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Deformation Traits in the Charnockitic Rocks of Akure Area, Southwestern Nigeria*

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Abstract: The charnockitic rocks of Akure constitute one of the petrologic units of the precambrian basement complex of Southwest Nigeria. The field studies indicate fresh outcrops that show little signs of weathering although the surfaces are rough. The rock is in contact with migmatite and granite gneiss of the migmatite gneiss complex. On the outcrops are the occurrences of pegmatite, aplite and quartz veins as minor intrusions. Petrographic studies revealed hornblende, plagioclase, hypersthene, biotite, quartz, muscovite and opaque minerals as major minerals while zircon is accessory. Bent lamellae in plagioclase, distorted twinning in plagioclase and micro-cracks in virtually all the minerals in the thin sections indicate some element of deformation. Joint sets trend N-S, E-W and NNE-SSW with the N-S set predominating. The trends of the joint sets tally with those of the minor intrusions. The directions of maximum compressional and tensional stresses inferred from the rose diagram are in consonance with the general directions imprinted by the Pan African orogenic events which affected the basement complex rocks. Since, virtually all minerals in the thin sections exhibit traits of deformation indicating that the deformation is penetrative, it is inferred that the cause of the deformation might be tectonic.

Key words: Charnockitic rock, distorted twinning, bent lamellae, undulose extinction, micro-cracks

INTRODUCTION

Charnockitic rocks generally have diverse origins, spanning a range of metamorphic and igneous derivations (Kilpatrick and Ellis, 1992) which implies that igneous or metamorphic fabric can be exhibited. In Nigeria, charnockitic rocks constitute one of the major petrologic units of the precambrian basement complex (Olarewaju, 2006). The charnockitic rocks of Akure area form a part of this unit. The rock suite has been of interest to the earth scientists partly because of aesthetic value particularly when polished and partly because of the controversy surrounding the origin. Oyawoye (1962, 1964) presented a model of metasomatic origin, Olarewaju (1988) presented the fractional crystallization model while Rahaman *et al*. (1988) presented the tectonic model and Dada *et al*. (1989) presented an igneous origin model.

The Nigerian basement complex lies within the remobilized zone of the West African basement. The major rock types in the area as classified by Adekoya *et al*. (2003) are (a) the gneiss-migmatite-quartzite complex; (b) the schist belts which are low to medium grade supracrustal and meta-igneous rocks; (c) the Pan African granitoids (Older Granites) and other related rocks such as charnockitic rocks and syenites and (d) minor felsic and mafic intrusives. The rock intruded into the migmatite-gneiss-quartzite complex. The study area lies

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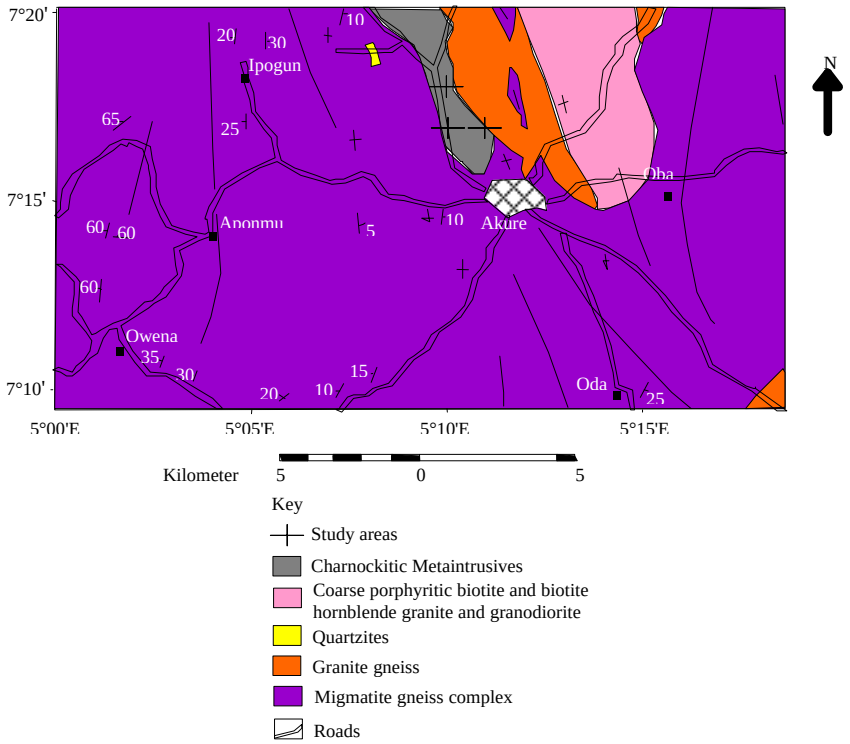


Fig. 1: Geological map of Akure showing study areas, Adapted from the Geological Map of Nigeria produced by the Geological Survey of Nigeria in 1974

within longitudes 5°00'E and 5°17'E and latitudes 7°10'N and 7°20'N in the Southwestern part of Nigeria (Fig. 1).

In the opinion of Adekoya (1977), tectonic joints are quantitative and directional manifestations of operative forces that can give a clue to possible stress distribution in a deformed rock. Workers that reported on the age/origin of the charnockitic rocks of the precambrian basement complex of the Southwestern and Southeastern Nigeria include Ekwueme and Kroner (2006), Rahaman (1976, 1988), Olarewaju (1988), Oyinloye and Obasi (2006) and Olarewaju (2006). It is suggested that the medium-coarse-grained hypersthene-granodiorite of Eastern Hebei Province, China is the product of crystallization of anatectic magmas of the same composition. Shitta (2007) described the three types of charnockitic rocks in Akure area on the basis of their textural characteristics as (1) coarse-grained as exemplified by the Akure body, (2) massive fine-grained which form along the margins of the granitic bodies as seen in Ijare, Uro and Edemo-Idemo and (3) the gneissic fine-grained types which were recognized within the bodies of the gneisses in Ilara and Iju. The charnockitic rocks of Akure-Ikerre-Ado Ekiti have earlier been described as an association (Olarewaju, 2006). It is concluded that alteration pathways from fresh to weathered charnokitic rocks are clearly different under each climate conditions.

MATERIALS AND METHODS

The outcrops of the rock in the area were observed for their texture, mineralogy, structure, field relationship and mode of occurrence. The joint system was studied for the

density and trend. Samples were collected for laboratory studies. The petrography was studied with the petrographic microscope and the modal analysis was done by visual counting. The photomicrographs were further studied with an application by the Sun Microsystems, Inc., 4150 Network Circle, Santa Clara, California 95054, USA, known as Image J version 1.40c (2008). To trace the grains with this application, click file and go to open. Select the photomicrograph to be studied. Then go to process and select find edges. The rose diagram was plotted with a bin size of 20 while the minimum and maximum values of the axis are 0 and 25, respectively.

RESULTS AND DISCUSSION

Mode of Occurrence and Field Characteristics

Charnockitic rocks in the study area occurred as small intrusions and pavement outcrops within the migmatite-gneiss-quartzite complex. The rock type was massive, greenish in color and medium to coarse grained. The outcrops were fresh showing little signs of weathering but the surfaces were rough with a lot of pegmatite intrusions that trend N-S, E-W and NNE-SSW cutting through the outcrops (Fig. 2 a, b). Joint sets trending N-S, E-W and NNE-SSW occurred on the outcrops. Some of the E-W trending joints cut through some of the veins.

Petrography

Hornblende, plagioclase, hypersthene, biotite, orthoclase, quartz, muscovite and opaque minerals (probably iron oxide) were the major minerals while zircon was the accessory identified in the thin section of the rock. The modal analysis of the thin sections of the rock gave an average of 25, 24, 14, 11, 8, 7, 6, 4 and 0.6%, respectively.

The grains carried inclusions of quartz and some particularly orthoclase displayed carlsbad twinning. The hornblende would likely to be of secondary growth. Plagioclase displayed albite twinning but some of the grains showed bent or distorted twinning, undulose extinction and most of them exhibited micro-cracks (Fig. 3a, b). Hypersthene grains showed a lot of cracks while biotite flakes carried inclusions of zircon (Fig. 4). Some of the muscovite flakes showed distorted cleavage and some carry inclusions of quartz and zircon. The opaque minerals which are most likely alteration products, probably iron oxide, had symplectic relation with hornblende and biotite.

Generally, the minerals had irregular shapes and possessed sutured edges in thin section. There were no evidences of weathering and virtually all minerals possessed micro-cracks and/or distorted twinning, bent lamellae and compressed twin plane (Fig. 3a-d).

Fig. 2: (a) N-S, E-W, NNE-SSW trending pegmatite veins in charnockitic rock and (b) pegmatite vein cutting through an outcrop of the charnockitic rock

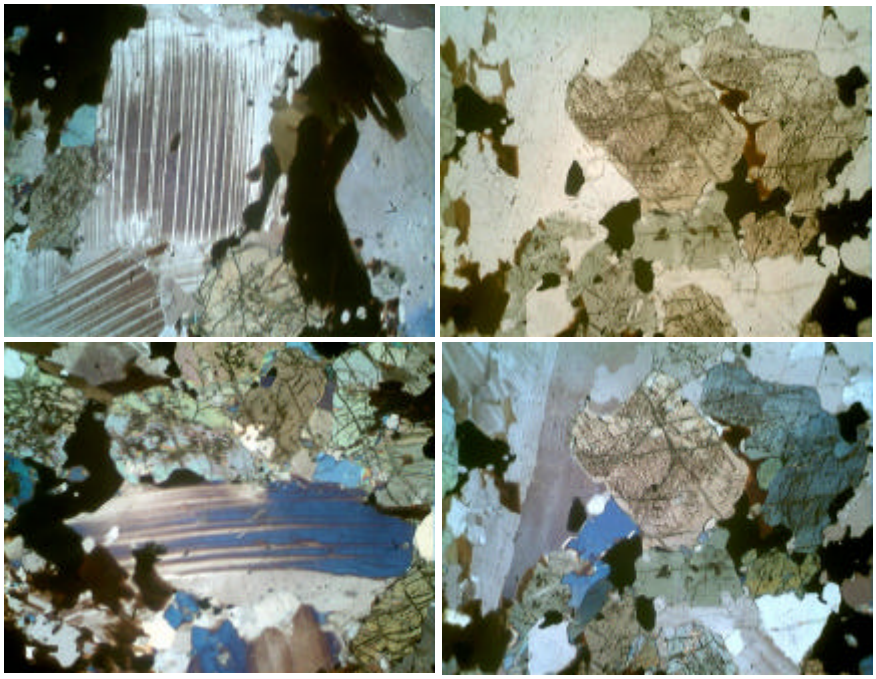


Fig. 3: Photomicrographs of the charnockitic rock showing signs of stress. Figure 3a, b and d were under crossed nicol while Fig. c was under plane polarized light. X40. (a) Plagioclase showing undulose extinction and distorted twinning; micro-cracks in diopside (hypersthene) and biotite with inclusions of zircon, (b) micro-cracks in almost all grains of the minerals and plagioclase showing undulose extinction as well as bent lamellae, (c) some of the minerals in the rock exhibiting micro-cracks and (d) some of the minerals in the rock exhibiting micro-cracks

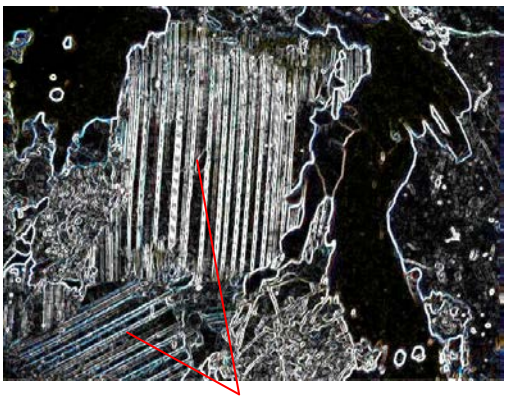
Grain trace of the photomicrographs with Image J provided clear evidences of distorted twinning in plagioclase (Fig. 4), undulose extinction and bent lamellae in plagioclase (Fig. 5) and compressed plane of carlsbad twin in orthoclase (Fig. 6).

Rose Diagram

The trend of the joints were analyzed and applied to plot a rose diagram (Fig. 7). The density of the joints as shown by the study was an average of 6 strike (N-S trending), 4 dip (E-W trending) and 2 oblique (NNE-SSW trending) joints per ten square meters. The result showed the predominance of the N-S trending set followed by the set that trend E-W and the set that trend NNE-SSW.

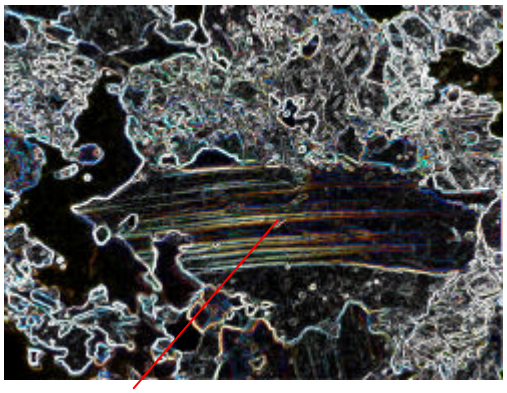
Observations of the studied rock in the field revealed massive, medium to coarse-grained texture and grains that are not aligned or elongated except at the margins of minor intrusions. This observation is in line with Rahaman (1976, 1988) and Shitta (2007) reports of massive coarse-grained rock in Akure. On the basis of textural characteristics, these workers differentiated the rocks from the massive fine-grained and the gneissic types in the area which implies that the rock is not deformed.

The trends of the joints are consistent with the trends of the minor intrusions registered in the rock (Fig. 2a, b). According to Turner and Verhoogen (1960), joint of tectonic origin are expected to have a simple relation to the rest of the rock fabric. This is an indication that



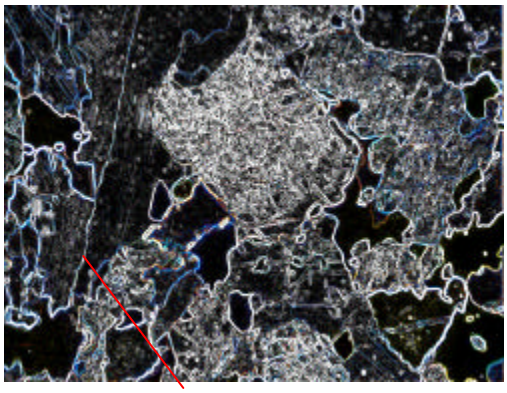
Plagioclase showing distorted albite twinning

Fig. 4: Grain trace of photomicrograph (Fig. 3a) with Image J showing distorted twinning in plagioclase



Undulose extinction and bent lamellae in plagioclase

Fig. 5: Grain trace of photomicrograph (Fig. 3b) with Image J showing undulose extinction and bent lamellae in plagioclase



Compressed plane of carslbad twin in orthoclase

Fig. 6: Grain trace of photomicrograph (Fig. 3d) with Image J showing compressed plane of carlsbard twin in orthoclase

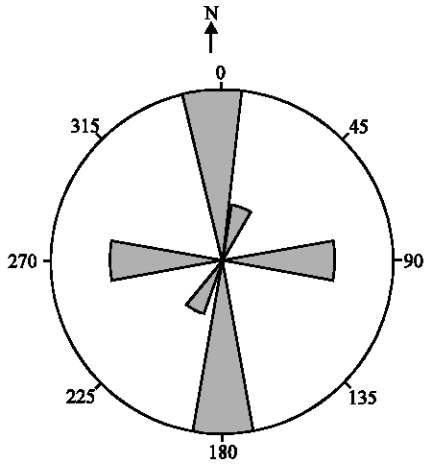


Fig. 7: Rose diagram of the joints in the charnockitic rock

the joints recorded in this work would most likely be of tectonic origin. Read and Watson (1962) suggested that joints are visible expressions of residual forces released after deformation. The presence of three joint sets is therefore an indication that the rock must have experienced deformation. Odeyemi (1981) suggested that the precambrian basement complex of Nigeria, of which this rock is a lithologic unit, experienced polycyclic deformation.

The petrography reveals (1) undulose extinction in quartz and plagioclase; (2) distorted twinning in plagioclase; (3) bent lamellae in plagioclase; (4) compressed plane of carlsbad twin of orthoclase and (5) micro-cracks in virtually all minerals of the rock. All these are traits of deformation and therefore a confirmation that the rock has indeed experienced deformation. Ekwueme and Kroner (2006) reported indications that zircons have recorded several precambrian high-grade metamorphisms which is an indication that granulite facies metamorphism affected the basement of Southeastern Nigeria. This is in consonance with the model of origin proposed by Olarewaju (2006) for the Idanre-Akure-Ado Ekiti charnockitic rock. The presence of zircon in this rock and the correlations in the proposals of Ekwueme and Kroner (2006) and Olarewaju (2006), makes it reasonable to infer that the rock, like those of the Southeastern Nigeria, might have experienced several precambrian high-grade metamorphisms with the consequence of accompanying deformation. Generally, since inclusions predate their hosts, the presence of inclusions of quartz and zircon in other minerals in the rock points to the fact that the rock has a transformation history.

Grain trace of the photomicrographs with ImageJ shows clearly the distortion of the albite twins in plagioclase as a result of compressional force (Fig. 4), undulosity and bent lamellae in plagioclase (Fig. 5) and compressed carlsbad twin plane in orthoclase (Fig. 6). All these signs of deformation confirm a directional stress which might have happened as a result of high grade metamorphism.

In line with the opinion of Adekoya (1977), the rose diagram (Fig. 7) shows the predominance of strike joint set which is an indication that N-S is the direction of least compressional stress. The dip joint set, which is less prominent, runs perpendicularly to the foliation meaning that E-W is the direction of maximum compressional stress. This follows the general trend of the Pan African orogenic event that affected the basement complex rocks which therefore, is an indication that the rock experienced some form of deformation.

CONCLUSION

Evidences from joint and petrographic studies suggest that the charnockitic rock in Akure area experienced deformation leaving imprints of sets of joints, undulosity, bent lamellae, distorted twinning, compressed twin plane and micro-structures. It is evident that this is a result of high grade metamorphism as virtually all minerals in the rock were affected in one way or the other showing the penetrative effect of the deformation. This implies that the deformation suffered by the rock will most likely be of tectonic origin.

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