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APPLICATION OF REMOTE SENSING IN LITHOLOGICAL DISCRIMINATION OF PRECAMBRIAN BASEMENT ROCKS OF ZUNGERU AREA, PART OF SHEET 163 (ZUNGERU NW), NORTH CENTRAL NIGERIA.

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ABSTRACT

Remote sensing technology has advanced significantly, making it useful for geological applications such as structural and lithological mapping, as well as mineral prospecting and mapping. This study looks at how certain enhancement techniques on Landsat 7 ETM+ data can be used to map surface geology, resulting in color composite imagery that can be interpreted and validated through field mapping exercises. Because some of these rocks are poorly exposed and some portions of the research region are inaccessible, field mapping was supplemented by remote sensing lithological mapping techniques. False Color Composite images for bands (7:4:1 and7:5:4), Principal Component analysis (PC1, 2, 3 and PC4, 5, 6) and RGB composite images of Landsat band ratios (1/3:5/7:3/5 and5/1:5/7:4) proved useful in determining the approximate boundaries of the various lithology in the research area. Gneiss and quartzites occur in the central and western quadrants of the study area, mylonites and schist in the eastern quadrant, and amphibolite in the southern and southeastern quadrants, according to GPS sample locations of the individual rock types found in the study area plotted on the processed images. The contact relationships between these rocks are mostly gradational and interlayered. As a result, a thorough examination of satellite optical imagery, such as Landsat data, can greatly aid lithological inquiry and the creation of more detailed geological maps in areas that are inadequately understood.

Keywords: Band Ratio, False Colour Composite images, Landsat 7 ETM+, Principal Component Analysis

1.0 INTRODUCTION

Nigeria is underlain by Precambrian Basement rocks, Jurassic anorogenic Younger Granites, Cretaceous to Recent sediments, and Tertiary to Recent volcanic rocks, with the basement rocks accounting for over half of the country's land mass (Black, 1980). The study area is in and around Zungeru, Niger State, Nigeria's north central region. It is located within 9°45' and 10°00' N, and 6°00' and 6°15' E, and is part of Zungeru (Sheet 163NW), which covers an area of approximately 770 km^2.

Geological mapping at all scales is one of geologists' principal goals. There are, however, certain drawbacks to geological field mapping and mineral exploration. Inaccessibility, insecurity and social instability, inadequate outcrop exposures, and so on are some examples of these limitations. In addition, conventional geologic field mapping methods are costly and time-consuming compared to remote sensing techniques and approaches, especially for vast areas (Abdelmalik, 2018).

Earth sciences, geography, archeology, and environmental sciences have all benefited from remote sensing technologies. Earth scientists have employed remote sensing data to look at worldwide experiences in environmental geology, mineral exploration, and hydrocarbon exploration (Kucukkaya 2004; Hellman and Ramsey 2004; Galvao et al., 2005; Watts and Harris 2005; Vaughan et al. 2005; Aminzadeh and Samani, 2006; Lammoglia and Filho 2011; Shi et al., 2012; Petrovic et al. 2012; van Ruitenbeek et al. 2012). For decades, remote sensing techniques have been utilized successfully for geological mapping and mineral exploration (Amer et al., 2010; 2012; Zhang et al., 2007).

Many studies have shown that remotely sensed data can be used to update an area's current maps (Chorowicz and Ragin, 1982; Ferradini, Cornee and Simon, 1993). Many of the disparities discovered between published maps and those produced from satellite images were determined to be attributable to omissions or inaccuracies in field geological mapping, as evidenced by succeeding field study. A range of criteria (such as overall geologic context, weathering, landforms, drainage, structural features, soil, vegetation, and spectral properties) obtained from remote sensing data are used to identify broad lithological contacts.

The present study aims to create the geological map of Zungeru by applying different image processing techniques for Landsat ETM+ satellite data in order to discriminate between the varieties of rock type. Landsat ETM+ imagery were examined

using optimization techniques like band ratios, color composites, and principal component analysis (PCA). Different lithologic units in the study area were mapped using visual interpretation, verified with ground-truth data, and combined using a geographic information system with the aid of these enhancing techniques.

2.0 GEOLOGICAL SETTING

2.1 The Nigerian Basement Complex

The Nigerian Basement is a component of a mobile belt located in between the Congo and the West African Cratons (Fig.1). Plate tectonic events are believed to have formed the belt around 600 Ma, when the passive continental continental margin of the West African Craton collided with the active continental margin of the Tuareg Shield (Burke and Dewey, 1972; Leblanc, 1981; Black et al., 1979; Caby et al., 1981; Ajibade et al., 1987; Garba, 2002). The Nigerian Basement is located in the belt's reactivated segment (Ajibade et al., 1987). The Nigerian Basement evolved through polyphase tectono-metamorphic history, including Liberian (2700±200 Ma), Eburnean (2000±200 Ma) and Pan-African (600±150 Ma) events (Grant, 1970; Ajibade *et al.*, 1987; Dada 1998).

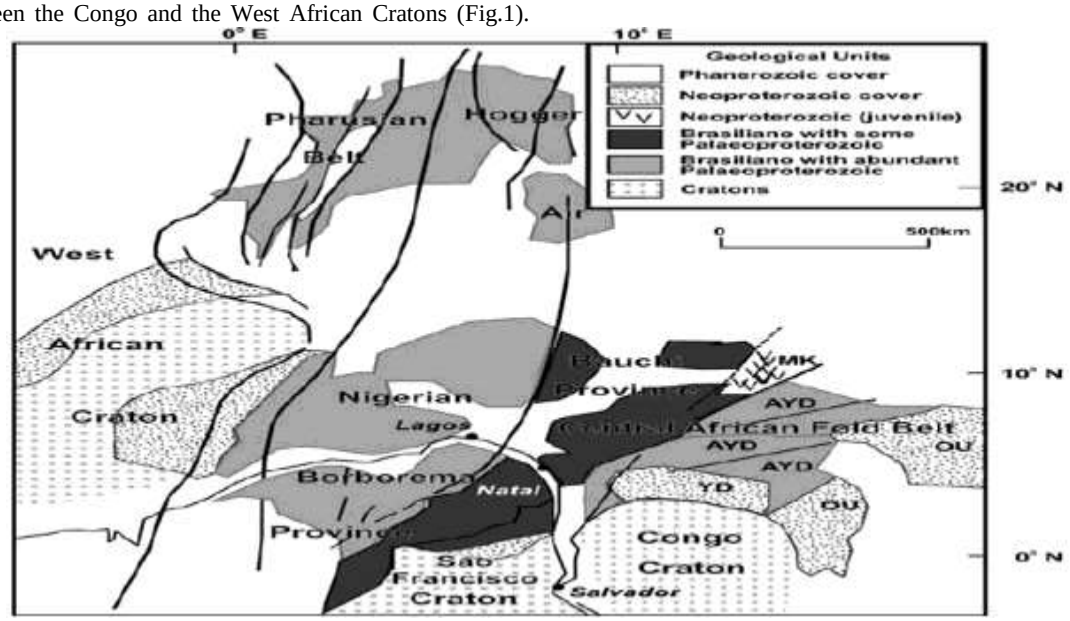

Fig. 1: The location of the Nigerian Basement Complex in reference to the provinces of Hoggar and Borborema (adapted from Dada, 2008).

The Migmatite Gneiss Complex (MGC), the metasedimentary belts, and the Older Granites are the three major lithologic units that make up Nigeria's basement complex.

The Migmatite-gneisses complex is commonly recognized as the basement stricto senso (Rahaman, 1988, Dada 2008). It is a heterogeneous assemblage comprising migmatized gneisses, orthogneisses, paragneisses, and a variety of metamorphosed basic and ultrabasic rocks with a metamorphic facie grade of mostly upper amphibolites (Dada 2008). Understanding the crustal evolution of the Migmatite Gneiss Complex is complicated by a dearth of geochronological data (Kroner et al., 2001).

The N-S trending syn-formational metasedimentary belts are restricted to the western Nigeria. The basement complex of western Nigeria has been divided into twelve distinct metasedimentary belts (Ajibade et al., 1987; Turner, 1983). They are mostly upper green schist to lower metamorphosed amphibolites that resemble the Archean greenstone belt. They include Zungeru-Birnin Gwari, Kushaka, Malumfashi, Kazaure, Wonaka, Maru, Anka, Zuru, Toto, Iseyin-Oyan River, Ife-Ilesha and Igara-Kabba-Lokoja belts (Turner 1983; Danbatta 2008). Psamatic schist, pelitic and semipelitic schist, metasandstone, metaconglomerate, quartzite, marble, mafic to ultramafic rocks, acid to intermediate volcanic rocks, calc-silicate rocks, and banded iron formations are among the most common lithologies (Turner 1983; Danbatta 2008).

The syn-collisional to post-collisional granitoids constitute the Older Granite suites. They intrude both the migmatite-gneiss complex and the metasediments. Rocks ranging in composition from granite to tonalite and charnockites with minor deposits of syenite, gabbro, and pegmatite make up the granitoids (Ajibade et al., 1987). The radiometric dates of the granitoids are in the 750-500 Ma range, which is within the Pan-African spectrum. To differentiate them from Mesozoic anorogenic granite ring-complexes (the Younger Granites), these Pan-African granitoids are referred to as the Older Granites in Nigeria.

3.0 MATERIALS AND METHODS

Remote sensing interpretation, field studies, and laboratory analyses are all part of the approach used in this research. Remotely sensed multispectral datasets including LANDSAT Enhanced Thematic Mapping (ETM+) imageries were processed. These Landsat bands (1, 2, 3, 4, 5, & 7) were downloaded from the Global Land Cover Facility's website (http://glcf.umd.edu/). Using ENVI 4.5 software, these images were calibrated and refined to create color composites, employing image processing techniques such as false color composite, band rationing, and principal component analysis.

The colors red, green, and blue (RGB) were chosen as the primary colors in these basic image processing techniques to emphasize the disparities between lithologies. A geological mapping exercise (ground truthing) which entails detailed observation of the various rock types in the field was used to confirm the accuracy of the results.
Field investigation was conducted in two(2) phases: the first was a five-day reconnaissance visit, followed by a two-week field camping period during which geological field mapping of the studied region was carried out on a scale of 1:50,000. Fresh rock samples were taken and the Location information of each sampling spot was recorded with the aid of a Global Positioning System (GPS). Representative rock samples were chosen from various rock types, and thin sections (slides) were created in the thin section laboratory of the department of geology, Ahmadu Bello University. Under a petrological microscope, the slides were inspected for minerals and other properties that had not before been seen in hand specimens.

4.0 RESULTS AND DISCUSSION

4.1 FALSE COLOUR COMPOSITE TECHNIQUE

For lithological mapping of rocks, false color composite techniques such as those used by Rowan et al.(1974), Raine et al.(1978), and Riley et al.(2006) were utilized, displayed in R:G:B. False color composites (FCC) are utilized to emphasize geologic features for visual examination (Gad and Kusky, 2007; Massironi et al., 2008; Qari et al., 2008). Up to three bands or ratio images have to be chosen in a false color composite method based on known mineral absorption properties. Visual analysis aids in the selection of optimal band combinations for more complex computational techniques, as well as providing a preliminary indication of the likelihood of mapping the chosen lithologies.

In fig. 2, false colour composite image for bands 7, 4, 1 displayed in R.G.B, the red and green colours are indicating different rock types and vegetation, while the blue colour delineates the major river in the southeastern quadrant of the map. The very dark reddish-purple colour at the eastern portion of the map is area occupied by both amphibolites and schist. Gneiss is represented at the central and northeastern portion of the map by light reddish-purple colour. The remaining rock types and vegetation in the area are represented by green colour. Fig. 3 depicts areas covered by gneiss, amphibolites, migmatites and mylonites by yellow colour while vegetation appears as blue.

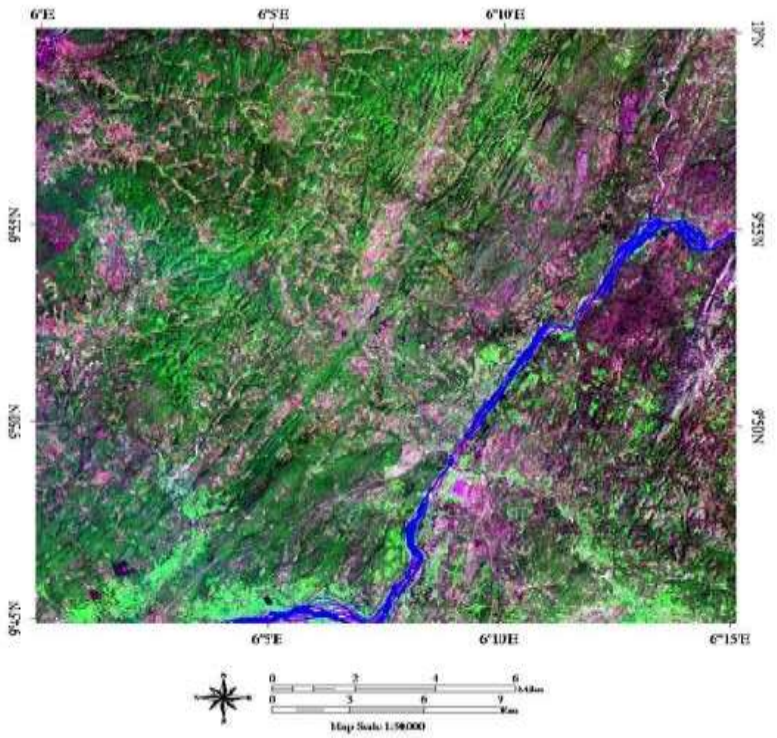

Fig. 2: False colour composite image for bands 7, 4, 1 displayed in R.G.B.

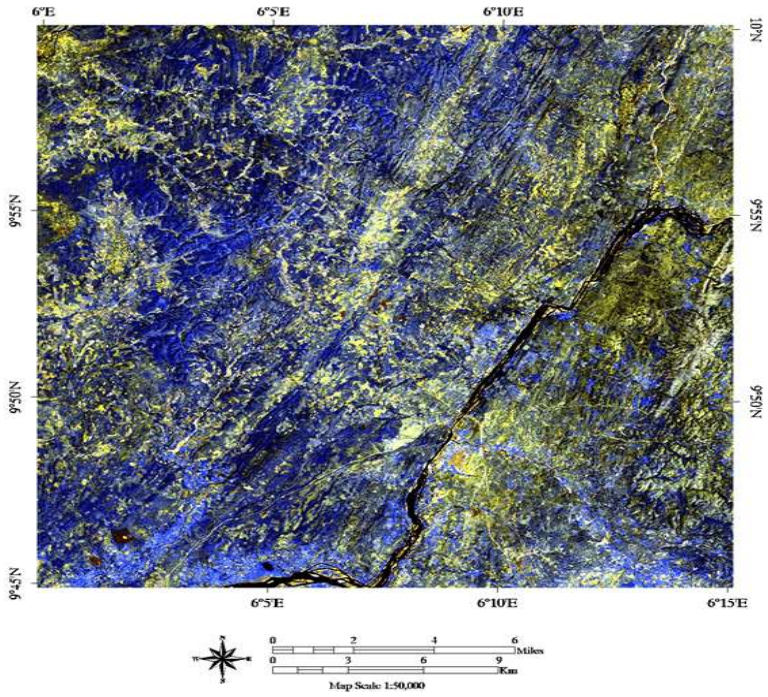

Fig. 3: False colour composite image for bands 7, 5, 4 displayed in R.G.B.

4.2 BAND RATIONING

In multispectral and hyperspectral images, band ratio is a very useful method for highlighting features. A specific mineral

potential could be mapped using the band ratio technique based on the absorption feature characteristics of the individual minerals. The R.G.B composited image and the Landsat band ratio both performed a key role in recognizing distinct rock types in the research area. Band ratios are more effective than single bands for distinguishing changes induced by geographic features and scene illumination conditions, especially when they are generated by integrating three ratio images in the red, green, and blue bands. The band ratio image methodology is carried out by dividing the digital number (DN) values of one band by the associated DN value of another band and displaying the resultant DN values as gray scale images (Sabins, 1997).

False colour composite in R.G.B of band ratio 1/3:5/7:3/5 (fig. 4) displays amphibolite and gneiss as blue while quartzite generally exhibit as greenish-yellow colouration. The major water body in the southeastern portion of the area is displayed as black while areas occupied by gneiss and amphibolites are light purple (fig. 5).

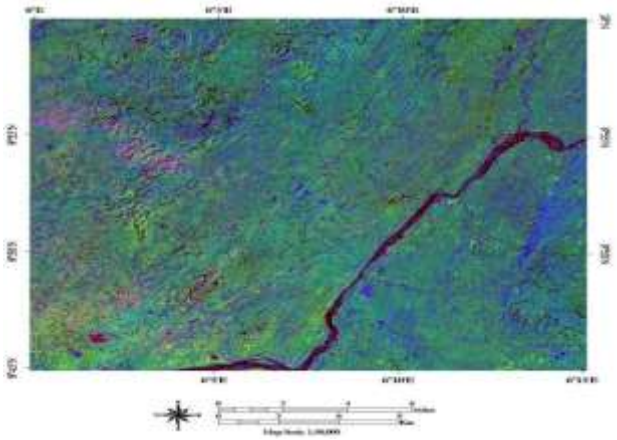

Fig. 4: False colour composite image for bands 1/3:5/7:3/5 displayed in R.G.B.

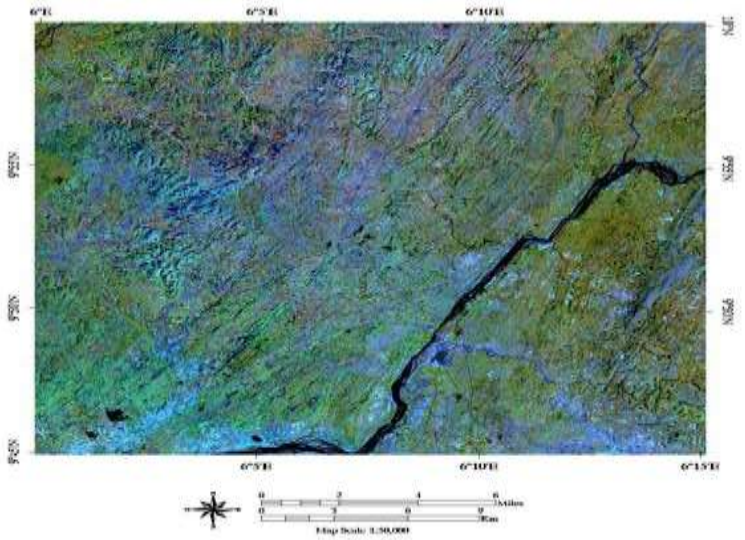

Fig. 5: False colour composite image for bands 5/1, 5/7, 4 displayed in R.G.B

4.3 PRINCIPAL COMPONENT ANALYSIS (PCA)

PCA is a powerful method for analyzing correlated multidimensional data, and many researchers have explored its applications in digital remote sensing (Kaneko, 1978; Byrne et al., 1980; Haralick and Fu, 1983). It is a data transformation process for simplifying a dataset by trying to reduce multidimensional datasets to smaller dimensions for analysis and eliminating information redundancy between bands in order to extract the important information from them (Loughlin, 1991; Gomez et al. 2005). PCA improves overall separability while lowering dimensionality, making it ideal for classification with equal number of input and output spectral bands. The first PCA band has the highest percentage of data variation, while the second PCA band has the second greatest percentage of data variance. The last PCA bands appear noisy because they have very little volatility, much of which is attributed to noise in the original spectral data (Sing and Harrison, 1985; Jensen, 2005; Chang et al., 2006). PCA is a popular tool for lithological and alteration mapping in metalogenic provinces (Crosta et al., 2003; Kargi,2007; Massironi et al., 2008; Moore et al., 2008; Amer et al., 2010).

PCA has the advantage of compressing most information within all bands (expressed by variance) into a significantly smaller number of bands with negligible data loss (Gibson and Power, 2000). PCA data bands are non-correlated and independent, and they are typically easier to process than the source data (Jensen, 1996).

For the visual interpretation of different rock units, the false color composites (FCC) images of principal component bands PC1, PC2, PC3, PC4, and PC5 shown in Red-Green-Blue (RGB) were generated for the study area (Fig. 6 & Fig. 7). This false color composite PC-image was successful in spectral characterization and differentiating the various types of rocks found in this location.

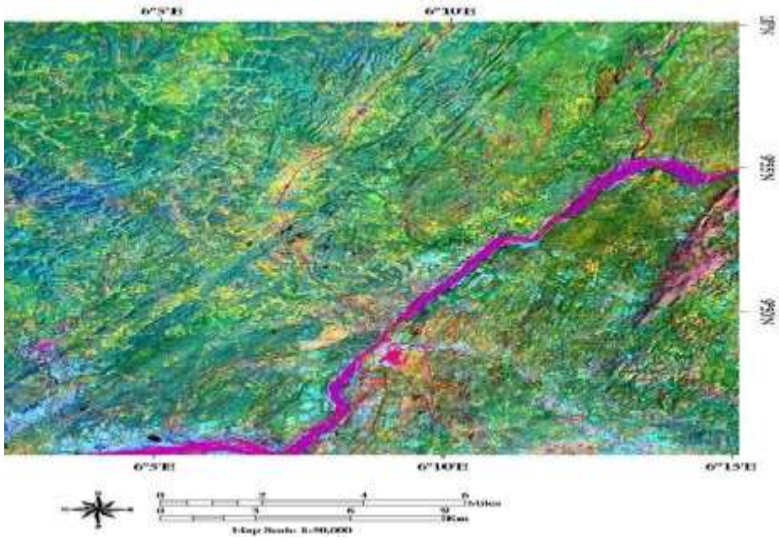

Fig. 6: Principal component analysis of bands 1, 2, 3 displayed in R.G.B

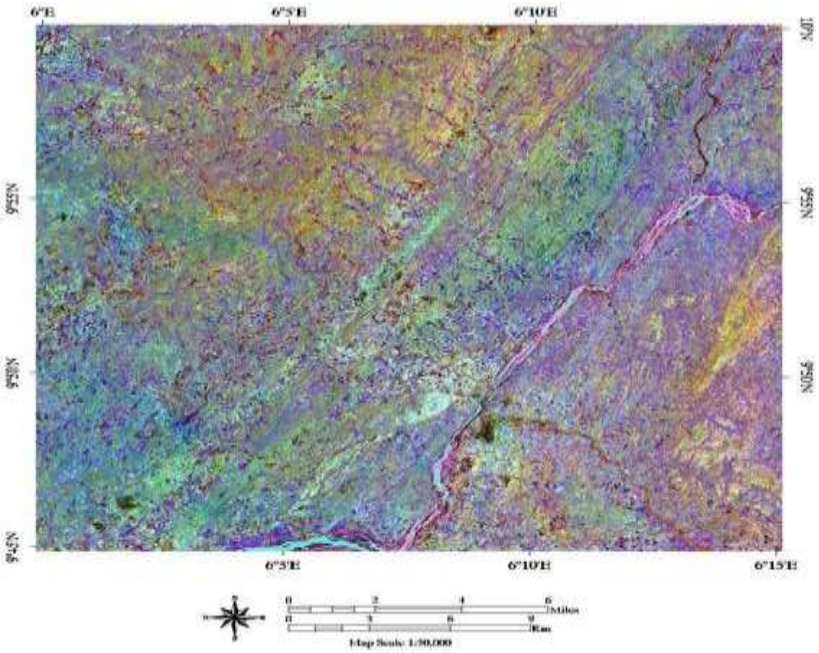

Fig. 7: Principal component analysis of bands 4, 5, 6 displayed in R.G.B

The major drainage system and an amphibolite region in the far eastern portion of the area are indicated by purple colour (Fig. 6). This river appears to be controlled by a major fracture, the Kalangai-Zungeru-Ifewara fault, as it flows through Zungeru. Such large transcurrent fault zones and other minor shear zones are visible on satellite imageries exhibiting a dextral sense of shear. Quartzites, gneisses and schists appear as yellowish-green on the eastern and western portions of the image. The various lithologies and drainage systems exhibit an almost uniform colour in Fig. 7.

4.4 FIELD GEOLOGY AND PETROGRAPHY

The results of Landsat imageries processing have been verified through intensive fieldwork. The lithological units mapped during the field investigation comprise of gneisses, migmatites, quartzites, phyllites, schists, amphibolites and mylonites which are consistent with what (Agbor, 2014) reported. Fresh rock samples from the field were obtained, and representative samples were chosen for petrographic examinations in order to establish their textural and mineralogical makeup.

4.4.1 AMPHIBOLITES

Good exposures of amphibolites are found in river and stream channels in the Eastern and South-Eastern portions of the study area. Some are found along road-cuttings in contact relationship with migmatites. Workers like (Ajibade, Anyanwu and Okoro, 2008) have documented large bodies of amphibolite within the study area. They described the contact between the amphibolites and the quartzo-feldsparthic rocks as sharp in some areas while in other areas, the contacts are transitional. Visually in the field, they are black to dark-green in colour (Fig. 8), fine to medium grained in texture and have distinct cleavage planes. Amphibolites appear as purple in the 7,4,1 composite, yellow in the7,5,4 and blue in the 1/3:5/7:3/5 composite. Principal component 1,2,3 shows the best contrast between this rock and the surrounding outcrops. The dominant constituents of this metabasic rock are hornblende, plagioclase and quartz. Orthoclase, plagioclase, biotite and augite occur as larger grains, while smaller grain quartz and some plagioclase feldspar form the matrix minerals.

Fig. 8: An amphibolite outcrop found along a fault zone. Location: (9° 47' 31.2" N, 6° 10' 21.7" E)

4.4.2 GARNET MICA SCHIST

These rocks occupy about 10-15% of the entire area mapped predominantly around the Eastern portion of the study area. They are soft, highly weathered and poorly exposed friable rocks (Fig. 9). Intense strain of the parental garnet mica schist has produced a mylonite from this rock in shear zones within the study area. They exhibit same unique colours as Amphibolite in composite 7,4,1 and 7,5,4 in R.G.B.

4.4.3 QUARTZITE

Quartzites are the most common, accounting for around 40% of the rocks in the studied region. Two varieties of quartzite were encountered: the whitish to light brown massive type and the reddish brown, fine to medium grained schistose variety (Fig. 10). Quarzite appears as green in composite 7,4,1 and dark-blue in composite 7,5,4. It exhibits a gradational contact with the gneiss outcrops.

Fig. 9: Photograph of mylonitic garnet mica schists dipping to the west and scattered chuncks of cataclastic quartzite all within a shear zone in the study area

Fig. 10: A Photograph of whitish massive quartzite outcrop at Garun Gabas. Location: (9° 51' 25.5" N, 6° 07' 37.5" E)

4.4.4 MIGMATITE

Only a few migmatite exposures have been mapped, mostly in the southeastern portion of the study area. They are rare and concentrated in the southern section of the study area, particularly around Jankwata and Dogon Ruwa (Fig. 13). The migmatites are medium to coarse grained rocks that are distinctively banded and grayish in colour (Fig. 11). Ptygmatitic folding occurs in vein-like structure with quartz-filled mineral composition. They are characterized by green and light-yellow in composite 7,4,1 and 7,5,4 respectively similar to the gneiss exposures. PC 4,5,6 (Fig. 7) did not result to any useful map interpretations for this rock type.

Fig. 11: Photograph of a flat-lying Migmatite outcrop around Dogon Ruwa with light and dark bands. Location: (9° 46' 48.0" N, 6° 12' 1.6" E)

4.4.5 GNEISS

This rock covers about 30% of the area mapped. They occur in places like Gulangi, Ushama, Jangaro and Kutuku. Most of the gneisses are highly weathered and breaks easily utilizing foliation planes. Some of the gneisses occur as massive and low lying outcrops especially where they are in contact with the schists. Three different types of gneiss were mapped: (a) an augen gneiss (b) banded gneiss and (c) granitic gneiss. Among these gneisses, the banded gneiss is the most abundant (Fig. 12). Gneiss appears as light purple on composite 7, 4, 1 image and shades of yellow on composite 7, 5, 4. They appear as yellowish-green on PC 1, 2, 3 and do not exhibit a distinct colouration in PC 4, 5, 6 displayd in R.G.B.

Fig. 12: A photograph of banded gneiss north of Zungeru town. Location: (9° 49' 57.9" N, 6° 10' 25.2" E).

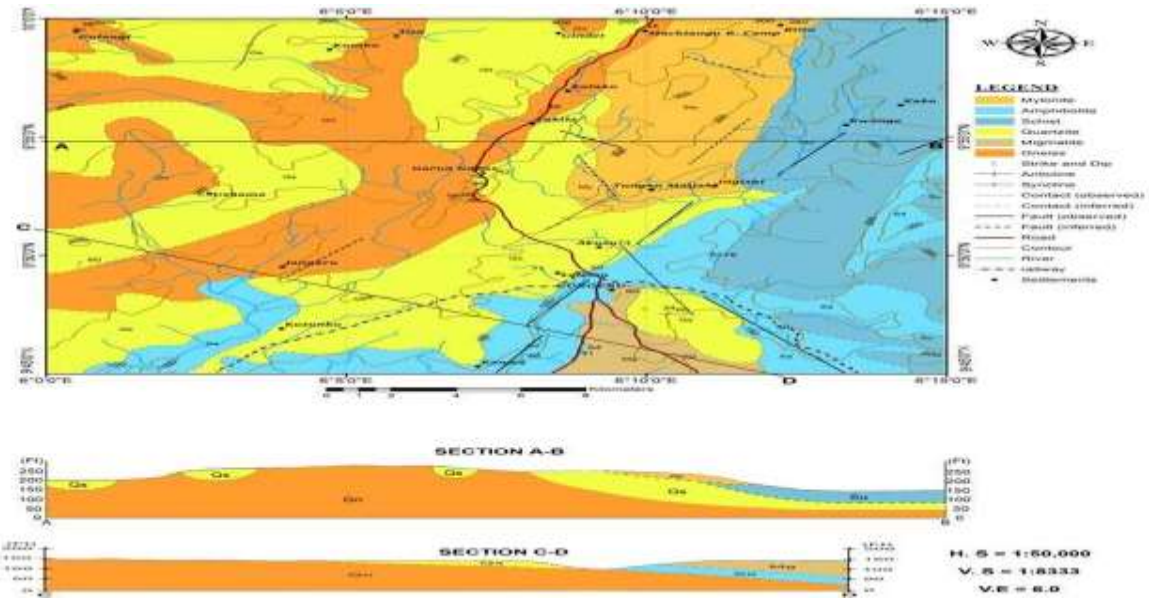

Fig. 13: Geological map and cross-section of the study area

5.0 CONCLUSION

In areas with poor outcrop exposures and inaccessibility as a result of logistical and socio-political constraints, such as part of the Zungeru, field geological mapping is met by a number of setbacks usually in the form of cost, feasibility and security. Because of the synoptic view and the ability to discern distinct lithologies based on their spectral properties, Landsat 7 ETM+ can provide a very useful and low-cost tool for quick mapping in such circumstances.

The rock types encountered in the study area include migmatite-gneisses, schists, amphibolites, quartzites and minor granitic intrusions (Agbor, 2014), but the contact relationship between these rocks is not well defined. In order to differentiate and map the lithologies, certain enhancement techniques such as Principal Component Analysis (PCA), Band Ratio, and False Color Composite techniques were employed on a Landsat 7 ETM+ subset of the Zungeru area in this study. Color composite images created by band rationing and principal component analysis have been especially valuable for visually identifying a variety of rock units within the region.

The most useful images were obtained using a false color composite image for bands 7, 4, 1; 7, 5, 4; and PC 1, 2, 3 presented in R.G.B, emphasizing the small spectral variations between distinct lithological units within the research area. The false color composite of band ratio 1/3:5/7:3/5 and PC 4, 5, 6 exhibited limited enhanced visual display of the rock types. The combination of information derived from these images and fieldwork data aided in the production of a comprehensive and up-to-date geological map which shows clearly the various rock types, their extent and their contact relationships (Fig. 13).

Multispectral remote sensing image enhancement and interpretation of Landsat 7 ETM+ has demonstrated efficacy in lithological rock unit identification and detection. This research shows that, when appropriately processed, low-cost optical satellite images can be a useful tool for rapid and accurate geologic mapping at a regional scale.

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