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Remote sensing analysis of a dextral discontinuity along Ifewara-Zungeru area, Nigeria, West Africa

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Abstract

The Ifewara-Zungeru megastructure is an over 550-km long NNE-SSW trending fault stretching from the south just east of Ijebu Ode, through Ifewara and Okemesi to the southwestern edge of the River Niger around Lafiagi. It reappears beneath the sediments of the Nupe Basin and extends northeastwards for over 300 km, through Zungeru to Kalangai. Detailed remote-sensing mapping of the lateral extent of this suspected shear zone using satellite imagery field mapping ground-truthing survey was carried out. Structural analysis of the fault system was done across the entire area that was traversed.The results obtained from this investigation revealed that satellite imagery study of a segment of the megastructure shows a ductile dextral fault zone with a drag towards the NNW direction in Zungeru area. High-level folding of meta-sediments exist within the area with directions almost perpendicular to the general NNE-SSW trend of the host rocks. This faulting caused a measure of morphostructural reorientation of the mylonites and enclosing schistose rocks.

Keywords: Ifewara-Zungeru, remote sensing, field mapping, structural analysis, metasediments.

Introduction

The Zungeru area is a part of Nigeria's Precambrian basement complex terrain which is a segment of the regional Dahomeyide fold belt (Affaton *et al.,* 1991) (Fig. 1). Thus, it is not excluded from the structural and deformational episodes that are known to have pervaded the terrain. Several studies have been carried out on the various components of the basement complex particularly in terms of petrological, structural and geochronological studies (Hubbard, 1975; Oversby, 1975; Grant, 1978; Elueze, 1988; Rahaman, 1988; Adekoya, 1993). With severe foliation in the rocks, evidence of primary structures has been completely obliterated, except for a few pockets where cross-stratification in quartzites survived deformation especially within the precinct of the study area (Okonkwo, 1992). The area covered by this study is basically underlain by three low-grade metamorphic belts of pelitic and semi-pelitic schists (the Ushama, Birnin-Gwari & Kushaka formations) which are surrounded by migmatite-gneiss complex in a synclinorium (Ajibade *et al.,* 1979). The Zungeru Mylonites flank the Birnin-Gwari Schist formation on both sides and thus impinge on the eastern and western flanks of the Ushama and Kushaka belts respectively (Fig. 2). Ajibade *et al.* (1979) described the character of the Zungeru Mylonites as a well-defined foliation resulting from the alignment of mica, quartz and lenticular feldspar porphyroclasts, accompanied by colour banding and compositional layering. The boundaries of the mylonites are marked by alternations of narrow and commonly discontinuous bands of cataclastic rocks comprising sheared gneisses, unsheared schists and phyllites. McCurry (1976) referred to the dark-coloured mylonites as hornblende schists and the light-coloured variety as meta-arkoses.

According to Odeyemi *et al.* (1999) the Ifewara fault in the southwest and the Zungeru/Kalangai fault in the north and north central parts of Nigeria are by far the most prominent lineament system in Nigeria (Fig. 2). Suggestions on the nature, structure and origin of the Ifewara fault favour an overthrust relationship between the amphibolites and the rocks of the Effon Psammite formation (Hubbard, 1975) while Turner (1983) opined that the fault may represent a collisional suture zone. However, it is generally agreed that there is lithostructural discordance between the rocks of the Effon Psammite formation and the older migmatites, gneisses and amphibolites. Field mapping and fracture data from an area located southeast of Osu town near Ilesa, show that the Ifewara fault is really a 3 to 5 km wide shear zone dominated by flat-lying mylonites, probably associated with some thrust tectonics (Affaton *et al.,* 1991). Various studies have also shown the existence of similar shear zones in northwestern Nigeria (Truswell & Cope, 1963; Garba, 2000). Therefore, both the Ifewara and the Zungeru/Kalangai faults are considered to be one and the same fault but separated only by Cretaceous sediments of the Nupe Basin that overlie a part of the continuity, and extends beyond Nigeria further towards the north into the Niger Republic.

The synoptic view provided by remotely sensed data is a convenient way of understanding the interrelationship between various meso and mega-linear features on the earth surface (Drury, 2001). Therefore, megascopic structural features and their trends consequent on the deformational episodes experienced by the rocks in the study area are clearly represented on satellite imageries. The thrust of this study is to establish the existence of a ductile dextral strike-slip fault zone displacing the megastructure at the Zungeru area.

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Material and methods

A pair of satellite imageries over the study area covering about 15,000 km^2 on a scale of 1:800,000 was acquired from Google Earth® in 2007 (Fig. 3). The area is bounded by Latitudes 07° 36' 36.71''N to 10° 04' 38.09''N and Longitudes 05° 53' 14.45''E to 06° 34' 09.01''E respectively. The imageries were manually analysed to identify and delineate lineaments as well as structural trends in order to facilitate geological interpretation. This exercise was followed by a detailed structural investigation using mirror stereoscopes whilst the imagery was covered with transparent overlay so as to ensure that lineaments missed out in earlier views were subsequently registered. The resulting lineament map was later digitized using ILWIS 3.3 Academic® (Fig. 4). Subsequently, the extracted lineaments were plotted as azimuth-frequency-length diagram following Odeyemi *et al.* (1999) method (Fig. 5). This was done with the aim of identifying significant lineament sets and their directions. Finally, ground-truthing involving field visits were made to some specific locations that have been identified from the satellie images in order to identify structures that were possibly responsible for the remotely-sensed structural signatures already identified on the satellite imageries.

Field observations

One of the strongest litho-structural controls observed in the study area is the one imposed on the Kaduna River as indicated by NNE-SSW trending mylonitic rocks (Fig. 7). The river, as it flows through Zungeru also appears to be controlled by a major fracture in the hornblende-schist mylonite whose susceptibility could probably be due to higher-temperature amphibole constituent compared to the siliceous meta-arkoses in the area. North-South trending outcrops are folded with plunge towards NW and NNW directions at the middle and southwestern parts of the study area respectively (Fig. 3). We deduced that the relatively higher resistance of the mylonites to denudation could be as a result of their cataclastic texture (Ajibade *et al.,* 1979). Southwest of Zungeru town, a NW-SE trending fault exists with a drag along NE-SW direction between Kann and Bogi. This drag controls the NE-SW kink along Kaduna River at this point. It is also exhibited by a high level of folding of the metasediments within these areas with a general trend along directions almost perpendicular to the general NNE-SSW trend of the host

Fig. 1. Geological map of Zungeru area & a geological cross-section taken across A-A.

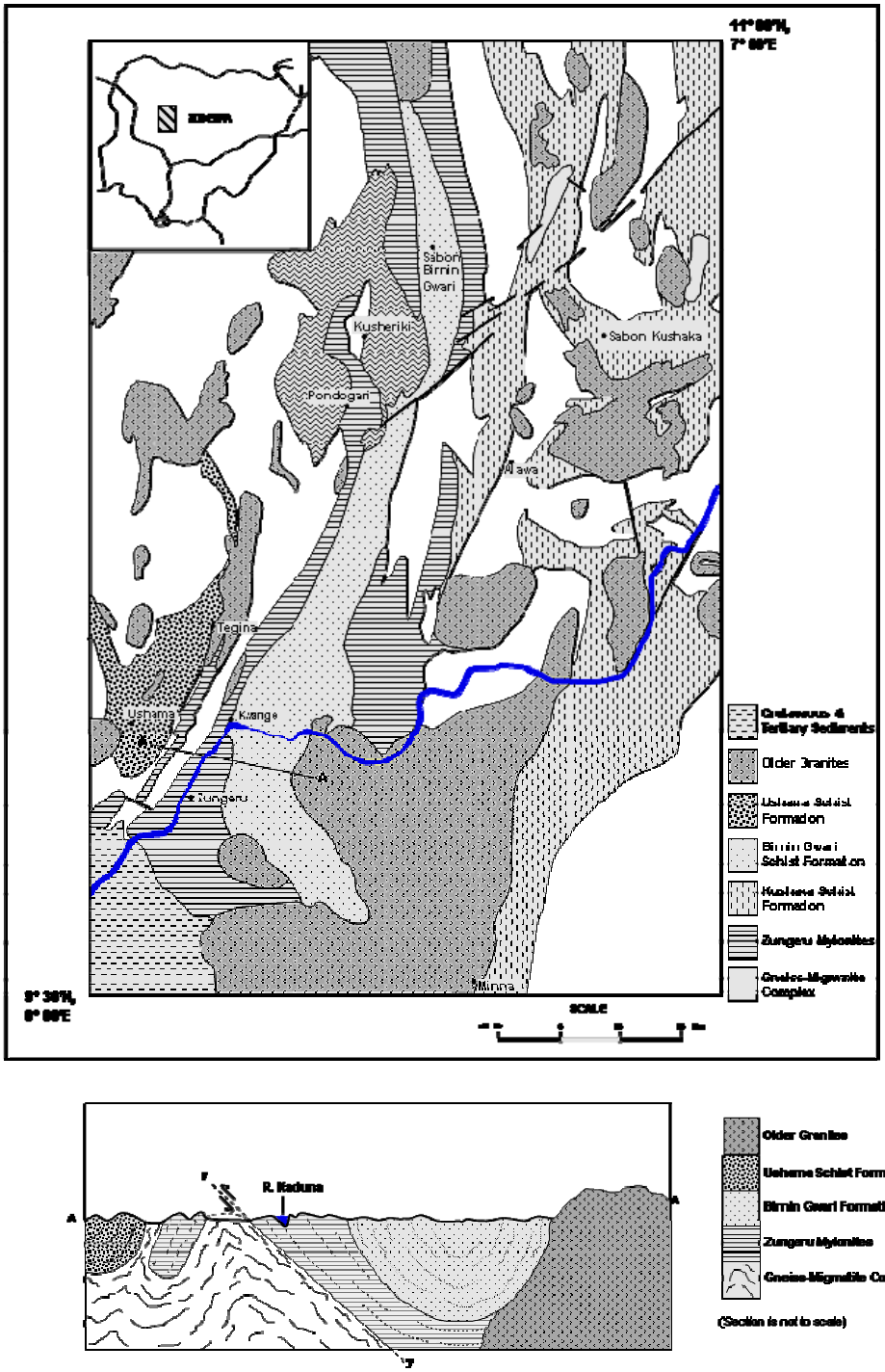

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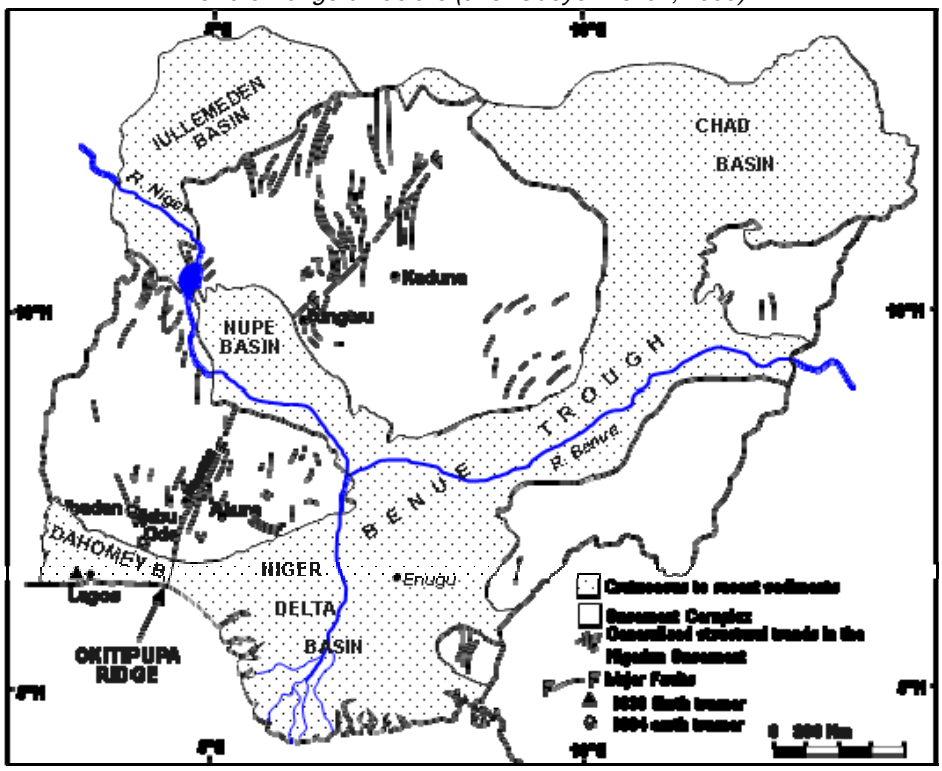
Fig. 2. A simplified geological map of Nigeria showing the extent of the Ifewara-Zungeru fracture (after Odeyemi et al., 1999).



rocks. Numerous dextral faults exist on the more brittle rocks (granite) enclosing the mylonites in areas between Minna and Zungeru. While on the relatively more ductile Zungeru mylonites, the fracture set is represented by joints which are quartz-filled in some places. The 45° rotation of the NNE-SSW trending mylonites and schists towards NNW-SSE directions, with closures at Umoru and Debbi respectively, signifies the influence of strike-slip movements along the latter direction. This dramatic swing of structural trends is easily observed in the progressive change in the strike of the rocks from schists (096°-relatively EW) (Fig. 9), to pebbly schists (strikes 160° & dips 88° NE) farther away (Fig. 10) this may possibly serve as the 'neck' of the swing; and finally to the 016° (NNE) mylonites in Zungeru area. Between Mallam Garba and Babegi, southeast of Zungeru, a tributary of the Kaduna River is structurally-controlled along a long NNW-trending fracture which, when projected upwards on the map, cuts across the displacement along the Kaduna River between Kann and Bogi. If projected further, the fracture runs parallel to the edges of folded rocks plunging at Umoru.

Discussion

Fig.4 shows the lineament map of the study area. The map depicts the distribution of structural trends mapped for the entire investigated area. From this study, the number of extracted lineaments totalled one thousand and fourty eight (1048). Also, distinct three lineament display directions were mapped and plotted in the rose diagram plotting (Fig. 5). These are along 0°-10°, 160°-170° and 170°-180°directions. It is evident from this figure that these lineaments all have corresponding peaks on the length sector of the rose diagram. Within the study area, the 0° - 10° set is attributed to the Ifewara-Zungeru fracture zone according to Anifowose (2004), while the 160°-170° and 170°-180° sets represent structures trending obliquely to the Ifewara fracture zone. Oluyide (1988) noted that the fracture sets are probable strike-slip faults, and among which many take a dextral sense of movement. On satellite imagery, these zones are marked by highly folded rocks which exhibit relatively higher resistance to

Fig. 3. Satellite imagery covering the study area (http://earth.google.com/Google Earth, 2007).

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Fig. 4. The digitized lineament map of Zungeru area obtained from the satellite image. Distinct orientation of the fault system is depicted.

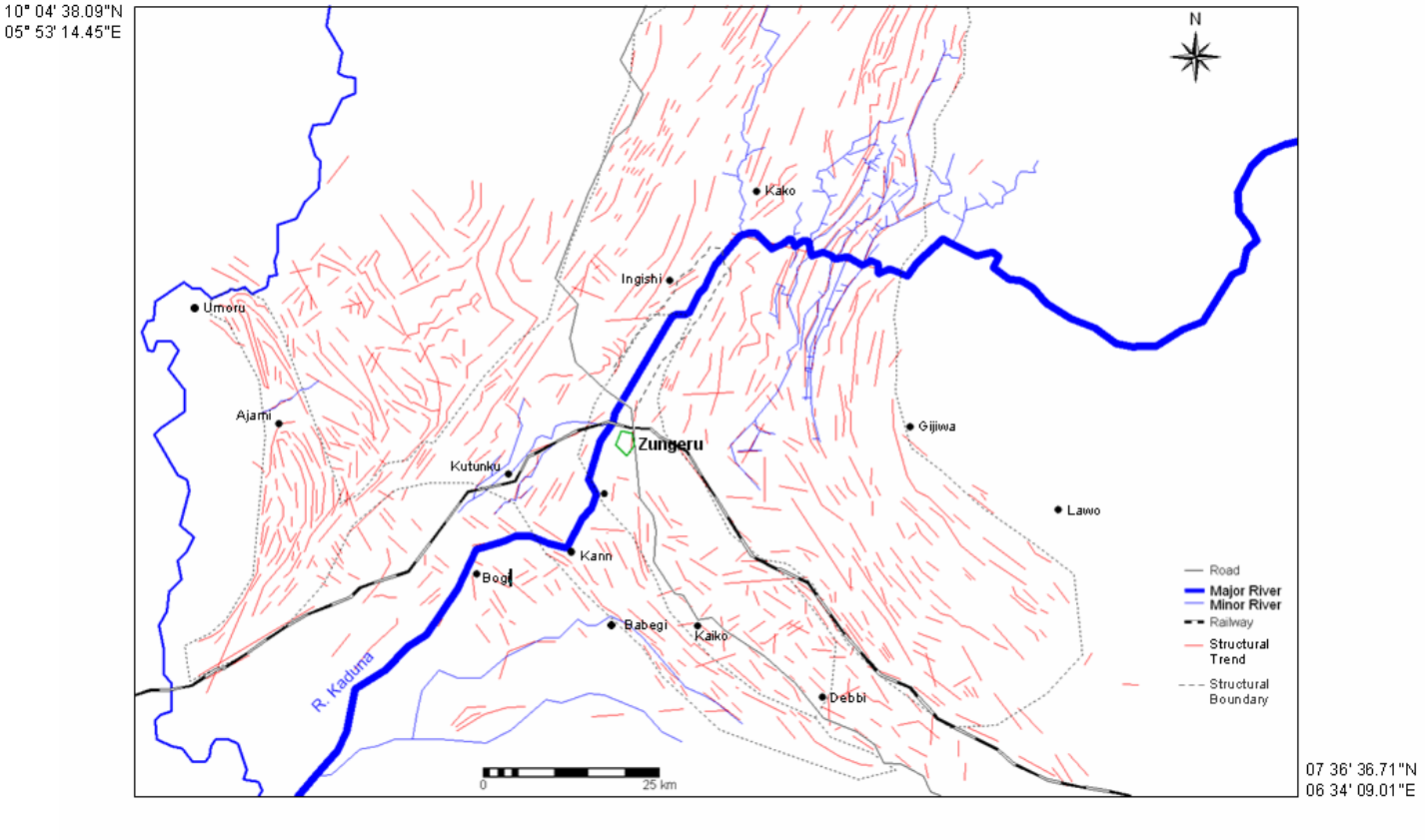

Fig. 5. Plot of the various directions of extracted lineaments obtained from the satellite images & plotted as a Rose diagram.

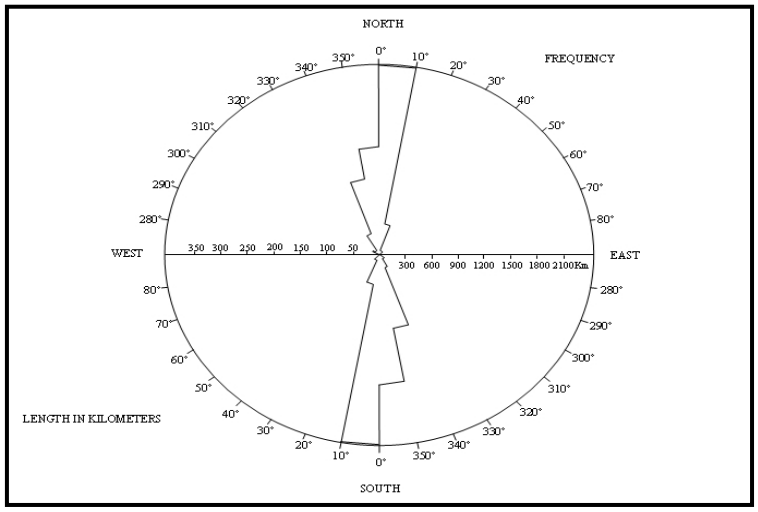

Fig. 6. North-south trending folded meta-arkoses in the study area obtained from the field (A- Meta-Arkose; B- Horblende Schist).

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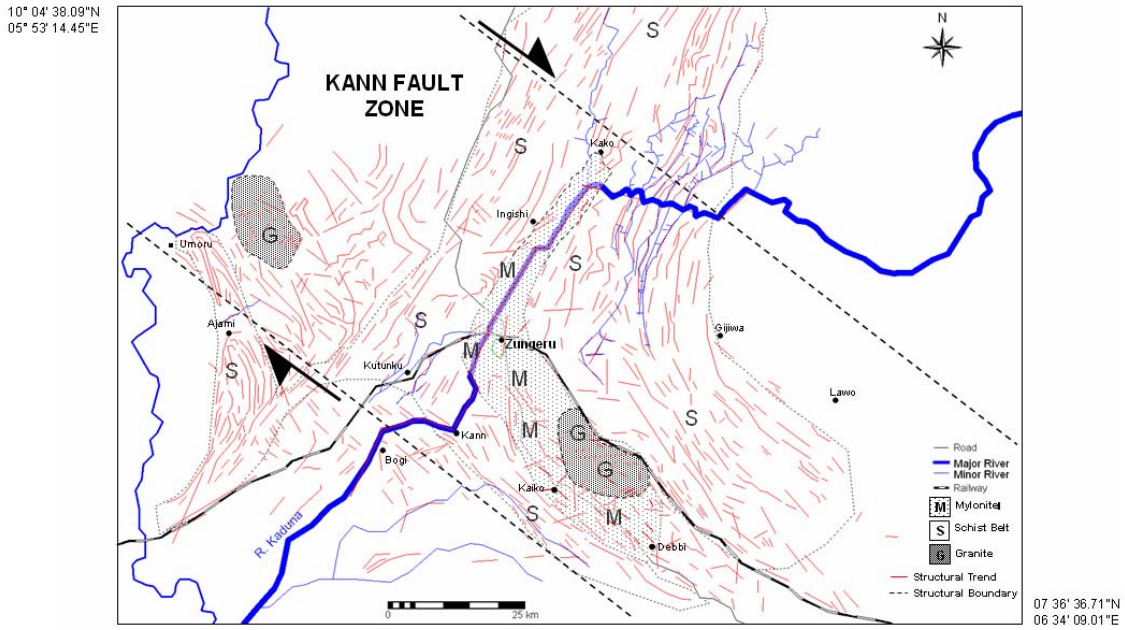
Fig. 7. Simplified geological map of Zungeru area showing the Kann Fault zone & the associated fault system obtained from the satellite image.



denudation compared with the surrounding basement rocks, as confirmed by ground truthing. Therefore, there are clear field evidences indicating that the drainage pattern within the study area is structurally controlled.

A morphostructural study of this dextral offset is shown in Fig. 7 with generalized boundaries for the affected zones. According to Onyedim and Ocan (2001), the Ifewara/Zungeru/Kalangai shear zone is contemporaneous with the emplacement of the mylonites both at Ifewara and Zungeru areas, thus suggesting that the mylonites might have been produced as a result of Pan-African shearing along the Ifewara-Zungeru fault; and that area could have been the locus of the fault system, since the relatively finer texture of the mylonites around Zungeru grade outwards into more clastic/pebbly transition horizons (McCurry, 1976).

While Ajibade *et al.* (1979) opined that the mylonites are Pan African in age; however, Oluyide (1988) opined that the Ifewara-Zungeru fault systems are continental projections of oceanic transform (transcurrent) faults, and Odeyemi (1998) proposed a possible pre-Pan African age for the megastructure. It is worthy of note that the later stands in the face of a long-standing theory of cross-cutting relationships in relative dating geologic phenomena; nevertheless, it is plausible. Guiraud *et al.* (2000) also suggested a similar relationship between the continental Tibesti Lineament and the Early Cretaceous rifting at the Alfa triple junction. Therefore, it is believed that the fault zone in focus, herein referred to as the Kann Fault zone, is relatively younger than the Ifewara fault, the Zungeru Mylonites and their enclosing formations. This strike-slip fault may not have caused significant recrystallization of the mylonites, otherwise there would have been a wide age variation between those around the intersection zone and those farther away. The faulting obviously caused a measure of ductile morphostructural reorientation of the mylonites and enclosing schistose rocks. In addition, the Kann Fault zone appears to control the trend of the northern boundary of the Nupe Basin, which implies that its age is likely to fall between Early Paleozoic and at most Late Cretaceous since, according to Reyment (1965), the Nupe Basin is Campanian-Maastrichtian. McCurry (1976) also observed a major NW-SE transcurrent fault similar to the Kann fault, occurring around Zaria area (Sheet 21) which dextrally displaces N-S trending metasediments by about 10 km, causing a swing in the structural trend of the metasediments by drag on either side of the fault.

Fig. 8. Field-observed local dextral faulting within the Zungeru Mylonites.

Conclusions

The mapped fault system using the satellite imagery confirms the existence of a ductile dextral strike-slip fault zone that extends from Ifewara through Kalangai to Zungeru over a distance of 550 km. Generally, we observed that the fault exists in conjunction with distinct mylonitic rocks throughout the region that it traversed. This rock was possibly produced during the widespread Pan-African shearing period. We further deduced that the formation of this shear zone probably resulted in morphostructural deformations observed in the Zungeru mylonites and the enclosing schistose rocks. The fault zone appears to control the trend of the northern boundary of the Nupe Basin. This implies that its age is

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likely to range between early Paleozoic and at most Late Cretaceous. From this study, three major lineament trends were delineated both from the satellite image and from field observations. These are: 0°-10°, 160°-170° and 170°-180°directions. The efficacy of using satellite images in mapping linear features was confirmed from this study. It is concluded that there is the need for more structural as well as geophysical investigation around the Zungeru segment of the megastructure in order to further analyse the influence of this discontinuity on the geodynamic history of the study area.

Fig. 9. Amphibolite schist outcropping beside college of arts & Islamic legal studies, Minna with 096° strike & 78°dip towards the north.

Fig. 10. Pebbly schist along Minna-Zungeru highway containing variably deformed clasts of granite, amphibolite schist, gneiss & quartzite. Strike is 160° with 88°NE dip.

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