Preliminary Lineament Analysis within the vicinity of Kainji Dam, Nigeria using ERS-1 SAR Image

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Preliminary lineament analysis within the vicinity of Kainji Dam, Nigeria, using ERS-1 SAR image.

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Abstract

Various affordable, operational technologies such as remote sensing, Geographic Information Systems (GIS) can significantly contribute to improved efficiency. The main focus of the project has been directed to the use of remote sensing to gain geological and geohazard information. This study examines the use of Remote Sensing (RS) technology in geological studies of Kainji area. Radar SAR images were used to classify the various geological fractures found in the area located in the Northern part of Nigeria. A wide variety of digital image processing techniques were applied such as the Principal Components (PC) analysis and ratioing. ERS-1 SAR image that has benefits of low resolution and cloud independence is used as data source to produce lineaments map after image processes such as edge enhancement, PCA and filters in an ILWIS 3.2 GIS environment. A total of 230 lineaments were observed using both a color composite image and the filtered images of the study area. The result indicates that the fractures in the area generally trend N-S, and E-W. There are also two prominent sets of fracture with both roughly oriented to NNE-SSW and most of the longer lineaments are concentrated in the NNW-SSE direction which implies that the lineament of the area are in the same direction with the tectonic forces that led to the fracturing of the outcrops. This was also shown and demonstrated by the direction of the digitized river channels.

Keywords: Lineament, Radarsat, Remote sensing, GIS, Fractures

Introduction

An effective approach for delineation of fracture zones is based on lineament indices extracted from satellite imagery for a detailed structural analysis and understanding of the tectonic evolution of the area. It provides useful information for geological mapping and understanding of groundwater flow and occurrence in fractured rocks (Marphany and Hashin, 2010).

Since the development of remote sensing technology, the mapping procedures have undergone continuous change. Now remote sensing techniques play an important role in mapping programs (Farina et al. 2005). Mapping of lithologies and alteration zones in inaccessible mountain and forest terrain has always posed a challenge. There always existed disputes on the accuracy of lithological boundaries and structural details in these maps. Vast area to be surveyed and its inaccessibility, forbids physical investigation of every outcrop. At this juncture, the potential of RS is appreciable. The greatest advantage of RS is the synoptic view that it provides. It gives a regional and integrated perspective of interrelations between various land features. The objective of this work is to carry out a structural study of the vicinity
of Kainji Dam area using RS techniques. Many geological studies have employed Radar data to discriminate the various lithologies, lineaments and minerals. Hung et al. (2002) suggested that fractured rocks could be analyzed by studying lineaments with the help of lineament indices. An application of the proposed methodology, on basis of Radar images, is given here for the Kainji area.

There have been reports of frequent lowering of the water level in the dam reservoir, with the consequent disruptions of the electricity supply to many parts of the country and neighboring countries. Ananaba (1991) attributed this lowering of the water level to high evaporation, and or possible leakage of the water through unmapped fractures in the vicinity of the dam. Lineament analysis techniques using remotely sensed data help researchers identify different structural regimes and mineralization zones. Some factors such as season, vegetation, solar angle, spectral and spatial resolution affect the recognition of lineaments. In this study, several image processing procedures along with visual interpretations have been used to delineate geologic lineaments. Faults of various types and sizes, alignments of tonal features, systematic fracture patterns, rectangular and trellis, drainage networks are some of the lineaments noticed in the area.

This study examines the use of Remote Sensing (RS) technology in geological studies of Kainji area. Radar SAR images were used to classify the various geological fractures found in area located in the Northern part of Nigeria. A wide variety of digital image processing techniques were applied such as the Principal Components (PC) analysis, ratioing, ERS-1 SAR image that has benefits of low resolution and cloud independence was used as data source to produce lineaments map after image processes such as edge enhancement, PCA and filters in an ILWIS 3.2 GIS environment.

**Geological Setting**

The study area is located in the north western part of Nigeria. It is bounded between latitude 9° 35” and 10° 45” North of the equator and longitude 3° 24” and 4° 30” East of the Prime Meridian. It is west of Kainji Lake and cover about 100 X 102 Km (10,200) Km². Accessibility to the area is restricted as the Borgu sector of Kainji Lake National park occurs at the Southern part of the study area. It is within the Nigerian Basement Complex which forms a part of the Pan- African mobile belt that is situated between the east of the West African Craton, north -west of the Congo cratons and south of the Tuareg Shield as defined by Black et al (1979). The area is within the northwestern basement complex of the northerly trending Nigerian Schist Belt. It is in the southern part of the Zuru Schist belt that generally made up of metasediment and igneous bodies that are distributed within ancient gneiss-migmatite complex.

According to Garba (2002), the metasediment of this Zuru belt is intruded by granodiorite batholiths which formed a narrow thermal aureole made of hornfels around the intrusion. He also observed a fault zone of about 300m wide which cut the granodiorite, the hornfels and the phyllite where gold mineralizing fluid have permeated the fault zone and deposited gold-sulphide, quartz and carbonate veins in the hornfels.

Danbatta and Ajibade (1995) identified the rock type in this schist belt as migmatite-gneiss metasediment and metavolcanic rocks called Zuru Quartzite Formation (ZQF) as well as Older Granite. They are of the opinion that the metasediment consist of quartzite (massive and schistous varieties), subordinate amount of quartz-biotite schist and micaceous schist which are predominantly coarse in nature. They also noticed three phases of regional deformation in the area as D₁, D₂ and D₃ which produce E-W trending foliation, isoclinal NNW-SSE and open to gentle NNE-SSW trending foliation respectively which are all associated with transcurrent fault zone called Yelwa Fault Zone (YFZ).

Kolawole (2005) encountered four lithostratigraphic units in this area. This includes variable migmatized- gniesses which contain concordant quartzite feldspathic bands and a thick intercalated N-S belt of quartzite unit at Kubili ridge, the metasedimentary rocks which consist of phyllite and mica schist is characterized by a well-developed cleavage and banded fabric in section and localized intrusion of porphyritic granite and medium-coarse grain granite that could be weakly foliated.
Materials and Methods

(1) ERS-1 SAR lunched on 17th July 1991 and it successor (ERS-2) lunched on 21st April 1995, data enable us to obtain an image where the illumination condition can be controlled and features beneath the thick vegetation cover in the area can be elucidated. In this work, several techniques including digital image processing and visual interpretation were used for ERS-1 SAR to delineate geological lineaments in the area. Visual interpretation was initially used to extract geologic lineament using several false color composite of the ERS-1 image. These include contrast stretching, directional filtering and color band rationing which have been used to enhance geological features and to extract structural lineament in the study area. Structural lineaments were extracted and interpreted carefully, excluding network of man-made lineaments such as roads, ditches, fences and other man-made linear structures.

To detect lineaments from SAR data, two procedures were carried out. First, a suitable color composite was generated from which lineaments were interpreted visually as define by Kavakacetin (2007). Second, directional filters were applied to all band images to enhance detection of lineaments.

A remotely sensed lineament map was produced using the application of directional filters and edge enhancement on ERS-1 SAR image. The same method was also applied using bands 1, 2 and 3 for decororation Stretches (principle components) which helped to map out major geological units and fault structures. Lineament map and their rose diagrams were prepared and interpreted using Canny (1986) classification indices in an.

Data processing and image products

Following a number of processing techniques, the images of all bands were compared in terms of contrast and definition of geological features (lineaments). As a result of visual evaluation, ERS-1 SAR image with partial resolution of 12.5m resolution and operates in a C wavelength band employing a VV polarization was selected for this study, since it shows good contrast and display geological lineaments compared to the other images.

In order to enhance the structural geological information (lineament) further, filtering techniques were applied to this image. The result shows that there are a number of directional filters of the following values which produced very good results enhancing the lineaments of the area. The filter values, according to Juhari and Ibrahim (1997), are as follows:
Therefore, the following images are used in this study:

a. FCC ERS -1 Image of the area which was digitally enhanced (Fig 3)

b. Three images, each one are filtered by directional filter in N-S, (Fig 4), E-W (Fig 5) and NE-SW (Fig. 6) directions.

c. RGB image of the three directions mention above (Fig 7).

In the study area, there are more than 230 lineaments (length of each one is more than 1 km) are traced with the total length is greater than 1400 km. However, only lineaments with length greater than 2 km are shown in the map (Fig 8) since they may represent geological faults of the area. The lineaments furthermore are analyzed in terms of their trend and position compared to the faults that previously mapped.

Fig 2 ERS-1 SAR panchromatic image of the Kainji area, NW Nigeria
Fig. 3 False color composite image of part Kainji Dam

Fig. 4 Laplace edge enhancement in N-S directional filtered image

Fig. 5 Laplace edge enhancement in E-W directional filtered image
Fig. 6 Laplace edge enhancement in NE-SW directional filtered image.

Fig. 7 RGB (N-S, E-W, NE-SW) color composite image of directional edge detection filtered image.

Fig. 8. Derived lineament systems from this RGB color composite images of the study area.
Results and Discussion

The lineaments extracted and rose diagram generated on the RGB color composite from the ERS-1 imagery were digitized and labeled according to their orientations. This shows four dominant sets of lineaments directions, 0°-60°, 60°-90°, 90°-120° and 120°-180° and interpreted as NS, NE, NW, and EW (Fig. 9). This corresponds to four deformation phases that the study area has undergone. The NE-SW and NW-SE lineament strike-slip fault system were the NW faulting succeeded the NE shearing. The last episode seems to have been another NE faulting which could have been contemporaneous or post NW faulting interpreted to be a brittle deformation form from later part of the Pan-African orogeny (Garba, 2002).

There are also two prominent sets of fracture with both roughly oriented to North- South, mapped by Ajakaiye et al. (1986) and highlighted by Ananaba (1991) as St Paul’s Fracture Zone (FZA) megalineament of Nigeria. These lineaments are as long as 25km or less which could be part of subsidiary faults suggested by Garba (2002).

A total of 230 lineaments were observed using both a color composite image and the filtered images of the study area and most of the longer lineaments are concentrated in the NW direction which is contrary to the NE direction from groundtrusting rose diagram (Fig 9b). Some of the classes of lineament expression are topography; man-made features, vegetation boundaries could coincide with topographic features.

Visual interpretation and digital image processing methods had very high correlation in lineament analysis (Kasak and Cetin 2007). Rationing and filtering directions methods helped remove topographic effects and enhance several features in the area. In this study, N-S NE-SW and E-W directional filtering processes were analysed and interpreted. The result shows clearly that the NW-SE is more than the N-S trending lineament systems which have developed in the region and most of the lineaments are associated with the tectonic setting of the area. Field and remote sensing studies indicate that most of the lineament are extensional fractures that corresponds to either dikes emplacement or normal fault (Garba, 2002). Most of these were subsequently reactivated into strike-slip shear fractures. The NW – SE and NNE-SSW lineaments represents dilational fractures. The N-S and WNW-ESE lineaments form conjugate shear fractures and are assumed to be the youngest while NNE-SSW trending lineaments are oldest (Danbatta and Ajibade, 1995). Blomquist and Wladis (2002) reported that lineaments represent zones of weakness in the bedrock and are assumed to also represent a topographic depression that streams usually flow along which could be tectonically controlled.
It has been proven in other areas that the area of higher points of fracture or lineament intersection usually become a good target for economic mineral exploration (Sabin, 1987). The relationship between the mineralized area and the fracture pattern and circular features by using the satellite data were Proceedings of the also reported by Juhari and Ibrahim (1975), Halbouty (1976), Offield et al (1977), Ahmad (1983) and Sabin (1987).

Conclusion

The use of Remote Sensing data allows a synoptic recognition and characterization of geologic regions of interest. It elucidates structures that are difficult to be identified field surveys due to environmental conditions, vegetation cover, anthropic infrastructures, slopes and other morphologic constraint.

Lineaments are extracted from satellite images by edge enhancement functions available in most remote sensing software packages. The ILWIS 3.2 software is regarded to be one of the best functions for lineament extraction. However, its result is often still confusing and contains many errors from a geological point of view. The results obtained from the satellite image interpretation have demonstrated the usefulness of remote sensing in lineament mapping and analysis in delineating productive zones of groundwater development, Dam construction as well as monitoring the water level reservoir (Antoninetti, 1996).

Reference


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