

Petrochemical Characterization of Basaltic Dykes in Nkor Noni Area of Mount Oku, Cameroon Volcanic Line: Constrain on the Source of Magma and the Geotectonic Setting

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Abstract The Nkor Noni area is located in Mount Oku, the fourth largest volcanic massif of the tertiary Cameroon Volcanic Line (CVL). The basement formation of the area is made up of Pan-African granitoids, crosscut by numerous basaltic dykes. Within the central domain of Pan-African Fold Belt in Cameroon, many basaltic dykes were subjected to detailed studies; but their sources and tectonic setting are still controversial. The basaltic dykes of Nkor Noni area are sub-vertical and strike N077°E to N085°E. They exhibit a microlitic/porphyritic texture made up of olivine, pyroxene, plagioclase and opaque minerals. Geochemically, the basaltic dykes of Nkor Noni area have a SiO₂ content of 44.72 - 45.68 wt%, low MgO of 5.90 - 6.22 wt%, Fe₂O₃ of 12.55 - 13.22 wt.%, low Mg# (31.7-32.9%), relatively high TiO₂ (2.54 - 2.63 wt%) indicating a more evolved magma, with an alkaline affinity similar to some basalts outcropping along the CVL. Primitive mantle normalized rare earth element (REE) patterns display a slight enrichment in Light Rare Earth Elements (LREE) over Heavy Rare Earth Elements (HREE) with LaN/YbN values of 7.5 - 8.7, and Eu/Eu* of 0.979 to 1.012, demonstrating a null or none Eu anomaly. The Nkor Noni basaltic dykes were generated from 15% partial melting of a source rock having a spinel-garnet lherzolite composition, with very slight crustal input. They show a subduction-to collision-related magmatism and Within Plate geotectonic setting. Their rare earth element patterns are similar to those of the Manjo, Dschang, Maham and Kedem basaltic dykes outcropping along the CVL, suggesting the same mantle source with variable degrees of crustal contamination.

Keywords: Nkor Noni, Basaltic dykes, alkaline, Within Plate, Cameroon Volcanic Line

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1. Introduction

The Cameroon Volcanic Line (CVL) is a unique feature in Africa even in the world, a geological lineament made up of volcanic massifs in the ocean and in the continent [1,2]. Those volcanic edifices were emplaced into the North Equatorial Pan-African Fold Belt (PAFB) and/or Tertiary sedimentary cover [3]. In the central part of the PAFB in Cameroon, dykes are found cutting across the Precambrian basement formed mainly by syn-to-late tectonic granitoids which intruded into gneissic basement [4]. A study of basaltic dykes intruding these Precambrian granitoids can give a better understanding of the tectono-

magmatic history of the region [4] and also throw more light as to whether these dykes are linked to the CVL or to PAFB fractures. According to Simeni et al. [5], the emplacement of dykes is controlled by pre-existing Precambrian fractures. Tchaptchet et al. [6], in kekem area demonstrated that the basaltic dykes in the area were generated by partial melting of sub-continental enriched lithospheric mantle. Some of these dykes have been dated in Cameroon and their isotopic ages gave a better understanding of the origin of these dykes. Poorly constrained K/Ar ages (417 ± 8.1 Ma; 214 ± 6.6 and 148 ± 3.8 Ma) for two of such mafic dykes in the Bangangte area indicated that these basalts could be related to the opening of the South Atlantic Ocean and less likely to the initial stages of the building up of the Cameroon Volcanic Line.

This study presents new petrographic and geochemical data for Nkor Noni basaltic dykes that intrude the panafrican granitoids. Data will be used to discuss the petrogenesis of the dykes, to investigate the possible nature of the mantle source beneath the mount Oku, and to compare their REE patterns with those of other dykes outcropping within the Adamawa Yade Domain (AYD) of the Pan African Fold Belt (Manjo, Dschang, Maham, kekem and Kedem dykes), and also those along the CVL (Mt. Cameroon, Barombi Koto, Mt Oku).

2. Geographical Context and Location of Study Area

Nkor Noni is located on the Oku Massif, specifically the NE flank of Mount Oku in Bui Division of the Northwest Region, Cameroon (Figure 1). The area lies between longitudes $10^{\circ}31'12''\text{E}$ and $10^{\circ}38'24''\text{E}$ and latitude $6^{\circ}21'30''\text{N}$ and $6^{\circ}26'30''\text{N}$. It has a total surface area of 88.7 km^2 bordered to the North by Awi and Kecheve, to the West by Ketcha, to the East by Mbinon and to the South by Mbizenaku and Barten. The area of study is accessible from Bamenda to Noni through the major road (national road N^o 3). Apart from these major roads, we have minor roads access. They also have footpaths especially on the hills (Figure 2.a). This area is covered by the Oku Volcanic Massifs made up of volcanic mounts with Mount Oku having the highest elevation of 3011 m [7]. The study area has an undulating topography with the highest elevation registered at 2250 m on the

mountains, and the lowest measured at 1100m above sea level in the valleys. The area has an interesting view of both U-shaped and V-shape escarpments. Mountains and hills in the area show characteristics of pointed, rounded to sub-rounded tops and few low lands (Figure 2b). Nkor Noni and surrounding area have many streams and rivers that take their source area from the various domes (Ebanaia, Esense and Etakum etc). The streams and their tributaries produce a dendritic drainage pattern into the landscape (tree-like drainage patterns, Figure 3).

3. Geological Background of Nkor Noni Area

The Nkor Noni area, located in the North-West region of Cameroon, geologically belongs to the mount Oku, the fourth larger volcanic massif of CVL, within the Adamawa Yade domain of the Pan African North Equatorial Fold Belt in Cameroon, regarding the Precambrian basement formations (Figure 4B). The Cameroon Volcanic Line (CVL) is a continental intraplate volcanic province [8,9], made up of Cenozoic volcanic massifs and, running for approximately 2000 Km from the Palagu Island in the Atlantic Ocean to Lake Chad (Figure 4B). Majority of volcanic rocks along the CVL are mafic, from alkaline to transitional basalts, but few felsic volcanic rocks have been described in mount Manengouba [10], mount Bamboutos [11,12], mount Bangou [13,14], Kapsiki plateau [15], and mount Bamenda [16,17,18].

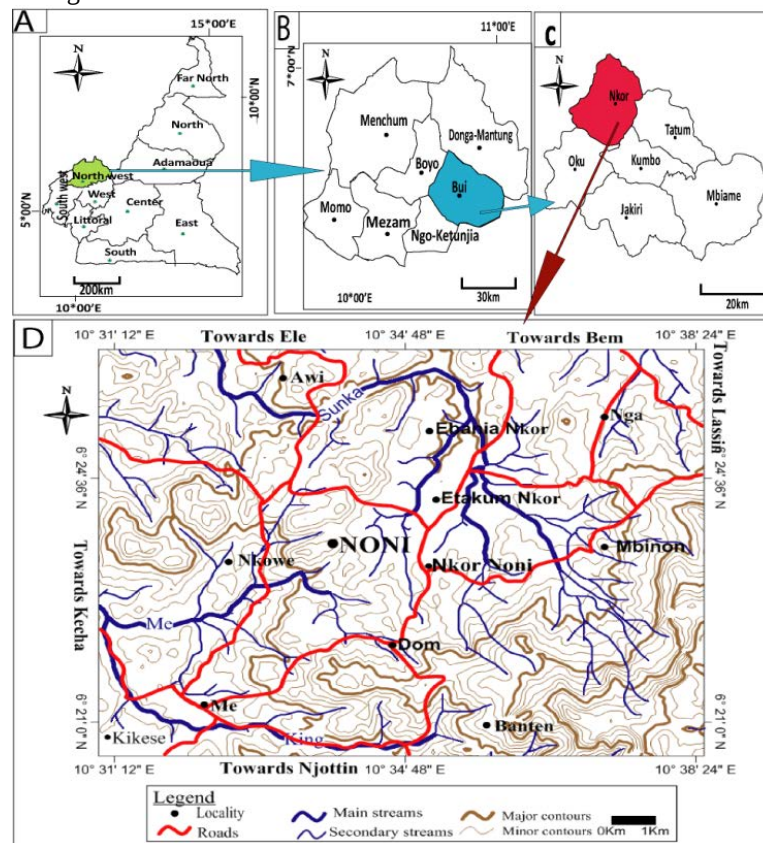


Figure 1. (A) Location of study area in Cameroon map; (B) Location of North West region; (C) Location of Nkor Noni in Bui Division; (D) Location of study area in Nkor Noni Sub Division

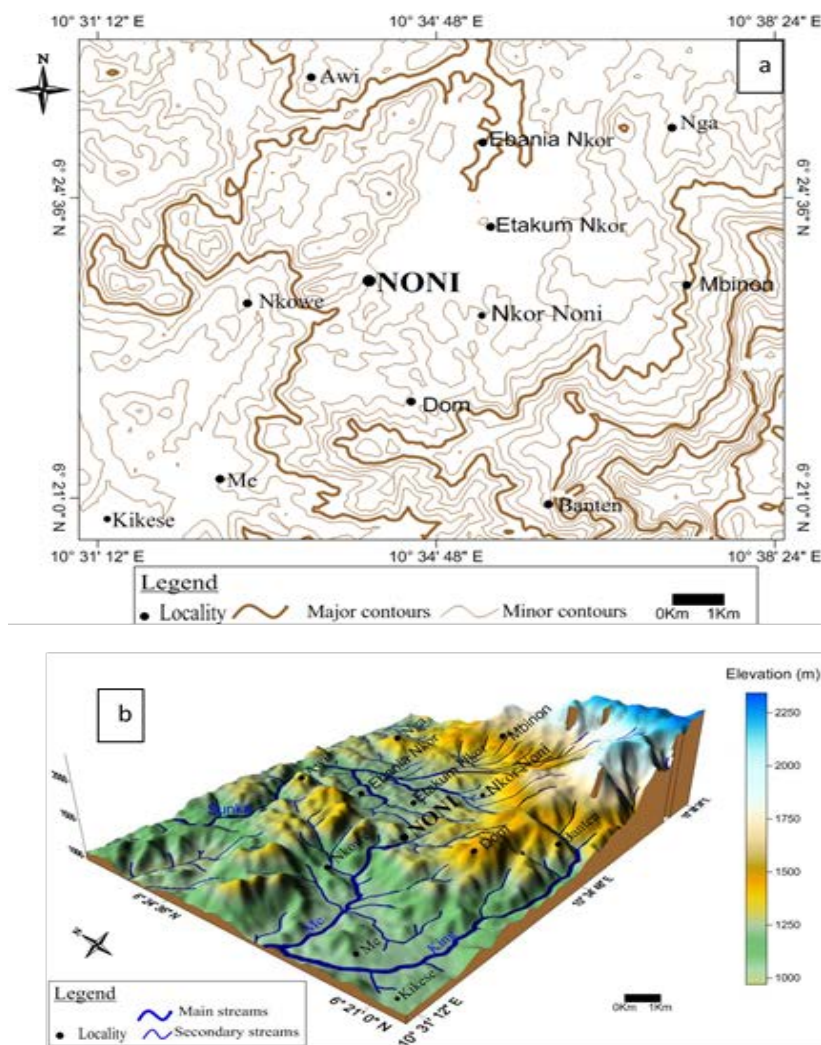


Figure 2. a) Topography map of the Nkor Noni area; b) 3D representation of Nkor Noni area showing the geomorphology of the area

The Pan-African Fold Belt located in the North of the Congo craton is a mega-tectonic structure defined by a system of NE-trending faults comprising Tchollire-Banyo Fault (TBF), Adamawa Fault (AF), Sanaga Fault (SF) and Kribi-Campo Fault [19], and consisting of metamorphic and plutonic rocks reworked or formed during the Pan African orogeny [20,21]. The Pan African domain in Cameroon is divided into of three geological domains (Figure 4C) namely: Adamawa Yade domain, Yaoundé domain and North-western Cameroon domains [22]. The Adamawa Yade Domain which yield our study area is the largest Domain. It extends eastward from Central Cameroon which is bordered to the North by the TBF and to the south by the Yaoundé Domain. The AYD is a complex and heterogeneous domain with high grade gneissic rocks extensively intruded by the Pan African granitoids and cut by late transcurrent faults [22].

Generally, the Pan African Fold Belt is assumed to be formed by convergence and collision between the Congo Craton-Sao Francisco and the West African Cratons [23,24] in the Neoproterozoic [22]. The enigmatic or ghost Saharan metacraton was also involved in this collision [25,26]. Post orogenic granitoids include sub-circular plutons of dominantly alkaline composition, which are concentrated generally East of the Tcholliré-Banyo fault. Doleritic, microgranitic, and basaltic dykes are also related to this group. A lot of work has been done on

basaltic (mafic) dykes in Cameroon especially in AYD, such as; the basaltic dyke swarms from Dschang, Bangante, Manjo areas [4], in Kekem area by [6], in Bafoussam area [27], Likok and Mbaoussi areas in Ngaoundéré [28,29], and Nyos dykes [30].

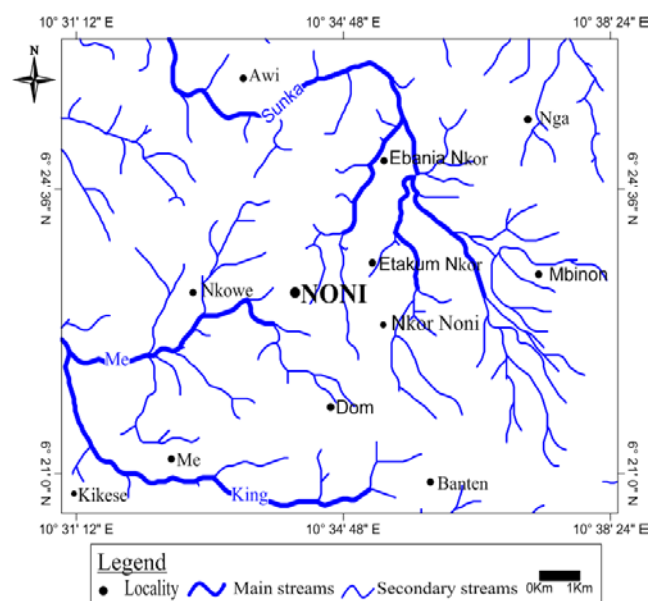


Figure 3. Hydrographic map of the Nkor Noni area

3. Analytical Methods

After the petrographic characterization of rock units of the Nkor Noni area, 07 representative samples were selected for whole rock chemical analysis. Major elements were analysed by X-ray fluorescence spectrometry (XRF) and trace elements by inductively coupled plasma-mass spectrometry (ICP-MS) from pulps. The samples were shipped to ACME Analytical Laboratory Ltd, Vancouver Canada for chemical analysis. Half of each samples collected was crushed, split, pulverized (250 g rock to 200 mesh, 85% passing 200 mesh) and analysed for a range of elements. After crushing and milling, samples were split and 50 - 60g of each sample was obtained for the analysis. These samples are decomposed by lithium tetraborate/lithium metaborate/ sodium nitrate ($\text{Li}_2\text{B}_4\text{O}_7/\text{LiBO}_2/\text{NaNO}_3$) fusion.

3.1. X-ray Fluorescence Analysis (XRF)

A prepared solution of 0.66g from each sample was dried at 1050°C to remove moisture and to ensure that the hygroscopic nature of the material does not add error to the analysis. A test portion of each of the dried material was then fused using lithium tetraborate/lithium metaborate/sodium nitrate flux in a platinum gold crucible and cast in a disc, well mixed and fused in a furnace at 1000°C . The resulting melt was then cooled and dissolved in 100ml of 4% nitric acid and 2% HCl. These solutions were then analysed by XRF (in an XRF spectrometer) and the results were corrected for spectral inter-element interferences. Oxides concentrations were calculated from the determined elemental concentration and the result were reported in that format. The oxides are calculated in percentages with an upper limit of 100 and a lower limit of 0.01. These oxides include Al_2O_3 , BaO , CaO , Cr_2O_3 , MgO , P_2O_5 , K_2O , SiO_2 , Na_2O , and TiO_2 . Samples with high contents in sulphide were substituted with peroxide fusion in order to obtain better results. Another portion of the dried samples were roasted at 1000°C to determine the loss on ignition.

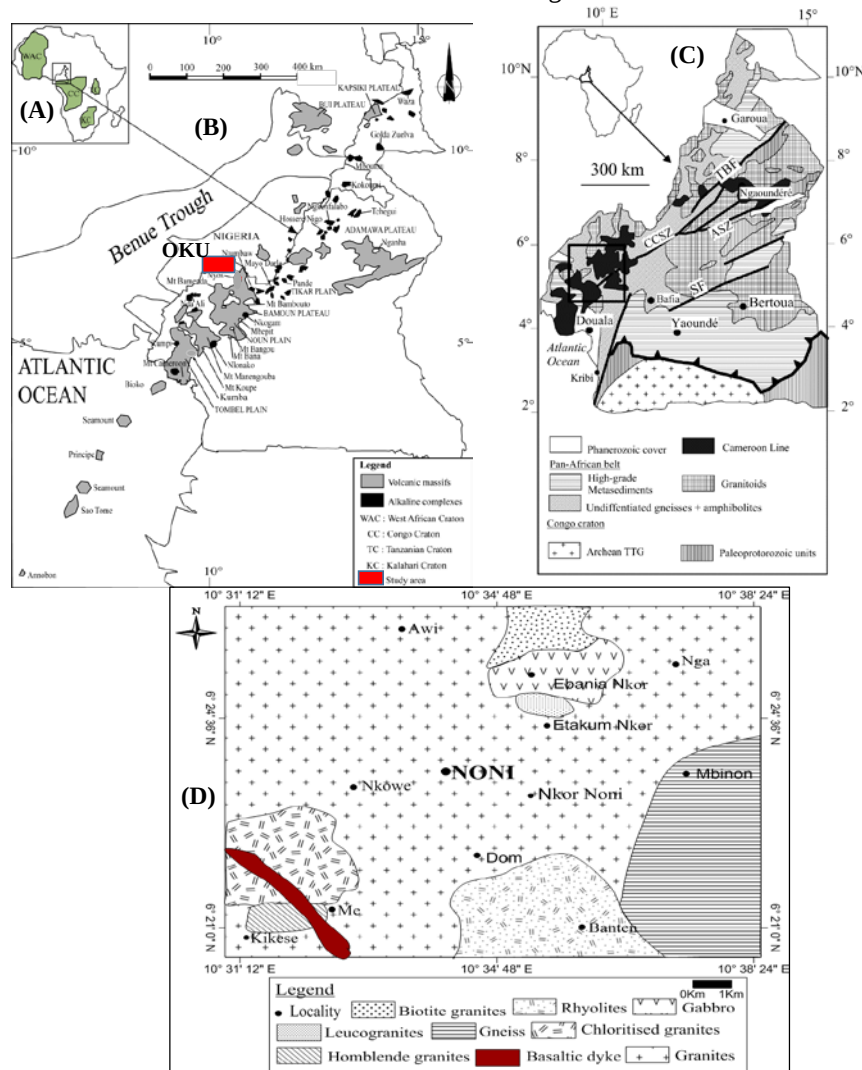


Figure 4. (A) The position of the Cameroon Volcanic Line (CVL) in Africa and the major cratons; (B) the CVL with major Cenozoic centers showing the position of Oku Volcanic Group (OVG - square) where Nkor Noni is located; (C) Geologic sketch map of Cameroon showing the main lithostratigraphic domains of the Neoproterozoic Pan-African orogenic belt, adapted from [59] and [60]. Dashed line represents the assumed geophysical limit of the Congo craton after Toteu et al. (2004); (D) Geologic map of study area. CASZ = Central African Shear Zone, SF: Sanaga Fault, ASZ: Adamawa Shear Zone, CCSZ: Central Cameroon Shear Zone, FSZ=Foumban Shear Zone, Inset shows the map of Africa. TBF: Tcholliré-Banyo Fault. Geology map of Cameroon after [60]

3.2. Laser Ablation with Inductively Coupled Plasma Mass Spectrometry (LA-ICP-MS)

Samples used in analyses of trace elements concentrations were decomposed by lithium borate fusion (FUS-LI01), and later analysed using Inductively Coupled Plasma-Mass Spectroscopy (ICP-MS). Here, a prepared sample of 0.2g was added to lithium borate flux (0.9g), well mixed and fused in a furnace at 1000°C. The resulting melt was then cooled and dissolved in 100ml of 4% HNO₃/2%HCl solution. The solution was then analysed by ICP-MS. These analyses included both the REE and trace elements.

4. Results

4.1. Petrography

4.1.1. Macroscopic Description

In the field, the investigated basaltic dykes are found intruding the granitic outcrops (Figure 5a) especially along the river beds (River Me). These dykes striking generally N077°E to N085°E are subvertical, with an average width of 30 cm. In hand specimen, the rock is fine-grained, dense and dark grey in colour with various dimensions (Figure 5b). The phenocrysts include: olivines, pyroxenes, plagioclases and opaque minerals occurring both as phenocrysts and groundmass.

4.1.2. Microscopic Description and Textures

Under the cross-polarized light microscope, the studied basaltic dykes from Nkor Noni mainly have microlitic porphyritic textures (Figure 5c, Figure 5d and Figure 5e), characterized by the occurrence of mineral crystals of varied sizes and proportion. **Olivines** (22%) crystals are euhedral with dimensions varying between 0.1 mm to 0.15 mm, they are light blue to light green in colour with a lot of cracks (Figure 5c, Figure 5d and Figure 5e). they are in association with opaque minerals (Figure 5e). **Pyroxenes** (32 %) minerals vary from 0.2 mm to 0.18 mm euhedral to subhedral crystals, with variable colours from blue to brown, bearing opaque mineral inclusions (Figure 5d et 5f), with cracks in some sections. In the most of samples, the large olivine and pyroxene crystals are strongly fractured (Figure 5c et 5e). **Plagioclase** (33%) crystals are disseminated in the whole rock and occur as elongated, prismatic crystals laths, they are grey to colorless, and some present polysynthetic twinning, (Figure 5c, 5d and 5f). **Opaque minerals** (13 %) appear commonly dark with subhedral to anhedral crystal habit– shiny to black in colour. The minerals sizes vary from 0.6 mm to 0.67 mm with inclusions of the microlites, with some crystals showing reaction rims (Figure 5e), and others occurring as inclusions in olivines and pyroxenes, while majority are disseminated in the groundmass.

4.2. Geochemistry

4.2.1. Major Elements

A total of eleven (11) oxides from seven (07) rock

samples were analyzed and the major elements concentrations are presented in Table 1. The results show that the Nkor Noni basaltic dykes are alkaline in composition. The Al₂O₃ contents vary from 15.98 to 16.35 wt. %. The SiO₂ contents vary between 44.73 to 45.68 wt%. The studied samples present high TiO₂ contents (2.54 - 2.63 wt%). The MgO concentrations are between 5.90 to 6.22wt %). The Mg# values vary between 31.7 to 32.9 wt% (Mg# = 100*Mg/Mg+Fe⁺²). K₂O contents range between 1.68 to 2.11 wt% and the total alkali (Na₂O+K₂O) vary from 4.97 to 5.33 wt%.

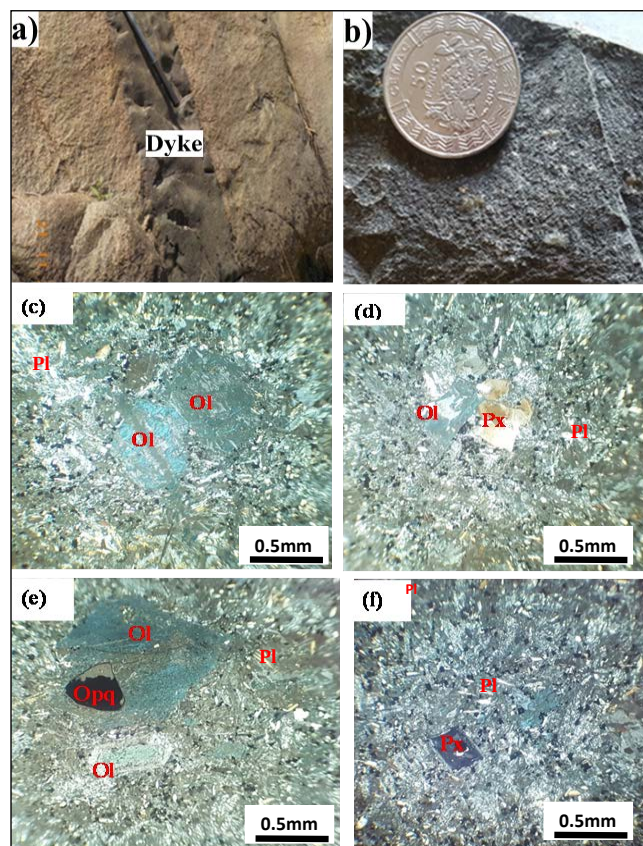


Figure 5. Field aspects and photomicrographs of the thin sections of the representative basaltic dyke. (a) Field characteristics of the dyke; (b) Hand specimen of the basaltic dykes; (c, d, e and f) Microlitic porphyritic textures showing a large Olivine and pyroxene crystals in mesostase; (e) Olivine with opaque mineral inclusion

Table 1. Whole rock major elements data (wt %) from the Nkor Noni basaltic dykes

Sample	FD1	FD3	FD4	FD5	FD6	FD7	FD8
SiO ₂	45.50	45.57	44.72	45.36	45.68	45.48	44.73
Al ₂ O ₃	16.19	15.98	16.02	16.35	16.04	16.17	16.10
Fe ₂ O ₃	12.55	12.84	13.22	12.63	12.65	12.67	13.09
MgO	5.90	5.97	6.14	5.91	6.22	6.21	6.10
CaO	7.78	7.43	7.76	7.58	7.63	7.66	7.55
Na ₂ O	3.44	3.20	3.40	3.33	3.37	3.41	3.02
K ₂ O	1.89	2.05	1.73	1.82	1.60	1.68	2.11
TiO ₂	2.54	2.65	2.59	2.55	2.63	2.60	2.57
P ₂ O ₅	0.48	0.45	0.45	0.42	0.44	0.44	0.40
MnO	0.21	0.21	0.22	0.23	0.22	0.22	0.25
Cr ₂ O ₃	0.013	0.014	0.014	0.014	0.013	0.014	0.016
TOTAL	99.56	99.59	99.39	99.65	99.63	99.67	99.64
K ₂ O+NaO	5.33	5.25	5.13	5.15	4.97	5.09	5.13
K ₂ O/Na ₂ O	0.55	0.64	0.51	0.55	0.47	0.49	0.70

According to the total alkali vs. silica (TAS) binary classification diagram [31], the Nkor Noni basaltic dykes plot in the basalt domain and are alkaline (Figure 6A). In the K_2O+Na_2O vs. SiO_2 classification diagram [32] the Nkor Noni basaltic dykes fall in the alkaline domain; the alkaline affinity is also confirmed by the K_2O vs. SiO_2 binary diagram, where the studied basaltic dykes are alkaline rocks (Figure 6B). The basaltic dykes of Nkor Noni are Low-Mg basic rocks as expressed by the binary diagram Fe_2O_3 vs. MgO [33], with $MgO < 7$ wt% (Figure 6C). The Low-Mg characteristics of the studied basaltic dykes have been observed by several authors in the basalts of the CVL.

4.2.2. Trace and Rare Earth Elements

Analyses of trace elements were carried out on 47 elements which are presented in Table 2. The Sr contents vary from 504.6 to 587.3 ppm. The Nb concentrations vary between 24.9 to 32.2 ppm. Co and Ni contents are from 36.6 to 44.1 ppm and 51 to 71 ppm respectively. The REE spectra normalized to chondrite and primitive mantle after [34], compared with others from Cameroon Volcanic Line [35, 36] show that the Nkor Noni basaltic dykes have fractionated REE patterns ($La_N/Yb_N = 7.57 - 8.71$), which revealed a slight enrichment in light Rare Earth Elements (La, Ce, Nd and Sm), and a depletion in heavy Rare Earth Elements (Gd, Dy, Er, Yb, and Lu) (Figure 7). The basaltic dykes show a null or none Eu anomaly with Eu/Eu^* (0.98 - 1.01) with $Eu/Eu^* = Eu/(Sm_N * Gd_N)^{1/2}$.

Table 2. REE and Trace elements data (ppm) from the Nkor Noni basaltic dykes

	FD1	FD3	FD4	FD5	FD6	FD7	FD8
	Rare Earth Elements						
La	28.1	26.7	29.6	27.7	25.9	26.5	24.9
Ce	59.7	56.7	58.3	54.2	55.8	56.0	50.4
Pr	7.05	6.79	7.13	6.63	6.56	6.60	6.02
Nd	29.3	26.8	30.4	27.1	27.8	27.8	25.3
Sm	6.23	5.81	6.11	6.02	6.06	5.81	5.33
Eu	2.06	1.95	2.06	1.99	1.99	1.99	1.80
Gd	6.56	6.37	6.78	6.41	6.05	6.23	5.74
Tb	0.96	0.87	0.96	0.95	0.90	0.94	0.86
Dy	5.29	5.17	5.32	5.36	5.22	5.40	4.86
Ho	1.01	1.00	1.03	1.00	0.96	1.01	0.95
Er	2.79	2.76	2.93	2.86	2.77	2.83	2.53
Tm	0.39	0.37	0.37	0.33	0.38	0.37	0.35
Yb	2.26	2.28	2.29	2.24	2.29	2.36	2.03
Lu	0.34	0.34	0.33	0.32	0.32	0.34	0.32
	Trace Elements						
Be	1	2	3	2	1	2	<1
Co	36.6	39.7	44.1	40.5	37.6	38.5	41.4
Cs	0.9	1.2	1.1	0.8	1.0	0.9	1.1
Ga	19.7	19.2	20.2	19.0	19.2	19.3	17.5
Hf	4.8	5.0	5.5	4.7	4.8	4.8	4.7
Nb	30.2	28.7	32.2	26.0	28.2	28.5	24.9
Rb	127.0	148.3	131.9	110.1	111.8	122.1	148.6
Sn	2	2	2	2	2	2	2
Sr	568.8	539.8	587.3	504.6	521.3	527.2	542.9
Ta	2.1	2.1	1.8	1.7	2.0	2.0	1.7
Th	2.4	2.4	2.3	2.2	2.1	2.1	2.0
U	0.7	0.9	0.6	0.8	0.8	0.7	0.7
V	209	228	228	227	227	226	242
W	0.6	<0.5	5.9	<0.5	0.5	<0.5	<0.5
Zr	220.6	217.4	242.9	197.8	217.9	213.0	195.1
Y	27.6	26.5	29.2	31.4	27.4	30.9	24.2
Th/U	3.429	2.667	3.833	2.75	2.625	3	2.857
Eu/Eu*	0.986	0.981	0.979	0.98	1.005	1.012	0.996
La_N/Sm_N	2.829	2.882	3.038	2.886	2.68	2.86	2.93
La_N/Yb_N	8.43	7.939	8.763	8.384	7.668	7.613	8.316
Dy_N/Yb_N	1.524	1.477	1.513	1.558	1.485	1.49	1.559

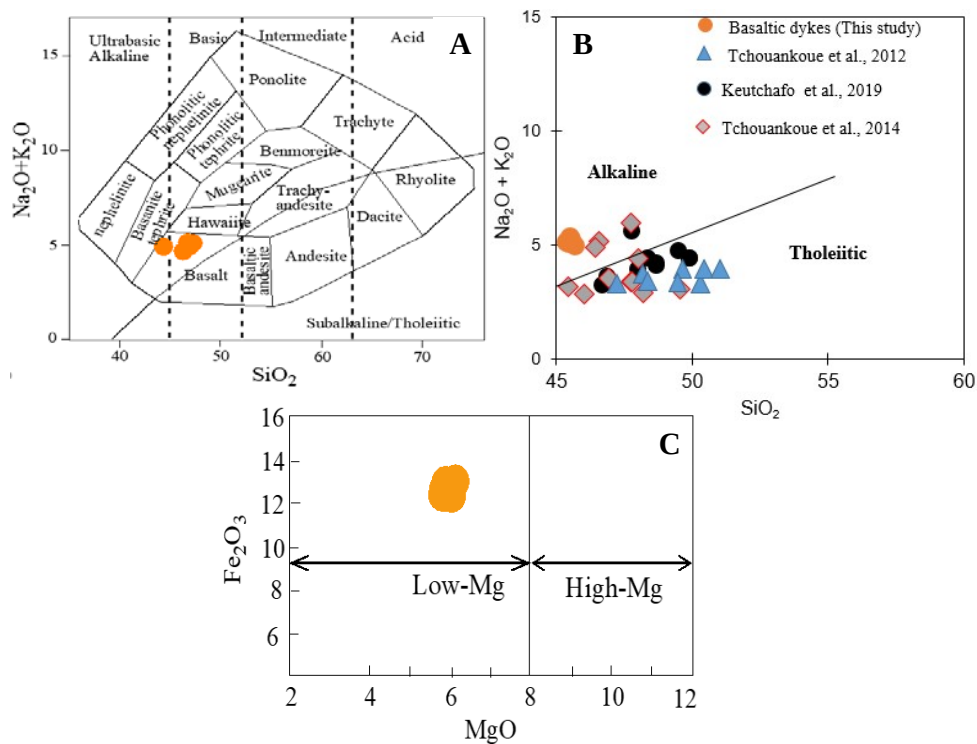


Figure 6. (A) The Total Alkali silica TAS ($\text{K}_2\text{O} + \text{Na}_2\text{O}$ vs. SiO_2) classification diagram of [31] for the Nkor Noni basaltic dyke. The line after [61] delineates the boundary between alkaline and subalkaline domains; (B) Total alkali-Silica classification diagram of [32] for Nkor Noni basaltic dykes. The line after [61] delineates the boundary between alkaline and tholeiitic domain; (C) Fe_2O_3 vs. MgO classification diagram of [33] for the Nkor Noni basaltic dykes showing low Mg- characteristics

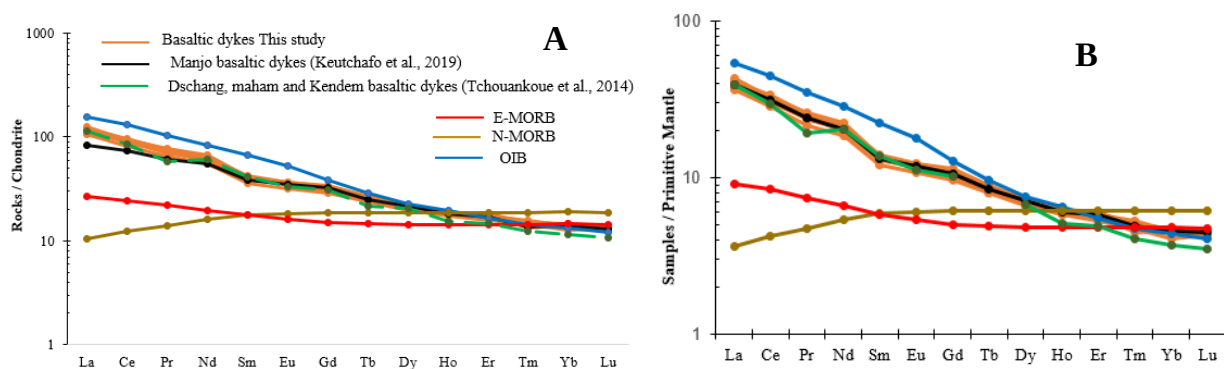


Figure 7. Rare Earth Elements pattern of the Nkor Noni basaltic dykes normalized to chondrite (normalized values are from [34]). OIB: Ocean Island Basalts; E-MORB: Enriched Mid Ocean Ridge Basalts; N-MORB: Normal Mid Ocean Ridge Basalts

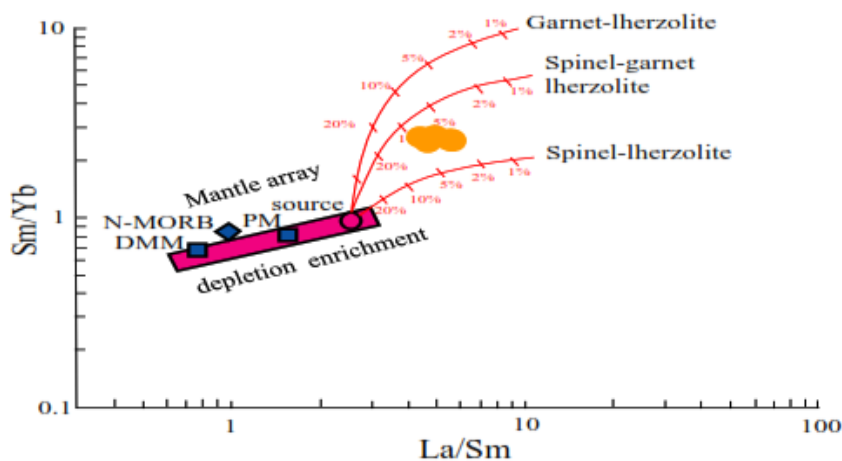


Figure 8. Sm/Yb vs. La/Sm diagram after [44] showing spinel-garnet lherzolite partial melting of the Nkor Noni basaltic dykes

5. Interpretation and Discussion

The chemical composition of the basaltic dykes of the study area is similar to other basalts along the CVL [6,37,38,39,40], but they relatively evolved basaltic magmas with Mg# varying between 31.7 and 32.9. They belong to alkaline series which is concordant with those of the volcanic massifs of Adamawa [41], a weakly Mount Cameroon alkaline series [42], Mount Bamenda and Mount Oku [44], also have an alkaline affinity [43]. This result confirms that the Nkor Noni basaltic dykes yield similar alkaline nature with the majority of the rocks along the CVL.

5.1. Partial Melting and Source of Magma

The magma that cooled to put in place the basaltic dykes was produced by the partial melting of 15% of a source rock having a spinel-garnet lherzolite composition (Figure 8). The low trace elements concentrations in the basaltic dykes also confirm a high degree of partial melting. This is illustrated by the Sm/Yb vs. La/Sm diagram [45,46]. The mineral/matrix partition coefficients are from the compilation of Depleted MORB Mantle (DMM) composition; [45], the Primitive Mantle (PM) and Enriched-Mid Oceanic Ridge Basalt (E-MORB) compositions [47].

The origin of the basaltic magma (source rock) is attributed to the lithospheric or asthenospheric origin. The partial melting of about 15% is clearly expressed by the Dy/Yb vs. La/Yb diagram [48], indicating the partial melting of a spinel-garnet lherzolite. From these diagrams (Figure 8 et 9), the basaltic dykes in our study area and most basalts along the CVL: Mount Cameroon, Mount Barombi-koto, Mount Bamenda and Mount Oku show a trend which is parallel to the melting curve of spinel-garnet lherzolite according to [49], indicating the same source of magma but different degrees of partial melting. The high degree of partial melting (15%) displayed by the basaltic dykes of the study area (Figure 9), compared to the medium degree partial melting of Mount Oku (12-14%), and the low degree partial melting of Mount Cameroon (8%) indicate the same source of magma but different degrees of partial melting due to the heterogeneity of the mantle.

The spinel-garnet peridotite revealed as source rock is from Enriched-Mantle (EM) as shown in the Zr/Nb vs. Nb/Th classification plot (Figure 10A) after [50,51], and from Primordial Mantle (PM) which has experienced little or no depletion. The primordial mantle (PM) source of basaltic melt of samples is illustrated in the Zr/Nb vs. MgO [66] differentiation plot (Figure 10B). This indicates that the Nkor Noni basaltic dykes represent a different episode of magmatism from that of Mount Oku, implying that Mt Oku and the Nkor Noni basaltic dykes were emplaced by different magmatic episodes.

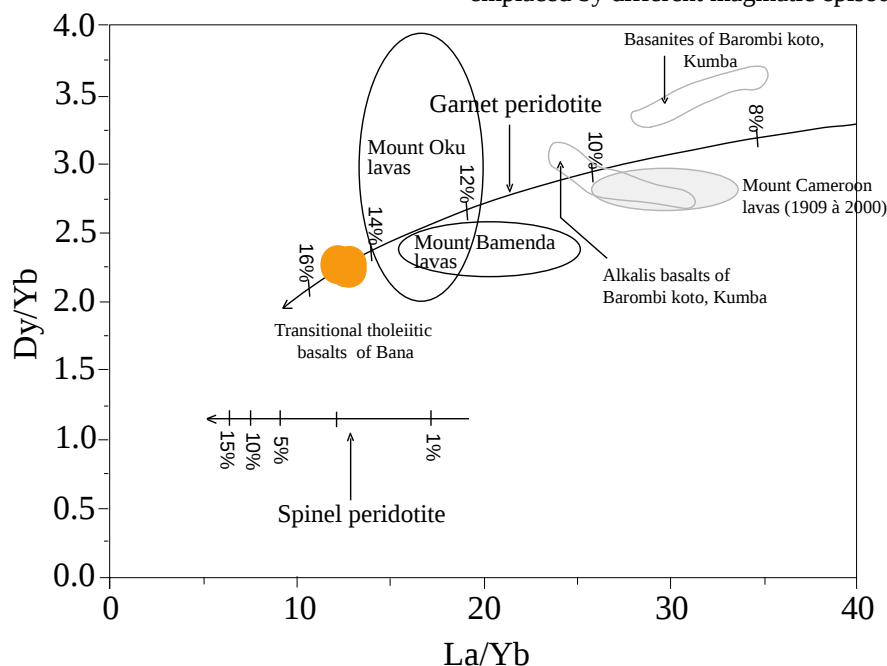


Figure 9. Partial melting curve for spinel-garnet lherzolite of Dy/Yb vs. La/Yb [47] compared with basic lavas from Mounts Cameroon and Barombi Koto [62,63]. The trend of the basaltic lava of the study area falls within the high degrees (15%) of partial melting of a spinel-garnet lherzolite compared to the low degree partial melting (garnet peridotite) of Mt. Cameroon (8-10%), medium degrees of Barombi Koto and high degree of Mt Oku (12-14%)

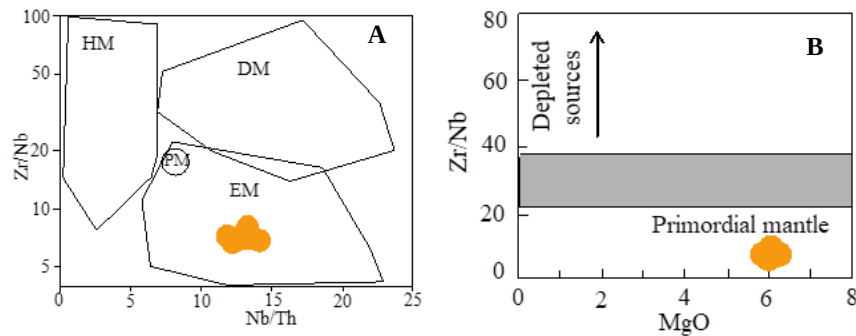


Figure 10. (A) Nb/Th vs. Zr/Nb diagram after [48,49]; (B) Zr/Nb vs. MgO diagram after [64]

5.2. Crustal Contamination

Trace elements ratios such as Nb/U, Th/Nb and La/Nb are used to assess the role of crustal contamination in basaltic rocks, because trace elements concentrations are not strongly modified from their source by processes like partial melting and fractional crystallization [6,52]. According to Rudnick and Gao [53], the continental crust has low Nb/U (4.4-25); high La/Nb (1.6-2.6) and Th/Nb (0.24-0.88). Ocean island basalt (OIB) and mid-ocean ridge basalt (E-MORB and N-MORB) yield high Nb/U (>45); low La/Nb (0.8–1.1) and Th/Nb (<0.1) ratios [40; 54], ratios. Nkor Noni basaltic dykes have high Nb/U (31.9-43.1), low La/Nb (0.9-1.1) and Th/Nb (0.1) ratios almost like that of the MORB and OIB, suggesting very slight crustal contamination. This is further confirmed by the negative Nb anomaly displayed on the Primitive mantle multi-elements patterns as compared to the Manjo and Kekem dykes with little or no crustal contamination. The nulle/none Eu/Eu* anomaly observed in Figure 7 indicates that plagioclase fractionation was minimal or irrelevant [52]. The low concentration of Ni, Cr and Co probably suggest their retention in the solid residue during partial melting in the mantle source region, or suggest crustal involvement during magma ascend. The Nkor Noni basaltic REE patterns is similar to the Manjo, Dschang, Maham, and Kedem dykes outcropping in the AYD of the PANEFB [38], suggesting same mantle source with variable degrees of crustal contamination.

5.3. Tectonic Setting

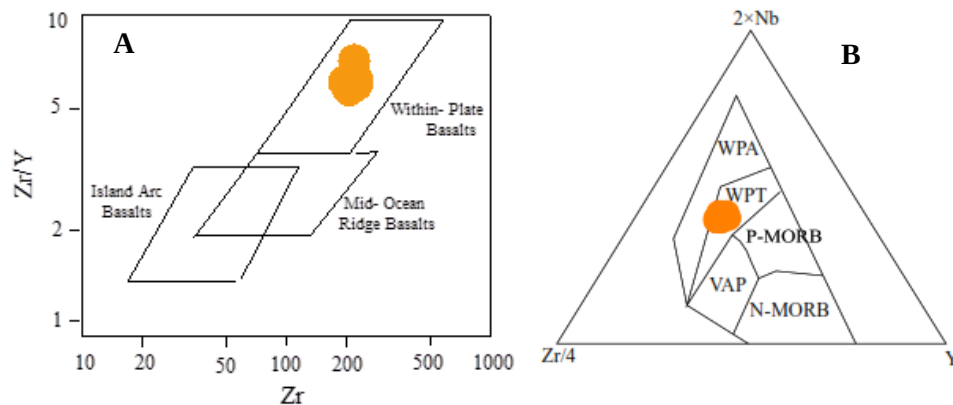


Figure 11. (A) The Zr vs. Zr/Y tectonic discrimination diagrams (after [53]); (B) Nb*2-Zr/4-Y diagram after [54]. The studied rocks fall within the tholeiitic plate (WPT)

The Zr/Y versus Zr geotectonic discrimination diagrams after [55,56] show that the Nkor Noni basaltic dykes plot in the field of Within Plate basalt or in a Within Plate Tholeiite Basalts (Figure 11A et 11B). Whereas on the Nb*2-Zr/4-Y diagram [56], the basaltic dykes of the study area fall in the Within Tholeiitic Plate (WPT), which is a similar result with Manjo dykes [52]. The Nkor Noni rocks show a subduction-to collision- related magmatism same as the Magba rocks [57], and therefore suggesting a syn-to post-collisional phase emplacement of the Pan African Orogeny.

LREE and HREE ratios such as La/Sm and Tb/Yb are used to evaluate the mantle source characteristics of Nkor Noni dykes because they are not strongly modified by processes such as fractional crystallization and crustal contamination processes. Subduction-zone related magmatism is characterized by (1) enrichment of light REE relative to heavy REE. (2) enrichment in LILE and (3) strong Nb negative anomaly [58]. Therefore, it is possible that the Nkor Noni basaltic dykes were generated from a mantle source that was metasomatized by subduction processes prior to the Neoproterozoic collision between the Congo-São Francisco, West African cratons and the Sahara Metacraton. This is supported by the works of Kwékam et al. [59] and Tchouankoue et al. [60] in the Pan African granitoids. Hence, we think that the Nkor Noni basaltic dykes just like the Manjo dykes were likely generated by partial melting of a metasomatized Sub Continental Lithospheric Mantle (SCLM, [50]) in a subduction related environment. There by pointing the fact that, the dykes are more related to the panafrican fractures, than to the formation of the CVL.

6. Conclusion

From the petrographic and geochemical investigations of the Nkor Noni basaltic dykes, the following conclusions can be drawn:

1. Nkor Noni area is characterized by basaltic dykes cutting across a granitic pluton. The basaltic dykes yield a microlitic-porphyratic texture made up of olivine, pyroxene, plagioclase opaque minerals and ground mass.
2. The Nkor Noni basaltic dykes are alkaline and show geochemical features which suggest the partial melting of metasomatized enriched sub continental lithospheric mantle source for a parent magma, in a subduction related environment with some crustal contamination in a within plate geotectonic setting.
3. The basaltic dykes in Nkor Noni show many similarities with other mafic dykes studied in Cameroon. They have similar REE patterns, same mantle source but variable degree of partial melting and crustal contamination. They show similar strikes, but no deformation features observed, indicating that the dykes were emplaced during the post Pan African tectonic events.

The rocks in Nkor Noni show a subduction to collision related magmatism, thereby suggesting their emplacement during the post-collisional phase of the Pan African Orogeny.

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