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Structural and tectonic interpretations from landsat 5 thematic imagery: case study of okposi brinelake and environs, lower benue trough, Nigeria

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ABSTRACT

The structural and tectonic analysis of Okposi and environs, Lower Benue Trough using Landsat-TM data was carried out with the aim of carrying out a detailed structural interpretation of the study area by identifying the lineaments associated with the study area and inferring their effect on the economic potentials of the study area. In addition, this study was aimed at determining whether the Okposi Brine Lake in the study area is structurally controlled. Several GIS softwares which include the ILWIS 3.1 Academic were used to analyze the data. Simple digital image processing techniques were applied on the data to enhance edges of linear features, followed by computer aided visual interpretation. Results revealed that high lineament frequencies/density were obtained in areas where basement rocks outcrop or are closer to the surface whereas low lineament frequencies are characteristics of areas with deeply buried basement rocks. Similarly, the absence of visible lineaments in parts of the area may not be indicative of complete absence of geological structures. Trend analysis of the lineaments computed by plotting the strikes and lengths of all the lineaments revealed on the image on a rose diagram revealed structural trends in the E-W, N-S, NW-SE and NE-SW directions with the NW-SE and NE-SW directions as the dominant trends. The NE-SW linear structures observed from the study are believed to be the continental extension of the known pre-Cretaceous trans-Oceanic Fracture Zones viz. Charcot and Chain Fracture Zones. The numerous lineaments in the study area make the region viable for mineral prospecting. Finally, the presence of a lineament zone around Okposi area may be responsible for the formation of the Okposi Brine Lake. It is believed that this linear feature must have cut through the basinal brine of the Asu River group of the Benue Trough.

Introduction

Land satellites have provided repetitive, synoptic, and global coverage of high resolution images of most parts of the earth surface for some decades now. The use of satellite imagery for regional mapping of geologic units and structures has long been demonstrated as a vital tool for regional geologic mapping. This is as result of its ease of operation, speed, accuracy, low cost and coverage. In addition, advancements lately in satellite and digital technologies have led to remarkable improvement in this technique. The use of Landsat Thematic Mapper (TM) marks a departure from Landsat Multispectral Scanner (MSS). Landsat Multispectral Scanner (MSS) senses four contiguous spectral bands that cover sequentially the wavelength interval from 0.5 to 1.1µm as against seven spectral bands of the Thematic Mapper (TM) that cover wavelength intervals between 0.45 and 2.35µm for the six bands in addition to the thermal infrared channel 10.4 to 12.5µm. Resolution is therefore increased from 30 to 80m in Landsat TM imagery, an advantage it has over MSS imagery. Similarly, Landsat TM has a total of 96 detectors for the reflective bands (0.45-2.35µm) and 4 for the thermal band (10.4-12.5µm); instead of the 24 detectors on the MSS.

Linear features shown on remote sensing imagery of increasingly smaller scale (greater extent) reflect increasingly more fundamental studies; their study often provide insights not only to the location of the mineral deposits, but also to metallogenic theories as well (O' Leary et al,1978).Furthermore, many studies have shown that remotely sensed data could be employed to improve the existing maps of an area(Chorowicz and Rangin, 1982; Ferrandini et al., 1993). These studies have revealed that many of the discrepancies found between the published maps and those derived from the imagery were mostly due to omission or errors in the field geological mapping as proved through subsequent field works. In addition, several studies have emphasized the importance of lineament interpretations and digital analysis in localizing the major mineral deposits and reveals that there is a strong correlation between mineral deposits and lineaments (Ananaba,1991; O' Leary et al,1978)

The interpretation of Landsat imagery using manual or digital image processing (Chorowicz and Rangin, 1982; Ferrandini et al., 1993) has found application in designing new maps and or revising and improving the pioneer maps on poorly outcropping areas. They have also found great applications in structural and tectonic mapping (Wenmenga,2005). Regional structural analysis by this process is effective and more with radar interpretation (Carrère and Chorowicz, 1982; Odeyemi, 1983). Broad lithological information is determined from a

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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 (O'Leary et al,1976). They are generally manifested by topography (including straight stream segments), vegetation, or soil type and are observable on landsat imagery. Finally, the drainage system which develops on a regional scale is controlled by the slope of the surface and the type and attitudes of the underlying rocks. Drainage is studied according to its pattern, texture or density. It is probably the most important single identifier of landforms.

The use of Landsat TM in geologic studies received a boost in Nigeria a decade ago with the creation of the National Space Research and Development Agency (NARSDA), the governmental agency responsible for the launching and monitoring of earth observation and telecommunication satellites(Ayeni et al., 2004; Igbokwe and Ayomaya.,2004; Ologun, et al.,2004). Bala et al (2000) used Landsat 5 imagery to identify lineaments that are favourable for the occurrence of groundwater, especially in the crystalline terrains of Dutsin-Ma, North Western Nigeria. Ologun (2004) generated and developed filtered images and clusters in order to obtain structural and geologic map of the Jos plateau while Igbokwe and Ayomaya (2004) carried out gully erosion mapping and monitoring in parts of southeastern Nigeria using satellite imagery.

Okposi and its adjoining areas form part of the lower Benue trough, Nigeria. It is delimited within latitudes $6^o 00^1$ to $6^o 30^1$N and longitudes $7^o 30^1$ to $8^o 00^1$E. The city of Enugu is located in the north-western margin of the map. This research work presents a Landsat based structural interpretation of Okposi area. The objectives of this study are to map the land forms, delineate linear features, and to determine regional structures and trends of deformation.

Background geology

The Benue trough is a Cretaceous folded rift basin which lies across Nigeria. It has extension from the Niger Delta through the Gongola Rift to the Chad basin in the north. It is NE-SW trending sedimentary basin, subdivided into the lower, middle and upper Benue troughs. It extends for about 1000 km in length (NE-SW direction) with width ranging from180 km to 250 km (Whiteman, 1982); see fig.1.

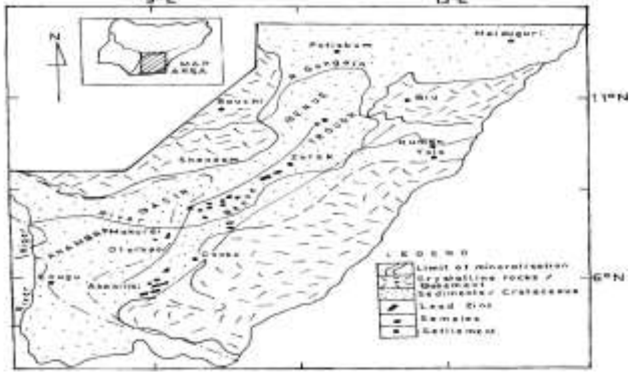


Fig.1 .Generalized geological map of the Benue Trough based on published maps of the Geological Surveys (after Olade,1976).

The depositional history of the trough is characterized by phases of marine regression and transgression (Murat, 1972; Reyment, 1965; Short and Stauble, 1967). These sedimentary sequences were interrupted by large scale tectonism which occurred in two phases: the Cenomanian and the Santonian deformations (Nwachukwu, 1972; Olade, 1975). 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. Benkhelil (1988), in a detailed report of geology of Abakaliki fold belt suggested that the compression responsible for the large scale folding and cleavage was directed N155^o E. The magmatism that occurred resulted in the injection of numerous intrusive bodies into the shale of the Eze Aku and Asu River Group while the Cenomanian deformation affected only Albian sediments. The litho-stratigraphy of the Benue trough comprises of formation ranging from Cretaceous to Tertiary in age.

The area studied is part of the lower the Benue Trough. The area is underlain by sediments that belong to the following geological formations: Asu River Group (Albian), Eze Aku Shale (Turonian), Awgu Shale (Coniancian) and Nkporo Shale (Campanian) (figure.1).Since the study area is part of the Lower Benue Trough, it shares in the tectono-stratigraphic history of the Benue Trough.

Theory and methods

A seven band landsat 5- TM image acquired on the 17th of November 1986 which belongs to a scene with path number 189 and row number 56 was acquired from the Earth Science Data Interface(ESDI) of the National Aeronautic and Space Agency(NASA). 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. Thus image rectification was carried out using existing geo-coded Landsat MSS and SPOT Multispectral data (that is image to image geo-coding) utilizing the universal Transverse Mercator (UTM) coordinate system. Each scene was radiometrically corrected. 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 while TM Band 3 is designed for detecting chlorophyll absorption in vegetation. TM Band 4 is ideal for detecting near Infra red reflectance peaks in healthy green vegetation and for detecting water bodies/ land interfaces. The two mid –IR red bands on TM(Bands 5 and 7) are useful for vegetation and soil moisture studies, and for discriminating between rock and mineral types. 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 iron staining (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 sandstone ridges. 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).

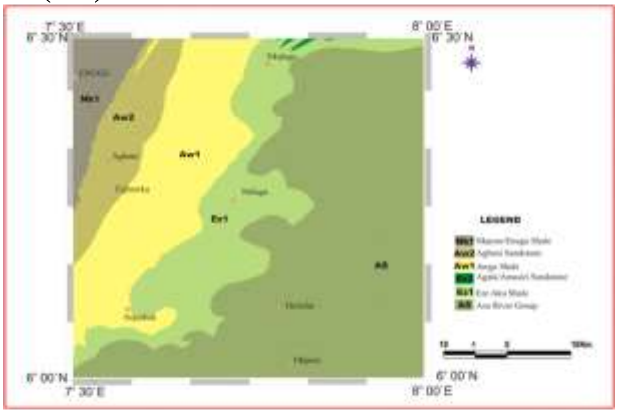


Fig. 2. Geologic map of study area showing Okposi and environs

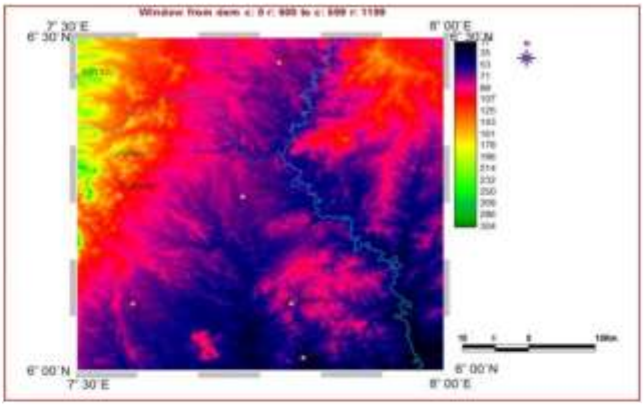


Fig.3: Digital Elevation Model (DEM) of the study area.

The landsat 5-TM 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.The ratios generated (3/4, 4/2, 3/1, 5/4) were employed to reduce the effects of shadowing as well as to enhance the detection of certain features. 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 detailed description of the composite images is shown in table 1. The ratios generated were studied in detail and information extracted along with those obtained from the digital elevation model was attributed to colour patterns observed from the colour composites.

Result presentation and interpretation

A Digital Elevation Model (fig.3) was created in IDRISI 32 by performing a colour shaded operation on Shuttle Radar Topographic Mission (SRTM) data.The DEM was converted into a contour map using the ERDAS and ArcView softwares. From the DEM, geomorphic units in study area were identified. Based on the image texture and tone; three geomorphic units: part of Enugu cuesta, scarp slope and low-lying plain were identified. The highest elevations represented as light green patches, is interpreted as a sandstone ridge. This feature seen on the top left corner of the map is suspected to be part of the Enugu cuesta, running in NE-SW direction. The scarp slope of the ridge is identified where light green, yellow and red colours are closely packed together; representing a sudden change in topography from 232 to 109 metres. The slope is characterized by numerous streams, gullies and a river. It will be correct to interpret the topographic high areas as characterized by sandstone and the low areas as characterized by shale and mudrock. This is justified by the dendritic drainage pattern expressed in the low lying area, which points to an underlying clayey lithology. Geologically the area with dendritic pattern correlates to the Ezeaku Formation. The sandstone ridge represents the watershed for the study area. Similarly, the elevation contour map (fig.4) reveals the highest elevation of the study area as green contours which correlate to the green patches on the DEM map. The low-lying plain of the study area is shown as blue on the DEM and the contour map. The slope of the ridge is similar to the interpreted one on the DEM imagery.

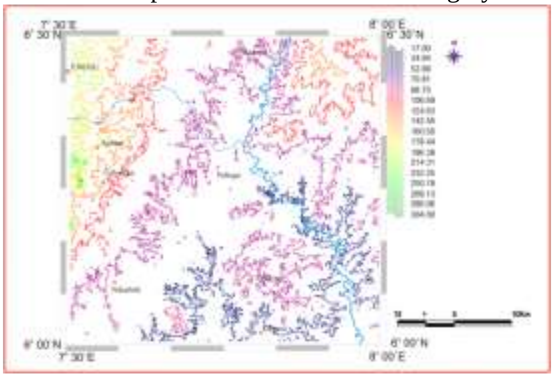


Fig.4: Contour Map of the study area

Linear features equal to or greater than 1km in length were considered. The longer lineaments have the greatest potential of being more fully developed and of penetrating greater depths. The lineaments reveal three groups of linear features. The maxima having NE-SW direction, others trend in N-S and NW-SE directions. Umeji (1988) recognized the Pan African Shield as characterized by NNW-SSE to NNE-SSW trending structures and varied intrusives and the lower Cretaceous characterized by NE-SW oriented shear zones and fractures controlled by volcanism. Murat (1972), described three tectonic trends : The first, of Albian age gave rise to Abakaliki-Benue trough with NE-SW trending faults.

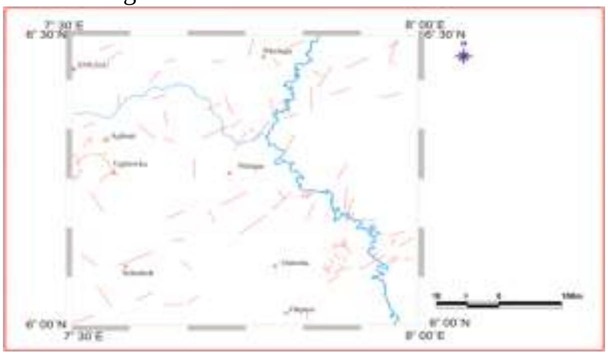


Fig.5: Lineament Map of the study area

The interpreted lineaments (fig.5) were superimposed on the edge enhanced map to show the relationship between geological formations and structural features. Similarly, the lineament density map of the study area is shown in figure 6. The lineament density map and enhanced filtered map (fig.7) reveal a high density fracture zone 5km east of Okposi, along the Ebonyi River. This zone is interpreted thus, because of the high density of lineaments seen in this area. This implies that there was intense tectonic activity along the river channel. Around Okposi, existence of lineament is interpreted. Finally, Statistical trend analysis was applied to the interpreted structural lineaments. The results obtained are displayed on the rose diagrams (figure 8). The azimuth frequency diagram (rose diagram) of the determined lineaments revealed that the commonest strikes of lineaments in the study area are in E-W, WNW-ESE, N-S and NE-SW trends. The E-W, WNW-ESE, and N-S, reflect the old and deeper tectonic trends. However, the NE-SW trend reflects the younger tectonic events, because the younger events are more pronounced and tends to obliterate the older events.

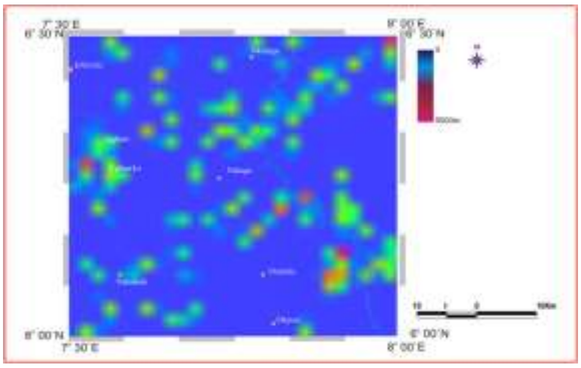


Fig.6: Lineament Density map of the study area.

Normalized Difference Vegetation Index (NDVI) relies on the chlorophyll content of a plant. This 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 (band 4) light and relatively low reflectance of red (band3) light. The calculation of the NDVI is based on the formula:

$$NDVI = (NIR - R)/ (NIR+R) \ldots\ldots (1)$$

Where NIR = Near Infrared and R = Red.

A closer look at the NDVI imagery (fig.9) revealed that the dark brown areas (-0.37 to – 0.47) correspond to bare rock zones which is observed around Enugu and eastern part of Ndiagu. Light brown areas (-0.17 to -0.27) correspond to soil + little vegetation, yellow areas (-0.07 to -0.12) correspond to sparsely vegetated areas and green (0.03 to 0.33) correspond to thick vegetation interpreted from Agbani and Ugbawka areas.

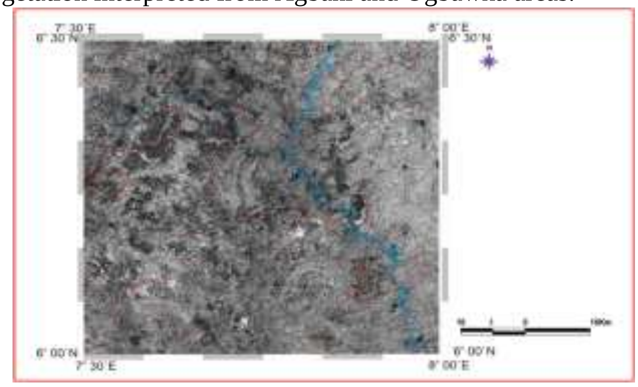
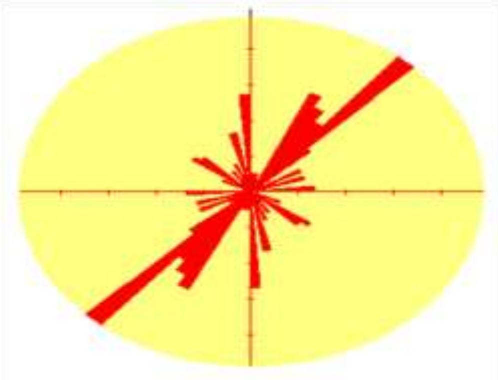


Fig.7: Lineament Draped over Filtered band 5 image

The colour composites are presented as RGB 432, 752 and 532. RGB321 (fig.10,11&12) representing the False Colour, SWIR and True colour composites. In the False Colour Composite Image, active vegetation appears red to pink, which is observed in Agbani, Nkalagu and Ndiagu areas. Bare soil appears as dull green patches located in the extreme top NW of the map, which was observed on the DEM. This is interpreted as a sandstone ridge. The drainage pattern of the study area is exhibited as a blue pattern, which corresponds to Ebonyi River channel. The drainage system reveals the presence of streams that are seen as small red patterns, which are seen as dendritic pattern.



Number of data plotted = 99; Sector Interval Angle = 5°; Scale spacing = 3% [3 data] Maximum = 14.6% [14 data]; Mean Resultant dir'n = 032; Circular Mean Dev. = 44°

Fig.8: Rose Diagram of the Lineaments of the study area

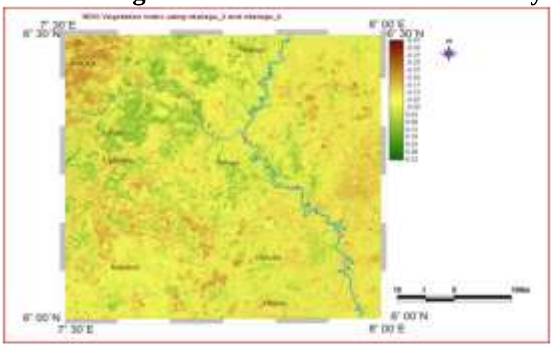


Fig.9: Normalized Difference Vegetation Index (NDVI) Composite Map of the study area

The dendritic pattern suggests that the underlying sediment is a homogenous unit. Similarly, the dendritic pattern may reveal that the lithology has least resistance to erosive action of the river and streams. Such litho-unit includes clay, mudstone, shale and limestone. These litho-units are covered within the areas underlain by Ezeaku Shale. This implies that the stream channels are covered with vegetation. Red patterns are prominent along the river channel. RGB752 composite (fig.11) is very descriptive, for it differentiates between the patterns. Bare soil area, interpreted as sandstone ridge from DEM are rendered as lavender and magenta, while urban areas are rendered in lavender pattern.

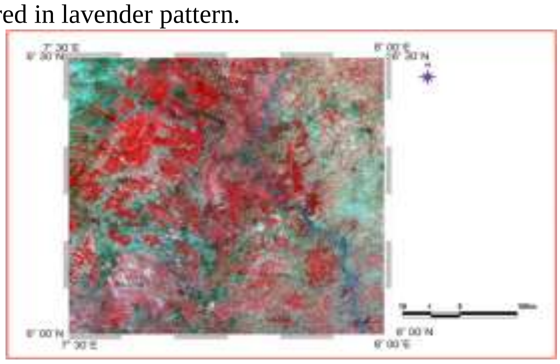


Fig.10: False Colour Composite RGB 432 of the study area

The vegetated areas showed shades of green pattern. Clay/shale area appeared as light blue pattern while the river appeared as dark blue. Detailed observation of the image (fig.11) the shades of green areas include Agbani and Ugbawka, light blue area includes Ndiagu, Okposi and Onicha have light blue and shades of green patterns. RGB 321 composite (fig.12) is portrayed in a True olour manner. Bare soil area is rendered in green pattern. Rivers and active vegetation areas are rendered in blue and mauve respectively (fig.12). Green patches seen in some of the areas on the image which implies areas of sandstone lenses. Other patterns interpreted are same with the previous composite images.

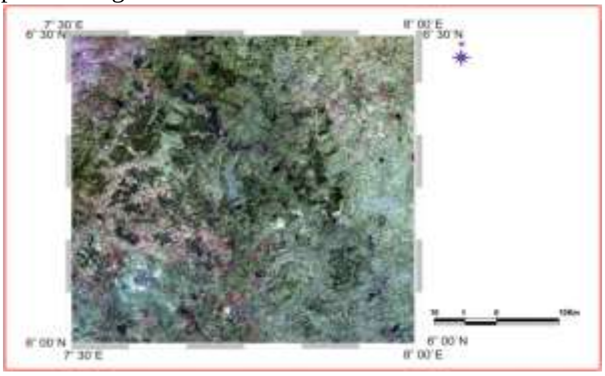


Fig.11: Short Wave Infra-red (SWIR) Colour Composite RGB 752 of the study area

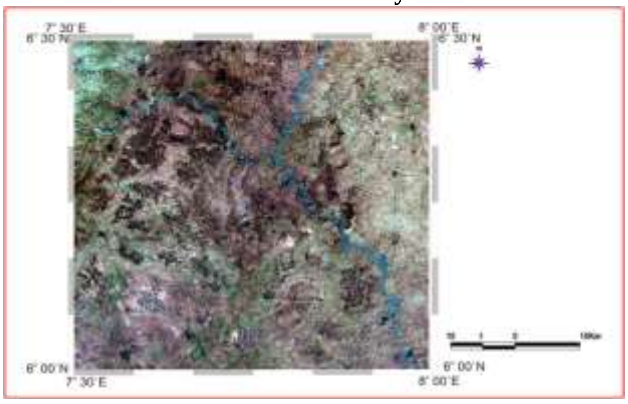


Fig.12: True Colour Composite RGB 321 of the study area

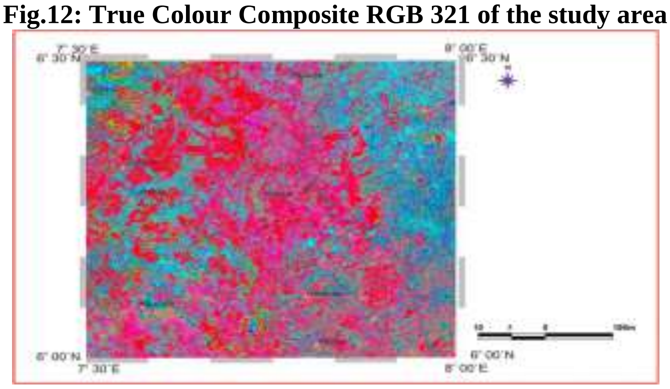


Fig. 13: Unsupervised Classification Image map of the study area

The unsupervised classification map relies on image classification tied around tonal differences of the patterns seen. In the study area, nine tonal features were observed. Looking at the image (fig.13), blue and green colours are observed in bare rock areas like Enugu. Other areas where this mixture of blue and green are observed include the eastern part of Nkalagu. This has been interpreted previously from the DEM and colour composites as sandstone units. The red and pink pattern dominate the low lying areas previously identified as an area covered by clay/shale because of the dendritic drainage exhibited on the DEM. This pattern is seen along the Ebonyi River channel. Around Okposi, Onicha and Ndeaboh areas, there is a jumble of blue, green and pink pattern which suggest the presence of sand bodies in the formation of the area.

Discussion and conclusion

Since the primary objective of this study is to identify structures expressed as lineaments and classify them according to their spatial and directional attributes, it was necessary to process the Landsat -TM data in a manner that would both enhance trends and facilitate the computation of locations and depths. Drainage pattern, termination of drainage line on linear trends and straight stream segments were some of the basic hypothetical models used to map fractures. O'Leary et al. (1976) defines lineaments 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. The Landsat lineament map (fig.6) revealed the existence of lineaments around Agbani, Ugbawka and northeast of Onicha that are close to Ugulangu. Similarly, lineament density and the filtered maps show heavy concentration of lineaments around the areas mentioned. This implies that the basement around the study area has suffered serious deformation. The last major tectonic event in the study area was the Pan African orogeny (650 ± 150) Ma. It produced geological structures trending NE-SW; some of the interpreted lineaments bear this strike while some deviate from it.The study area has been affected by the many sedimentary phases(Short and Stauble, 1967; Murat, 1972). The first phase produced two principal sets of faults trending NE-SW and NW-SE directions. It is worthy to note that the initial rifting of the Southern Nigeria Continental Margin in the Mesozoic Era produced two principal sets of faults trending NE-SW and NW-SE. The NE-SW fault bound the Benue Trough, while the NW-SE faults define the Calabar Flank and Niger Delta (Zarboski, 1998).

The inferred structural trends from the Rose diagram (fig.8) are in the orientations:NE-SW, E-W and N-S. The NE-SW trend is the dominant orientation from the Rose diagram. According to Uzuakpunwa (1974), the NE-SW trending Abakaliki-Benue trough is thought to be the result of a pre-Albian rifting of the African shield prior to the opening of the South Atlantic. Linear structures running NE-SW observed from the study are suggested as the continental extension of the known pre-Cretaceous oceanic fracture zones viz. Charcot and Chain fracture zones (Ananaba, 1991; Burke et al 1971; 1972) which run along the trough axis beneath the sedimentary cover.

The colour composites, DEM and unsupervised classification were incorporated in the development of an updated GIS based geologic map (fig.14) of the study area. The DEM (fig.3) reveal the presence of a topographic high interpreted as sandstone ridge suspected to be the Enugu cuesta. The contour interpretation from the contour map (fig.4) shows the escarpment of the cuesta as the region where contours different colour mixed in a disorderly manner.

The presence of lineaments around the Okposi brine Lake revealed that the lake is structurally controlled. The Okposi Brine Lake could therefore be suggested as emanating along a deep fracture trace (fault trace) that must have cut through the basinal brine of the Asu River group. It is possible that the fault trace have provided a migration pathway for the brine. This suggests that the Brine Lake is structurally controlled.

Elsewhere, lakes with similar features include: the Loch Ness in Scotland and Baikal in Asia.

This present research 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, NESW,N-S and E-W directions(Chukwu-Ike and Norman(1997); Ananaba and Ajakaiye (1987); Onyedim(2006); Udoh(1988).Furthermore, it is geologically plausible that the landward intersections of the transform fracture zones may have influenced the formation of the river patterns and basin formation. The NE-SW trend and the other strikes confirm that Nigeria was subjected to Pan African orogeny.

References

Ananaba, S.E., (1991). Dam sites and crustal mega-lineaments in Nigeria. ITC Journal Vol. 1, pp. 26-29.

Ananaba, S.E. and Ajakaiye, D.E.,1987. 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.

Ayeni,O.O., Nwilo, P.C ., and Badejo,O.T.,2004.application of NigeriaSat-1 in monitoring erosion along Lagos Coastline; NASRDA News Bulletin;pp.40-42.

Bala, A.E., Batelaan, O., and 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.

Benkhelil, J., (1989). The Origin and Evolution of the Cretaceous Benue Trough (Nigeria). Journal of African Earth Sciences 8, 251-282.

Burke, K.G., Dessauvagie, T.F.J. and Whiteman, A.J., (1971). Opening of the Gulf of Guinea and Geological History of the Benue Depression and Niger Delta.Nature (Phy.Sc.). 233, 51 - 55.

Burke, K.G., Dessauvagie, T.F.J. and 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.

Carrere, V. and Chorowicz, J., (1982). Etude structurale du linéamentligureobservésur les images spatiales. Bull. Soc. Geol. Fr. 7, T XXIV, (1) pp. 33-47.

Chorowicz, J. and Rangin, C., (1982). Essai de catographiegéologique de la bassecalifornieobtenue á partie de l'analyse des images spatiales methods et resultants. Bull. Soc. Geol. Fr. 7, T XXIV, (1) pp. 139-143.

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

Ferradini, J., Cornee, J.J., and Simon, B., (1993). Etude linéamentairesur images Landsat 2 du Haut Atlas accidental (Maroc): conséquencesGéodinamicaActa, 6 (3), pp.161-173

Igbokwe, J.I., and Ayomaya, T., (2004). Gully Erosion Mapping/Monitoring in Parts of Southeastern Nigeria. NARSDA News.Pp.13-15.

Igbokwe, J.I., and Ayomaya, T., 2004. Gully erosion mapping/ monitoring in parts of Southeastern Nigeria; NASRDA News Bulletin ;pp13-15.

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.

Nwachukwu, S.O. (1972). The tectonic evolution of the Southern portion of the Benue Trough, Nigeria Geol. Mag. 109, 411-419.

Odeyemi, I.B., (1993). A comparative study of remote sensing images of structure of the Okemesi fold belt, Nigeria.ITC Journ.1, pp.77-83.

Olade, M.A. (1975). Evolution of Nigeria's Benue Trough (aulacogen): A tectonic model. Geol. Mag. 112, 576-583.

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

Ologun, J.A.A.,2004. Geological mapping of parts of Jos Plateau using Nigeria Sat-1 Image; NASRDA News Bulletin;pp.35-37.

Onyedim, G.C.(1996).An investigation of structural and lithologic controls of drainage patterns in parts of Ilesha area using remote sensing data; Journal of Mining and Geology; vol. 32; no.1; pp. 53-58.

Reyment,R.A.,1965.aspects of the geology of Nigeria, university of Ibadan press, Nigeria;145pp.

Short, K.C., and Stauble, A.J., (1967). Outline geology of the Niger Delta. Am. Assoc. Petrol. Geol. Bull. 51, 761-779.

Udoh, A.N.(1988). Remote sensing imageries of Nigeria, north of 70401:In: Oluyide, P.O.,et. al., (eds).

Precambrian Geology. Geological Survey of Nigeria, Publ., pp.99- 102.

Umeji, A.C., (1988). The Precambrian of part of the SE Nigeria: A magmatic and Tectonic study. In :P.O. Oluyide, W.C. Mbonu, A.E Oguzie, I.G. Egbuniwe, A.C. Ajibade and A.C. Umeji (Eds.), Precambrian Geology of Nigeria, Geological Survey of Nigeria, pp.69-75.

Uzuakpunwa, A.B., (1974). The Abakalikipyroclastics-eastern Nigeria: New age and tectonic implications, Geological Magazine III, pp. 65-70.

Wenmenga, U., (2005). Landsat and Aeromagnetic interpretation of the structural features of the Palaeoproterozoic Basement of Boussouma area, Burkina Faso.Journal of Mining & Geology Vol. 4(1), pp.33 – 40.

Whiteman, A., (1982). Nigeria: Its Petroleum Geology, Resources and Potential. Graham and Trotham, London.

Zaborski, P.M., (1998). A Review of the Cretaceous System in Nigeria. African Geoscience Review vol. 5, No. 4, pp. 385.

Table 1: Appearance of Geological Features on Landsat 5 TM Composite Images.

DESCRIPTION	TRUE COLOUR	FALSE COLOUR	SWIR (GEO-COVER)
	Red: Band 3 Green: Band 2 Blue: Band 1	Red: Band 4 Green: Band 3 Blue: Band 2	Red: Band 7 Green: Band 5 Blue: Band 2
Trees and Bushes	Olive Green	Red	Shades of green
Crops	Medium to light Green	Pink to red	Shades of green
Wetland vegetation	Dark green to black	Dark red	Shades of green
Urban areas	White to light blue	Blue to gray	Lavender
Water	Shades of blue & green	Shades of blue	Black to dark blue
Bare soil	White to light gray	Blue to gray	Magenta, lavender, or pale pink.