

PETROCHEMISTRY OF CHARNOCKITIC ROCKS OF AWO-OSUNTEDO AREA, SOUTHWESTERN NIGERIA

Adetunji, A.

Department of Geology, Obafemi Awolowo University, Ile-Ife, Nigeria.
Corresponding Author's Email: adetunjia@oauife.edu.ng; aamutiwa@yahoo.co.uk
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ABSTRACT

The petrochemistry of charnockitic rocks from the Awo-Osuntedo area of southwestern Nigeria were investigated with the objectives of presenting their petrogenesis and geotectonic setting at the time of their emplacement. The rocks were mainly found within the migmatitic gneiss country rock and associated pegmatites. They occurred as small intrusive bodies and are composed mainly of orthopyroxene, clinopyroxene, quartz, biotite, secondary amphibole, plagioclase and alkaline feldspars with a small compositional range between basic and intermediate respectively for Awo and Osuntedo rocks. The small Eu* anomalies (0.9-1.47) with an average of 1.2 combined with elemental signatures indicate that the rocks were derived from an enriched mantle with some crustal contamination and emplaced in an environment similar to the arc region of tectonic setting. Though, the rocks have dry mineral assemblages, there is no geochemical evidence to suggest they were derived from melting that was associated with granulite facies metamorphism rather the small sizes of the plutons and the geochemical signatures particularly high magnesian and calc-alkaline nature are typical of the Caledonian type charnockite formed during delamination of thickened continental crust after collisional orogeny.

Keywords: Awo, Calc-alkaline, Charnockitic rocks, Granulite facies, Nigeria, Osuntedo.

INTRODUCTION

Charnockitic rocks constitute a major petrological unit of the Precambrian Basement Complex in southwestern Nigeria (Oyawoye, 1964; Cooray, 1972; Olarewaju, 1987; Rahaman, 1988). In most places here, charnockitic rocks occur in the amphibolite facies country rocks in contrast to most worldwide occurrences in granulite facies terranes (Olarewaju, 1987; Rahaman, 1988). However, the mineral composition of the charnockitic rocks includes ortho pyroxenes, clinopyroxene, quartz, two feldspars, hornblende and other iron-bearing assemblages that correspond closely to those of granulite facies. Because of this, many workers have equated charnockitic rocks as synonymous with granulite (Frost and Frost, 2008). Both plutonic and metamorphic charnockites have been reported in Nigeria (Olarewaju, 1987). This author reported the occurrence of charnockitic rocks in three modes, first within the core of granitic rocks. The second mode of occurrence is along the margins of the granite body and thirdly, as discrete individuals in the gneiss complex. Olarewaju (1987) categorized charnockitic rocks that are spatially associated with granites as opdalite (orthopyroxene-bearing granodiorite) and true charnockites. He concluded that this category of

charnockites is calc-alkalic, magmatic and intermediate in composition which could have resulted from granulite facies grade of metamorphism. Geochronological evidence by Tubosun *et al.* (1984), Dada *et al.* (1989), as well as structural evidence (Annor and Freeth, 1985), linked the emplacement of charnockitic rocks to the Pan-African magmatism. Earlier workers (for example, Olarewaju, 1987) have reported the absence of garnet in charnockites in southwestern Nigeria and thus concluded that the rocks were generated at a low-pressure crustal level. The different modes of occurrence, absence of garnet, petrology and occurrence in amphibolite facies terrane which differ from most charnockitic occurrences around the world should make any study on southwestern Nigeria charnockitic rocks to be of great interest. The data presented will find useful comparisons with occurrences outside Nigeria. The present study examines in details the petrology and geochemistry of small intrusive charnockites in the Awo and Osuntedo areas of Osun State, Southwestern Nigeria with the objectives of presenting the probable petrogenesis and compare these data with published ones on Eastern Nigeria. This in an attempt to present geotectonic setting of southwestern Nigeria at the time of emplacement

of the rocks.

THE REGIONAL GEOLOGY

The area is situated in the most southern part of the Trans-Saharan fold belt which was last deformed and reactivated during the Pan-African orogeny in the Neoproterozoic. The Neoproterozoic evolution resulted from the collision between passive West African craton and active terrane to the east (Figure 1). The Trans-Saharan fold belt extends from north Africa to the Borborema region in Brazil. The northern part is referred to as Air-Hoggar shield and consists from east to west, East Hoggar, LATEA and the Pharussian. The southern section, Benino-Nigerian shield (or Dahomeyide) consists of six zones from the margin of the West African Craton. The Southwestern Nigeria is fairly correlated with the LATEA in the North Africa and is composed of amphibolite facies grade migmatite-gneiss complex, largely greenschist to amphibolite facies grade metasedimentary rocks, meta-mafites to - ultramafites and Pan African granitoids (600 ± 150 Ma). The Pan-African granitoids include syenites, pegmatites, diorite and charnockitic rocks (the focus of this study). The migmatite gneiss complex consists of granite gneiss, hornblende-biotite gneiss and banded or grey gneiss.

THE PETROLOGY OF THE CHARNOCKITIC ROCKS

Charnockitic rocks underlie a small area that includes the entire Awo community within the pegmatite and migmatite gneiss complex (Figure 2). It is exposed as small, rounded boulders. It is slightly greenish, fine-medium-grained, hard and dense rock. However, in Osuntedo area, it occurs as a small hill with twin peaks and as low-lying outcrops in areas around this hill. The rock has a medium-grained texture and appears to be slightly lighter in colour than that of Awo occurrence.

Under the microscope, samples of the rocks from the two localities consist of interlocking mineral grains. However, thin sections from some parts of the Awo body show crude alignment in the preferred orientation of the longer axes of biotite. Generally, the rocks consist of clinopyroxene, orthopyroxene, plagioclase, biotite, quartz, amphibole and opaque ore. The pyroxenes occur as large subhedral to anhedral crystals in the rocks. **Clinopyroxene** is colourless to faintly pinkish. It is a non-pleochroic mineral. Many of the mineral grains are rimmed by amphibole (Figure 3a). This probably indicates a dehydration reaction during the cooling of the rock. Some of the clinopyroxene crystals show combined polysynthetic and carlsbad twinning (Figure 3c). **Orthopyroxene** is faintly pinkish, greenish to neutral with weak pleochroism. It is cut with series of microfractures. Some of the crystals have their margins lined with biotite (Figure 3b). This secondary biotite is also recognized along the fractures in some of the orthopyroxene grains. The biotite probably formed from the hydration reaction of ortho-pyroxenes during late magmatic or sub-magmatic conditions according to this equation: orthopyroxene + k-feldspar + H_2O = biotite + quartz. There are inclusions of tiny biotite grains in the mineral. These inclusions are crystallographically oriented in most of the grains. **Plagioclase** occurs as large anhedral crystals in the rocks. Some of the crystals are crystallographically oriented in the same direction and have a composition in the range of oligoclase to andesine. Some grains have bent twinned lamellae indicating post-crystallization deformation. **Biotite**, apart from its association with orthopyroxene, also occurs as platy mineral in the rocks with some of the grains showing preferred alignment of the longer axes in the same direction. The colour of biotite is deep brown with strong pleochroism that varies from deep brown to greenish brown. Equally, some biotite grains occur as intergrowth with quartz.

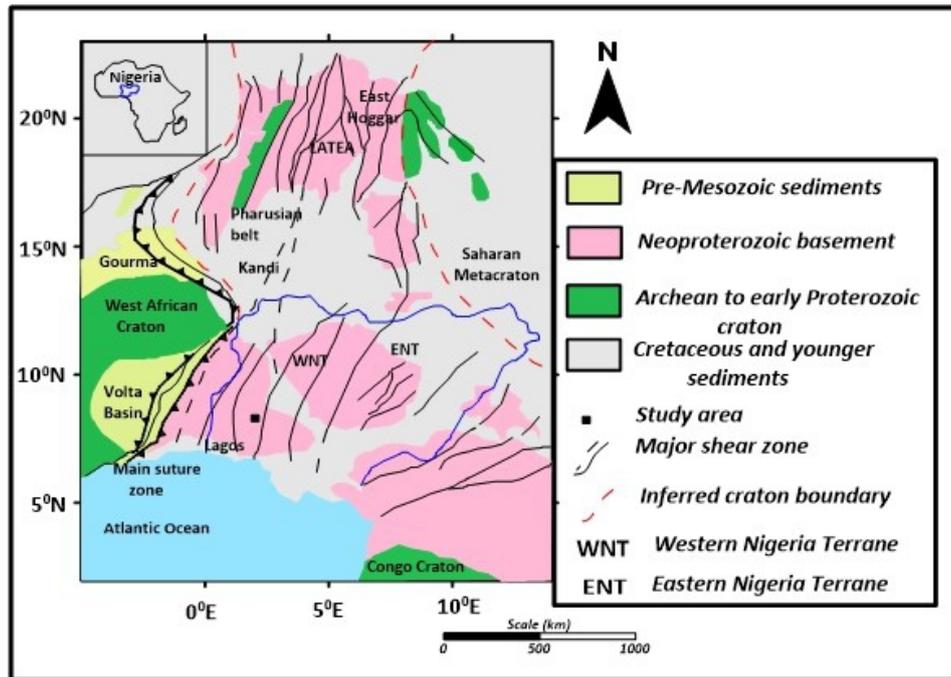


Figure 1: The relative position of the study area in the Trans-Saharan fold belt (modified from Caby, 1989; Black *et al.*, 1994; Liégeois *et al.*, 1994; Ferre *et al.*, 1996; Ferre *et al.*, 2002; Adetunji *et al.*, 2016; Bute *et al.*, 2020).

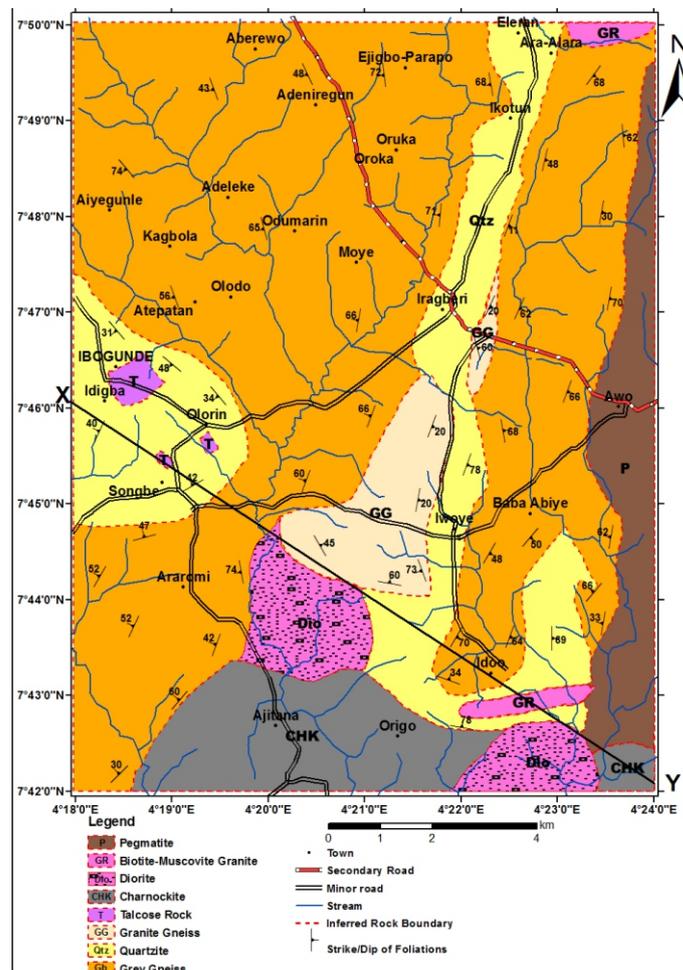


Figure 2: Geological map of the adjacent areas to the study charnockites (after Owoeye, 2019).

The relationship between biotite and other minerals indicates the former to be post-magmatic. The alkali feldspar is essentially microcline with its characteristic grid iron twinning.

MATERIALS AND METHODS

Samples of the rocks were collected during fieldwork. Due to the fact that the mineral composition of individual bodies are uniform and essentially medium-grained about 50 g of each sample was crushed into a fine powder (particle size $< 70 \mu\text{m}$) with a jaw crusher and milled in a

tungsten-carbide Zibb mill, while only 10 g was prepared into fused discs for major and trace elements analyses. Whole-rock major element compositions were determined with XRF (X-Ray Fluorescence Spectrometer) of model PANalytical Axios Wavelength Dispersive spectrometer while the trace and rare earth elements were analysed with an Agilent7700 ICP-MS (Inductively Coupled Mass Spectrometer) coupled with Resolution 193 nm Excimer laser unit at the Central Analytical Facilities, Department of Geology, Stellenbosch University, South Africa.

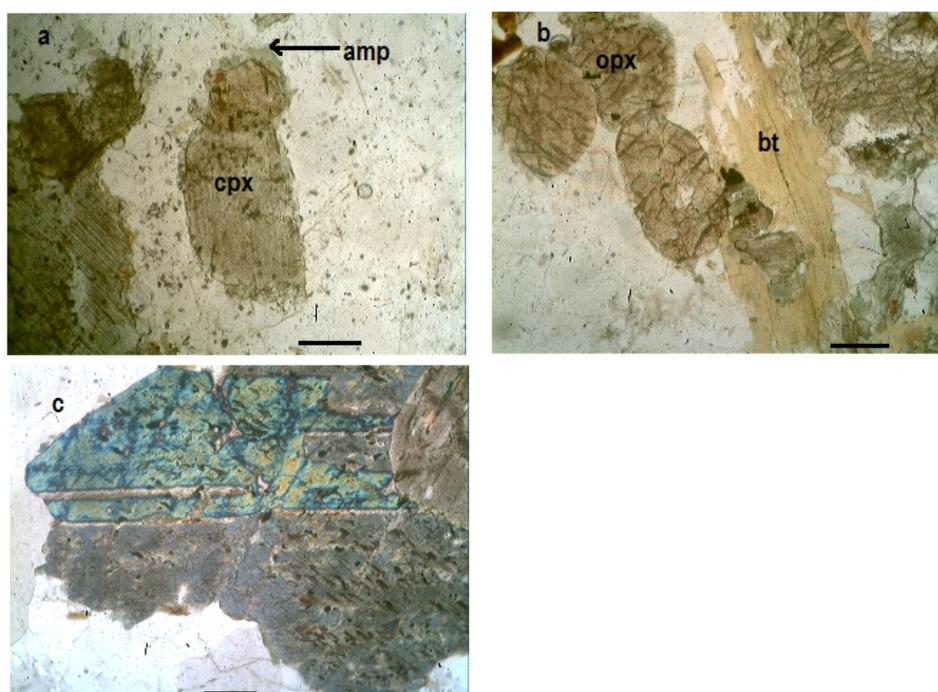


Figure 3: Photomicrograph of the charnockites from the study area. a: clinopyroxene (cpx) rimmed by amphibole (amp), b: orthopyroxene (opx) partially surrounded by biotite (bt), c: combined carlsbad and polysynthetic twinning in clinopyroxene. a and b in ppl while c is xpl. Bar scale: 2 μm .

RESULTS

A total of ten (10) whole rock samples of charnockites from Awo and Osuntedo in the study area were analyzed for major, trace and rare earth elements. The results of the analysis are presented in Tables 1 and 2. The REE are normalized to chondrite values of McDonough and Sun (1995). The variations of selected major elements with respect to others are shown in Figures 4 and the AFM diagram (Figure 5) while the REE chondrite normalized curve is shown in Figure 6.

As shown in Table 1 on the average, the rocks are characterized by a small range of composition of SiO_2 (52.13-57.44 wt. %) with an average of 55.49 wt. %; low concentration of TiO_2 (0.94-1.3 wt. %) with an average of 1.04 wt. %; high Al_2O_3 (13.23-15.70 wt. %) with an average of 14.64 wt. %; high Fe_2O_3 (5.44-8.43 wt. %) with an average of 7.67 wt. %; low MnO (0.1-0.13) with an average of 0.12 wt. %; MgO has high value (4.73-8.23 wt. %) with an average of 6.60 wt. %. The rock generally has moderate to high CaO ranging from 4.92 to 7.61 wt. % with a mean of 6.50 wt. %; moderate Na_2O

(3.17-3.78 wt. %) with an average of 3.57 wt. %. The concentrations of K₂O and P₂O₅ are generally low, ranging from 1.66-3.92 wt. % and 0.44-0.79 wt. % with averages of 2.96 wt. % and 0.59 wt. %, respectively, while the values of Cr₂O₃ range from

0.030-0.054 wt. % with an average of 0.09 wt. %. The Osuntedo rocks only show higher average values for SiO₂ and K₂O while Awo charnockite has higher mean values for other major elements (Table 2).

Table 1: Major element compositions of charnockites in the study area (oxides in wt. % and elements in ppm).

Sample	1	2	3	4	5	6	7	8	9	10	n
SiO ₂	52.13	52.74	52.15	52.84	57.07	57.23	57.17	59.05	57.44	57.03	55.49
TiO ₂	1.08	1.2	1.30	1.12	0.99	0.97	0.94	0.87	0.94	1.00	1.04
Al ₂ O ₃	15.70	15.60	15.44	15.50	13.66	13.84	13.95	15.45	13.23	14.04	14.64
Fe ₂ O ₃	8.10	7.86	8.43	7.92	8.13	7.85	7.66	5.44	7.53	7.79	7.67
MnO	0.13	0.13	0.13	0.13	0.13	0.13	0.12	0.10	0.12	0.12	0.12
MgO	8.23	8.05	8.07	7.59	6.01	5.80	5.73	4.73	6.13	5.64	6.60
CaO	7.61	7.52	7.54	7.40	6.20	6.13	6.05	4.92	5.53	6.11	6.50
Na ₂ O	3.41	3.42	3.43	3.45	3.20	3.21	3.28	3.78	3.17	3.21	3.57
K ₂ O	1.86	1.80	1.66	2.11	3.46	3.57	3.62	3.73	3.92	3.83	2.96
Cr ₂ O ₃	0.052	0.50	0.051	0.052	0.040	0.038	0.036	0.030	0.054	0.040	0.09
P ₂ O ₅	0.79	0.75	0.76	0.74	0.48	0.49	0.50	0.50	0.44	0.49	0.59
LOI	0.3	0.3	0.4	0.5	0.2	0.3	0.5	0.9	1.1	0.2	0.47
Total	99.33	99.87	99.38	99.37	99.57	99.56	99.79	99.51	99.58	99.51	99.55
Rb	52.7	44.8	44.9	60.3	96.9	105.3	97.6	93	123.7	100.2	81.9
Sr	1743	1670	1681	1621	909.0	887.3	956.6	1215	699.8	924.4	1230.7
Cs	1.0	1.3	0.8	1.3	3.2	3.5	3.3	2.5	3.2	2.3	2.2
Ba	2366	2170	1943	2166	1364	1417	1443	1891	1130	1495	1738.5
Be	1	2	1	2	2	2	1	2	2	2	1.7
Ga	20.4	19.7	19.7	20.1	19.0	18.1	18.7	19.2	16.1	17.5	18.9
Hf	1.8	2.7	0.9	2.8	4.0	5.1	2.8	3.2	5.5	3.1	3.2
Sn	2	1	bdl	1	1	2	2	bdl	2	1	1.2
Nb	6.1	8.2	8.5	8.3	12.5	11.7	11.4	13.4	13.8	12	10.6
Ta	0.3	0.5	0.6	0.5	0.7	0.8	0.8	0.9	1	0.8	0.7
Th	2.6	3.3	2.1	3.4	5.6	8.5	6.8	5.1	6.2	3.2	4.7
Tl	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.4	0.3	0.2	0.2
U	0.6	0.7	0.5	0.8	1.6	1.9	1.6	1.7	1.6	0.9	1.2
W	70.7	73.8	57.0	74.1	83.1	91.2	72.3	38.0	98.9	151.6	81.1
Y	19.0	19.5	17.9	19.6	20.3	20.3	20.8	15.4	19.1	19.4	19.1
Zn	32	28	31	29	18	24	18	42	27	17	26.6
Zr	48.1	85.7	35.4	85.9	128.9	182.3	76.4	123.1	192.5	91.7	105.0
K	15441	14943	13781	17516	28724	29637	30052	30965	32542	31795	24573
Rb/Sr	0.03	0.03	0.03	0.04	0.11	0.12	0.10	0.08	0.18	0.11	0.1
K/Sr	0.89	0.89	0.82	1.08	3.16	3.34	3.14	2.55	4.65	3.44	2.4
K/Rb	293	334	307	290	296	281	308	333	263	317	300
K/Ba	0.65	0.69	0.71	0.81	2.11	2.09	2.08	1.64	2.88	2.13	1.6
Ba/Rb	44.90	48.44	43.27	35.92	14.08	13.46	14.78	20.33	9.14	14.92	25.9
La	45	43.5	42.7	43.6	40.3	41	42.6	49.5	39.8	37.7	
Ce	97.3	95.8	95.5	96.2	87	90.3	89.5	101.5	82.5	75.7	
Pr	11.23	11.07	10.84	11.09	9.68	9.68	9.93	11.06	9.42	8.96	
Nd	43.9	43.8	45.8	44.3	37.9	37.3	37.8	40.1	34.9	34.4	
Sm	7.58	6.98	6.97	7.26	6.28	6.40	6.39	6.46	6.31	6.28	
Eu	2.59	2.20	2.56	2.47	1.81	1.73	1.80	2.06	1.51	1.79	
Gd	5.83	5.68	5.48	5.71	5.33	5.72	5.35	4.80	4.77	4.92	
Tb	0.75	0.76	0.73	0.78	0.73	0.68	0.74	0.61	0.7	0.71	
Dy	3.50	3.77	3.36	3.79	3.80	3.71	3.56	3.01	3.7	3.58	
Ho	0.63	0.71	0.69	0.71	0.72	0.69	0.71	0.58	0.66	0.66	
Er	1.81	1.75	1.72	1.76	2.10	1.96	1.85	1.48	1.9	1.78	
Tm	0.23	0.23	0.23	0.23	0.29	0.22	0.26	0.19	0.28	0.26	
Yb	1.44	1.59	1.42	1.61	1.81	1.76	1.77	1.30	1.74	1.69	
Lu	0.20	0.22	0.20	0.22	0.26	0.25	0.24	0.21	0.25	0.24	
La/Yb	31.25	27.36	30.07	27.08	22.27	23.30	24.07	38.08	22.87	22.31	

Table 2: Average compositions of charnockites in the study area (Oxides in wt % and elements in ppm).

Sample	Awo (n = 4)	Osuntedo (n = 6)
SiO ₂	52.47	57.50
TiO ₂	1.18	0.95
Al ₂ O ₃	15.56	14.03
Fe ₂ O ₃	8.08	7.40
MnO	0.13	0.12
MgO	7.99	5.67
CaO	7.52	5.82
Na ₂ O	3.43	3.31
K ₂ O	1.86	3.69
Cr ₂ O ₃	0.16	0.04
P ₂ O ₅	0.76	0.48
LOI	0.38	0.53
Total	99.49	99.59
Rb	50.68	102.78
Sr	1678.75	932.02
Cs	1.10	3.00
Ba	2161.25	1456.67
Be	1.50	1.83
Ga	19.98	18.10
Hf	2.05	3.95
Sn	1.00	1.33
Nb	7.78	12.47
Ta	0.48	0.83
Th	2.85	5.90
Tl	0.20	0.25
U	0.65	1.55
W	68.90	89.18
Y	19.00	19.22
Zn	30.00	24.33
Zr	63.78	132.48
Rb/Sr	0.03	0.12
K/Sr	0.92	3.38
K/Rb	306.00	299.67
K/Ba	0.72	2.16
Ba/Rb	43.13	14.45
La	43.70	41.82
Ce	96.20	87.75
Pr	11.06	9.79
Nd	44.45	37.07
Sm	7.20	6.35
Eu	2.46	1.78
Gd	5.68	5.15
Tb	0.76	0.70
Dy	3.61	3.56
Ho	0.69	0.67
Er	1.76	1.85
Tm	0.23	0.25
Yb	1.52	1.68
Lu	0.21	0.24
La/Yb	28.94	25.48
Ce/Ce*	4.38	4.34
Eu/Eu*	0.39	0.33

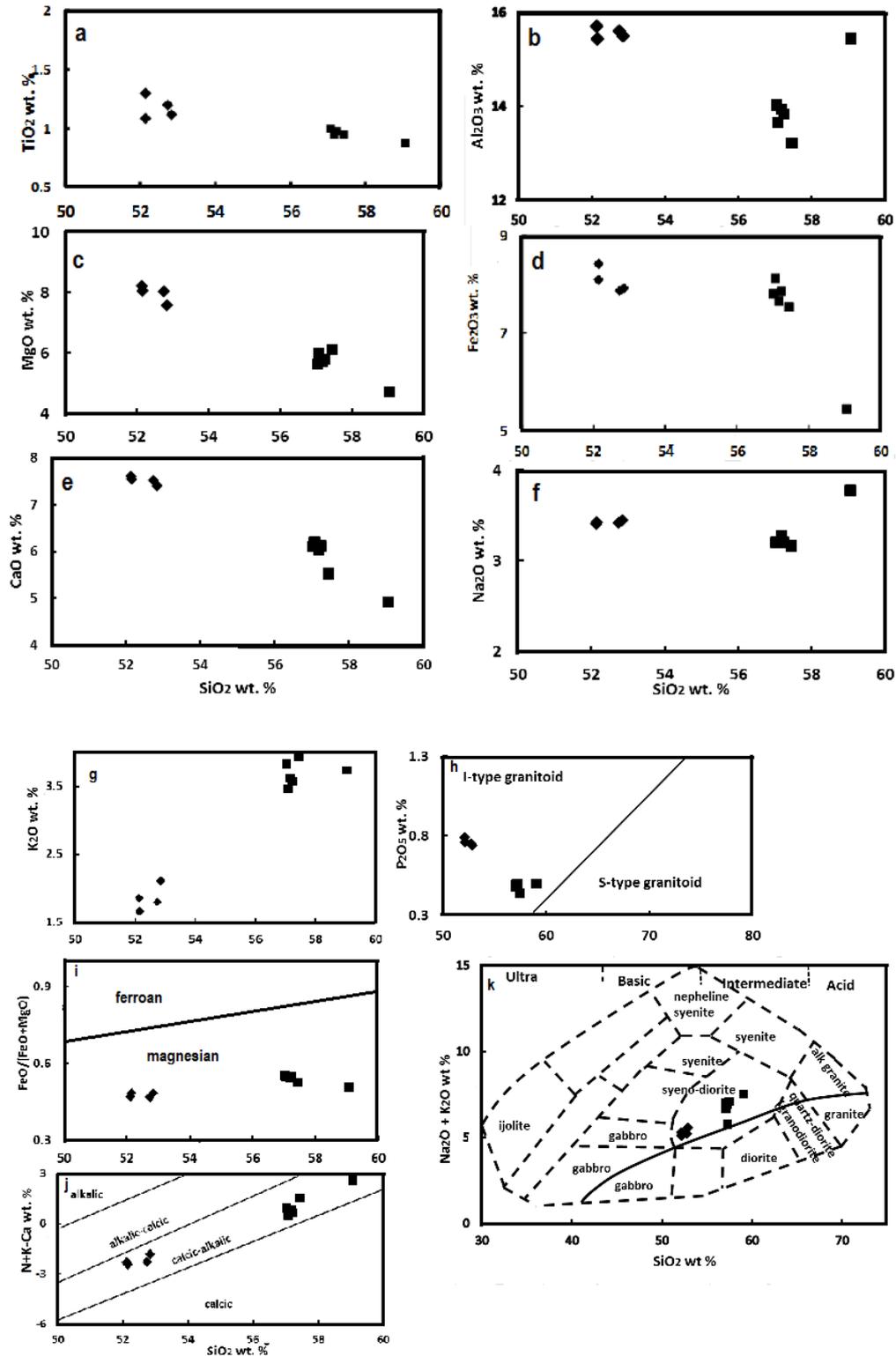


Figure 4: Harker diagrams for the charnockites in the study area, ♦: Awo charnockite, ■: Osuntedo charnockite

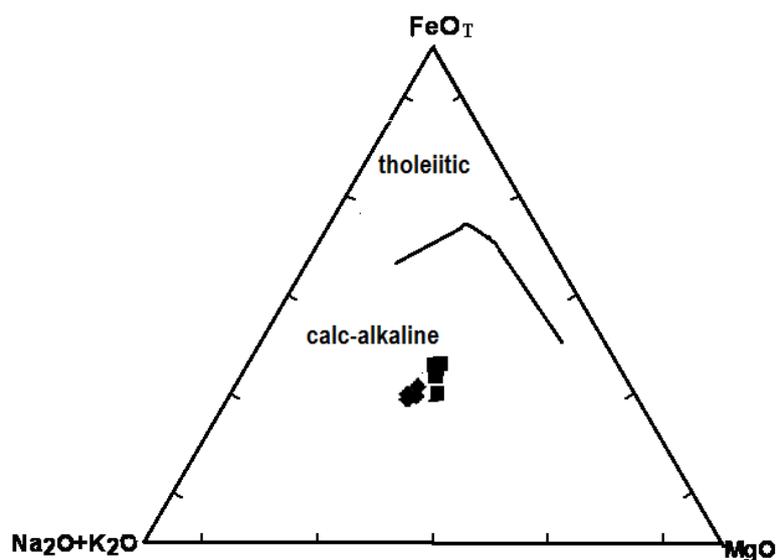


Figure 5: AFM diagram for the charnockites in the study area. Symbols as defined in Figure 4.

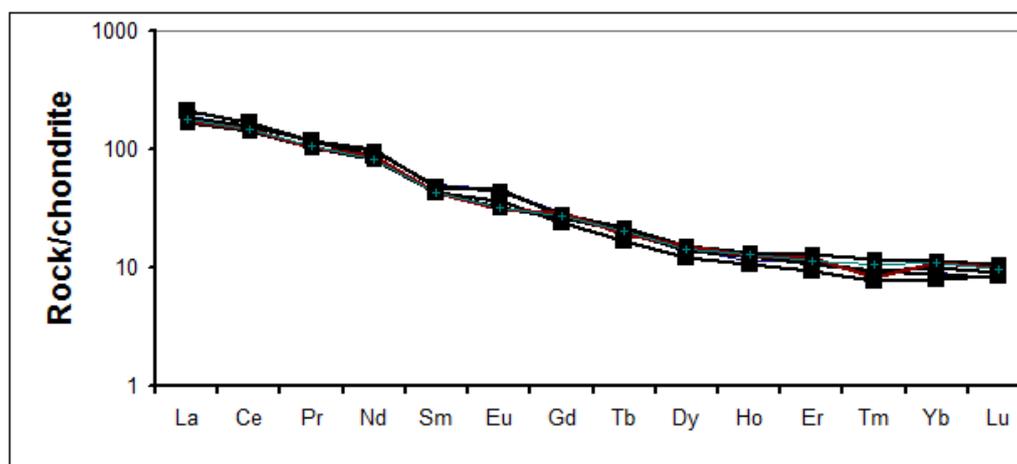


Figure 6: Chondrite normalized REE diagram for all the charnockites in the study area

The variations of SiO_2 with major elements are shown on the Harker variation diagrams (Figure 4). The data generally cluster into two groups on these diagrams. This is due to the slight differences in the chemical compositions of the charnockites from both Awo and Osuntedo areas. The Osuntedo charnockite is more enriched in SiO_2 than that of Awo. There are fairly simple negative correlations between SiO_2 and TiO_2 , MgO , CaO , Na_2O , Al_2O_3 and P_2O_5 (Figure 4a, b, c, e, f and h) while K_2O shows positive correlation (Figure 4g). Olarewaju (1988) and Frost *et al.* (2000) got similar trends for charnockites around Ado-Ekiti/Akure in Nigeria and Louis Lake Batholith, Wyoming, United States of America, respectively. On the plot of SiO_2 vs P_2O_5 (Figure 4h), the charnockites

fall in the field of igneous granitoid (I-type granitoid) of Chappel (1999). The average aluminum saturation index (ASI) is ~ 1.0 for Awo charnockite and 1.3 for the Osuntedo rock. Aluminum saturation index is deduced from $\text{Al}/(\text{Ca}-1.67\text{P}+\text{Na}+\text{K})$ (Frost *et al.* 2001). This shows that the rocks are weakly peraluminous. There is presence of a small amount of other mineral phases (other than feldspars) that can accommodate Al. The Plot of SiO_2 vs. $\text{FeO}/(\text{FeO}+\text{MgO})$ (Figure 4i) shows the charnockites to be essentially magnesian (Frost *et al.* 2001). The alkali-lime index plot: SiO_2 vs. $\text{Na}_2\text{O}+\text{K}_2\text{O}-\text{CaO}$ (Figure 4j) and the AFM diagram (Figure 5) indicate that the rocks belong to the calcic-alkalic plutons.

On the plot of total alkalis vs SiO_2 (Figure 4k), the Osuntedo rock plot in the syeno-diorite field but that of Awo nearer the gabbroic field, both correspond to rocks of basic to intermediate compositions respectively. The Awo charnockite is more basic while Osuntedo tends to intermediate.

The trace and rare earth elements data presented in Tables 1 and 2 show that the Osuntedo charnockite has higher mean abundances of Rb, Be, Hf, Sn, Nb, Ta, Th, U, W, Y, K, Er, Tm, Yb, Lu and K/Rb, K/Sr, La/Yb, Ce/Ce* and Eu/Eu* ratios while mean values of other trace elements are lower than that of Awo rock. The rare earth elements (REE) data are presented as a chondrite-normalized plot (Figure 6). Generally, the rocks show similar REE chondrite normalized patterns with almost flat plateaus at Eu indicating neither strong enrichment nor depletion of Eu, and very small europium anomalies ($\text{Eu}/\text{Eu}^* = 0.99\text{-}1.47$) with an average of 1.2. Eu* is the value obtained at the europium position by a straight-line interpolation between the plotted points for Sm_n and Gd_n (chondrite normalized values).

The REE pattern is almost flat at Eu. Although, the REE chondrite pattern gently slopes to the right (Figure 6), there is not much deviation from the curvilinear pattern of the Masuda-Coryell diagram. This indicates a lack of tetrad effects in this rock except for very weak tetrad effect two (TE2) at Nd to Gd. Tetrad effects are indication of melt/fluid interaction during crystallization. The lack of tetrad effect in the charnockites corroborates the dry assemblages in the rocks.

The average La/Yb ratios of 28.94 and 25.48 are respectively for Awo and Osuntedo charnockites. These indicate a greater LREE fractionation in the rock.

From the plots of $\log \text{Th}/\text{Yb}$ vs $\log \text{Ta}/\text{Yb}$ and $\log \text{Y}+\text{Nb}$ vs $\log \text{Rb}$ (Figures 7 and 8), the charnockites have an affinity to rocks derived from enriched mantle (EM), that is primary magma and were emplaced in terrane similar to arc region of an active continental margin (AC). The mantle origin of the charnockitic melt is further confirmed by the spider diagram (Figure 9). The values used for the plotting of the spider diagram were normalized to those of the primordial mantle of McDonough and Sun (1995). In the spider diagram, there are pronounced troughs at Nb, Ta, Hf and Zr with peaks at K, Sr and Ba (Figure 9). These patterns are characteristics of subduction-related crustal components (Wilson, 1989). This again supports derivation from mantle with contamination from the crust. Equally, the charnockites by their contents, particularly high Ba and Sr, suggest rock of calc-alkaline suite. The high Cr (in ppm.) may also indicate mantle or deep crustal origin. It has been noted that granitic rocks are rarely formed from a single source, but mixtures of melts derived from mantle and crustal materials (John and Wooden, 1990). The stability of anhydrous mineral assemblage of the charnockites may be due to the enrichment of Fe (Frost *et al.*, 2001). From the above observations, the charnockites can be categorized as Fe-enriched magnesian I-granitoid of calc-alkaline with basic to intermediate composition derived from the mantle with crustal input.

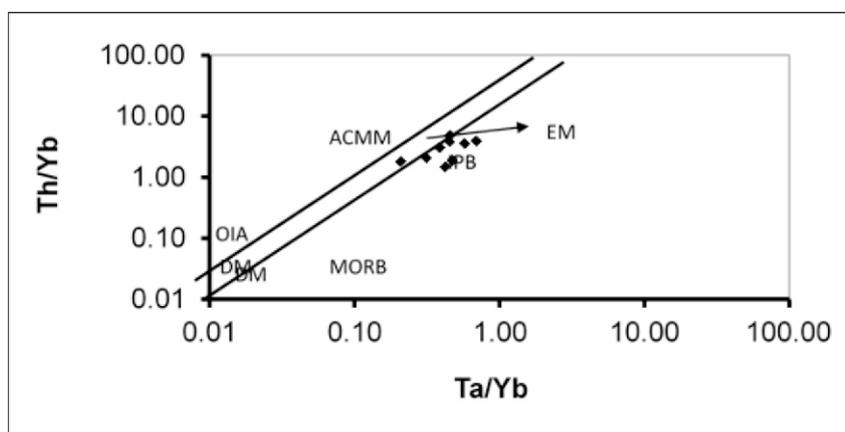


Figure 7: Plot of $\log \text{Ta}/\text{Yb}$ vs. $\log \text{Th}/\text{Yb}$ for charnockites in the study area (after Pearce, 1983; Wilson, 1989)

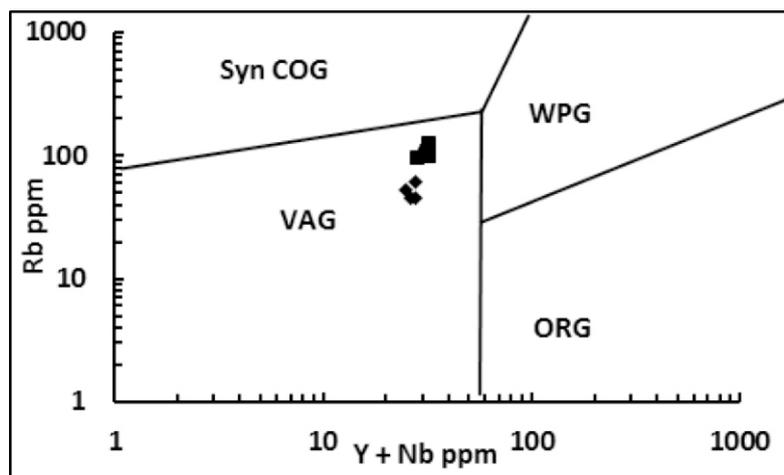


Figure 8: Plot of log Y+Nb (ppm) vs log Rb (ppm) for charnockites in the study area (after Pearce *et al.*, 1984). Syn-COG: syn-collisional granitoids, WPG: within plate granitoids, VAG: volcanic arc granitoids, ORG: ocean ridge granitoids. Symbols as defined in Figure 4.

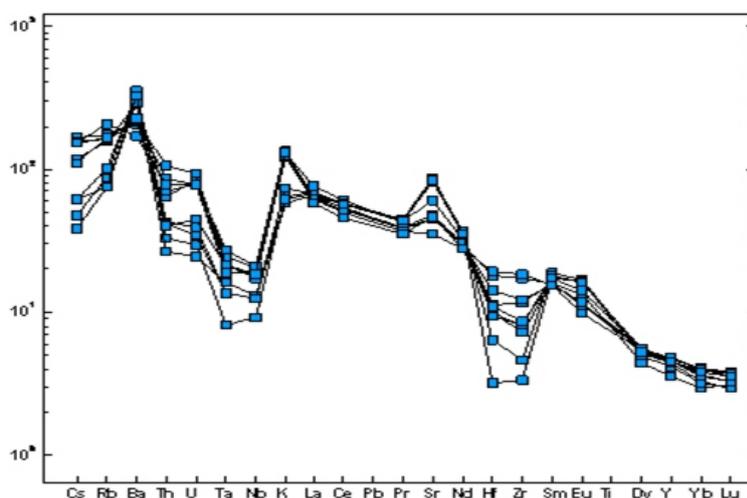


Figure 9: Spider diagram for charnockites in the study area. Elements are normalized to primordial mantle values of McDonough and Sun (1995).

DISCUSSION

The charnockite in southwestern Nigeria has been thought of to be products of granulite facies metamorphism, though they occur in amphibolite facies terrane. The new geochemical data particularly the K/Rb ratios (306 for Awo and 300 for Osuntedo rocks) do not support this widely held view. Guo *et al.* (2002) put K/Rb ratios of less than 350 of basic rocks corresponding to products of normal igneous rocks. This is further supported by the fact that no rock of granulite facies has been reported in that area. Ukaegbu and Beka (2007) recorded lower ratios (179-288) for the charnockites in some areas of eastern Nigeria where they exclusively occur in granulite facies terrane. The near linear variation of major elements in Harker diagrams, the calc-alkaline

nature of the rocks and small range in compositions of K_2O and Na_2O suggest a single source of magma for charnockites.

The compositional trend of the charnockites differs significantly from the Fe-enriched C-type magmas of Kilpatrick and Ellis (1992). Many charnockites are of tholeiitic affinity (have A-type characteristics), but some, like the charnockites of the study area and those from south India and Louis Lake Batholith, have a calc-alkalic affinity. Using the propositions of several workers on the classification of igneous, it is curious that Awo charnockite plots in the alkali-calc alkali fields (for example R1-R2 plot of Frost *et al.*, 2001; Kilpatrick and Ellis, 1992). Fe number is most strongly affected by the differentiation path, this is

expected to give more information better than diagrams that deal with the tectonic on differentiation path of the parental charnockite. Frost and Frost (1997) suggested that iron-enriched melts from reduced basaltic sources (either tholeiitic or mildly alkali) make an important contribution to ferroan granitoids. Magnesian granitoids are probably related to island arcs. It must be noted that there is no reason for any type of granitoid to be restricted to a particular tectonic environment (Frost *et al.*, 2001). This is because the geochemistry of granitoids is a reflection of the chemistry of the source magma (Pearce *et al.*, 1984). Although, charnockitic plutons can have a wide range of FeO/FeO+MgO from fairly magnesian to very iron-rich (Frost and Frost, 2008), the charnockites under study correspond to those of high magnesian which is similar to those of Amaravathi (Ramaswamy and Murty, 1973), Desliens (Percival *et al.*, 2003), Louis Lake (Frost *et al.*, 2000) and Mawson (Young *et al.*, 1997). Kilpatrick and Ellis (1992) considered the intermediate between ferroan and magnesian to correspond to C-type” magmas.

According to Frost and Frost (2008), charnockites are formed in four tectonic environments: i. rift-related, ferroan magmatism; ii. deeply eroded cordilleran-type plutons; iii. Caledonian-type plutons; and iv. deep crustal melting related to granulite metamorphism or to the emplacement of hot ferroan magmas. The studied charnockites have an affinity with the Caledonian-type variety which occurs as small, magnesian, alkali-calcic to alkalic plutons that formed during delamination of thickened continental crust after a collisional orogeny. The charnockite of Ballachulish has also been recognized to be in this category (Frost and Frost, 2008).

CONCLUSION

Though the rocks have dry assemblage, the present geochemical evidence does not support granulite melting derived charnockite but purely igneous origin derived from the mantle with crustal input. The rocks also did not undergo any appreciable fractionation.

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CONFLICT OF INTEREST

The author declares there is no conflict of interest.

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