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Petrographic and Geochemical Characterization of Basalts in Bangangte Area (West Cameroon): Implications on Their Source

Pierre Wotchoko[1, *], Joëlle Flore Tene Djoukam[2], Gus Djibril Kouankap Nono[1], Patrice Arnaud Kouske[3], David Guymollaire Nkouathio[4], Solange Atenkia Fonkem[1]

[1]Department of Geology, Higher Teacher Training College, University of Bamenda, Bambili, Bamenda, Cameroon
[2]Department of Earth Sciences, Faculty of Sciences, University of Yaoundé 1, Yaoundé, Cameroon
[3]Institute of Technology, University of Douala, Douala, Cameroon
[4]Department of Earth Sciences, Faculty of Sciences, University of Dschang, Dschang, Cameroon

Email address:
pierrewotchoko@yahoo.fr (P. Wotchoko), joeflora2003@yahoo.fr (J. F. T. Djoukam), kouankap@yahoo.fr (G. D. K. Nono), arnaudpatricek@gmail.com (P. A. Kouske), nkouathio@yahoo.fr (D. G. Nkouathio), atenkiasolangefonkem@yahoo.com (S. A. Fonkem)

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Abstract: The Bangangte area belongs to the Cameroon Volcanic Line. The volcanic rocks exposure in the area consist of fine microlitic porphiritic Basalts which still poorly surveyed. Petrographically, the studied rocks are made up of minerals like plagioclase, clinopyroxene, olivine phenocrysts and a lot of opaque minerals within a very fine grained matrice. The Bangangte basalts are quartz normative free and are olivine, Diopside, Hypersthene normative. Alkaline (Na_2O + K_2O) contents vary from 2.247% to 5.46%. These rocks are low-Mg basalts with the Mg# values vary from 42.86 to 45.95 which are characteristic of primitive mantle source. The studied rocks are alkali to transitional basalts with Nb/Y ratio>1.5. Chondrite normalized spider diagram pattern of REE shows uniform patterns with enrichment in LREE and a relative depletion in HREE. While MORB normalized spider diagram pattern of multi elements reveals a negative anomaly with K_2O, with enrichement in LILE and depletion in HREE. The Eu anomalies are positive to nulle and are typical of alkali basalts. The Bangangté transitional alkali basalts were formed in intraplate setting of continental part of the CVL. They are the products of partial melting of about 13% of an asthenosphere made up of garnet peridotite. Geochemically, the studied basalts are similar to alkali basalts from Mount Bamenda.

Keywords: Bangangte, CVL, Alkali to Transitional Basalts, Asthenosphere, Garnet Peridotite

1. Introduction

The West Cameroon region constitutes an integral part of the Cameroon Volcanic Line (CVL), which is a megastructure in central Africa oriented N30°E and extending ~ 2000km in a length and ~ 100km in width. In Cameroon the tertiary volcanism seems to be related to a regional fracture trending N30°E [1], reactivated during the tertiary volcanism, [2, 3, 4, 5].

Basaltic rocks of various affinities constitute the greatest proportion of exposed rocks in the west Cameroon where they form a series of plateau basalts on which numerous works have been done [6, 7, 8]. Basaltic rocks along the CVL are Alkaline, tholeiitic, and transitional with the alkali basalts been the most studied along the Cameroon Volcanic line [9, 10]. Transitional basalts in the Cameroon Line Contain mostly clino-pyroxenes, high iron, plagioclases and are found to be within plate basalts [11]. Subalkaline, tholeiitic rocks are enriched in Fe relative to Mg, compared to calc-alkaline rocks, while silica remains relatively the same [12].

Investigation of basalts has been a subject of very few researchers in Bangangte area. In this paper, we present the preliminary data of transitional to alkalic basalts from Bangangte area, this include detailed petrographic description and whole rock geochemical characterization with the aim to constraint the source of their magma; therefore contribute to the knowledge database of the CVL.

2. Geological Setting

The Bangangte area (10°29'-10°42' E and 5°2'-5°15'N) is located along the Cameroon Volcanic Line (CVL) which extends from the island of Pagalu in the Atlantic ocean through the Gulf of Guinea up to the Lake Chad [13, 14, 15, 16]. The volcanism along the CVL began during the Eocene with the emplacement of the Bamoun plateau between 51.8 and 46.7 Ma [17] and mount Bangou between 44.7 and 43.1 Ma [8] and is still active, Mount Cameroon in 1999 and 2000 eruptions [18].

The CVL (Fig. 1) shows characteristic alignments of volcanoes, anorogenic complexes and grabens. The anorogenic complexes (about sixty: [19]) occur only on the continental section along the Cameroon Volcanic Line. They contain a range of rock types from very basic through intermediate to acid and have both plutonic and volcanic facies. The anorogenic complexes are therefore termed plutonic-volcanic anorogenic complexes [20]. The investigated massifs are composed of gabbros, diorites, monzonites, syenites and granites, and associated slightly younger volcanic rocks such as basalts, trachytes, phonolites and rhyolites (e.g., [21, 22, 20]). Basalts along the Cameroon Volcanic Line showed that they were derived from a depleted asthenospheric source beneath the sub continental lithosphere [23, 24], or from amphibole-bearing lithospheric mantle for the continental basalts [25]. Geophysical studies revealed that the Cameroon Volcanic Line is underlain by a thin crust of ca 30–34 km thickness [26, 27, 28]. The CVL origin has been the subject of several studies [25, 29, 16]. Recent studies suggest that the Cameroon Line follows a major structural zone in the lithosphere [28]. Bangangté area has a crystalline basement covered by volcanic projections which have not yet been studied in details.

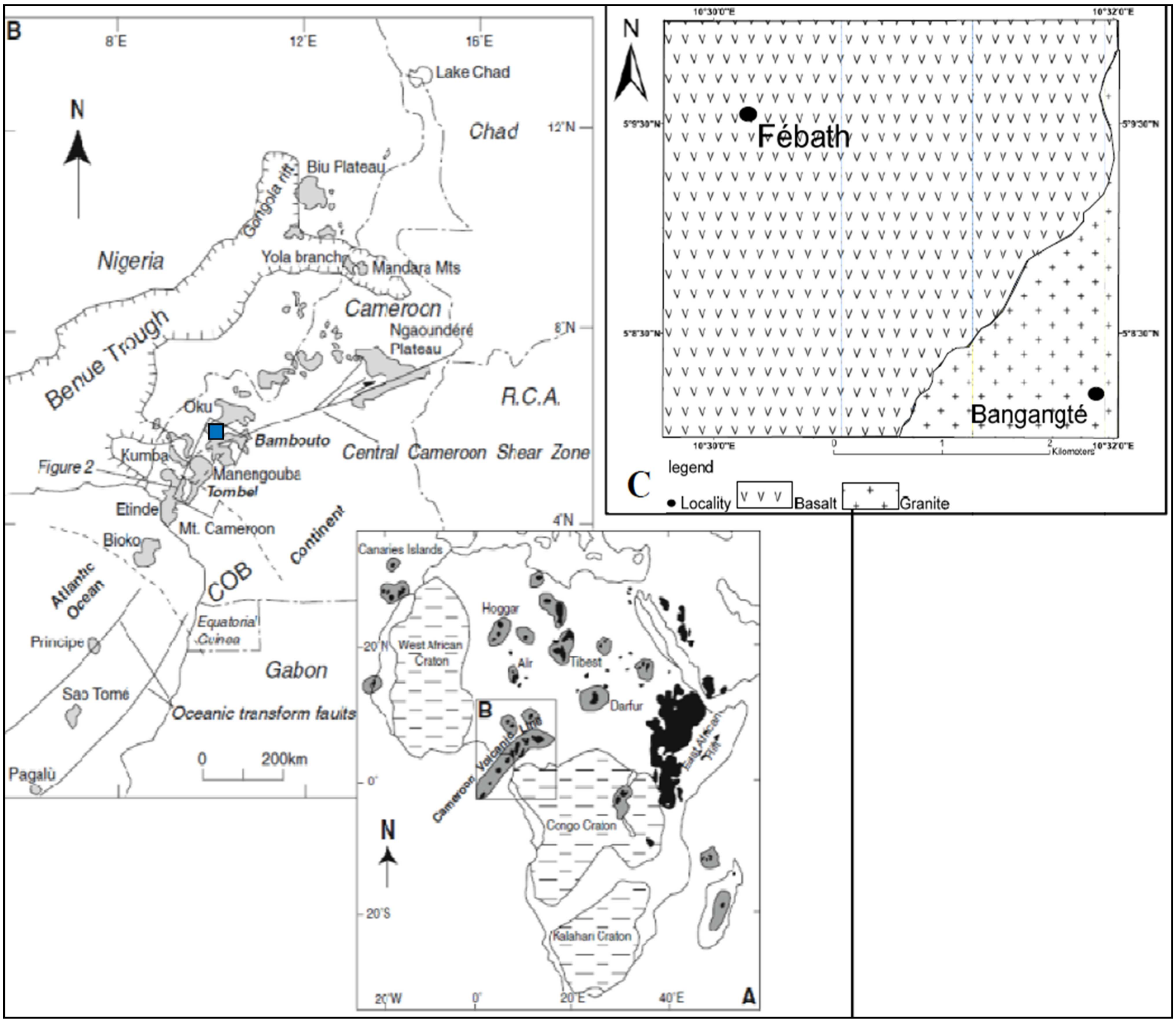

Figure 1. Location map and geological map of the study area; Modified after [30].

A) Location of CVL with other African major features, B) location of the CVL within a Cameroon map, the blues square represents the approximate position of Bangangté area, C) Sketch of geological map of Bangangté area showing the granitic basement cover by the volcanic rock.

3. Analytical Methods

Selected fresh samples were sent to Geotech lab Vancouver for thin sections and Nine (09) representative samples were sent to ALS Commercial Laboratories Canada for whole rock geochemistry.

For whole rock geochemistry, all the samples were pulverized to obtain homogenous samples. Analysis ofmajor oxides and trace elements was done by: Inductively Coupled Plasma - Atomic Emission Spectroscopy (ICP-AES).A prepared sample (0.200 g) is added to lithium metaborate/lithium tetraborate flux (0.90 g), mixed well and fused in a furnace at 1000°C. The resulting melt is then cooled and dissolved in 100 mL of 4% nitric acid/2% hydrochloric acid. This solution is then analyzed by ICP-AES and the results are corrected for spectral inter-element interferences. Oxides concentrations were calculated from the determined elemental concentration and the result was reported. The total oxide content is determined from the ICP analyte concentrations and loss on Ignition (L.O.I.) values. A prepared sample (1.0 g) is placed in an oven at 1000°C for one hour, cooled and then weighed. The percent loss on ignition is calculated from the difference in weight.

4. Petrography

Basalts in the study area occur both as blocks and massifs (Fig 2; A & B). The hand specimens are dark gray to black, dense and made up of fine grains minerals. Some samples contain cavities filled by quartz crystals. The main minerals that could be identified on the hand specimen are olivine and plagioclases.

Under the cross-polarized light microscope, the studied basalts from Bangangté area mainly have porphyritic textures (Fig2: C & D) and contain phenocrysts of olivine, clinopyroxenes, plagioclase and abundant opaque minerals.

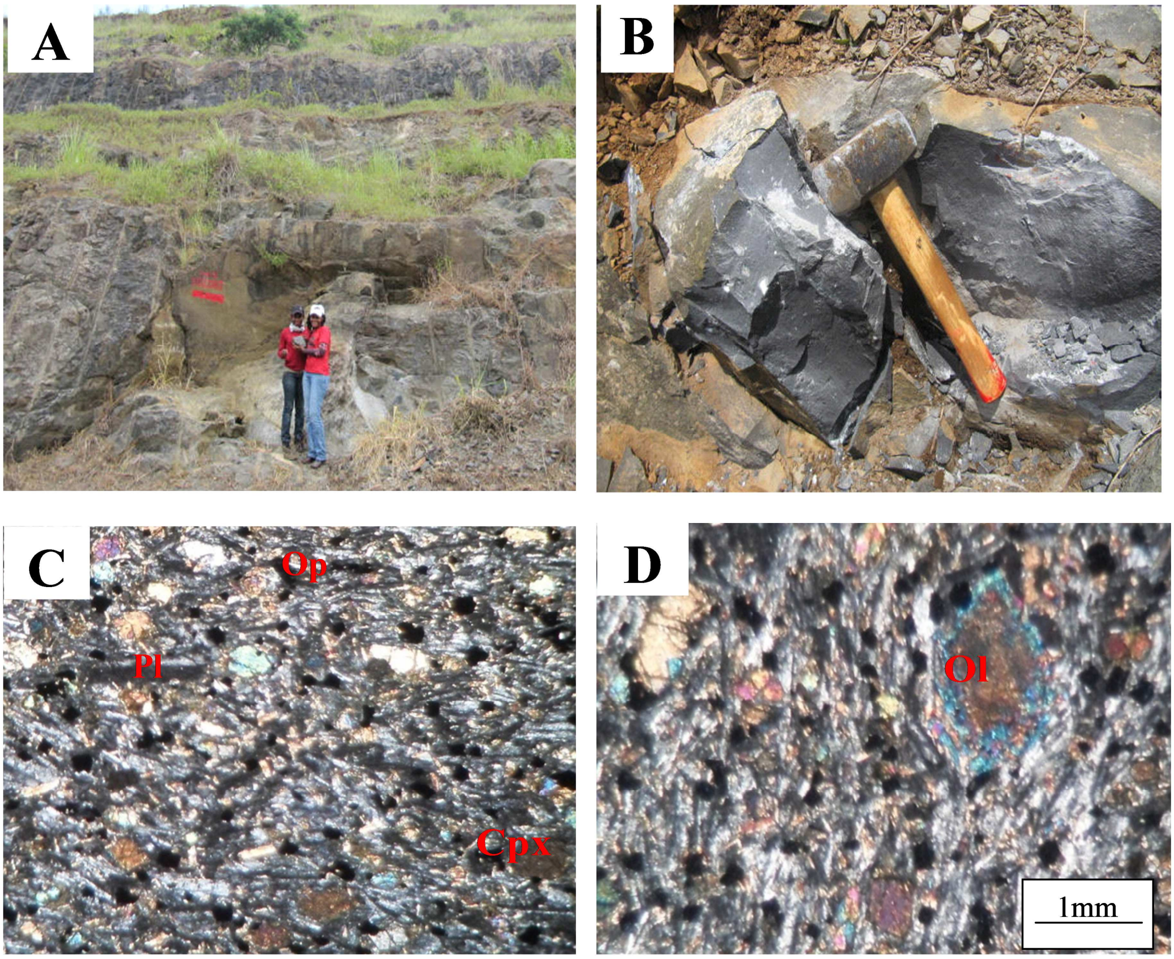

Figure 2. *Photographs (A & B) and photomicrographs (C & D) of basalts from Bangangté area.*

Olivine occurs as euhedral, subhedral or skeletal crystals, and makes up to 25% of the total volume of rock. They are about 0.002mm to 0.01mm in diameter and show irregular cracks, cleavages and slide alteration. Plagioclases phenocrysts are 45% of the total volume with dimensions of about 0.005mm to 0.002mm. Large plagioclase phenocrysts range from 5 to 15 mm in length. The groundmass is dominated by plagioclase microlites. Clinopyroxenes constitute about 10% of the total volume and are about 0.002mm to 0.001mm in length mostly as microlites isolated in the groundmass. Opaque minerals are fine sub rounded crystals occur in the groundmass. They occupy about 20% of the total rock volume and are about 0.003mm to 0.001mm in diameter.

5. Geochemstry

5.1. Major Elements

Major elements concentrations are listed in Table 1.Contents of SiO_2, Al_2O_3, TiO_2 and MgO in the studied rocks are 45.6%-47.5%, 14.0%-14.45%, 2.64%-2.79, 6.24%-6.82% respectively. Alkaline (Na_2O + K_2O) contents vary from between 4.27% to and 5.46%. The total alkaline versus silica diagram of [31] shows that all the samples are alkaline basalts (Fig3: A). The MgO content (<08%wt) traduce the low-Mg characteristic of the studied rocks which confirm their alkali properties (Fig3: B). The Mg# varies from 42.86 to 45.95, indicating that the lavas of the studied rocks are from primitive mantle and has undergone little fractionation. Except for samples BB1b1 (1.328) and BB2a2 (0.916) the studied rocks are quartz normative free, also these two samples are olivine normative free while the remains rocks are olivine, Diopside, Hypersthene normative.

Table 1. *Major element contents and CIPW norms of alkali basalts from Bangangté.*

Wt (%)	BB1b1	BB1b2	BB2a1	BB2a2	BB2a3	BB4d1	BB6C1	BB6C2	BB6C3
SiO_2	47,4	46,3	45,6	46,5	46,3	45,9	47,1	47,1	47,5
TiO_2	2,7	2,64	2,68	2,71	2,75	2,71	2,72	2,72	2,79
Al_2O_3	14,25	14,1	14	14,2	14,15	14	14,3	14,3	14,45
Fe_2O_3	13,6	13,55	13,45	13,55	13,7	13,7	13,7	13,85	14,05
MnO	0,2	0,19	0,19	0,2	0,2	0,2	0,2	0,2	0,2
MgO	6,41	6,38	6,66	6,7	6,82	6,24	6,28	6,39	6,53
CaO	8,57	8,17	8,15	8,43	8,32	8,3	8,43	8,51	8,6
Na_2O	3,4	3,86	3,72	3,28	3,76	4,1	4,09	4,16	4,22
K_2O	1,04	1,22	1,19	0,99	1,15	1,18	1,25	1,27	1,24
P_2O_5	0,61	0,6	0,61	0,61	0,63	0,61	0,62	0,61	0,63
TOTAL	98,18	97,01	96,25	97,17	97,78	96,94	98,69	99,11	100,21
Mg#	44,44	44,44	45,95	45,95	45,95	42,86	44,44	44,44	43,24
				CIPW	NORM				
Q	1.328	0.000	0.000	0.916	0.000	0.000	0.000	0.000	0.000
Or	6.146	7.210	7.033	5.851	6.796	6.973	7.387	7.505	7.328
Ab	28.770	32.662	31.478	27.754	31.816	34.693	34.608	35.201	35.708
An	20.549	17.543	17.987	21.099	18.335	16.311	16.968	16.594	16.823
Di	7.287	8.265	7.683	6.292	7.808	9.516	9.429	10.079	9.958
Hy	12.588	5.281	5.417	13.772	6.269	0.031	2.388	0.132	0.001
Ol	0.000	4.750	5.333	0.000	4.975	7.779	6.225	7.787	8.162
Il	0.428	0.406	0.406	0.428	0.428	0.428	0.428	0.428	0.428
Hm	13.600	13.550	13.450	13.550	13.700	13.700	13.700	13.850	14.050
Tn	6.075	5.956	6.054	6.100	6.198	6.100	6.124	6.124	6.296
Ap	1.445	1.421	1.445	1.445	1.492	1.445	1.469	1.445	1.492

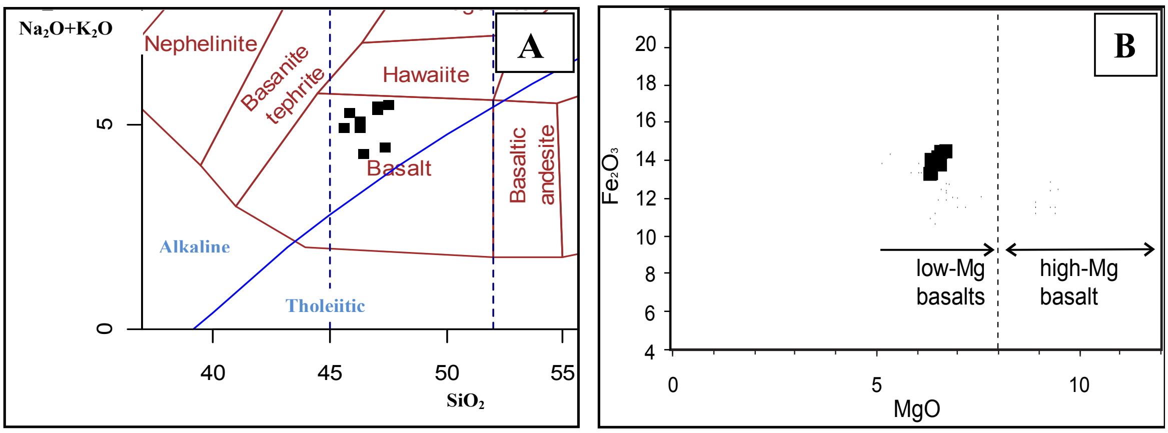

Figure 3. *Bangangte Basalts plotted in the classification diagram of [31] and Fe2O3 versus MgO classification diagram showing the characteristic of low-Mg of these rocks.*

5.2. Trace and Rare Earth Elements

Trace elements and rare earth elements contents of alkali basalts from Bangangté are listed in Table2. The sum of REE is comprised between 182.79 ppm and 197.02 ppm. The ratio values of $(La/Yb)_N$, $(Gd/Yb)_N$ and $(Ce/Sm)_N$ are respectively

10.987-11.572; 2.740-3.005 and 2.019-2.146. Based on the binary diagram TiO_2 versus Nb (Fig4) the studied basalts are transitional and based on the ratio Nb/Y which is >1.5, the studied basalts are alkaline.

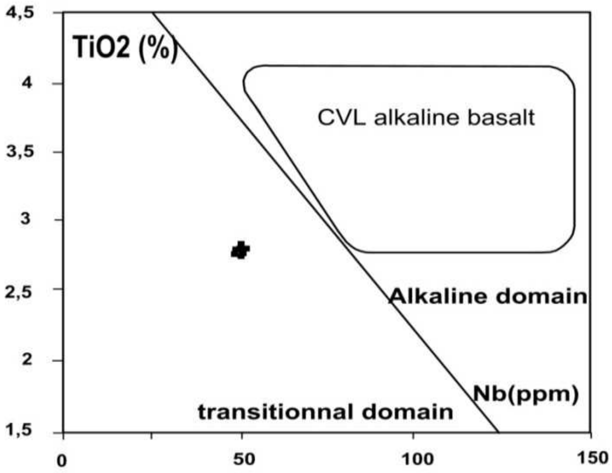

Figure 4. *Bangangte basalts within the TiO_2 versus Nb diagram according to [32].*

The values of Eu/Eu* are ≥1.05 in samples BB1b1, BB1b2, BB2a3 and BB6c1 (positive anomalies in Eu). These values of Eu/Eu* values are between 0.96-1.04 (nulle anomalies in Eu) in samples BB2a1, BB2a2, BB4d1, BB6c2, BB6c3.The REE spider diagram normalized with Chondrite [33] shows uniform patterns having a slight enrichment in LREE and a slight depletion HREE (Fig.5), this REE pattern show no significant negative anomalies in Eu, which is typical for alkali basalt. Multi-element spider diagram normalized with MORB [34] shows a negative anomaly for K_2O. It also shows enrichment in LILE and depletion in LREE and HREE (Fig.6).

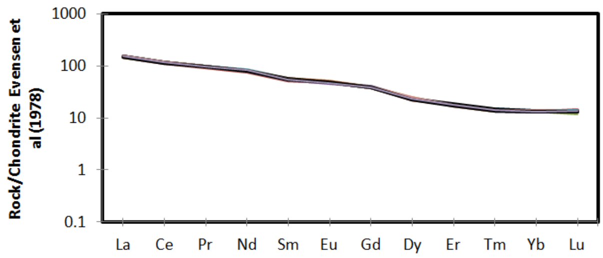

Figure 5. *REE spider diagram normalized with Chondrite [33].*

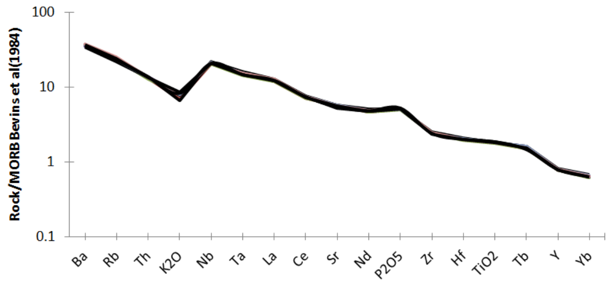

Figure 6*. Multi-elements spider diagram normalized with MORB [34].*

Table 2. *Trace elements and rare earth elements of alkali basalts from Bangangté.*

ppm	BB1b1	BB1b2	BB2a1	BB2a2	BB2a3	BB4d1	BB6C1	BB6C2	BB6C3
Ba	438	440	419	441	412	435	454	435	430
Rb	24,2	23,4	22,6	24	21,8	23,3	25	24,2	23,1
Th	2,59	2,52	2,71	2,73	2,68	2,69	2,67	2,67	2,74
Nb	50,3	50,4	52,6	54,4	52,4	52,8	52,4	51,5	51,6
Sr	785	773	748	775	710	770	757	752	744
Ta	2,6	2,4	2,6	2,7	2,6	2,6	2,6	2,5	2,5
Cr	150	150	140	140	130	140	140	140	140
Y	28,5	28,6	29,4	30,1	29,2	29,6	29,2	28,8	29,3
Zr	212	209	211	221	212	210	213	208	213
Ga	18,4	18,8	19,5	20,4	19,5	18,9	19,2	19,2	19,2
V	192	191	192	203	194	196	194	192	197
Hf	5	4,8	5,1	5,2	5,1	5,1	5	4,9	5
Sn	2	2	2	2	2	2	2	2	2
U	0,64	0,67	0,72	0,76	0,68	0,72	0,64	0,62	0,65
Cs	0,12	0,14	0,17	0,18	0,15	0,21	0,2	0,26	0,2
La	35,6	35,4	37	38,4	36,7	36,9	37,8	36,7	36,9
Ce	71,1	71,1	74,2	76,4	74	74,1	74,8	72,9	74,2
Pr	8,98	9,07	9,41	9,64	9,34	9,38	9,46	9,16	9,43
Nb	50,3	50,4	52,6	54,4	52,4	52,8	52,4	51,5	51,6
Sm	8,14	8,4	8,45	8,94	8,56	8,77	8,33	8,41	8,36
Eu	2,79	2,77	2,75	2,9	2,89	2,76	2,82	2,78	2,69
Gd	7,74	7,64	8,08	8,18	7,82	7,74	7,84	7,84	7,85
Tb	1,13	1,12	1,19	1,21	1,16	1,19	1,14	1,15	1,1
Dy	5,72	5,67	6	6,28	6,05	5,9	6,06	5,76	5,95
Ho	1,16	1,11	1,13	1,22	1,24	1,18	1,23	1,17	1,17
Er	2,93	2,85	2,97	2,98	2,85	3,02	2,88	2,84	2,91
Tm	0,36	0,35	0,35	0,39	0,35	0,38	0,35	0,35	0,36

ppm	BB1b1	BB1b2	BB2a1	BB2a2	BB2a3	BB4d1	BB6C1	BB6C2	BB6C3
Yb	2,17	2,15	2,18	2,35	2,22	2,29	2,26	2,19	2,2
Lu	0,36	0,3	0,34	0,36	0,33	0,33	0,33	0,33	0,34
(Ce/Sm)N	2,087	2,022	2,098	2,042	2,066	2,019	2,146	2,071	2,121
(La/Yb)N	11,186	11,226	11,572	11,141	11,271	10,987	11,404	11,426	11,436
(Gd/Yb)N	2,892	2,881	3,005	2,822	2,856	2,740	2,813	2,903	2,893
(Ce/Yb)N	8,699	8,780	9,036	8,631	8,850	8,591	8,787	8,837	8,954
(Tb/Yb)N	2,332	2,333	2,444	2,305	2,340	2,327	2,259	2,351	2,239
Eu/Eu*	1,1	1,09	1,05	1,07	1,12	1,06	1,1	1,08	1,06

6. Discussion

Source of magma and geotectonic context

The Mg# values of Bangangté basalts which are <50 show that their parent magma may come from primitive mantle magma. According to previous work in [35], basalts which come from asthenosphere typically have the characteristics of La/Nb<1.5 and La/Ta<22 while basalts from lithosphere are on contrary [36]. The ratio La/Nb of transitional alkalic basalts from Bangangté varies from 0.70 to 0.72, and La/Ta from 13.69 to 14.76; which may simply shows that the parent magma of the studied rocks may come from mantle asthenosphere. The ratio Zr/Nb<20 confirm also a mantle source as indicates by the binary diagram Zr/Nb versus MgO (Fig7: A). On the other binary diagram Zr/Nb versus Zr the Bangangté studied basalts are plotted in the field of mantle source (Fig7: B)

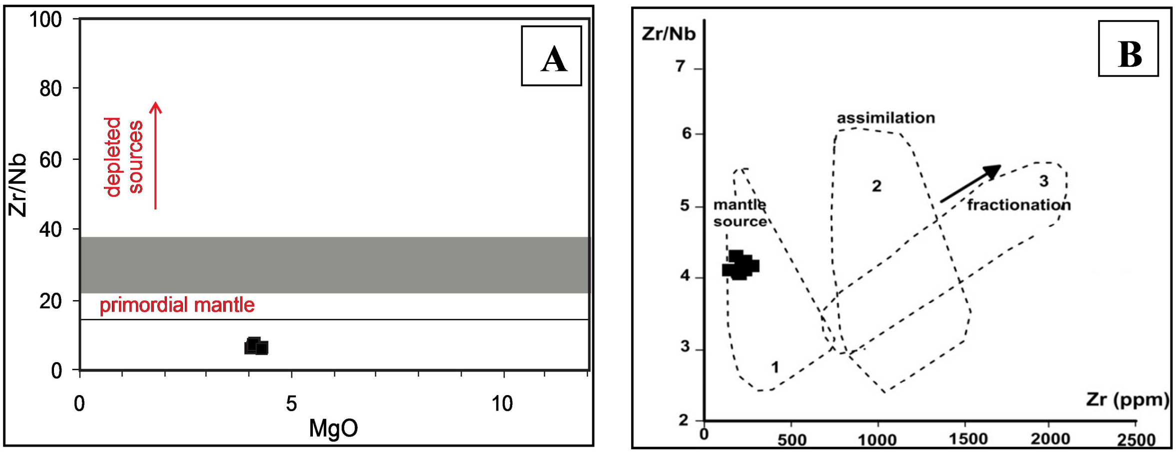

Figure 7. *A) Bangangte basalt within the TiO_2 versus Nb diagram according to [32]. B) Zr/Nb versus Zr diagram for Bangangte basalts.*

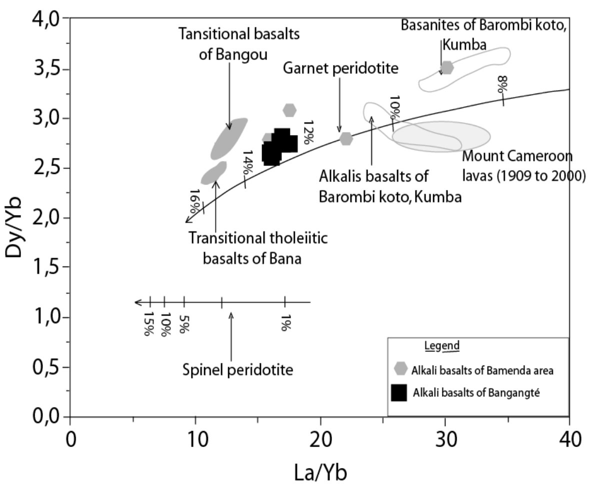

Figure 8. *La/Yb versus Dy/Yb diagram for rocks from Bangangte. Melt curves for garnet peridotite and spinel peridotite [37]. Also shown are the basic lavas from Mounts Cameroon [38, 39].*

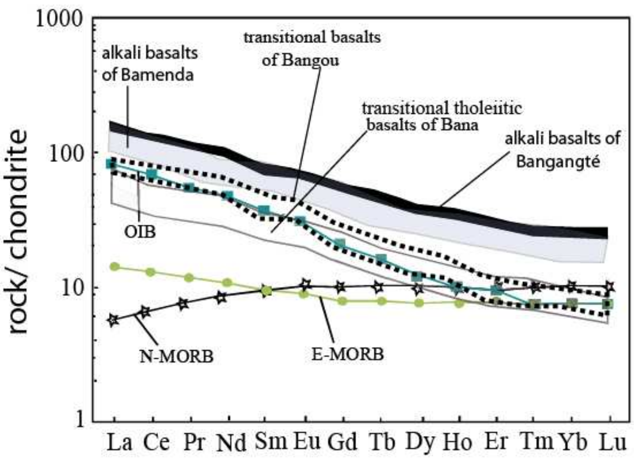

Figure 9. *Comparative chondrite-normalized REE parttens of Bangangté alkali basalt with some relevant most studied basalts.*

Basaltic lavas originate from different sources with variable proportions. A chemically homogeneous mantle can yield a variety of basalt types from partial melting of peridotite. Plotted in the binary diagram La/Yb versus Dy/Yb

[37] showing the melt curves for garnet peridotite and spinel peridotite, the studied Bangangte basalts were originated from partial melting of garnet peridotite at about 13% melting (Fig8). This source is similar to the one of alkali basalts from Mont Bamenda [9].

When comparing REE contents and REE chondrite-normalized patterns of Bangangte alkali basalts, it is clearly appear that, their patterns are parallels to the one of Bamenda alkali basalts and even to the one of OIB, the slide differences being the various elements contents which are higher in Bangangté alkali basalts (Fig.9).

This geotectonic discrimination binary diagram Zr/Y-Zr [40] reveals that the transitional alkali basalts from Bangangte are within plate basalts (Fig10).

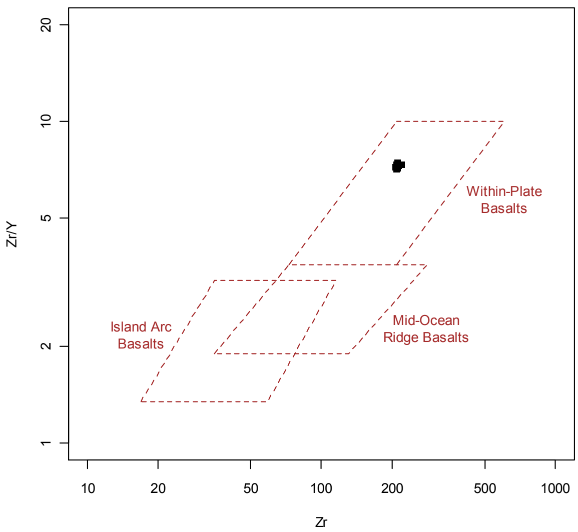

Figure 10. *Geotectonic discrimination diagram of basaltic rocks [40].*

7. Conclusion

Bangangte Basalt petrographicallyisa dark massive volcanic rock having few cavities filled of quartz. The studied rocks yield microliticporphirtic texture made up of minerals like plagioclase, clinopyroxenes, olivine phenocrysts and a lot of opaque minerals within a ground mass.

The Geochemical analysis shows that the Bangangte basalts are transitional alkali basalts. The alkaline contents vary from 4.27% to 5.46%.The MgO content (<08%wt) traduce the low-Mg characteristic of the studied rocks which confirm their alkali properties. The Mg# varie from 42,86 to 45,95, indicating that the lavas of the studied rocks are from primitive mantle and has undergone little fractionation. Except for samples BB1b1 (1,328) and BB2a2 (0,916) the studied rocks are quartz normative free, also these two samples are olivine normative free while the remains rocks are olivine, Diopside, Hypersthene normative. The Mg# values of Bangangté basalts which are <50 show that their parent magma may come from primitive mantle magma.

Chondrite normalized spider diagram pattern of REE shows uniform patterns with enrichment in LREE and relative depletion in HREE. While MORB normalized spider diagram pattern of multi elements reveals a negative anomaly with K_2O, with enriched LILE and depletion in HREE. The Eu anomalies are positive to nulle. The Bangangté transitional to alkali basalts were formed in intraplate setting of continental part of the CVL. They are the products of partial melting of about 13% of an asthenosphere made up of garnet peridotite. Geochemically, the studied basalts are similar to alkali basalts from Mount Bamenda.

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