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Upward Continuation and Reduction to Equator Filters on Aeromagnetic Data of Nkalagu and Abakaliki Regions of Lower Benue Trough, Southeastern Nigeria

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Abstract: This paper adopts two magnetic filtration techniques to enhance the Aeromagnetic maps of Nkalagu and Abakaliki regions of lower Benue trough, Southeastern Nigeria. This aim is to enhance the effectiveness of the map in characterizing the study area. Upward continuation (UPC) and reduction to magnetic equator (RTE) filters were applied to sufficiently improve the interpretation of the aeromagnetic data of the area in terms of recognition and understanding depth continuation and discrimination between shallow and deeper magnetic sources within the study area. The total magnetic intensity and reduction to the equator showed variations in anomalies. The variations were invariably related to magnetic susceptibility, depth, degree of strike, lithology or basement complex rocks harboring varying amounts of magnetic minerals.

Keywords: Aeromagnetic data, Upward Continuation reduction to the equator and anomalies

I. Introduction

Magnetic survey is one of the ancient geophysical methods employed for the investigation of hydrocarbon and mineral deposits. The method probes the internal structures of the earth based on magnetic field variations that occur due to magnetic properties of the underlying rocks. [1] opined that magnetic method tends to probe the geology of an area of interest due to its earths magnetic field differences. The differences being the responses' results of magnetic features of the rocks in subsurface. This method is very effective in the determination of the probable depth to basement beneath sedimentary rocks [2]. The upward continuation process is a technique that projects data higher above the original height the data was taken. Its effect is that short wavelength features are smoothed out because one is moving away from the anomaly [3]. The upward continuation method is also introduced in oil exploration geophysics to estimate the values of a magnetic or gravitational field by using the measurements at low elevation and extrapolating upwardly; thereby assuming continuity. In terms of magnetic interpretation, upward continuation attenuates high wave number anomalies concomitant with the shallow magnetic sources, thus by allowing comfortable interpretation or explanation of deeper magnetic sources. It is also adopted to separate a regional magnetic anomaly resulting from deep-seated sources from the observed magnetic sources whereas the reduction to magnetic equator is employed in low magnetic latitudes; That is, areas with geomagnetic inclination less than 15˚ to center the peaks of low magnetic anomalies over their sources or exact positions. This enhancement over extreme or outermost magnetic anomalies is over their sources, thereby enabling magnetic interpretation easier. In reduction to the equator, it is not with little rigors when it is required to correlate the observed abnormal maxima and the positions of sources since magnetic signature of magnetized bodies at low latitudes always have two extreme values because of their bipolar nature [3]. [4] also proposed that the magnetic data can be reduced to the equator (RTE) such that the magnetic bodies will appear horizontal at the equator. Therefore, the aim of this study is to employ two magnetic enhancement procedures to the reduction to equator and in upward continuation at various levels on the aeromagnetic data of Nkalagu and Abakaliki regions. It is expected that from selected regions of both in the Lower Benue troughs, it would be observed that the picture of the differences between the shallow and deeper magnetic sources would be unvailed. Thereafter, variations would be noticed from the aeromagnetic data which ones are evident to the change in magnetic susceptibility of near surface rocks.

II. The Study Area

The study area is located within the latitudes of $6.0^0$and $6^030'$ N and logitude $7^030'$ and $8^030'E$. With a coverage area of approximately 110km long by 65 km wide within the lower Benue Trough.As discribed by many authors [5, 6, 7, 8, 9, 10]. The lower Benue trough is underlain by a thick sedimentary sequence, which is traced from the tectonic processes that accompanied the division of the africa and south america plates in the early crateceous . The major component units of the lower Benue Trough include the Anambra Basin, the Abakaliki Anticlinorium and the Afikpo Syncline. The oldest sediment of the sequence belongs to the Asu River Group which unconformably overlies the Precambrian basement complex that is made up of granitic and magmatic

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rocks [11]. The Asu River Group whose type outcrops in Abakaliki has an estimated thickness of about 2000 m [12] and is of Albian age. It comprises of argillaceous sandy shales, laminated sandstone units and minor limestones with an interfingering of magnetic volcanics [7]. The shales are fissile and highly fractured, deposited on top of these Asu River Group sediments in the area are the Upper Cretaceous Eze-Aku shales. The Turonian Eze-Aku shales consist of nearly 1000m of calcareous flaky shales and siltstones [13]. They are Turonian in age and are overlain by younger sediments of the Awgu Shale (Coniancian). The Awgu Shales consist of marine fossil ferrous grey bluish shales, limestones and calcareous sandstones. Overlined by the Nkporo Shales (Campanian) which are also mainly marine in character and has sandstone members. The geological map of the study area (Figure.1).

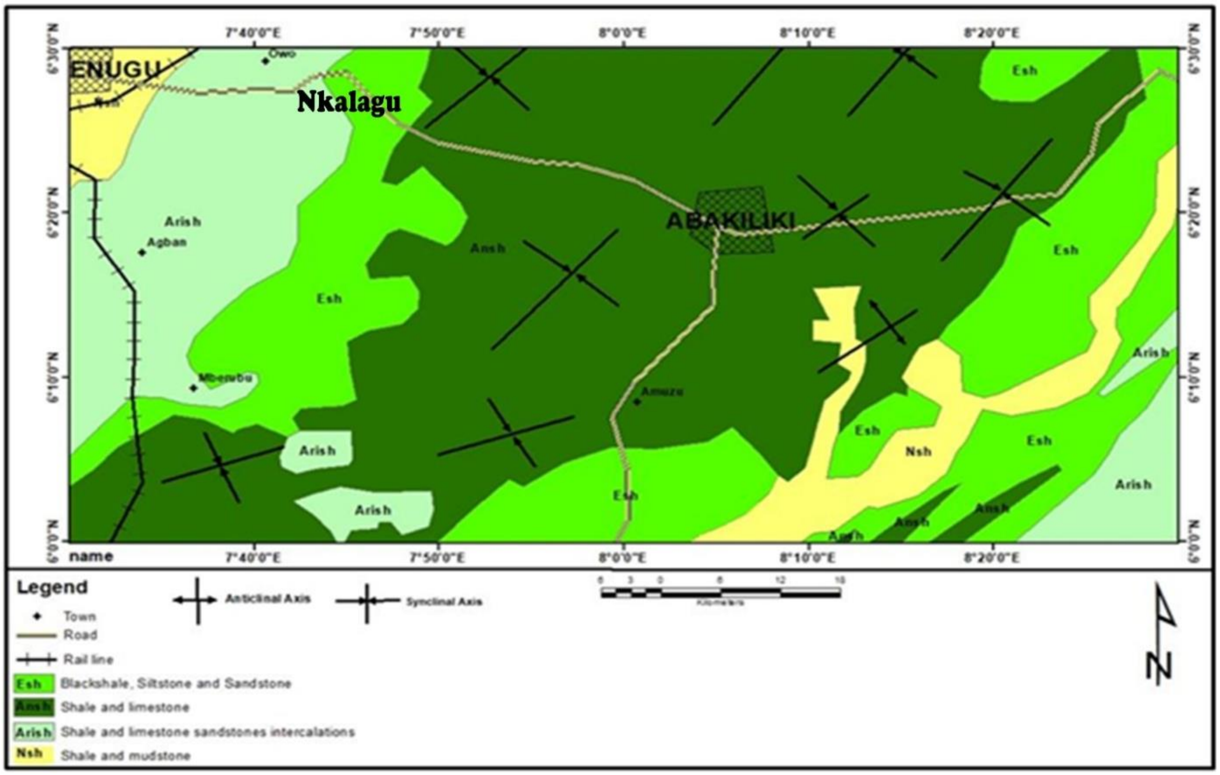

Figure 1: the geological map of the study area

III. Methodology

Two sheets of aeromagnetic data comprising Nkalagu (302) and Abakaliki (303) were adopted for this research. Both are digitized data obtained from Nigeria Geological Survey Agency (NGSA) Abuja, Nigeria. The data acquisition was carried out in Nigeria between the years 2005-2009 at a flight altitude of 80 m above the ground surface at a tie line spacing of 2 km. The flight line spacing is 0.5 km and the digital data was made available on scale of 1:50000. The Software application employed to interpret and analyze the data includes the *Oasis Montaj 8.4* software and the *ArcGis*. In performing operations for the reduction to equator, the two aeromagnetic data covering the study area were merged to form a single data base using the *Oasis Montaj 8.4* software, hence, the Total Magnetic Intensity (TMI) map of the area was be produced. This was carried out using Bi-directional line gridding method. Afterwards, the Total Magnetic Intensity map produced was reduced to the equator (TMI-RTE) in accordance with the I.G.R.F 2005 standard reduction method (Equation 1). Amplitude corrections of inclination -9.3 and declination of -1.7 were used as basic inputs.

$$L(\theta) = \frac{[\sin(I) - i\cos(I).\cos(D-\theta)]^2 X\left(-\cos^2(D-\theta)\right)}{[\sin^2(Ia) + \cos^2(Ia).\cos^2(D-\theta) X[\sin^2(I) + \cos^2(I)\cos^2(D-\theta)]} \qquad \rightarrow 1$$

Such that if $(/Ia/</I/)$, Ia= 1

Where $L(\theta) = TMI$ reduced to the equator (TMI-RTE), I = geomagnetic inclination, Ia = inclination for amplitude correction which should not be less than I, D = geomagnetic declination, $Sin\ I = amplitude\ component$ and $icos\ Icos\ (D - \theta) = phase\ components$.

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The upward continuation method projects data higher above the original height the data was measured. This technique accentuates anomalies caused by deeper sources at the expense of anomalies caused by shallow sources (Mekonnen, 2004). The upward continuation processes of 2, 5, 10 and 30, km were carried out on the TMI-RTE data at various points *P* $(x^1, y^1, -h)$ *above* the ground surface at height *h* (Equation 2).

$$F\left(x, y, -h\right) = \frac{h}{2\pi} \iint \frac{f\left(x, y, 0\right) dxdy}{\sqrt{\left(x - x^1\right) + \left(y - y^1\right) + h^2}} \rightarrow 2$$

Where *F (x, y, -h)* is the total field at the point *P* $(x^1, y^1, -h)$ above surface on which *F* $(x^1, y^1, 0)$ *is known, h is the elevation above ground surface*. Thus, the issue posed with calculating the field at higher level from the knowledge of the field at a lower level is a straight forward one of numerical integration of the surface data. In practice, the computations were done by replacing the surface integral with a weighted sum of values taken on a regular grid. The empirical formula of (14) given to the field at an elevation h, above the plane of the observed field (z = 0) in terms of the average value ΔF (ri) over a circle of radius ri centred at the point (x, y, o) multiplied by the appropriate weighting coefficients. These coefficients enable calculations of the upward continued field to accuracy within 2% [15].

IV. Results And Discussion

Having performed the reduction to magnetic equator (RTE) filtering operation on the aeromagnetic data, it is observed that the contoured maps reflected similar features of faulted zone at the southeastern portion of the study area as seen on the total magnetic intensity (TMI) map of the area (Figure 2). This faulted zone signifies structures which could be areas of mineral emplacements or deposits. The reduction to the magnetic equator (RTE) map (Figure 3) appeared smother and clearer defining the high and low centers better than total magnetic intensity map (Figure 3). This is because the regional field has been separated from the total field data.

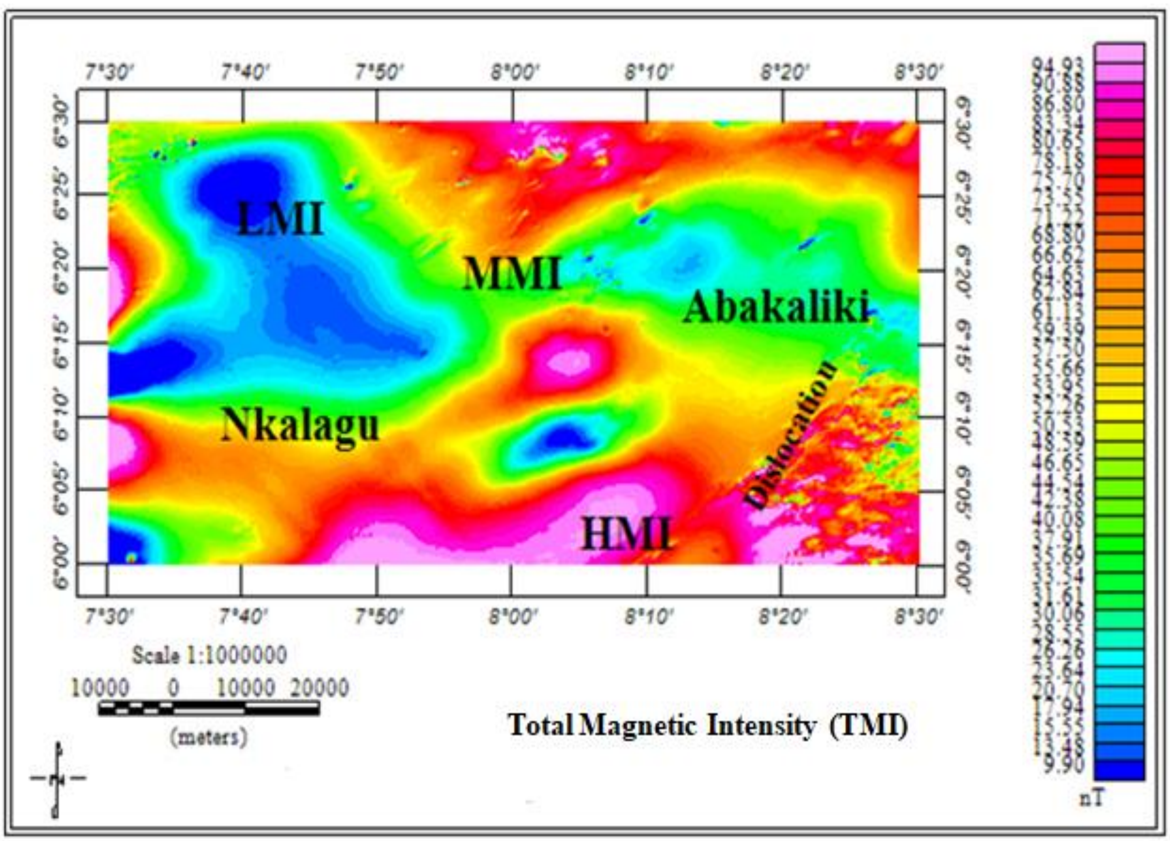

Figure 2: total magnetic intensity map of the study area

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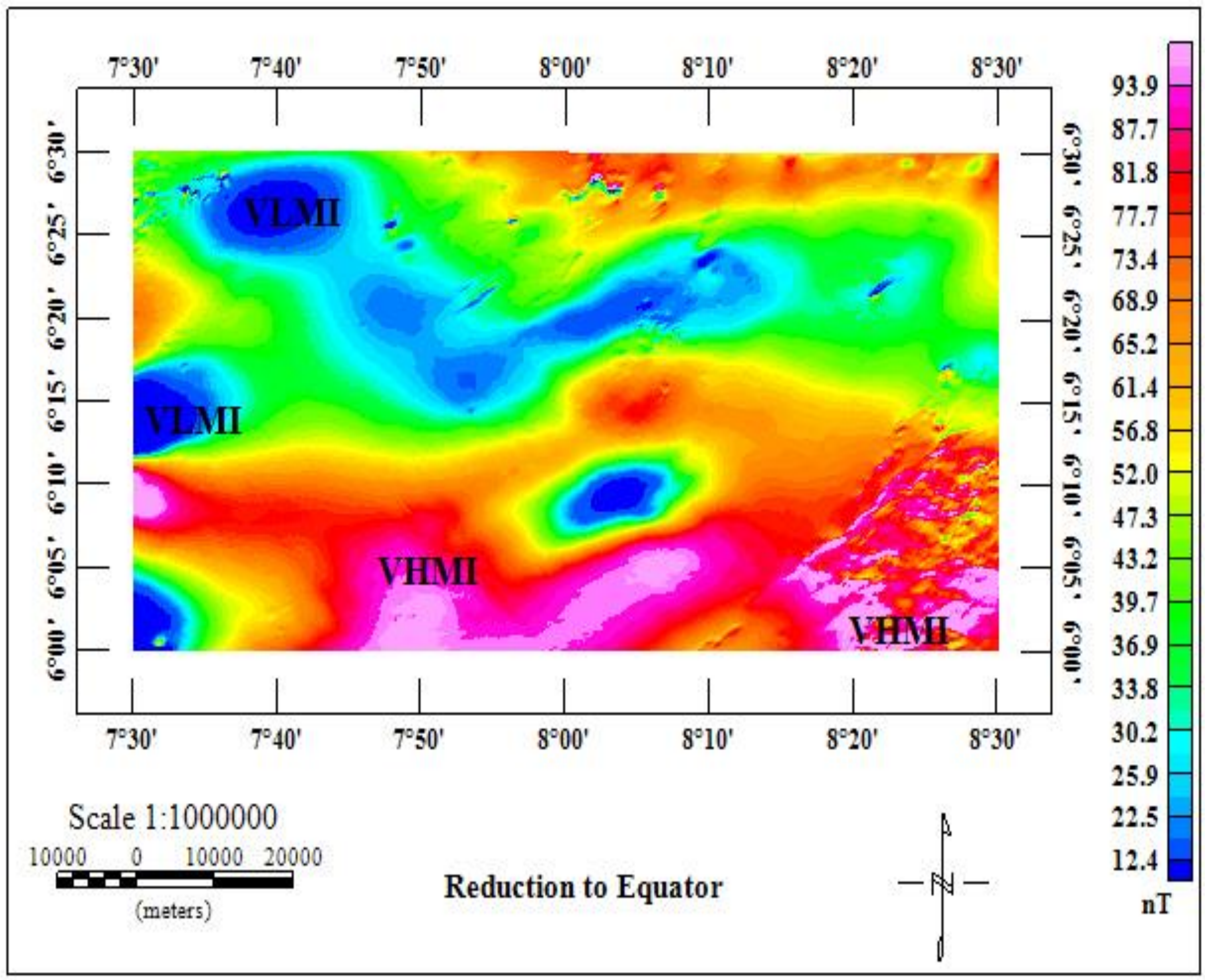

Fig. 3: reduction to equator map of the study area

The upward continuation filters were therefore performed on the aeromagnetic data with respect to the distance of continuations. The upward continuation process applied at certain heights of 2, 5, 10 and 30 km respectively uncovers the basements at various heights as shown in Figure 4, 5,6 and 7 respectively. Observation of the upward continued maps revealed the various magnetic intensities that would have been obtained if the data were recorded at the heights of 2, 5, 10, and 30 km respectively higher than the original 500 m (0.5 km) datum, at which the data was originally collected. [16] opined that if magnetic data is upward continued with different perspective at heights, the effects of smaller, narrower and thinner magnetic bodies would progressively disappear relative to the effects of larger magnetic bodies with considerable depth extent. Comparing the respective maps of the 2 km and 5 km upward continuation (Figures 4 and 5) with the RTE map (Figure 3); similar features were observed but the deformation observed at the south-eastern (SE) portion of the study area were not seen, depicting that the magnetic signatures are emanating from depths shallower than the 2 km and 5 km. Thus, the magnetic bodies producing the anomalies may be seated deeper and higher than the 500 m but below 2 km depth. Also, patterns of anomalies in the subsurface were revealed to be trending in NNW-SW, WSW-ESE and NNW-ENE directions of the study area from the 2 km and 5 km heights. The 10 km and 30 km upward continued maps (Figures 6 and 7) reflected similar results by providing quality views of the study area undistorted by the local, high amplitude, high gradient anomalies of the magnetic sources within the shallow and deeper areas of the study showing deep-seated anomaly sources aligned NE-SW direction with shallow sources at NNE-WSW directions. Moreover, the increased attenuation and broadening of the high wave number anomalies with increase in height was also noticed thereby illustrating the change in anomaly characteristics with an increase in observation to magnetic source distance. It is therefore understood that the attenuation of the shallow source anomalies in the upward continuation process has enabled a clearer view of the deeper anomalous source [17].

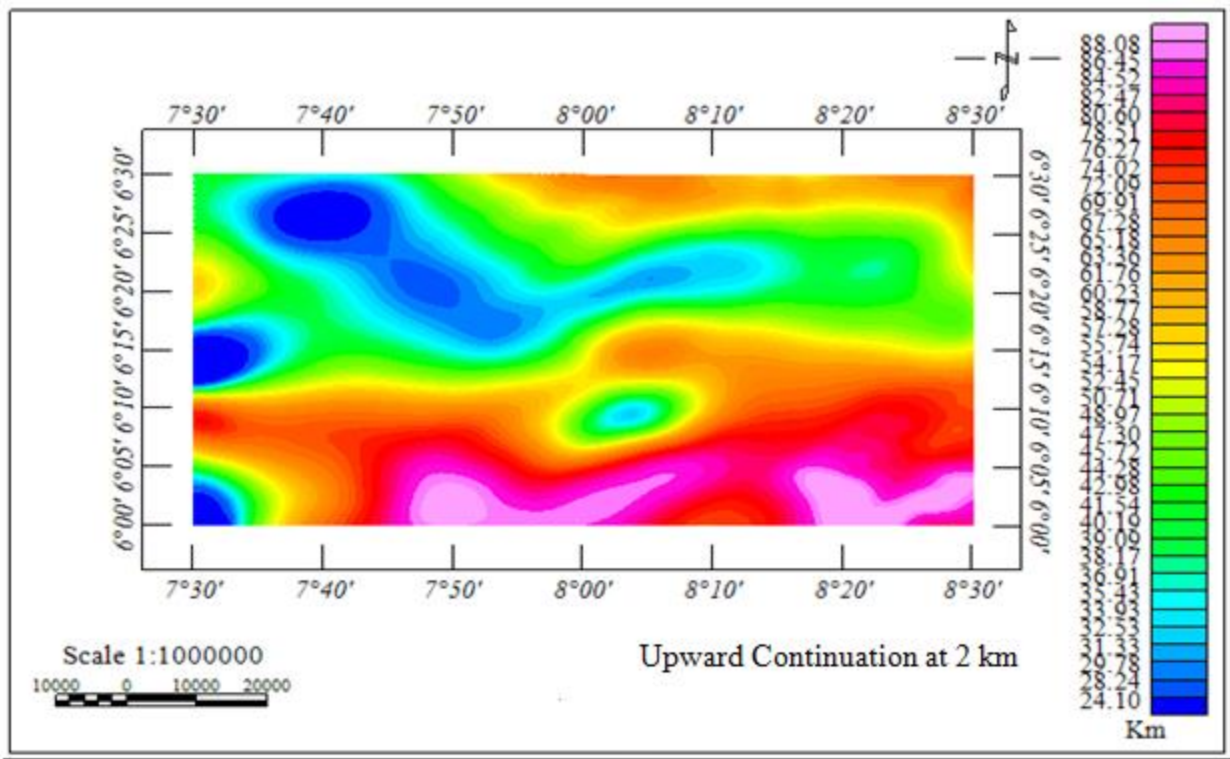

Fig.4: upward continuation mapof the study area at 2km

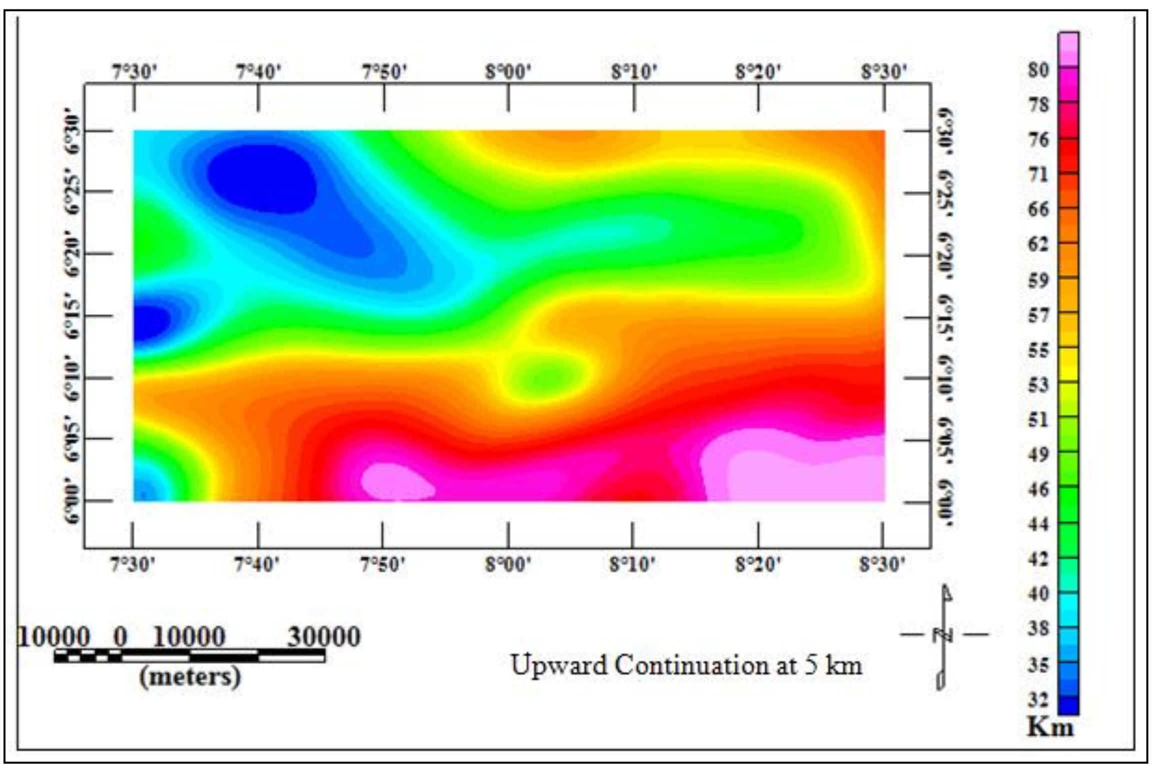

Fig. 5: upward continuation map of the study area at 5km

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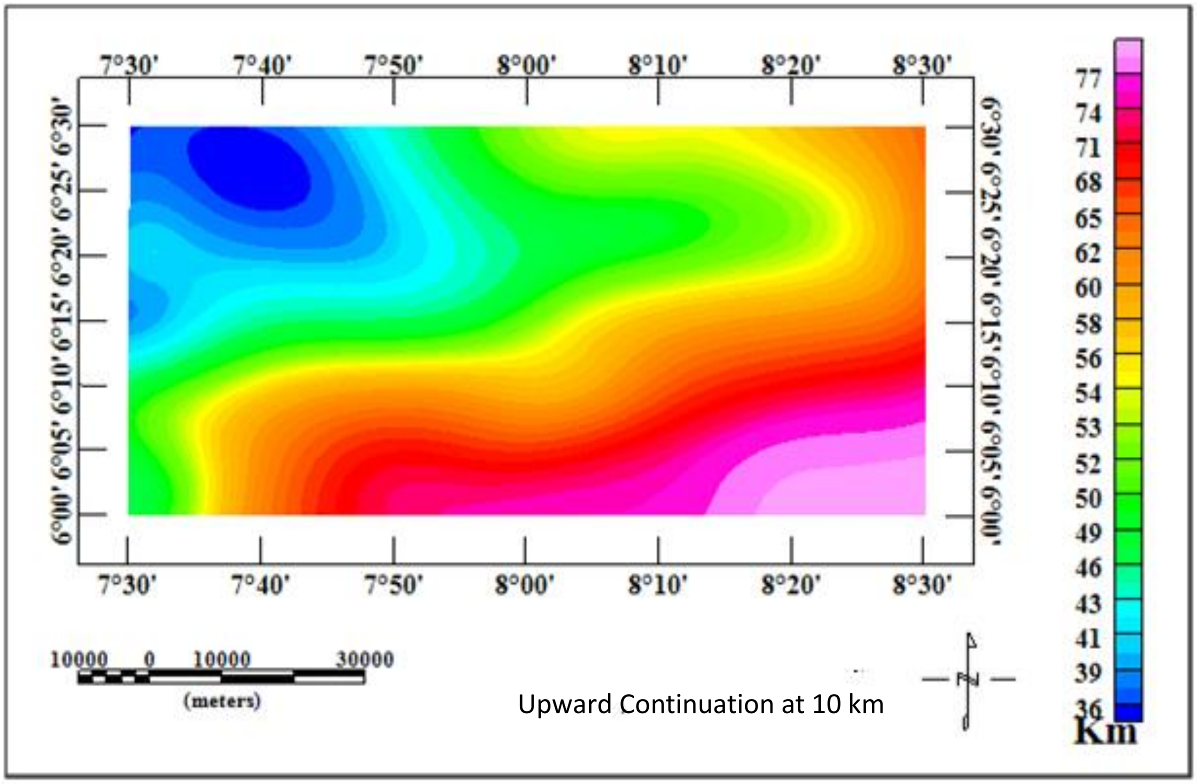

Fig. 6: upward continuation map of the study area at 10 km

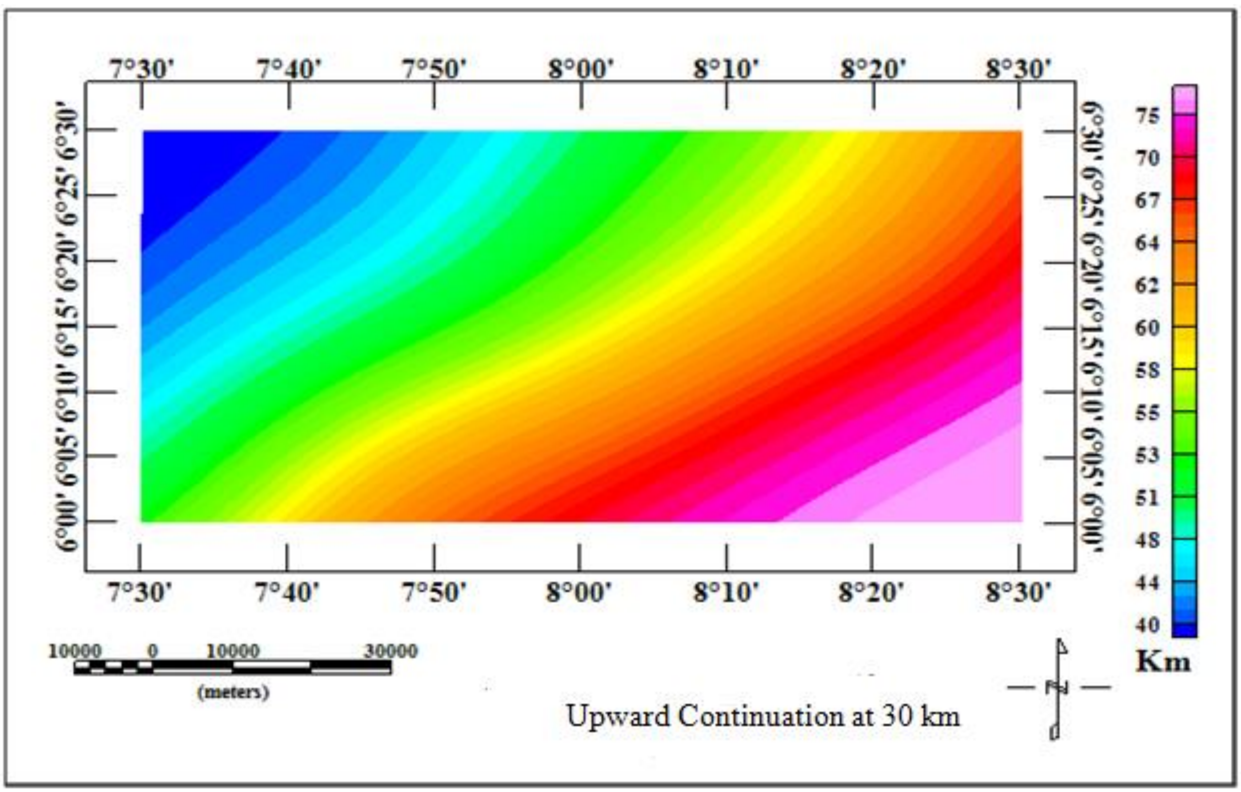

Fig. 7: upward contiuation map of the study area at 30 km

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V. Conclusion

The aeromagnetic data has helped in transforming and enhancing the magnetic anomalies shapes and locations within the study area. The structural deformed areas revealed from the total magnetic intensity (TMI) and reduction to the magnetic equator (RTE) maps of the area signifies structures/lineament which will serve as conduits for mineral deposits. The upward continuation maps at various heights have depicted regional anomaly sources aligned NNW-SW, WSW-ESE, NNW-ENE NE-SW and NNE-WSW directions. The continuation filters further showed attenuations and broadening of shorter wavelength anomalies with respect to increase in observations to their source distance. These observations enhanced the knowledge of both the deeper and the shallow anomalous bodies.

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