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Full Length Research Paper

Application of remote sensing techniques in hydrogeological mapping of parts of Bosso Area, Minna, North-Central Nigeria

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The study focuses on the hydrogeological mapping of Bosso area of Minna, Niger State using remote sensing techniques whilst considering integration of geophysical and hydrogeological investigation in a synergistic approach. Landsat enhanced thematic mapper band 4 and 7 were used for the study. The satellite imagery that was acquired from Global Land Cover Facility website was rectified and geo-referenced using various ground control points that were obtained during ground thruthing. The analysis of the imageries using ILWIS 3.3's included filtering, stretching clustering. The outcome module gives results on both the structure and the lithology of the area. Structural elements that were remotely mapped are majorly lineaments which trend NW-SE and NE-SW. These were correlated with the results of the field mapping and radial geo electric sounding results. The geological map shows principal NE-SW trending joint with minor NW-SE direction. The radial geo-electric sounding at three different locations as interpreted from the anisotropic polygons showed NW-SE, NE-SW and N-S fracture directions respectively. There are three basic rock types that are represented in this region which include; N-S trending schist in the western part and around the water bodies (Bosso Dam and River Chanchaga), granite in the Northern and Southern parts of the area and gneiss in the central part. The use of remote sensing in hydrogeological investigation has been found very effective in the area. It has saved time, reduced risk of project failure and was cost effective when compared to other traditional mapping techniques especially when used alongside geophysical method.

Key words: Remote sensing techniques, satellite imagery, data acquisition, processing and interpretation, hydrogeological mapping, radial geo-electric sounding, Minna.

INTRODUCTION

Hydrogeological mapping nowadays is being greatly assisted by the application of remote sensing (Amadi, 2007). Remote sensing is the science and art of acquiring information about the earth's surface without being in contact with it. This is done by sensing and recording reflected or emitted energy and processing, analyzing and applying that information. The data come in the form of aerial photos, multispectral satellite imagery and radar imagery. Remote sensing allows for large area, synoptic or regional coverage (Canadian Centre for remote sensing tutorial, 1997; Short, 2007). The study is aimed at demonstrating the effectiveness of remote sensing techniques in geological and structural mapping. Understanding structures is the key to interpreting crustal movements that have shaped the present terrain (Ajibade, 1980). Structures also indicate potential sites for locating water, oil and gas reserves by characterizing both the underlying subsurface geometry of rock units and the amount of crustal deformation experienced by the rock body (Amadi, 2007).

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LOCATION AND PHYSIOGRAPHY OF THE AREA

The study area lies between longitudes 6°30 and 6°33'E of the Greenwich meridian and latitudes 93°7 to 9°41'N of the equator. It covers a total area of about 297.5 km^2. The area is accessible through Minna-Suleja road and Minna-Tegina road. The vegetation

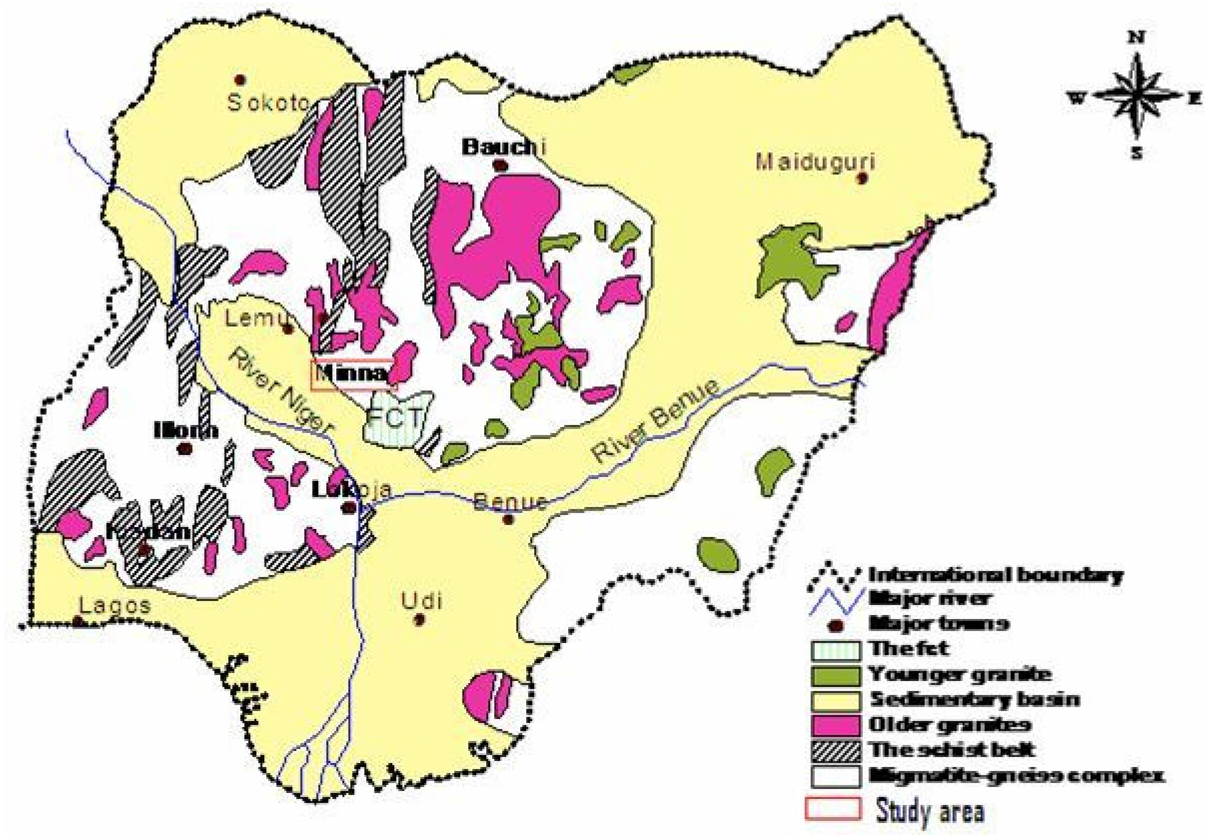

Figure 1. Geological map of Nigeria showing study area (Ajibade, 1980).

is mainly guinea savannah which is characterized by grasses, shrubs and trees. The study area lies within the Middle-Belt of Nigeria which is a transitional zone between the rainforest of Southern Nigeria and the Guinea Savannah of the Northern Nigeria (Figure 1). This area is characterized by tall grasses with light forest, evenly distributed trees along the major river channels. The annual rainfall distribution pattern shows a maximum of 1300 and minimum of 1000 mm rainfall (Minna Airport, 2002). The area has a fairly flat-lying terrain with few gentle hills and drained by River Chanchaga.

GENERAL GEOLOGY OF THE AREA

The area investigated is part of the North-central part of the Nigerian Basement Complex which is composed of two lithological units: low-grade schist belts and the granite (Truswell and Cope, 1963; Ajibade, 1980; Ajibade and Wright, 1988). Geological mapping revealed that the study area is underlain by granite and schist with granite occupying greater portion of the area (Figure 2). The fieldwork shows that the granite did not digest completely the schist through which it intruded, which gives rise to migmatite (mixed rock) in most locations. The principal joint directions in the area are NE-SW followed by NW-SE direction.

Data acquisition from remote sensing satellite

The raw data of the study area was captured by a remote sensing satellite (Figure 3) before it was downloaded from Global Land Facility Covers website. Data acquired from satellite platforms need to be electronically transmitted to Earth, since the satellite continues to stay in orbit during its operational lifetime. The data received at the Ground Station (GRS) in a raw digital format. They are then processed to correct systematic, geometric and atmospheric distortions to the imagery and be translated into a standardized format. The data were written in form of storage medium such as tape, disk or CD LANDSAT. This was used for the study; it is established at an altitude of 700 km in a polar orbit and is used mainly for land area observation in landsat imagery of 30 m resolution. LANDSAT TM and ETM are extensively used in geological mapping; they come in various bands; each of which has its own specific features (Table 1).

Data processing

The imageries used were downloaded from Global Land Facility Cover Website. These images come in very large scenes which were later reduced to cover the specific area of interest. This was achieved by the aid of ILWIS 3.2 software. Further processing was done on band 4 and 7 of the Landsat ETM imageries to bring out both structures and lithologies. Band 4 imagery was subjected to image processing such as filtering, stretching and clustering. The stages involved in image processing as applied to this were: the images were first preprocessed prior to the supply of the images used. The imagery was acquired from global land cover facility (GCLF) the organization of which is in band sequential (BSQ) presented in seven bands in raster format. To rectify the imagery, ground control points and satellite orbit information were utilized

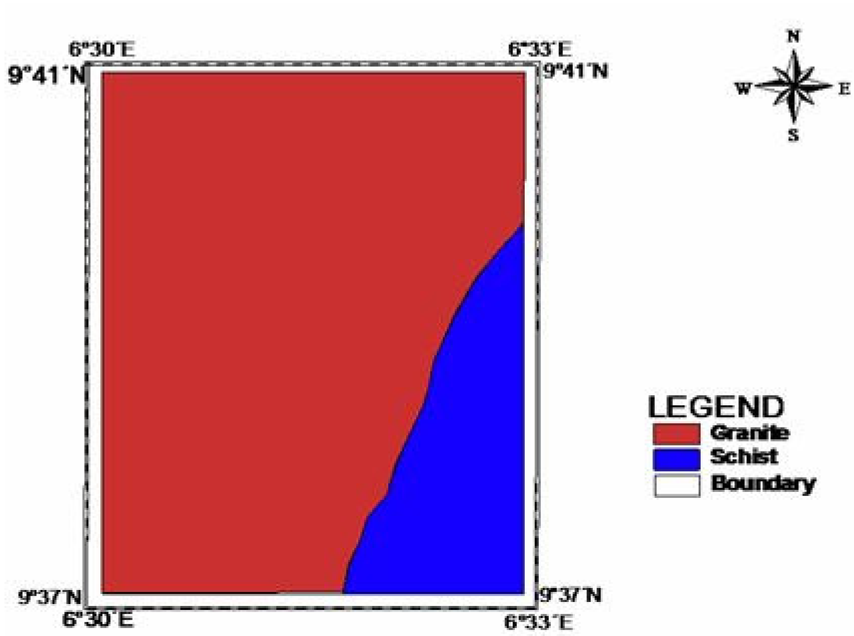

Figure 2. Geological map of the study area (Okoye, 1974).

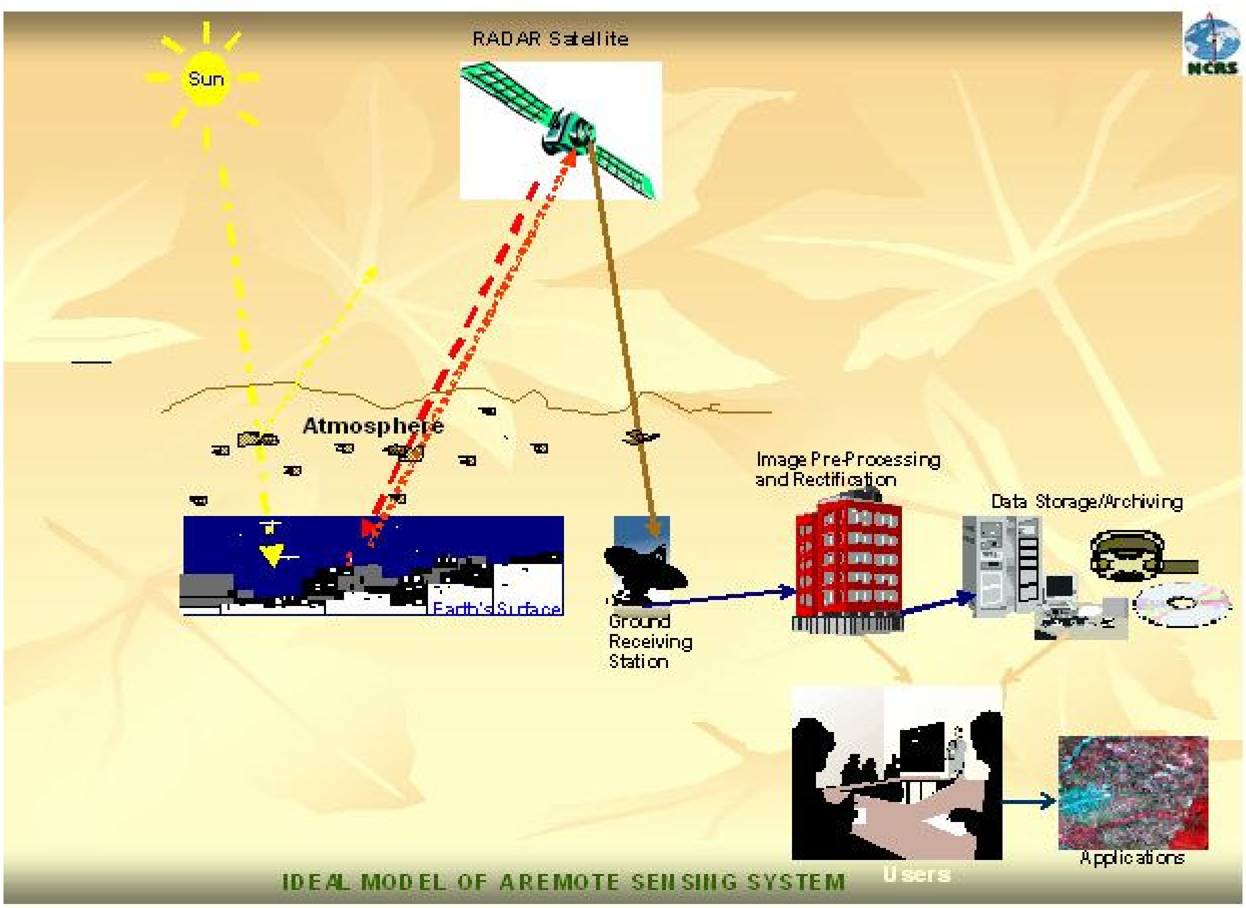

Figure 3. Model of a remote sensing system (National Centre for Remote Sensing, 2008).

Table 1. Thematic mapper bands and their applications (Canada Centre for Remote Sensing, 1997).

Channel	Wavelength	Application
TM1	0.45 - 0.52 (Blue)	Soil/vegetation discrimination; bathymetry/coastal mapping; cultural;/ urban feature identification.
TM2	0.52 - 06. (Green)	Green vegetation mapping (measures reflectance peak); cultural/urban features identification.
TM3	0.63 - 0.69 (Red)	Vegetation vs.; non-vegetation and plant species discrimination (plant chlorophyll absorption); cultural/urban features identification.
TM4	0.76 - 0.90 (Near 1R)	Identification of plant/vegetation types, health, and biomass content; water body delineation; soil moisture
TM5	1.55 - 1.75 (Short wave 1R)	Sensitive to moisture in soil and vegetation; discriminating snow and cloud-covered areas.
TM6	10.4 - 12.5 (Thermal 1R)	Vegetation stress and soil moisture discrimination related to thermal radiation; thermal mapping (urban, water).
TM7	2.08 - 2.35 (Short wave 1R)	Discrimination of mineral and rock types; sensitive to vegetation moisture content.

since there is no Digital Elevation Model (DEM) for Nigeria, hence imagery rectification was to existing geocoded landsat MSS and SPOT multispectral data (image-to-image geocoding) utilizing the universal transverse mercator (UTM) coordinate system (Short, 2007).

The area of study was subset from the Landsat main scene using Submap Module of ILWIS 3.1 software by supplying the coordinates of the area of study. In order to improve the scene quality, all the six visible and infrared bands of the imagery were linearly stretched, after inspecting the histograms of each image band. As further enhancement routine, selected bands were subjected to spatial filters in order to enhance edges using EDGESENH. Principal component analysis was then applied on the six non–thermal bands to reduce dimensionality of the data. In order to spectrally enhance the specific features of interest e.g. lineaments, faults and drainages, spectral ratio was carried out on selected bands based principally on the centering of the relevant TM bands on the EM spectrum. The ratio images were subsequently aligned and converted into formats that can be projected into colour composite in RGB guns. Single TM bands were also selected for colour composites in order to enhance the spectral classes of the surface materials. Upon forming the images of data required, supervised classifications (both hard and soft) were carried out in order to recognize the patterns of the distribution of the spectral classes in the images used in the area, which involved interactively searching the whole images to extract areas of lithology and structures.

FINDINGS/RESULTS

Remote sensing pictures

From the remote sensing imageries that were obtained, the following were found:

(1) A major river; River Chanchaga, was identified at the southern part of the study area (Figure 4). This and Bosso dam which is located at the extreme North Western part of the study area were identified on the processed band 4 imagery.
(2) Two major rock types were identified in the study area: N-S trending Schist in the west and around river Chanchaga and Bosso Dam, gneiss in the centre and granite in the northern and southern parts.
(3) The major structural features in the study area were fractures and lineaments. In the North, the lineaments trend NE-SW direction while in the South, close to the river Chanchaga, lineaments trend NW-SE. This implies that the flow of the river is structurally controlled (Figures 4, 5 and 6). From field investigation, locations in the Southeast part of the study area with low fracture density correspond with areas covered by soil and highly weathered thick overburden. The study area might have been affected by the Pan African Orogeny, which is the major tectonic events that produced structural deformation of the area (Ajibade and Wright, 1988).

Topography

A topographical mapping of the area was drawn from the GPS reading; Digital Terrain Model (DTM) of the area was made using Surfer 8.0 software as shown in Figure 7. The highland is at the north while the area slopes southward. The highlands are occupied by granite while the lowlands are occupied by granite, gneiss and schist. River Chanchaga flows from east to west through the granite and schist while Bosso Dam to the north is underlain by granite. The intervening ground is occupied by granite-gneiss. The southeast region is highly weathered and covered by vegetation.

Groundwater flownet

The groundwater flowline and flow direction were superimposed (Figure 8). A general NE-SW and NW-SE groundwater flow direction was observed, but a slight change in groundwater flow direction occurs in the

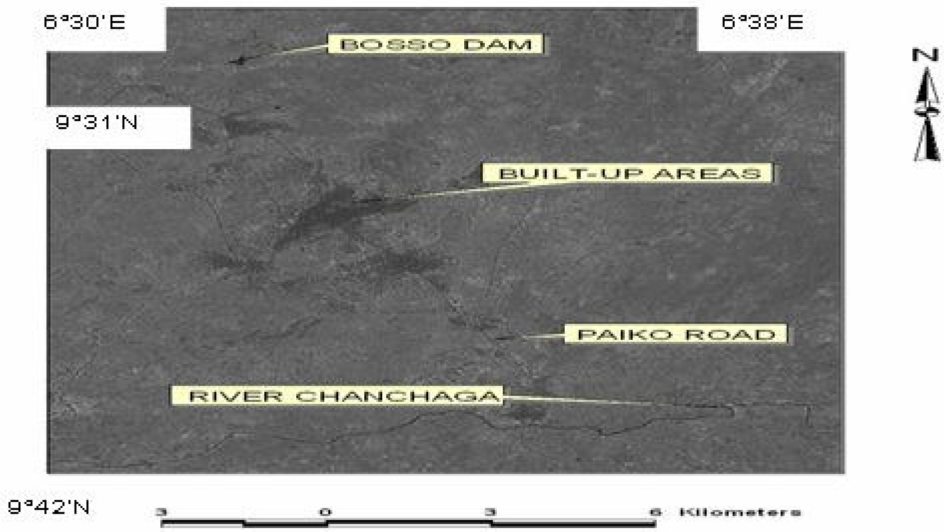

Figure 4. Interpreted band four imagery after filtering with EDGESENH. (Global Land Facility Cover, 2008).

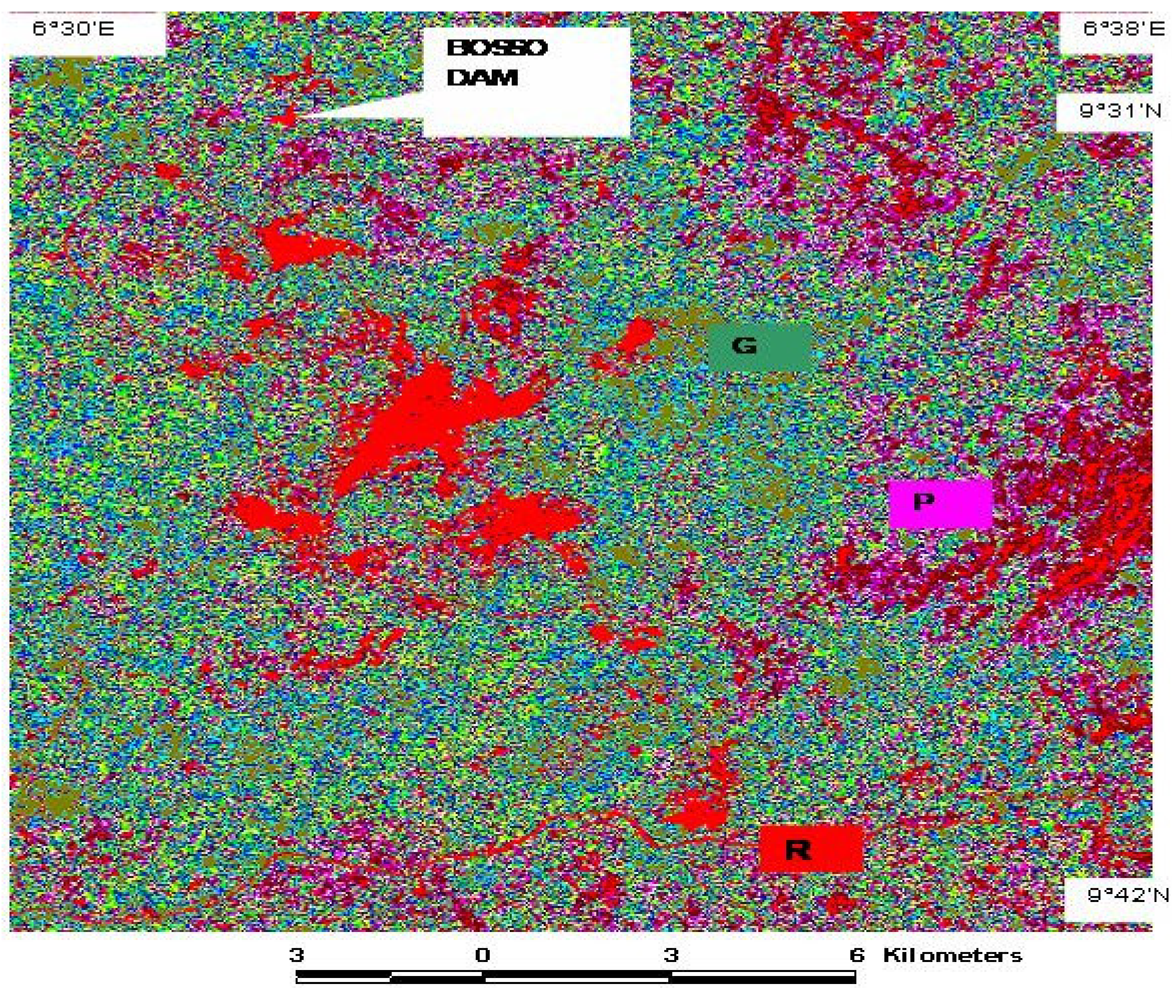

Figure 5. Clustering on band four (4); P (Purple) = Granite; R (River) = River Chanchaga; (Greenish) = Vegetation and Land Cover over granite, gneiss and schist (Source: Global Land Facility Cover, 2008).

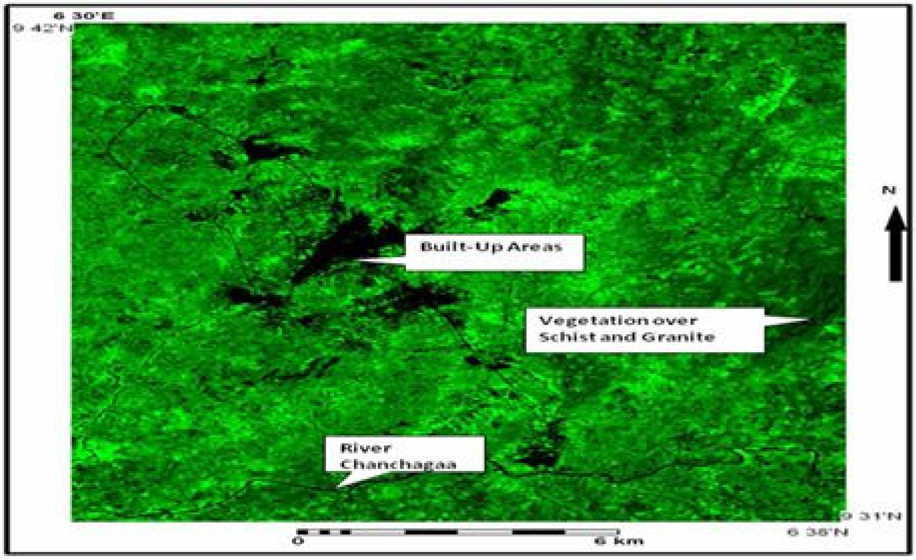

Figure 6. Interpreted band four imagery on stretching (Global Land Facility Cover, 2008).

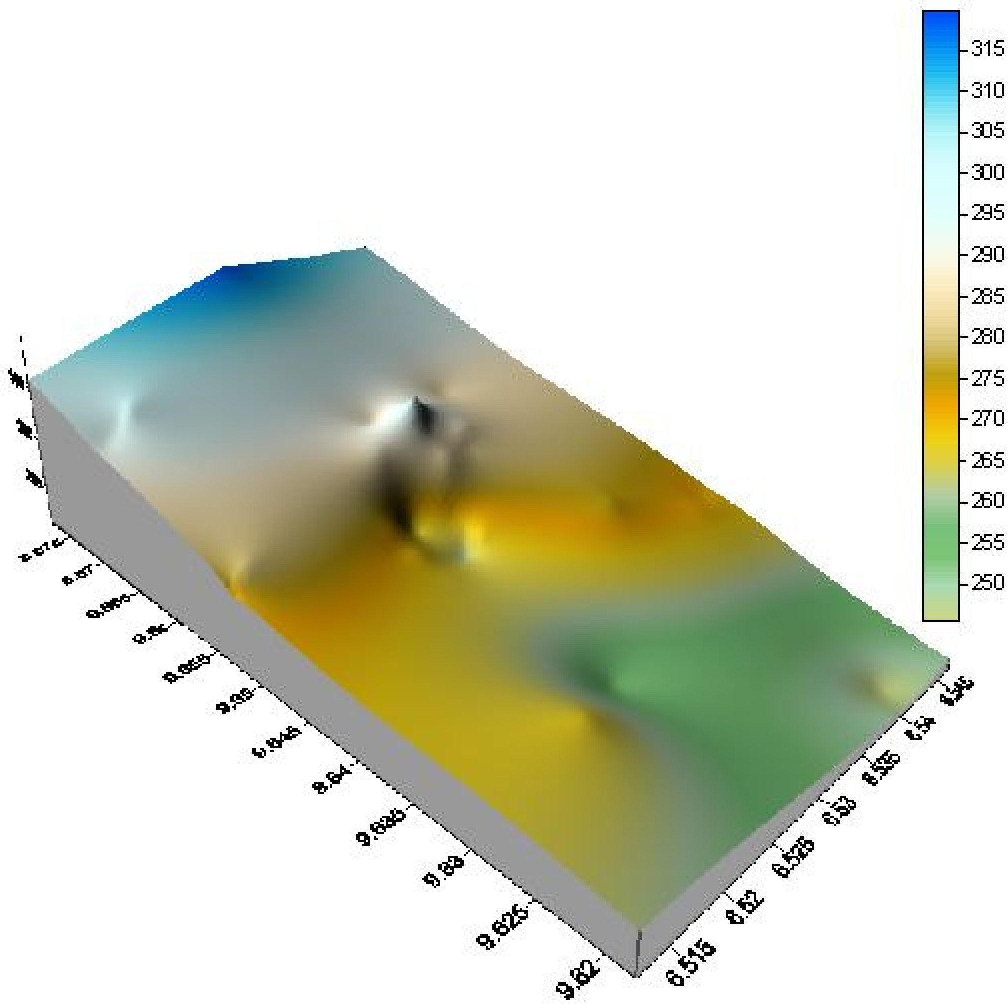

Figure 7. Digital terrain model (dtm) of the study area using surfer 8.0 software (Amadi, 2007).

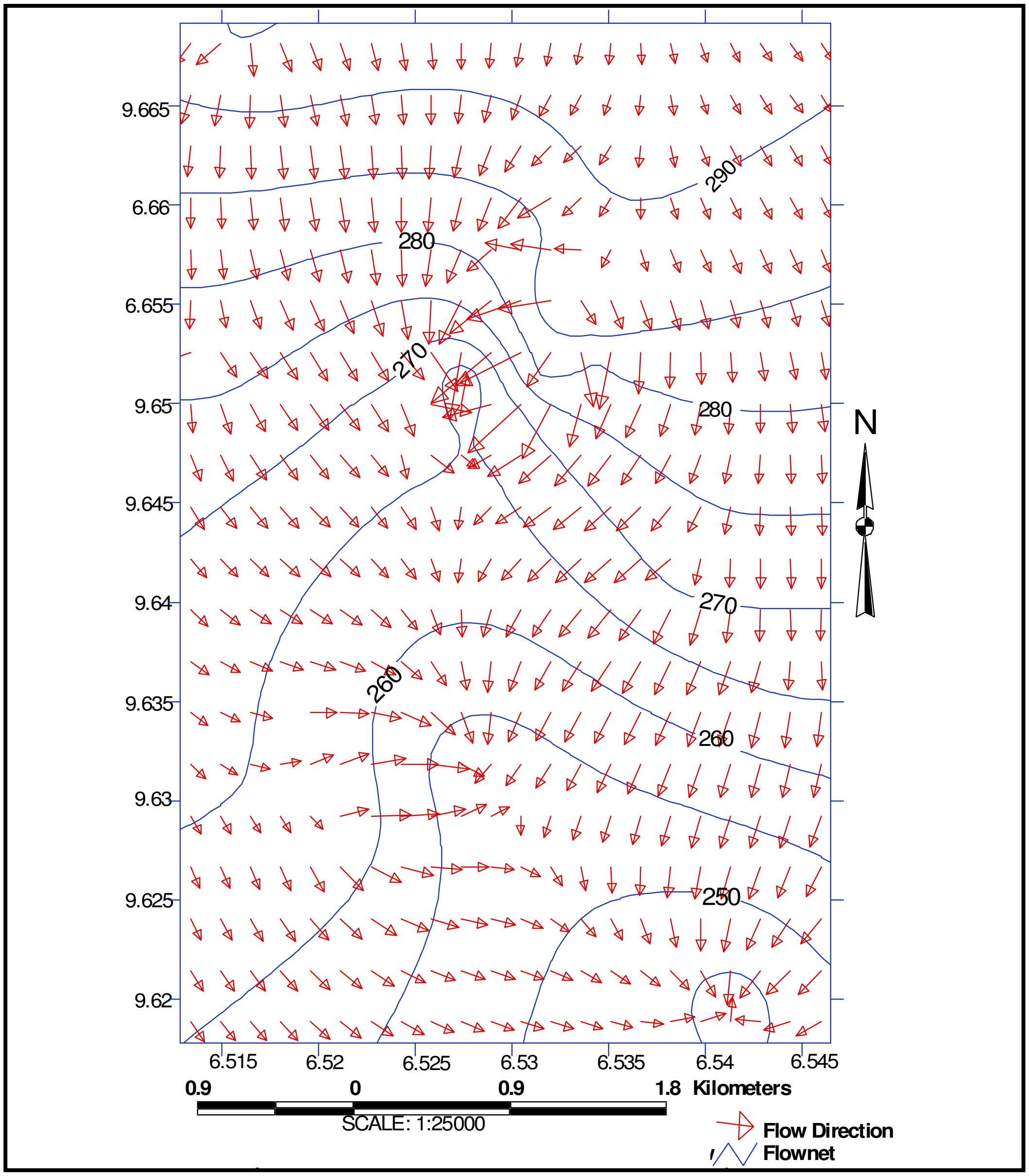

Figure 8. An overlay of groundwater flownet in the study area (Amadi, 2007).

northern sector due to higher elevation. Groundwater flow is NW-SE and NE-SW directions away from the high topographic area and converges towards the Central Southern part of the area (Figure 7). The convergence of the groundwater in the central portion is due to the presence of fractured/weathered basement rock.

Structural mapping using redial geo-electric sounding

This is Vertical Electrical Sounding (VES) in three directions of: 0, 60 and 120º. The results of the radial geo-electric sounding carried out in some locations in the study area were used in determining the fracture patterns. The concept behind this is that, lowest resistivity values are obtained along directions where fractures and weathering have taken place. The resistivity data for constructing the anisotropy polygons are shown in Table 2. The anisotropy polygons of the area indicate NW-SE, N-S and NE-SW joint directions (Figure 9).

Assumption

If the earth is homogeneous and isotropic the values of resistivity should be equal irrespective of direction. However, the earth is anisotropic and non-homogenous.

Table 2. Radial geo-electric sounding data.

Station	AB/2(m) → / Azimuth direction	5	10	15	20	25	30	35	40	45	50	55	60
Radial geo-electric sounding data (Mechanic road, Minna)													
VES 1-1	0º	219	382	549	713	1200	2231	2000	1700	1579	1500	1600	1800
VES 1-2	60º	228	401	671	709	1300	2074	1800	1100	1333	950	1500	1600
VES 1-3	120º	430	346	600	613	800	1595	1300	1100	1055	1200	1300	1400
Radial geo-electric sounding data (Dutsen Kura Hausa, Minna)													
VES 2-1	0º	37	38	45	39	100	222	190	160	143	140	160	170
VES 2-2	60º	-	18	15	77	210	291	340	360	368	360	340	380
VES 2-3	120º	21	40	47	75	320	233	380	360	405	400	400	440
Radial geo-electric sounding data (Okada road, Minna)													
VES 3-1	0º	150	113	87	165	340	582	480	420	379	360	400	440
VES 3-2	60º	151	177	220	287	550	1038	850	750	700	650	750	800
VES 3-3	120º	150	99	88	160	300	582	360	400	379	380	400	420

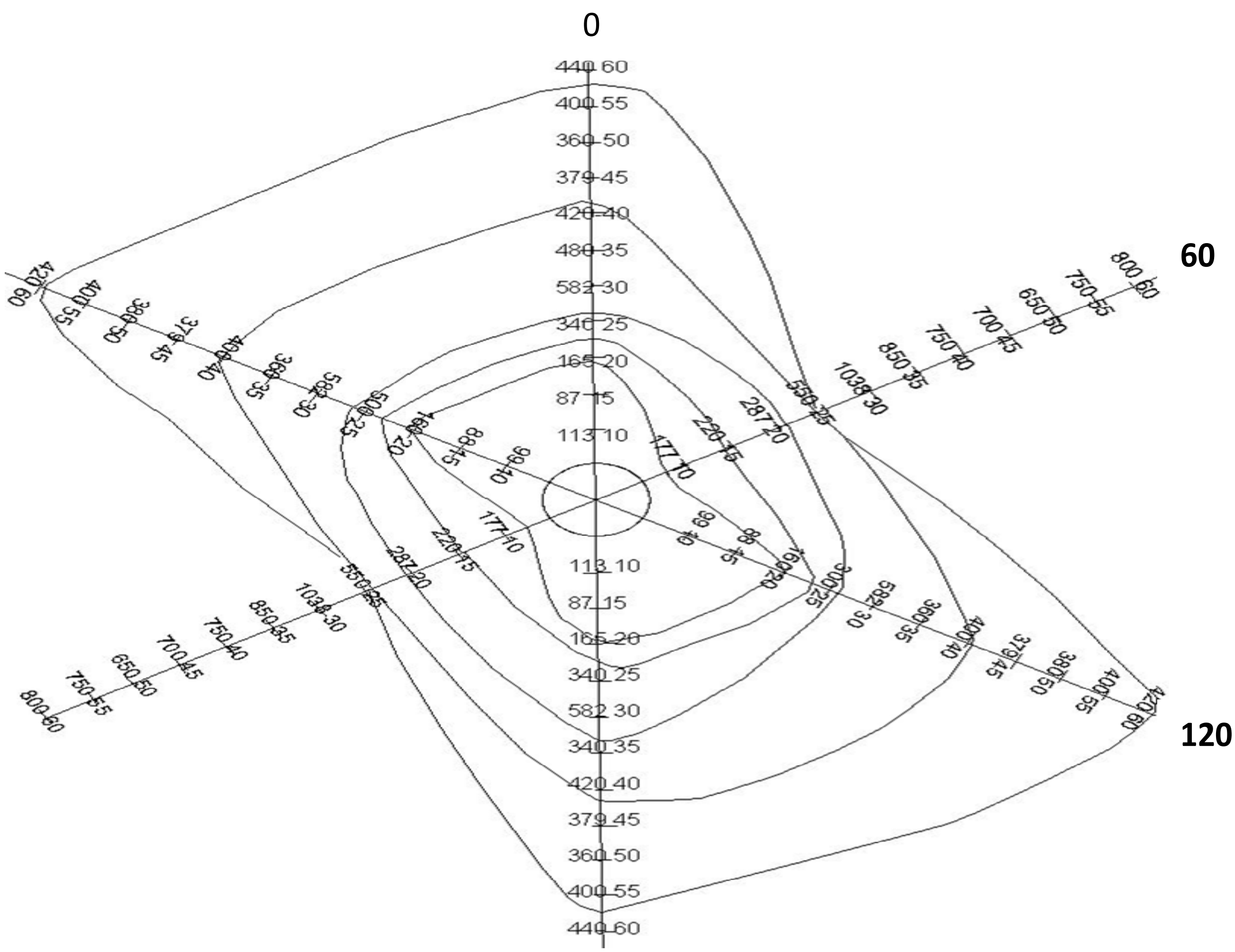

Figure 9. Resistivity anisotropy polygon for Kaka Village, Okada road (Olasehinde, 1999).

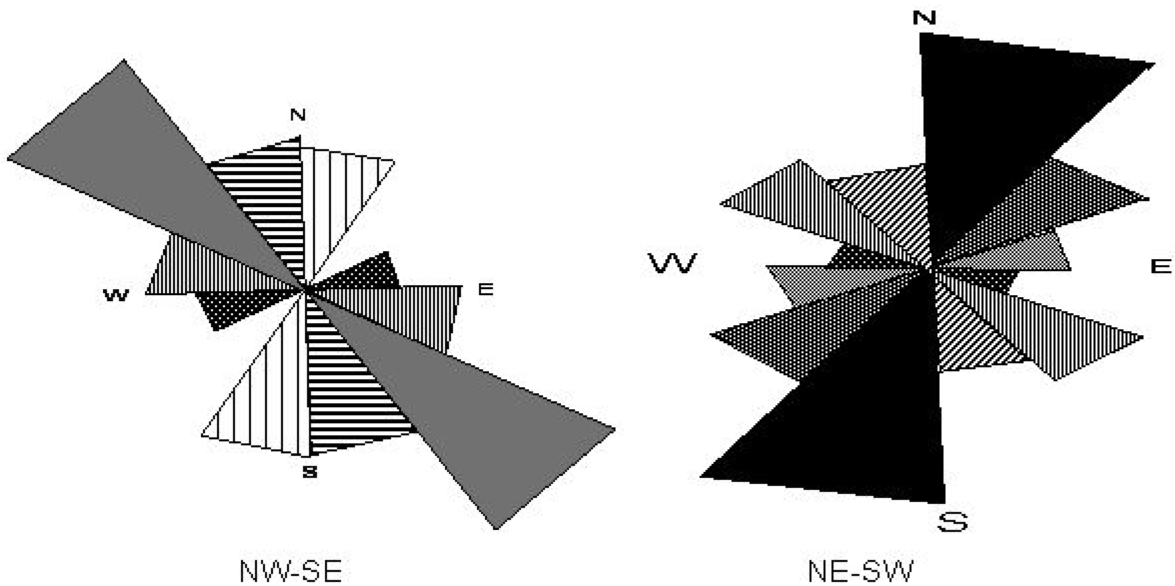

Figure 10. Rosset-diagram showing NW-SE and NE-SW major joint directions.

This implies that when VES are done in three different coordinates, the lowest resistivity values are obtained along the direction where fractures and weathering have taken place. This implies that the polygon drawn (Figure 9) from the radial geo-electric soundings will have a long axis along the fraction directions (McCurry, 1976; Olasehinde, 1999). The resistivity data for constructing the anisotropy polygons are shown in Table 2. A typical anisotropy polygon of the area is shown in Figure 9. The results show that the Mechanic road has a joint direction of NW-SE; Dutsen Kura shows a N-S joint directions while Kaka Village has two sets of joint directions; N-S and NW-SE respectively.

Rosette diagram

Structures can be generated in different ways through compressional forces, tensional forces and gravitational forces. The major fracture pattern (joints and faults) in the area were observed during the geological mapping. The values of the joint directions taken during the structural mapping with the aid of compass and clinometer were used to plot the Rosset-diagrams shown in Figure 10. The principal joint directions in the area are along NE-SW and NW-SE direction.

MAJOR FINDING

This study has explored the effectiveness of using remote sensing technique in geological mapping of both structure and lithology in parts of Minna, Niger State. Landsat ETM of 30 m resolution was used for this study. Through this operation, features such as dam, river, vegetation and undifferentiated basement rocks were identified. The band 7 imagery was principally used for the structural and lithological studies; through filtering and stretched histogram operations, structures such as faults and lineaments were identified. The common orientations of lineation are NW-SE and NE-SW which must have resulted from Pan-African Orogeny. The Pan-African Orogeny produced geological structures with North-south orientation. The orientation of the lineation was further correlated with the joint values that were taken from the field. These were used to construct a rosette diagram. The rosette diagram also shows principal NE-SW trending joint direction, which further confirmed the findings via remote sensing. Radial geo-electric sounding was carried out in some specific locations in the study area and the result interpreted. However, due to the earth anisopropic and non-homogenous nature, vertical electrical sounding (VES) were done in three different coordinates. The lowest resistivity values were obtained along the direction where fractures and weathering have taken place. Thus the polygon drawn has the longest axis along fracture direction. This confirmed further the imprint left by the Pan-African Orogeny. Unsupervised classification of landsat ETM band 7 imagery provided the means for the identification of the lithologies. This was based on the fact that rocks of the same type give the same spectral characteristics. The schist with N-S orientation occupies the western part and around water bodies, gneiss at the central parts while granite occupies the Eastern, Northern and Southern part of the area. The schist is particularly found around the Bosso dam and along River Chanchaga. The ground water condition of the area was studied using flownet method, which shows that the ground water flow in the area is generally N-S direction. This is majorly attributed to the geology of the area. The movement of the groundwater in this direction can also be traced to the topography of the area which has a N-S gradient.

Conclusion

Geological mapping today is being greatly assisted by the application of remote sensing. While remote sensing will never replace traditional field explorative geological mapping, it will provide geologists with invaluable techniques for improving the mapping process. We can be sure that the very future of geological mapping will rely heavily on such remote imaging systems. The use of other mapping methods such as geophysical method will give synergy in the application of this technique and cause a reduction in error that may result from using a single technique. The use of remote sensing in mapping is very effective especially in the area of rugged terrain where the terrain is inaccessible. It saves time, reduces risk and is cost effective compared to other traditional mapping techniques.

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