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Research paper

Petrology of peridotite host basaltic lavas of northern Ngaoundéré (Adamawa plateau, Cameroon, Central Africa)

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Abstract

Small volcanoes and flows of Cainozoic basaltic lavas, containing numerous mantle peridotite xenoliths, outcrop at northern Ngaoundéré in Adamawa plateau. They are composed of arena of decimeter to meter in size of bowls and blocs of dark matrix, showing crystals of olivine, clinopyroxene and oxides. All lavas present microlitic porphyritic texture with euhedral to subhedral crystals of the same phases drowned in the matrix of the same minerals plus plagioclase microlites.
Microprobe analyses show that olivine phenocrysts are relatively Fo-rich (80.9-84.3 %) compared to microphenocrysts and microcrysts (Fo71.1-75.9 %). Olivine xenocrysts are highly magnesian (83.9-89.8 %). Clinopyroxene are diopside and augite. Oxides crystals are Ti-magnetite and plagioclase are labradorite and bytownite.
ICP-AES and ICP-MS whole rocks analyses show that the host peridotite basaltic lavas of northern Ngaoundéré are undersaturated basanites of typical alkaline lava series. They seem not contaminated by crustal materials. They are the results of low partial melting rate of the garnet mantle source located at more than 80 km depth. The eruptions of northern Ngaoundéré lavas have been facilitated by Pan African cracks and they have sampled the subcontinental lithospheric mantle as xenoliths at different pressures and depths on their way to the surface.

Keywords: *Adamawa plateau; Basanite; Cameroon; Peridotite; Xenolith.*

1. Introduction

Northern Ngaoundéré area belongs to Adamawa plateau (AP), an asymmetrical horst of central Africa (Fig. 1A) bounded north and south (Fig. 1B) by pan African N70 strike-slip faults (Moreau et al. 1987). Those faults extend from Cameroon to Soudan on about 2000 km (Cornacchia & Dars 1983) and crosscut the Adamawa basement and upper mantle down to depths greater than 190 km (Dorbath et al. 1986, Poudjom Djomani et al. 1992, Nnange et al. 2000). Adamawa faults have served as pathway for ascending basaltic magmas to reach the surface (Moreau et al. 1987, Guiraud & Maurin 1992). Those lavas have sampled numerous fragments of sub-continental mantle xenoliths on their way. Three volcanic units are broadly distinguished in the Adamawa region (Nono et al. 1994, Temdjim et al. 2004, Nkouandou et al. 2008): The (1) Cretaceous-Paleogene lower black series mostly consists in basaltic lava flows completely transformed to lateritic soils ; The (2) white intermediate series of Miocene age consists in numerous trachytes and phonolites plugs mostly North and East of Ngaoundéré and the (3) upper black series consisting of Pliocene-Quaternary basaltic strombolian cones and their associated lava flows mostly South of Ngaoundéré. The third Pliocene-Quaternary lava series is composed of three sequences lava flows (Nono et al. 1994) distinguished by their stratigraphic and surface-weathering characteristics as Upper Flow Unit (UFU), Middle Flow Unit (MFU) and Lower Flow Unit (LFU). Previous studies on the volcanic series of Ngaoundéré area (Nkouandou et al. 2008 and 2010, Fagny et al. 2012, Tiabou et al. 2015) have constrained the main petrogenesis processes at the origin of Adamawa plateau volcanism of Pliocene LFU and MFU lava series. In the Northern Ngaoundéré, basaltic lava flows (UFU) of upper black lava series have been emitted by numerous centres now observed as necks (Ngao Mokon, Ngao Kobi and Do Guessa in Mazélé area). Most of the lavas flowed radially around the centres. Only the UFU of upper black lava series contain numerous fragments of sub-continental mantle xenoliths.
This work presents the petrogenetic features of Pliocene-Quaternary volcanism from the Northern Ngaoundéré upper lava flow unit (UFU) of upper black lava series.

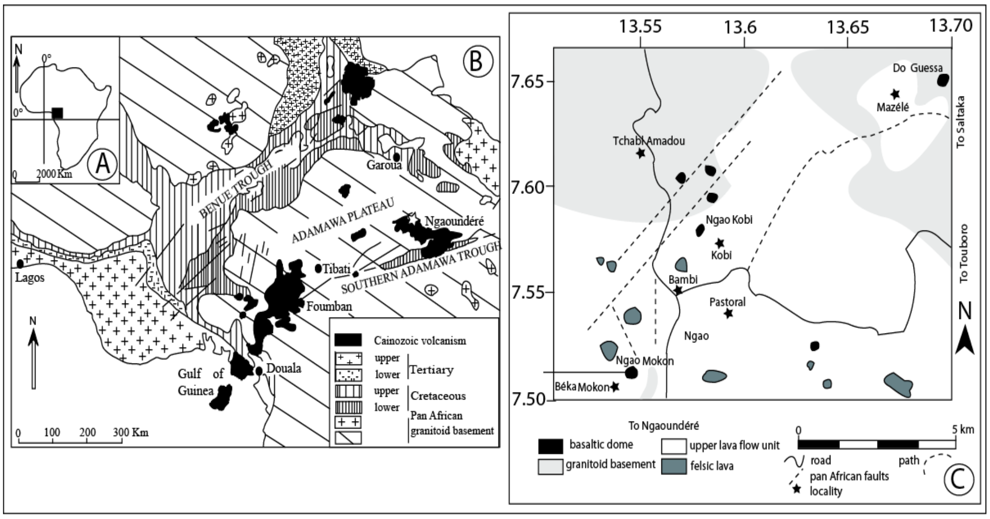

Fig. 1: Geological Sketch Map of Northern Ngaoundéré Region A: Location of Adamawa In Central Africa, B: Adamawa Plateau Location Relative to Benue Trough and C: Sketch Map of Studied Area. Fig. 1A and 1B Modified from Dumont (1987) and 1C Modified from Njankouo Ndassa (2019, Unpublished Data).

2. Geological setting

Adamawa plateau is an uplifted horst in central Cameroon (Fig. 1A and B) divided roughly into three blocks by two sub vertical boundaries striking ENE and traversing both the crust and upper mantle down to depths greater than 190 km (Dorbath et al. 1986). It results from the interaction of a regional anomalous upper mantle associated with the West African Rift System and the Central African Shear Zone (Dorbath et al. 1986). Adamawa basement limited north by Benue trough and south by Southern Adamawa trough (Fig. 1B) is hashed by numerous pan African strike-slip faults which have facilitated the ascending volcanic lavas at Cainozoic times to the surface (Moreau et al. 1987). Northern Ngaoundéré basement is composed of calco-alkaline granitoids of pan African age (500-600 Ma) displaying negative Nb and Ta anomalies (Tchameni et al. 2006, Nkouandou et al. 2008). Adamawa volcanism is composed of basaltic and felsic lavas (Nkouandou et al. 2008 and 2010) belonging to Na-under saturated suites (Temdjim et al. 2004, Nkouandou et al. 2008). There is a gap between basaltic and felsic lavas (Nkouandou et al. 2008). Felsic lavas may have been generated by differentiation by fractional crystallization of basaltic lavas coupled to minor magma mixing process and selective crustal contamination (Nkouandou al. 2008). Silica-saturated lavas of crustal origin have recently been described in Adamawa plateau in Saltaka region (Nkouandou et al. 2016).

3. Analytic method

Petrographic studies have been carried out on about ten thin sections prepared from the representative samples of ultramafic xenoliths host lavas at the laboratory GEOPS of the University of Paris-Sud Orsay, France. Microprobe mineral analyses of peridotite host basaltic lavas were performed on Camebax SX100 at the service Camparis of the University of Pierre et Marie Curie, Paris 6, France. The operating conditions were an accelerating voltage and a beam current as follow: olivine and clinopyroxene: 15 kV and 40 nA, 20 s except Si for olivine (10 s) and Ti for clinopyroxene (30 s); plagioclase: 15 kV, 10 nA, 10 s; titanomagnetite: 15 kV and 40 nA, Si, Ca, Ni: 10 s; Mn: 25 s; Cr; 15 s; Al: 30 s; Ti. Fe; Mg: 40 s. Standard used were a combination of natural and synthetic minerals. Data corrections were made using the PAP correction of Pouchou & Pichoir (1991).

Whole rock major and trace element analyses of host lavas peridotite were determined on representative samples by ICP-AES and ICP-MS at the Acmel laboratory of Vancouver, Canada and supplement analyses at the ‘Centre de Recherches Pétrographiques et Géochimiques’, CRPG, Nancy, France. The prepared sample is mixed with $LiBO_2/Li_2B_4O$ flux. Crucibles are fused in a furnace. The cooled bead is dissolved in ACS-grade nitric acid and analyzed by ICP and/or ICP-MS. Loss on Ignition (LOI) is determined by igniting a sample split then measuring the weight loss. The method used is that of Carignan et al. (2001) for trace elements. CIPW norm calculations have been done assuming Fe_2O_3/FeO ratio of 0.15.

4. Results

4.1. Field work and petrography

Volcanic lavas of northern Ngaoundéré outcrop as lava flows and dome shape structures. Basaltic lava flows of studied area extend on more than 2 km^2 from Béka Mokon to Mazélé locality (Fig. 1C). They are considered as Pliocene-Quaternary Upper Lava Flows (ULF) relative to the sequential volcanic eruptions which have occurred in the area (Fig. 2A). The main characteristic of northern Ngaoundéré basaltic lavas is the occurrence of numerous fragments of mantle peridotite (Nkouandou & Temdjim 2011, Nkouandou et al. 2015, Njombie et al. 2018). Lava flows and small volcano massifs are composed of dark blocks and bowls of basaltic lavas, decimeters to meter in size (20 cm to 1.5 m). Many vacuoles, 7 to 20 cm wide, observed on those lavas may have been occupied by mantle peridotite xenoliths now completely altered. Slim dark brown patina covers the matrix of dark color containing blue yellowish 2 to 5 mm olivine crystals (10 to 15 vol %), dark crystals of pyroxene (2 to 3 mm and 5 to 10 vol %) and abundant fine sparkling microlites of plagioclase (1 mm and 30 vol %). Numerous fragments of yellow blackish peridotite of 5 to 15 cm in size are found in almost all basaltic outcrops. Peridotite fragments are rounded or sub-angular to angular shape (Fig. 2B and 2C). They are respectively composed of abundant (60 to 80 vol %) of 3 to 6 mm in size crystals of yellow greenish olivine crystals. Pyroxene, spinel or amphibole are suspected.

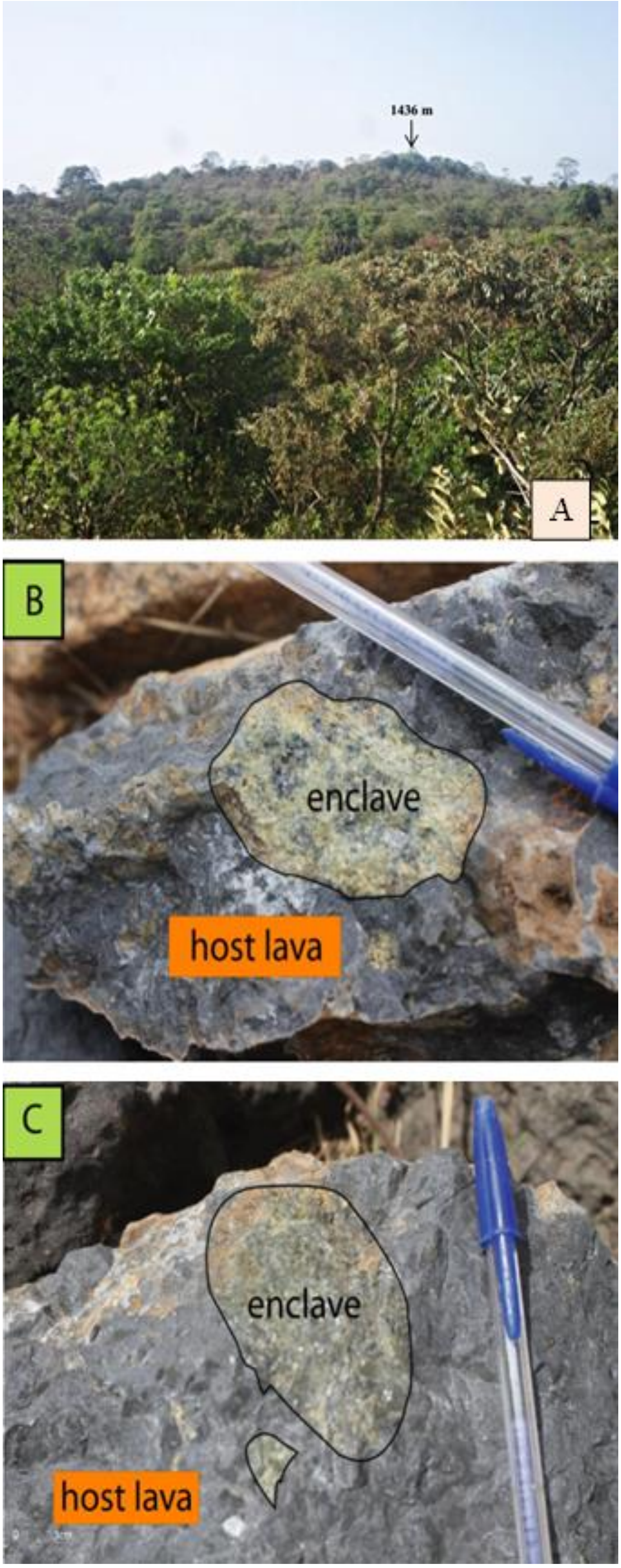

Fig. 2: A) View of Hillside of Do Guessa Volcano Exhibiting the Flow Dome Shape Form, B): Yellow Greenish Peridotite Enclave in Lava of Do Guessa Volcano and C): Egg-Shaped Peridotite Enclaves in Host Dark Lava. The Pen Is 14 Cm Long for Scale.

Small volcanic massifs of the studied area (Fig. 1C) are Do Guessa in Mazélé (N7.651539° and E13.694999°), Ngao Kobi in Kobi (N7.585833° and E13.582222°) and Ngao Mokon in Béka Mokon (N7.521649° and E13.543954°) localities. Northern Ngaoundéré volcanoes are aligned, following N130E and N30E pan African faults. They are fragmented and they exhibit parallelepiped shape of 350mx260mx17m to 150mx80x20m. These volcanoes are composed of angular blocks and bowls of 20 to 50 cm, which exhibit the same petrographic characteristics as those of basaltic lava flows of the same area. Peridotite fragments (7 to 10 cm) are omnipresent in blackish matrix of host basaltic lavas (Fig. 2B and 2C).

On plate polarized light (Fig. 3A, 3B and 3C), all samples show microlitic porphyritic textures. They are composed of phenocrysts of olivine, clinopyroxene and oxides. Microlites and microcrysts in the matrix are the same mineral phases plus plagioclase microlites.
Two types of olivine crystals are distinguished: (1) euhedral and subeuhedral phenocrysts (10 % in volume of lava and 0.3x0.5 mm to 3x4 mm) showing squat aspect and rare oxides inclusion in cores and rims (Fig. 3B). The second type crystals (2) are probably olivine xenocrysts stood out from xenoliths (less than 5 vol % and 0.7x1.2 to 1.1x2 mm). They are strongly cracked, serpentinized and without oxides inclusions (Fig. 3A. 3B and 3C). Microphenocrysts and microcrysts of olivine crystals of euhedral, subeuhedral and sometimes xenomorph shape are relatively abundant (7 to 15 % in volume, 0.1 to 0.3 mm). Microcrysts of olivine are frequently associated to those of oxides in the matrix. Oxides phenocrysts (5-10 % in volume and 0.1x 0.3 mm to 0.5x0.7 mm) are subeuhedral to xenomorph (Fig. 3C) and show rounded shapes. Oxides microcrysts (12 % in volume and 0.1x0.2 to 0.2x0.3 mm) are square, rectangular or triangular in shape. Some are included or stuck in rim of olivine phenocrysts (Fig. 3A, 3B and 3C).
Clinopyroxene (3 to 5 % in volume, 1.1x1.8 to 1.3x2.2 mm) phenocrysts are euhedral (Fig. 3D). They contain oxides microcrysts and sometimes show skeletal shape. Clinopyroxene microlites (less than 5 volume %, 0.2 mm long) are needle shape and intimately associated with oxides microcrysts.
Plagioclases are present exclusively as microlites (about 25 % in volume, 0.1 mm long) acicular in shape, scattered in the matrix; they have frequently grown with oxides microcrysts (Fig. 3A, 3B, 3C and 3D).

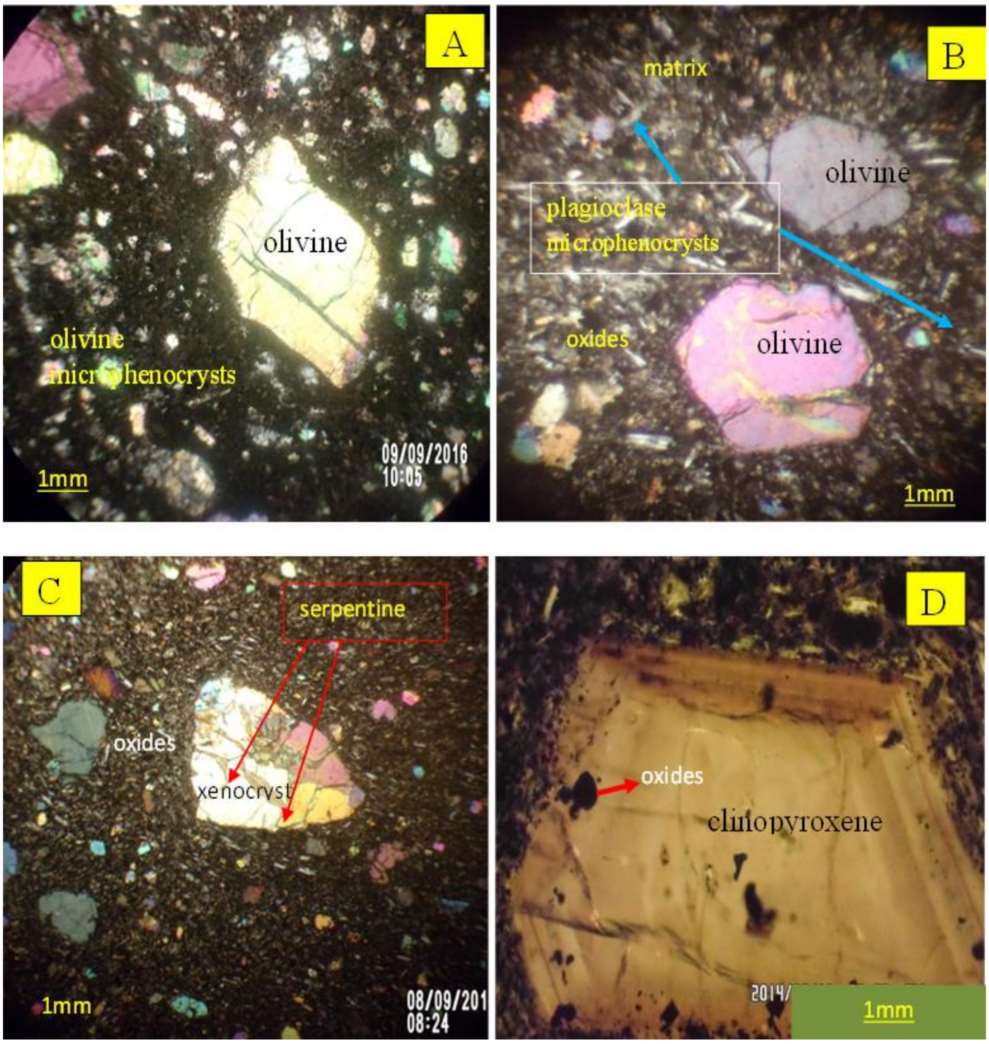

Fig. 3: A & B: Euhedral Olivine Crystals, C: Olivine Xenocryst and D: Euhedral Zoned Clinopyroxene Phenocryst Containing Small Oxides Microcrysts.

4.2. Mineralogy

Microprobe chemical analyses of olivine of host peridotite basaltic lavas of northern Ngaoundéré are shown in Table 1. Olivine phenocrysts have relatively high Fo (80.9-84.3 %), CaO (0.11-0.75 wt %) and low NiO (0.06-0.26 wt %). Olivine microphenocrysts and microcrysts are less magnesian (Fo71.1-75.9 %) with lowest Fo found in microcrysts. Reversely, olivine xenocrysts have very high Fo (83.9-89.8 %) and NiO (0.23-0.37 wt %) for low CaO contents (0.09 wt %).
Phenocrysts and microlites of clinopyroxene (Table 2 and Fig. 4) are essentially diopside ($Wo_{47.00-48.40}$ $En_{-41.50-47.10}$ $Fs_{5.34-10.08}$) in compositions (classification after Morimoto et al. 1988). They have rather high TiO_2 (2.7-4.8 wt %) and Al_2O_3 (5.3-9.3 wt %) contents for rather low Na_2O content (0.6-0.8 wt %). Mg# are up to 87.8. One analysis is very peculiar (Table 2): this seems an augite ($Wo_{43.20}$ $En_{42.56-}$ $Fs_{14.23}$), Al_2O_3 (12.39 wt %) and Na_2O (1.6 wt %) rich.

Table 1: Microprobe Analyses and Structural Formulae of Olivine Crystals of Host Peridotites Basaltic Lavas. Ph = Phenocryst, Mph = Microphenocryst, Mic = Microcryst and Xeno = Xenocryst

lava	basanite														
sample	LNJ13			LNJ12			LNZ8				LTZ13		LNJ115	
type	ph	ph	ph	ph	ph	mph	mph	mph	mph	mph	mic	mic	xeno	xeno
SiO_2 (wt %)	39.04	38.03	38.33	39.26	39.06	39.51	39.97	38.24	37.62	37.94	38.26	37.68	39.23	40.35
FeO	14.92	17.91	17.16	14.83	15.65	21.03	21.41	22.12	23.73	22.40	25.09	23.41	15.01	9.79
MnO	0.23	0.27	0.30	0.28	0.30	0.44	0.43	0.51	0.46	0.56	0.56	0.49	0.27	0.08
MgO	44.70	42.42	43.30	44.67	43.85	37.90	36.47	38.43	37.67	38.42	35.44	37.89	44.52	48.46
CaO	0.11	0.22	0.22	0.20	0.24	0.76	0.61	0.30	0.37	0.24	0.55	0.36	0.09	0.09
NiO	0.26	0.21	0.22	0.24	0.22	0.16	0.14	0.11	0.21	0.16	0.06	0.15	0.23	0.37
sum	99.26	99.05	99.53	99.49	99.32	99.80	99.04	99.71	100.06	99.72	99.95	99.98	99.35	99.15
Si (apfu)	0.989	0.982	0.980	0.992	0.992	1.010	1.035	0.986	0.989	0.992	1.010	0.989	0.993	0.994
Fe2+	0.316	0.387	0.367	0.313	0.333	0.461	0.471	0.490	0.521	0.490	0.554	0.514	0.318	0.203
Mn	0.000	0.000	0.000	0.000	0.007	0.010	0.010	0.011	0.010	0.000	0.012	0.011	0.006	0.000
Mg	1.688	1.633	1.651	1.682	1.661	1.483	1.429	1.516	1.476	1.498	1.395	1.483	1.680	1.793
Ca	0.003	0.006	0.006	0.005	0.006	0.021	0.017	0.008	0.011	0.007	0.016	0.010	0.003	0.002
Ni	0.005	0.004	0.005	0.005	0.004	0.003	0.003	0.002	0.005	0.003	0.001	0.003	0.005	0.007
Fo (%)	84.2	80.9	81.8	84.3	83.0	75.9	74.9	75.2	73.5	75.4	71.1	73.9	83.9	89.8

Table 2: Microprobe Analyses and Structural Formulae of Clinopyroxene Crystals of Host Peridotites Basaltic Lavas

lava	basanite							
sample	LMB110		LNZ-G1	LMZ11		LNZ-B1	LTZ13	
SiO_2 (wt %)	44.70	47.22	44.21	45.95	44.91	42.43	47.53	48.83
TiO_2	3.94	2.80	4.48	3.40	3.65	4.80	2.70	3.10
Al_2O_3	8.07	5.26	8.62	7.00	7.67	9.25	7.28	12.39
Cr_2O_3	0.02	0.03	0.04	0.04	0.00	0.00	0.00	0.00
FeOt	7.40	7.16	7.25	6.69	7.36	7.60	6.46	5.58
MnO	0.13	0.17	0.15	0.11	0.11	0.17	0.07	0.04
MgO	11.73	13.27	11.43	12.66	12.04	10.94	11.74	9.36
CaO	22.45	22.65	22.51	22.56	22.49	22.21	22.87	18.62
Na_2O	0.59	0.61	0.65	0.62	0.69	0.74	0.84	1.60
sum	99.02	99.17	99.34	99.01	98.93	98.15	99.49	99.64
Si (apfu)	1.684	1.766	1.662	1.722	1.689	1.617	1.773	1.816
Ti	0.112	0.079	0.127	0.096	0.103	0.138	0.076	0.087
Al	0.358	0.232	0.382	0.309	0.340	0.415	0.320	0.543
Cr	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
Fe	0.141	0.103	0.142	0.111	0.107	0.111	0.200	0.170
Mn	0.004	0.005	0.005	0.004	0.004	0.005	0.002	0.001
Mg	0.659	0.740	0.641	0.708	0.675	0.622	0.653	0.519
Ca	0.906	0.908	0.907	0.906	0.907	0.907	0.914	0.742
Na	0.043	0.044	0.047	0.045	0.050	0.055	0.061	0.115
Wo	47.00	47.58	47.24	47.23	47.67	47.87	48.38	43.20
En	44.36	47.08	43.76	46.37	46.25	45.41	41.54	42.56
Fe	8.64	5.34	9.00	6.40	6.08	6.72	10.08	14.23
Mg#	82.40	87.78	81.89	86.42	86.29	84.85	76.00	75.00

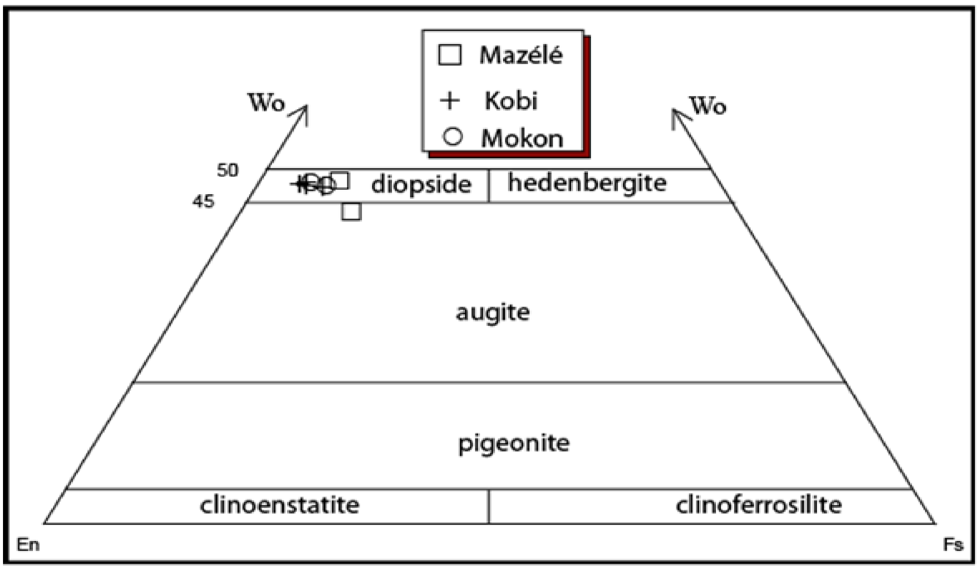

Fig. 4: Compositions of Analyzed Clinopyroxene Crystals of Host Peridotite Basaltic Lavas in Wo-En-Fs Triangle (After Morimoto Et Al. 1988).

Plagioclase microlites (Table 3 and Fig. 5) of studied lavas are labradorite in composition ($Or_{1.6-11.3}$-$Ab_{18.66-44.81}$-$An_{50.00-69.55}$). One crystal has nearly bytownite composition ($Or_{0.67}$-$Ab_{29.78}$-$An_{69.55}$). FeOt contents of plagioclase microlites are between 0.8 and 1.4 wt %.
Oxides crystals of studied lavas (Table 4) are Ti-magnetite in composition (TiO_2 : 20.6-26.3 wt % and FeOt : 64.5-68.6 vol %). Al_2O_3 (1.6-4.9 wt %), Cr_2O_3 (0.1-2.7 wt %) and MgO (3.4-5.6 wt %) show little variations and correspond to Usp contents between 61.5 and 64.5 wt %. One crystal is peculiar with a chemical composition intermediate with those of spinel, with 9.0 wt % Al_2O_3 and 7.1 wt % Cr_2O_3 for Usp content close to 2 wt %.

Table 3: Microprobe Analyses and Structural Formulae of Plagioclase Crystals of Host Peridotites Basaltic Lavas

lava	basanite										
sample	LNZ11	LMB110	LTZ13	LNZ2	LNZ8			LTZ13			
SiO_2 (wt %)	54.43	51.93	53.65	52.87	60.38	59.25	56.07	60.77	51.99	53.65	56.86
Al_2O_3	28.12	29.83	28.86	28.64	24.88	26.96	24.89	21.62	32.69	28.86	28.24
FeOt	0.64	0.80	0.79	0.66	0.00	0.32	1.41	0.81	0.67	0.79	0.63
CaO	10.54	12.70	11.23	11.32	6.31	7.64	7.83	4.33	7.08	11.23	8.03
Na_2O	5.02	4.24	4.78	4.81	8.12	6.70	5.56	7.02	5.08	4.78	4.93
K_2O	0.99	0.27	0.34	0.71	0.12	0.62	3.23	5.15	1.75	0.34	0.78
BaO					0.01		0.26	1.01	0.17		0.15
sum	99.75	99.77	99.65	99.00	99.82	101.49	99.25	100.71	99.42	99.65	99.64
Si (apfu)	2.449	2.346	2.414	2.410	2.690	2.611	2.580	2.763	2.359	2.414	2.554
Al	1.519	1.619	1.560	1.558	1.306	1.400	1.350	1.159	1.748	1.560	1.495
Fe3+	0.025	0.031	0.030	0.025	0.002	0.000	0.054	0.031	0.025	0.030	0.000
Ca	0.518	0.627	0.552	0.560	0.301	0.361	0.386	0.211	0.344	0.552	0.386
Na	0.447	0.379	0.425	0.430	0.703	0.574	0.497	0.621	0.448	0.425	0.431
K	0.058	0.016	0.020	0.042	0.007	0.035	0.189	0.299	0.101	0.020	0.045
Ba					0.000	0.000	0.005	0.018	0.003		0.003
Or	5.69	1.57	2.02	4.07	0.67	3.58	17.66	26.43	11.34	2.02	5.22
Ab	43.68	37.07	42.63	41.69	29.78	37.22	35.96	18.66	38.54	42.63	44.81
An	50.63	61.36	55.34	54.24	69.55	59.20	46.38	54.91	50.12	55.34	49.98

Table 4: Microprobe Analyses and Structural Formulae of Ti-Magnetite Crystals of Host Peridotites Basaltic Lavas

lava	basanite						
sample	LMB110	LHL		LHW		LNZ8	
SiO_2 (wt %)	0.17	3.55	0.94	0.08	0.69	0.02	0.07
TiO_2	26.28	15.28	21.93	21.89	21.79	9.00	20.58
Al_2O_3	4.86	4.56	2.68	1.75	1.58	9.00	4.18
Cr_2O_3	0.37	0.45	0.23	0.12	0.17	7.14	2.69
FeOt	68.62	57.94	65.38	67.79	65.01	61.30	64.54
MnO	0.65	0.58	0.94	0.90	1.03	0.48	0.60
MgO	3.67	12.09	4.01	3.54	3.41	5.60	5.56
CaO	0.34		0.24	0.07	0.70	0.05	0.11
NiO	0.16						
sum	100.96	94.44	96.33	96.15	94.38	92.59	98.33
Si (apfu)	0.006	0.125	0.272	0.024	0.206	0.001	0.003
Ti	0.660	0.404	4.768	4.813	4.872	0.479	0.555
Al	0.191	0.189	0.911	0.603	0.552	0.228	0.177
Cr	0.010	0.012	0.052	0.029	0.04	0.202	0.076
Fe3+	0.468	0.741	4.793	5.527	5.081	0.608	0.629
Fe+2	1.448	0.879	11.009	11.047	11.082	1.163	1.236
Mn	0.019	0.017	0.231	0.224	0.259	0.014	0.018
Mg	0.183	0.633	1.727	1.545	1.513	0.299	0.297
Ca	0.012		0.073	0.022	0.224	0.002	0.004
Ni	0.004						
Ulvöspinel	2.01	44.32	64.51	61.49	64.51	2.01	

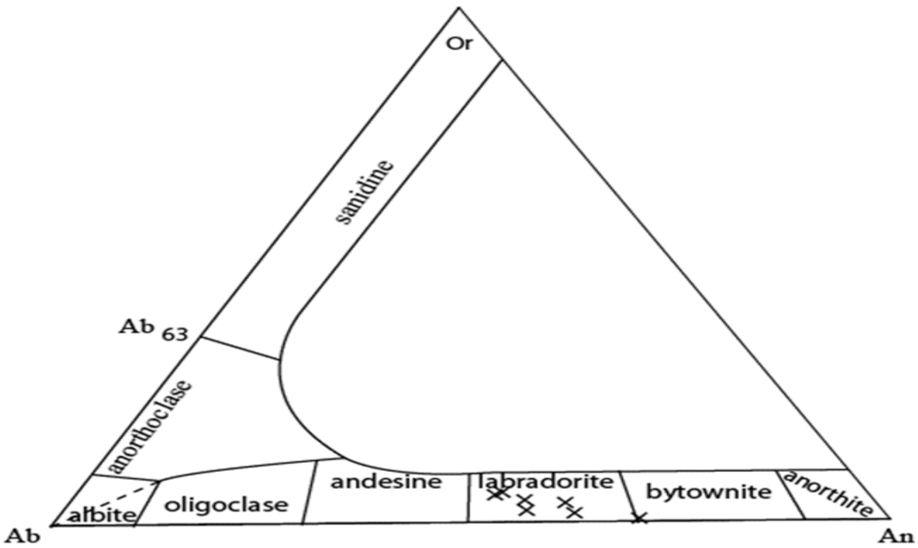

Fig. 5: Plagioclase Microlites Composition of Host Peridotite Basaltic Lavas in Or-Ab-An Triangle.

4.3. Geochemistry

Representative host peridotite basaltic lavas (Table 5) of northern Ngaoundéré exhibit the features of under saturated basanite lavas composition (Fig. 6) according to SiO_2 content less than 45 wt %, normative olivine of 16.2-25 % and normative nepheline more than 10 % (10.3-13.9 %) (Le Maitre 2002). TiO_2 (2.7-3.9 wt %) and alkali (Na_2O+K_2O) contents (4.7 to 6.0 wt %) are typically high. Mg# varies between 49.7 and 68.5 %. Ni (123.0-402.7 ppm) and Cr (65-510.6 ppm) contents vary wildly while Co (43.9-59.7 ppm) and V (188-257 ppm) contents are relatively constant. Rb contents (38-49 ppm) are low and Sr (758.9-1127.4 ppm) and Ba (538.0-795.0 ppm) are high. Nb (73-107 ppm), Ta (3.5-5.8 ppm), Hf (5.5-7.9 ppm) and Th (7.4-10.2 ppm) contents are low. Y (22.5-26.8 ppm) contents are constant. Zr/Nb (41.2-47.7) and Nb/Ta (14.3-19.6) ratios are relatively constant. Y/Nb ratios (0.24-0.32) are low. REE patterns (Fig. 7) show regular decreased normalized values from LREE to HREE and very high LREE ratios (up to 100 times the mantle values). (Ce/Yb)n ratios (14.2-20.3) are high. Regular decreased values are also shown by spider diagram (Fig. 8) from high incompatible to compatible elements. Positive anomalies are observed in Nb, Ta and Zr and negative anomalies are observed in K, P and Ti.

Table 5: ICP-MS and ICP-AES Analyses of Host Peridotite Basaltic Lavas of Northern Ngaoundéré

locality	Kobi	Kobi	Béka	Béka	Mazélé
lava	basanite	basanite	basanite	basanite	basanite
sample	LNZ8	LNZ2	LNJ9	LNJ36	LTZ13
SiO_2 (wt %)	43.75	42.48	42.26	42.29	43.26
TiO_2	3.12	3.07	3.90	3.45	2.68
Al_2O_3	12.96	12.31	13.28	12.79	12.26
Fe_2O_3	12.19	12.10	14.47	13.54	11.49
MnO	0.19	0.18	0.20	0.20	0.17
MgO	12.17	12.33	8.03	9.86	14.02
CaO	9.42	9.54	9.58	9.16	9.95
Na_2O	3.52	3.13	3.63	3.57	3.20
K_2O	1.75	1.60	2.36	2.21	1.48
P_2O_5	0.94	0.90	0.94	0.94	0.64
LOI		1.70	0.80	1.4	0.20
sum	100	99.34	99.49	99.44	99.55
Fe_2O_3/FeO	0.15	0.15	0.15	0.15	0.15
CIPW Norm					
Orthoclase	10.32	9.48	13.95	13.06	8.75
Albite	8.28	7.40	5.03	5.50	4.58
Anorthite	14.41	14.79	12.97	12.35	14.72
Nepheline	11.63	10.35	13.91	13.38	12.18
Diopside	21.07	21.43	23.22	21.87	24.41
Olivine	23.02	23.14	16.22	19.60	24.95
Magnétite	2.10	2.09	2.49	2.33	1.98
Ilmenite	5.93	5.82	7.41	6.55	5.09
Apatite	2.17	2.08	2.18	2.18	1.48
Mg#	64.02	64.49	49.73	56.48	68.50
Be (ppm)	1.9	2.0	6.0	2.0	2.0
Rb	49	43	49	40	38
Sr	930	1034	1127	1193	759
Cs		0.52			0.40
Ba	539	570	721	795	538
V	188	203	257	226	220
Cr	452.1	510.6	86.9	150.2	65.0
Co	48.8	53.9	43.9	47.9	59.7
Ni	345.1	402.7	123.0	207.0	382.8
Cu		43			38
Sc	18.27	19.45	19	17	
Y	25.4	26.8	25.9	26.3	22.5
Zr	324	340	326	338	237
Hf	7.0	7.1	7.9	7.9	5.5
Ta	5.78	5.72	5.20	5.70	3.70
Th	7.90	8.16	9.20	10.20	7.40
Ga	18.0	18.9	20.2	19.8	
Sn	3	2	2	2	
W	0.9	1.2	1.2	1.2	
Nb	83	83	97	107	73
Zn	109	120	113	116	73
La	61.6	63.2	75.4	83.3	54.5
Ce	119	122	149	157	97
Pr	13.5	14.1	15.6	16.3	11.1
Nd	52	55	58	63	42
Sm	10.1	10.6	10.9	11.4	8.0
Eu	3.1	3.3	3.2	3.4	2.5
Gd	8.02	8.40	9.26	9.36	7.20
Tb	1.077	1.130	1.210	1.210	0.980
Dy	5.73	5.98	5.93	6.06	5.04
Ho	1.01	1.06	1.07	1.05	0.91
Er	2.32	2.44	2.56	2.55	
Tm	0.30	0.30	0.32	0.29	0.28

Yb	1.76	1.84	2.00	2.04	1.80
Lu	0.25	0.27	0.23	0.28	0.24

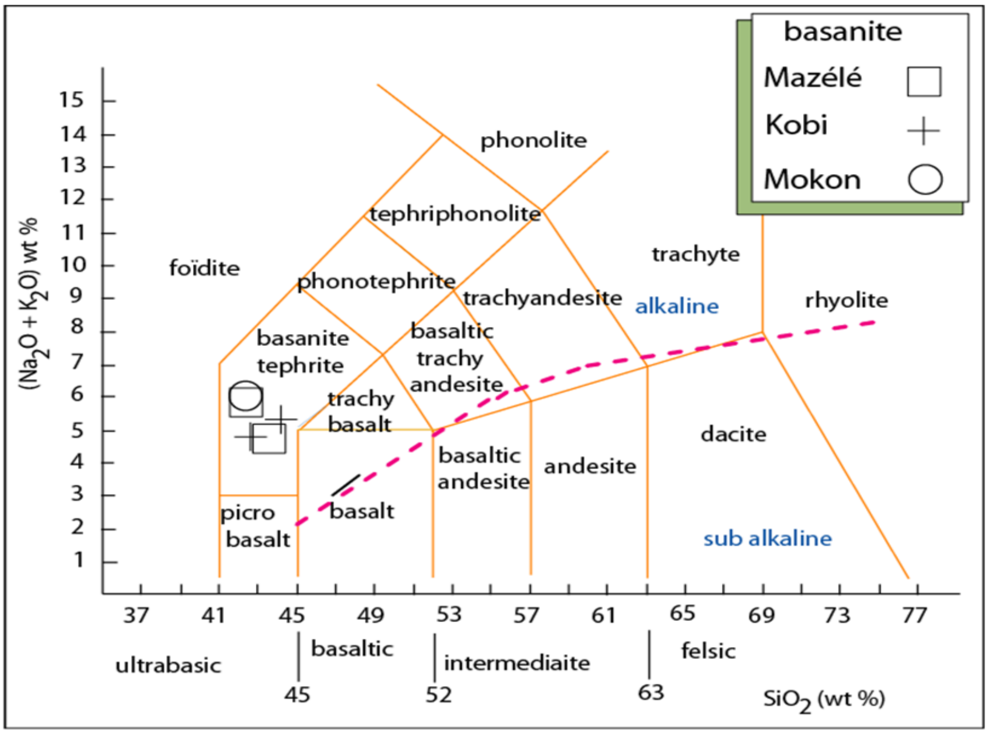

Fig. 6: TAS Diagram (After Le Maitre 2002) of Upper Lava Series Northern Ngaoundéré Located in the Basanite Field. Dashed Line Separating Alkaline and Sub Alkaline Fields (after Miyashiro 1978).

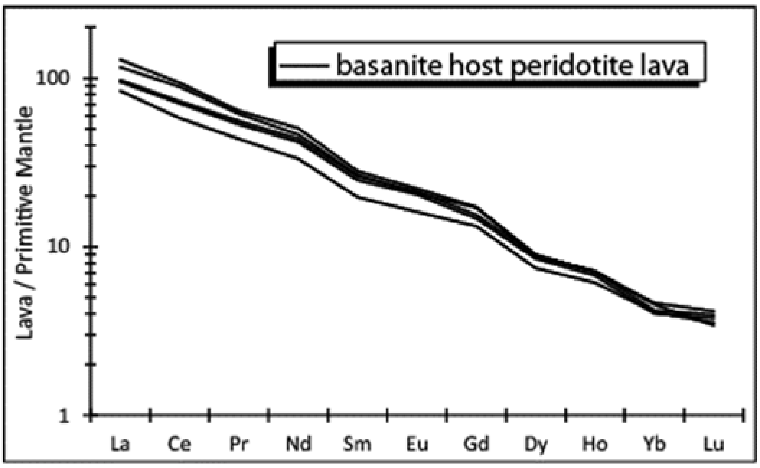

Fig. 7: Normalized (After Mcdonough & Sun 1995) REE of Peridotite Host Basanite Lavas of Northern Ngaoundéré.

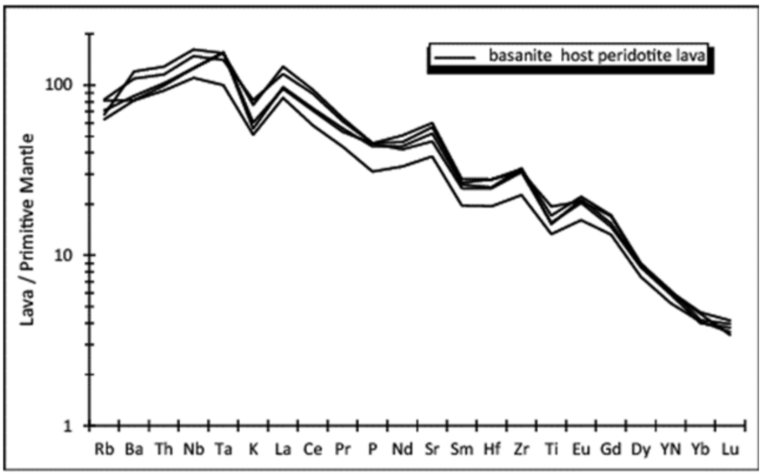

Fig. 8: Multielements Spiderdiagram (Normalization after Mcdonough & Sun 1995) of Peridotite Host Basanite Lavas of Northern Ngaoundéré.

5. Discussion

Representative compositions of host peridotite basanite lavas of northern Ngaoundéré exhibit the characteristic features of undersaturated alkaline basaltic lavas worldwide (Le Maitre 2002). SiO_2 contents are low, alkali and TiO_2 contents are high. High normative olivine and nepheline lead to deep under saturated alkali lava series. Studied basanite show some rather evolved characters (Ni: 123.0-402.7 ppm; Cr: 65-510.6 ppm and Co: 43.9-59.7 ppm) probably due to early olivine, oxides, clinopyroxene and late plagioclase microlites crystallization. Basanite host peridotite lava with high Mg# (68.5) closed to mantle materials (Wilkinson & Le Maitre 1987) but with low Cr, Co and relatively low Ni contents might have undergone a magma process other than fractional crystallization. High (Ce/Yb)n (14.2-20.3) and (La/Yb)n (20.6-27.8) ratios of studied lava are consisting with a low partial melting rate of a deep mantle source as suggested by the low values of heavy REE (Fig. 7), probably not far from 2 to 3 % partial melting (Nkouandou et al. 2008 and 2010) of the Adamawa basaltic mantle source. Low HREE may also suggest the presence of garnet phase in the host basanite mantle source i.e. at more than 80 km and between 2 to 3.5 Gpa (Stern et al. 1990) or 3.6 to 4.2 Gpa obtained from the Scarrow & Cox (1995) formula. Thus, northern Ngaoundéré basanite have sampled mantle peridotite at different pressures and different depths. The assumption of the presence of the garnet phase in the basanite mantle source is sustained by positive ΔNb (0.1-0.3) of basanite lavas (Fitton et al. 1997) and their high (Dy/Yb)n ratios (Blundy et al. 1998). Spiderdiagram of host peridotite lavas (Fig. 8) show negative anomaly in K, P and Ti. K anomaly can be considered as the characteristic feature of the peridotite host lavas mantle source as have been suggested by Nkouandou et al. (2010) for whole Adamawa plateau Mio-Pliocene basaltic lavas. P and T anomalies are ascribed to the early crystallization of apatite and Ti-oxides phases in those basanite. Crustal contamination is not conceivable as the presence of ultrabasic mantle fragments of centimeters size in those lavas strongly suggest the rapid ascent of the host peridotites basanite from the magma chamber in their way to the surface, trough Pan African cracks of northern Ngaoundéré (Dumont 1987, Moreau et al. 1987, Poudjom Djomani et al. 1997, Fagny et al. 2016). High contents of Nb and Ta are in favor of the non-contamination of studied lava by the crustal materials.

6. Conclusion

Northern Ngaoundéré basaltic lavas are Pliocene-Quaternary upper black alkaline lava series of basanite in composition. Those lavas have sampled numerous fragments of mantle peridotite during their rapid ascent from the magma chamber in their way to the surface, trough Pan African cracks of the area, at different pressures and depths. They exhibit the little evolved characters after an early crystallization of olivine, clinopyroxene, oxides and late crystallization of plagioclase microlites. Basanite host peridotite lavas of northern Ngaoundéré are not contaminated by crustal materials. They are the results of the low partial melting rate of the garnet mantle source, located at more than 80 km.

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