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Lineament Mapping Using Multispectral Satellite DATA of Lineaments Patterns in North-West of Talata Mafara, Zamfara, Nigeria

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ABSTRACT:- Lineaments express surficial form of dislocation and or displacement such as Fault, Fracture and Fissure within the earth's crust and are recognizable on landsat images. In the selection of landsat data for geologic, geomorphic and hydrologic purposes, the images acquired just after wet or rainy season and post winter periods are recommended. This paper present results of investigation using landsat TM data for discernment and mapping of lineament patterns in the basement complex used for structural map production in North West of Talata Mafara, Zamfara state, Nigeria. Though, the area is stable tectonically, there are evidences of earth tremor recently. In this study, procum-2, an optical mechanical device is used to manually analyze the digitally processed Landsat MSS FCC –ve image. The relationships of the mapped Lineaments were synthesized to develop structural and stratigraphic interpretation. It is found that, fracture traces and fracture intersections, chemically altered rock, alluvial deposits along with lineaments are indicative of localized concentration of subsurface water deposits in the area. Here, five areas with such characteristics have been noted as potentially suitable for location of ground water reservoirs in fissures, fissured zone, in areas of deeply indurated crust and beneath alluvial deposits. The lineaments mapped s used to establish that, such areas of dislocation within the crust are tectonically unstable and should be avoided for construction of buildings bridges, high rise dams, etc.

Keywords: Landsat image, Procum-2, Basement Complex, Lineament, Structural, Map, Groundwater and Construction.

I. INTRODUCTION

The manual of photogrammetry (1980 and 1981 Editions) observed that there has been confusion in literatures regarding the various definitions of lineament. The meaning has been used in describing linear features occurring in images for analysis in geologic remote sensing. It include fracture traces and other micro and macro fractures, mega joints, etc. which are generally embodied in lineament description. They are also used for features in small and large scale images as well as aerial photographs of places covered with dense vegetation and considerable over burden such as soil. The details on lineament definitions were contained in the proceedings of the second international conference on basement tectonics published by the Basement and Tectonics Committees in 1979, and the proceedings of the third international conference on Basement Tectonics published in 1981 and later the fourth one in 1984. Another key work on the progress in using satellite observation is the proceeding of the 5th pecore symposium on remote sensing (Denish et al, 1981) which features satellite structural geology. The pages 1370-1825 provided a table summarizing applications, data sources, precautions and limitations to be aware of, in using satellite structural data in geologic and linear features identification and mapping. O'Leory et al., (1976) defined lineament as a mappable single or composite linear features of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs distinctly from the pattern of adjacent features to presumably reflect subsurface phenomena. The term according to him, is an adjective that describes the line like character of some object or objects. Lineament could be used in general term to include all linear features (Chivasa, 1999). In line with the above definition, Sabins, (1978) defined it as mappable single or composite linear feature of a surface whose parts are aligned in a rectilinear or slightly curvilinear relationship and which differs directly from patterns on adjacent feature and presumably reflect subsurface phenomena. Remotely sensed data on lineament, is primarily based on technical enhancement procedures involving the use of digital imaging systems and optical processing of large array of data handled with computer to produce ready to interpret images (Kinabo, 1999).According to . Arlegui and Sorian (1998) and Akmen and Tufekci, 2004, Lineaments are associated with displacement and represent the trace of fault or fault zones, They characterised lineaments features for the sub-surface character of lineament features to include; fracture traces with their significance to ground water prospecting that involve scaling on linear traces (without obvious displacement on the surface feature), sizes, and mapping based on other possible structures. These are:

a. Joint traces of few cm(s) to tens of m length for outcrop on map, small scale and large scale aerial photos image that could be observed and described as bedding.

b. Fracture traces have l00m to 1.6km length on map with aerial photos, it define large scale topographical maps to define joint concentration of about 33m wide.

Lineament studies could be divided into local and regional categories. The high altitude aircraft and satellite based observations are generally most applicable to regional exploration whereas, low altitude aerial photographs and ground based remote sensing, apply to local studies Regional studies typically cover an area to 1000 Km^2 and large (Alia and Pirasteto, 2004).

II. STATEMENT OF THE PROBLEM

Landsat images have been used to identify several sets of linear features that provide basis for the definition of structure zones, trends and fractures traces, system and pattern that help in defining areas of major dislocation, structural weakness with or without significance. These areas are unstable tectonically after the Pan African orogeny to deformation. The lineament prone areas are therefore cure to be mapped and recommended for construction of dams, high rise, bridges, other buildings, etc. The Sudano-Sahelian, semi-arid region is one of the most critically water sensitive zone resulting from climate and human problems. The lineament faults and fissues indicated and used for structural map production, would help in prospecting for the underground water resources in the area. On the other hand, Lineaments are advantageous for resources prospecting in hydrologic and hydrogeological mining as they act as concentration of water, mineral zone and natural gas. Finally, such methodology have been successfully used for location of groundwater, in basement complex in the semi-arid region where there is acute water shortage.

NEED FOR STUDY

i. There is the need to use remote sensing technique to spatially and temporally map lineaments fracture and fracture traces, and joints.

ii. There are recent tremors in the basement complex that have been naturally stable tectonically. Hence, the need to define lineaments in the area.

AIM AND OBJECTIVES OF STUDY

This study is aimed at using remotely sensed data in generating and analysing lineaments in presenting structural map in the project area. Also, an ancillary data were collected especially on the geology, hydrology, geomorphology and other related discipline that aid for comprehensive presentation of result. Specific objectives include;

i. To use Landsat multi-spectral (MSS) data for lineament mapping using manual analysis techniques in mapping the fractures, fracture traces, their extent, directions, amongst others.

ii. To identify surface and subsurface lineaments and map them based on the geomorphic, geologic and hydrologic analysis indices together with ancillary data and inferences drawn based on the field observation.

iii. To evaluate mapped lineaments and characteristics such as fracture trends, traces, patterns, and directions, and their characteristics based on their measured frequency.

STUDY AREA

Talata Mafara is located at the boundary between rocks and the basement complex rocks in the sub-Saharan region of West Africa. The project area covers about 1,860km2 reflecting a regional based study. It is situated between latitude 12°05[1]N and 12°36[1]N, longitude 6°03,E and longitude 6°33',E respectively in Appendix 1 (fig,.1). The area of study is chosen for the following reasons

i. The study area is located on preterozoic mobile belt West Africa Graton (1,800 $\pm$ 200my). It is a polycyclic mobile belt, reworked upon by Orogenis of Tensional forces that resulted faults, fractures fissures, etc. on the basement rocks. The area was rejuvenated and marked with overprint of events.

ii. The Study area is located in the sudano sahelian zone and is a representative of the potentially water critical area (in events of unexpected water resources shortages in related part of the world) due to prevailing global climatic change effect, could use lineament traces as potential area of water presence.

Climate

Climate and climatic variation do considerably influence research in any environmental study area. The resulting effects are usually manifested through its major variables namely evapotranspiration, temperature and rainfall. The climate of the area is characterized by high rate of evaporation, transpiration and low amount of rainfall.

With the 2019 data obtained on the nearest synoptic station obtained from the Department of Meteorology Oshodi, the mean annual air temperature of 28.1°C is recorded from the mean annual minimum and maximum temperature of 35.5^{o} C and 210°C respectively. Also, the mean annual rainfall of l000mm is recorded that results in negative water balance.

III. LITERATURE REVIEW

The international reference papers on lineaments are in the proceeding volumes of international conferences on Basement Tectonics and published in journals of Photogramatric Engineering and Remote sensing, American Association of Petroleum Geologist Bulletin, etc. The proceedings of the first international conference on the new basement tectonics was edited by R.A Hodgson, S. Parker G. Jr,. and J.Y Benjamin, and published by the Utah Geological Association, Pub. #5, in 1976.

In the study carried out by Chivasa (1999) on post- karoo fault pattern in Hwange Coal Field located in the Western extension of the mid-Zambezi in North-West Zimbabwe. Lineament identification and analysis of landsat images were used in detecting those faults and analysing their relationship in the regional fracture trend and zone. The technique offers an analysis of subsurface element through surface inference that are invisible to exploration tools aimed at locating fractures in the area. He observed several significant directions of lineaments present: W-E, ENE and E-W directional fractures originating from several faults zones (Entuba, Deka, and Inyantue) that are suggested to be splays from the main faults. Isachien (1978, 1994, 2018) posited the 4-stage detailed on investigative procedure for extracting and identifying geological information from landsat image products based on studies of brittle deformation in the Adirandack mountains. This helped in producing structured map of all the linear features that are clearly visible on landsat image.

Warne, (1978) in a research conducted by the Australian National University explore the extent to which landsat MSS image is used. He confirmed the technique in principle and also demonstrated a number of implementation difficulties. To overcome the problem, he recommended an integrated approach involving satellite image computer analysis, human interpretation and ground truth collection. Their relationships were synthesized to develop structural and stratigraphic interpretation.

In the study carried out by Mkwete et al (1986), on the eastern Adamawa plateau, central Cameroun with digitally processed Landsat MSS image and aerial photographs, found that fracture traces and fracture intersections, chemically altered rock, alluvial deposits along with lineament are indicative of localized concentration of sub-surface water in the area. Here, five areas with each characteristics have been noted as potentially suitable for location of ground water in fissures, fissured zone, in areas of deeply indurate crust and beneath alleviate deposits. Landsat ETM-7 Satellite data were used by Anwai et al, (2013) and band 5 was fund as the mosat suitable band in automatic delineation. Furthermore, most researches prefer manual technique as it allows a higher degree of operator control despite the fact that it is more time-consuming and subjective according to Ramli et al, (2009). In the reviewed works of Ramli et al (2009) on linear mapping and its application in Landslide hazard that most studies are based on aerial photos re satellite images with either digital or manual analysis methods. According to them, most researches prefer manual techniques despite the fact is more time-consuming and subjective through, it allow a higher degree of operator control.

Anwar et al, (2013), stated that ETM enhanced Landsat satellite image band 5 is found to be most suitable in automatic delineation of lineaments and satellite feature image has higher spatial resolution (30m) for lineament study and analysis. Maged and Naziani (2010) researched on lineament mapping using Landsat-7m satellite data observed that geological feature such as lineament and faults are key paraeters that describe the earth's generation or disaster mechanism and are significant indicator for oil exploration and water storages. Mogaji et al, (2011) working in the South Western Basement Complex (Ondo State Nigeria by mapping lineament for groundwater targeting illustrated the application and importance of RS and GIS for efficient ground water resource exploration and management. They use landslide ETM^{+} with geological maps for mapping and analyses of lineament for groundwater targeting and identified

IV. RESEARCH METHOD

The research method emphasizes on the manual analysis of remotely sensed data and ancillary data as the primary sources of data for this research. The use of geographic information systems (GIS) in the analysis of geographic data is most frequently used. But this methodology of research employ digitally processed satellite image data, well enhanced for manual image analysis using specialised Projector as in the works of Newton (2007) and Vijoen & Vijoen (2008). Maged and Maziuz are of the opinion that the major task of geologist is documentation of temporal and spatial variation in the distribution and abundance of geological features.

Vijoen and Vijoen (2018) stated that, in the selection of landsat data for geologic, geomorphic and hydrologic purposes, the images acquired just after wet/rainy season or post winter periods are recommended. The components of the framework is explained as follows: The landsat MSS is enlarged using Procom 2- specialized projection compositor equipment (donated by Canadian government to geography Department, University Lagos that plannimetrically registered the projected images onto a projected topographical base map. The equipment projects image transparencies to the base map at optional scales (in line with Gregory Geosciences Procom manual, 1984). The features are directly delineated and allocated into known categories on a transparent overlay to correspond with area of uniform characteristics of the interpretative elements. These are limited, exclusive and exhaustive in a domain separated by a discontinuity in the range of observed properties (Imbrue and Purdy;, 1962). This helps to define the unit (class). There is need to emphasize here that only geomorphic and geologic enhanced band 5, 6 and 7 generate good results for detailed interpretation, classification and mapping. In carrying out lineament identification for structural mapping (within the concept of geologic and geomorphic mapping), based on reference level (professionalism), recognition and identification of the units on the image is based on a number of criteria. That manmade lineament such as roads, rail cuttings, lithological lineament produced by lithological contracts and features were validated on either topographic or geologic map. The basic identification elements used in mapping using the above format as follow.

a. **Geologic Mapping:** The procedure for mapping is to plot directly onto a projected base map. These boundaries in compiling the discerned rocks, features and structures. The collateral or ancillary materials are used in identifying the lineament structures and other man made features to change them to solid line on the interpretative base map. Oyawoye (1970) classification and nomenclature of the rocks types is adopted for this work.(See Appendix1, fig. 2).

b. **Geomorphologic Indicators:** This is the study of the surface features of the terrain by means of the imageries. The distinctive forms and character of the landforms is attributed to the dominance of a given feature and structure that result from a particular process which normally persists to the limit of the lithologic boundaries. Therefore, an angular discontinuity defined by break in slope and visible colour boundary is also used to infer the geologic boundaries. The geomorphic analysis together with the basic elements of interpretation was used to delineate the boundaries between the rock units for the entire interpretative mapping process. The symbols for these are also indicated on the map. However, this geomorphic analysis aided the entire interpretative mapping process

c. **Ground Truthing:** It has been established that, unless ground truth is available, image tones and textures have the lowest relative confidence as indicator of the surface parameters in an enhanced images. In the laboratory, only structural data on geology and geomorphology were mapped together with lineaments and confirmed with ground trothing for presentation.

SOURCES OF DATA

The data sources and their characteristics obtained in November 2019and January 2020 respectively are employed for this research work are shown on Table 1.

The landsat imageries of hydrologic bands 5, 6 and 7 that show the geologic features are used. Landsat ETM-7 Satellite data were used by Anwai et al. (2013) and band 5 was fund as the most suitable band in automatic delineation. Furthermore, most researches prefer manual technique as it allows a higher degree of operator control despite the fact that it is more time-consuming and subjective according to Ramli et al, (2009). Other data for this study consist of existing ancillary information on the area. They include: climatic data from meteorological Stations, topographic maps, form the Federal Survey's and geologic maps from Federal Ministry of Mines and Power.

Table 1 Data Sources and Characteristics

Type	Date	Scale	Acquisition Source/Code	Comments	Equipment for Interpretation
Landsat4 MSS FCC +ve transparency	Nov. 18, 2001	1:1,000,000	Eros Data Centre, Sioux sid USA, E-12401-1023, 1800	FCC Bands 5,6,7 Enhanced Hydrologic index Band	PROCOM-2
Lansat4 MSS FCC + ve Transparency	Jan. 31, 2002	--	Eos Data Centr Sioux Fall S.D USA, E – 50701-09221	FCC Band 1,2,3	PROC-OM-2
Topographic Maps	Pub 1978	1.50,000 1:1,000,000	Fed. Survey Dept., Lagos, Sheet 4,1011,300 & 31		Grant projector
Hydrologic Maps	''	1:250,000	Fed Survey Dept. Lagos, No. 31 42 No.32,9 No. 31, 16 No.32 13		Grant projector
Geological Maps	''	1:250,000	Fed. Min of Mines & power, Sheet 7 & 8		Grant projector

DATA PRESENTATION

The data obtained using the images are of significant importance to the structural mapping. The proposed identification keys is based on the elements of interpretation for the lineament in the study area. These are presented in Table 4, Appendix 2).

DATA INTERPRETATION AND ANALYSIS

The data in the table 4 shows the various colours to which the terrain properties especially rocks and Lineament are well correlated in mapping them.

The relationships of the mapped Lineaments were synthesized and synchronized to develop structural and stratigraphic interpretation. It is found that, fracture traces and fracture intersections, chemically altered rock, alluvial deposits along with lineaments are indicative of localized concentration of subsurface water deposits in the area. Here, five areas with such characteristics have been noted as potentially suitable for location of ground water reservoirs in fissures, fissured zone, in areas of deeply indurated crust and beneath alluvial deposits.

V. RESULT

The satellite data revealed that rocks found together with identical mineralogy e.g. granite, aplite with meta-gabbro, hornblende schist with meta-sediments, meta-gabbro and hornblende are difficult to identify, but possible with the integration of ancillary data. The various lineaments in the basement complex rocks have their outline clearly defined by the images .The general pattern of clearly mapped fault direction and frequency and indicated figure 3 .(See Appendix 2) of Ross diagram showing the general strike of rocks in NNE-SSE direction dipping at an angle of $10\text{-}30^0$ as shown in the structural map of figure 5, (Appendix 2)..

VI. CONCLUSION

The lineaments- faults and fault traces in the area are mapped to established that, areas of dislocation to be avoided for construction of buildings bridges, high and dams amongst others.

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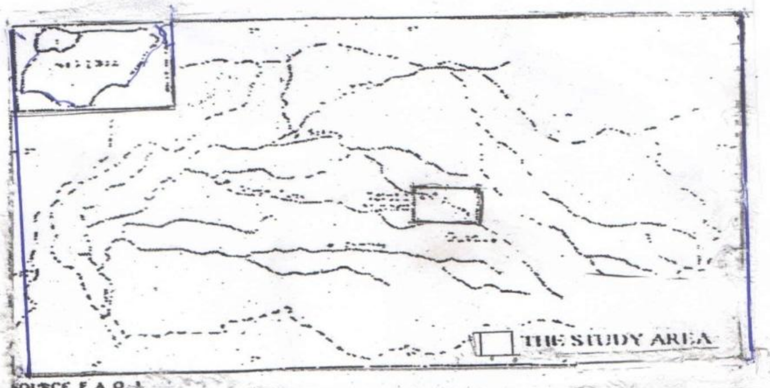
Appendix 1



SOURCE F A O

FIG 1: MAP SHOWING THE SOKOTO RIMA BASIN

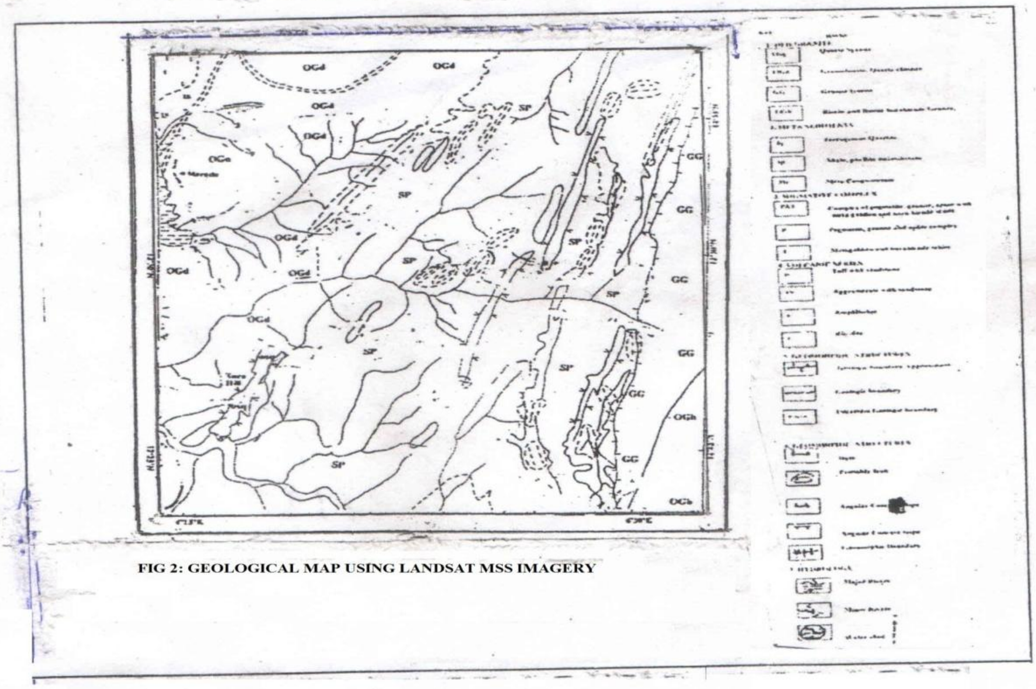


FIG 2: GEOLOGICAL MAP USING LANDSAT MSS IMAGERY

Appendix 2

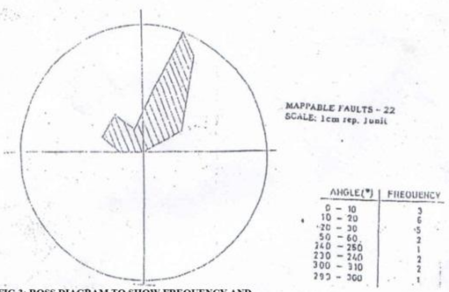


FIG 3: ROSS DIAGRAM TO SHOW FREQUENCY AND DIRECTION OF FAULTS OF PRODUCED MAP

TABLE 4: SHOWING LANDSAT IMAGERY INTERPRETATIVE KEY

ROCK TYPES/FEATURES	SYMBOLS	TONAL COLOUR	GEOMORPHIC ATTRIBUTES	ELEMENTS THAT AIDED INTERPRETATION / ELEMENTS THAT DID NOT AID INTERPRETATION: Colour/Tone	Size	Shape	Texture	Pattern	Height	Site/Association
A. OLDER GRANITE										
1. Quartz syenite	Oeq	Light	High hill Elongated	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
	Oeq	Red	Elongated	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. Granodiorite quartz diorite	OGd	Yellow	High hill	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. Granite Gneiss	GG	Light Pink	High hill	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
4. Biotite and Biotite Hornblende Granite	OGb	Yellowish brown	Circular high hill	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
B. MIGMATITE COMPLEX [illegible]										
1. Complex of pegmatite, granite, aplite with metaquartzite and [illegible] schist	P&E	Light yellow	Not distinct	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. Pegmatite, granite and aplite complex	P			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
3. Migmatite and [illegible]	[illegible]			[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C. METASEDIMENTS										
1. Ferruginous quartzite	fq	Deep brown	Elongated ridges with	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
2. Shale, phyllite, metasiltstone	Sp	Brown	Lineaments, low hill							
3. Metaconglomerate	Mc	Brown	Elongated hill, associated With near parallel flow pattern	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
D. VOLCANIC SERIES										
1. Tuff with sandstone	[illegible]	Light yellow		[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

FIG 5: STRUCTURAL MAP USING LANDSAT MSS IMAGERY