Study Of The Trend And Structural Control Of Lead Zinc Mineralization At Zurak Using Field Data And Satellite Imagery. Wase L.G.A Of Plateau State

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STUDY OF THE TREND AND STRUCTURAL CONTROL OF LEAD ZINC MINERALIZATION AT ZURAK USING FIELD DATA AND SATELLITE IMAGERY. WASE L.G.A OF PLATEAU STATE.

BY

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04/15252/1

SUBMITTED TO APPLIED GEOLOGY PROGRAMME ATBU BAUCHI IN PARTIAL FULFILMENT FOR THE REQUIREMENT OF THE AWARD OF B.TECH APPLIED GEOLOGY

SEPTEMBER 2010

DECLARATION

I hereby declare that this report was written by me and is a record of my own research work at Abubakar Tafawa Balewa University Bauchi. None of the contents of this report was presented in support of an application of another degree or qualification in this or any other institution of learning.

Abanitus O. Frama	-----------------------	6/09/10
	Signature	Date

CERTIFICATION

I hereby certify that this project work was carried out by Abanitus O. Frama of Applied Geology Programme, Abubakar Tafawa Balewa University Bauchi and had met the requirement of the award of Bachelor of Technology [B. Tech (Hons)] in Applied Geology.

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PROGRAMME CORDINATOR

DEDICATION

I dedicate this work to my parents Mr. and Mrs. Othniel Abanitus who have stood by me in every facet of my life.

ACKNOWLEDGEMENT

I acknowledge the financial and moral support of my parents because this work will not have been possible without them. I do acknowledge the suggestions and contributions of my supervisor; Mr. Dieter A. Bassi who has also consistently followed up during the study to ensure that things are moving well.

I also acknowledge Mr. Mohammed (Senior Geophysicist, Nigerian Geological Survey Agency) who taught me the use of ILWIS 3.4, Dr. Rod Holcombe and Dr. Tim Coughlin of Holcombe Coughlin and Associates made the GEOrient 32 Version 9.4 available as an online resource which aided the rose plots for the field data. Mr. Yaro of the Center for Remote Sensing and GIS in Jos assisted in making the satellite image of the study area available, the ruler of the people of Zurak was very accommodating and hospitable thus contributing immensely to the study.

The lecturers and staff of Geology Programme form the base and foundation of my knowledge in Geology. I acknowledge their teachings as a major contribution to this work. I also acknowledge and thank the external examiner for taking out time to travel down to read through this work thoroughly.

Finally not to leave anyone out, I acknowledge the help of everyone in the project group who has contributed to making this work a success

ABSTRACT

The Landsat enhanced Thematic Mapper (ETM+) which is covering part of the Zurak Lead Zinc field has been digitally processed to enhance the visibility of lineaments. The contrast stretched of band 3, 2, 1 was found to be the best in displaying lineaments for the area, hence was further processed by using directional filters. After tracing all lineaments, their orientations were determined and measured, and then analyzed by preparing rose diagrams for analysis, interpretation and comparison with the published geological map of the Nigerian Geological Survey Agency 2006.

This study indicates that the Landsat ETM+ data is useful for locating and interpretation of the lineaments in the area. Geologic features, particularly lineaments, are readily interpreted. The study has shown that remote sensing data such as Landsat ETM+ can be used in locating new in addition to previously known features, probably faults, which may be of economic importance in the area. Hence, lineament mapping and analyses from satellite data of the area can provide a new, rapid and stimulating overview for regional structural (lineament) study for mineral exploration and planning the development of the selected area.

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INTRODUCTION

The first satellite photographs of Earth were made on August 14, 1959 by the U.S. satellite Explorer 6 and in 1972 the United States started the Landsat program, the largest program for acquisition of imagery of Earth from space. Landsat 7, the most recent Landsat satellite, was launched in 1999.

All satellite images produced by National Aeronautic and Space Administration (NASA) are published by Earth Observatory and are available to the public. Several other countries have satellite imaging programs, and a collaborative European effort launched the Earth Resource Satellite and Envisat satellites carrying various sensors. There are also private companies that provide commercial satellite imagery. In the early 21st century, satellite imagery became widely available when affordable, easy to use software with access to satellite imagery databases became offered by several companies and organizations.

Satellite images have many applications in agriculture, geology, forestry, biodiversity conservation, regional planning, education, intelligence and warfare. Images can be in visible colors and in other spectra. There are also elevation maps, usually made by radar imaging. Interpretation and analysis of satellite imagery is conducted using software packages like ERDAS Imagine, ENVI, or ILLWIS. Some of the first image enhancement of satellite photos was conducted by the U.S.

Government and its contractors. Satellite imagery also has use in seismology and oceanography in deducing changes to land formation, water depth and sea bed by color caused by earthquakes, volcanoes, and tsunamis.

There are two different types of resolution when discussing satellite imagery: radiometric, and geometric. Radiometric resolution refers to the effective bit-depth of the sensor (number of grey scale levels) and is typically expressed as 8-bit (0-255), 11-bit (0-2047), 12-bit (0-4095) or 16-bit (0-65,535). Geometric resolution refers to the satellite sensor's ability to effectively image a portion of the Earth's surface in a single pixel and is typically expressed in terms of Ground Sample Distance (GSD). GSD is a term containing the overall optical and systemic noise sources and is useful for comparing how well one sensor can "see" an object on the ground within a single pixel. The resolution of satellite images varies depending on the instrument used and the altitude of the satellite's orbit.

Satellite imagery is sometimes supplemented with aerial photography, which has higher resolution, but is more expensive per square meter. Satellite imagery can be combined with vector or raster data in a Geographic Information System provided that the imagery has been spatially rectified so that it will properly align with other data sets.

Regional study of linear features such as faults, joints, folds, dikes, crustal fracturing, and lithological contacts, using particular satellite images, has made important advances in geological research (Rowan and Lathram, 1980). Recognition of lineaments has been used for investigating active fault patterns in areas of difficult accessibility (Tibaldi and Ferrari, 1991), water resources investigations (Waters, 1990), mineral deposit exploration (Rowan and Lathram, 1980), and in the study of the structural or tectonic history of a region.

In this study the spectral band 3, 2, 1 of Landsat 7 (ETM+) electromagnetic spectrum, is used in this analysis. The pixel resolution of this band is 30 m and has a repeat cycle of 16 days while delivery of archived data takes 2 weeks but its sensor is fixed to view vertically. This is known as an important band for discrimination of geological rocks and detection of linear geological features like faults (C. Ayday, 2008).

The study area is located in Zurak town of Wase Local Government Area of Plateau State which is part of the Upper Benue Trough Lead Zinc field. Early descriptions of the mineralization at Zurak were provided by Tattam (1930) and Mackay (1947, 1948), while reviews of the Pb-Zn belt as a whole was given by Mackay (1950) and Farrington (1952).

1.1 LOCATION AND ACCESSIBILITY

The study area is bounded by two major towns which are Bashar and Muri districts and lies within Longitude E 10^0 30' 00" to E 10^0 40' 00" and Latitude N 9^0 10' 00" to

N 9^0 20' 00" of sheet 193 Muri South East. It is accessible through Bashar – Zok – Sabon Gida by road and foot path. The road is however bad during the rainy season.

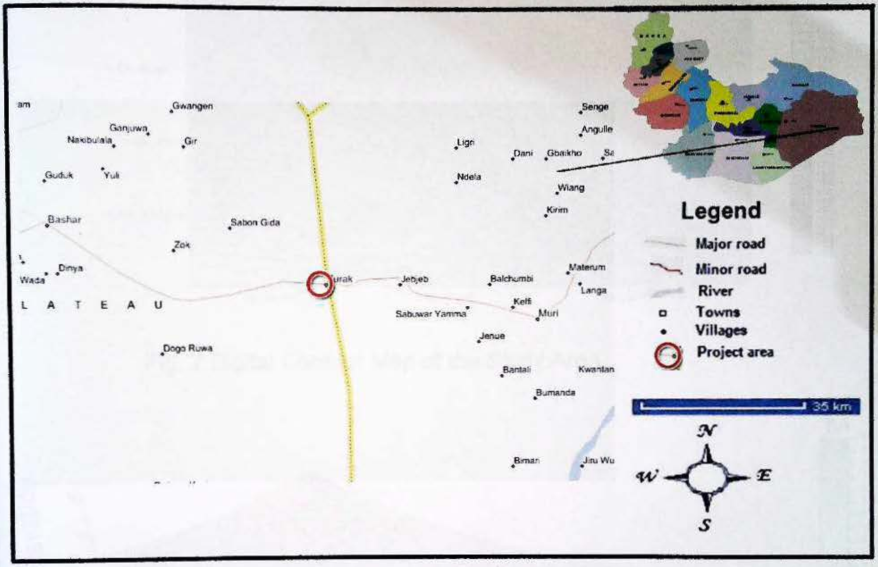

Fig 1: Map Showing Location of the Study Area (After Multimaps 2010)

1.2 TOPOGRAPHY AND DRAINAGE

The area is typically a flat terrain with little or no undulations. Global Position Satellite (GPS) co-ordinates lie within the range of 200m-215m above sea level. It constitutes a few meandering streams which are being enriched from several tributaries during the rainy season.

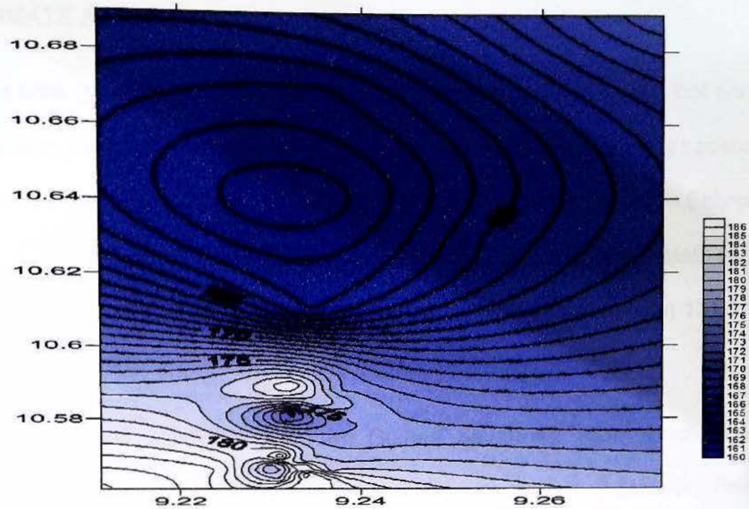

Fig. 2 Digital Contour Map of the Study Area

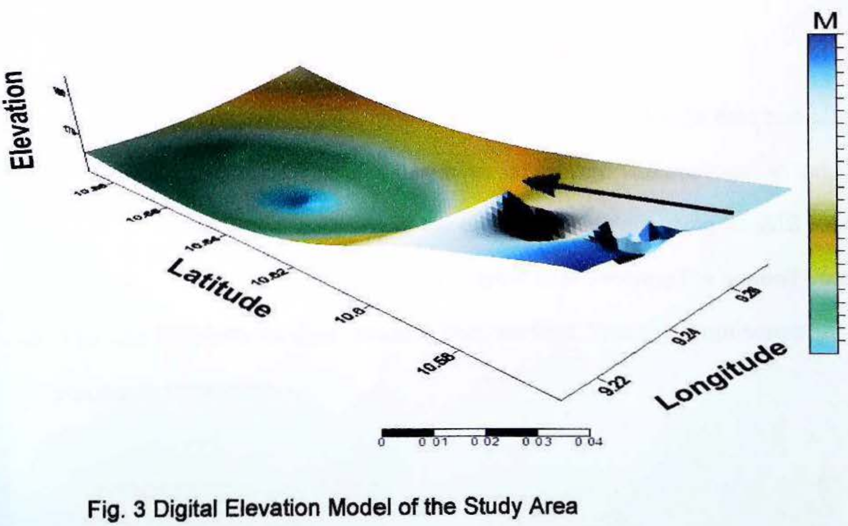

Fig. 3 Digital Elevation Model of the Study Area

1.3 CLIMATE AND VEGETATION

The study area unlike the near temperate climate on the Jos Plateau is a hot and humid climate. Generally, weather conditions are warmer during the rainy season (April-October) and much colder during the harmattan period (December - February). The mean annual temperature in the area which conforms to that of the state ranges between 20^0c and 25^0c, while the mean annual rainfall figures range from 131.75cm in the southern part where the area lies to 146cm on the Jos Plateau.

Zurak falls largely within the Northern Guinea Savannah zone which consists mainly of short trees, grasses and the Plateau type of mosaic vegetation. Fringing woodlands or gallery forests can be found in its surroundings along some river valleys.

1.4 AIMS AND OBJECTIVE

This study seeks to determine the general trend of the Zurak Pb-Zn field and also to determine the structural control of this mineralizing belt. The approach in this study is to use computer processing of the original digital data using ILLWIS 3.4 for the production of a lineament map with the objective of verifying the general trend with the rose diagrams for data obtained from the field. This in a large sense contributes to knowledge.

1.5 PREVIOUS WORK

Regional study of linear features such as faults, joints, folds, dikes, crustal fracturing, and lithological contacts, using aerial photographs and particular satellite images, has made important advances in geological research (Rowan and Lathram, 1980). Recognition of lineaments has been used for investigating active fault patterns in areas of difficult accessibility (Tibaldi and Ferrari, 1991), water resources investigations (Waters, 1990), mineral deposit exploration (Rowan and Lathram, 1980), and in the study of the structural or tectonic history of a region.

The use of computerized, scanned data analysis for the detection of linear features from digital satellite images can reduce to a minimum the bias of the subjective decision of the interpreter. Sijmons (1987) distinguished between two categories of computerized lineament processing. The first involves mainly enhancement of linear features using standard image processing methods [such as edge detection directional filters) for later visual interpretation while the second category involves automatic computer processing of the original digital data for the production of a lineament map. Obviously, the majority of studies which have been done up to date belong to the first category. For all of the cases in this category, interpretation of lineaments is still subjective, and considerable experience is required to detect weak features or to separate close ones. In order to overcome these limitations, an automatic objective procedure is required. This type of procedure is not common

(Oakes, 1987; Simon *et al.,* 1989; Zlatopolsky, 1992). Special interest has been shown in using the Hough transform algorithm for this purpose, but with limited success (Cross, 1988; Cross and Wadge, 1988; Wang and Howarth, 1989; Wang and Howarth, 1990).

In Nigeria, Edet et al., (1994) carried out lineament analysis of the Precambrian Oban massif and Obudu Plateau S.E, Odeyemi (1992) carried out remote sensing analysis of the region around Ifewara fault using remotely sensed images, Odeyemi (1993) also did a comparative study of some remotely sensed images on the structure of the Okemesi Fold Belt, Southwestern Nigeria. Anifowose (2004) carried out an integrated remote sensing analysis of the Ifewara- Zungeru Mega linear using remotely sensed images,

However this study is focused on the Zurak Pb-Zn field which lies largely in the Upper Benue Trough of the North Eastern Nigeria. Early descriptions of the mineralization at Zurak were provided by Tattam (1930) and Mackay (1947, 1948), while reviews of the Pb-Zn belt as a whole was given by Mackay (1950) and Farrington (1952).

Early studies of the Upper Benue Trough were carried out by Falconer (1911), Jones (1932), Raeburn and Jones (1934) and Baber et al., (1954). The basis for all later work was provided by Cater et al., (1963) who undertook a regional study of the area covered by Geological Survey of Nigeria 1: 250,000 Series map sheets 25

(Potiskum), 36 (Gombe) and 47 (Lau). The Upper Benue Trough has since become known in greater detail and has been almost entirely remapped through the work of Allix (1983), Benkhelil (1985, 1986, 1988), Popoff (1988), Guiraud (1989, 1990a, 1991a, 1993) and Zarboski et al., (1998)

The Benue Trough Pb-Zn field in its entirety is considered as a belt of mineralization which extends for about 500km along the axial part of the Benue Trough. Galena and Sphalerite are the main ore minerals, occurring in steeply dipping to subvertical fractures varying from a few meters to a maximum of about 2km in length and from a few cm to about 20m in width. Maximum vertical extents of the lodes are about 150m. In the Upper Benue Trough the main occurrence of Pb-Zn is at Zurak. Here Sphalerite and Galena (argentiferous at shallow depth) occur in a mainly Quartz gangue, Zn increasing at the expense of Pb at depth. The host rock dominantly argillaceous lithologies within a sequence of alternating Shale, Siltstone and Sandstone with thin oyster-bearing Limestone, belong to the Yolde Formation.

Cratchley and Jones (1965), Wright (1968), Murat (1972) and Reyment and Tati (1983) related the mineralization to the Santonian folding. Nwachukwu (1972) noted two generations of Galena in the Nyeba-Ameri-Ameka veins, one granular and deformed the other coarsely crystalline and undeformed. The latter was regarded as post-dating or accompanying the Santonian deformation, the former predating it. Emplacement occurred during the postulated Cenomanian folding event. Almost all subsequent authors have assigned the mineralization to the Cenomanian to Early Turonian time interval.

Grant (1971a, 1971b) rejected a magmatic origin for the Benue Lead. Since Pb isotope data for the Galena indicates a deviation from low U/Pb sites (Jacobson et al., 1963), he regarded the Lead as leached from preexisting basement sources (preexisting ores or Potassium Feldspars) by brines circulating under the influence of a deep geothermal reservoir.

Maurin and Lancelot (1989) showed that Galena from around Zurak and Abakaliki have homogenous Pb isotopes compositions. The Pb is highly unradiogenic in view of its Cretaceous age and was regarded as derived from Uranium depleted source. The Pb sources were thought most likely to be detrital feldspars contained within arkoses produced by erosion of granitic and migmatitic Basement rocks; strong uranium sources were removed into separate argillaceous lithologies. Ofoegbu and Odigi (1990) believed that ancient basement fractures were rejuvenated as conduits for hydrothermal solutions of magmatic origin which leached the base metals from the sedimentary pile.

Uma (1998) believed the brine springs of the Benue Trough were sourced by connate waters of common origin occurring in host rocks of marine or transitional marine origin and held interstitially under pressure. The brines were not regarded as related to evaporate deposits. Migration to the surface was thought to occur wherever appropriate conduits are present, notably along the flanks of anticlinal structures. Furthermore, an enrichment of Be, Pb, Zn and Fe, among others, relative to seawater was reported. These findings are consistent with their postulated role in the Benue Mineralization.

CHAPTER 2

LITERATURE REVIEW

The Benue Trough is the most important of all the Cretaceous Sedimentary Basins in Nigeria. Reviews of the origin and evolution of this linear, mega structure were provided by Benkhelil (1989) and Freeth (1990). At its northeastern and an area commonly known as the Upper Benue Trough, it bifurcates into an E-W trending Yola arm and an N-S trending Gongola arm or Gongola Basin. The Benue Trough was terminated by a Late Santonian episode of compressional folding. Subsequent sedimentation was centered on Basins developed on the northern western flank of the resultant deformed sediments.

2.1 NATURE AND ORIGIN OF THE BENUE TROUGH

The Benue Trough of Nigeria is a rift basin in central West Africa that extends NNE – SSW for about 800 km in length and 150 km in width. The southern limit is the northern boundary of the Niger Delta, while the northern limit is the southern boundary of the Chad Basin (Fig. 4.0). The trough contains up to 6,000 m of Cretaceous – Tertiary sediments of which those predating the mid-Santonian have been compressionally folded, faulted, and uplifted in several places. Compressional folding during the mid-Santonian tectonic episode affected the whole of the Benue Trough and was quite intense, producing over 100 anticlines and synclines (Benkhelil, 1989). Major such deformational structures include the

Abakaliki anticlinorium and the Afikpo syncline in the Lower Benue, the Giza anticline and the Obi syncline in the Middle Benue, and the Lamurde anticline and the Dadiya syncline in the Upper Benue Trough.

In attempting to deduce the origin and evolution of the Benue Trough authors have sought to explain its fundamental crustal structure and the folding which occurs parallel to its length. The main folding is undoubtedly of Santonian age but de Sward and Casey (1961), Nwachukwu (1972) and Olade (1975), among others, have suggested that a minor Cenomanian folding event occurred in the Lower Benue Trough and this belief has influenced certain models.

Lees (1952) regarded the Benue Trough as a compressional downwarp, the folding being induced by deep seated Basement contraction. King (1950) regarded the Benue Trough and the Bida Basin/Gao Trough as extensions of the rifts which produced the Equatorial and South Atlantic oceans respectively. Cratchley and Jones (1965) concluded that the Benue Trough was a rift and on the basis of gravity data, inferred marginal faulting or step-faulting along most of its Middle and Upper parts, the faults being concealed by Cretaceous sediments. Stonley (1956) also proposed a rift origin. Wright (1968) related the opening and slight Santonian closure of the Trough to the separation of Africa and South America which commenced from the south, induced a tensional stress on the African continent. Final separation was supposed to have occurred during the Santonian.

The Benue Trough is arbitrarily subdivided into a lower, middle and upper portion

(Figures. 3, 4 and 4). No concrete line of subdivision can be drawn to demarcate the individual portions, but major localities (towns/settlements) that constitute the depocentres of the different portions have been well documented (Petters, 1982; Nwajide, 1990; Idowu and Ekweozor, 1993; Obaje et al., 1999).

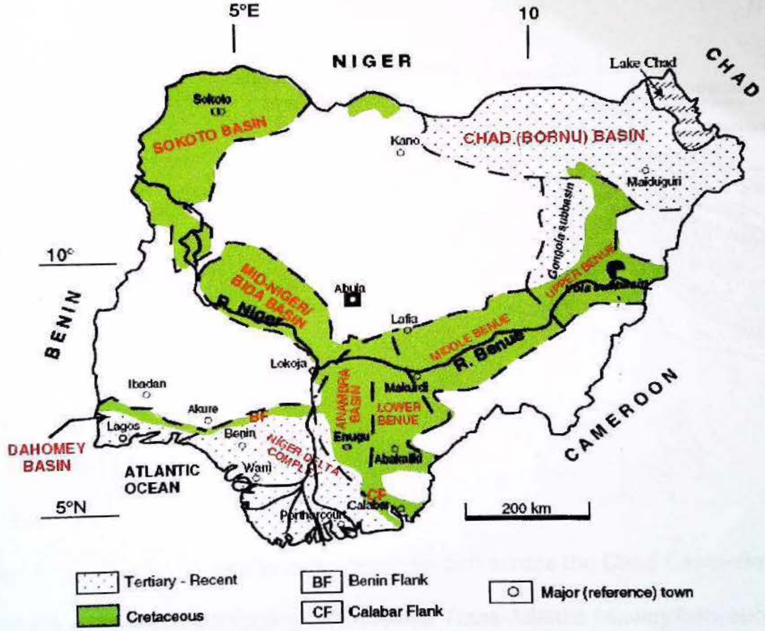

Fig. 4: Map of Nigeria Showing the Sub-divisions of the Benue Trough (After Obaje 2009)

The depocentres of the Lower Benue Trough comprise mainly the areas around

Nkalagu and Abakaliki, while those of the Anambra Basin centre around Enugu, Awka and Okigwe. The Middle Benue Trough comprises the areas from Makurdi Through Yandev, Lafia, Obi, Jangwa to Wukari. In the Upper Benue Trough, the depocentres comprise Pindiga, Gombe, Nafada, Ashaka (in the Gongola Arm) and Bambam, Tula, Jessu, Lakun, and Numan in the Yola Arm.

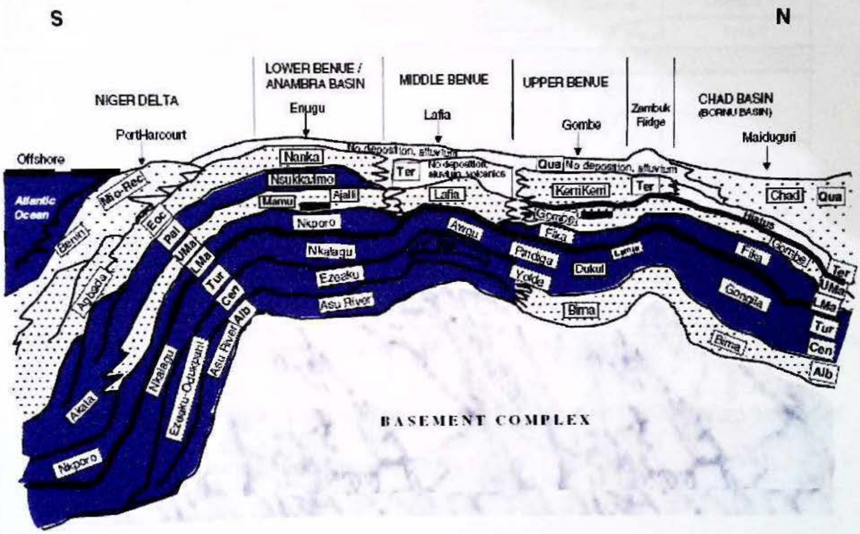

Fig. 5: Idealized N–S Stratigraphic cross-section across the Chad Basin–Benue Trough – Niger Delta depicting a connected Trans-Atlantic seaway between the South Atlantic and the Tethys Sea during the Coniacian – Turonian (After Obaje 2000)

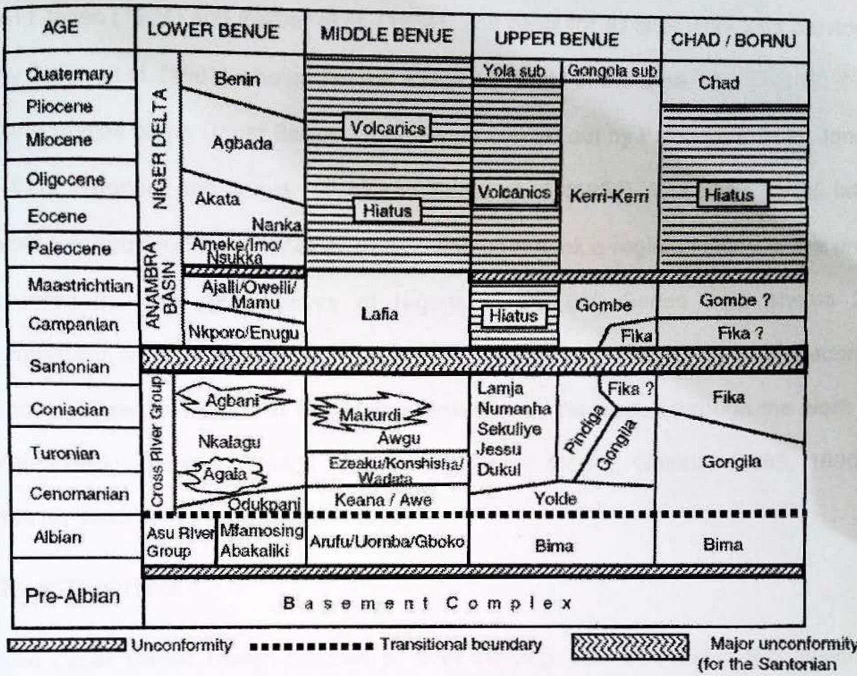

Fig. 6: Stratigraphic successions in the Benue Trough and the Nigerian sector of the Chad Basin (After Obaje 2000)

2.2 UPPER BENUE TROUGH

The Upper Benue Trough comprises the area extending from the Bashar-Mutum Biyu line as far North as the Dumnulwa-Bage high of Zaborski et al. (1998) which separates it from the Bornu Basin. Early studies of the Upper Benue Trough and Southern Bornu Basin were carried out by Falconer (1911), Jones (1932), Raeburn and Jones (1934) and Barber et al. (1954). The basis for all later work was provided by Carter et al. (1963) who undertook a regional study of the area.

Early studies of the Upper Benue Trough were carried out by Falconer (1911), Jones (1932), Raeburn and Jones (1934) and Baber et al. (1954). The basis for all later work was provided by Cater et al. (1963) who undertook a regional study of the area covered by Geological Survey of Nigeria 1: 250,000 Series map sheets 25 (Potiskum), 36 (Gombe) and 47 (Lau). The Upper Benue Trough has since become known in greater detail and has been almost entirely remapped through the work of Allix (1983), Benkhelil (1985, 1986, 1988), Popoff (1988), Guiraud (1989, 1990a, 1991a, 1993) and Zarboski et al. (1998)

2.3 STRUCTURE

The Upper Benue Trough includes an E-W trending Yola arm and a N-S trending Gongola Basin (Fig. 4). These two branches are separated by an area structurally dominated by four major NE-SW trending sinistral strike-slip faults, the Gombe, Bima-Teli, Kaltungo and Burashika faults; Basement inliers, notably the Kaltungo inlier, are associated with them. Benkhelil (1988, 1989) regarded this median zone as the partially exposed Basement high characterizing the axis of the Benue Trough. Cater et al. (1963) referred to it as the "Zambuk Ridge". This term has frequently been applied to a line marked by a single fault which passes Zambuk Village.

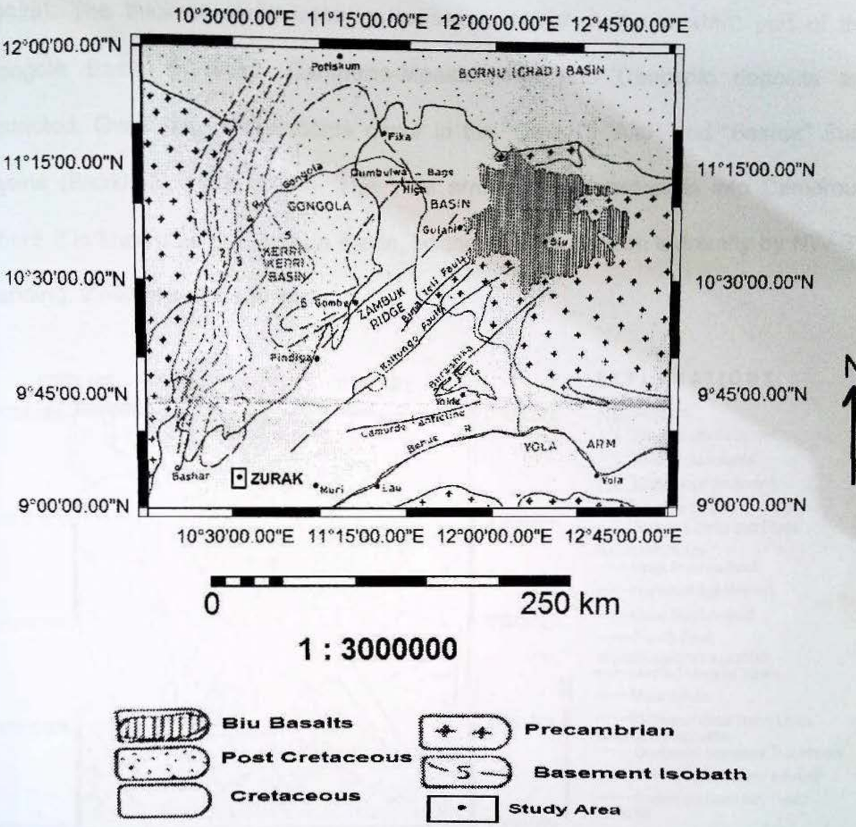

Fig.7 Simplified Geological Map of the Upper Benue Region (Modified After Benkhelil 1988)

A series of N-S to NNE-SSW trending faults controls the trend of the Gongola Basin (Zaborski et al., 1998) while deep seated E-W trending fractures appear to characterize the Yola arm (Benkhelil, 1988, Maurin and Guiraud, 1989, 1990, Braide, 1992a). The thickest sedimentary successions occur in the western part of the Gongola Basin to which Campano-Maastrichtian and Cenozoic deposits are restricted. Over 5km of sediments occur in the "Dukku", "Ako" and "Bashar" Sub-basins (Benkhelil, 1988, 1989). The Yola arm extends eastwards into Cameroun where it is known as the Garoua Basin, bounded at its eastern extremity by NW-SE trending, sinistral strike slip faults.

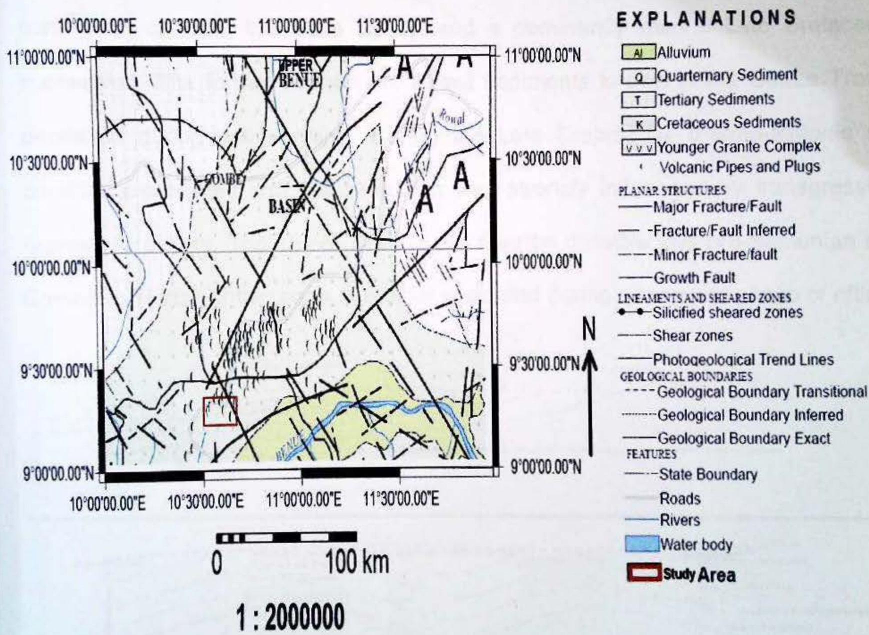

Fig.8: Map showing Geology and lineaments of the Upper Benue Trough. (Extacted from Lineaments Map of Nigeria, NGSA 2006)

A number of small, Barremo-Aptian, E-W trending half grabens of transtensional origin also occur in this region, the Hama-Koussou, Figuil, Mayo-Oulo, Koum (Mayo Rey) and Baouan basins, which have a fluvio lacustrine infill (Maurin and Guiraud, 1989, 1990).

2.4 STRATIGRAPHY OF THE UPPER BENUE TROUGH

The Cretaceous succession in the Upper Benue Trough comprises Early Cretaceous continental clastics, the Bima Group and a dominantly marine Late Cretaceous succession. The former include the oldest sediments known in the Benue Trough deposited during active rifting. During the Late Cretaceous thermo-tectonic sag conditions prevailed and sedimentation was strongly influenced by transgressive-regressive events. The Upper Cretaceous may be divisible into pre-Santonian and Campano-Maastrichtian parts, the latter deposited during a renewed phase of rifting.

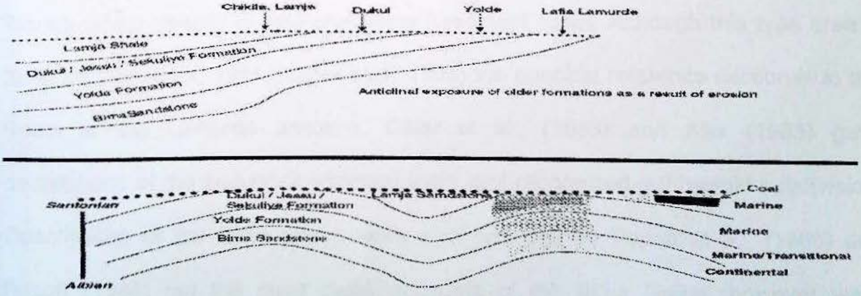

Fig. 9: Stratigraphic successions in the Upper Benue Trough(Yola Arm) (After Obaje 2000)

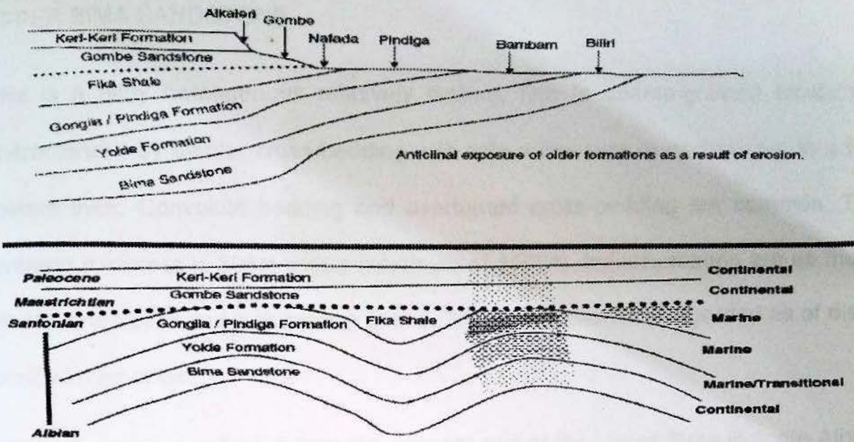

Fig. 10: Stratigraphic successions in the Upper Benue Trough(Gongola Arm) (After Obaje 2000)

2.4.1 BIMA FORMATION

The continental Bima Group comprises the oldest sediments in the Upper Benue Trough which directly overlie crystalline Basement rocks. Although this type area is Bima hill (Falconer, 1911: Cater et al. 1963) the principal reference section is to the South in the Lamurde anticline. Cater et al., (1963) and Allix (1983) gave descriptions of the sequence exposed there and recognized a threefold subdivision. Descriptions of the Bima Group were also provided by Popoff et al., (1986) and Popoff (1988) but the most detail accounts of the Bima Group, however were provided by Guiraud (1990a, 1991a) who described its three parts:

UPPER BIMA SANDSTONE

This is a fairly homogenous relatively mature, fine to coarse-grained sandstone characterized by tabular cross-bedding with sets a few tens of centimeters to a few meters thick. Convolute bedding and overturned cross-bedding are common. The average thickness is 500m with a maximum of 1500m. Individual beds are as much as 1m to 3m thick and lack erosive bases. These deposits were regarded as of distal braided river origin.

Although samples collected from the younger part of the Upper Bima indicate Albian age (Allix, 1983). Precise age date on the Bima formation as a whole is scanty (Zaborski et el., 1997).

MIDDLE BIMA SANDSTONE

This consists of widely distributed fairly uniform unit consisting of fining upward sequence each 5-10m thick. Trough and tabular cross-bedding characterizes the sandstones, while clays and palaeosols may occur at the top of individual cycles. The overall thickness is some 100-500m. These deposits were regarded as of proximal braided river origin. Guiraud (1991a) assigned a Late Aptian age based on fossil collected.

LOWER BIMA SANDSTONE

A highly variable unit ranging in thickness from 0 to over 1500m. Lithofacies distributions were controlled by syn-sedimentary tectonics which created a number of fault bounded sub-basins within which marginal alluvial fan/distal debris. How deposits pass laterally into fining upward fluvial sequence and in places into lacustrine deposits comprising interbedded clays, fine-grained sandstones and calcareous beds. Radiometric ages from interrelated lavas suggest an age from Neocomian to Late Aptian or Early Albian.

2.4.2 YOLDE FORMATION

The Yolde Formation has been described in the Yola arm by Cater et al., (1963) and Allix (1983) and in the Gongola Basin by Zarboski et al., (1998).

It consist largely of alterations of coarse to fine-grained, cross-bedded or ripple-bedded sandstones and grey to greenish shales. Thin limestones of calcareous sandstone occur, especially in its upper part where oyster beds are common. It fines upwards, channel filling coarse grained sandstones with trough cross-bedding occur in the lower part, thinly bedded, medium to fine grained often bioturbated sandstones appear higher. The boundary with the Upper Bima Sandstone is transitional. Cater et al., (1963) defined it at the appearance of marine shales. Allix (1963) used the appearance of thick, laterally continuous siltstones or silty shales or the base of a maker horizon comprising greenish fine grained sands with disturbed cross-bedding found in parts of the Yola arm. The Yolde Formation represents fluvial and coastal plain palaeoenviroments in its lower part and shallow marine conditions higher up.

The Yolde Formation records the initial stages of the late Cenomanian to early Turonian transgression but the overlying beds [lower part of the Turonian Limestones and Shales of the Benue valley and lower part of the Turonian limestones of the Gongola valley of Falconer (1911; pg. 161); Calcareous Group of Jones (1932); lower part of the Limestone-Shale and Calcareous Beds of Barber et al., (1954)] represent its peak. They consist mainly of Shales, dark grey when fresh but weathering to light blue-green to grey colors.

Lawal (1982) and Lawal and Moullade (1986) suggested a Late Albian to Late Cenomian age for the Yolde Formation on the basis of its Palynofossils. The marine upper part of the Yolde Formation is probably of early Late Cenomanian age.

2.4.3 PINDIGA FORMATION

The name "Pindiga Formation" was proposed by Cater et al., (1963) for the Calcareous Beds and Clay Shales previously described by Baber et al., (1954). It makes up the greater part of the Upper Cretaceous deposits in the Upper Benue Trough. Its type section is Pindiga stream to the southwest of Gombe where about 80m of shalely mudstones with limestones intercalations are overlain by about 160m of strata consisting almost entirely of shalely mud stones. Cater et al., (1963) referred age equivalents beds in the Gongola Basin to the Gongila Formation which is made up of a lower Limestone-Shale member and an upper Sandstone Shale Member, and to the Fika Shales for the overlying argillaceous beds.

In the Gongola Arm, the laterally equivalents Gongila and Pindiga Formations and the possibly younger Fika Shale lie conformably on the Yolde Formation. These Formations represent full marine incursion into the Upper Benue during the Turonian – Santonian times. Lithologically, these formations are characterized by dark/black carbonaceous shales and limestones, intercalating with pale colored limestones, shales and minor sandstones. The type locality of the Gongila Formation is at the Quarry of the Ashaka Cement Company at Ashaka, while that of Pindiga Formation is at Pindiga village. The Fika Shale is lithologically made of bluish-greenish carbonaceous, sometime pale gypsiferous, highly fissile shales and occasional limestones in places. The formation is entirely marine and has its type locality at Nafada village on the Gombe – Ashaka road. In the Yola Arm, the Dukul, Jessu and Sekuliye Formations, the Numanha Shale, and the Lamja Sandstone are the Turonian – Santonian equivalents of the Gongila and Pindiga Formations. The Turonian – Santonian deposits in the Yola Arm are lithologically and palaeoenvironmentally similar to those in the Gongola Arm, except the Lamja Sandstone which has a dominating marine sandstone lithology. The recovery of diverse assemblages of arenaceous alongside planktonic Foraminifera from samples obtained from the Dukul, Jessu and Sekuliye formations indicate deposition in shallow marine – neritic – shelfal environments.

Peters (1978), and Cater et el., (1963) base on ammonites suggested lower Turonian age for the Pindiga Formation. However, Poppof et al., (1986) based on similar Ammonites facies established an upper Cenomanian age to Turonian age for the Formation.

2.4.4 GOMBE FORMATION

The Gombe Formation corresponds to the name " Gombe Sandstone " which was proposed by Cater et al., (1963) for the Gombe grits and clays previously identified by Falconer vary from a few millimeters to a few centimeters in thickness. Passing upwards, the sandstone beds become more persistent and make up the greater part of what is here termed the "bedded facies". This lithofacies, which is well exposed at Guiwa, consists of extremely regularly bedded, fine to medium-grained white and grey quartz arenites (and occasional feldspathic sandstones) with Interbedded silts, silty clays and both flaggy and vesicular ironstones. Individual beds vary from a few centimeters to over 1meter in thickness but even the latter beds are characterized by internal lamination. Dike (1995) has reported coal horizons in the upper part of the Gombe Sandstone encountered in boreholes penetrating the subcropping part of the Formation.

At Pindiga the contact between the bedded and red sandstone facies is deeply erosional with reliefs of some 2m or more displayed. Elsewhere such a relationship has not been clearly established though between the Gombe and Gamawa the channel-filling sandstones occur greatest towards the base of the red sandstone facies. Around Bashar the Gombe Formation lies partly unconformably upon the Pindiga Formation. For some 50km North of Bashar. However, it oversteps the crystalline Basement to the West. These sandstones around Bashar are interpreted as the proximal part of a coarsening-upward deltaic like deposit prograding from the Southwest into a sea open only to the north. The red sandstone facies is believed to be a fluvial deposit while the bedded facies was laid down in a shallow, quiet hyposaline sea.

Cater et al., (1963) interpreted the Gombe Formation as a deltaic and estuarine deposit. Lawal (1982) found a marked decrease in marine microfossils at the boundary of the Pindiga Formation and the Gombe Formation. The pollens in the latter indicated a Maastrichtian age.

2.4.5 KERRI-KERRI FORMATION

The Cretaceous Gongola Basin is concealed to the West by the Kerri-Kerri Formation. The continental clastics of the Kerri-Kerri Formation, which reach a thickness of over 320m, have been described by Adegoke et al., (1986) and Dike (1995). Age data for the formation is scanty. Paleocene pollens have been recovered (Adegoke et al., 1979) but Eocene beds may also occur (Adegoke et al., 1996). The irregular topography of the unconformity surfaces that separates the Kerri Kerri Formation from the Gombe Formation is exposed on the northern outskirts of Gombe town. The Gombe Formation was folded, faulted and deeply dissected prior to the deposition of the Kerri Kerri Formation. The latter shows rapid changes in thickness along the eastern margin of its outcrop due to its deposition upon an irregular topography. Numerous small inliers of Gombe Formation often associated with Late Cretaceous Faults occur in this region

CHAPTER 3

METHODOLOGY AND STRUCTURAL GEOLOGY

3.1 INTRODUCTION

The methodology used in this study follows the standard sequence for lineaments analysis and the integration of their results for geological assesment. This approach was used successfully for many years with both aerial photographs and satellite images for the above tasks. However, the recent advance in remote sensing has allowed for this study several improvements and additions such as:

1. All data were in digital format and stored in a geo-database as GIS layers;
2. All analysis and interpretations were performed directly from the computer screen.
3. A comprehensive geo-database was created including all GIS layers which were considered of interest for the study; for instance data on location, vector data on geology, drainage, lineaments, and raster data on satellite images.
4. By using the potentiality of GIS software, which allows stacking of geo-referenced data for comparison and integration and data query for sub setting the needed information leading to a well-substantiated set of interpretation assumptions.

The creation of a GIS database, including the data format and entry, is a time-consuming and laborious exercise, as high accuracy is definitely mandatory. The time required for its preparation is also related to the area under consideration. However, once the database was completed, interpretation of features was carried out easily and quickly.

3.2 FIELD WORK

Field data was acquired by the use of a Global Position System (GPS) for the acquisition of co-ordinate data; compass was used for the strike directions of the object of analysis. Though some the ground verification was not carried out comprehensively, some of the potential mines at Office mines and Clarke quarters mine were observed and data was acquired from them.

In this framework, the results obtained from the field were processed and analyzed using the GEOrient 9.4 Rose plots were plotted from these data sets so as to determine the trend of linear structures and comparism was made with the rose diagram obtained from the extracted lineament map.

3.3 LANDSAT IMAGE ACQUISITION

The Landsat image of the study area (Fig. 16) was acquired from the National Centre for Remote Sensing Jos. The underlying principle is based on Image Processing System (IPS). This refers to the hardware and software that provides the full capabilities for the reception, archival, cataloging, user query, and processing of the remote sensing image data. The IPS is used to receive, process, and archive the bit sync remote sensing image data from the X-band Antenna System (XAS) of Landsat 7 (ETM+). The XAS is dedicated for receiving the high-rate link of the earth remote sensing data from the Landsat 7 (ETM+) satellite, and has the capability of receiving down link data rate up to 320Mbps. It can also be expanded to receive data from other remote sensing satellites. Remote sensing data comes to the IPS via either a satellite link or some other high-speed network and is placed in to mass storage. Users can then process the data through some of interface.

3.4 LINEAMENT EXTRACTION

A lineament is a mappable linear or curvilinear feature of a surface whose parts align in a straight or slightly curving relationship. They may be an expression of a fault or other line weakness. The surface features making up a lineament may be geomorphological. Straight stream valleys and aligned segments of a valley are typical geomorphological expressions of lineaments. On the earth, lineaments could be straight stream and valley, aligned surface depressions, soil tonal changes, alignments in vegetation, vegetation type and height changes, or abrupt topographic changes.

Lineament identification via remotely sensed data is achieved by using two principal techniques:

1. Lineament data can be visually enhanced using image enhancement techniques (image ration, image fusion, directional edge-detection filters) and a lineament vector map can be produced using manual digitizing techniques (Arlegui and Soriano; 1998; Suzen and Toprak, 1998).
2. Second, a lineament map may be produced using computer softwares and algorithms (Burdick and Speirer 1980, Karnieli et al., 1996; Baumgartner et al. 1999, Hung et al. 2002, 2003, Kim et al., 2004)

From previous studies, there are two common methods for the extraction of lineaments from satellite images:

1. Visual extraction: At which the user first starts by some image processing techniques to make edge enhancements, using the directional and non directional filters such as the Laplacian, and Sobel, then the lineaments are digitized manually by the user.
2. Automatic (or digital) extraction: various computer-aided methods for lineament extraction have been proposed.

The most widely used software for the automatic lineament extraction is the LINE module of the PCI Geomatica but for this study ILLWIS 3.4 was used for the lineament extraction.

3.5 LINEAMENT ROSE PLOT

A rose diagram is a circular histogram which displays directional data and the frequency of each class. Rose diagrams explain the frequency of lineations in a given orientation. Rose diagrams are commonly used in Sedimentary Geology to display palaeocurrent data, or the orientation of particles. In Structural Geology rose diagrams are used to plot the orientation of joints and dykes.

From the field data rose diagrams were plotted using GEOrient 9.4 and comparism was made with the rose diagram plotted from the extracted lineament map using ILWIS 3.4 so as to observe the overall conformity or deviation from the previously published trend.

3.6 STRUCTURAL CONTROL OF MINERALIZATION

The Pb-Zn ore bodies occur as open-space fillings within steeply dipping fracture systems. They are shallow and relatively small, although they have continued to be mined intermittently. Mineralization is believed to be structurally controlled and is found to be dominantly of argillaceous lithologies within a sequence of alternating Shales, Siltstones and Sandstone belonging to the Yolde Formation.

Grant (1971) and Olade (1975) believed that the Benue Trough originated in the early Cretaceous as an 'abandoned' rift basin (aulacogen). Olade and Morton (1985) stated that Lead-zinc mineralization is localized within a series of steeply dipping fractures and sheeted zones within sediments that are intruded by sills. They also stated that the dominant hydrothermal minerals are Sphalerite, Galena, Marcasite, Quartz and Siderite. Less common are Pyrite, Chalcopyrite, Bornite, Caldte, Barite and Dolomite. The typical paragenetic sequence is Sphalerite (oldest) - Galena - Siderite - Quartz - Marcasite (youngest). Zarboski (1998) stated the occurrence of Sphalerite and Galena (argentiferous at shallow depth) in a mainly Quartz gangue, Zn increasing at the expense of Pb at depth. Less common are Pyrite, Chalcopyrite, Bornite, Caldte, Barite and Dolomite. The typical paragenetic sequence is Sphalerite (oldest) - Galena - Siderite - Quartz - Marcasite (youngest).

3.7 STRUCTURAL GEOLOGY

Ajakaiye et al., (1986) demonstrated the existence of NE-SW trending magnetic lineaments in Jos Plateau area and in the middle Benue Trough, N-S normal faults which were inherited Pan African structures and remained active throughout the Cretaceous.

The Gongola Basin which the study area also lays has been seen as a graben or half graben structure forming a relay zone between the Benue Trough and the Chad rifts (Benkhelil and Robineau, 1983; Benkhelil et al., 1988; Fairhead and Green, 1989; Guiraud and Maurin, 1991, 1992). Benkhhelil (1982, 1986, and 1989) however has consistently stressed that the Benue Trough and the Gongola Basin have been strongly influenced by sinistral strike-slip movements along Basement faults. Zarboski et al., (1997) stated that the outcropping part of the Cretaceous Gongola Basin actually exhibits faults with three main trends which are; NE-SW, N-S, and NW-SE

3.7.1 FRACTURES

A fracture is any local separation or discontinuity plane in a geologic formation, such as a joint or a fault that divides the rock into two or more pieces.

Fractures in the study area are believed to have been caused by stress exceeding the rock strength. These fractures provided permeability for fluid movement.

Fracturing in rocks can also be formed from either due to compression or tension. Fractures due to compression include thrust, normal, and strike-slip faults, which is the dominant fracture system found in the Upper Benue Trough.

Plate 1: Fractures in the Shale bed (Yolde Formation) of the Office Mines.

3.7.2 VEINS

A vein is a distinct sheet like body of crystallized minerals within a rock. Veins form when mineral constituents carried by an aqueous solution within the rock mass are deposited through precipitation.

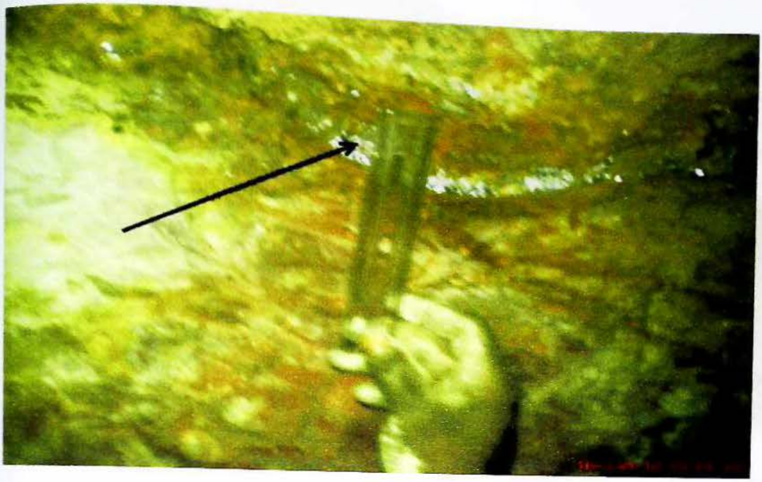

Plate 2: Pb-Zn vein in Sandstone (Yolde Formation) of the Office Mine

Plate 3: Poorly Mineralized Pb-Zn Vein in the Clarke Quarters Mine.

Veins are classically thought of as being the result of growth of crystals on the walls of planar fractures in rocks, with the crystal growth occurring normal to the walls of the cavity, and the crystal protruding into open space. Veins are of prime importance to mineral deposits, because they are the source of mineralization either in or proximal to the veins.

Prominent veins were observed at both mines that were visited and these veins were seen to have a preferred NW-SE orientation which also corresponds to the strike direction of the fractures in these mines. Most of these veins are made up of Pb-Zn mineralization which extends for a considerable distance and their thickness range is 0.05m-0.4m with sharp contacts with the host rock.

3.7.3 JOINTS

Fractures were found to also occur with no lateral movement in the plane of the fracture. This makes it different from a fault which is generally characterized by displacement.

Joints normally have a regular spacing related to either the mechanical properties of the individual rock or the thickness of the layer involved and also generally occur as sets, with each set consisting of joints sub-parallel to each other.

Plate 4: Joint sets in the Office Mines Yolde Formation

Tectonic joints found in the study area were formed during the deformation episodes whenever the differential stress is high enough to induce tensile failure of the rock, irrespective of the tectonic regime. Measurement of tectonic joint patterns can be useful in analyzing the tectonic history of an area because they give information on stress orientations at the time of formation

Plate 5: Joint sets in the Clarke Quarters Mines Yolde Formation

CHAPTER 4

RESULTS AND DISCUSSION

4.1 CLARKE QUARTERS MINES

There are three active mines located here. These mines lie within N9^{0} 13' 55.1" and E 10^{0}34' 19.9" with a length of 15m-33m and a width of 20m-45m. Figure 11, 12 and 13 shows the rose plot for these readings respectively.

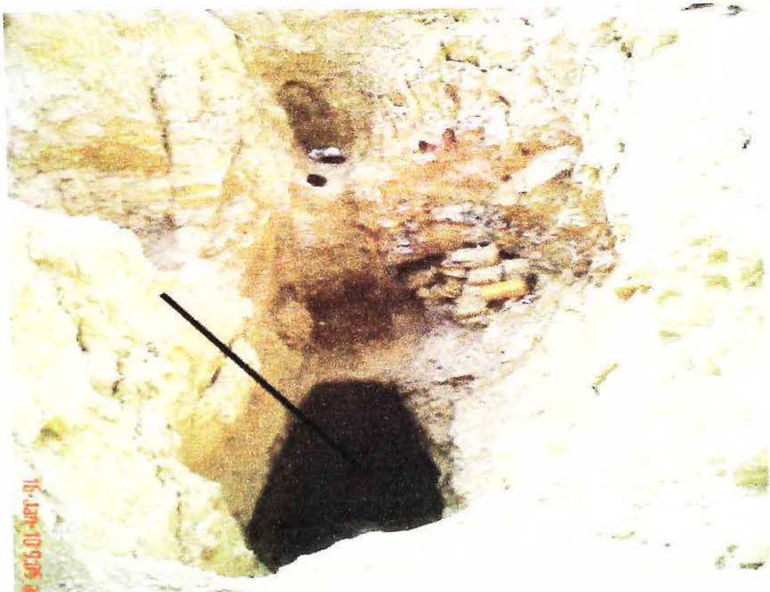

Plate 6: Clarke Quarters Mine

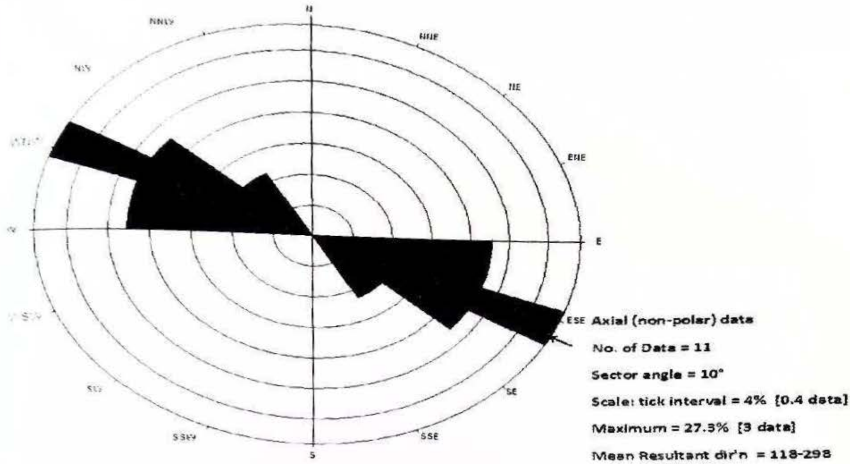

Fig. 11: Rose Plot for fractures in Clarke Quaters Mine 1

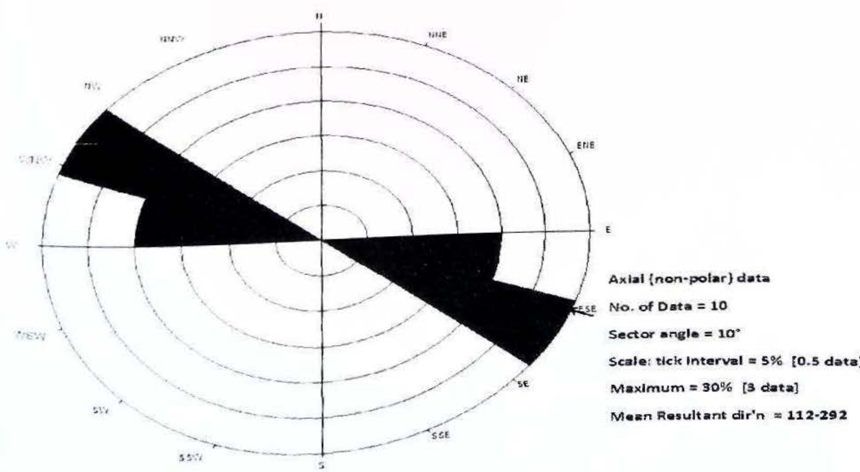

Fig. 12: Rose plot for fractures in Clarke Quarters Mine 2

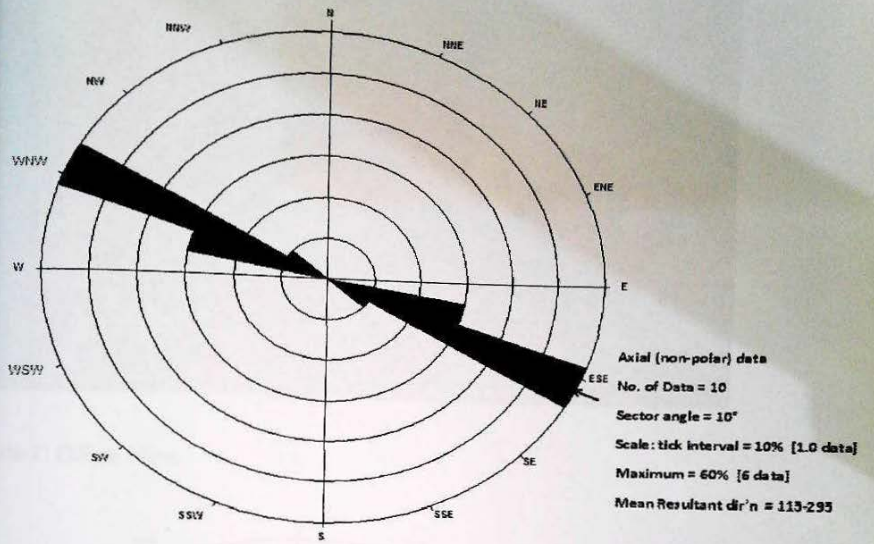

Fig. 13: Rose plot for fractures in Clarke Quarters Mine 3

4.2 OFFICE MINES

There are two active mines located here. These mines also lie within N9^0 13' 55.1" and E 10^{0}34' 19.9" with a length of 15m-33m and a width of 20m-45m.

Figure 14 and 15 shows the rose plot for these readings respectively.

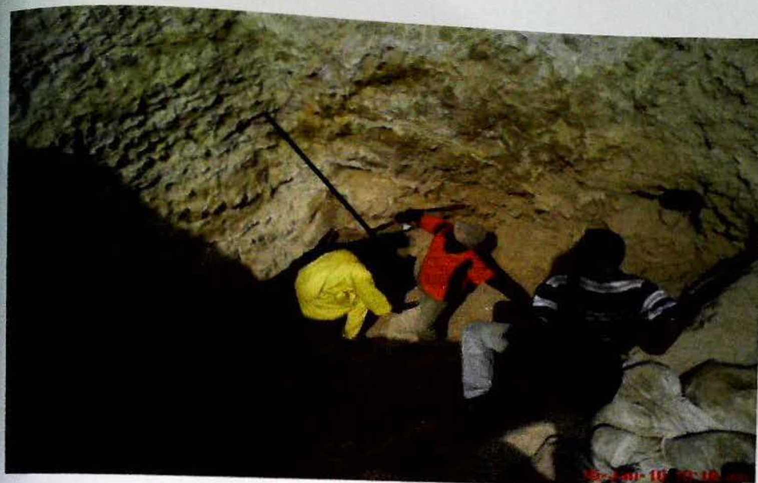

Plate 7: Office Mine

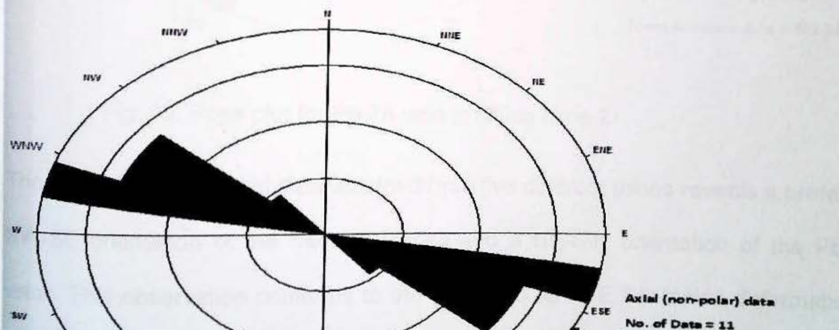

Fig. 14: Rose plot for Pb-ZN veins in Office Mine 1

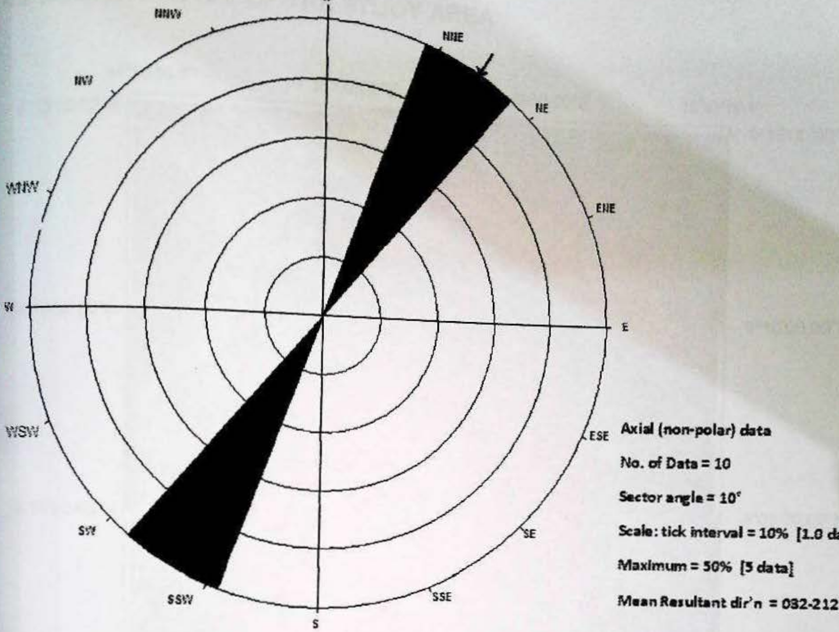

Fig. 15: Rose plot for Pb-Zn vein in Office Mine 2

The rose plots of the field data obtained from five different mines reveals a preferred NW-SE orientation of the fracture planes and a NE-SW orientation of the Pb-Zn veins. This observation conforms to the proposed NW-SE Santonian deformational episode and the NE-SW Maastrichtian deformational episode that has affected the sedimentary sequence in the Benue Trough proposed by Benkhelil (1986)

4.3 LANDSAT IMAGE OF THE STUDY AREA

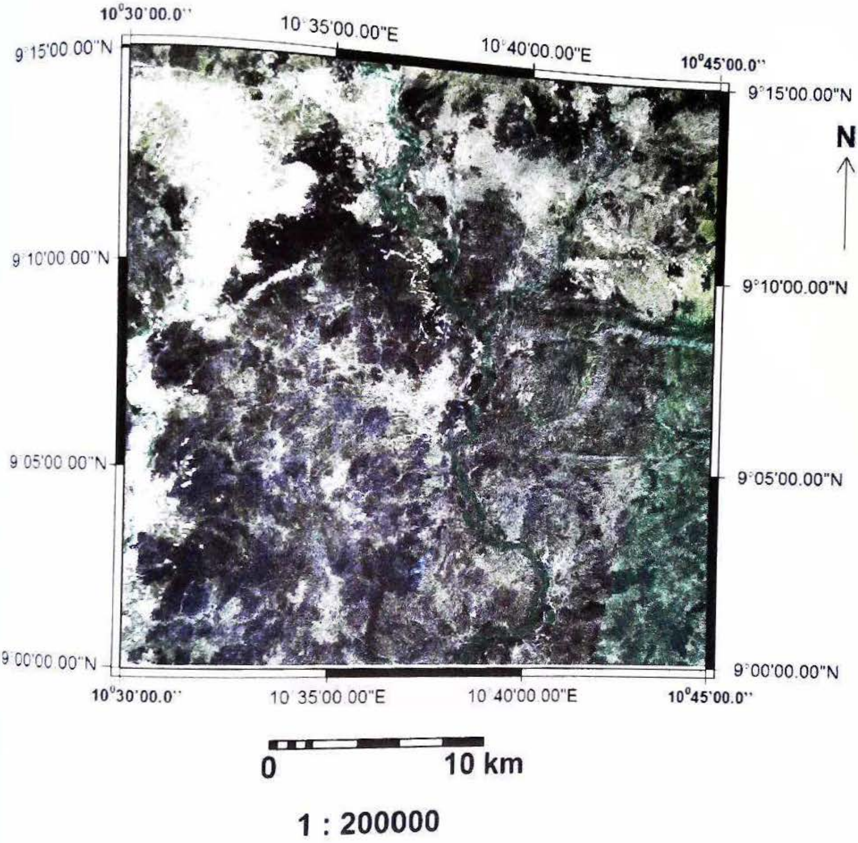

Fig. 16: Landsat Image of the Study Area.

4.4 LINEAMENT OF THE STUDY AREA

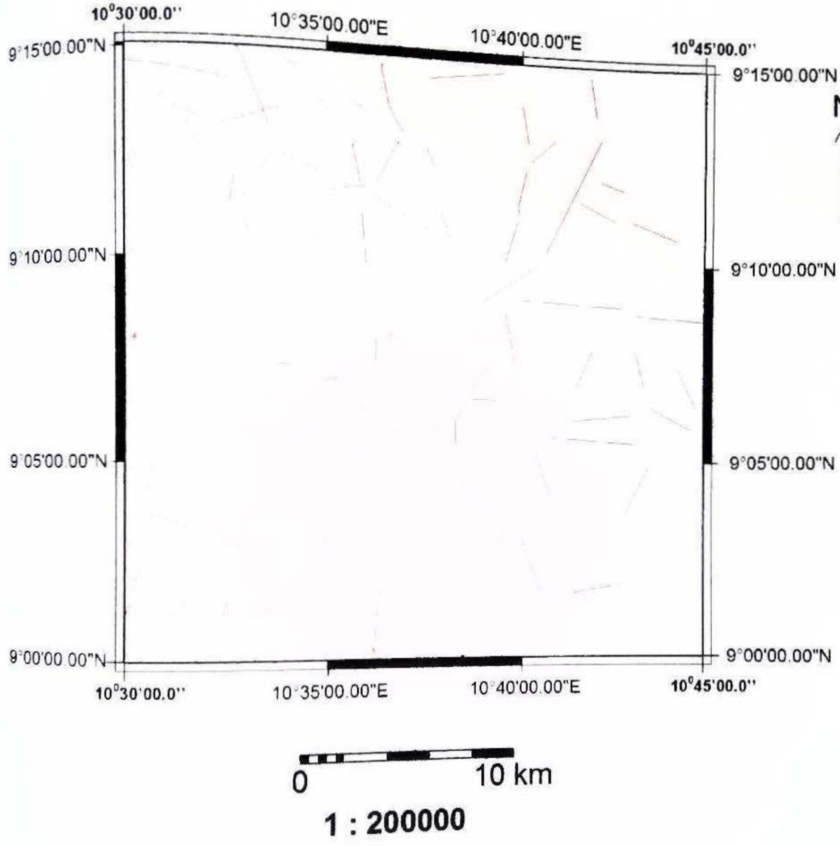

Fig. 17: Lineament Map of the Study Area.

4.5 ROSE PLOT FOR LINEAMENT MAP

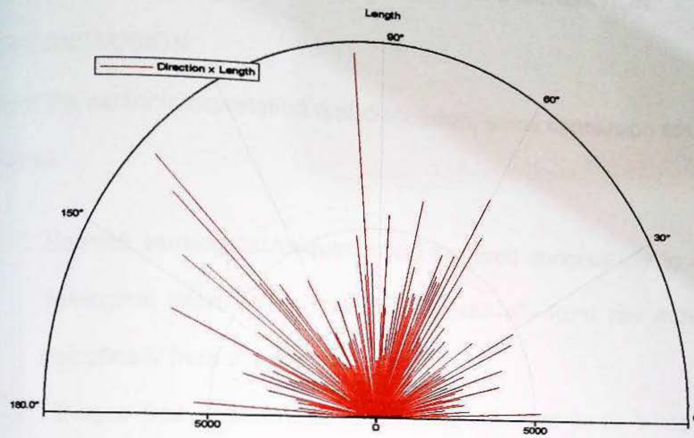

Fig. 18: Rose Plot of the Study Area.

CHAPTER 5

CONCLUSION AND RECOMENDATION

5.1 CONCLUSION

From the earlier interpretation and discussion, some conclusion could be drawn as follows:

1. Remote sensing techniques could be used successfully to extract structural geological information (lineaments) generally from any area in Nigeria and specifically from this area.
2. Images from the contrast enhanced TM band 3, 2, 1 are suitable for the enhancement of structural information (lineaments) of the area.
3. The interrelated lineaments correlate to the faults shown on the published map of the area and this indicate that the digitally processed remote sensing data could confirm most of the previously mapped fault.
4. There are regions with high lineament density probably related to mineralization area and need to be study in more detail.
5. From the results obtained from the field data, those obtained from satellite image data compared with previous accounts of the trending direction, the trend of the mineraliszation and fractures in the host rock can be said to be trending NW-SE and NE-SW with the dominant trend in the NW-SE

5.2 RECOMMENDATION

The result of this type of study might be useful to help further detailed geological mapping and If other remote sensing data such as SPOT or RADAR of the area are available which could display better texture and other surface morphology, possible better and more detail result could be presented then, the potential of using remote sensing techniques in such study in Nigeria will be higher.

Finally the automatic integration of remote sensing spatial information database should be under the support of expert knowledge.

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