Field and Petrographic Relationships between the Charnockitic and Associated Granitic Rock, Akure Area, Southwestern Nigeria

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Abstract**—**The charnockitic and associated granitic rocks of Akure area were studied for their field and petrographic relationship's. The outcrops locations were plotted in *Surfer 8*. The granitic rock exhibits a porphyritic texture and outcrops in the north-eastern side of the study area while the charnockitics outcrop in the central/western part. An essentially dark coloured and fine grained intrusive exhibiting xenoliths and xenocrysts (plagioclase phenocrysts) of the granite outcrops between the granitic and charnockitic rocks. Mineralogically, the central rock combines the content of the other two indicating that it is most likely a product of their hybridization. The charnockitic magma is believed to have intruded and assimilated the granite substantially thereby contaminating itself and consequently emplacing the hybrid. The presented model of emplacement elucidates the hybridization proposal. Conclusively, the charnockitics are believed to be (a) younger than the granite, (b) of Pan-African age and (c) of igneous origin.

Keywords**—**Charnockitic rock; Hybrid rock; ImageJ; Xenocryst

I. INTRODUCTION

CHARNOCKITIC rocks generally have diverse origins, spanning a range of metamorphic and igneous derivations [1] which implies that igneous or metamorphic fabric can be exhibited. Various models of origin have been presented by workers in the field. The metasomatic model presented a hydrothermal fluid rich in Fe^{2+}, soaking and depositing its' Fe^{2+} in a pre-existing granite converting them to charnockitic rocks [2], [3]. The geochemical model considers that fractional crystallization of dacitic-andesitic magma at depth will produce massive fine-grained charnockitic rocks and subsequent partial melting of the crustal rock by the residual melt phase will produce acidic magma, which when emplaced produces coarse grained charnockitic rock [4]. The tectonic model has to do with the opening and closing of the ocean with the attendant deposition of large volumes of sediment followed by metamorphism of the sediments and the evolution of granites and charnockitic rocks [5]. The igneous model involves the melting of the lower crustal rocks during the Pan African orogenic event leading to the production and upward rise of granitic magma to higher levels and eventually charnockitic magma will be produced and emplaced by fusion under dry granulite facies conditions [6]. Olarewaju [7] collated field, chemical and petrographic evidences in support of igneous origin of charnockitic intrusives of Nigeria as presented by different workers. The geology, petrography and geochemistry of these rocks have been studied by the workers cited in this report.

The major rock types in the area as classified by Adekoya *et al*. [8] 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 charnockitic rocks of Akure intruded into the migmatite gneiss quartzite complex and the older granite suite. The study area lies within longitudes 5^0 00'E and 5^0 17'E and latitudes 7^0 10'N and 7^0 20'N in the southwestern part of Nigeria (Fig.1).

Rahaman [9], [5] and Olarewaju [10] believed that the Idanre-Akure-Ado Ekiti area gneissose and massive charnockites were emplaced during the Pan African orogeny contrary to the ages of Kibaran and older suggested by Hubbard [11]. Rahaman [9], [5] distinguished three types of charnockitic intrusives on the basis of their structure as follows: (i) gneissic charnockitic rocks that possess a planar penetrative fabric; (ii) foliated charnockites which show a magmatic foliation due to the platy parallelism of feldspar megacrysts and the concentration of mafic minerals into discrete planes; and (iii) coarse-grained, massive, non-foliated, often porphyritic charnockitic rocks. Olarewaju [7] opined that igneous charnockitic intrusives are identified and distinguished from the metamorphic ones by their igneous texture and field relationships, even though the former resemble the latter in their mineral assemblages and that igneous charnockites are closely associated with non-charnockitic granites in some places, suggesting contemporaneous emplacement of both rock types. It was explained that crystallization temperatures range from 718^0C to 958^0C and that a model of origin involving melting in the lower crust under granulite facies conditions of low water pressure or high CO_2 contents ($PCO_2 >> H_2O$) during the Pan-African episode is favoured for the genesis of the charnockitic magma. Shitta [12] described the three types of charnockitic rocks in Akure area on the basis of their textural characteristics as (i) coarse-grained as exemplified by the Akure body, (ii) massive fine-grained which form along the margins of the granitic bodies as seen in Ijare, Uro and Edemo-Idemo and (iii) the gneissic fine-grained types which were recognized within the bodies of the gneisses in Ilara and Iju. Oyinloye and Obasi [13] concluded that the granitic and charnockitic rocks were emplaced by fractional crystallisation

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of magma which was derived from the subduction of an ocean slab into the mantle in a back arc tectonic setting. The charnockitic rocks of Akure-Ikerre-Ado Ekiti have earlier been described as an association by Olarewaju [7]. Ademeso [14] concluded that the charnockitic rocks of Akure area experienced deformation.

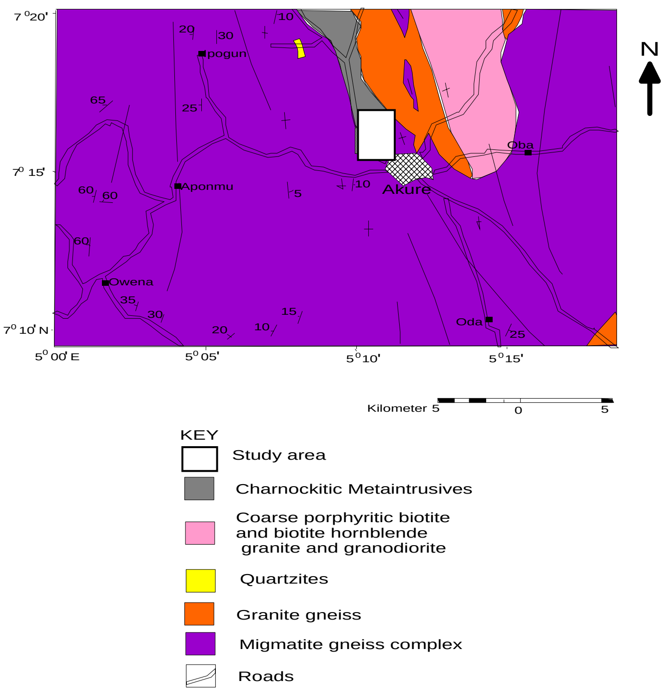


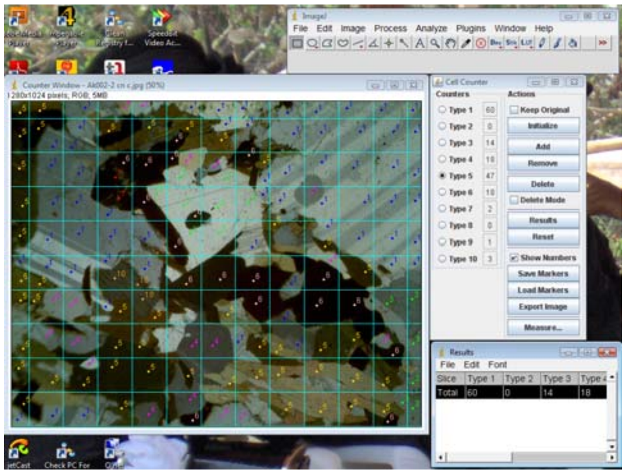
Fig.1: Geological Map of Akure showing study Area (Adapted from Ademeso, 2009)

II. MATERIALS AND METHODS

Road and footpath traverse of the study area was carried out with the aid of the GPS, compass-clinometer and hammer. The outcrops of the rock were observed for their texture, mineralogy, structure, field relationship and mode of occurrence.

The coordinates of the outcrops were converted to Universal Transverse Mercator (UTM) with *Transfo* and then plotted in *Surfer 8*. The contact of the rocks was traced based on the field evidences and the plots of the outcrops. The thin sections were prepared in the laboratory and studied with the petrographic microscope. Photomicrographs were taken with digital camera and the modal content of the rocks analysed by studying the photomicrographs with *ImageJ* [15]. The procedure is as follows:

Click on *File* and go to *Open* and then select the photomicrograph to be studied. The counter window will open and the selected photomicrograph will be displayed in it. Thereafter, click on *Plugins*, go to *Analyze*, select *Grid;* and then go to *Analyze* again and select *Cell Counter*. The cell counter dialogue box will be displayed. After the counting might have been completed, click on *Result* in the cell counter dialogue box to display the result in a table (Fig.2). Repeat this procedure for at least three photomicrographs taken from three different views of each thin section.



Cell Counter Legend

Type 1 is plagioclase, Type 2 is Orthoclase, Type 3 is quartz, Type 4 is Biotite, Type 5 is Hornblende, Type 6 is Mymerkite, Type 7 is Hypersthene, Type 8 is Muscovite and Type 9 is Pyroxene.

Fig. 2: Determining modal composition of rocks with *ImageJ*.

III. RESULTS

Mode of Occurrence and Field Characteristics

The rocks in the study area occurred as intrusions within the migmatite-gneiss-quartzite complex. The granitic rocks outcropped as domes and small hills in the area. They are generally light coloured, exhibited porphyritic texture and are fairly weathered. The charnockitic rocks outcropped as pavement and oval or semi-circular hills of between five and ten meters (10m) high with a lot of boulders at some outcrops. They are generally massive, dark-greenish in colour and medium to coarse grained. The fresh outcrops with little or no sign of weathering have a lot of quartz, aplite and pegmatite intrusions occurring in it. The general trend of the intrusions is N-S. The dominant trend of the joints that occur on the rock is N-S. An essentially dark coloured and fine grained intrusive rock carrying a lot of xenoliths of the porphyritic granite and xenocrysts of the large grains of plagioclase occur in some parts of the intrusive bodies (Fig.3). Their outcrops are similar to those of the charnockitic rocks in occurrence.

Xenocrysts of Plagioclse in intrusive

Fig.3: Large grains of plagioclase (phenocrysts of the porphyritic granite) embedded in some parts of the intrusive (xenocrysts) alongside the xenoliths of the porphyritic granite.

A particular outcrop which is about five meters (5m) above the ground level and located at coordinates

N07^{0}15'29.3", E005^{0}10'18.8" revealed the capping of the intrusive body by a rock which exhibits large crystals of greyish plagioclase in finer but medium to coarse grained groundmass of plagioclase, biotite, quartz and hornblende indicating a porphyritic texture (Fig.4). Generally, the porphyritic granite is light coloured and showed signs of having been fairly weathered. The intrusive body is fine grained and contains plagioclase, quartz, hornblende and a lot of biotite indicating hybridization of the intrusive rock and pre-existing porphyritic granite as in an aureole. Assimilated but not completely digested portions (xenoliths) of the porphyritic granite occur in the hybrid rock in the outcrops.

Fig. 4: Remnant of Porphyritic granite capping on hybrid rock at the outcrop.

Xenocrysts of greyish plagioclase, believed to have been of the porphyritic granite parentage, occur alongside the xenoliths in some parts of the intrusive body indicating the extent of digestion of the pre-existing rock (Fig.3). The essentially leucocratic centre of the large xenoliths contains phenocrysts of the greyish plagioclase in coarse grained groundmass while the margins are darker, fine grained and the phenocrysts tend to disappear. The locations of the outcrops of the different rock types were plotted and the inferred boundaries traced to show their field relationships (Fig.5).

The petrography showed the porphyritic granite having plagioclase, quartz, biotite, hornblende, mymerkite as major minerals and apatite as accessory (Fig.6). The average modal composition is 35% 31% 19% 4% 12% respectively. The charnockitic rocks contain plagioclase, hypersthene, biotite, quartz, hornblende, muscovite and orthoclase as major minerals while zircon is accessory (Fig.7) with modal composition of 32%, 16%, 16%, 16%, 11%, 5%, 3% and 1% respectively. The hybrid rock contains biotite, quartz, plagioclase, hornblende, hypersthenes, orthoclase, pyroxene, muscovite, mymerkite and accessory garnet with the following modal composition 36%, 24%, 20%, 10%, 3%, 3%, 2%, 1%, 1% and 0.5% respectively (Fig.8). This indicates that the hybrid rock combines the mineralogy of the charnockitic rock and porphyritic granite. Conspicuously, two generations of minerals particularly plagioclase and quartz were exhibited by the hybrid rock (Fig.9). The plagioclase xenocrysts (probably inherited from porphyritic granite) showed signs of being converted while the newer generation showed freshness as the twinnings were clearly recognised. This is also the case with the quartz and feldspar grains. Intergrowth of biotite on inherited feldspar further confirms that the later are older.

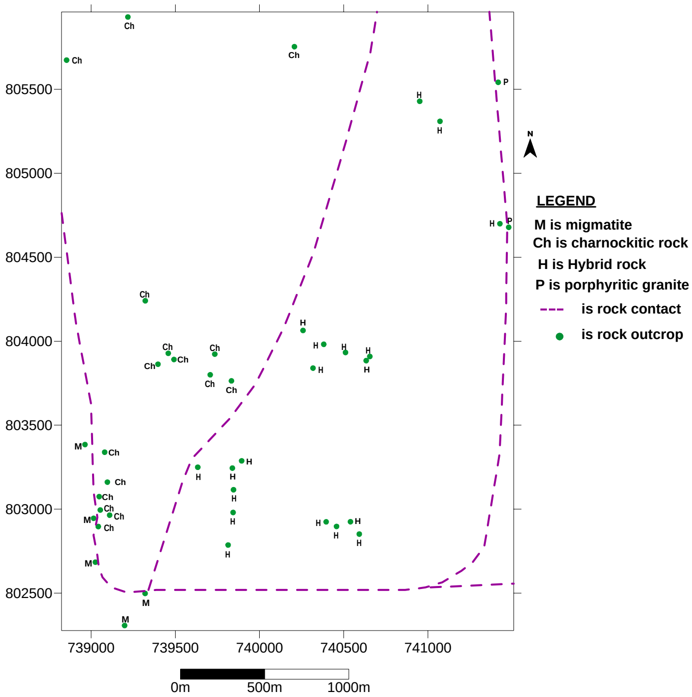


Fig. 5: Plots of outcrops locations in the study area (coordinates converted to UTM with Transfo and plotted in Surfer 8). Note: Rock contact is inferred.

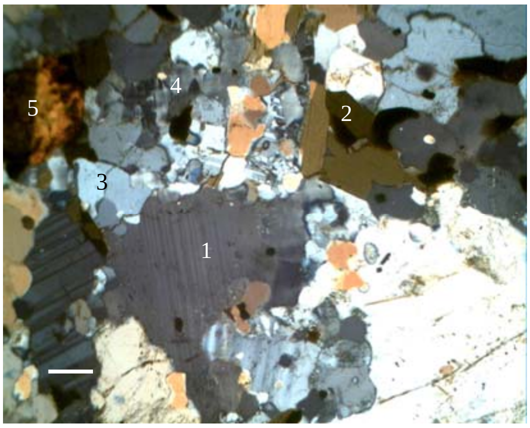


Fig. 6: Photomicrograph of Porphyritic granite (Pgr b) showing plagioclase (1), biotite (2), quartz (3), microcline (4) and orthoclase (5). Bar Scale is 1µm.

Fig. 7: Photomicrograph of Charnockite (Ak007b a) showing hornblende (1), biotite (2), quartz (3), zircon (4), hypersthenes (5) and plagioclase (6). Bar Scale is 2µm.

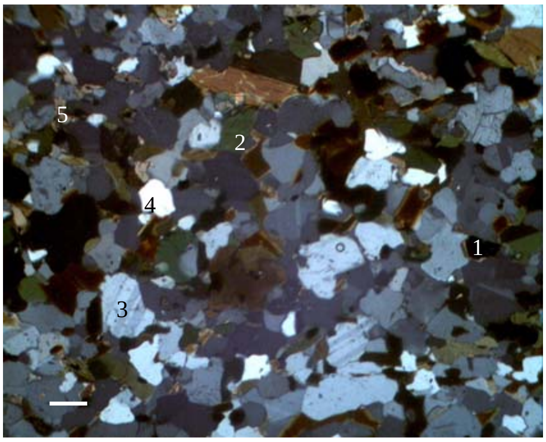


Fig. 8: Photomicrograph of Hybrid rock (H1 c) showing hornblende (1), biotite (2), plagioclase (3), quartz (4) and hypersthenes (5). Bar Scale is 1μm.

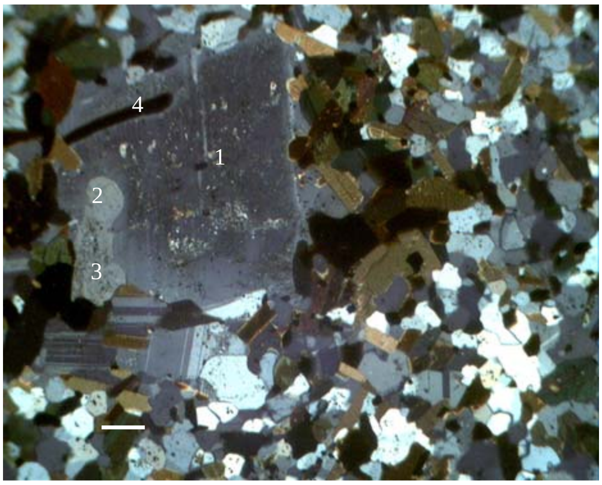


Fig. 9: Photomicrograph of Hybrid rock (H2 b) showing plagioclase xenocryst (1), inherited quartz (2), inherited feldspar (3) and biotite intergrowth (4). Bar Scale is 1μm.

IV. DISCUSSION

The evidences offered by this report further confirm that the charnockitic rock of this area could not have been formed by metasomatic processes as suggested by the metasomatic model of Oyawoye [2], [3]. Rather, the process of magmatic intrusion into the pre-existing older rocks as suggested by either the tectonic model of Rahaman *et al*., [5] or the igneous model of Dada *et al*., [6] must have been responsible for the emplacement. The hybrid rock recorded in the area suggests that the igneous model must have been responsible for the emplacement of the charnockitic rocks in line with the report of Olarewaju [16], [7]. The presence of assimilated rocks in the hybrid rock is suggestive of the fact that the rock must have been intruded at a fairly high temperature.

The N-S trend formed by some of the outcrops of this hybrid rock is an indication that the rocks must have been emplaced by the Pan-African activities since this orogeny is known to be responsible for this type of trend in this area [17]. Since it is also generally believed that the older granite suite, of which the porphyritic granite is a part, is of Pan-African age [18], a rock that assimilates the porphyritic granite is definitely younger in age of emplacement. This is in line with Rahaman [9], [5] and Tubosun *et al*. [19] that suggested Pan-African age of emplacement for the coarse grained charnockitic rocks. This therefore leads to the believe that (i) the charnockitic rock is younger than the porphyritic granite but it is definitely of Pan-African age since there is no younger orogenic event and (ii) there must have been multiple episodes of rock emplacements during the Pan-African [6], [16], [17].

The presence of the xenoliths of the porphyritic granite in the hybrid rocks and the level of weathering of the two rock types is a confirmation that they were not contemporaneously emplaced contrary to the suggestion of Olarewaju [7].

The model of the emplacements of the charnockitic and the associated granitic rock (Fig.10) as inferred from the evidences from this work is presented as follows:

1. Granitic magma was introduced into the earth crust to form the plutonic porphyritic granite as a result of slow cooling due to emplacement at great depth into the part of the study area marked A.

2. Charnockitic magma was later introduced or separated out of igneous magma at a shallower depth into the part of the study area marked B.

3. The intersection of the two areas marked C is the domain of contact aureole of the two rocks where the hybridization of the newly intruded charnockitic and the pre-existing granitic rocks took place. The resultant rock is fine grained unlike the granitic and charnockitic rocks and this must have resulted from the fast cooling occasioned by the lowering of temperature by the process of assimilation and digestion. A comparison of the mineral composition and fabric of the rocks revealed a substantial difference between the hybrid rock and the two other rock types. The hybrid seems to have combined the mineral contents and the colors of the two other rocks. The width of the aureole is about 500-1500m in the study area. It is wide in the south, narrowing towards the northern part of the study area.

4. The charnockitic magma emplaced coarse grained, dark greenish, hypersthene bearing rock into the area marked D. This shows that the cooling was slow and devoid of assimilation and digestion of any other rock type during emplacement. This area is wide in the northern part of the study area (over 2000m) and narrow (about 250m) in the south.

5. The area marked E is the location of the remnants of the porphyritic granite although its' outcrops are mainly in the northern part.

V. CONCLUSION

Following the discussion, the charnockitic rocks of Akure area are believed to of igneous origin. They are younger in age than the porphyritic granite and are therefore not contemporaneously emplaced which further confirms multiple emplacement of rocks during the Pan-African orogeny. The fairly high temperature of emplacement is responsible for the assimilation and digestion of the pre-existing porphyritic granite by the charnockitic magma leading to its' contamination and the eventual formation of the hybrid rock.

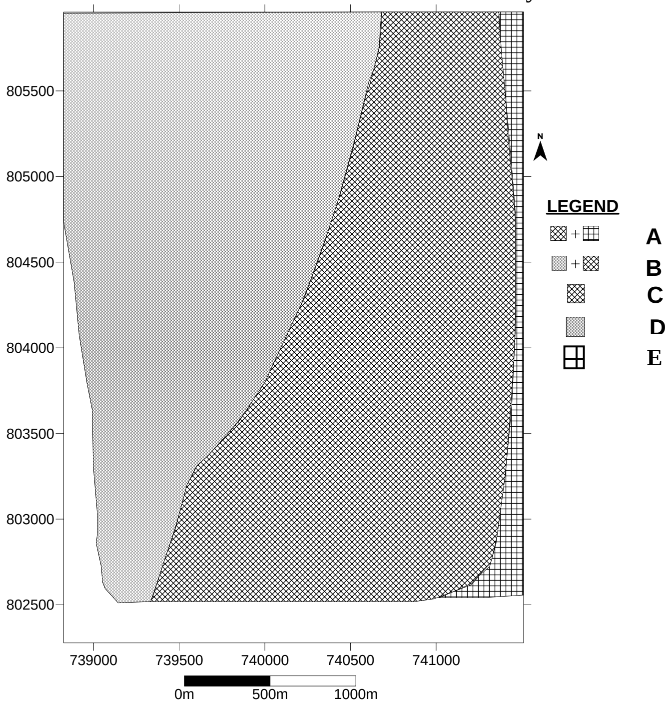


Fig. 10: Proposed model of the emplacement of the charnockitic and associated granitic rocks in the study area.

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