Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2017, 4(9):31-43**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Litho-Structural Mapping of Udi and Okigwe Area, Southeastern Nigeria using Landsat 5 Enhanced Thematic Mapper (ETM$^+$) Imagery

Onyewuchi R.A.*, Ugwu S. A.

Department of Geology, University of Port Harcourt, River State Nigeria

Abstract Litho-structural mapping of Udi and Okigwe area was done with the aim of carrying out geological interpretation of the area using Landsat 5 enhanced thematic mapper (ETM$^+$) imageries. The objectives of the study include: mapping of geomorphic and hydro-geomorphic attributes, delineation of surface linear features, classification of land cover and discrimination of lithologic units. The obtained landsat data was digitally processed and enhanced to produce single band images, band ratios, colour composites, and classified images complemented by digitized geologic map for the study area. IDRISI 32 software modules were used in transformation and enhancement of the data to produce band ratios and colour composites respectively. Results revealed the topography of the study area to be predominantly low-lying and sparsely elevated features with heights of 10 and 539 metres respectively. The elevated features are interpreted as Awgu-Okigwe escarpment and Awka-Orlu cuesta. The low-lying areas are underlain by plains and river drainage channels. Similarly, the lithology of the study area falls between clay/shale and sandstone members. Isolated occurrence of limestone is suspected around Umuahia and environs. The interpreted lithology was based on the dendritic and trellis drainage patterns observed in the area. Short and long surface linear features delineated from the study area revealed dominant structural trend of NE-SW direction. This trend is a suspected continental extension of oceanic Chain and Charcot fracture zones. Heavy lineament density is observed around Ogbabu, Ihube, Leru and Lokpaukwu areas which are interpreted as suspected zone of sedimentary/magnetic basement contact. In addition, such areas suggest a tectonically active zone. Land cover of the study area is classified into: bare soil, sparse and forest vegetation. These vegetations can support farming and logging activities. However, some sections of the study area are flood and erosion prone, based on the permeable and impermeable nature of its lithology.

Keywords Geomorphic, Lineament, drainage pattern, permeability, Anambra basin

1. Introduction

The essence of geological study involves the mapping of lithology. This involves the identification of landforms, rock types and associated structural features (folds and fractures). Lithological maps are thus produced to show the surficial distribution of rock types within an area under study.

Traditionally, litho-structural mapping has been done by geologists who traverse an area on foot, recording the rock features and the exposed structures on maps. The field record of the structural features and the lithology in conjunction with the topographical map of the traversed is used in the preparation of the geological map of such area. Information garnered from such maps has been of great importance; especially in the areas of agricultural production, environmental management, mineral exploration and exploitation. Litho-structural mapping has provided the information needed to solve practical land use problems, such as ground water quality, earthquake, volcano, landslide and flooding hazards.

Field geologic mapping is costly, time consuming and faces the challenge of inaccessibility of some areas. The advent of photo-geology and later remote sensing became a cheaper alternative to field geologic mapping.

Therefore, remote sensing is deemed necessary to provide rapid access and broad spatial coverage of geologic structures to facilitate or supplement traditional geological mapping produced from multiple seasons of fieldwork [1]. Remote sensing data provide many advantages for improving the regional geological mapping process [2, 3].

Many studies have revealed that remotely sensed data could be employed to improve the existing maps of an area [4, 5]. These studies have shown that many of the discrepancies found between the published maps and those derived from the satellite imagery were mostly due to omission or errors in the field geological mapping as proved through subsequent field works. Broad lithological boundaries are determined from a number of parameters (such as general geologic setting, weathering, landforms, drainage, structural features, soil, vegetation and spectral characteristics) observed from remote sensing data. Indeed, examination of lineament density, drainage density, pattern and texture, and vegetation patterns may also provide clues to lithology even when beds are not directly exposed. Similarly, lineaments are mappable linear surface features which differ distinctly from the patterns of adjacent features and presumably reflect subsurface phenomenon [6]. They are generally manifested by the topography (including straight stream segments), vegetation, or soil type and are observable on Landsat imagery. The attitudes, type and slope of the underlying rocks directly have a bearing on the drainage system which develops on a regional scale. Drainage is studied according to its pattern, texture or density. It is probably the most important single identifier of landforms.

Landsat 5 Enhanced Thematic Mapper (ETM^+) with seven spectral bands has been used for regional scale geological mapping whereas the Shuttle Radar Topography Mission (SRTM) data has been deployed for many applications of digital elevation data, including geomorphology, hydrology, forest ecology, glaciology and volcanology [7, 8]. Several workers have used Landsat imagery to identify geomorphological expressions and regional structural features [2, 9-12]. [13] used Landsat 5 imagery to identify lineaments that are favourable for the occurrence of groundwater, especially in the crystalline terrain of Dutsin-Ma, North Western Nigeria. [14] generated and developed filtered images and clusters in order to obtain structural and geologic map of the Jos plateau while [15] carried out gully erosion mapping and monitoring in parts of southeastern Nigeria using satellite imagery.

Therefore, the aim of this study is to carry out geological interpretation of the area using Landsat imageries. The study will cover the following scope: mapping of geomorphic and hydro-geomorphic attributes, delineation of surface linear features, classification of land cover and discrimination of lithologic units. This study brings in the use of satellite imagery in geological mapping of part of Anambra basin. The study covers the southern part of the Anambra basin and is organized into: introduction, materials/methods, results/discussion and conclusion.

1.1. Geological Setting

The study area is part of the Anambra basin, southern Benue Trough. It is located within latitudes 5^o 30′ to 7^o 00′N and longitudes 7^o 00′ to 8^o 00′E (Fig. 1).

The geologic history of the Anambra basin is closely connected to that of the Benue Trough. Benue Trough originated as an arm of the triple junction rift-ridge system that initiated the separation of South America from Africa in the Aptian/Albian [16-18]. The separation of the South Atlantic had reached the Gulf of Guinea and extended north-east to form the Benue-Abakaliki Trough (aulacogen) in the early Albian [19]. The stratigraphic history of the region is characterized by phases of marine regression and transgression [17, 20-21]. The phase are: the Aptian-Santonian, Abakaliki-Benue phase, the Campanian-Mid Eocene, Anambra-Benin phase, and the late Eocene-Pliocene Niger Delta phase [22-24].These phases are interrupted by large scale tectonism which occurred during the Cenomanian and Santonian times [22, 27].

The Santonian deformation was characterized by compressive folding, generally along a NE-SW direction, parallel to the trough margin. The folding episode that took place during the Santonian strongly affected the development of the Abakaliki Anticlinorium. The predominantly compressional nature of the folds that developed during this period is revealed by their asymmetry and the reversed faults associated with them. In a detailed report of geology of Abakaliki suggests that the compression responsible for the large scale folding and cleavage was directed N155^o E [25]. The magmatism that occurred resulted in the injection of numerous intrusive bodies into the shale of the Eze Aku and Asu River Group. Similarly, minor folding events have been reported during the Cenomanian deformation [26-27].

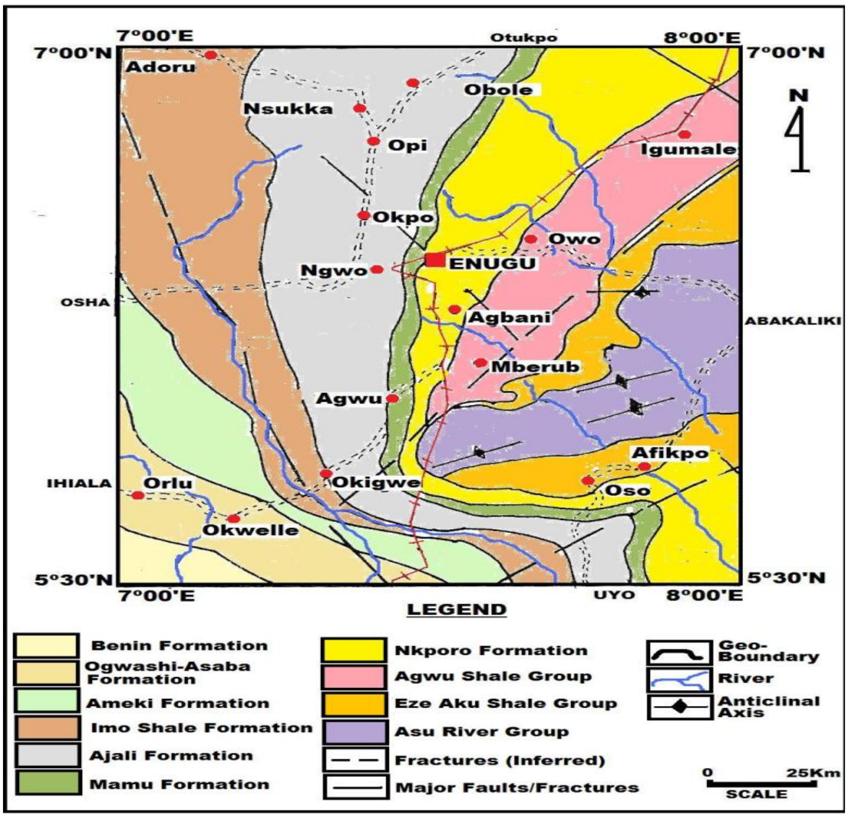

Figure 1: Geologic Map of the Study area

The study area is underlain by sedimentary facies which include: the Asu River Group, the Eze-aku Formation, the Awgu Shale Group, Nkporo Shale, Mamu Formation, Ajali Formation, Imo Shale, Ameki Formation, Ogwashi-Asaba Formation and Benin Formation. The Asu River Group (Albian-Cenomanian) consists of alternating sequence of shales and siltstones with occurrences of sandstone having its maximum thickness as 1500 m. It represents the first and oldest cycle of shallow marine to brackish water sediments deposited on the basement complex. There has been reported presence of Cenomanian sediments and Santonian intrusives of dykes and sills extrusives. The Eze-aku Formation (Turonian- coniacian) comprises flaggy calcareous shale with thin sandy or shaley limestone and calcareous siltstone. Eze-aku Formation overlies the Asu River Group with the formation deposited as a result of renewed transgression in the second depositional cycle of the Benue Trough. The thickness of the Eze-aku Formation is highly variable and may get to a thickness of 1200 m [28, 29]. The Awgu Shale (Coniacian) consists of shale with thin limestone bands and lenticular sand bodies. It is deposited in a marine environment. The Nkporo Shale Formation (late Campanian–Maastrichtian) was deposited in various environmental settings including shallow open marine paralic and continental regimes [30]. It consists of dark grey, fissile shale, brown silty and sandy shale, mudstone and fine-grained sandstone. Mamu Formation (Maastrichtian) comprises tidal estuarine facies dominated by poorly consolidated carbonaceous sandstones, siltstones and mudrock with coal seams [30]. The Ajali Formation consists of mainly fluvial to marginal marine facies comprising unconsolidated to poorly cemented, coarse to fine grained sandstones, siltstones and carbonaceous mudrock which are characterized by a lateritic surface [30]. The Ajali Formation is overlain by the Paleocene Imo Shale Formation which is characterized by well laminated blue and dark grey clayey shale with occasional bands of calcareous sandstone, marls, and limestone. [31] identified two depositional sequences in the Imo Shale with each bearing a striking similarity to estuarine cycles. The shales are very compacted, unjointed and impervious. Large ventricular sands often occur in places. Gravelly and silty sandstones units of the Umuna and Ebenebe sandstones are also interbedded within this formation but these members have limited coverage. The Imo shale was deposited under marine conditions. Shallow marine clastics facies and deeper marine clastic facies can be recognized [21]. The Eocene to Oligocene aged Ameki Formation consists of medium to coarse-grained white sandstone, bluish calcareous silt, with mottled clays and thin limestone. Ameki Formation is characterized by lateral and vertical variations in lithology [32, 33]. Its lateral equivalent is the Nanka Sands. The lithologic units of the Ameki Formation are divided into two general groups [26, 33]: the upper grey-green sandstones and sandy clay; and a lower unit with fine to coarse sandstones and intercalations of calcareous shales and thin shelly limestone. The Ogwashi-Asaba Formation (Oligocene) consists generally of an alternation of seams of lignite with clays. This Formation represents the Nigerian lignite formation [26]. The Benin Formation is the youngest formation (Miocene to Recent) in the study area. It made contact with the Ameki and Ogwashi-Asaba Formations and dips south westward. The Benin Formation consists mainly of sandstone and clays. The Benin Formation is partly marine and partly continental. The Benin Formation consists of thick friable sands with lintel intercalations of clay beds and lenses. Its thickness ranges from 200 to 2000 metres within certain areas across the region.

The abundance of pyroclastics and intrusives which are associated with explosive eruption of lava and magmatic processes respectively; have been observed widely in most part of the study area especially around Lokpanta and Lokpaukwu. These pyroclastics are interpreted as being subaerial falls of submarine explosions during the upper Albian [27]. Elsewhere pyroclastics occur in places such as: Ngbo and Abakaliki Juju hill within the Abakaliki Anticlinorium [34]. The deposition of pyroclastics in these places reflects the past igneous activities which must have taken place in the study area.

2. Materials and Methods

The seven-band Landsat 5 TM image acquired on the 11th of October 2015, belongs to a scene with Path number 188 and Row number 56. The dataset was prepared and supplied by EROS EDC in the new National Landsat Archive Production System (NLAPS) and the National Data Format (NDF) to National Centre for Remote Sensing Jos. The image organization is in band sequential (BSQ) and the same data, in raster format, is presented in seven bands; each scene was also radiometrically corrected. A shuttle radar topographic mission (SRTM) image of the same area was also obtained. Ground control points (GCP's) and satellite orbit transformation were used to rectify the imagery. The image rectification was done by utilization of the Universal Transverse Mercator (UTM) coordinate system. Band 1 of TM data penetrates water for bathymetric mapping along coastal areas and is useful for soil vegetation differentiation and for distinguishing forest types. TM Band 2 detects green reflectance from healthy vegetation. TM band 3 responds in the visible spectrum, and is designed for detecting chlorophyll absorption in vegetation. On the other hand band 4 responds well in the near infra-red ideal for detecting near Infra-red reflectance peaks in healthy green vegetation and water bodies/ land interfaces. The mid –Infra red (mid-IR) bands 5 and 7 are useful for vegetation and soil moisture studies, as well as mineralogical discriminations. The thermal-IR band on TM band 6 is designed to assist in thermal mapping and is used for soil moisture and vegetation studies.

The landsat 5 -TM data of the study area was digitally processed and enhanced to produce single band images, band ratios, colour composites, and classified images complemented by digitized geologic maps for the study area. Drainage patterns and textures, bare rocks and vegetated areas were enhanced in single band images while secondary features such as gossan and clay rich sediments are identified in image ratios. The SRTM data was utilized in the production of a digital elevation model (DEM) which is valuable in the identification of structures and morphometric features of the study area. The colour composites were used as background data for both supervised and unsupervised image classification. Information extracted from these image processing routines were integrated in a geographic information system (GIS).The enhanced landsat 5-ETM^{+} data obtained was subjected to various image enhancement and transformation routines. For the image transformation, band ratios were generated using the calculator module in IDRISI 32. For image enhancement, three band (RGB) colour composites were created using the composite module of IDRISI 32. This process was employed to enhance the spectral quality of the images. Generated composites include RGB 321, RGB 432, RGB 752 and NDVI composite. The generated composites were studied in detail to extract information on the lithology and structural features of the area.

Another approach that was adopted in this study involves the use of the drainage pattern as an aid in lithological mapping. Examination of drainage pattern or drainage density provides clue to the lithology even when the rocks are not directly exposed. This is because, the drainage density is more in the hard rocks where infiltration of water downwards is less as compared to loss rocks (alluvium) where water easily percolates beneath the top soil and gives rise to low drainage density.

3. Results and Discussion

3.1. Results

A digital elevation model (DEM) or digital terrain model (DTM) for the area was created using IDRISI 32 by performing a colour shaded operation on Shuttle Radar Topographic Mission (SRTM) data.

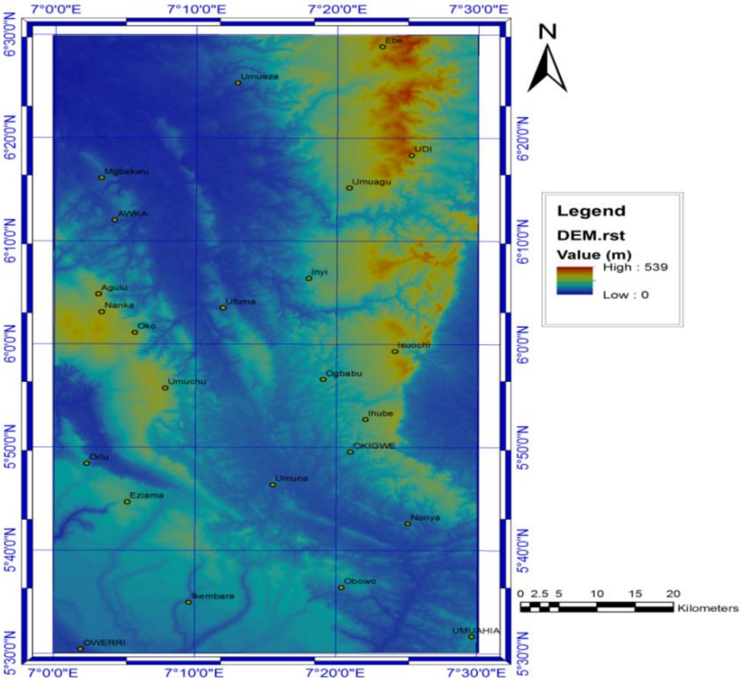

Figure 2: Digital Elevation Model (DEM) of the Study area

The created DEM of the study area is shown as figure 2. The highest elevation in the study area has a value of 539m whereas the lowest falls around 10m. The highly elevated areas run in a north-south direction from Ebe through Udi, down to Isuochi and terminating at Ihube. These areas are suspected to be part of the Awgu-Okigwe escarpment. Another part of the study area with high elevation is the eastern portion covering Agulu, Nanka, Oko and Umuchu; suspected of being a section of the Awka-Orlu cuesta. The slope of the ridge-like features is identified where brown, yellow and blue colours are interwoven; representing a sudden change in topography from 502 metres to 10 metres. The slope of the highly elevated features is marked by numerous rivers and streams. Another sharp gradient change in elevation is observed in the east central portion of the study area. This may be suspected as a surface lineament.

On the other hand, areas with low elevation dominate most part of the study area (Fig. 2). These areas have blue colours on the DEM and estimated heights between 10m to 20m. This feature is interpreted as a drainage channel, which runs in a NW-SE direction across the study area. The feature represents the Mamu River and its tributaries in the northern portion and Imo River with its own in the southern part of the study area. The drainage patterns observed in the study area from the DEM (Fig. 2), show predominance of dendritic and trellis patterns. The dendritic pattern is seen in most part of the study area: from Ebe to Udi, Awka to Oko, Lokpanta to Okigwe, and Orlu to Owerri; which is interpreted for areas with horizontal sediments or uniformly crystalline rocks. Also, it could be inferred that there was a regional gentle slope at the inception of drainage of sediments from their provenance. The dendritic pattern suggests that the underlying sediment is a homogenous unit. In addition, dendritic pattern reveals that the lithology has least resistance to erosive action of the rivers and streams. On the other hand, trellis pattern which is interpreted for a dipping or folded sedimentary terrain is isolated around Umuahia area. It could be suspected for an area that has parallel fracture system.

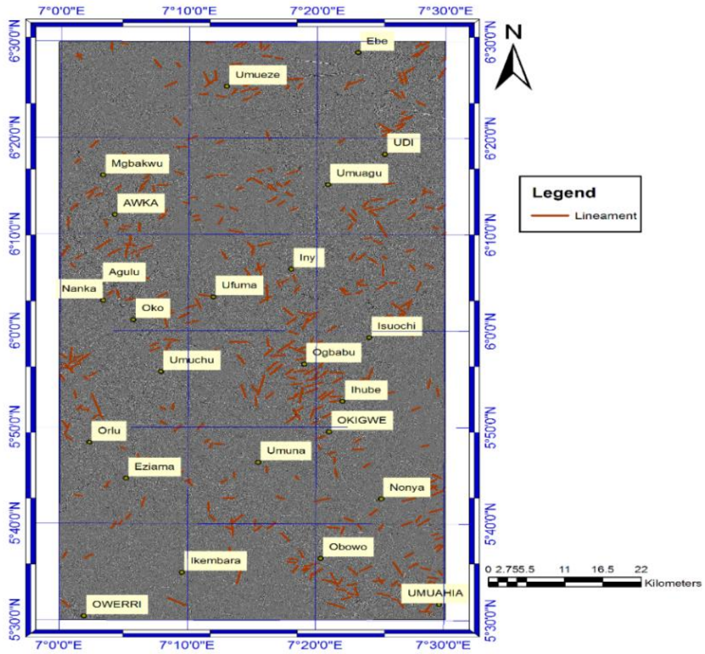

Figure 3: Lineament on Edge Enhanced Map of the study area

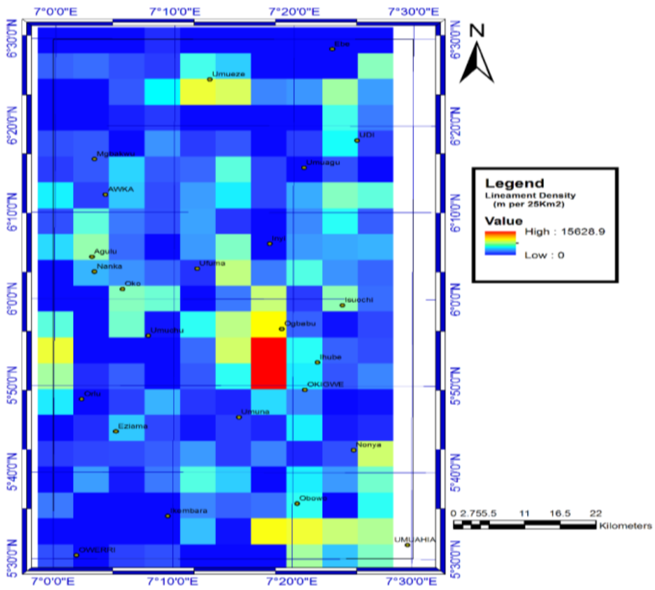

Figure 4: Lineament Density Map of the study area

The lithology of the topographic high areas is constituted by sandstone and the low areas being shale and mudrock. This is justified by the dendritic drainage pattern expressed in the low lying area, which points to an underlying clayey lithology. The high elevation interpreted as being part of the Enugu-Okigwe escarpment correlates to the area underlain by the Ajali Sandstone. The other high elevated feature interpreted as portion of Awka-Orlu cuesta correlates to the area underlain by Bende/ Ameki Formation which has sandy lithology. The low elevation areas are underlain by Imo Shale and Nsukka Formation which have dominant shale and mudstone lithology respectively. The lithology of the area with trellis drainage pattern comprises alternating soft and hard sedimentary rock deposited within a dipping terrain. The underlying geologic formation in the area is the Bende-Ameki Formation which has alternating sequence of shale and sandstone lithology with shelly limestone.

Similarly, both short and long linear features are observed in the study area. The lineament on edge enhanced and lineament density maps (Figs. 3 and 4), reveal high concentration of lineament around Ogbabu, Ihube, Leru and Lokpaukwu; which are areas with magnetized rock outcrops. Lineaments on these areas cross-cut each other and some run parallel to each other. This implies that these areas have experienced severe tectonic events. Such areas suggest sedimentary and magnetic basement contact [35]. Other areas with high concentration of lineaments are Umueze, Awka and Umuahia. Beside these areas, there are isolated lineament concentrations around Umuagu, Ebe, North of Mgbakwu and the southwestern fringe of the study area. High concentration of lineaments in those areas means that they are more tectonically active than the rest of the study area.

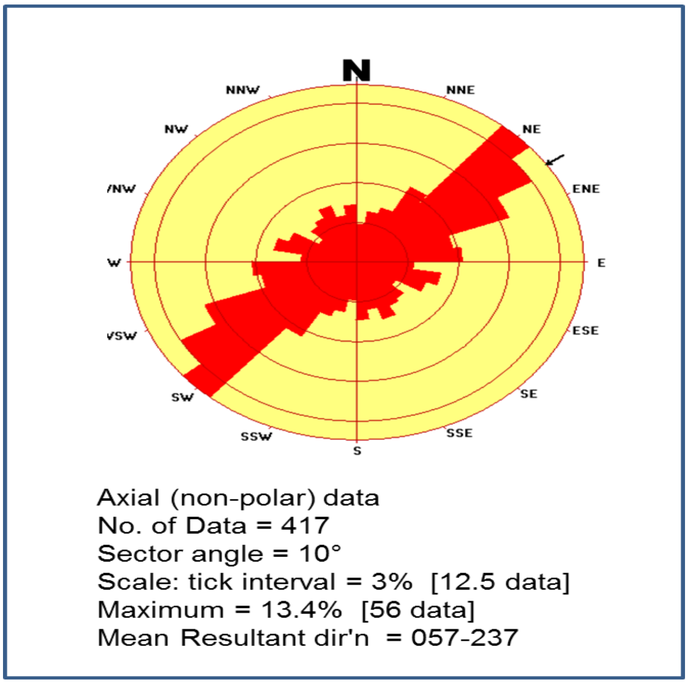

Figure 5: Rose diagram of the Study area

Statistical quantification of the lineaments was carried out. The results obtained are shown as a rose diagram (Fig. 5). The rose diagram shows a predominant peak direction of NE-SW trend and other directions of NW-SE, NNW-SSE and N-S trends. These trends suggest that the study area has been affected by more than one tectonic event. The dominant surface trend derived from the Landsat data showed a NE-SW trend. This NE-SW trend is the dominant azimuth direction which reflects that of the basin. The NE-SW trend suggests that the lineaments interpreted from the study are of deep-seated origin. Similarly, the observed predominant structural trend of NE-SW direction suggests a continental extension of the known pre-Cretaceous oceanic fracture zones viz: the Chain and Charcot fracture zone [36-38].

Colour composites of the Landsat imagery are presented as RGB 432, 532 and 751 (Figs.6, 7 and 8). RGB 432 represents the false colour infra-red imagery. This colour composite allows for the viewing of variations in the Near Infra-Red (NIR) reflectance associated with photosynthesizing vegetation. Water appears in black colour because it absorbs NIR radiations, vegetated areas appear as red based on the absorption of radiation from the red and blue wavelengths, and reflection of green wavelength by chlorophyll in leaves. In addition, non-vegetated areas appear as shades of light grey colour. On the other hand soil appear as light to dark brown colour and urban areas appear as cyan blue. In the study area water bodies are not discerned clearly from this colour composite. Rather the drainage channels earlier interpreted from the DEM (Fig.2) appear in red colours on the RGB 432 (Fig.6); which suggests that vegetation cover are seen along the river and stream channels. Darker red patches are observed around Udi and Umuagu suggesting the presence of denser or forest vegetation cover within the area. Similarly, the areas interpreted as escarpment and cuesta on the DEM (Fig. 2) appear as cyan colours on the RGB 432 composite. It means that both observed morphic features have bare soil cover.

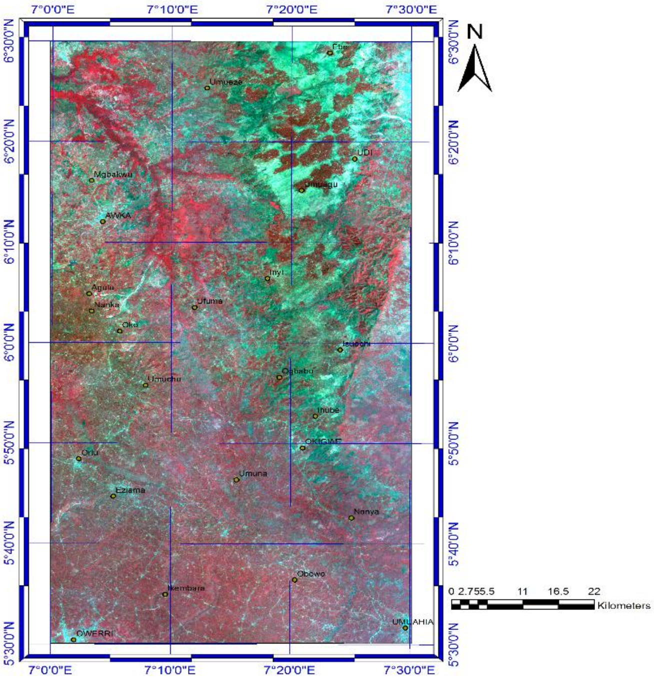

Figure 6: Colour Composite RGB432

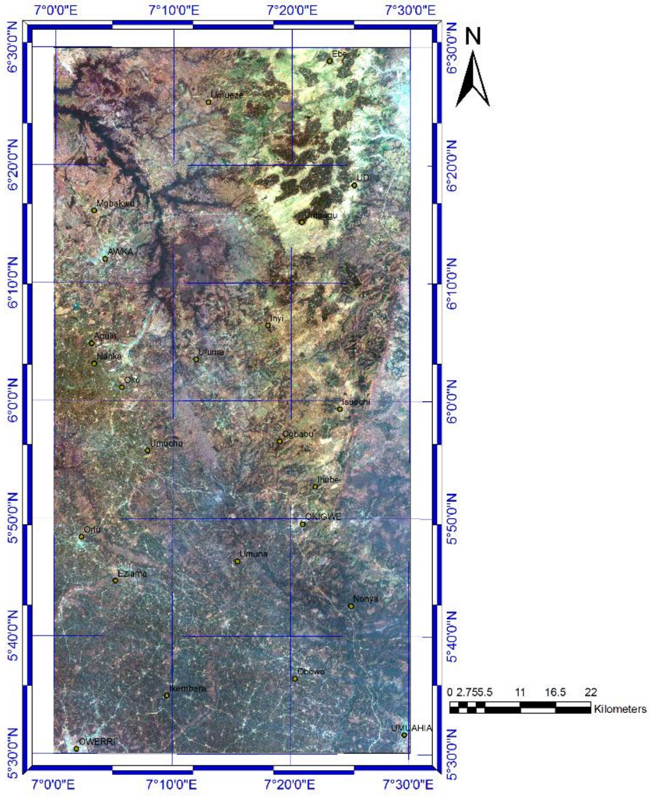

Figure 7: Colour Composite RGB 532

Other areas like Owerri, Orlu, Obowo and Umuahia have red colour sparsed with light cyan patches (Fig. 6) which suggest that they have sparse vegetation reminiscent of urban centres. RGB 532 (Fig. 7) composite highlights areas affected by hydrothermal alteration of volcanic rocks, water bodies, vegetation and soil. Water appears black under this colour composite because it absorbs all the three wavelengths. But sediment filled water have blue colour as a result of the reflection of visible light which it undergoes. A river channel was identified which appears black in colour is seen running north of Awka and Mgbakwu. The river is suspected to be part of Mamu River. Other river pathways identified are in the southern portion of the study area. Areas with patches of Green colour are seen in some parts of the study area. This implies areas of sandstone lenses. Areas with sparse vegetation interpreted in band 432 (Fig. 6) appears as shades of greenish mauve on RGB 542 (Fig. 7). Similarly, RGB 751 is appropriate for discriminating aquatic life, moisture, soil cover and geology mapping. The earlier interpreted portion of the Awka-Orlu cuesta and part of the Enugu-Okigwe escarpment interpreted as sandstone ridge from DEM (Fig. 2) are rendered as magenta interspersed with shades of green colour on the RGB 751 (Fig.8). Urban and bare soil areas are rendered in lavender pattern (Fig.8). Vegetated areas show shades of green pattern on RGB 751. The river channel interpreted earlier from DEM, RGB 432, and RGB 532 appear as black on RGB 751 (Fig. 8).

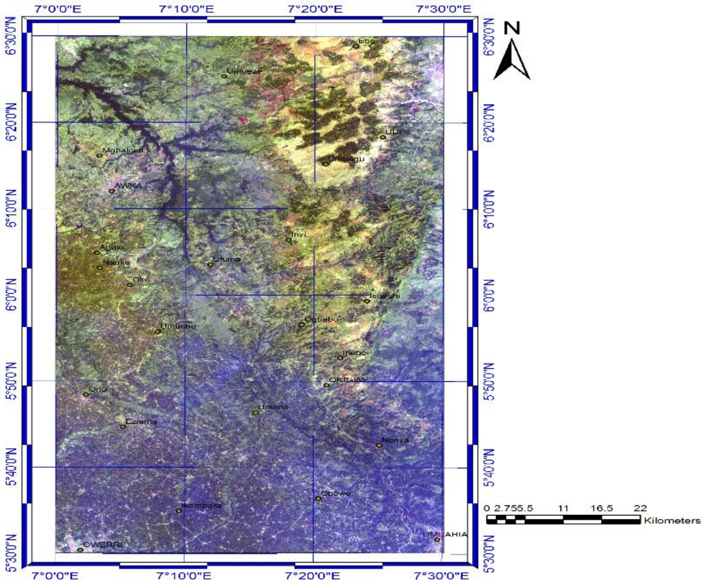

Figure 8: Colour Composite RGB 751

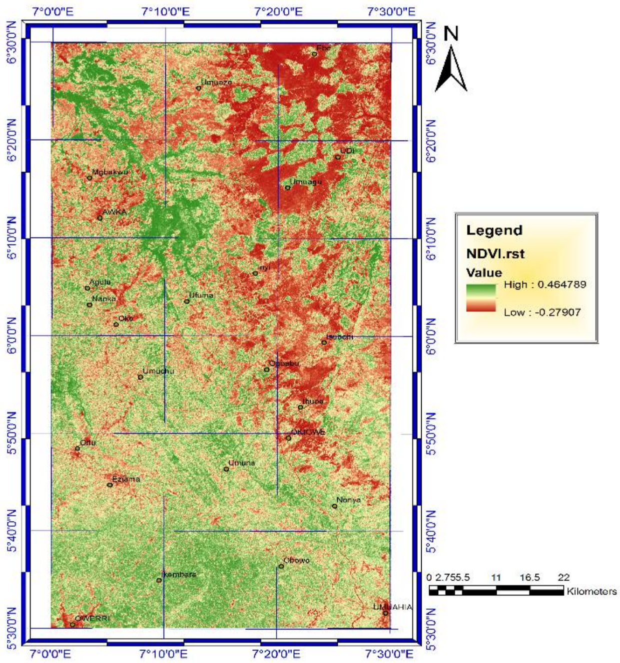

Figure 9: Normalized Difference Vegetative Index (NDVI) of the Study area

The NDVI colour composite (Fig.9) was generated to delineate zones of vegetation and bare rocks. Healthy plants have a higher value of NDVI because of their high reflectance of infrared light and relatively low reflectance of red light. For the study area, the NDVI reveals bare soil which appear as reddish-brown colour on the composite around Umuagu, Udi, Inyi, Ogbabu to Okigwe (Fig.9). However, heavy green patches suggestive of forest vegetation cover are observed along Udi Hill area; and green patterns connected with vegetation are seen within Umuna, Obowo and the along the interpreted river channels (Fig. 9).

3.2. Discussion

The Landsat imagery was processed in a manner that the lithology, morphology and surface lineations are discriminated. The DEM revealed topographic high areas identified with brown colours on the DEM map (Fig. 2) and topographic low areas known by the blue colours on the DEM map (Fig. 2). Similarly, the DEM map (Fig.2) revealed the presence of dendritic and trellis drainage patterns in the study area. These drainage patterns suggest the lithology of the study area to be mainly clay/ shale and sandstone. The low lying areas with dendritic drainage pattern are underlain by clayey lithology whereas the high elevated portions are the ridge of the cuestas underlain by sandstone.

The permeability of the study area can be inferred from the drainage density of the DEM (Fig.2). Low drainage density correlates to permeable soil or lithology; conversely, high drainage density correlates to impermeable lithology. Based on the drainage density, the study area can be subdivided into two: the permeable areas covering Owerri, Ikembara, Umuchu, Oko, Nanka, Udi and Ebe; and the impermeable areas covering Awka, Nonya, Ufuma and Umuna. Most of the surface water in the permeable areas ends up underground thereby enhancing reduced overland flow. Most of the permeable areas are prone to various stages of erosional activities. These areas are underlain by Coastal Plain Sand (Benin Formation), Bende/Ameki Group and Ajali Formation respectively, which are all sandstone (both consolidated and unconsolidated). In addition, the underground water potential of these areas is high. On the other hand, surface water in the impermeable areas is retained on the surface; thereby making them amenable to flooding. Such areas are underlain by Imo Shale and Nsukka Formation. In addition such areas are ideal for rice farming and similar agricultural produce owing to the water-logging nature of the Formations.

Both the lineament draped on edge enhanced and lineament density (Figs. 4 and 5) revealed heavy cluster of lineaments around Ogbabu, Lokpaukwu and Lekwesi areas; which implies that the basement under these areas have suffered strong deformation. It produced geological structures trending NE-SW; some of the interpreted lineaments bear this strike while some deviate from it. It is noteworthy to point out that the initial rifting of southern Nigeria continental margin during the Mesozoic era produced two sets of principal faults whose trend are in: NE-SW and NW-SE directions. This trend suggests that the study area has been affected by one of the earliest tectonic deformations of Cenomanian to Santonian times (97 to 81Ma). [39] mentioned that magmatism of this period is represented by alkaline rocks, mainly volcanics. It suggests that Ogbabu, Leru, Lekwesi and Lokpaukwu areas hold good deposit of igneous materials as well as potential sources for construction aggregate materials. Also, the study area has been affected by the many sedimentary phases [20-21]. The inferred structures from the Rose diagram (Fig. 5) showed peak trends of NE-SW, NNW-SSE, and N-S directions. The predominant NE-SW is suggested as continental extension of the oceanic fracture zones of the Chain and Charcot fracture system [36, 38]. This linear trend is believed to run along the trough axis of the basin under sedimentary cover.

4. Conclusion

The study area is divided into tectonic active and inactive zones based on the concentration of lineaments in those areas; such places like Lekwesi, Lokpaukwu and Ogbabu are classified as tectonic active zone because of heavy concentration of lineaments in those places. Those areas are a bound with igneous rocks which serve as construction materials. Other areas with less clusters of lineaments are tectonically quiet zones with zero prospect for igneous rocks.

Structural interpretation was carried using the lineament map and rose diagram of the study area. Surface structural identified for the area are in the NW-SE, NE-SW, N-S and E-W. This present work is therefore in agreement with previous studies which suggested that Nigeria has a complex network of fractures and lineaments with dominant trends of NW-SE, NE-SW, N-S and E-W directions [40-42]. In addition, the high density of lineament around those river channels suggests hydrographic origin and structure-controlled rivers.

Furthermore, it is geologically plausible to posit that the landward intersections of the transform fracture zones may have influenced the formation of the river patterns and the basin formation. The NE-SW trend and the other strike direction confirm that Nigeria was subjected to the Pan African orogeny.

The permeability of surface rock materials was assessed using the drainage pattern distribution of the study area. The area is divided into permeable and less permeable zones. The permeable zones are faced erosional activity and covers places such as: Nanka, Oko, Owerri and Udi. The study has shown that apart from Nanka and Oko which have been ravaged by erosion, that Owerri and Udi areas may face similar challenges. The less permeable zones are faced with risk factor of flooding, and cover places such as Awka, Umuna, and Nonya.

References

[1]. Harris, J.R., Wickert, L., Lynds, T., Behnia, P., Rainbird, R., Grunsky, E., McGregor, R., & Schetselaar, E. (2011). Remote predictive mapping 3. Optical remote sensing—A review for remote predictive geological mapping in northern Canada. *Geosci. Can*., 38, 49-83.

[2]. Hashim, M., Ahmad, S., Johari, M.A.M., & Pour, A.B. (2013). Automatic lineament extraction in a heavily vegetated region using Landsat Enhanced Thematic Mapper (ETM+) imagery. *Adv. Space Research*, vol.51, pp. 874-890.

[3]. Pour, A.B., & Hashim, M., (2015). Structural mapping using PALSAR data in the Central Gold Belt Peninsular Malaysia. *Ore Geology Reviews*, vol.64, pp. 13-22.

[4]. Chorowicz, J. & Rangin, C., (1982). Essai de catographie géologique de la basse californie obtenue á partie de l'analyse des images spatiales methods et resultants. *Bull. Soc. Geol*. Fr. 7, T XXIV, (1) pp. 139-143.

[5]. Ferradini, J., Cornee, J.J., & Simon, B., (1993). Etude linéamentaire sur images Landsat 2 du Haut Atlas accidental (Maroc): conséquences Géodinamica. *Acta*, 6(3), pp.161-173.

[6]. O'Leary, D.W. Friedman, J.D. & Phn, H.A. (1976). Lineament, Linear, Lineation: Some proposed new standard for old terms. *Geol. Soc. Amer. Bull.*, Vol. 87 pp. 1463-1469.

[7]. Frey, H. & Paul, F., (2012). On the suitability of the SRTM DEM and ASTER GDEM for the compilation of topographic parameters in glacier inventories. *International Journal of Applied Earth Observation and Geoinformation*, Vol.18, 480-490.

[8]. Pan, F. Liao, J. Li, X. & Guo, H. (2013). Application of the inundation area-lake level rating curves constructed from the SRTM DEM to retrieving Lake levels from satellite measure inundation areas. *Computers & Geosciences*, 52, 168–176.

[9]. Raharimahefa, T., & Kusky, T.M., (2009). Structural and Remote sensing analysis of the Southern Betsimisaraka Suture in northeastern Madagascar. *Gond. Research*, vol.15, 14-27.

[10]. Pour, B.A. Hashim, M. & Van Genderen, J. (2013). Detection of Hydrothermal alteration zones in a tropical region using satellite remote sensing data: Bau goldfield, Sarawak, Malaysia. *Ore Geology Reviews*, 54: 181-196.

[11]. Opara, A.I., Onyewuchi, R.A., Selemo, A.O.I., Onyekuru, S.O., Ubechu, B.O., Emberga, T.T., Ibim, D.F., & Nosiri, O.P. (2014). Structural and Tectonic Features of Ugep and Environs, Calabar Flank, Southeastern Nigeria: Evidences from Airborne Magnetic and Landsat- ETM Data. *Mitteilungen Klosterneuburg Journal*, Vol. 64

[12]. Ali, S.A., & Ali, U. (2015). Litho-Structural Mapping of Sind Catchment (Kashmir Basin), NW Himalaya, using Remote Sensing and GIS Techniques. *Int. Journ. of Science and Research*, Vol. 4 (7), 1325-1330

[13]. Bala, A.E., Batelaan, O., & De Smedt, F., (2000). Using LANDSAT 5 Imagery In the Assessment of Groundwater Resources in the Crystalline rocks Around Dutsin-Ma, Northwestern Nigeria. *Journal of Mining & Geology*, Vol.36 (1), pp.85 – 92.

[14]. Ologun, J.A.A. (2004). Geological Mapping of Parts of Jos Plateau Using NigeriaSat-1 Image. *NARSDA News*. 35-37.

[15]. Igbokwe, J.I., & Ayomaya, T. (2004). Gully erosion mapping/monitoring in parts of Southeastern Nigeria. *NASRDA News Bulletin*, pp 13-15.

[16]. Burke, K.G., Dessauvagie, T.F.J., & Whiteman, A.J., (1972). Geological History of the Benue Valley and Adjacent Areas. *In: African Geology (Eds, Burke, K.G., and Whiteman, A.J)*, Geol. Dept., Univ. of Ibadan, Nigeria. 188 - 205.
[17]. Obi, G.C., Okogbue, C.O., & Nwajide, C.S. (2001). Evolution of the Enugu Cuesta: A tectonically driven erosional process. *Global Journal Pure Applied Sciences.* Vol. 7(2): 321-330
[18]. Odunze, S.O., & Obi, G.C. (2013). Sedimentology and sequence stratigraphy of the Nkporo Group (Campanian-Maastrichtian), Anambra Basin, Nigeria. *Journ. of Paleogeography*, Vol.2 (2), 192-208
[19]. Stoneley, R., (1966). The Niger Delta region in the light of the theory of continental drift. *Geological Magazine*, 103: 385-397.
[20]. Short, K.C., & Stauble, A.J. (1967). Outline geology of the Niger Delta. *Amer. Assoc. Petrol. Geol. Bull.*, Vol. 51, 761-779
[21]. Murat, R.C., (1972). Stratigraphy and Palaeography of the Cretaceous and Lower Tertiary in Southern Nigeria. *In: T.F.J. Dessauvagie and A.J. Whiteman (Eds.), African Geology*, University of Ibadan, Nigeria, pp. 251-266.
[22]. Nwachukwu, S.O. (1972). The tectonic evolution of the Southern portion of the Benue Trough, Nigeria. *Geol. Mag.*, 109: 411-419.
[23]. Avbovbo, A.A. (1978). Tertiary Stratigrapy of the Niger Delta. *Bull Assoc. Petro Geol.*, 62: pp 295-300.
[24]. Akande, S.O., & Erdtmann, B. (1998). Burial metamorphism (Thermal Maturation) in Cretaceous sediments of the southern Benue Trough and the Anambra Basin, Nigeria. *AAPG* 82, 1191 – 1206.
[25]. Benkhelil, J. (1988). Structure et evolution geodynamique du Basin intracontinental de la Benoue (Nigeria). *Bull.Centres Rech.,Explor. Prod. Elf Aquitaine*.,1207: 29-128.
[26]. Reyment, R.A., (1965). Aspects of Geology of Nigeria.*Ibadan University Press*, Ibadan Nigeria. p.106
[27]. Olade, M.A. (1975). Evolution of Nigeria's Benue Trough (aulacogen): A tectonic model. *Geol. Mag.*, 112: 576-583.
[28]. Okereke, C.N., & Ananaba, S.E. (2006). Deep crustal lineament inferred from aeromagnetic anomalies over the Niger Delta, Nigeria. *Journ. Of Mining and Geol.*, Vol. 42(2), 127-131
[29]. Edet, A.E. (1993). Hydrogeology of parts of Cross River State, Nigeria: Evidence from aerogeological and surface resistivity studies. PhD Dissertation, University of Calabar, Calabar, Nigeria. 316p.
[30]. Obi, C.G. (2000). Depositional model for the Campanian-Maastrichtian succession, Anambra basin, Southeastern Nigeria. Unpublished Ph.D Thesis University of Nigeria, Nsukka. p.291
[31]. Oboh-Ikuenobe, F.E., Obi, C.G., & Jaramillo, C.A. (2005). Lithofacies, palynofacies, and sequence stratigraphy of Palaeogene strata in Southeastern Nigeria. *Journ. of Afr. Earth Sci.*, Vol. 41, 79-101
[32]. Akpabio, I., & Ekpo, E. (2008). Geo-electric investigation for groundwater development of Southern part of Nigeria. *Pacific Journal of Science and Technology*, Vol. 9(1), 219–226.
[33]. Wright, J.B. (1985). Geology and mineral resources of West Africa. *George Allen & Unwin*, London. 187 pp
[34]. Ozoko, D.C. (2015). Origin of dissolved solids in Cretaceous Aquifers at Ngbo, Ebonyi State, Nigeria. A Preliminary Assessment. *Int. Journal of Innovative Science, Engr. and Technology*. Vol. 2(6) 247-253.
[35]. Ofoegbu, C.O. (1988). An Aeromagnetic Study of Part of the Upper Benue Trough, Nigeria. *Journ. Afr. Earth Sci.*, 7, 77- 90.
[36]. Ananaba, S.E. (1991). Dam sites and crustal megalineaments in Nigeria. *ITC Journal*, Vol. 1: 26-29.
[37]. Oluyide, P.O., & Udoh, A.N. (1989). Preliminary Comments on the Fracture Systems of Nigeria. *Proceedings of National Seminar on Earthquakes in Nigeria*, 97-109
[38]. Okereke, C.N. and Ananaba, S.E. (2006): Deep crustal Lineament inferred from aeromagnetic anomalies over the Niger Delta, Nigeria. J. of Mining and Geol. Vol. 42, pp.127-131.
[39]. Mascles, J., Marhino, M., & Wanesson, J. (1986). The structure of the Guinean continental margin: implications for the connection between the Central and the South Atlantic Oceans. *Geologische Rundschau*, 75: 57-70.

[40]. Chukwu-Ike, I.M. & Norman, J.W., (1997). Mineralized crustal fractures shown on satellite imagery of Nigeria. *Inst. of Min. and metatransactions*, vol.86; pp. 55-67.

[41]. Ananaba, S.E., and Ajakaiye, D.E., (1987). Evidence of tectonic control of mineralization of Nigeria from lineament density analysis: A Landsat study. *Int. Journal. Rem. Sensing*, vol.1 (10), pp. 1445-1453.