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Interpretation of Ring Structures in Jos Plateau Using NigeriaSat 1 Imagery

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Abstract: **Remotely sensed images acquired from National Centre for Remote Sensing (NCRS) Jos, using NigeriaSat 1 imagery were processed (filtering, edge enhancement, digitization etc.) to delineate the major geological ring structures/trends such as lineaments and drainage patterns of Jos Plateau. In addition, to decipher the relationship, if any, between the ring structures and the tectonism in the Plateau. The data was geo-referenced in accordance to topographic map coordinates of the Naraguta Sheet, and convolution models in ILWIS 3.1 software program were specifically employed to enhance and facilitate the recognition of the linear features in the area. Structural analysis shows that numerous fractures and lineation occurs at the northwestern, central and southwest of the satellite image. The strikes and lengths of all lineaments were measured and computed to obtain the rose diagram. The important structural trends are NE-SW, N-S and NW-SE, which corresponds to the directions and positions of the paleo-tectonic fracture zones in the area and mineralization tracks. Areas where basement rocks outcrop or underlay just beneath to the surface (i.e. areas with thin overburden) are known for the high lineament frequencies they exhibit, whereas, areas with little or no lineament frequencies are characteristic of areas with deeply buried basement rocks. Cross-referencing the lineament densities and Younger granites occurrences in Jos Plateau, a correlation is found between them emblematic of tectonic control most likely connected with paleo-tectonic structures; thus, associating their emplacement with the epeirogenic uplift. Mineralization in the Plateau is inferred to have been controlled by the same correlation.**

Keywords: **Lineaments, fracture, faults, complexes, granites, structures.**

I. INTRODUCTION

Remote sensed satellite observations from space have fundamentally changed the way in which scientists study the earth. Internal processes occurring deep down the earth's surface subject the earth to changes that bring about certain surface structures that may appear as fracture, faults, lineaments and drainage pattern in an area. These structures sometimes are of regional extent and need a wide coverage for its full understanding. Remote sensing is the science and art of obtaining information about an object, an area or phenomenon through the analysis of data acquired by a remote device [1]. Remote sensing views the earth's surface in a detailed map like form, providing a synopsis of areas that are far larger than can be encompassed by a ground view and much faster than field mapping [2]. Remote sensing especially using satellite is a quick and efficient way to scan broad areas and reveal features that are difficult to map at the surface and allows field observation to be extrapolated in unvisited areas. In this regard, it reduces the amount of field work needed to achieve project objective and directs further investigations to areas containing most critical evidence. Remote sensing methods encompass all those means of examining planetary features that do not involve direct contact, rather they rely on detection, recording and analyzing of wave transmitted energy into visible light, infrared radiation and others. Examples of remote sensing include aerial photograph, radar mapping of surface topography and air borne magnetic survey.

Interpretation of drainage patterns, lineaments and related surface features from LandSat imagery in different parts of the world have given rise to understanding of the structural trend in those areas. Historically, remote sensing in the form of aerial photograph has been an important source of land cover and land use information. The NigeriaSat 1 is a new microsatellite launched in Nigeria in the year 2003. It is a third-generation satellite (LandSat 6 and 7 series), called Enhanced Thematic Mappers (ETM) because they have high resolution than other generations of satellites and an accurate digitized area surface viewed.

The remotely collected data can be in form of a variation in the force distribution or acoustic wave distribution or electromagnetic energy distribution. The main elements in data acquisition in remote sensing are: the object to be studied, the observer or sensor, the electromagnetic radiation (EMR) - the carrier of the information, and the source of the electromagnetic radiation

A. Landsat Imagery and Uses:

- The synoptic view of the sensor provides coverage of large geographic area.
- The images are widely used in environmental monitoring and pollution control.
- Analysis of lineaments and modeling for natural disaster mitigations are made possible via LandSat imagery.
- Structural and geomorphologic interpretation of a remotely sensed data aids mineral assessment and evaluation.
- Post classification change detection has enabled quantification and analysis of land cover overtime.

B. Limitation of Imagery:

Imagery has helped tremendously in human and environmental development in so many ways. However, some conditions and factors limit the use of LandSat imagery technology. LandSat images should be considered as a complementary interpretive tool instead of a replacement for low altitude aerial photographs for housing quality studies. Most LandSat images can only be viewed in 2D, i.e. cannot be viewed in stereo except in areas of side of adjacent orbit passes. Vertical exaggeration when viewed on LandSat image in stereo is quite small compared to conventional air photos. In addition, some objects with similar reflectance cannot easily be distinguished due to resolution level and some atmospheric corrections needed in the LandSat imagery. LandSat Multi-Spectral Scanner and Thematic Mapper are across-track scanning process that produce images having one-dimensional relief displacement only in the scan direction and not in the flight to flight direction.

C. Aim of the Study:

✓ To delineate the major geological ring structures/trends such as lineaments and drainage pattern of the area which are track for mineralization.

✓ To decipher the relationship if any between the ring structures and the tectonism of the area.

D. The Study Area:

Jos-Plateau is a city in the Nigeria’s middle belt and is the administrative capital of Plateau state, between latitude 9˚30′N & 10˚10′N, and longitude 8˚15′E & 9˚15′E; and topography comprising of chains of highland of variable heights coupled with flatter topography. With an altitude of 4062feet above sea level, it enjoys a more temperate climate (average monthly temperatures range from 20°C to 25°C and annual rainfall approximately ranges between 1500-2000mm). The vegetation area is tropical wood-lands characterized by tall grasses, shrubs and stunted trees.

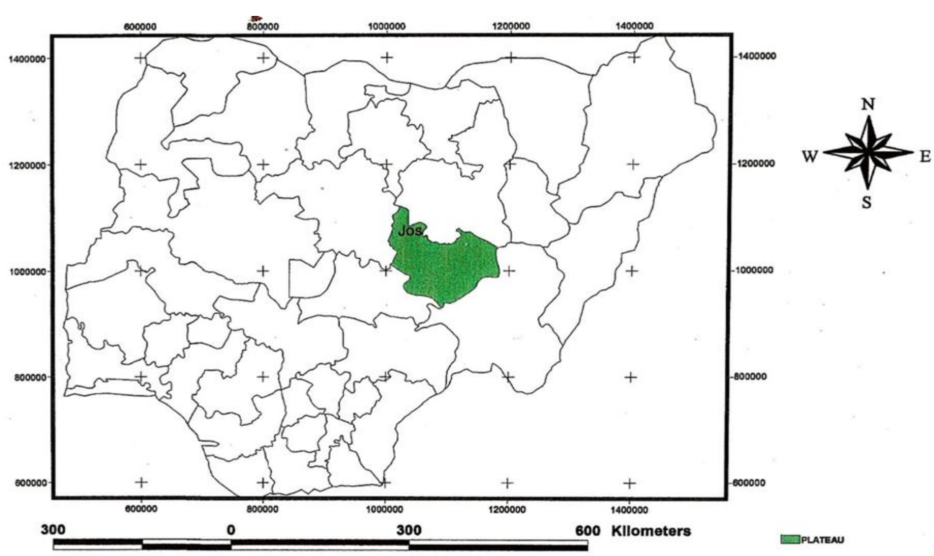

Fig. 1. Map of Nigeria showing the location of the study area; Jos, Plateau State

The geology of Jos-Plateau comprises of plutonic and volcanic rocks classified into four main groups. The rocks of Jurassic age [Younger Granites[1] 140-190MA (mega-annum)], Precambrian rocks and intrusive older granites of Pan African Orogeny [>500MA, Migmatites[2], Gneisses[3], Crystalline basement rocks[4]] are predominant rocks of Jos-Plateau [3]. The Jurassic younger-granites ring complexes intrude the late Precambrian to lower Paleozoic basement rocks of northern Nigeria in the N-S zone. This zone is parallel to the main Pan African trends in the basement, indicating control by earlier structures. It also lies on a continuation of the African continental margin to the south and possibly formed in a region of crustal arching developed prior to the separation of the Pan African and American plates in the cretaceous.

The Pan African Orogeny that occurred on the African continent led to structural deformation and regional metamorphism. The earliest rocks are volcanic, preserved from erosion through cauldron subsidence. A two-fold volcanic sequence is characteristic: early rhyolites (ignimbrites and peralkaline commendites in bedded sequence with minor associated basalt and trachytes) and late rhyolites (porphyritic, thick caldera filling flows and intrusive stocks, plugs and dykes, closely associated with the emplacement of outer ring dykes of granite-porphyry, with later annular and stock-like intrusions of arfvedsonite and biotite granite) [3].

The Younger Granites are a petrologically distinctive series of alkali feldspar granites, associated with rhyolites and minor gabbros and syenites. They occur in sub-volcanic intrusive complexes as ring dykes and related annular and cylindrical intrusions. They are richly mineralized with tin and niobium [4].

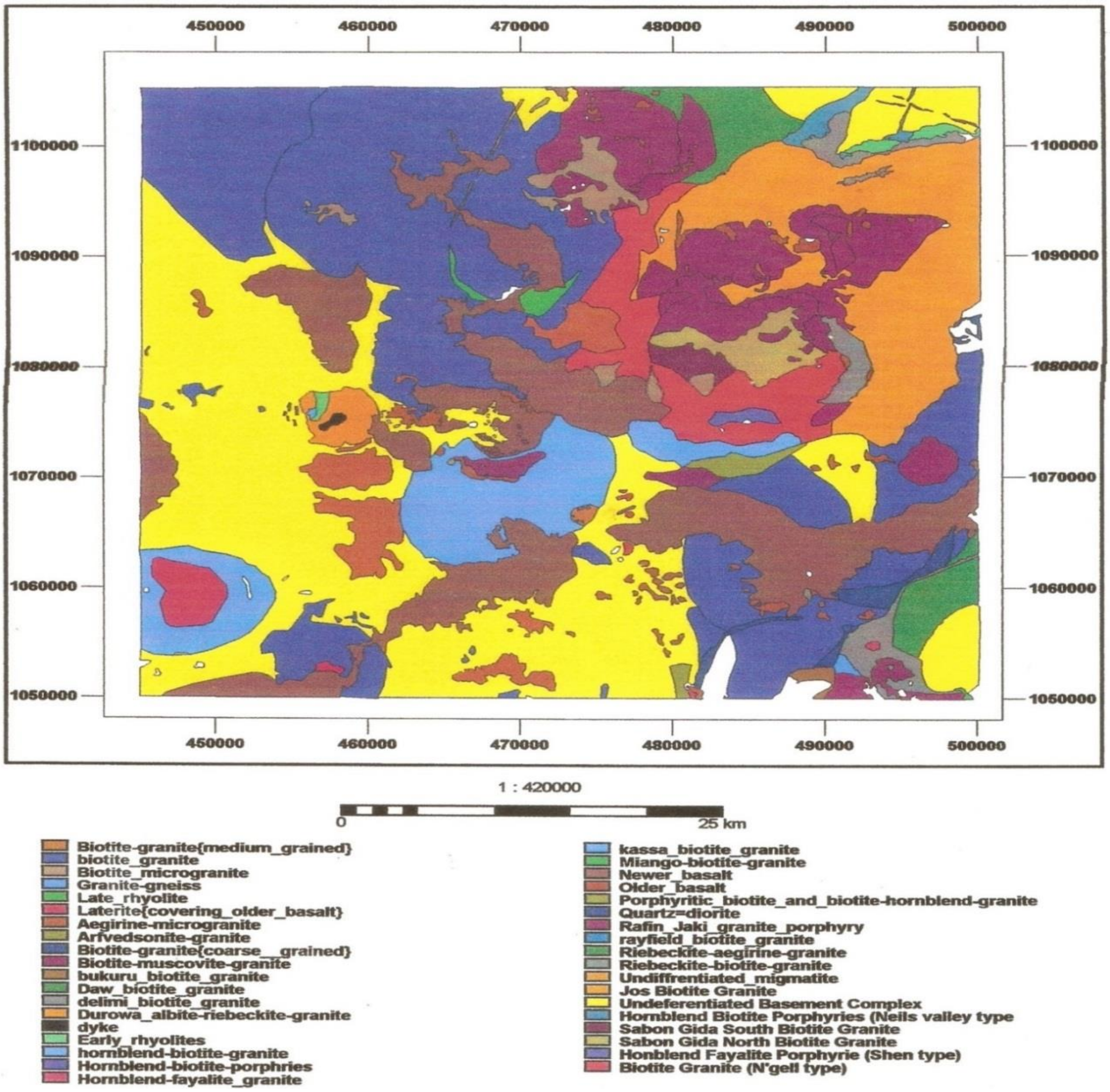

Fig. 2. Geological Map of the Study Area (Naraguta Sheet 168)

II. LITERATURE REVIEW

According to Drury [2], geological structures or features originate due to tectonic processes that occur deep down the earth's crust. The processes that occur down the earth's crust are manifested on the earth's surface giving to various surface features like drainage patterns, linear features and lineaments. Furthermore, study of this surface features give insight to the origin and direction of such tectonic events. Consdine [5] defined structural geology as the branch of geology which deals with the form, arrangement and internal structures of the rocks especially with the description, representation and analysis of structures chiefly on a moderate to small scale. Evidence for the changes caused by deformation on rocks are commonly implanted into geologic bodies in the form of recognizable structures such as fault and joint, fold and cleavage, foliation and lineation. These deformations are best understood by the nature of the drainage pattern. Since these structural trends cover a large area in most cases, the best approach to the study of these features is remote sensing of the earth's surface.

Lineaments are generally defined as any feature that can be picked out as lines (appearing as such or evident because of contrasts in terrain or ground cover on either side) in aerial or space imagery. If geologically caused, they are faults, joints or boundaries between stratigraphic formations. Other causes of lineament include roads and railroads, contrast emphasized contacts between natural and manmade geographic features (e.g. fence lines) or vague "false arm" caused by an unknown factor. O'Leary et al, [6], defined lineament as a mappable simple or composite feature of surfaces whose part are aligned in a rectilinear or slightly curvilinear relationship and differs distinctly from patterns of adjacent features and presumably reflects a subsurface phenomenon. Ilyin [7] showed that lineaments happen to be sites of high-discharged thermal springs of mineralized water used for medical treatments. They also serve as path for sweet water circulation and a lot of big ascending springs are confined to lineaments. Lineaments give a better understanding of the old structural pattern for mineral deposits exploration and groundwater exploration. Transverse faults accompanied with alkaline intrusion can be located.

Bhate [8] stated that the lineaments in imagery has been classified into three (3) categories based on their linear extent. The lineament extending for a length of more than 300km are classified as mega lineaments, those extending from 100-300km as intermediate lineaments and those extending less than 100km by length as micro lineaments. The mega and intermediate lineaments are considered to represent major faults in an area; micro lineaments on the other hand mostly reflect the major joint and fracture pattern in an area.

According to Ananaba et al, [9], regional analysis of lineaments based on their spatial and directional attributes of their assemblages suggests a general Northeast-Southwest, Northwest-Southeast and North-South (NE-SW, NW-SE and N-S) tectonic trends. Lineaments have tectonic origin which also affects drainage in places of high primary mineralization. They interpreted that lineament distribution are zones of mineral entrapment which fall along the same general tectonic trend in Nigeria. He also found that the lineament trend to cover an area where igneous activity (basalt) has been reported. He concluded that the primary ore bodies in Nigeria are probably oriented following lineament trends.

Werner [10] defined photo-lineaments as either a continuous linear or curvilinear features or alignments of discrete features and short segments of lines. Lattman [11] restricts the use of terms of lineaments to vegetation, topographic or soil tonal anomalies identified on satellite imagery. Silbaugh [12], based on results of several previous studies established a set of definitions for topographic lineament which are purported to allow a high degree of reproducibility. He classified lineaments as Short Straight Lineaments (SSLs) with length between 500-2000m, Short Curvi-lineaments (CVLs) with uniform length between 200-500m and Long Topographic Lineaments (LTLs) with length over 2000m. Mabee et al, [13] defined lineaments as naturally occurring alignments of soil, topography, stream channels, vegetation or a combination of these features that are visible on a remotely sensed imagery and aerial photographs.

The drainage patterns which develop in an area are of dependency on the nature, slope and attitude of bedrock, and the regional and local fracture pattern. The drainage pattern is considered on its pattern type texture. The texture is related to the rock or soil permeability and type. According to Way [14], six drainage patterns and three textures patterns can be identified. They include: dendritic, trellis, parallel, radial, annular and rectangular. Then, the textures are: fine, medium and coarse

III. METHODOLOGY

The study was carried out using NigeriaSat 1 imagery (Figure 3) acquired from National Centre for Remote Sensing (NCRS) Jos. The raw data was geo-referenced using the coordinate of the topographic sheet 168 Naragutta. The geo-referenced projection is universal transverse Marcator (UTM), Datum-Minna, Datum area, Nigeria; Ellipsoid, clerk 1880, zone 32 with Erdas Imaging software. Image processing & enhancement (filtering, edge enhancement), interpretation and digitization (contours, drainage) were carried out using computer software known as ILWIS 3.1.

The datasets in hard copy were first scanned and the rows & columns of the resulting scanned raster formats were related to real world coordinates by creating a coordinate system and geo-reference using 'tiepoints'. After geo-referencing, a value domain is created for the maps separately. This is to assign ID values to the data base being created since the values of the contours to be digitized, represent elevations and total intensity of the respective maps. When creating domain for datasets that do not use values, they are created either as image, unique or class domain, as applicable.

The maps were digitized by creating a segment map that allows you use the segment editor to trace each contour line, the contour values are entered at the end of each trace. The purpose of digitizing is to convert the analog maps or objects to digital formats acceptable by ILWIS for processing and manipulation; then, the maps are composed and printed out. Simple digital image processing techniques were applied on the image (fig 3) to enhance edges or linear features.

In an attempt to apply some consistency to lineament mapping and terminology, and to really identify lineament on the map, the Werner [10], Lattman [11], Silbaugh [12] and Mabee et al [13] definitions and approaches were adopted. Lineaments were drawn on a transparent paper placed over figure 3. Prevalent lineaments orientation was noted and compared to known geologic structural features in the area. Only prominent lineaments that were clearly visible on the images were recorded. They were re-examined two months later to evaluate the observer's ability to produce lineaments at the same geographic location. New lineament map was made and compared with the first set of lineament map and corresponding lineaments were noted. These prominent lineaments were thus verified by their multiple repetitions in several traces of the transparent paper at different times. Several iterations of lineament mapping on the satellite imagery were made and only lineament that appeared on all the resulting maps were used in the final analysis.

A rose diagram was drawn and the lineament were identified and re-examined to ensure that it conforms to the structural trend in the area. The approach used in obtaining the rose diagram is as follows;

✓ A transparent paper was placed over the LandSat imagery (Figure 3) and the linear features were traced out as a map.

✓ Starting from one of the lineaments, a protractor was used to measure the angle it makes with the horizontal from 0° to 180°.

✓ The angle measured was recorded and each of the lineaments was marked with a cross-mark to indicate that its measurement (strike and length) has been completed. The same thing was done to all the lineaments and their angles were obtained.

✓ A plot of narrow wedges and their angular width for all the intervals was made.

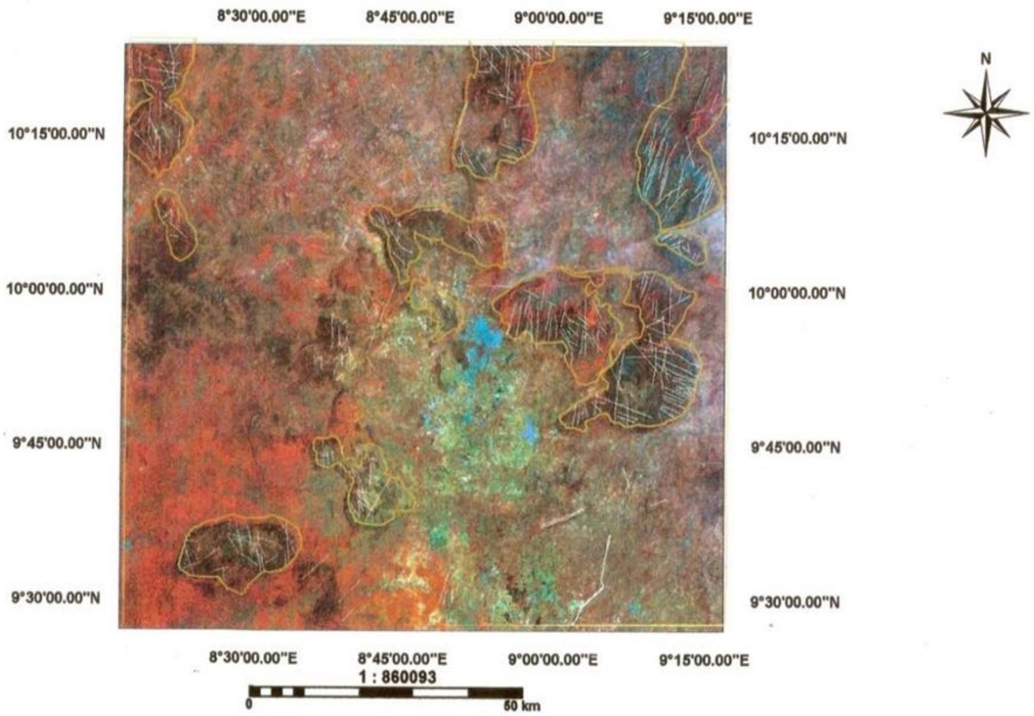

Fig. 3. NigeriaSat 1 Image of Younger Granites Region of Jos Plateau Overlain with Ring Structures/Lineaments (Source: National Centre for Remote Sensing Jos)

IV. RESULTS & INTERPRETATION

The observable structural geological features were carefully traced out (Figure 4), features like fractures, joints, drainage and dykes as lineation/linear features and ring structures. Thus, the result of the structural analysis shows that numerous fractures and lineation occurs at the NW, SW and Central of the satellite image. A dolerite dyke related to a major NE-SW striking fracture, occurs in NW of the study area. The important structural trends are NE-SW, N-S and NW-SE. Cross-referencing the lineament densities and Younger granites occurrences in the study area, a correlation is found between them emblematic of tectonic control probably associated with paleo-tectonic structures; thus, associating their emplacement with the epeirogenic uplift. The epeirogenic uplift resulted from the intrusion of large masses of basic magmatic materials into the lower part of the continental crust in the area. The marked relationship between the Younger granites and the lineaments is inferred to have controlled mineralization in the study area.

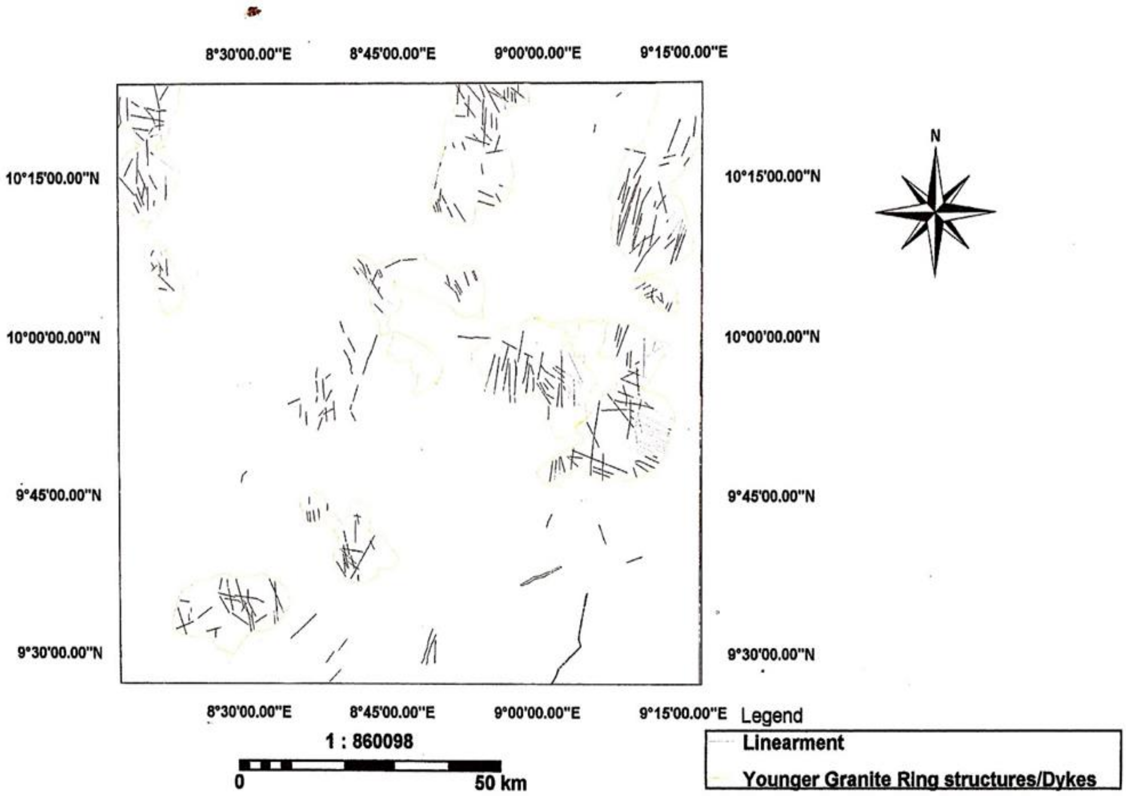

Fig. 4. The Ring Structures/Dykes and Lineaments extracted from the Image

A. Fracture Analysis:

The study area had been affected by major tectonic events that produced structural deformation of its geology. An example is Pan-African orogeny dated 500-600Ma during which older granites also called Pan African Granites were emplaced. The Pan African orogeny produced geological structures with N-S orientation [15]. Some of the fractures in the image bear this strike. The fractures show high density in the NE-SW. However, the absence of visible fracture and lineaments in parts of the image does not indicate absence of geological structures. From field investigation, locations in the southeast of the study area with low fracture density correspond to areas covered by soil and highly weathered thick overburden.

B. Drainage Pattern Analysis:

The drainage of the area extracted from the image and existing topographic map shows that the drainage system which develops in the area is strictly dependent on the slope, the nature and attitude of bedrock, and on the regional and local fracture pattern. The observed drainage of the area is said to be dendritic (branching courses) and it is indicative of crystalline rock, which is typical of the geology of the area that consists mainly of crystalline rocks. Also the drainage texture of the area is coarse. It is characteristic of resistant, permeable bedrock materials and coarse permeable soil material, such as the coarse-grained porphyritic.

C. Lineament Analysis:

The patterns of lineaments indicated in the rose diagram (Figure 5) are also consistent with the regional photogeologic interpretation of the tectonic fracture of the central Nigeria basement complex by Chukwu-Ike [16]. High lineaments frequencies are obtained in areas where basement rocks outcrops or closer to the surface (i.e. areas with thin overburden) whereas between lineaments frequencies are characteristic of areas with deeply buried basement rocks. Similar information/delineation of various lithological units could be extracted from other enhancement methods e.g. AVG Cluster, Edge. From the image, we can see that the area comprises of chains of high hills surrounded by lowers areas. Though not conclusive in some cases, differences in topography imply different lithologies.

Rose Diagram of the Lineament Map:

The result of the structural analysis, the orientation and the relative importance of recognizing the lineament using the rose diagram (Azimuth distribution diagrams) show that the lineament in the study area trend at the NE and SW of the NigeriaSat image (Fig 3). Therefore, the rose diagram is established to determine the structural trends of lineaments (Figure 5).

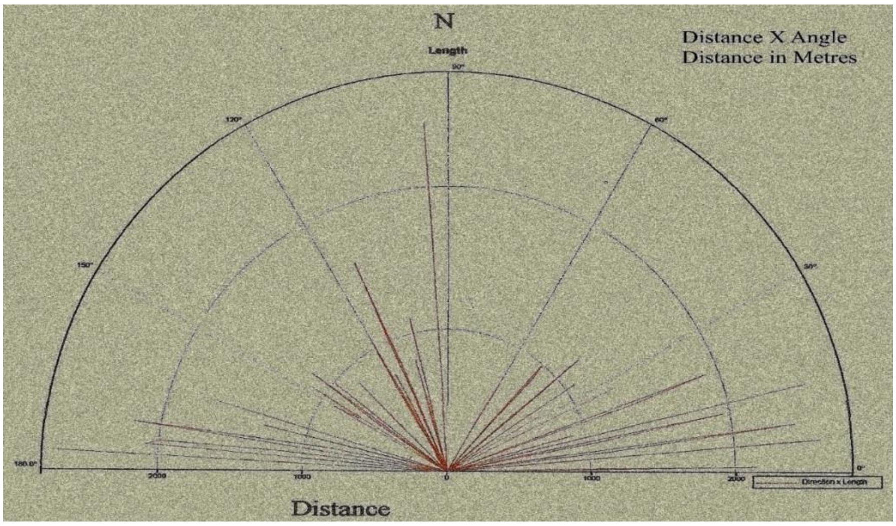

Fig. 5. The Rose Diagram of the Lineament Parts of Jos and its Environments

D. Younger Granite Complexes/Ring Structures:

The younger granite complexes and dolerite dykes clearly delineated from the country rock in Figure 6 are as follows:

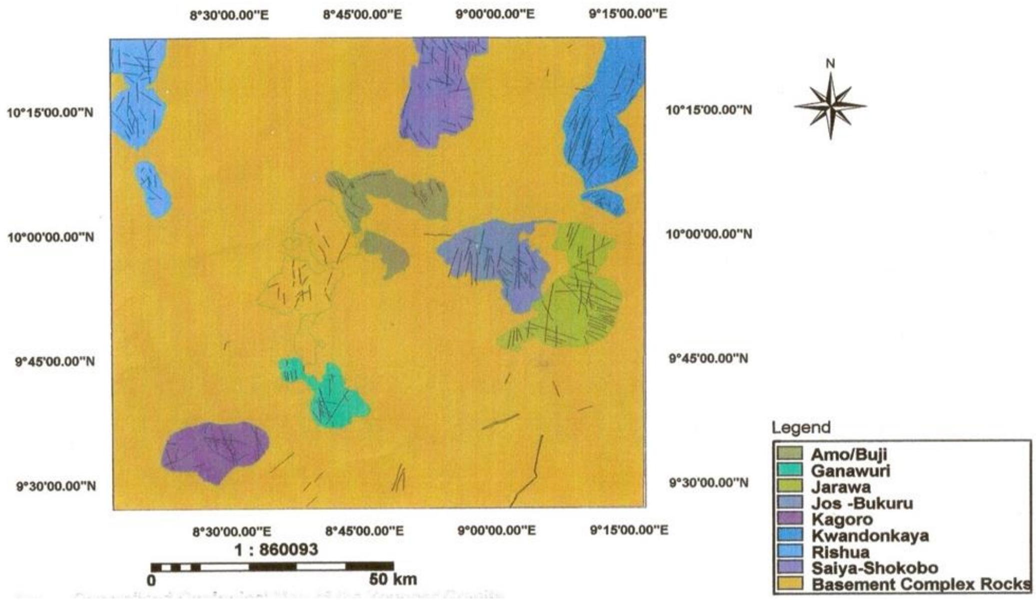

Fig. 6. Generalized Geological Map of the Younger Granites Rocks Created from the NigeriaSat 1 Image

Amo/Buji Complexes: These complexes as seen from the geological map of younger granites (figure 6) lies between latitude 9˚53′N & 10˚07′N, and longitude 8˚43′E & 8˚56′E. The lineaments show a directional attribute of NE-SW, NW-SE trend and mostly occur at the eastern and western margin of the complex. These are zones of mineral entrapment and tectonic activity [9]. The lineaments extend less than 100km by length and therefore are referred to as microlineaments [8] and they reflect the major joints and fracture pattern in the area.

Ganawuri Complex: The complex lies between latitude 9˚38′N & 9˚45′N and longitude 8˚36′E & 8˚45′E from the map, and covers an area of about 70sq. miles. The complex is clearly defined in two prominent hill masses which are both roughly circular in outline. The smaller hill mass has the lineaments occurring at the southern margin, while other hill mass shows a high density of lineament at the southeastern area. The complex can be said to be sites of high-discharge thermal springs of mineralized water and serve as path for sweet water circulation [7]. The length of the lineaments show that they are mostly microlineaments and show a NE-SW, N-S and NW-SE trend; they are tectonic trend that matches with areas of primary mineralization in Nigeria; thus, suggesting that mineralization is tectonically controlled [9].

Jarawa Complex: The complex lies between latitude 9˚45′N & 10˚02′N and longitude 9˚00′E & 9˚15′E. The Jarawa cycle of igneous activity appear to have been contemporaneous with part of the early granite cycle of the Jos-Bukuru Complex [3],. Lineaments were mapped at every part of the complex except at the central part, which therefore implies no fracture density i.e. areas covered with soil or highly thick weathered overburden [17]. The complex generally shows a high fracture density stemming from the density of lineaments in the area, which are mostly microlineaments [8]. The high fracture density suggests the presence of groundwater and mineralization; areas where the occurrences of most primary minerals have been reported [9]. The lineaments and primary mineralization show a Northeast-Southwest, North-South and Northwest-Southeast tectonic trend. The presence of big descending springs can also be inferred.

Jos-Bukuru Complex: The complex lies between latitude 9˚48′N & 10˚00′N and longitude 8˚54′E & 9˚06′E, at the focal point of Younger granite magmatic activity and the complex is elliptical in surface plan with the longer axis extending for a distance of 30 miles from Shere hills in the North-east to the Forum river in the south, with a deviation above sea level ranging from 3,800ft near the west and north margins to nearly 6,000ft in the Shere Hills [3]. The lineaments show a general NE-SW and N-S tectonic trend; a high density at the central part, thus implying a high fracture density [8] and presence of ground water and mineralization at the central part of the complex [9]. Macleod et al [3], stated that the form of the Jos-Bukuru complex has been determined by this elliptical ring-fracture which extends around the northern, western and southern margins of the massif and embraces the separate Jarawa complex to the east.

Kagoro Complex: The complex is situated about 30miles southwest of Jos where it forms an extensive westward prolongation of the main plateau, lying precisely between latitude 9˚30′N & 9˚37′N and longitude 8˚22′E & 8˚36′E. The lineaments in the complex are sparsely scattered over the whole complex, indicating sites of high-discharged thermal springs of mineralized water and paths for sweet water circulation [7].. The drainage pattern in the complex tends to maintain the major lineament trend (North-South) since the radial drainage pattern has been an important factor in the wide alluvial distribution of minerals [3].

Kwandonkaya Complex: The complex forms a prominent hill mass, situated about 25miles north-east of Jos, precisely between latitude 10˚03′N & 10˚30′N and longitude 9˚10′E & 9˚15′E. The lineaments maintain a NW-SE trend thus corresponding to the tectonic trend in the complex and equally zones of mineral entrapment. They lineaments show a high density at the southern part of the complex; this generally suggests presence of groundwater and mineralization [9]. The zones of high fracture density and tectonic activity or say igneous magmatic activity and primary mineralization in the complex follow the same trend since it is tectonically controlled. There are presence of outcrops or near-surface rocks and deposition in the area occurred in the northeast direction, carried from areas of high fracture density.

Rishua Complex: The complex shows two prominent hill masses which both lie between latitude 10˚10′N & 10˚30′N, and longitude 8˚15′E and 8˚22′E. The lineaments in the complex are sparsely scattered all over the tow hill masses of the complex, with the lengths indicating microlineaments; sites of high-discharged thermal springs of mineralized water and serve as path for sweet water circulation [7]. The lineaments show a general NE-SW, N-S, NW-SE tectonic trend, thus inferring zones of igneous activity and primary mineralization in the complex.

Saiya-Shokobo Complex: It exists between latitude 10˚10′N & 10˚25′N, and longitude 8˚50′E & 9˚00′E and forms a northerly trend ellipse. The lineament shows a high density at the northern margin of the complex, thus representing zones of high igneous activity and presence of groundwater mineralization. The southern margins which shows low fracture density due to little number of lineaments [8] suggests areas covered with thick weathered overburden. The lineaments show a NE-SW, N-S, NW-SE tectonic trend; thus, indicating paths of sedimentation. The principal structural feature of the complex is the elliptical fracture about 11mile in diameter, which has largely determined the outline of the central massif of the Saiya-Shokobo Hills and has controlled the emplacement of several intrusions of the complex [3].

V. CONCLUSION

NigeriaSat 1 MSS digital datasets and processed images have been proven valuable for a variety of sues among which are the mapping of ring structures in Jos. Structural applications include identification of faults, lineaments and linear features. LandSat MSS images provide synoptic views of structural geomorphology, drainage pattern and bedrock structures that facilitate interpretation of significant geological features.

Prominent lineaments have been identified in Jos which appears to be related to bedrock fracture zone. The lineaments are of regional extent, parallel and have a general NE-SW, N-S, NW-SE orientation; the dendritic drainage pattern follows the same trend. There are discontinuities of these lineaments down the trough which may be because of increase in sediment deposition on top. Deductions show that the area is subjected to series of tectonic events because of the underlying rocks controlling drainage pattern and its structural trends. The drainage pattern suggests that the area has the same structural, lithological and topographical homogeneity since the tributaries are closely spaced, the underlying structures may have poor resistance to erosion.

NigeriaSat 1 MSS Datasets are a resource with great potential for research application at modest cost.

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