Integrating Landsat-ETM and Aeromagnetic Data for Enhanced Structural Interpretation over Naraguta Area, North-Central Nigeria.

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ABSTRACT- Structural interpretation over Naraguta area was carried out using aeromagnetic and Landsat ETM data with the objective of delineating the linear features of the study. Several image processing and analytical techniques were applied to the aeromagnetic and landsat data to improve the data quality and resolution. Linear features identified in the study area revealed principal trend directions in the NW-SE, NE-SW, N-S and E-W directions with the N-S trend been dominant. Results of the 2-D spectral analysis of the aeromagnetic data revealed a two depth source model. The depth to the deeper magnetic source bodies has an average depth of 2.03km. This layer may be attributed to magnetic rocks of the basement, lateral variations in basement susceptibilities and intra- basement features like faults and fractures. The shallower magnetic sources with an average depth of 0.265km could be attributed to near surface magnetic sources, which are magnetic rocks which intruded into the sedimentary overburden. Most of the interpreted lineations were observed to correspond to the trends and positions of the trans-oceanic fracture zones in the area. There is also a marked correlation of the location of the Younger Granite Ring complexes and the lineaments in the study area. This observed relationship may be attributed to tectonic control of secondary mineralization in the study area. Most of the lineaments also correlated with the orientation of the drainage lines indicating that the drainage system in the area may be structurally controlled. Finally, the drainage pattern in the study area was observed to be dendritic which is indicative of lithological heterogeneity.

Keywords: Aeromagnetic, Basement depth Landsat-ETM, Naraguta, Lineaments, Younger granite, Structural interpretation

1.0 INTRODUCTION

The significance of airborne magnetic survey in the interpretation of linear features and other geological structures has been tremendous over the past few decades. It has been proven as one of the verifiable tools used by geoscientist in carrying out depth- to -source estimation and interpretation of geologic features that may lead to identification of mineral fetch areas [1], [2]. The interpretation of aeromagnetic maps in the past decade has moved from the interpretation of basement structures to detailed examination of structures and lithologic variations in the sedimentary section.

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Magnetic anomalies are the major forerunner of mineralization, especially along fault planes. The magnetic anomaly signature characteristics are results of one or more physical parameters such as the configuration of the anomalous zone, magnetic susceptibility contrasts as well as the depth to the anomalous body. The broad magnetic closures seen on the total magnetic intensity anomaly maps are often due to changes in the rock composition within the basement. If the magnetic units in the basement occur at the basement surface, then depth determinations will map the basin floor morphology. Magnetic basement is an assemblage of rocks that underlies sedimentary basins and may also outcrop in places [2], [3]. In many sedimentary basins, magnetic anomalies arise from secondary mineralization along fault planes, which are often revealed on aeromagnetic maps as surface linear features. Most mineral deposits are therefore related to some type of deformation of the lithosphere, and most theories of ore formation and concentration embody tectonic or deformational concepts [1], [3], [4], [5]. In areas where there is exposure of the basement, magnetic anomalies are due mainly to the mineralogical content of the basement. These are chiefly magnetic minerals present in the basement rocks. On the

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other hand, the application of satellite imagery in regional geologic mapping has been phenomenal as a result of its ease of operation, speed, accuracy, low cost and wide area coverage[6],[7],[8]. The usefulness of landsat interpretation has come handy in production of new geologic maps as well as revision of old ones [8]. Also, in the area of hydrogeology, the importance of satellite imagery is heavily felt in the exploration of groundwater especially within areas underlain by the basement complex.

This research therefore aims at making geological interpretation over Naraguta area based on aeromagnetic and Landsat satellite imagery. The objectives are to determine the basement depth, establish the basement topography and relief; determine the structural and tectonic features associated with the younger granite complex and to infer the effect of such structures on the basin.

1.1 Background Geology

The area being studied lies within the Jos-Bukuru Younger Granite Ring Complex of North Central Nigeria of Jos Plateau in the main mining area, with its location at about latitudes 9°301 – 10°001N and longitudes 8°301 – 9°001 E. The Nigerian Younger Granites Ring Complexes are a series of petrologically distinctive crystalline igneous rocks of granitic composition. Several individual complexes have been identified with varying sizes and named after their localities with individual massifs ranging from 640km2 to less than 1.68km².The Younger Granites are discordant high level intrusions emplaced by means of piecemeal stoping through the collapsed central block [9], [10], [11],[12]. Their emplacement is completely unrelated to orogenic activity. Their age is Jurassic, around 160 to 170 million years; the older granites and accompanying metamorphism of the basement are dated at about 500 to 600 million years, and represent the Pan African orogeny in Nigeria[11],[10]. However, it seem likely that emplacement of the Younger Granites was associated with epeirogenic uplift. Indirect evidence for this is lack of sediments associated with the volcanic rocks of Younger Granite age, which are apparently erupted on to a land surface undergoing erosion, not deposition. The major components of most complexes are granitic ring dykes that range from 5 km or less to over 30 km in diameter [9], [11], [13].

Generally, the younger granites are characterized as anorogenic, peralkaline rocks that intrude the basement discordantly to form highly steeped hills. They occur generally as ring dykes and cone sheets. The province contains approximately 50 Jurassic ring complexes (165 MA) intruded into a Cambrian to Precambrian basement complex (600 MA) which forms the central plateau region; the Jos Plateau of Nigeria [14]. These complexes include soda pyroxene and amphibole biotite, fayalite granites, syenites, and trachytes with minor gabbros and dolerites. There are rare volcanic compositions such as rhyolites, tuffs, and ignimbrites [15]. Kinnaird [16] recognized a series of hydrothermal alteration processes with related mineralization in the anorogenic ring complexes. Early sodic metasomatism may have affected both peralkaline and peraluminous granites whilst latter processes, beginning with potash metasomatism, may have affected only the biotite granites. Acid metasomatism, subsequently resulted in processes of greisenization and silicification, with each defining clearly a sequence of ore deposition. Chloritization and argillization are important but more restricted processes in the study area [9], [13].

The geological map of the study area (Fig.1) revealed that the area is underlain by the Precambrian crystalline basement of Migmatite-Gneiss complex which is directly overlain by older granites, subsequently by younger granites and newer basalts of quaternary-tertiary age that occurs as lava flows and volcanic cone[9],[13].

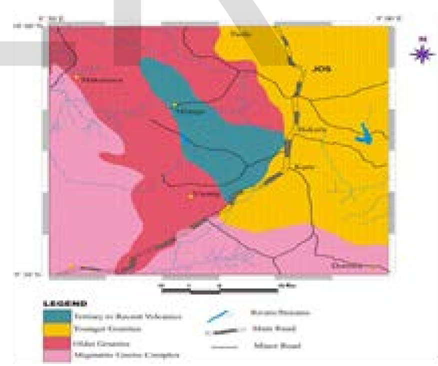


Fig. 1. Geological Map of Study area

2.0 THEORY AND METHODS

The data used in this research work is part of the high resolution airborne aeromagnetic data obtained from the Geological Survey of Nigeria (GSAN) in 2009 and the seven-band Landsat ETM imagery acquired on 29th March 2013. They are both extensively used as reconnaissance tools in oil and mineral exploration. Similarly, both have surficial discontinuities recognized by the common correspondence of linear anomalies to surficial evidence of faulting across most areas [6].

The aeromagnetic data used were subjected to a lot analytical procedures including low pass filtering operations. The nature of filtering applied to the aeromagnetic data in this study in the Fourier domain was chosen to eliminate certain wavelengths and to pass longer wavelengths. Several potential field softwares with different analytical modules were used in the interpretations of the aeromagnetic map. These include Geosoft Oasis Montaj 7.4.2.HJ version, U.S. Geological Survey Potential-Field geophysical software Version 2.0, Surfer 12 and Matlab 7.5. Regional - residual separation was carried out using polynomial fitting. This is a purely analytical method in which matching of the regional field 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) was given as:

T (R) = 7612.158 + 0.371x – 0.248y …………… (1)

The regional trend is represented by a straight line, or more generally by a smooth polynomial curve. The fitting of polynomials to observed geophysical data is used to compute the mathematical surface giving the closest fit to the data that can be obtained within a specified degree of details. This surface is considered to approximate the effect of deep seated or regional structures if it is of low degree.

Average depth values to buried magnetic rocks using the power spectrum of the total intensity field were achieved using spectral inversion. 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 by[17], [18],[19]as:

$$T(x,y) = \sum_{n=1}^{N}\sum_{m=1}^{M} P_m^n \cos\left\{\left(\frac{2\pi}{l}\right)(nx+my)\right\} + Q_m^n \sin\left\{\left(\frac{2\pi}{l}\right)(nx-my)\right\} \ldots (2)$$

where, l = dimensions of the block, and 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:

$$G(u,v) = \int\int_{-\infty}^{\infty} g(x,y)\, e^{(u_x+v_y)} dxdy \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

and g(x,y) = $\int\int_{-\infty}^{\infty} G(u,v)\, e^{j(u_x+v_y)} dudv \ldots\ldots\ldots..(4)$

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

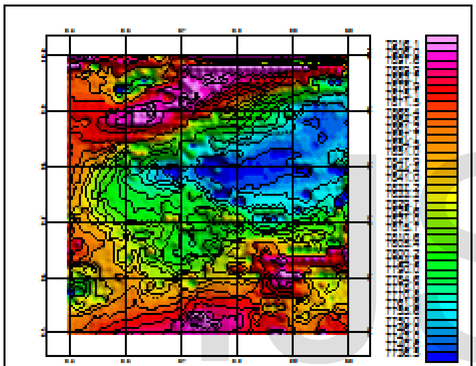
The use of this method involves some practical problems, most of which are inherent in the application of the Discrete Fourier Transform (DFT). They include the problems of aliasing, truncation effect or Gibb's phenomenon and the problems associated with even and odd symmetries of the real and imaginary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

Other analytical methods used include Reduction-to-Pole, Second vertical derivatives and trend surface analysis. Reduction-to-pole (RTP) transformation was applied to the aeromagnetic data to minimize polarity effects [20]. The RTP transformation usually involves an assumption that the total magnetizations of most rocks align parallel or anti-parallel to the earth's main field. Similarly, second vertical derivative filters were used to enhance subtle anomalies while reducing regional trends. These filters are considered most useful for defining the edges of bodies and for amplifying fault trends. Mathematically, a vertical derivative is seen as a measure of the curvature of the potential field, while zero second vertical derivative contours defines the edge of the causative body. Thus, the second vertical derivative is in effect a measure of the curvature, i.e., the rate of change of non- linear magnetic gradients. The zero magnetic contours of the second vertical derivative often coincide with the lithologic boundaries while positive and negative anomalies often match surface exposures of the mafic and felsic rocks respectively [21].

3.0 RESULTS AND INTERPRETATION

The aeromagnetic data used in this research was obtained from the Geological Survey of Nigeria (GSN) being part of the nationwide survey carried out in 2009. Flight line direction was NNW-SSE at station spacing of 2km with flight line spacing of 20km at an altitude of about 150m. Tie lines were flown in an ENE-WSN direction. Regional correction of the magnetic data was based on the IGRF (epoch date1 of January, 2010). For this study, aeromagnetic total magnetic intensity data of Naraguta (Sheet 168) was used. The regional gradients were removed by fitting a plane surface to the data using multi- regression least squares analysis.

The total magnetic field intensity map derived after digitization of the contour map is presented as: total field intensity map and basement surface map respectively (Figs.2&3).



Total magnetic field intensity of Naraguta

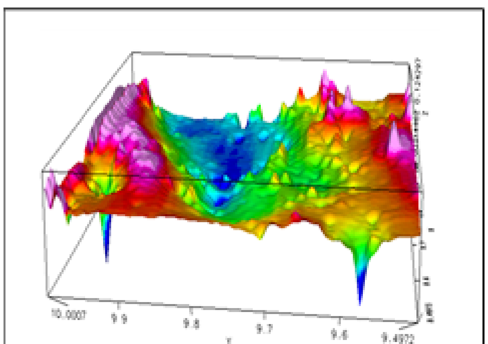


Fig 3 3-D model of the aeromagnetic data of the study area showing basement relief and topography

Other maps presented include regional polynomial surfaces map (Fig. 4), first to fourth degree residual maps(Fig.5) and reduction-to-pole map (Fig.6).The Reduction-to-Pole aeromagnetic map was computed from the grid of total field magnetic data to minimize polarity effects[20]. The RTP transformation usually involves an assumption that the total magnetizations of most rocks align parallel or anti-parallel to the Earth's main field. The total field of the aeromagnetic data is characterized by low magnetic anomalies with intensity values ranging from 7770 to 7740 gammas trending in the NE-SW direction. This area has a broad low intensity surrounded by fairly high intensity area (Fig.2). Broad low intensity anomalies are normally attributed to basins which contain sediment infill; but in this case, the younger granite complex is rather part of the basement complex. The down-warping in the basement may be attributable to faulting, prolonged weathering and erosion of the exposed basement surface. Areas with this down-warped topography cover Jos, Bukuru and Kuru areas. Within the northwestern section of this map, there exist magnetic linear features which could be interpreted as deep-seated faulting of regional extent. There are chains of small circular magnetic anomaly closures, interpreted as granitic intrusions observed within the northern fringe of the map (Fig.2).This feature noticed around Tsofo, has an E-W trend and is suspected to be part of the ring complex. Apart from the low magnetic intensity seen around the central portion of the map, high magnetic intensity values are observed on the northwestern and southeastern sections of the map. A prominent high magnetic closure with intensity values of 8000gammas was observed around Makasuwa on the southern portion of the map. Another linear anomaly in the southeastern portion with a sharp gradient may be interpreted as a fault. The study area may be interpreted as being tectonically active with the northwestern and southeastern portion being more active than the central portion. This low anomalous region appears to be a product of basement subsidence (Figs.3and4). The feature earlier observed at Tsofo appears as see-saw feature on the basement surface and 3-D relief maps. The magnetic closures interpreted previously appear as spiky intrusive surfaces on the 3-D relief map.

Subsurface linear structures identified in the study area from first - fourth degree regional and residual maps (Figs. 4&5) revealed lineation with trend directions in NW-SE, E-W,N-S and NE-SW. The N-S trend is probably the most dominant orientation in the study area. The N-S and NE-SW linear trends are believed to have played a major role in the control of the geodynamic evolution of the study area. Previous aeromagnetic anomalies suggest that a series of buried NE–SW lineaments of incipient rifts controlled the disposition of the individual complexes [22].Similarly, second vertical derivative filters were used to enhance subtle anomalies while reducing regional trends as shown in figure 7. These filters are considered most useful for defining the edges of bodies and for amplifying fault trends. Mathematically, a vertical derivative is shown as a measure of the curvature of the potential field, while zero second vertical derivative contours defines the edge of the causative body.Thus, the second vertical derivative is in effect a measure of the curvature, i.e., the rate of change of non- linear magnetic gradients. The zero magnetic contours of the second vertical derivative often coincide with the lithologic boundaries while positive and negative

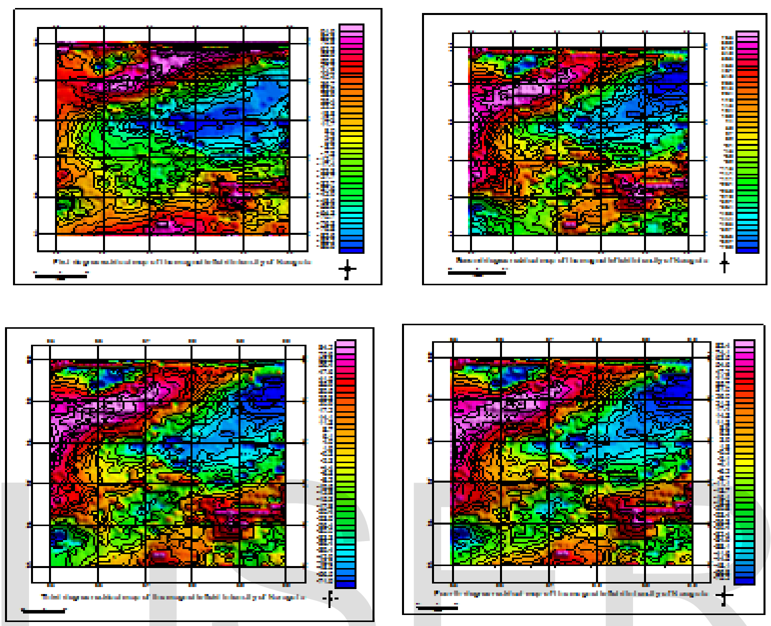


Fig.5. First to Fourth Degree residual fields of the Aeromagnetic data.

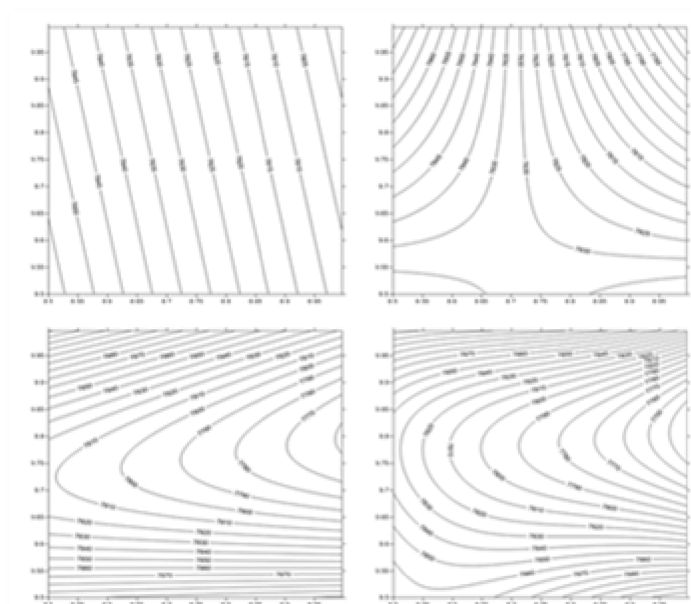


Fig.4. First to Fourth Degree (polynomial) surfaces of the regional fields of the aeromagnetic data

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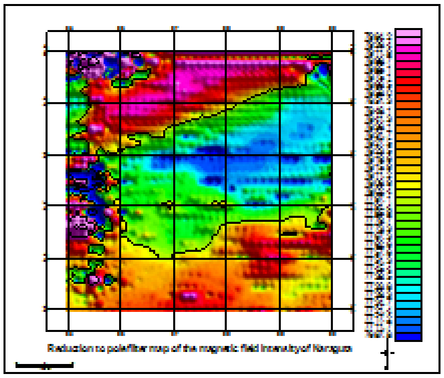

Fig. 6. Reduction to pole map of the magnetic field intensity of the study area

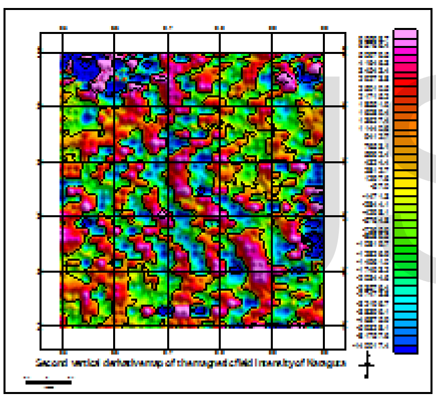

Fig. 7 Second vertical derivative map of the total magnetic field intensity of the study area

anomalies often match surface exposures of the mafic and felsic rocks respectively[21].The zero contours of the second vertical derivative represented by the black contours in figure 7 represent lithological boundaries. Similarly, positive second vertical derivative features with values ranging from 1297.6 – 95,598.7 and may be attributed to mafic rock forming minerals. The most striking petrographic feature of the whole province is the overwhelmingly acid nature of the rocks and the similarity of the rock types found in all areas. Over 95% of the rocks can be classified as rhyolites, quartz-syenites or granites, with basic rocks forming the remaining 5%. Many of the rocks have strongly alkaline to peralkaline compositions, others are aluminous to peraluminous [9]. These positive derivative features have dominant trend directions in the NE-SW and NW-SE. On the other hand, the negative second vertical derivatives ranging from -140,017.4 to -57.0 are believed to be as a result of felsic rock forming minerals. However, NE trending alignments of the ring complexes of the study area are noticeable, perhaps reflecting deep seated zones of weakness in the basement, but there are no obvious surface relationships between location and regional tectonic features [23].

The local anomalies in the original aeromagnetic field map were modeled in terms of intrusions using non linear optimization techniques. The method seeks to minimize a non linear objective function which represents the difference between the observed and calculated fields through an iterative change of the non linear parameters (location, thickness and depth) by non-linear optimization while simultaneously, obtaining optimum values for the linear parameters (magnetization components, quadratic regional and composite magnetization angle) by least-square analysis. Graphical methods (Peter's, slope method, Hannel and Tiburg methods) were used in calculating depth estimates to the anomalous bodies (Fig.8). Results of the 2-D spectral analysis of the aeromagnetic data revealed a two depth source model (Fig.9). The depths to the deeper magnetic source bodies have an average depth of 2.03km. This layer may be attributed to magnetic rocks of the basement, lateral variations in basement susceptibilities and intra- basement features like faults and fractures. The shallower magnetic sources with an average depth of 0.265km could be attributed to near surface magnetic sources.

The processing of the Landsat ETM imagery data was done in such manner that helps the image analyst perform the functions of image rectification, enhancement, transformation and classification of the data. For this research work, ERDAS, IDRISI 32 and other appropriate modules in ILWIS 3.2 academic were used for the image enhancement. Two major filters were applied to the imagery using ILWIS 3.2 filter module: Laplace filter and edge enhancement filter. This was done to increase the spatial frequency of the imagery so as to enhance high frequency features, which would include fractures (lineaments).The Younger granite ring structures were conspicuously revealed on the false colour composite image and the edge enhanced band 5 image respectively (Figs.10&12).The edge enhancement filter image was observed to be more appropriate for this study as it clearly enhanced edge of anomalous bodies. The interpreted lineaments were draped over the edge enhanced map to show the relationship between anomalous geological bodies and structural features observed on the map (Fig.12).

A detailed lineament map generated from the GIS processed landsat imagery is presented in

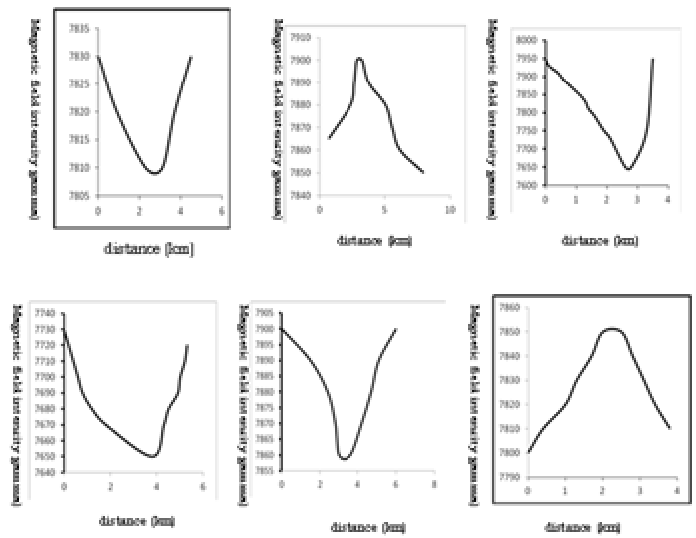

Fig. 8: Interpretation of some linear magnetic anomalies from Naraguta Sheet. Profiles A→F were taken as follows: Profile[A], 7Km NW of Manchok; Profile[B], 9Km East of Barkin Dorowa; Profile[C], 7.5Km North of Damakasuwa; Profile[D], 8Km NW of Bukuru; Profile [E], 7Km NE of Miango; Profile [F], 1Km West of Jos.

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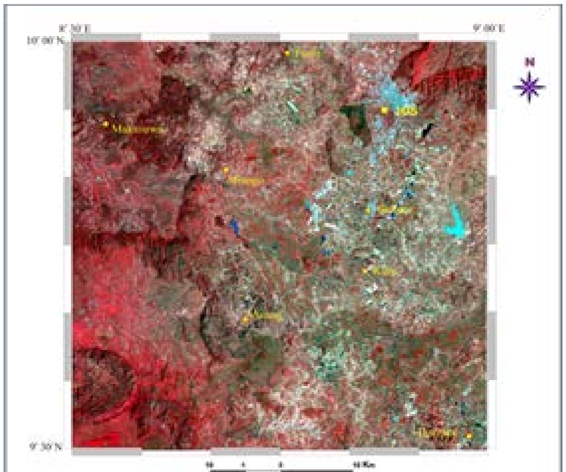
Fig. 11 while the lineament density map is presented in Fig.14. Lineament quantification and statistical analysis were used to establish the orientation/ frequency of these lineaments and further applied to construct the rose diagram (Fig.13). The rose diagram revealed four major trends: N-S, NE-SW, NW-SE, and E-W directions. The E-W trend is however poorly developed within the study area.On the other hand, the lineament density map in Fig.14 revealed a high density fracture zones around Miango, Makasuwa, east of Tsofo and Vwang. Generally, the western half of the study area has a higher lineament density than the eastern half of the study area. These zones where the lineament densities are high correlated well with the trend and positions of the mapped Younger Granite Ring Complexes in the area. The zones are thus interpreted because of the high density of lineaments seen within the area. High lineaments frequencies are obtained in areas where basement rocks are closer to the surface or outcrops; mostly regions with thin overburden. Conversely, low lineament frequencies are characteristics of areas with deeply buried basement rocks. Therefore, it could be interpreted that there are outcrops of basement rocks (probably the Young Granite Ring Complexes) around Miango, Makasuwa east of Tsofo and Vwang while there is existence of deeply buried basement around Jos, Kuru and Bukuru areas based on the observed lineament density. The lineament density is greater on landsat images than on aeromagnetic data, partly due to the resolution of the landsat data and also because not all landsat lineaments have a magnetic signature. The derived maps revealed several previously undetected linear structures.



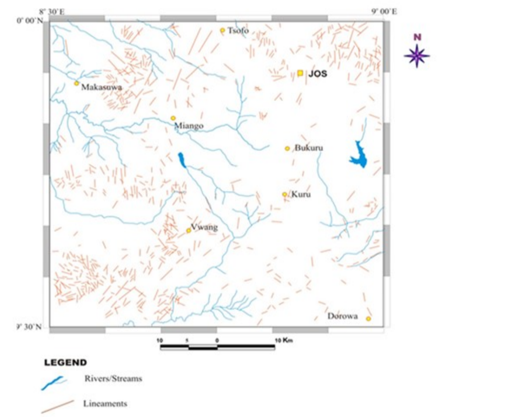


Fig. 11. Lineament map of the study area showing lineaments drapped over the drainage

Fig. 12. Lineament on edge enhanced Band 5 images of the study area

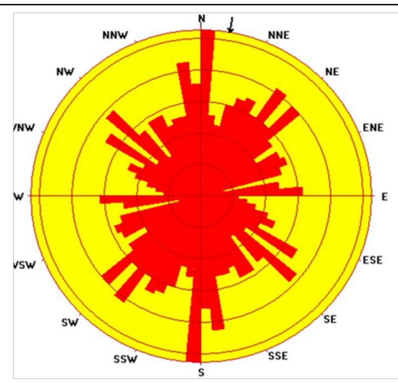


Fig.13. Rose (azimuth frequency) diagram of the lineaments of the study area

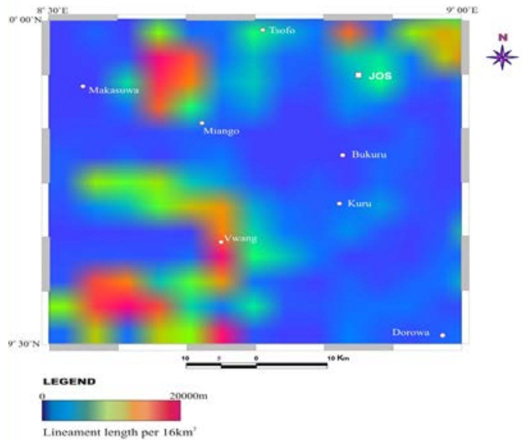


Fig 14: Lineament density map of the study area

4.0 DISCUSSION

The presence of the circular /ring geological features and the extensive linear anomalies around them suggest that the area may be tectonically active. There is an outcropping of the basement rocks around Miango, Makasuwa and Vwang. Lineaments are surface expression of subsurface deformation that reveals the hidden architecture of the basement rock. However, [1] defined lineament as a mappable, simple or composite linear feature of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differ from the pattern of adjacent features and presumably reflects some sub-surface phenomenon. Based on the above premise, it can be established that there is possible correlation between the lineaments and the mapped ring structures around Makasuwa and environs.

The geological interpretation of the landsat imagery revealed a number of lineaments and mega lineaments over 15 km in length trending in the NE – SW, N- S, NW – SE and E – W directions. The trend surface analysis of the tectonic and structural features of the area in relation to the interpreted lineaments from the rose diagram revealed surface trend of NE – SW, N- S, NW – SE, and E – W directions with the dominant structural trends being in the N – S and the NE – SW, which corresponds to the major lineament trend of the study area. This shows that the area has a rugged topography and it is partly deformed by tectonic activities. The lineament trends are in line with the results of previous works of [24], [25], [26]. Their interpretation of aeromagnetic data across the Nigerian continental mass identified the NE-SW trending anomalies as the dominant magnetic feature of most of this shield area. They deduced that these lineaments coincide with major structural trends such as the Benue trough in Nigeria. These authors further pointed out this concentration of magnetic lineaments appeared to be connected with the occurrence of Younger Granites since almost all known Younger Granite Complexes lie within the region dominated by this trends.

These findings are in line with earlier works, which suggested that Nigeria has a complex network of fractures and lineaments with dominant directions of NE-SW, NW-SE and N-S[4],[24],[25],[26],[27],[28]. Similarly, [4] revealed how lineament density maps can be correlated with the primary mineral occurrences map of Nigeria. These correlations showed good comparisons between the areas where the occurrences of most primary minerals like iron, cassiterite, lead-zinc and uranium have been reported with areas of high lineament density. This comparison revealed that primary mineralization is generally tectonically controlled [1],[4].

5.0. CONCLUSION

Aeromagnetic and Lansat data were integrated in this study for the interpretation of lineaments and other geological structures in Naraguta and environs.Results of these study revealed several lineaments with principal trend directions in the NW-SE, NE-SW, N-S and E-W directions with the N-S trend been dominant. Results of the 2-D spectral analysis of the aeromagnetic data revealed a two depth source model revealing an average basement depth of 2.03km. This work also established a relationship between lineaments and some primary minerals in the study area.

6.0. REFERENCES

[1] D.M.O'Leary, J.D.Friedman, and H.A.Pohn, " Lineament, linear, lineation, some proposed new standards for old terms'' Geol. Soc. Am. Bull.,vol. 87,no.2,pp. 1463-1469, 1976.

[2] P.J.Gunn, "Application of aeromagnetic surveys to sedimentary basin studies" AGSO Journal ofAustralian Geology and Geophysics, vol.17, no.2, pp.133-144, 1997.

[3] P.J.Gunn, "Quantitative methods for interpreting aeromagnetic data: a subjective review" AGSO Journal of Austrialian Geology and Geophysics, vol.17, no.2,pp.105-113.

[4] S.E.Ananaba, and D.E.Ajakaiye, "Evidence of tectonic control of mineralization of Nigeria from lineament density analysis: A Landsat study" Int. Jour. Rem. Sensing, vol.1, no.10, pp. 1445-1453, 1987.

[5] A.I. Opara, S.A.Ugwu, and R.A. Onyewuchi, "Structural and tectonic interpretations from landsat 5 thematic imagery: case study of okposi brine lake and en virons, lower benue trough, Nigeria. Elixir Remote Sensing, 49, 9708-9713, 2012.

[6] A .I..Opara, R.A.Onyewuchi, A.O..I..Selemo, S.O.Onyekuru, Ubechu, B.O, T.T.Emberga, D.F.Ibim, and O.P.Nosiri , "Structural and tectonic features of Ugep and Environs, Calabar Flank, South-eastern Nigeria: Evidences from aeromagnetic and Landsat-ETM data"Mitteilungen Klosterneuburg,vol. 64, no.7, pp.33-54,2014.

[7] H. Al-Moush, N.Hammoun, M.Al-Farajat, E.Salameh, D Diabat.,M. Hassonah, and R.Al-Adamat, "Integrating of aeromagnetic data and landsat imagery for structural analysis purposes: a case study in the southern part of Jordan" Journal of Geographic Information System,vol. 5, no.2,pp.15- 22,2013.

[8] W.S.Kowalik and W.E. Glenn, "Image processing of aero magnetic data and integrating with landsat images for improved structural interpretation. Geophysics, vol.52, pp. 875-884,1987.

[9] N.G.Obaje, "Geology and Mineral Resources of Nigeria" Springer-Verlag, Berlin Heidelberg, pp.31- 48,2009.

[10] E.S.Akanbi, F.X.O. Ugodulunwa, and B.N. Gyang, "Mapping Potential Cassiterite Deposits of Naraguta Area, North Central, Nigeria using Geophysics and Geographic Information System(GIS)'' Journal of Natural Sciences Research,vol.2, no.8,pp. 132- 143,2012.

[11] P. Bowden, and J.A.Kinnaird, "Geology and mineralization of the Nigerian anorogenic ring complexes"Geologisches Jahrb (Hannover), B56,pp. 3–65,1984.

[12] C.A.Samaila and N.Y, "Groundwater Potential on the Jos-Bukuru Plateau, North Central Nigeria, using lineaments from gravity measurements'' Journal of Water Resource and Protection, vol. 3, pp. 628-633, 2011.

[13] D.C.Turner, "Structure and Petrology of the Younger Granite Ring Complexes" Geology of Nigeria , C.A Ogbe, eds., Rock View International, France, pp. 175-190. 1989.

[14] C.A.Kogbe, "The Cretaceous and Paleogene Sediments of Southern Nigeria"Geology of Nigeria, C.A Ogbe, eds., 2nd Edition. View International, France, pp. 325-334, 1989.

[15] E.C. Ike,"The structural evolution of the Tibchi Ring Complex: A case study of the Nigerian Younger Granite province" Geol. Soc. London,vol.140, pp.781–788,1983.

[16] J.A.Kinnaird, "Hydrothermal alteration and mineralization of the alkaline anorogenic Ring Complexes of Nigeria" J. Afr. Earth Sci., vol. 3, pp.229–251,1985.

[17] A. Spector and F.S.Grant, "Statistical models for interpreting aeromagnetic data" Geophysics, vol.35, pp.293-302,1970.

[18] X, Liu, "On the use of different methods for estimating magnetic depth" The Leading Edge, pp. 1090- 1099, November,2003.

[19] C. O.Ofoegbu, and K. . M .Onuoha, "Analysis of magnetic data over the Abakaliki Anticlinorium of the Lower Benue Trough, Nigeria", Marine and Petroleum Geology, vol. 8.pp. 174-183, 1991.

[20] R.J.Blakely, "Potential theory in gravity and magnetic applications" Cambridge Univ. Press.210pp,1995.

[21] D.E.Ajakaiye., "Deep structures of alkaline Ring Complexes from geophysical data. In: Abstract, international conference on alkaline ring complexes in Africa. Zaria, Nigeria,1983.

[22] V.H.Gupta and S.D. Ramani, "Optimium second vertical derivative application in geologic mapping and mineral exploration"Geophysics,vol. 24, pp. 582-601,1982.

[23] R.Black and M. Girod, "Late Paleozoic to Recent igneous activities in West Africa and its relationship to basement structures" African magmatism and tectonics, T.W, Clifford and I.G.Gass, ,eds., Oliver and Boyd, Edinburgh, pp. 185–210,1970.

[24] I.M.Chukwu- Ike, "Interpretation of marginal en- echelon lineaments in the mid-Benue Trough, Nigeria" Nigeria Journal of Mining and Geology,vol. 15,no.1, pp.14 -18, 1997.

[25] A.N.Udoh, "Remote sensing imageries of Nigeria, North of $7^0 40^1$N, P.O.Oluyide, et. al.,eds., Precambrian Geology, Ge ological Survey of Nigeria, Publ.,pp.99- 102, 1988.

[26] I.M.Chukwu-Ike and J.W.Norman, "Mineralized crustal frac tures shown on satellite imagery of Nigeria" Inst. of Min. and Metatransactions; vol.86; pp. 55-67, 1997

[27] P. I. Olasehinde and M. O. Awojobi, "Geological and Geophysical Evidences of a North—South Fracture System East and West of the Upper Gurara River in Central Nigeria"Water Resources Journal, Nigerian Association of Hydrogeologist, vol. 15, no.2 , pp. 33-37,2004.

[28] I. B. Odeyemi, Y. B. Anifowose and Y. A. Asiwaju-Bello, "Multi-Technique Graphical Analyses of Fractures from Remote Sensing Images of Basement Regions of Nigeria," Journal of Mining and Geology, vol. 35, no. 1, pp.88-105,1999.