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Full Length Research Paper

Bulk strain estimation on gneisses in Central Nigeria: A preliminary assessment

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The challenges of regional metamorphism and the need to investigate the petro-structural strain and tectonic evolution of the Nigerian basement using central Nigeria contact zone is useful in mineral exploration. Meso-structural data were plotted using GEOrient to obtain general trend as well as the axial folds of the Pre-Pan African deformation. Strain estimation was done on photomicrographs of the gneisses cut normal to the planes of foliation across the lithologies in order to establish the homogeneity and amount of strain. The centres of the quartz grains were digitized using the Fry method from which the axial ratios of the strain ellipsoids were used to estimate and compare the amount and orientation of strain across the different rock types in the study area. Petro-structural bulk strain estimation on the gneisses around Kaduna, central Nigeria show a generally moderate but inhomogeneous strain with axial ratios of the finite ellipsoids ranging between 1.6 and 3.8 with strain geometries that are consistent with the NW- SE metamorphic foliation. The amount of strain across the rock types correspond to grain size variation signifying probably that quartz responds differently to strain with decrease in grain size. In response to the generally NW-SE tectono-metamorphic ductile deformation that produced the steeply dipping gneisses of the area, there is heterogeneity in the bulk strain. The orientation is essentially concordant to the metamorphic deformation and probably unconnected with the latter but brittle Pan-African and predominantly NE-SW fracture systems.

Key words: Petro-structural, bulk strain, gneisses, central Nigeria.

INTRODUCTION

Macro and micro-structural strain measurement was carried out on rocks of the areas covering Rijana, Sabon Kasarami and Wuya situated 43 km south of Kaduna along Kaduna–Abuja Road (Figure 1). The study was within Latitude 7°00’00” N and 10°08’40 N and Longitude 7°13’40”E and 7°19’20”E. Strain measurement involves the use of selected relevant strain markers that are consistently distributed within the studied rock body and which can be easily used. The choice of which method to apply is also depended on a good exposure of the long and short axes of the strain markers as well as availability of the processing package (Ogezi, 1977; Ajibade and Wright, 1988; Annor and Olasehinde, 1996). The gneisses around Rijana do not show adequate exposure of macroscopic porphyroblasts that can be easily measured on the field. This posed a major challenge to field estimation of strain hence the Fry (1979) method was adopted. Deformation patterns on the basement rocks of Nigeria are so complex (Rahaman, 1988; Ogezi, 1977; Ajibade and Wright, 1988; Mc Curry, 1976) and hence require a detailed study to understand their strain history. Additionally, the homogeneity of deformation on the rocks which is dependent on the degree of response to the prevailing stress fields is important in elucidating the tectono-metamorphic conditions that affected the rocks. These, in addition to other geological and geochemical parameters can give clues to the geodynamic evolution of this Pan-African mobile terrain (Amadi and Olasehinde, 2010).

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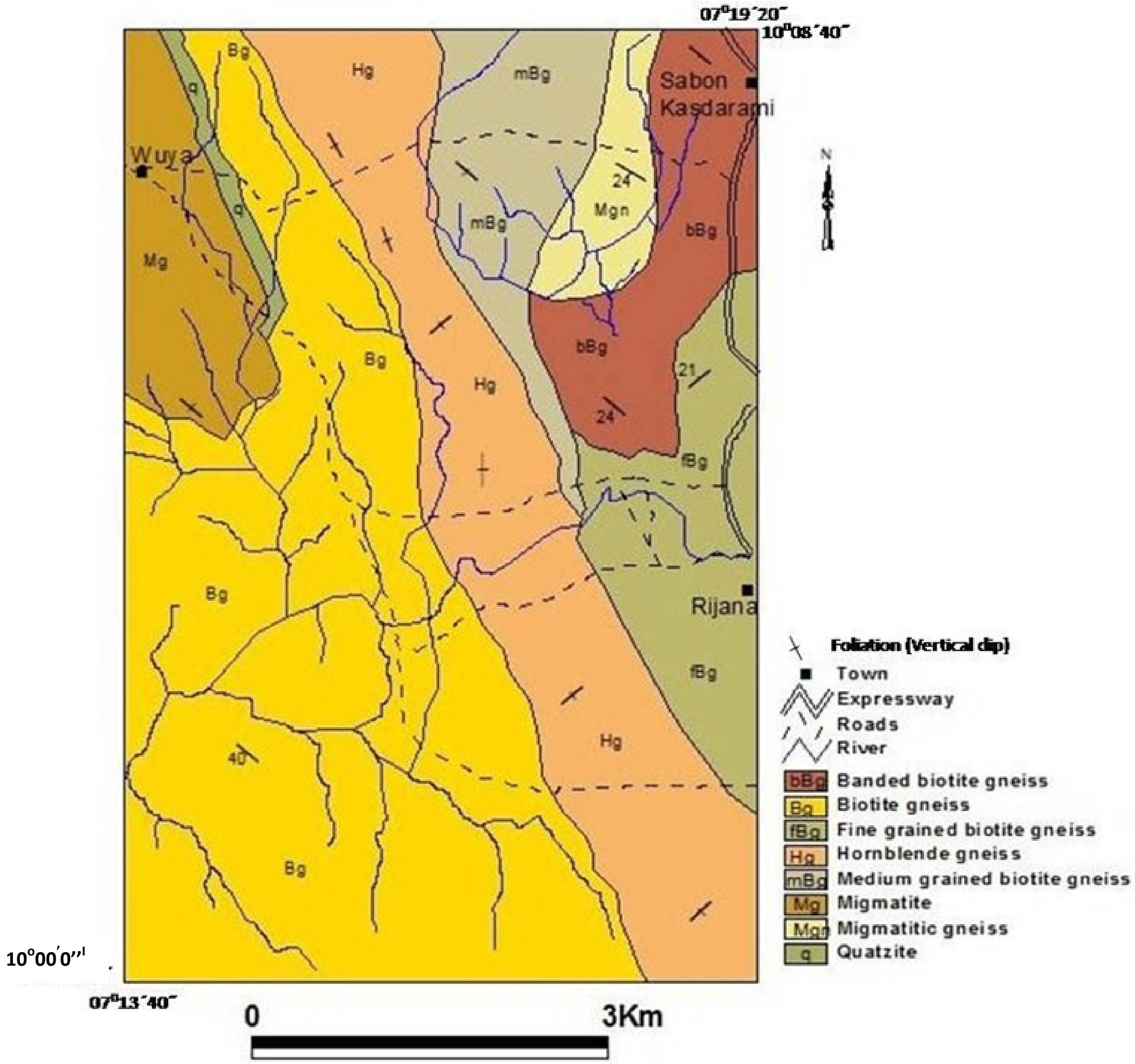

Figure 1. Geological map of the study area (Southern Kaduna, Nigeria).

METHODS OF STUDY

Geology

The area forms part of the basement complex of Nigeria (Figure 1) which consists of migmatites, gneisses, schist, metasedimentary rocks and granitoids (Rahaman, 1988; Dada, 1989; Oyawoye, 1972). The rocks of this area consist mainly of vertically dipping hornblende and biotite gneisses of variable grain sizes and migmatites (Figure 2). Unlike the biotite and migmatitic gneisses, the hornblende gneisses form a generally NW – SE dissecting ridges which are litho-stratigraphically conformal and parallel to quartzitic ridges. Compositionally, the gneisses range from hornblende to biotite banded to foliated gneisses. Petrographically, the gneisses are dominated by undulous and strained quartz, which is obliquely sub-parallel to micas. The biotite display alteration rims and elongate sphene occur in accessory quantity. Plagioclase and microcline coexist in most of the samples studied but in many samples, myrmikites are formed at the expense of alkali feldspar (Amadi et al., 2010).

Locally, the gneisses are foliated and banded with a sub-vertical to vertical dips and a generally complex but general NW-SE structural grain except for some few exposures of alkali feldspar dominated gneisses around Rijana along the River Sarkin Pawa where NE-SW foliation surfaces were observed. Evidence of shearing is displayed by cracks with similar trends in the porphyroblasts in the gneissose bands.

RESULTS AND DISCUSSION

Meso-structural data and interpretation

The structural relationships and their interpretations were investigated and analyzed in detail with the aim of

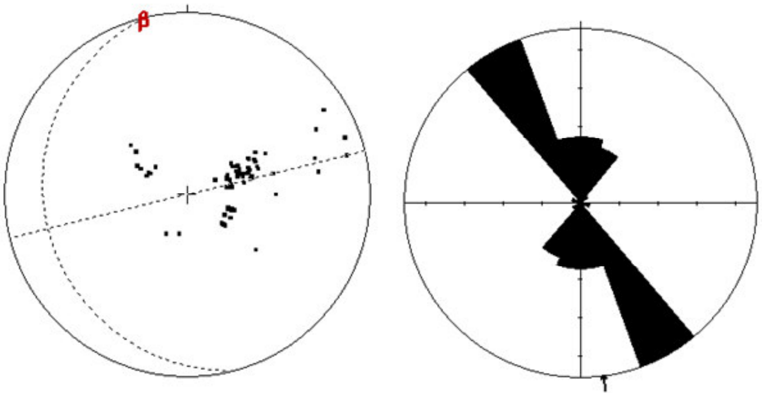

Figure 2. Lamberts equal area projection of foliation surfaces from the area.

unravelling the tectonic evolution of the basement. Measurements and tabulation of structural data as well as their plots are restricted to the study area only. The main planar structures encountered are foliations and fractures. The predominant foliations are mineralogical and textural foliations are vertical to oblique with variable trend patterns but comparatively constant over a large area and often parallel to the gneissose banding.

A total of 240 measurements of dips, strikes of foliation and fracture surfaces were taken during the fieldwork, with 80 measurements for each. The data were plotted on frequency-azimuth rose diagrams and Lambert equal area plots and show that most of the foliation planes have a dominant NE-SW and NW-SE trends with minor NNE- SSW and NNW-SSE and marginal N-S trends. The Lambert equal area plots revealed more than one axial plane for folds with one to the east of the poles while the other west of the poles in which more values plot, and the fold axes averagely plunging inclined. The fold axes trend NNW-SSE to NNE-SSW. The foliation surfaces have low (19 - 40°) to high (60 - 90°) dips predominantly to the NW, while the fracture planes are all near vertical.

Comparison of these data and the plotted diagrams show variation in trend. Generally, the strikes of foliation show a dominant NE-SW and NW-SE trends and the minor NNE-SSW and NNW-SSE trends which could be twin conjugates of the major probably Pan-African NE-SW and NW-SE trends whose effects may have also given rise to the marginal N-S trend. Careful observation and analysis of the plots of fracture surfaces show a great similarity. The similarity in the trends of the fracture surfaces show that they are resulting from the same stresses but with local variations.

Micro-structural strain estimation and interpretation

Strain estimates were carried out to determine bulk strain and to interpret correctly the degree and variability of metamorphism as well as the extent of deformational effects on the different rock types, resulting from the different tectono-metamorphic cycles. Several methods of estimating two dimensional strains from the deformed rocks have been proposed, according to Hari (2009) most of which require the measurement of long and short axes of deformed objects called strain markers. The Fry method, according to Fry (1979) is based on the assumption that initially uniform anti-clustered distribution of points will change after deformation into a non-uniform distribution. In this method, centre of the entire grains screen digitized on the selected micrographs of the gneisses using GeoFry package which creates a vacancy called Fry hallow of ellipsoidal shape giving directly the long and short axes (Figure 3). The orientation of the ellipse also gives the orientation of the strain ellipse. Consequently, the finite strain ellipsoid that is almost circular shows low degree of grain deformation, while the flattened type shows a greater degree of grain deformation.

The ellipsoidal shapes of the grains generated using the Fry method on the photomicrograph of the thin sections of rocks from the study area has revealed heterogenous and varying grain deformation as well as varying orientations corresponding also to the marginal N-S, NE-SW, NW-SE and NNE-SSW and NNW-SSE (Figure 4). The shapes range from near circular type (axial ratio 1.68) on the migmatite, biotite gneiss, migmatitic gneiss and the medium grained biotite gneiss on the western and central portion of the study area, which is indicative of low degree of deformation, hence little grain elongation in the directions of NE-SW, NW-SE, NNE-SSW and NNW-SSE, to the flattening type on the hornblende gneiss, banded biotite gneiss and fine grained biotite gneiss which show the highest grain elongation of axial ratio 3.8 signifying a flattening type (Genier and Epard, 2004) in the directions of the marginal N-S, NE-SW and NW-SE. The result is the strain and structural map shown in Figure (5).

Critical observation of the ellipsoidal shapes of the different rock types across the study area shows

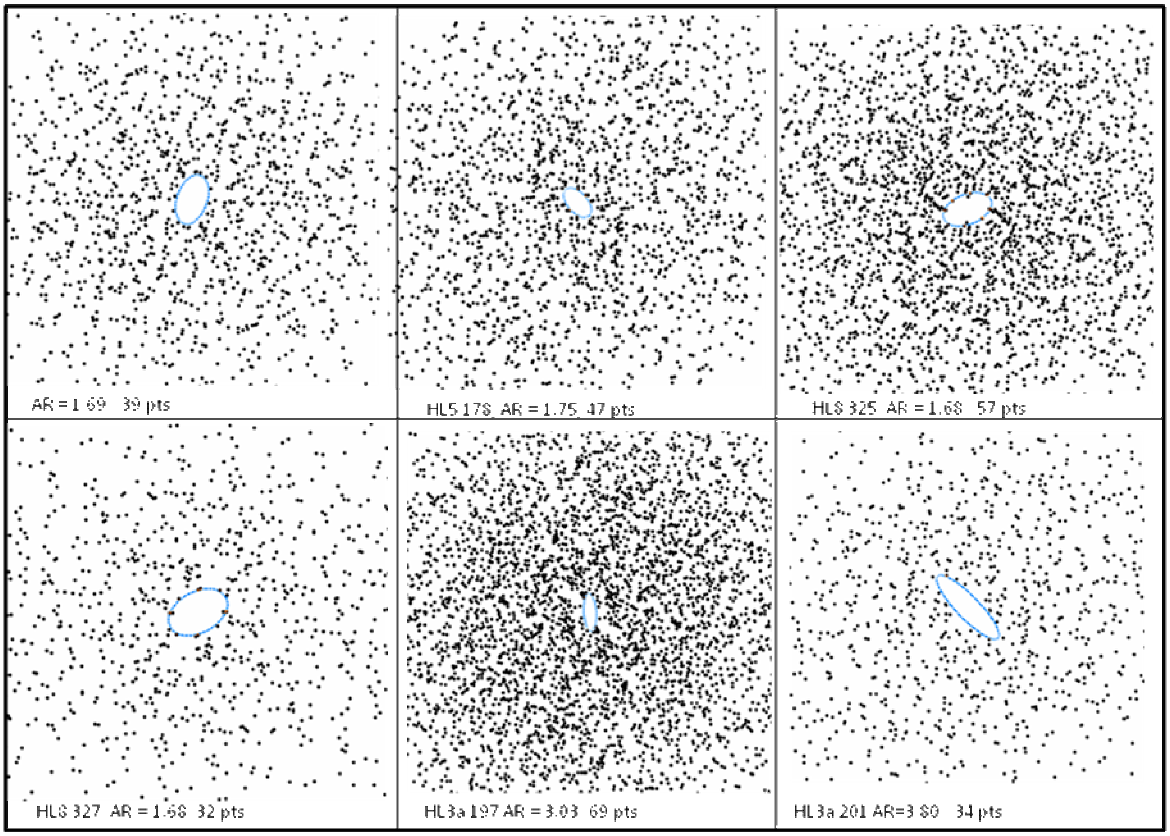

Figure 3. Fry haloes from selected samples generated from micrographs of the study area.

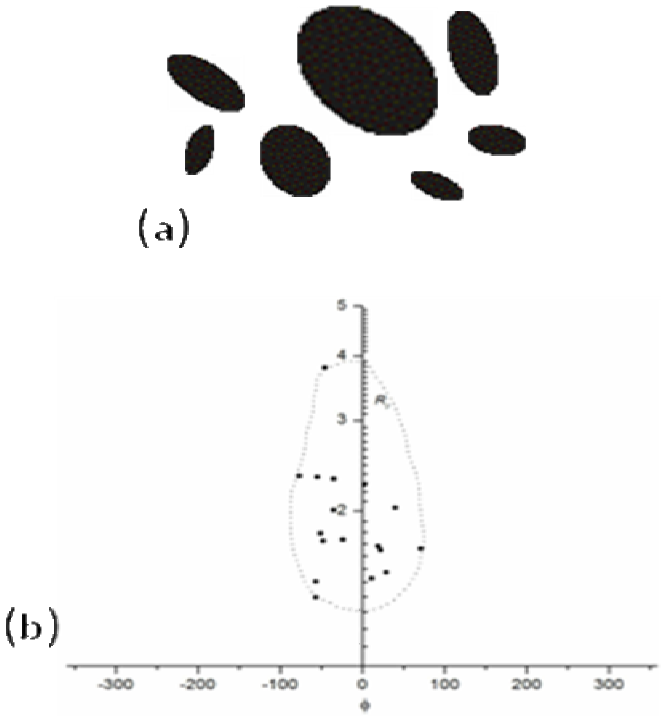

Figure 4. Micro-structural strain data from deformed quartz grains from the rocks. (a) Strain ellipsoids, (b) R_f and φ values for ellipses in (a) plotted on log R_f /linear φ scale.

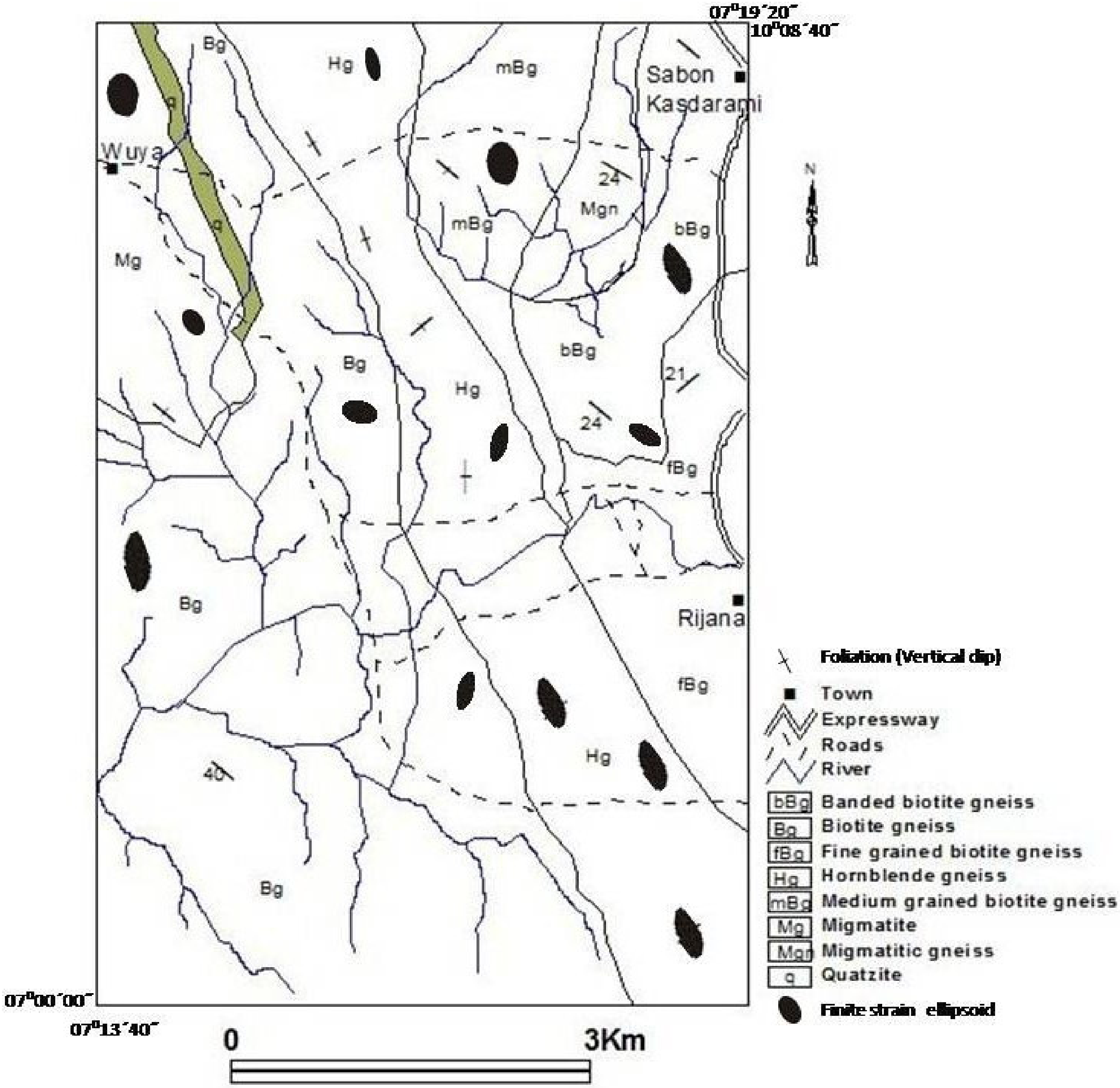

Figure 5. Strain ellipsoids and orientation distribution map of the study area.

progressive grain deformation from the migmatite and the biotite gneiss down to the banded biotite gneiss and fine-grained biotite gneiss corresponding to west-east strain variation. Using grain size distribution, the progressive increase in grain deformation is corresponding to the decrease in grain sizes across the study area. The heterogeneous and varying grain deformation could be attributed to variation in mineral assemblage, heterogeneity of rock composition and probably variation in temperature and pressure conditions of metamorphism across the study area or the entire region.

Conclusions

It concluded from this research that in response to the generally NW-SE tectono-metamorphic ductile deformation that produced the steeply dipping gneisses of the area, there is heterogeneity in the bulk strain. The orientation is essentially concordant to the metamorphic deformation and probably unconnected with the latter but brittle Pan-African and predominantly NE-SW fracture systems.

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