Integration of Aeromagnetic and Landsat Data in the Analysis of Dump Site (Landfill) in Owerri, Imo State

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Abstract
Magnetic study over South Eastern Nigeria was performed as part of a multi-technique geophysical investigation. Various magnetic data enhancement procedures such as, qualitative (second vertical derivative, total horizontal derivative, analytic signal, theta map, tilt derivative, total horizontal derivative of tilt derivative and horizontal tilt angle) and quantitative (Werner and Euler deconvolutions) interpretation techniques were employed to determine their effectiveness in characterizing landfills. The study area has revealed that upward continuation, calculated vertical patient processing, and wavelength filtering significantly improved the interpretability of magnetic data in areas of discrimination between shallow and deep magnetic sources within the landfill. Furthermore, the vertical gradient calculated from surface observations is separable to gradients obtained from bi-level surveys, suggesting that the efficiency of surveys can be increased by calculating, rather than observing the vertical gradient. Lineaments trending NE – SW and other adjoining lineaments are revealed by the second vertical derivative map. Similar indications are observed from the maps of first vertical derivative, theta, total horizontal derivative, tilt and horizontal tilt derivative.

Keywords: *Aeromagnetics, Landsat, Landfill, Qualitative analysis, Dumpsite*

Introduction

An important objective in the structural interpretation of geophysical data is to map joints and faults. These features are characterized by their distinct linear or curvilinear nature and therefore can be identified through lineament interpretation of processed potential field data or enhanced remotely sensed images (Michael and Steven, 2014).

Traditionally, potential field data are displayed in the form of contour maps. On such maps, joints and faults appear as elongated closed contours, noise in the contours, abrupt terminations of contours and discontinuities in the contour pattern. Faults of regional dimensions are characterized by alignments of the contour features listed above signatures which can be tedious and time consuming, particularly for large areas. The problem is further compounded even for small areas if the dynamic range of the potential field anomaly associated with the fault is small (Michael and Steven, 2014).

Aeromagnetic data reflects the distribution of magnetic minerals in bedrock and is unaffected by non-magnetic cover. The interpretation of the aeromagnetic survey has serve as basis for revealing the structural pattern of the basement complex, and the shallower structures (El-awady *et al*., 2008). Aeromagnetic applications are well known in a wide variety of geological studies and they play an important role in tracing lithological contacts and to recognize the structures like faults, lineaments, dykes and layered complexes. Aeromagnetic data can be used along with conventional geological maps for various earth resource evaluation applications (Reeves, 1999). The regional aeromagnetic study of anomaly map brings out the regional geological pattern and structural features and provides an exceptional background for interpretation for specific purposes (Maritta, 2007). Linear aeromagnetic anomalies and gradients corresponding to thrust and tear faults are associated with fault scarps on the ground. The scarps are otherwise difficult to identify in the highly populated areas and under widespread, dense vegetative cover (Grauch and Ruleman, 2013).

Grauch and Ruleman (2013) have noted earlier that the past two decades have seen a revolution in application of aeromagnetic surveys, from interpretation of solely basement structure to detailed examination of structure and lithologic variations in the sedimentary section as well (Millegan, 1998). Several recent collections of papers attest to this growing revolution (Gibson and Millegan, 1998; Peters and Peirce, 1998a; Society of Exploration Geophysicists, 1998). These papers illustrate the range in types of sedimentary sources that can be inferred from aeromagnetic data, from intrasedimentary structures to paleochannels. Yet, our understanding of the specific sources of these anomalies is still rudimentary: Is the magnetic material detrital, geochemical, or lithologic in origin?

Two critical issues concerning magnetic anomalies interpreted as faults are (1) distinguishing anomalies related to faults from those associated with a paleochannel filled with detritral magnetite, and (2) distinguishing anomalies produced by the juxtaposition of sediments having different magnetic properties at faults from anomalies related to secondary geochemical processes that have either destroyed or introduced magnetic minerals along the fault zone. Many studies have addressed the first issue by providing independent evidence for faulting in another data set, such as seismic-reflection profiles (Gunn, 1997; Spann-Reitz and Stowel, 1996; Peters and Peirce., 1998). The second issue is commonly difficult to address because the interpreted faults are buried. One study from northern Alberta (Peters and Peirce, 1998) concluded from magnetic modeling, depth analysis, and comparison to seismic reflection data that intrasedimentary faults are commonly magnetized along fault planes. The authors further proposed a geochemical process related to vertical fluid flow that can explain the deposition of magnetic minerals along fault planes.

The exploration of mineral resources has been described as a four-step operation involving regional reconnaissance, surface and subsurface mapping, ground geophysical surveys and actual drilling (Oladele and Ojo, 2013). A mineral indicator has further been defined as a physical or chemical phenomenon which has been found to correlate with known mineral occurrence. Some indicators that have been found useful in the exploration of minerals include faults, fractures, linear, arched or domed strata and oxidized and hydrothermally altered area (Peters and Pierce, 1998). Proven relationships do exist between known mineral deposits and certain types and directions of lineament (Lattman and Akaolisa, 2006). Only detailed ground geological and geophysical follow-up can distinguish between the classifications of lineament (faults, joints, etc.). Primary minerals results from fracturing, as the primary ore bodies in Nigeria are probably oriented following the tectonic trend (Ananaba and Ajakaiye, 1997). The magnetic method is frequently used in studies over landfill in search of buried magnetic materials. (French et.al 1991).

1. <u>Geological Background</u>

The study area lies at about latitude $5^{0}15^{1}$N to $5^{0}30^{1}$ N and longitude $7^{0}00^{1}$E to $7^{0}00^{1}$E (Figure 1) with its geology being predominantly the geology of the Lower Benue Trough.

The study area is underlain by the Benin Formation (Rayment, 1995). The Benin formation (Mocene –Recent) is an extensive stratigraphic unit in the Southern Nigerian sedimentary basins. It has been referred to as the coastal plain sands (Simpson, 1997) and was formalized as Benin formation by Rayment (1995). It consists of porous and permeable fresh water bearing sandstones with minor intercalations of clay. The formation is generally water bearing and hence it is the main source of portable ground water in the municipality.

Benin formation varies in thickness with an average of 700m. The unconsolidated sands and inter-lingering clays have given rise to systems of aquifers. The Benin Formation has about 70% to 90% sandstone with minor intercalations of shale in some places. The Shale is grayish brown, sandy to silt and contain some part remains and dispersed lignite.

The Benin formation is of the deltaic alluvium composed mainly of coarse grained, pebbly sorted and certain lenses of fine grained sands (Kogbe, 2012).

Petrographic studies of several thin sections by Onyeagocha and Awoyemi (1980) show that quartz makes up about 99% of all grains. The quartz grains show undulose extension; the rock is mineralogically matured and texturally immature.

The Benin formation (Figure 2) conformation overlies the Ogwashi formation. The Ogwashi Asaba formation was formally known as the Lignite Series by Simpson (1997). Rayment (1995) formalized it and described the lithology as consisting of alternation of seams and clays. The average thickness is 300 m, Kogbe (2012) suggested parts of the formation maybe of Oligocene age.

Aeromagnetic and Remotely sensed imagery (Landsat) was used in the study area to provide information that has higher image resolution, sharper spectral separation, improved geometric fidelity and greater radiometric accuracy. This is as a result of the fact that geologic maps may be inaccurate and at best are usually generalizations. Hilly terrains and minute figures drawn on the ground stand out clearly when viewed from the air.

Therefore, this work is an attempt to give a detailed structural interpretation with view of the distribution of dump sites in the study area using aeromagnetic and landsat thematic mapper.

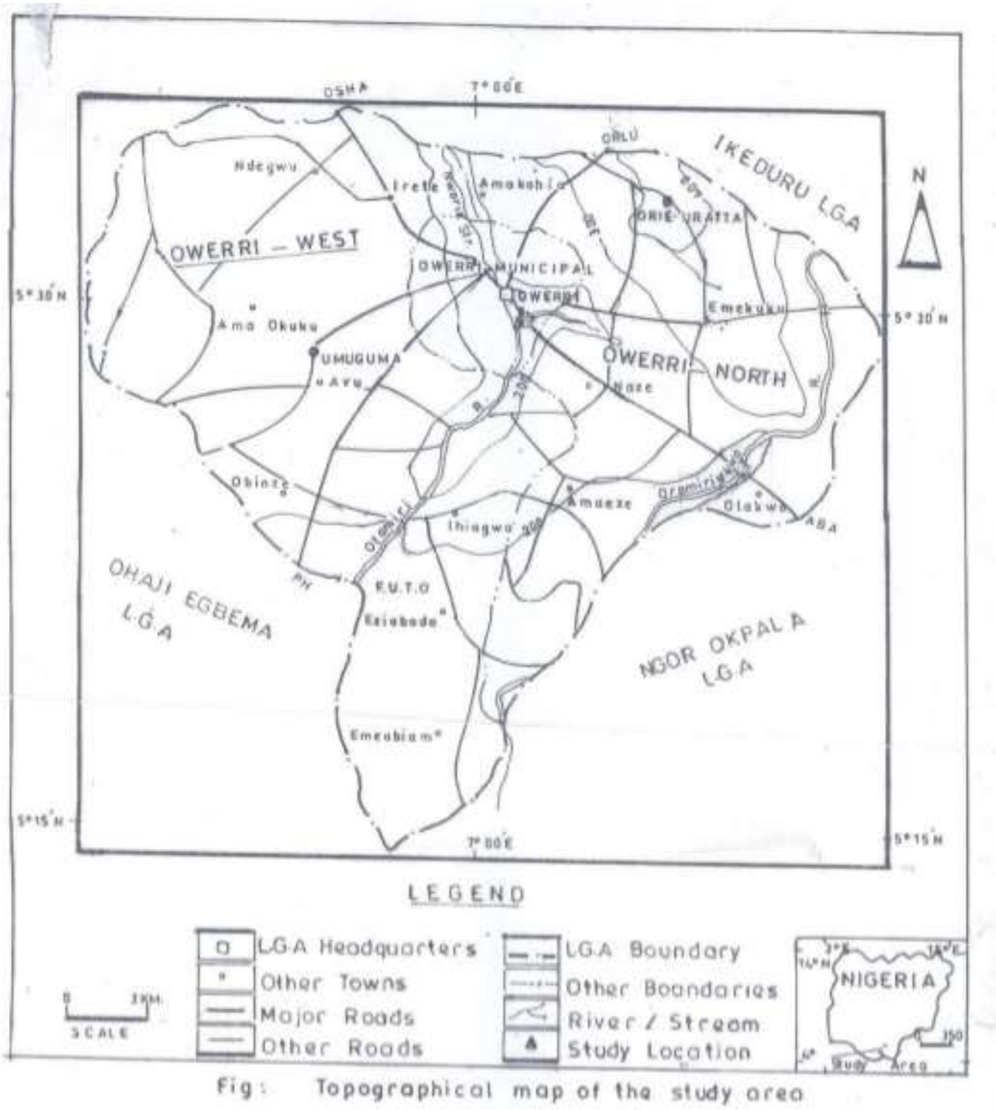

Figure 1: Topographic map of the study area, southeastern Nigeria.

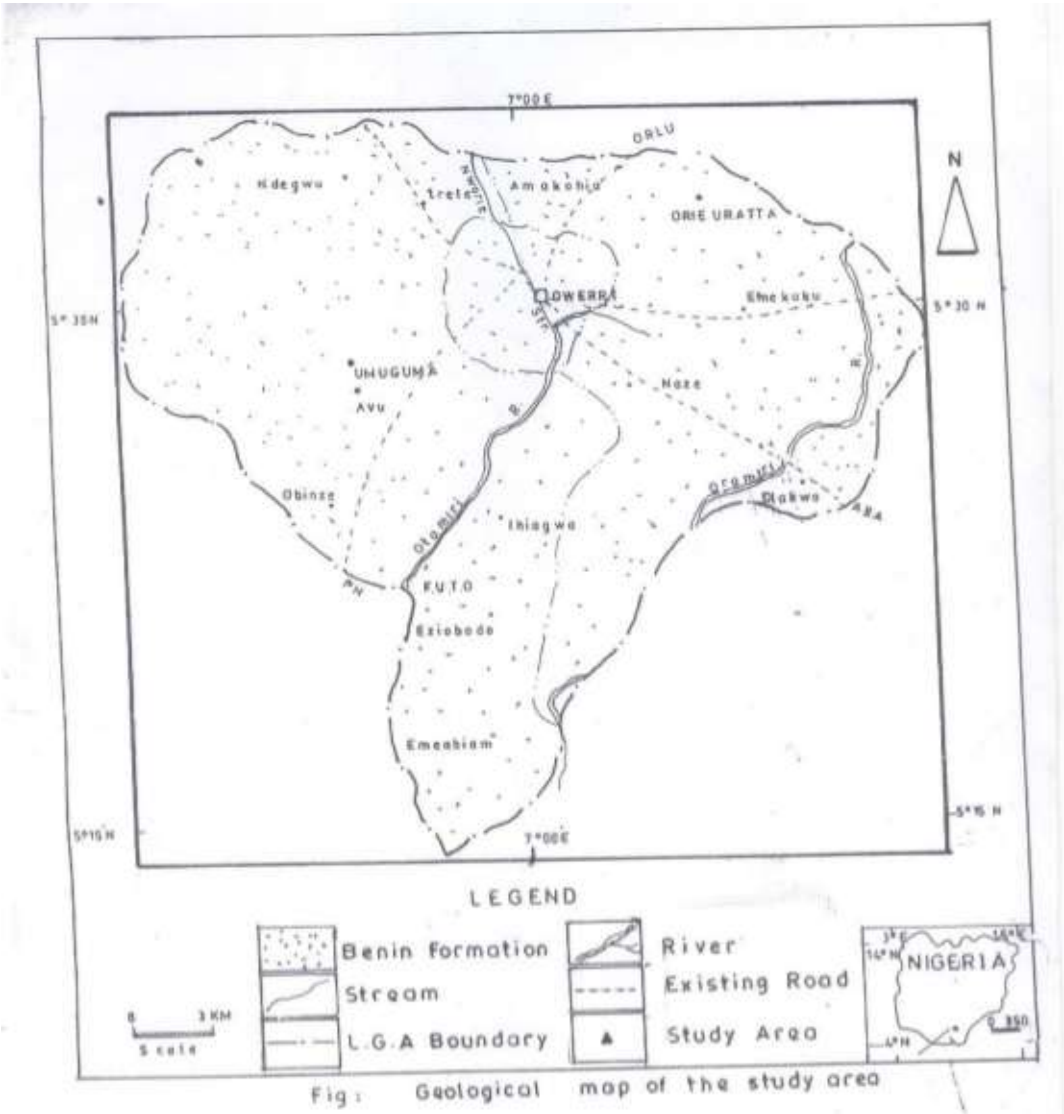

Figure 2: Geology map of the study area, southeastern Nigeria.

2. Methodology

2.1 Regional-Residual Separation

Regional-Residual separation involves a careful analysis of the potential field profile in the area within and beyond the area of immediate concern the map. In most cases such analysis is subjective because limited knowledge is known about the geology of the area under investigation.

Regional - residual separation can be carried out using polynomial fitting. This is a purely analytical method in which matching of the regional by a polynomial surface of low order exposes the residual features as random errors. For the magnetic data, the regional gradients were removed by fitting a plane surface to the data by using multi- regression least squares analysis. The expression obtained for the regional field T(R) is given as:

$$T(R) = 761.158 + 0.371x - 0.248y \quad \ldots \quad (1)$$

Average depth values to buried magnetic rocks using the power spectrum of total intensity field were achieved using spectral analysis. These depths were established from the slope of the log- power spectrum at the lower end of the total wave number or spatial frequency band. The method allows an estimate of the depth of an ensemble of magnetized blocks of varying depth, width, thickness and magnetization. Most of the approaches used involve Fourier

transformation of the digitized aeromagnetic data to compute the energy (or amplitude) spectrum. This is plotted on a logarithmic scale against frequency. The slopes of the segments yield estimates of average depths to magnetic or gravity sources of anomalies.
Given a residual magnetic anomaly map of dimensions l x l, digitized at equal intervals, the residual total intensity anomaly values can be expressed in terms of a double Fourier series expression given as:

$$T(x,y)=\sum_{n=1}^{N}\sum_{m=1}^{M}P_m{}^{n}\cos(\frac{2\pi}{L})(nx+my)+Q_m{}^{n}\sin[(\frac{2\pi}{L})(nx+my)] \quad \ldots(2)$$

where L = dimensions of the block, $P^n{}_m$ and $Q^n{}_m$ is the Fourier amplitude and N and M are the number of grid points along the x and y directions respectively. Similarly, using the complex form, the two dimensional Fourier transform pair may be written as:

$$G(U,V)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}g(x,y)e^{-j(ux+vy)}dxdy \quad \ldots(3)$$

$$g(x,y)=\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}G(U,V)e^{-j(ux+vy)}dudv \quad \ldots(4)$$

where *u* and *v* are the angular frequencies in the *x* and *y* directions respectively.

The use of this method involved some practical problems, most of which are inherent in the application of the Discrete Fourier Transform (DFT). These include the problems of aliasing, truncation effect or Gibb's phenomenon and the problems associated with even and odd symmetries of the real and imaginary parts of the Fourier transform. However, in this research, these problems were taken care of by the software used in the analysis.

The aliasing effect arises from the ambiguity in the frequency represented by the sampled data. Frequencies greater than the Nyquist frequencies, tend to impersonate the lower frequencies and this is known as the aliasing effect. To avoid or reduce the effect of aliasing, the frequencies greater than the Nyquist frequency must be removed through the use of an alias filter, which provides high attenuation above the Nyquist frequency. Aliasing can also be removed or reduced through the use of an alias filter which provides high attenuation above the Nyquist frequency. Aliasing can also be removed or reduced through the use of small sampling interval (Bath, 1974) such that the Nyquist frequency is equal to or greater than the highest frequency component present in the function being analyzed.
When a limited portion of the aeromagnetic anomaly is subjected to Fourier synthesis, it is difficult to reconstruct the sharp edges of the anomaly with a limited number of frequencies and this truncation leads to the introduction of spurious oscillations around the region of discontinuity. This is known as Gibb's phenomenon. This truncation is equivalent to the convolution of the Fourier transform of the function with that of a regular window, which is a sine cardinal function. This convolution introduces ripples at the edges of the function, which manifests itself as spurious oscillations at the discontinuity. Increasing the length of the window makes the Fourier transform tends towards a delta function with a subsequent reduction of the ripples at the edges. The function effect can therefore be reduced through the use of short sampling intervals and by selecting a large portion of anomaly or a long profile centered around the feature of interest .An alternative and even more effective approach to reducing the problem of Gibb's phenomenon is by the application of a cosine taper to the observed data (Bath,1974).

However, the analysis of the problems associated with aliasing and truncation or Gibb's phenomenon, have been taken care of by the computer software. An alias filter has been incorporated into the computer program to reduce the aliasing effect and a cosine taper has been applied to the data to reduce the effects of truncation.

2.2 Spectral Analysis

The application of spectral analysis to the interpretation of potential field data is one method that can be used to determine the basement depth, and is now sufficiently well established (Spector and Grant, 1991). Several authors have applied spectral inversion techniques in the determination of sedimentary thickness in various basins of the world (Ofoegbu and Onuoha, 1991 and Lius, 2009).

The power spectrum derived from a two-dimensional dataset such as a grid of Bouguer gravity data, also has inherently a two-dimensional form. For ease of interpretation an azimuthal average of the two-dimensional power spectrum is taken to produce a simplified one-dimensional output as shown in the figure 3 below. Sometimes the power spectrum can be divided into two or more straight line segments. The gradient of each segment may be related to the depth to an ensemble of anomalous sources which are within the range of spatial frequencies defined by the segment. The 'break points' (intersections of the straight line segments) provide suitable estimates of cut-off wavelengths for regional-residual separation. The azimuthally-averaged power spectrum of Bouguer gravity can also be used to derive regional depth estimates. (Spector and Grant, 1970).

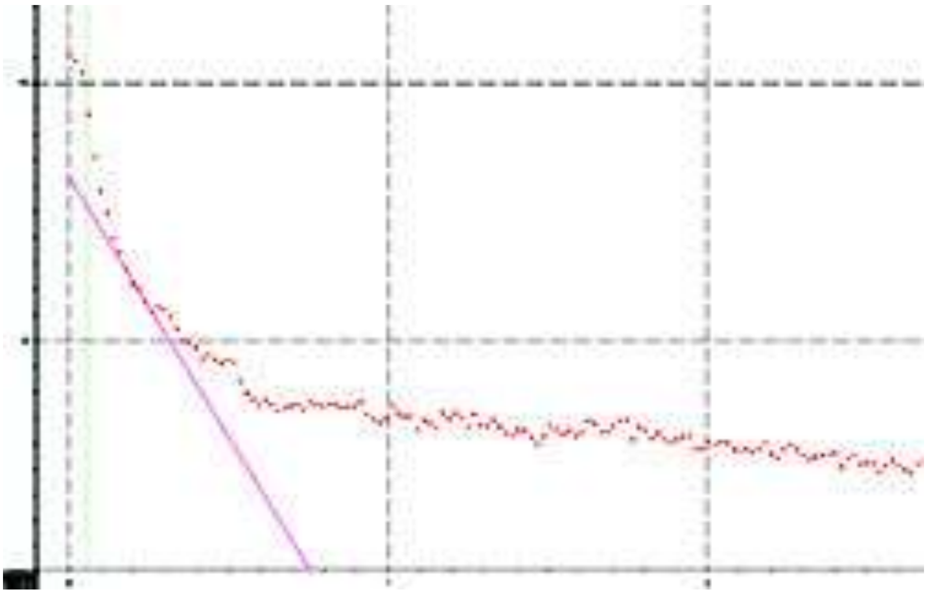

Figure 3: showing a one-dimensional output of a power spectrum

2.3 Vertical Derivatives

Vertical Derivative transforms are intended to facilitate the interpretation of gravity and magnetic RTP (or RTE) maps. They are enhancement techniques which amplify the shorter wavelength features relatively to those with longer wavelengths.

The second vertical derivative (SVD) transform is a mathematical transform based on Laplace`s equation. It has the effect of accentuating the shorter wavelength (shallower source) components at the expense of longer wavelength (generally deeper) features. Vertical derivatives of any order may be prescribed. The higher the order the greater is the relative amplification of higher frequencies and greater too is the risk of accentuating noise to an unacceptable degree. For this reason vertical derivatives of order three and above are hardly

ever calculated. Thus, the First Vertical Derivative (FVD) and second vertical Derivative (SVD) transforms are the only transforms of this type that are routinely generated.
The primary property of the SVD transform is that the ZERO CONTOUR represents the point of inflexion on the original anomaly curve which approximates the locations of edges of the causative bodies, providing that the bodies are shallow and have vertical sides.
The first vertical derivative can be used as an alternative to a residual display. The SVD or FVD is calculated using a filtered and unmasked grid of the Bouguer gravity or RTP/RTE magnetic anomaly.

2.4 Horizontal Derivatives

Gradient transforms are non-linear (so their order in relation to other processing steps such as frequency filtering will affect the final result) and are of two kinds. The Horizontal Gradient H[F] of an anomaly field F is calculated as the Pythagorean sum of the gradients in the orthogonal directions, choosing the directions to be along the ones of the grids.
This is thus the absolute value of the horizontal gradient at x, y, i.e. the value of the horizontal gradient in the direction of greatest increase.
Generally when calculating the Horizontal Gradient, the primary option is to calculate H[F], though options also exist to calculate the direction of the greatest rate of change and the trend.
The ridges of maxima on the Horizontal Gradient of Bouguer gravity are recognized by the industry generally as being good locators of shallow, vertical body edges. The same is true of magnetic data which has been transformed to pseudogravity. However, current ARK practice is to use the magnetic anomaly RTP rather than pseudogravity. The Total Gradient T[F(x,y)] of the field extends the Horizontal Gradient concept to three dimensions. For magnetic data the Total Gradient is the absolute value of a complex quantity known as the Analytic Signal and maxima also are indicators of body edges, independent of the Earth's magnetic field and direction of magnetization in bodies. The advantages of calculating the Total Gradient for gravity, if any, are not known.
The magnetic data used were obtained as part of the nationwide aeromagnetic survey which was sponsored by the geologic survey of Nigeria (GSN) and completed in 1976. Flight line direction was NNE-SSW at station spacing of 2 km with flight line spacing of 20 km at an altitude of about 150 m. Tie lines were flown in an ESE-WSN direction. Regional correct of the magnetic data was based on the IGRF (Epoch date 1 of January, 1974). For this study, aeromagnetic sheets 311, 312, 320 and 321 were used. The aeromagnetic maps were removed by fitting a plane surface to the data by multi-regression least squares analysis. The total intensity maps of the magnetic data are presented as surface plot in Figure 4, while the first to fourth degree regional and residual fields are presented in figure 5, respectively.
Similarly, Landsat Thematic Mapper (Landsat TM) imagery acquired on 17/ 02/ 2001 from NASRDA; Nigeria was used to map linear structures in the study area. The raw data was geo-referenced using the coordinates of the topographic sheets in the study area. The geo-reference projection was carried out using the Universal Transverse Marcator (UTM).
Image processing, enhancement and analysis were carried out using ILWIS 3.1 academic software. Image enhancement operations carried out include, contrast stretching, spatial filtering and edge detection, which were done to enhance sharpness of the satellite image for better visual interpretation, reduce noise in the image and to aid structural interpretation. Figure 6 is the Landsat- TM imagery. Arcview 3.2 software was used to extract the linearments and carry out statistical analysis of the interpreted linearments are further superimposed on the geology map. The linearment trend directions were summarized by using a rose diagram as shown in figure 7.

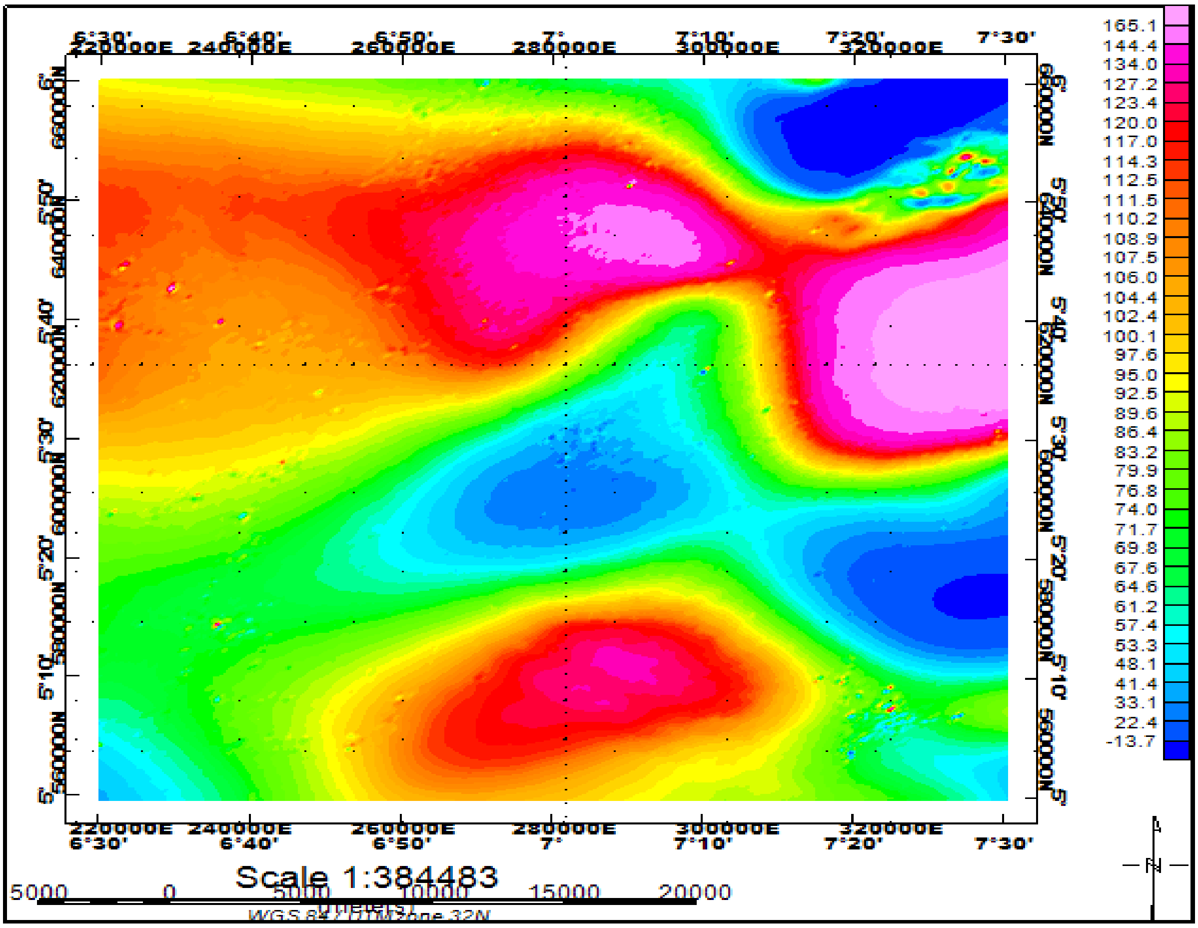

Figure 4: Total intensity map of the magnetic Data of the study area.

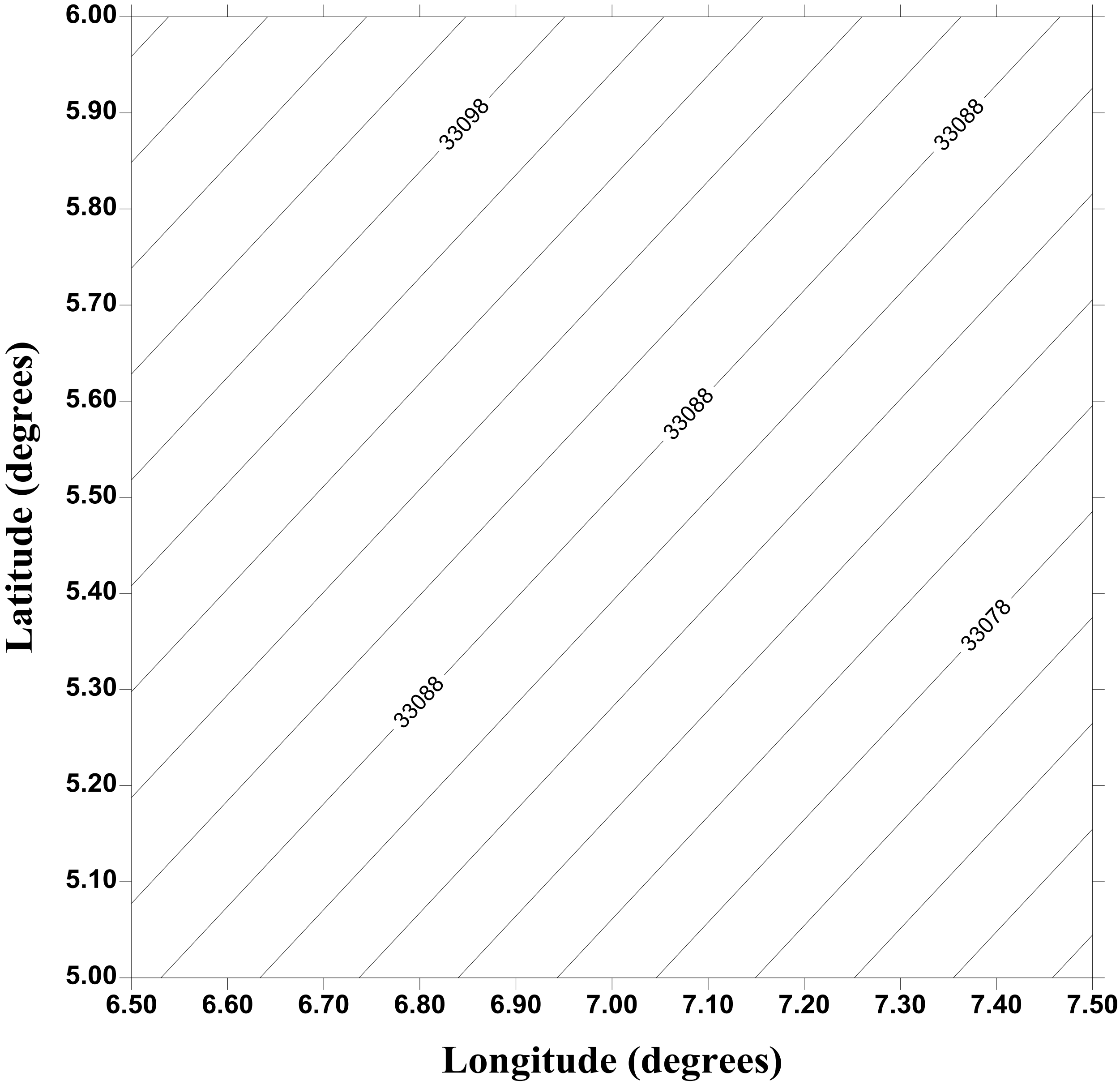

Figure 5: first degree regional fields of the Aeromagnetic Field of the Study Area.

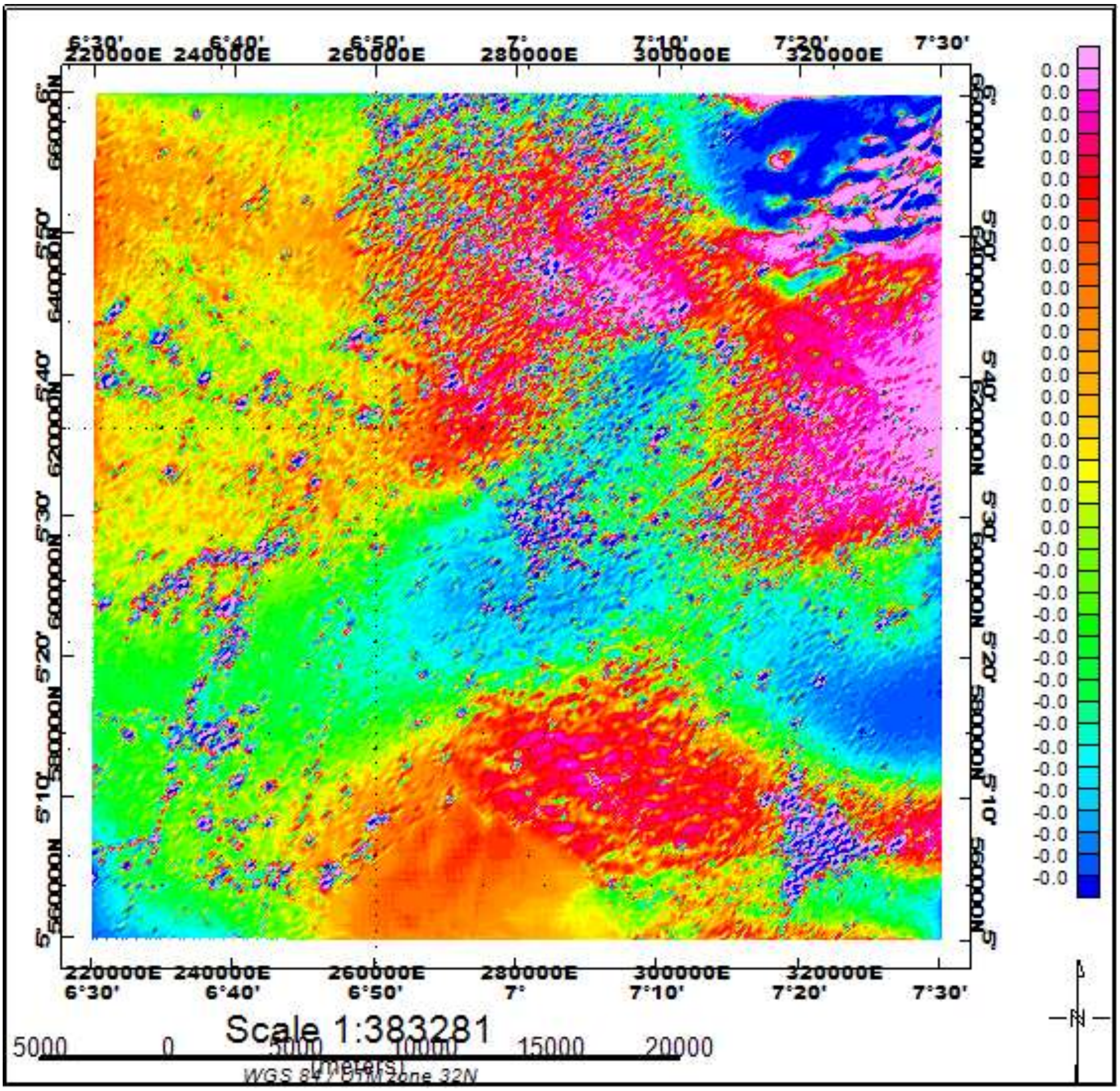

Figure 6: Non linear filter (NLF) contour Map of the magnetic data of the study area.

3. Result Interpretation and Discussion

The high resolution aeromagnetic (HRAM) data of Owerri were obtained from the Nigerian Geological Survey Agency (NGSA). The four-sheet data (5°00' - 6°00'N and 6°30' – 7°30' E) and in scale of 1:100000 were acquired at a flight altitude of 80 m, along NE-SW flight lines that were spaced at 500 m. The spatial variation effect in the geomagnetic field caused by the geomagnetic field derived from the outer core of the earth was removed (IGRF; 2040). The total magnetic field intensity ranges between 165.1 and -13.7nT (see figure 4). Most of the anomalies trend NE–SW, but some most especially at the southern segment of the map (figure 7) trend E-W. A very high magnetic intensity was observed between longitude 6°00' - 53°00'E, and latitude 5°15' – 5°30'N (see figure 1).

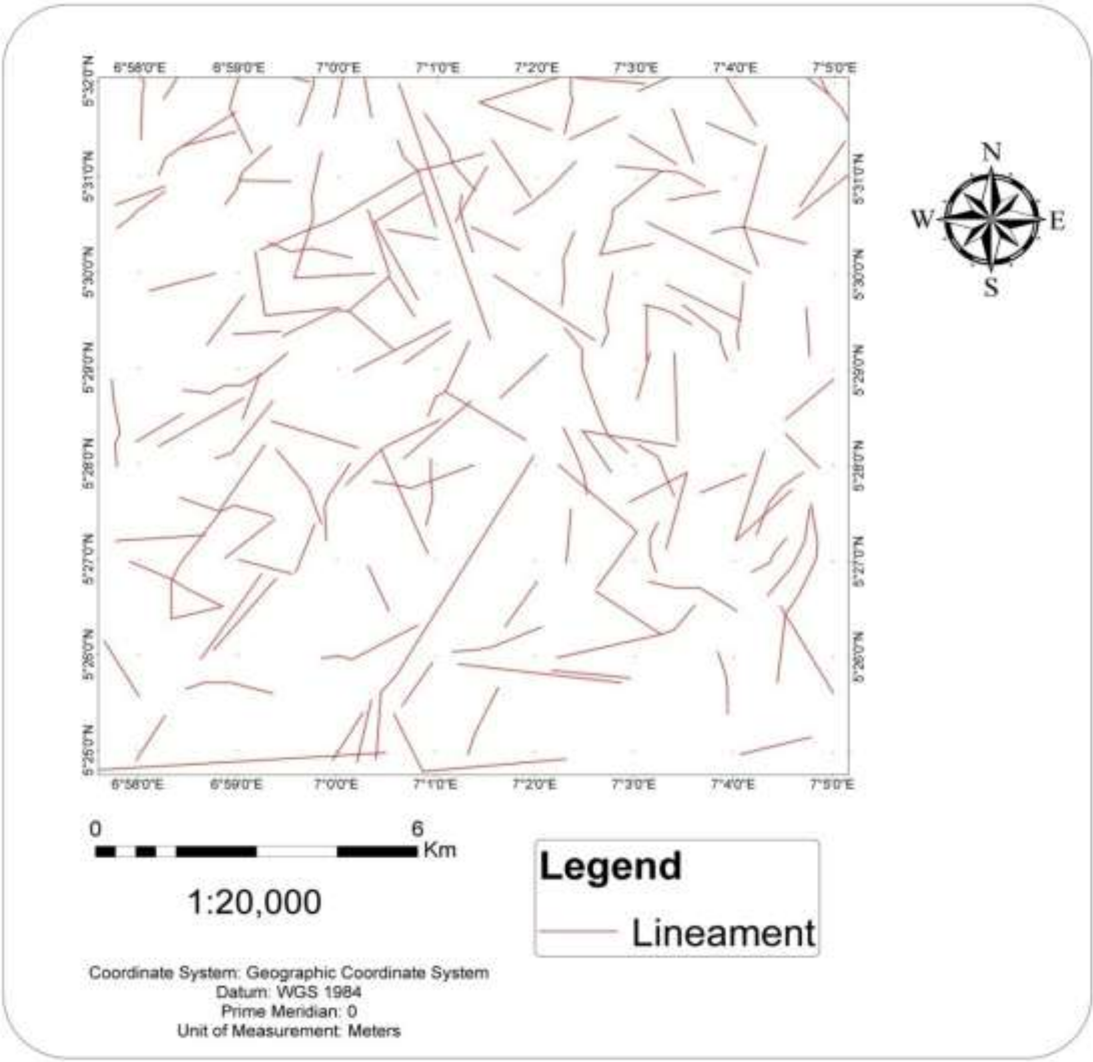

Figure 7: Land sat – ETM image of the study Area showing interpreted Lineaments and Drainage.

The low-pass filtering with a cut-off wavelength was applied to the residual magnetic field data. The choice of the cut-off wavelength was guided by the spectral data for the study area (see figure 6).

For the low-pass filtered (figure 9), frequencies ranging from the minimum value to the cut-off are thus passed without modification. Figures 6 show the contour map of the low-pass filtered residual data, the low pass filtered map reveals the characteristics of the deep anomaly.

Vertical gradient (Vertical derivative) can be thought of as component of the rate of change of the anomaly values as the potential-field data are upward continued. Nonetheless, vertical-gradient maps help highlight the details, discontinuities and breaks in anomaly texture. Derivatives are intended to outline boundaries.

Second vertical derivatives $\left(\Delta T'' = \frac{\partial^2(\Delta T)}{\partial Z^2}\right)$, given that ΔT and Z are changes in magnetic field and vertical displacement respectively, are conventionally used to enhance near-surface

effects obscured by the regional trends and also as aid in the definition of the edges of source bodies. The second vertical derivative has even more resolving power than the first vertical derivative, but its application requires high quality data as its greater enhancement of high frequencies result in greater enhancement of noise. It was shown that second vertical derivative is zero and rapidly changes sign at a point vertically over the contact. In magnetic data interpretation, second vertical derivatives are used to delineate the plain-view boundaries of intra-basement anomaly sources and are also found to be effective for enhancement of magnetic anomalies.
From the second vertical derivatives (figure 11) map which outlines the edges of the anomalous bodies, the depth to the top of a body is estimated to be half the width of the distance between the zero contours. The first and second vertical derivatives of the low-pass filtered aeromagnetic data were derived using Geosoft oasis Montaj software.

The horizontal derivative (figure 12) is a technique that enhances the strike of the anomaly. The analytic signal (or total gradient) is the combination of vertical and horizontal gradients i.e. a calculation of the first derivative of magnetic anomalies, to estimate source characteristics. It is independent of the angle of inclination and declination of the magnetic field vector and the magnetization vector. For a thin sheet-like body (dyke), the location of the source in the horizontal plane can be deduced from the positive peaks of the amplitude of the analytic signal. The analytic signal of the reduced aeromagnetic data was computed and the map was subsequently plotted.
The tilt derivative (TDR) procedure, introduced in 1994 and tested in gravimetric data, has as its main characteristic to equalize the maximum amplitudes, making it independent from the source depths, and positioning them directly over their centers. This last attribute, however, shows that TDR is not a method for detecting the borders, as mentioned by Naudy (1971). Due to the trigonometric characteristics of the tangential arc, TDR varies from $-\pi/2$ to $+\pi/2$ and depends on the magnetic inclination.

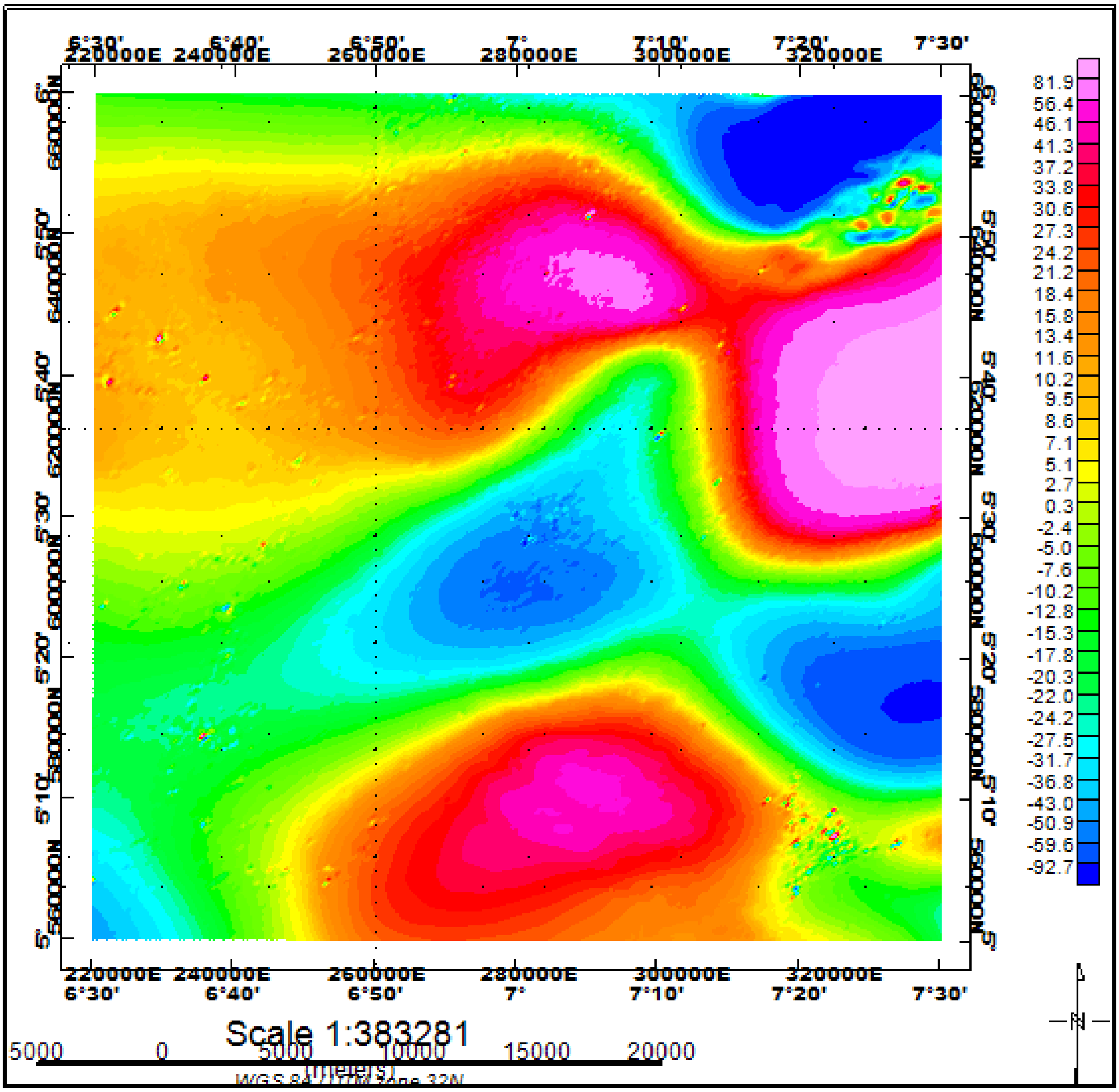

Figure 9: A low-pass filtered map of the study area.

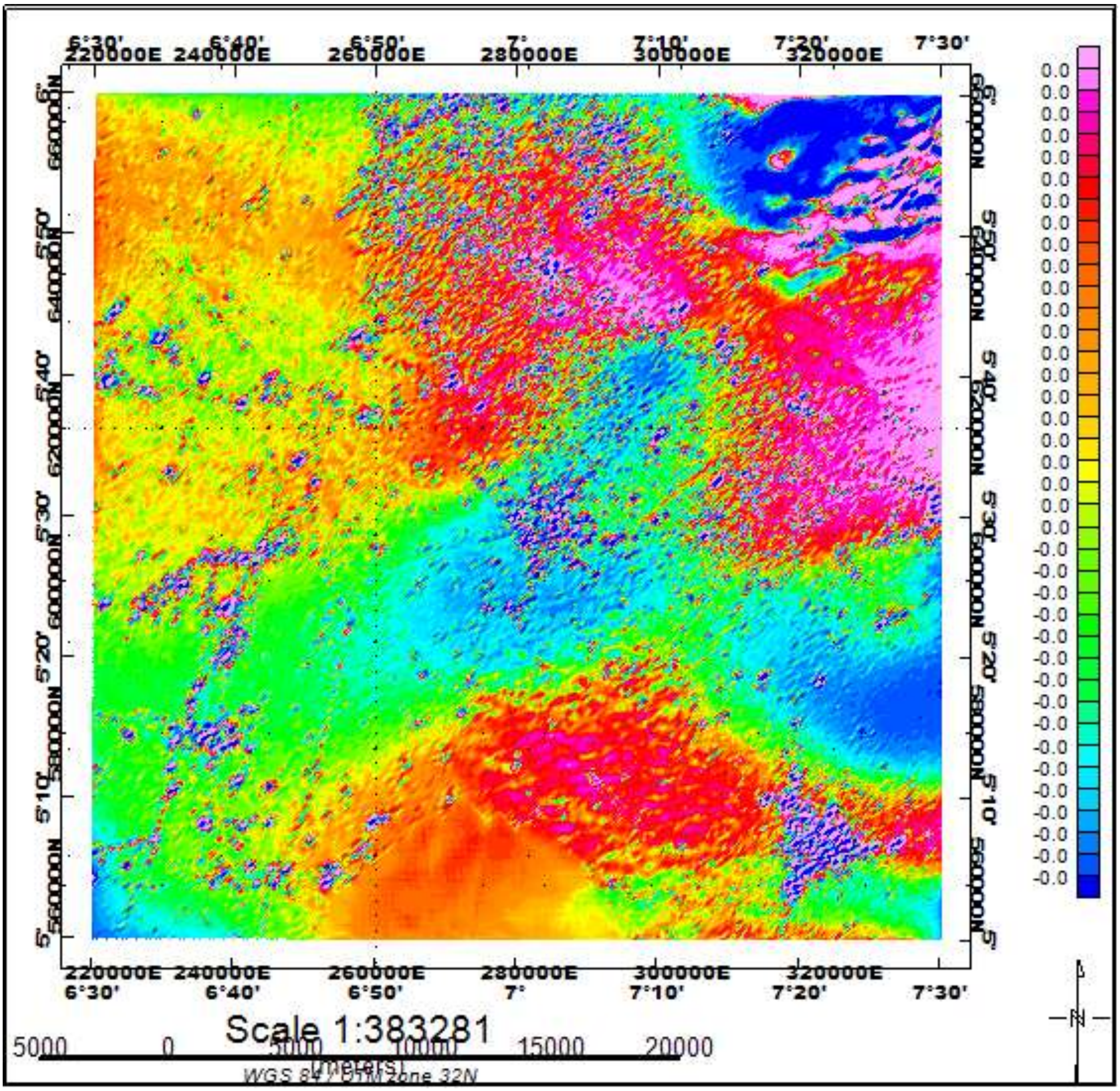

Figure 10: First vertical derivative map of the study area.

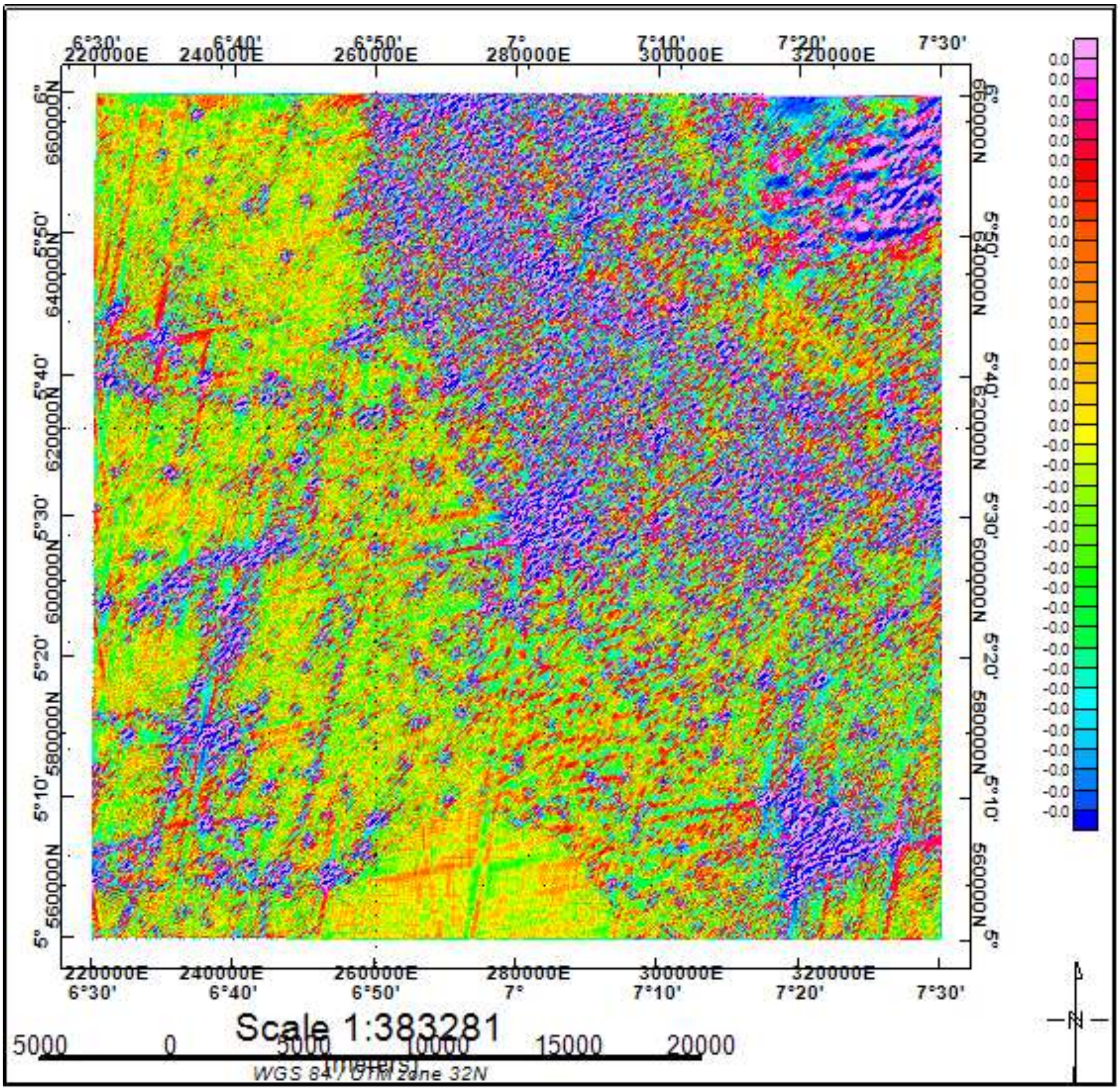

Figure 11: Second vertical derivative of the study area.

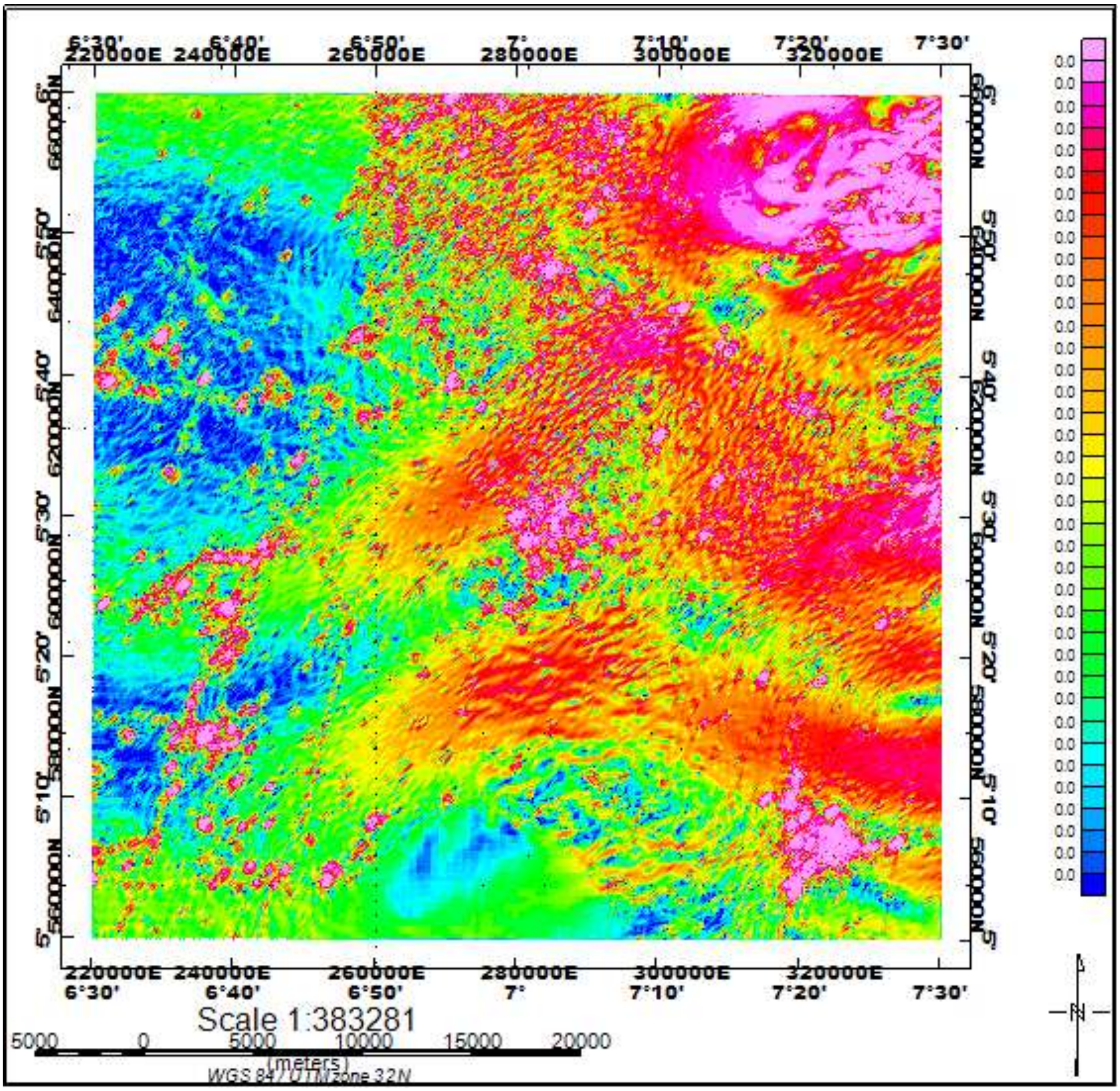

Figure 12: Total horizontal derivative map of the study area.

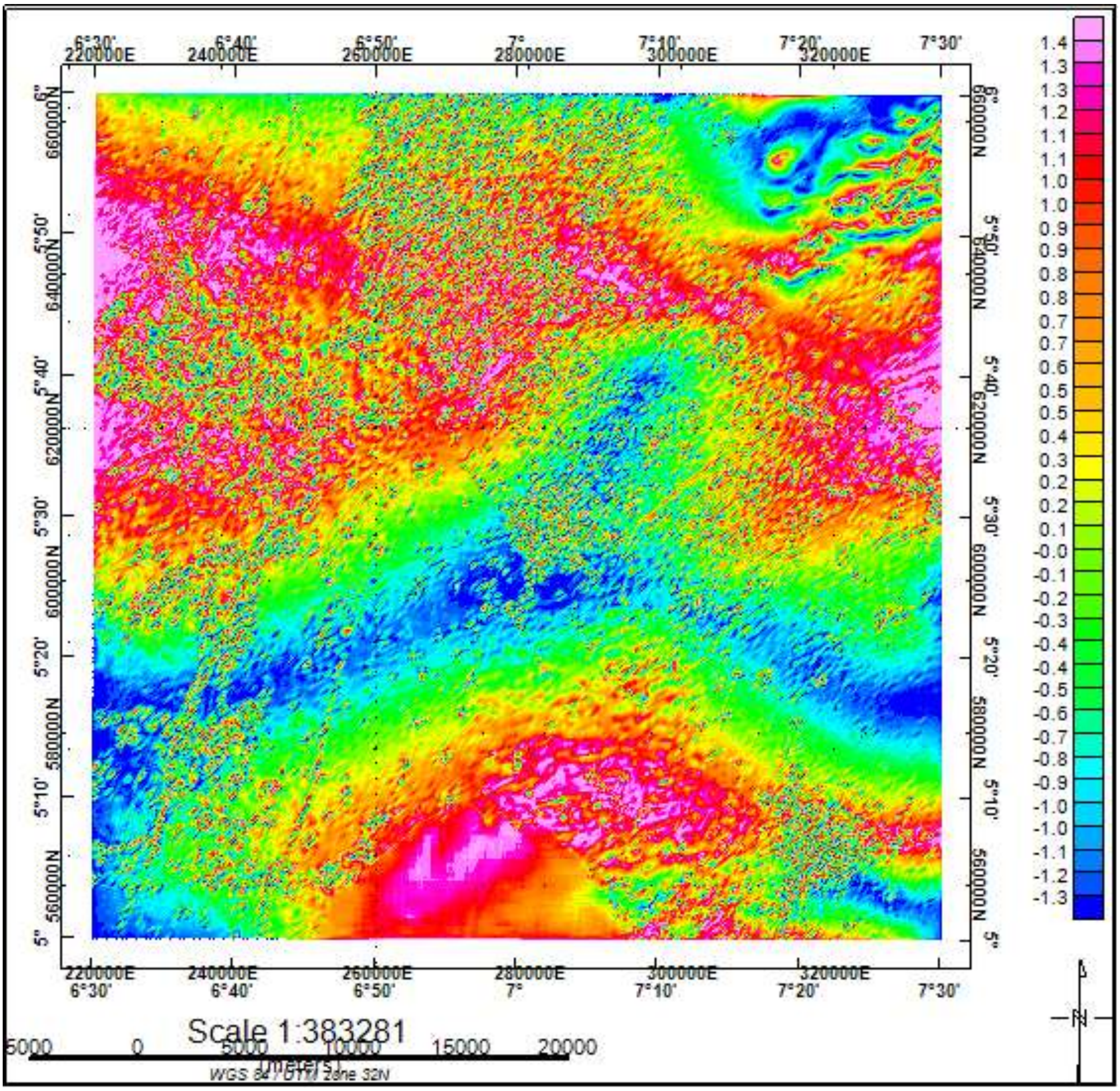
Figure 13 : Tilt derivative map of the study area.

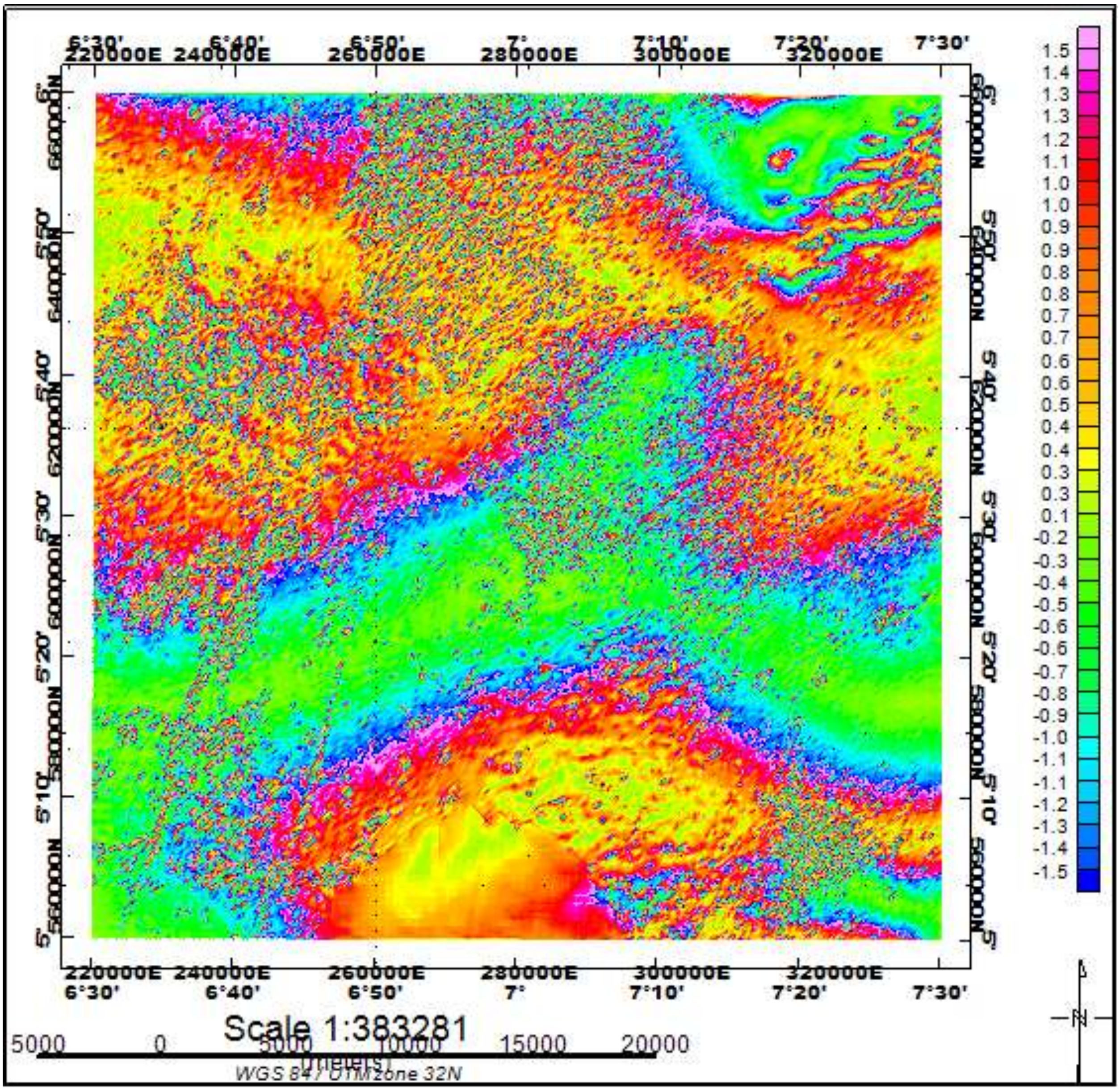

Figure 14: Horizontal tilt derivative map.

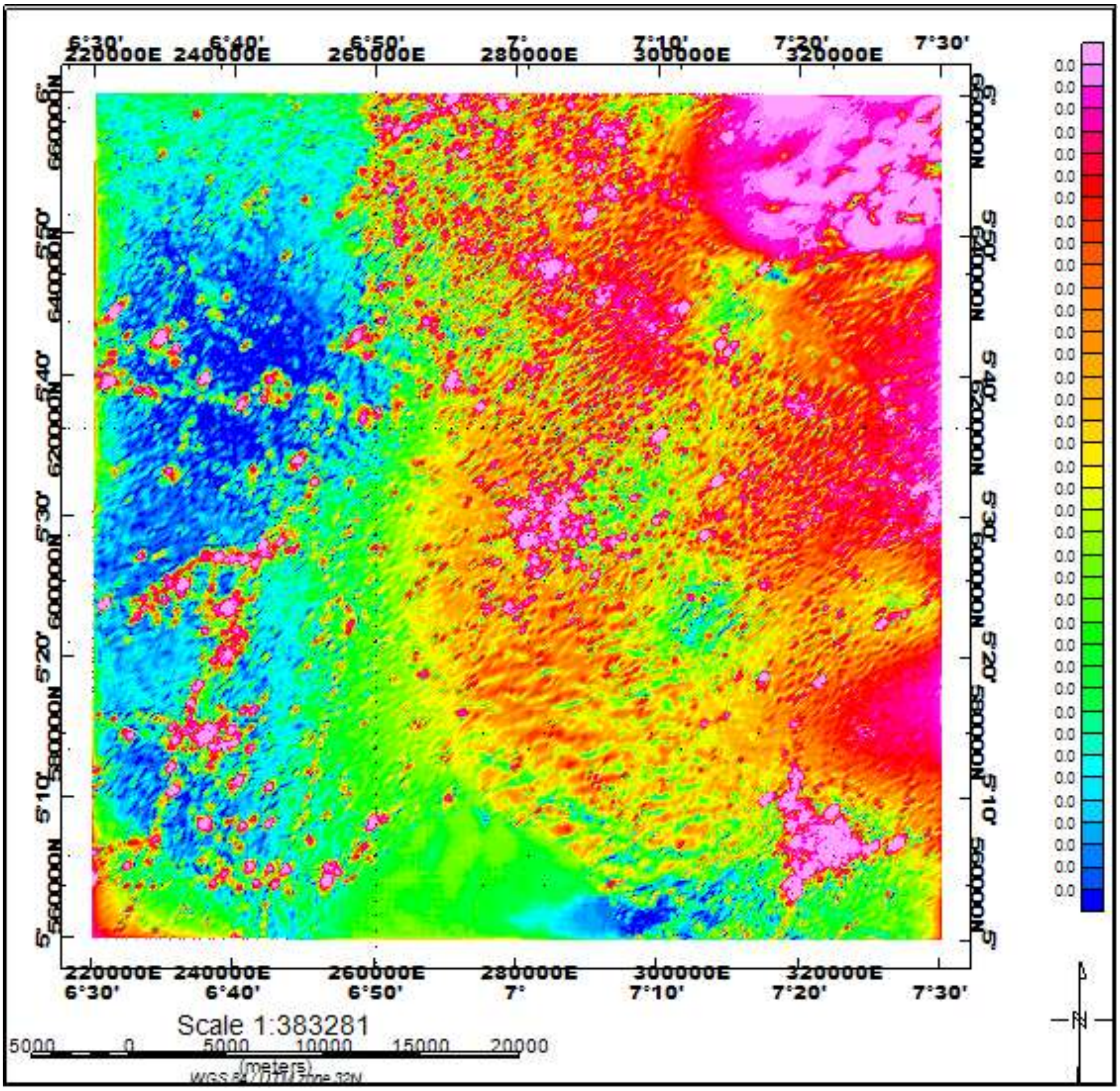

Figure 15: Analytic signal map of the study area.

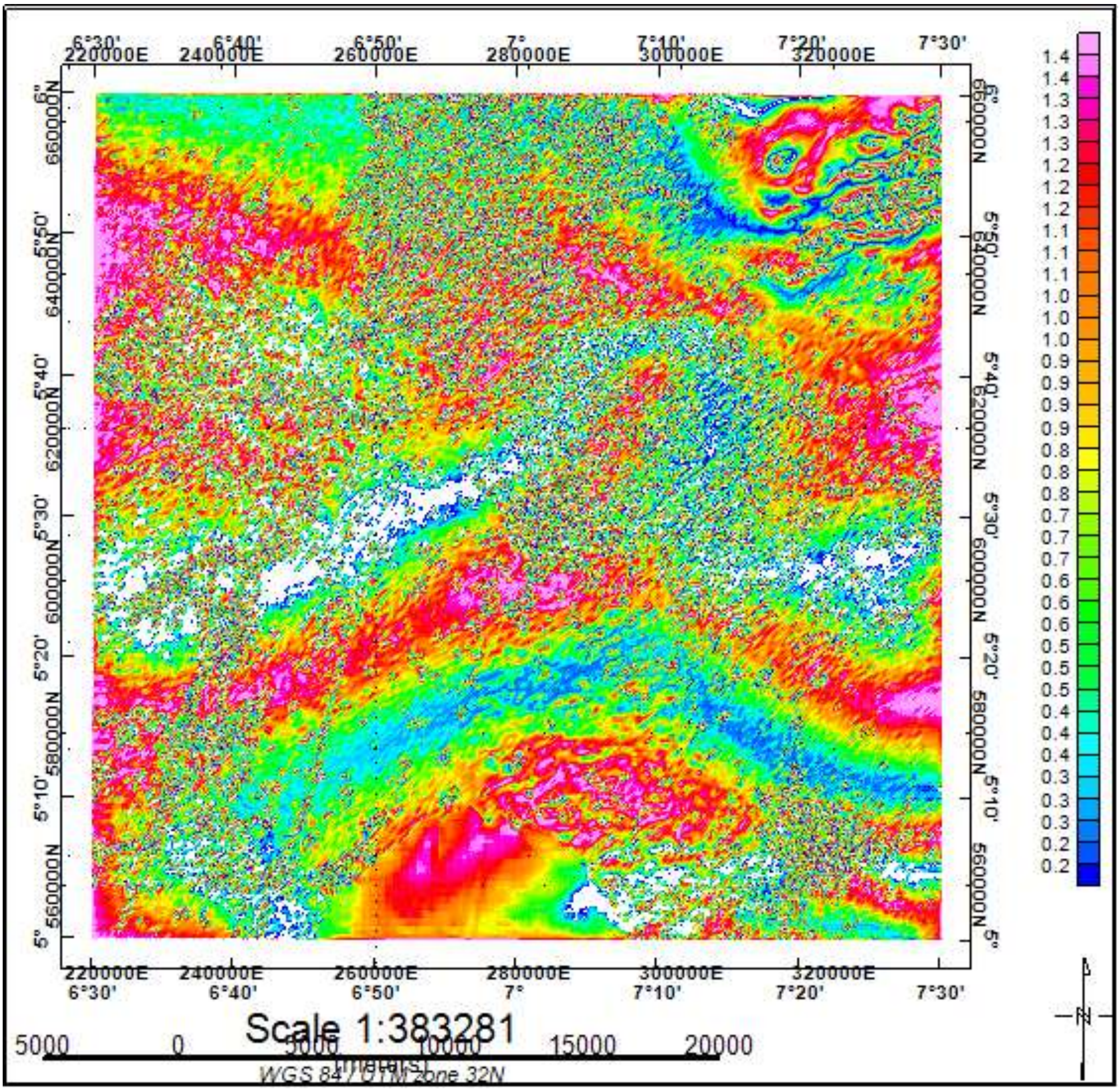

Figure 16: Theta map of the study area.

The magnetic method is a powerful tool that can be successfully applied in structural studies. Since magnetic method provides a relatively direct mapping of the abundance of magnetic minerals, it also serves as a useful indicator of lithology, structure, weathering and alteration processes. Aeromagnetic survey is utilized to delineate the subsurface structure which controls the anomalous mineralization zones.

The second vertical derivative (figure 11) analysis provides a means of discriminating local features while suppressing broad and regional structures. The zero value of the second vertical derivative map, which indicates the presence of a boundary, clearly defined the edges of the anomalies in the study area.

THDR and the analytic signal amplitude have been reported to be useful for outlining the gross shape of some features. The amplitude of both total horizontal derivative (figure 12) and analytic (figure 15) is high around Itakpe mineralized hill, 7°36'52" N,6°19'07" E (see figures 4.2 and 4.3). This could be due present of Hematite and magnetite.

Unlike ASA and THDR that enhances the shallow anomalies alone, the theta map (figure 16) enhances both shallow and deep anomalies simultaneously, thereby producing a balanced result.
In this research, aeromagnetic maps have been used to investigate the presence of faults in the study area. Both qualitative second vertical derivative, total horizontal derivative, analytic signal, theta map, tilt derivative (figure 13), total horizontal derivative of tilt derivative and horizontal tilt angle (figure 14) and quantitative Werner and Euler deconvolution interpretation techniques were chosen to achieve the outlined objectives of this research.

4. **Conclusion**

Wave number – domain processing of magnetic data observed over landfills will enhance particular attributes of the magnetic field which will aid in the interpretation of the anomaly sources. Upward continuation, vertical gradients, and wave length filtering are shown to be effective procedures. Furthermore, the calculated vertical gradient suggesting that the dual observations at a station are eliminated except during periods of extreme temporal magnetic-field variations.
Lineaments trending NE – SW and other adjoining lineaments are revealed by the second vertical derivative map. Similar indications are observed from the maps of first vertical derivative (figure 10), theta, total horizontal derivative, tilt and horizontal tilt derivative.
Some lineaments might serve as conduits for leachate of dumpsites. This was observed from the analytic signal map, the inferred dumpsites are characterized by high susceptibility contrast sandwiched in a low magnetic susceptibility. The leachate may be containing high iron component resulting in high magnetic intensity.
A magnetic highs and lows is observed consistent at the northeastern edge of the maps of tilt derivative, second vertical derivative, first vertical derivative, horizontal tilt derivative and theta. This magnetic characteristic is indicative of folds.

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