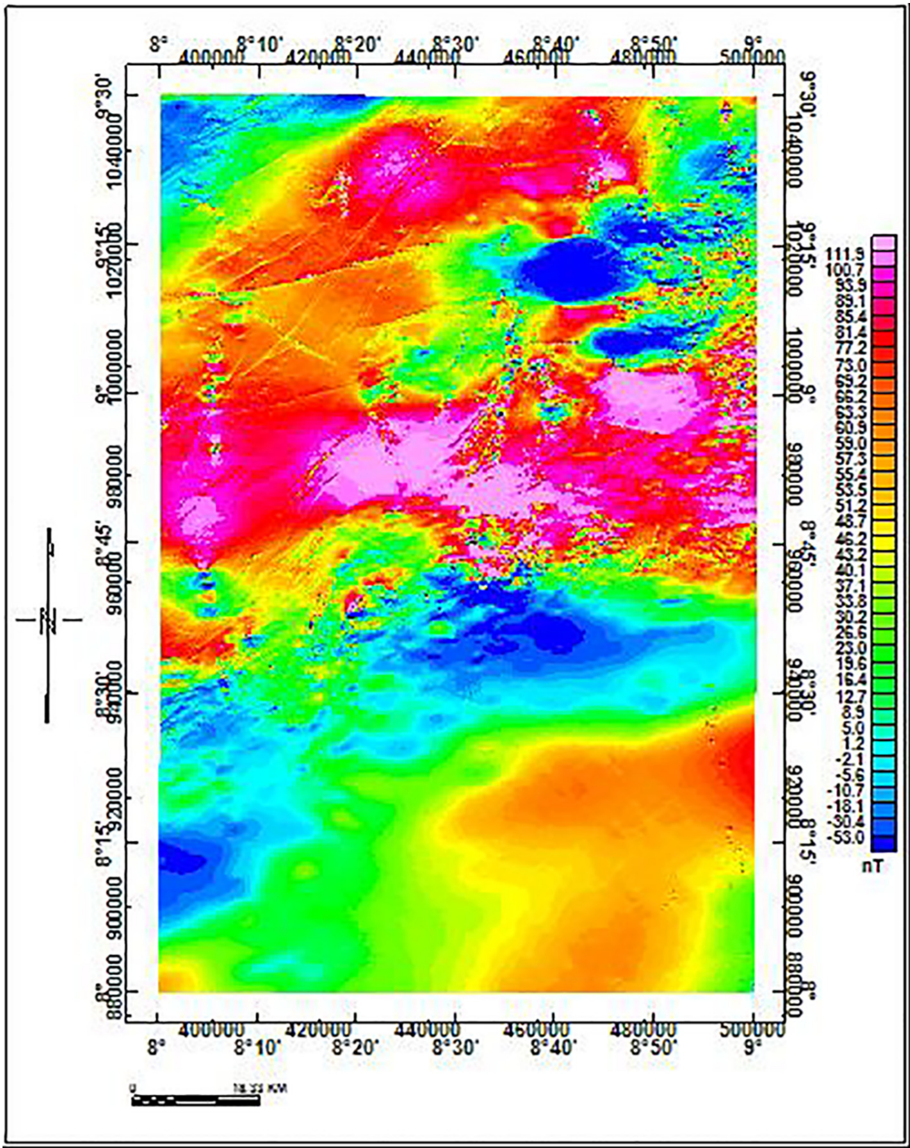

Fig. 6. Map of Downward Continuation at the height of 50 m.

3.4. Tilt derivative analysis

The tilt derivative and its total horizontal derivative are useful for mapping shallow basement structures and mineral exploration targets [8].

The tilt derivative is defined as:

$$TDR = \tan^{-1}(VDR/THDR), \quad (5)$$

where VDR and THDR are first vertical and total horizontal derivatives, respectively, of the total magnetic intensity T.

$$VDR = \frac{dT}{dz} \quad (6)$$

$$THDR = \sqrt{\left(\frac{dT}{dx}\right)^2 + \left(\frac{dT}{dy}\right)^2} \quad (7)$$

The total horizontal derivative of the tilt derivative is defined as:

$$HD\_TDR = \sqrt{\left(\frac{dTDR}{dx}\right)^2 + \left(\frac{dTDR}{dy}\right)^2} \quad (8)$$

4. Result and discussion

4.1. Total magnetic intensity map

The total aeromagnetic field map of the study area (Fig. 4) after removal of IGRF of 33,000 nT was produced in colour aggregate, with pink to red colour depicting positive anomalies while green to blue depicts negative anomalies. The Total Magnetic Intensity map of the study area exhibits both positive and negative anomalies ranging from −51.2 nT to 110.4 nT. The map reveals variations in magnetic signature of highs and lows. The high magnetic signature occupies the north-western and north-central part of the study area which corresponds to Akwanga and Nasarawa Eggon. The major high magnetic signature trends east-west. While the low magnetic signature which is of sediment deposition also occupies southwestern and part of the eastern part of the study area which corresponds to lafia and Doma. The greenish part of the study area indicates alluvium deposition. The magnetic intensity map agree with the geological map of the study area. The geology of the area is majorly divided into two components; the basement complex and the sedimentary basin. The basement complex occupies areas of Akwanga, Wamba and Nasarawa Eggon; these are

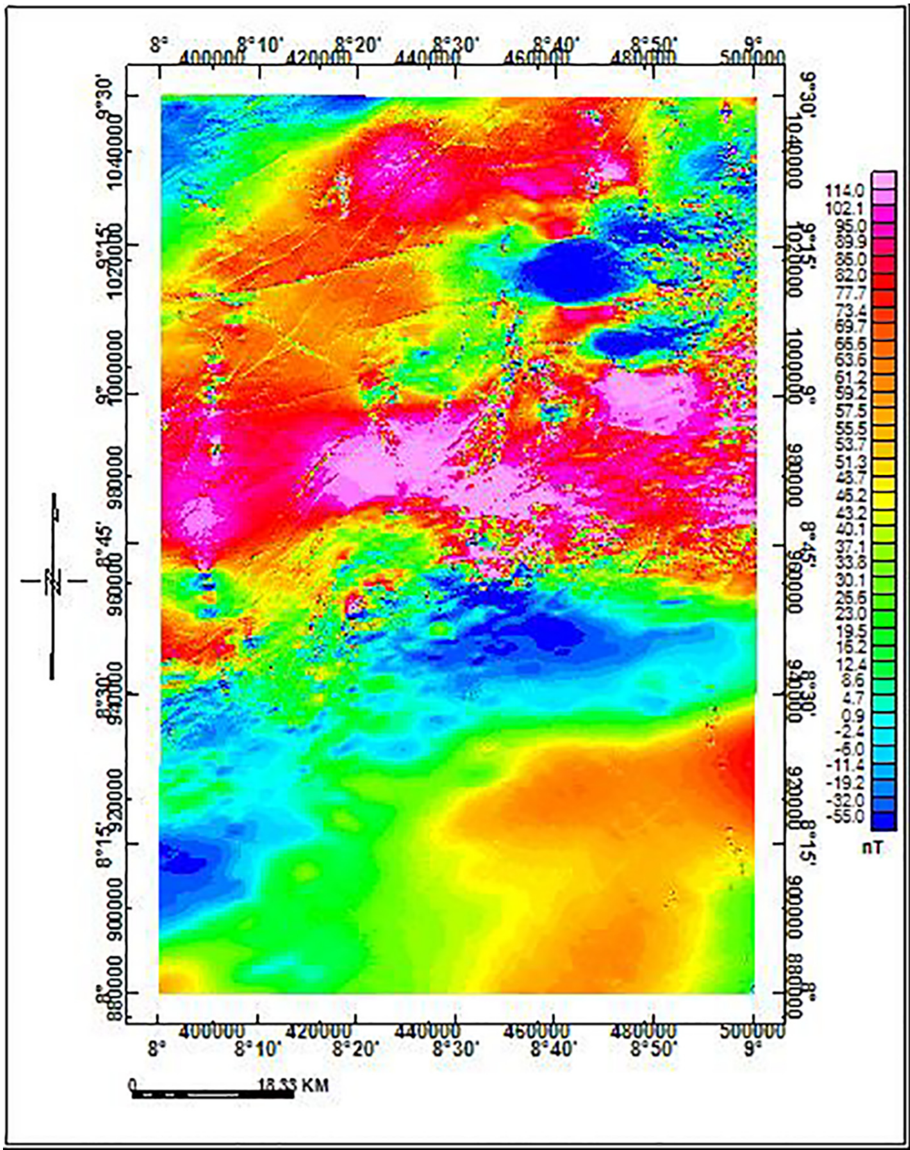

Fig. 7. Map of Downward Continuation at the height of 100 m.

areas with promising solid minerals of economic potentials like, gold at Wamba; Tin, Columbite and Tantalite at Akwanga; Granite rocks at Nasarawa Eggon. While the sedimentary basin occupies Lafia and Doma which also host some industrial minerals like Clay, glass Sands and the Salt Brines at Keana. The demarcation between the basement complex and the sedimentary basin occurs around southern part of Nasarawa Eggon.

4.2. Vertical derivative maps

Vertical derivatives (FVD & SVD) are filters that enhance the shallowest geologic anomalies; the enhancement sharpens up anomalies over bodies and tends to reduce anomaly complexity, allowing a clearer imaging of the causative structures. The first vertical derivative (Fig. 5a) comprises of basement and sedimentary region; the basement occupy the northern part while the sedimentary region occupy the southern part of the study area. It reveals the types of structures like lineament present in the study area. One of the important applications of first vertical derivative is finding magnetic lineament and determine the border between lithological units more precisely. The major magnetic features (lineament) found on the study area aligned northeast-southwest at the northern part of the study area. Since minerals are structurally controlled, the structures found in the study area might host the minerals present in the study area. The SVD of total magnetic field intensity (Fig. 5b) measures the curvature of the magnetic field and it is used for resolution of anomalies in magnetic field to aid geological mapping; for delineation of geological discontinuities in the subsurface.

The trend of structures found on the FVD map agrees with the trending of the structures (lineaments) found on the SVD map. The SVD map shows the trend of structures like faults in the area. Since minerals are usually structurally control, the trend of faults on the second vertical derivative map may indicate the alignment of minerals that could be found in the study area. The major structures delineated on the second vertical derivative map trends both northeast-southwest and northwest-southeast.

4.3. Downward continuation of total magnetic field intensity at 50 m and 100 m

The total magnetic intensity was downward continued at the height of 50 m and 100 m to enhance the shallow anomalies present in the study area (Fig. 6). At the height of 50 m, the total magnetic intensity map was a little bit refined but the shorter

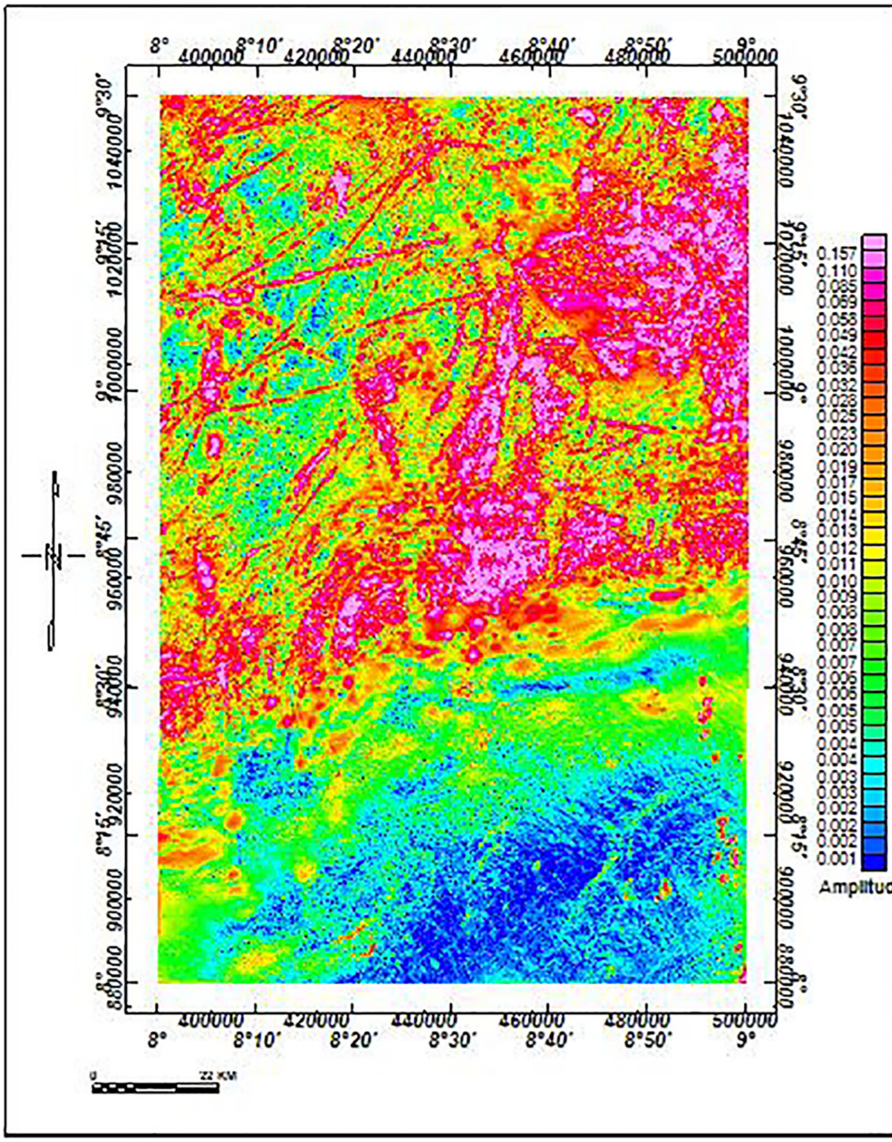

Fig. 8. Analytic signal Map of the Study Area.

wavelength became more visible. And at the height of 100 m (Fig. 7), the shallow anomalies become more pronounced compared to the when the magnetic intensity was downward continued at the height of 50 m.

The veins where magnetic minerals most especially gold are known to settle along igneous or metamorphic rocks are more pronounced at the northwestern part of the study area which correspond to Wamba where there is deposition of gold according to the mineral map of Nasarawa State. The veins that host the magnetic mineral (Gold) trends northeast-southwest. The central north to the eastern part of the study area, corresponds to part of Akwanga and Nasarawa Eggon also shows the presence of magnetic minerals like granite rocks which is of economic potential. The southern part, is made up of sedimentary rocks, which also host some industrial minerals like Clay, Glass Sands and the Salt Brines at Keana when compared with the mineral resources map of the study area.

4.4. Analytic signal map

Analytical Signal map helps in delineating the area into regions of outcrop, intermediate structures and basement under the influence of thick sedimentation. Two major regions can easily be observed (Fig. 8); regions whose amplitude responses are high which are predominantly basement outcrops with varying degree of deformations and regions whose amplitude are low, which depicts regions with relatively good sedimentation.

4.5. Tilt derivative map

The tilt derivative map (Fig. 9) enhances short wavelength anomalies which could be used to mapped shallow basement structures and mineral exploration targets. The map agrees with the vertical derivatives maps. It reveals the structures (lineament) that host minerals could found at the north-western part of the study area. The structures trends northeast-southwest.

5. Conclusion

Qualitative analysis of aeromagnetic data of part of Nasarawa State had been carried out with the aim of delineating mineral potential zone. The results from this study shows the presence of minerals of economic potential and the areas where the minerals

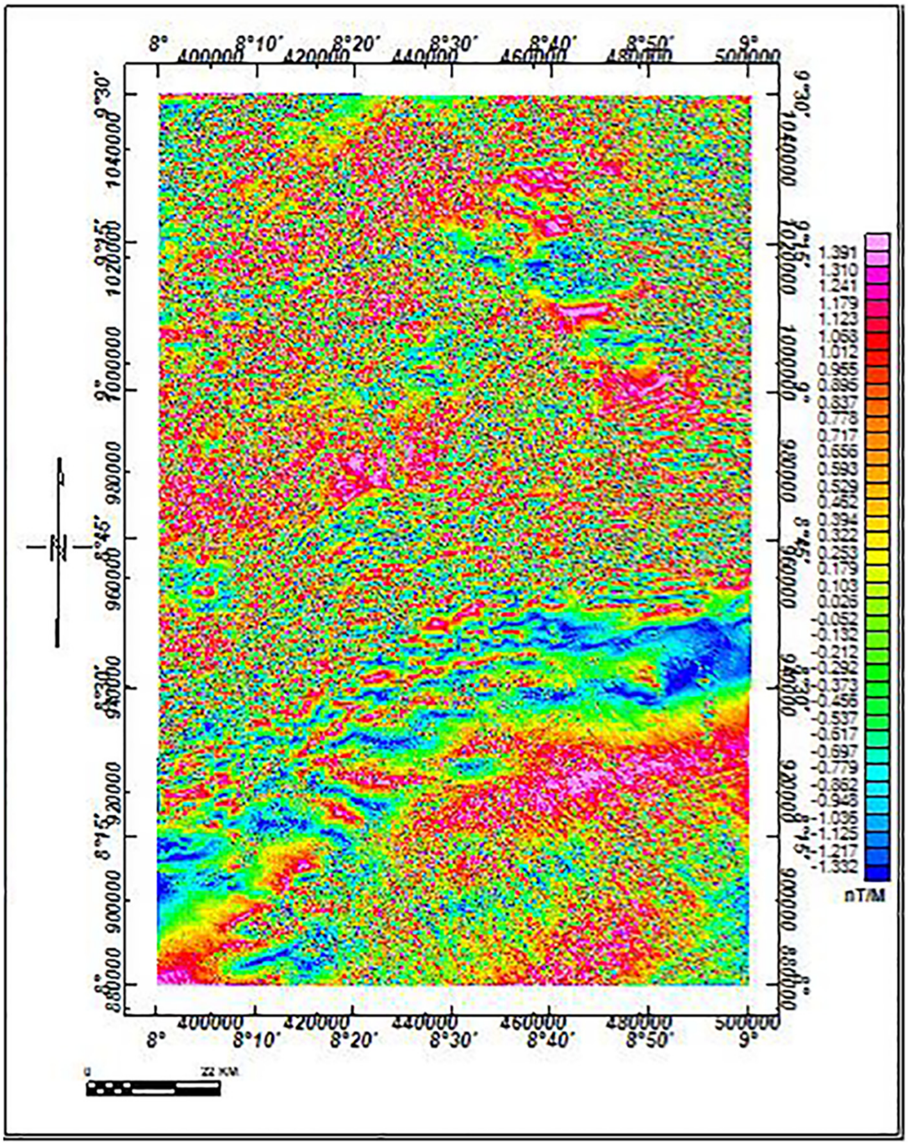

Fig. 9. Tilt Derivative Map of the Study Area.

can be located. At the northeastern and northwestern part of area which is made up of basement complex that corresponds to Wamba, Akwanga and Nasarawa Eggon host magnetic minerals like Gold, Gemstone and granites etc. while the southern part which is made up of sedimentary rocks that corresponds to Lafia and Doma, host industrial minerals like Clay, glass Sands and the Salt Brines at Keana. The results of the filters used in this study agreed largely and since most magnetic minerals are structural controls, it is expected that those lineaments identified, most especially at the northern part, could play host to those minerals aforementioned. These minerals, if harnessed will help in boasting the economy of Nigeria and pave way for business opportunities which will provide a lot of jobs and thereby eradicating poverty in Nigeria.

References

[1] J.A. Adekoya, Environmental effect of solid minerals mining, J. Phys. Sci. Kenya (2003) 625–640.
[2] D.E. Ajakaiye, D.H. Hall, T.W. Millar, Interpretation of aeromagnetic data across the central crystalline shield area of Nigeria, Geophys. J. Int. 83 (2) (1985) 503–517.
[3] A.A. Idzi, A.M. Olaleke, I. Shekwonyadu, E.A. Christian, Geochemical studies of mineral bearing ores from Nasarawa Eggon and Udege Beki areas of Nasarawa State, Nigeria, Int. J. Basic Appl. Chem. Sci. 3 (2013) 93–108.
[4] Benkhelil, J., Guiraud, M., Ponsard, J. F., Saugy, L. The Bornu–Benue Trough, the Niger Delta and its offshore: Tectono-sedimentary reconstruction during the Cretaceous and Tertiary from geophysical data and geology. Geology of Nigeria. 2nd ed. Rock view, Jos, 1989.
[5] N.G. Obaje, H. Wehner, M.B. Abubakar, M.T. Isah, Nasara-1 well, Gongola Basin (Upper Benue Trough, Nigeria): source-rock evaluation, J. Pet. Geol 27 (2) (2004) 191–206.
[6] N.G. Obaje, A. Jauro, M.O. Agho, M.B. Abubakar, A. Tukur, Organic geochemistry of Cretaceous Lamza and Chikila coals, upper Benue trough, Nigeria, Fuel 86 (4) (2007) 520–532.
[7] P.R. Milligan, P.J. Gunn, Enhancement and presentation of airborne geophysical data, AGSO J. Geol. Geophys. 17 (2) (1997) 63–75.
[8] Geosoft Inc., OASIS Montaj Version 4.0 User Guide. Geosoft Incorporated, Toronto, 1996.
[9] M.N. Nabighian, The analytic signal of two-dimensional magnetic bodies with polygonal cross- section: Its properties and use for automated anomaly interpretation, Geophysics 37 (3) (1972) 507–517.
[10] M.N. Nabighian, Toward a three-dimensional automatic interpretation of potential field data via generalized Hilbert transforms – Fundamental relations, Geophysics 49 (1984) 780–786.
[11] N. Debeglia, J. Corpel, Automatic 3-D interpretation of potential field data using analytic signal derivatives, Geophysics 62 (1) (1997) 87–96.