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The Mount Cameroon stratovolcano (Cameroon Volcanic Line, Central Africa): Petrology, geochemistry, isotope and age data

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Abstract. Mount Cameroon, a Plio-Quaternary stratovolcano, is the most important volcano along the Cameroon Volcanic Line, located at the boundary between the continental and oceanic lithosphere. Effusive, explosive and hydromagmatic eruptions were the three main types of volcanic activity. Mount Cameroon has a weakly differentiated alkaline series: mainly basanites, alkaline basalts, hawaiites, and mugearites. Mount Cameroon lavas are a typical alkaline series, characteristic of the interior of plates: high TiO_2 contents (2.4-3.7 wt.%), Na_2O between 2.9 and 5.2 wt.%, K_2O between 1.1 and 3.0 wt.%. Trace element patterns confirm the general evolution by fractional crystallization from a source in a mantle plume. Magmas beneath Mount Cameroon were generated at great depths from a garnet-lherzolite mantle, with an additional contribution from spinel-lherzolite, with small amounts (0.2-2 %) of melting. ^{40}K-^{40}Ar analyses have yielded ages of 2.83 to 0 Ma. The $^{87}Sr/^{86}Sr$ ratios of mafic lavas are low (0.703198-0.703344), and $^{143}Nd/^{144}Nd$ ratios are intermediate (0.512851-0.512773), as typical of a mantle origin with a HIMU component. $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{208}Pb/^{204}Pb$ ratios are respectively 18.8270-20.3911, 15.5999-15.6793 and 40.2093-38.6517.

Key words: Mount Cameroon, K-Ar ages, isotopes (Sr, Nd, Pb), HIMU

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Жан-Пол Фердинанд Тсафак, Пиер Ванджи, Жак-Мари Барделзеф, Херве Белон, Херве Гийу. Стратовулканът Маунт Камерун (Камерунска вулканска верига, Централна Африка): петрология, геохимия, изотопи и възраст

Резюме. Плиоцен-кватернерният стратовулкан Маунт Камерун, най-важният вулкан в Камерунската вулканска верига е разположен на границата между континенталната и океанска литосфера. Ефузивната, експлозивната и хидромагматична дейност са трите основни типове вулканска активност. Маунт Камерун е изграден от скалите на слабо диференцирана алкална серия: главно базанити, алкални базалти, хаваиити и муджиерити. Лавите на вулкана принадлежат на типична вътрешноплочова алкална серия: високо TiO_2 съдържание (2,4-3,7 wt.%), Na_2O между 2,9 и 5,2 wt.%, K_2O между 1,1 и 3,0 wt.%. Съдържанията и поведението на елементите-следи сочат фракционната кристализация като основен фактор при еволюцията на магмата и източник – мантийна струя (plume).

Магмата под Маунт Камерун е генерирана на голяма дълбочина в гранат–лерцолитова мантия с допълнително участие на шпинелов лерцолит при ниска степен на топене (0,2-2%). ^{40}K–^{40}Ar възраст е от 2,83 до 0 Ma. $^{87}Sr/^{86}Sr$ отношение на мафичните лави е ниско (0,703198 – 0,703344), а $^{143}Nd/^{144}Nd$ отношение е с промеждутъчни стойности (0,512851-0,512773). Те са типични за магми с мантиен произход с HIMU компонент. $^{206}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ и $^{208}Pb/^{204}Pb$ отношения са съответно 18,8270-20,3911, 15,5999-5,6793 и 40,2093-38,6517.

Introduction

Mount Cameroon (4095 m) belongs to the Cameroon Volcanic Line (CVL), a major structural feature, oriented N30 in Central Africa (Fig. 1) and characterized by the alignment of continental volcanoes, plutons and oceanic volcanic islands (Bioko, Principe, Sao Tomé, Pagalu) (Fitton and Dunlop 1985). CVL extends from the Atlantic Ocean to Lake Chad. During the 20th century, after five eruptions (1909, 1922, 1954, 1959, 1982), Mount Cameroon is still active and has had two more recent eruptions on 28 March–22 April 1999 and 28 May–19 June 2000 (Déruelle et al. 2000; Wandji et al. 2001; Suh et al. 2003; Fig. 2 and 3). About 140 strombolian cones are scattered on the flanks of this huge stratovolcano: 100 of them are located on the South, South East and South West flanks, which extends towards the Atlantic Ocean.

The aims of this study are to present new petrological, geochronological and isotopic data, and their implications for better understanding the petrogenetic processes.

Geological framework

The CVL tectonic structure (Fig. 1) is the consequence of a series of parallel fissures oriented N30 and of some transversal events (Burke and Whiteman 1973). This line is made up of 12 main volcanic centres with ages ranging from 51.8 Ma to the Present (Fitton and Dunlop 1985; Itiga et al. 2004; Fosso et al. 2005; Déruelle et al. 2007; Moundi et al. 2007).

The regional map of the cones shows three major tectonic axes that control the volcanic activity (Tsafack 2009): the Debundscha axis (N60 – 70), the Limbe axis (N140 – 150) and the Batoke axis (N30 – 40).

Morphologically, Mount Cameroon is a stratovolcano, situated on a horst with boundary faults that are expressed by breaks of slopes (Déruelle 1982). It is bounded by the Tombel graben to the North and the Douala basin to the South. It has an elliptical shape, 50 km long and 35 km wide. Its basement (Pan-African granite and gneiss) is covered by cretaceous to quaternary sediments, observable in the Bomana maar at the NW of the massif (Dumort 1967; Tsafack et al. 2007).

Mount Cameroon appears to be a rather complex edifice produced by three main types of volcanic activity (Bardintzeff and McBirney 2000):

(i) Effusive eruptions, responsible for the lava flows covering parts of the stratovolcano;

(ii) Explosive activity which has built about 140 strombolian cones;

(iii) Hydromagmatic activity that formed the maars of Debundscha and Bomana in the sedimentary basement at the North West of the volcano (Tsafack 2009).

Mount Cameroon lavas are essentially basanites (60 vol.%), alkaline basalts (25 vol.%), hawaiites (10 vol.%) and rare mugearites (5 vol.%). Camptonite, a type of lamprophyre composed mainly of plagioclase and brown hornblende, has been recently described (Ngounouno et al. 2006). Moreover, xenoliths (1-5 cm × 0.5-4 cm) of dunites, wehrlites and clinopyroxenites have been discovered in the basanites of the strombolian Batoke cone located on the south flank of the massif, at 500 m above sea level (Tsafack 2009; Wandji et al. 2009). Similar xenoliths of wehrlites and clinopyroxenites have been found in basaltic tephra of a strombolian cone situated at 3000 m elevation on the north-western flank of Mount Cameroon (Déruelle et al. 2001; Ngounouno et al. 2001).

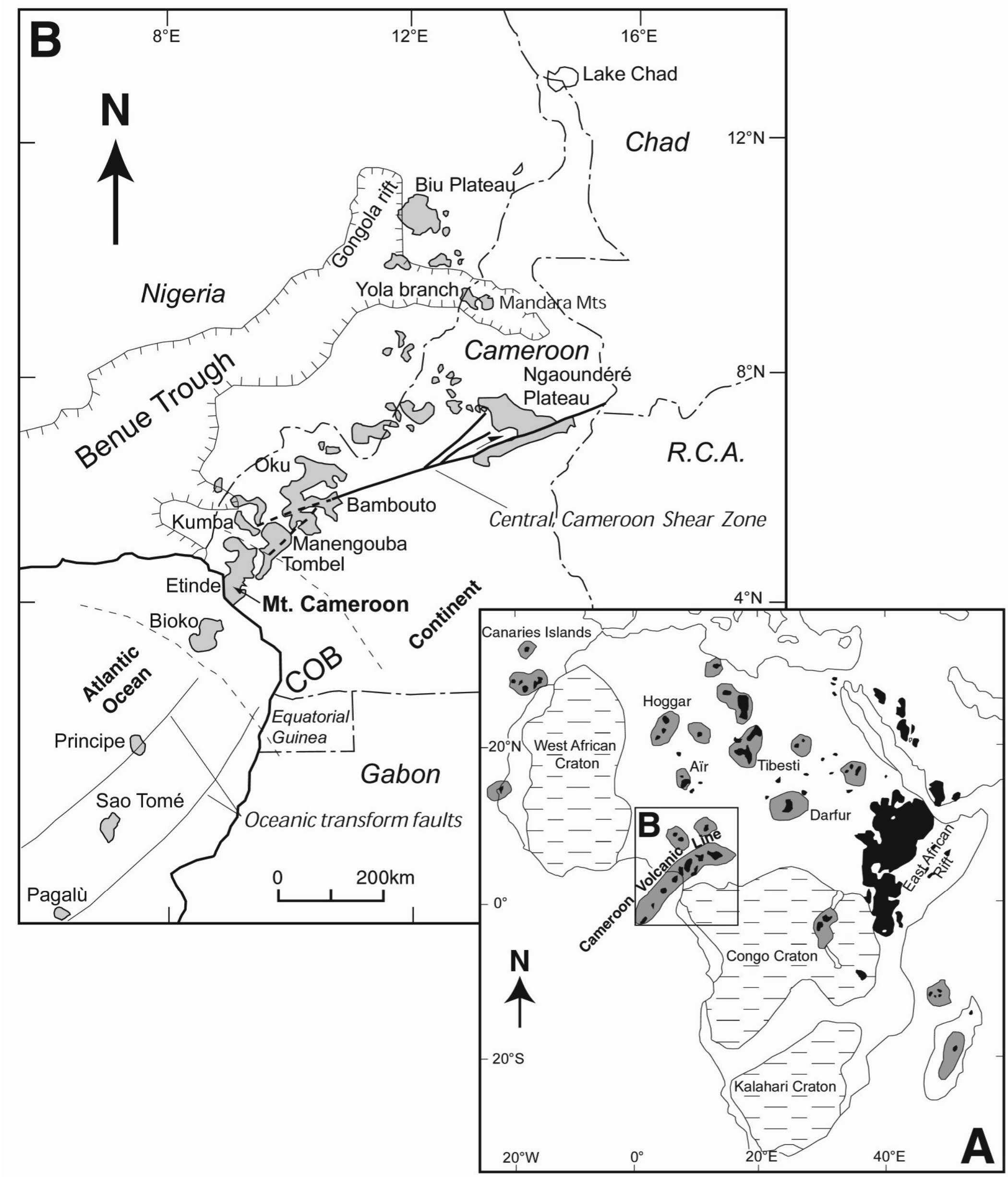


Fig. 1. A) Location map of the Cameroon Volcanic Line (CVL). The main geological features of Africa are indicated: eastern African volcanism linked to rifting (black) and intra-plate (continental or oceanic) volcanic provinces (grey). B) Location of Mount Cameroon and other main volcanic centres (grey) along the Cameroon Volcanic Line. Dashed lines are boundaries between the CVL segments: Atlantic Ocean, Continental Ocean Boundary (COB) and continent. (after Wandji et al. 2009, modified according to Nkouathio et al. 2008)

Fig. 2. Lava flows from Mount Cameroon, destroying forest and vegetation during the April 1999 eruption (photos J.M. Bardintzeff)

Analytical studies

In our study, 42 samples from Mount Cameroon have been analyzed for major and trace elements (Centre de Recherches Pétrographiques et Géochimiques CRPG, Nancy, France): 24 basanites, 10 alkaline basalts, 4 hawaiites, 2 mugearites and 2 xenoliths (1 dunite and 1 wehrlite) (Tsafack, 2009). 11 of them have been published in Wandji et al. (2009). Others eight of them are presented in Table 1. Major element analyses have been made by ICP-OES (Inductively Coupled Plasma-Optical Emission Spectrometry) and trace element analyses by ICP-MS (Mass Spectrometry). Five international geostandards have been used (basalt BR, diorite DRN, serpentinite UBN, anorthosite ANG and granite GH, Carignan et al., 2001).

Eight effusive rocks (or ancient lava flows) have been dated by ^{40}K–^{40}Ar method. Five of them have been dated on whole-rock (fraction 150 – 300 µm) at the University of Brest, France. The analytical procedure is detailed in Bellon and Rangin (1991). The three other samples have been dated on groundmass at CNRS of Gif-sur-Yvette, France, following the methods detailed in Guillou et al. (1998).

Isotopic analyses were made by D. Demaiffe at the Laboratoire de Géochimie isotopique, Université Libre de Bruxelles, Belgium, with a Micromass VG 54 multi-collector thermo-ionisation mass spectrometer.

Petrography and geochemistry

The samples are grouped into two geographic sectors: LA for low altitude and HA for high altitude. In the TAS diagram after Le Maitre (2002) (Fig. 4a), most of the lavas plot within the fields of basanites alkaline basalts and hawaiites, that is to say DI less than 35. The most differentiated lavas are mugearites sampled above 2500 m (HA sector). Hawaiite and mugearite generally outcrop in the HA sector, except for a few hawaiites that are located in the LA sector.

Fig. 3. Lava flow from Mount Cameroon, cutting the road between Limbe and Idenau on the morning of April 16, 1999. People at the right of the lava flow give the scale (photo J.M. Bardintzeff)

Table 1. *Selected chemical analyses from Mount Cameroon alkaline series. Main elements in wt.%, trace elements in ppm. (nd) not detected. Negative values of LOI are due to recalculations of* Fe_2O_3 *total*

Rock	Basanite		Basalt			Hawaiite		Mugearite
Sample	TM160	TM404	TM1	TM407	TM106	TM403	TM282	TM272
SiO_2	41.85	44.96	45.23	45.38	46.62	46.52	47.20	51.86
TiO_2	3.46	3.21	3.62	3.27	3.23	3.76	3.41	2.38
Al_2O_3	11.97	16.07	15.32	15.08	15.31	16.09	16.40	17.82
Fe_2O_3tot	13.88	12.00	12.89	12.71	12.46	12.40	12.54	8.73
MnO	0.21	0.20	0.19	0.20	0.17	0.20	0.17	0.15
MgO	10.00	5.55	6.34	6.33	6.40	4.77	4.79	3.27
CaO	12.07	10.61	11.15	10.89	10.44	9.48	9.98	6.99
Na_2O	3.78	4.44	2.08	3.39	3.69	3.88	3.79	4.68
K_2O	1.42	1.97	1.45	1.53	1.21	1.82	1.63	2.97
P_2O_5	0.79	0.73	0.69	0.63	0.49	0.95	0.53	0.58
LOI	-0.38	0.08	1.50	0.42	-0.08	0.46	-0.36	0.55
Total	99.05	99.80	100.46	99.83	99.94	100.32	100.08	99.98
Ba	528.90	595.90	460.80	463.10	336.80	557.60	406.70	693.50
Rb	45.15	50.69	31.84	35.60	25.39	45.83	33.83	70.59
Cs	0.52	0.47	0.38	0.37	0.21	0.48	0.45	1.00
Sr	1163.00	1192.00	899.70	998.10	746.10	1231.00	831.40	1013.00
Y	32.98	32.26	30.28	29.86	28.55	39.62	31.17	37.57
Zr	464.70	442.90	360.30	332.70	286.70	539.10	355.70	576.60
Hf	9.13	8.44	7.52	7.05	6.33	10.45	7.73	11.10
Nb	113.80	111.60	80.27	85.96	62.15	106.80	72.30	117.00
Ta	8.07	7.97	5.93	6.20	4.60	7.30	5.49	8.11
Th	9.47	10.12	6.90	7.20	5.32	8.05	6.90	13.89
U	2.45	2.49	1.87	1.72	1.24	2.24	1.82	3.57
Pb	4.29	4.88	3.52	3.48	2.73	4.30	4.40	8.93
Ga	23.60	24.90	23.71	23.88	23.33	30.77	24.89	27.94
Ge	1.59	1.58	1.45	1.46	1.49	1.64	1.46	1.53
Zn	139.50	129.80	125.70	136.60	118.90	175.00	138.30	120.50
Cu	63.31	66.08	51.69	73.38	70.50	23.29	22.48	27.83
Ni	183.40	53.23	59.51	76.10	91.28	17.56	20.29	18.73
Cr	414.20	66.13	124.60	156.40	157.80	5.12	18.81	16.39
Co	57.36	35.51	40.85	42.79	41.62	35.72	34.52	21.66
V	310.80	264.60	287.30	293.90	275.20	284.20	299.20	188.30
Cd	0.34	0.32	nd	nd	nd	0.35	nd	nd
Be	2.17	2.10	1.71	1.67	1.46	3.09	1.73	2.97
W	1.04	1.15	0.65	0.83	0.69	0.79	0.61	1.25
Sn	2.95	2.61	2.27	2.50	2.04	3.13	2.68	3.33
Sb	nd	0.16	nd	nd	nd	nd	0.12	0.20
Mo	4.10	4.07	2.42	2.78	2.22	3.99	3.10	4.25
La	91.40	90.99	63.51	69.19	49.63	82.76	57.98	96.90
Ce	189.80	178.90	130.10	139.60	101.20	171.00	122.40	193.10
Pr	21.62	19.58	15.65	16.09	12.19	20.72	14.85	21.67
Nd	82.15	72.31	61.13	61.76	47.81	83.78	58.73	80.37
Sm	13.89	12.26	11.51	11.04	9.32	15.94	11.20	13.93
Eu	4.20	3.78	3.46	3.44	2.95	4.82	3.42	4.07
Gd	10.49	9.42	9.12	8.93	7.93	12.45	8.92	10.60
Tb	1.41	1.34	1.25	1.23	1.12	1.66	1.26	1.46
Dy	7.10	6.93	6.67	6.47	6.05	8.35	6.62	7.61
Ho	1.19	1.17	1.10	1.09	1.03	1.36	1.15	1.32
Er	2.97	3.05	2.79	2.76	2.62	3.27	2.95	3.36
Tm	0.39	0.40	0.36	0.36	0.35	0.41	0.39	0.47
Yb	2.35	2.53	2.25	2.28	2.18	2.46	2.42	2.95
Lu	0.34	0.36	0.32	0.33	0.31	0.34	0.35	0.43

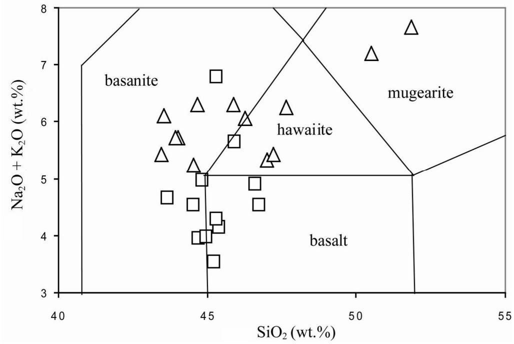


Fig. 4a. Total alkalies *vs.* silica plot for the studied lavas (according to Le Maitre 2002). Squares: low altitude (LA) lavas below the altitude of 2500 m; Triangles: high altitude (HA) lavas above the altitude of 2500 m

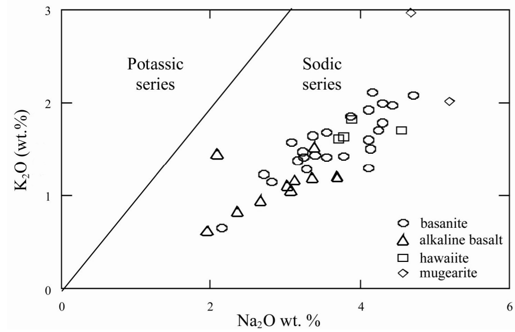


Fig. 4b. K_2O *vs.* Na_2O diagram of Mount Cameroon lavas (according to Irvine and Baragar 1971)

Basanites exhibit porphyric texture and microlitic groundmass. Phenocrysts are olivine (chrysolite) and diopside ($Wo_{44–47}En_{43–50}Fs_{19–30}$). Some xenocrysts are present. Microlites are olivine, clinopyroxene, Ti-magnetite, spinel, plagioclase and nepheline.

Alkaline basalts have porphyric texture and groundmass close to the doleritic texture as it was more or less totally crystallized. Olivine phenocrysts and microphenocrysts are chrysolite. Clinopyroxene (diopside) is abundant as microphenocrysts. Plagioclase microlites are bytownite, labradorite, andesine. Scarce alkali feldspars (sanidine Or_{34}) are present as microlites. Oxides (0.2-0.3 mm in size) are Ti-magnetite (28 wt.% TiO_2).

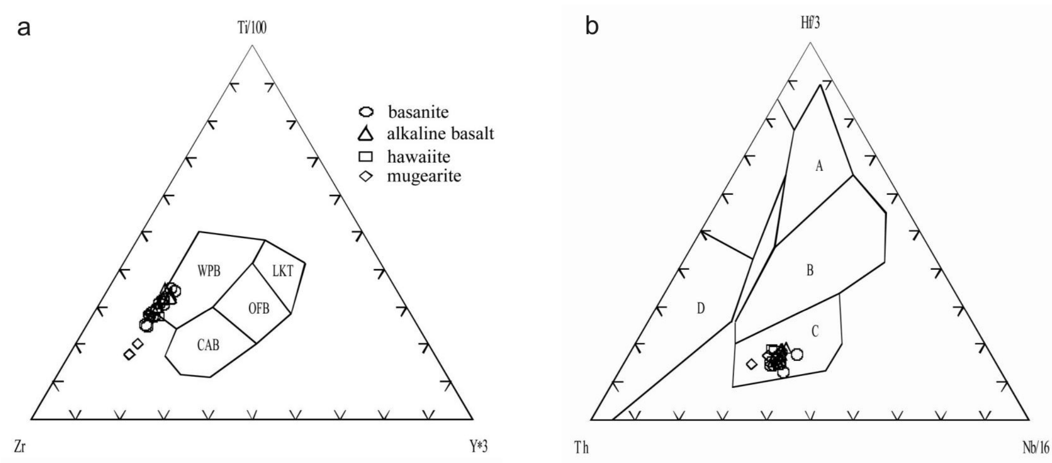
Hawaiites have porphyritic texture and microlitic groundmass with megacrysts of olivine (hyalosiderite $Fo_{61–80}$), clinopyroxene (diopside), and plagioclase. Microlites of plagioclase (labradorite and andesine) are abundant in groundmass, where automorphous Ti-magnetite microphenocrysts are present too.

Mugearites have porphyritic texture with microlitic groundmass. Prismatic plagioclase (labradorite and andesine) megacrysts and phenocrysts are very abundant. Cllinopyroxene ($Wo_{43–45}En_{42–44}Fs_{18–24}$) microphenocrysts are present too. Microlites of alkali feldspars are anorthoclase ($Ab_{59–62}$, $Or_{27–32}$) and sanidine ($Ab_{49–57}$, $Or_{36–45}$). Oxides are Ti-magnetite and ilmenite (51 wt.% TiO_2).

These lavas form a typical alkaline series: TiO_2 contents are high (2.39-3.62 wt.%), Na_2O contents range between 2.88 and 5.19 wt.% and K_2O between 1.11 and 2.97 wt.% (Table 1). K_2O/Na_2O ratios range mostly between 0.3 and 0.5, typical of sodic lavas according to Irvine and Baragar (1971) (Fig. 4b). All lavas contain normative nepheline (3.6-16.9 wt.%) that witness of significant silica undersaturation, except lava TM1 that contains a small amount (2.4 wt.%) of normative hypersthene.

There is a progressive increase in SiO_2, Na_2O, K_2O and Al_2O_3 contents and a significant decrease in CaO, MgO (from 10.5 to 3.2 wt.%) and Fe_2O_3 contents from basanite to mugearite, that reflect the magmatic differentiation. A strong decrease in MgO (from 10.5 to 6 wt.%) in the basanites and basalts shows the effect of early crystallization of olivine (chrysolite). Further on, clinopyroxene and Fe-Ti oxides must have crystallized, followed by plagioclase (bytownite to andesine) and alkali feldspar (sanidine, anorthoclase).

Basanites and alkaline basalts are characterized by high Ba (up to 609 ppm) and La (up to 93 ppm) contents, typical of alkaline



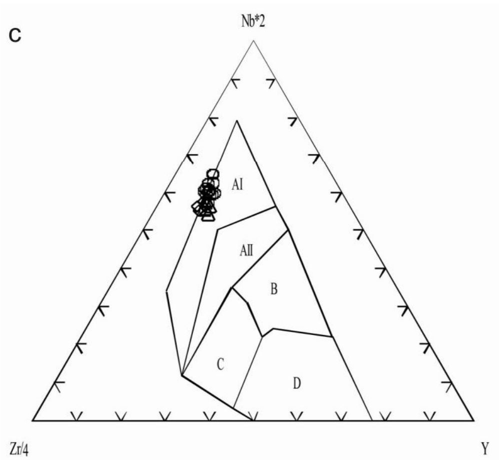


Fig. 5. Mount Cameroon lavas in the: a) Zr–Ti–Y discriminating diagram (Pearce and Cann 1973). (LKT) Low potassium Tholeiites; (OFB) Ocean Floor Basalts; (CAB) Calc-Alkaline Basalts; (WPB) Within-plate basalts; b) Th–Hf–Nb discriminating diagram (Wood 1980). (A) N-type MORB; (B) E-type MORB and tholeiitic within-plate basalts and differentiates; (C) Alkaline within-plate basalts and differentiates; (D) Destructive plate-margin basalts and differentiates; c) Zr–Nb–Y discriminating diagram (Meschede 1986). (AI) Within-Plate Alkaline Basalts (WPA); (AII) WPA and Within-Plate Tholeiites (WPT); (B) P-type MORB; (C) WPT and Volcanic Arc Basalts (VAB); (D) N-type MORB and VAB

series. These samples with high Nb contents (mostly between 70 and 120 ppm) differ from those (less than 50 ppm) of transitional basalts described by Moundi et al. (2007) in Bamoun Plateau, Cameroon. In that way, K/Nb, Y/Nb, Rb/Nb and Zr/Nb ratios of Mount Cameroon lavas are rather low. Some basanites and alkaline basalts have geochemical features (Cr > 500 ppm, Ni > 200 ppm) of more or less primary magmas as observed in Tombel graben and in Mount Bamboutos by Nkouathio et al. (2008).

Transition elements contents decrease (Cr from 622 to 5 ppm, Ni from 236 to 12 ppm, Co from 57 to 22 ppm) with decreasing MgO (from 11.0 to 3.3 wt.%) content in agreement with fractionation of mafic minerals such as olivine and diopsidic pyroxene. As differentiation progressed, V contents also decrease (in the same way of Fe_2O_3 and TiO_2), indicating that Fe-Ti oxides also crystallized during the intermediate stage.

Incompatible element (Rb, Zr, Y) contents increase, along with K during differentiation while Sr is roughly constant. The positive correlations between Zr (an element very little affected by weathering) and some trace elements such as Sr, Yb, Rb, Ba, Nd, La, Sm and Lu illustrate the weakness of the alteration phenomenon.

The mafic lavas of Mount Cameroon plot in the fields of within-plate alkaline basalts according to Zr–Ti–Y diagram defined by Pearce and Cann (1973), as well as the Th–Hf–

Ta and the Th–Hf–Nb diagrams of Wood (1980) and the Zr–Nb–Y diagram of Meschede (1986) (Fig. 5 a-c).

Nb/U ratios range between 33 and 51 while Ce/Pb ratios range between 22 and 53. They are close to typical values for Ocean Island Basalts (OIB) and Mid Ocean Ridge Basalts (MORB) (47±10 and 25±5 respectively, according to Hofmann et al., 1986) and distinct from the very low values for continental crust (10 and 4 respectively) indicating very low crustal contamination of the Mount Cameroon lavas.

In the Nb/Y *vs.* Zr/Y diagram (Fig. 6), all the Mount Cameroon lavas fit in the strip constrained by Fitton et al. (1997) and confirmed by Upton et al. (2000) for the Reunion Island, representing the basalts generated by a mantle plume.

The trace element patterns of the analyzed effusive rocks are all parallel, indicating that they are cogenetic (Fig. 7). Light Rare Earth Elements (*LREE*) are 100 – 200 times enriched compared to the chondrite standard. Intermediate rare earths are 20 – 50 times enriched while Heavy Rare Earth Elements (*HREE*) are enriched by a factor of 10 to 15. For example, La contents range between 96.9 to 49.6 ppm while Lu contents are only of 0.27 to 0.43 ppm. $(La/Yb)_N$ ratio range between 17 and 26. Nb positive anomaly *vs.* Rb and Ba (Fig. 7) is typical of basalts of HIMU type (high μ with $\mu = {}^{238}U/{}^{204}Pb$) according to Woodhead (1996).

The Ba/Th (average of 50-60) *vs.* Rb/Nb (0.3-0.5), as well as Ba/La (average of 5-7) *vs.* Ba/Nb (5-6) suggest that the HIMU mantle

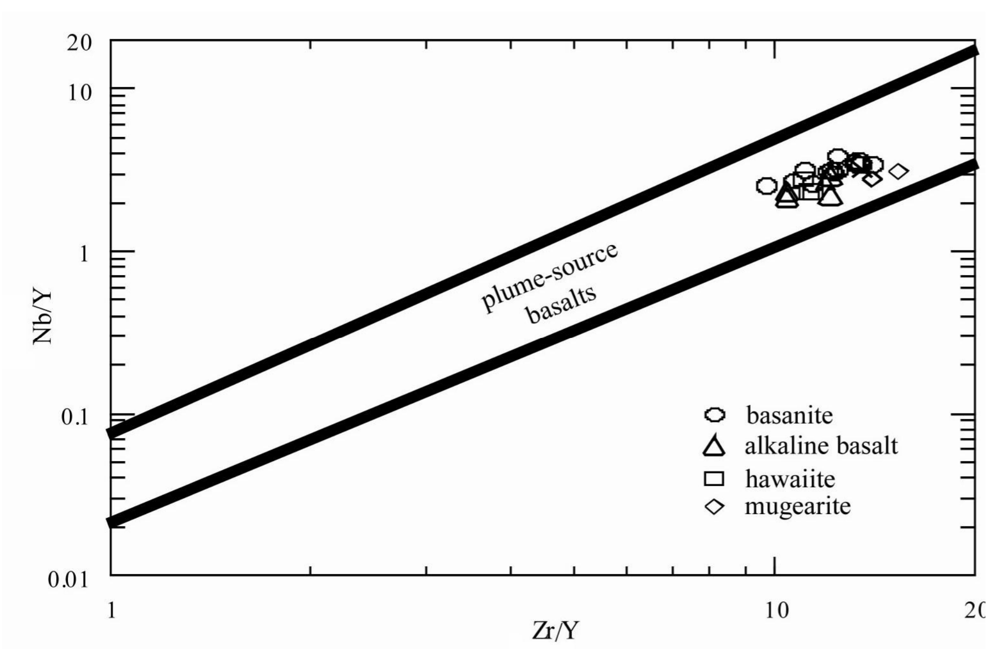


Fig. 6. Nb/Y *vs.* Zr/Y plot for Mount Cameroon lavas. The lines indicate the constraints, placed by Fitton et al. (1997) for plume-source basalts

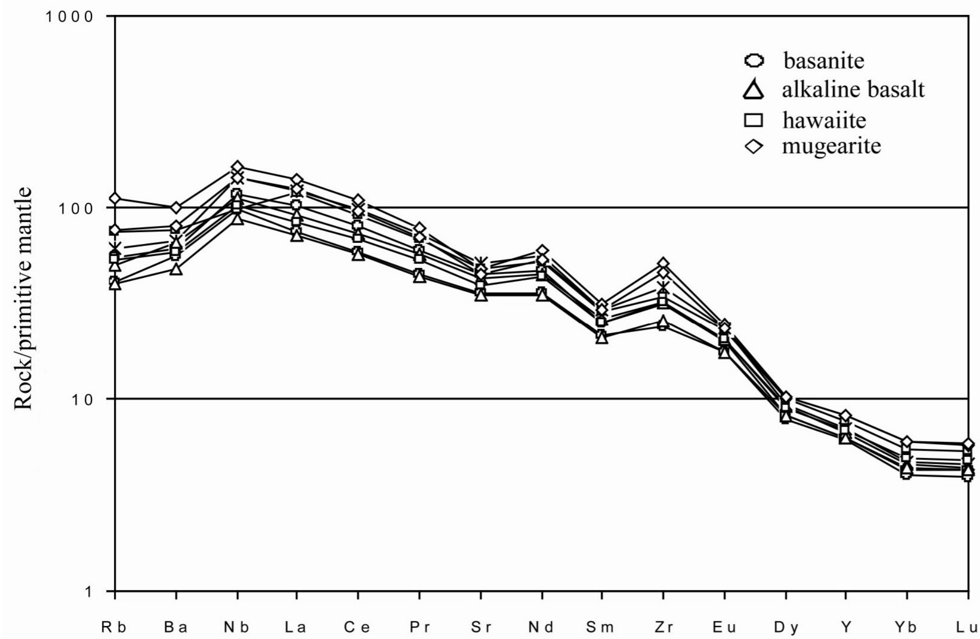


Fig. 7. Primitive mantle-normalised trace element patterns for the effusive rocks. Normalising values from Sun and McDonough (1989)

reservoir was involved in the genesis of the Mount Cameroon magma according to the criteria of Weaver (1991).

The Ce/Y *vs.* Zr/Nb diagram (Fig. 8) illustrates the relation between the composition of the source and the degree of partial melting, in the case of a model taking in account the fractional melting, calculated for depleted and primitive mantle compositions and for spinel and garnet-lherzolite parageneses (Hardarson and Fitton 1991). Most samples of representative lavas of Mount Cameroon (Fig. 8) fall between the depleted garnet lherzolite curve and the primitive garnet lherzolite curve, and between the garnet lherzolite and spinel lherzolite curves for the other. Hence, magmas beneath the Mount Cameroon are generated at great depths (more than 60 km), in a garnet–lherzolite mantle, with a contribution of spinel–lherzolite with a small degree (0.2-2 %) of melting.

Geochronology and isotopic data

Eight lava flows have been dated by ^{40}K-^{40}Ar method. The five whole rock dating has yielded ages in the range of 2.83±0.11 (Late Pliocene) to 0.00±0.09 Ma. The groundmass dating is very recent (29±2 ka, 20±3 ka, 0 ka) (Table 2).

In view of the very young ages of the lava flows, the measured Sr and Nd isotopic ratios (results obtained by D. Demaiffe) can be used as initial ratios. The $^{87}Sr/^{86}Sr$ ratios (Table 2, Fig. 9) fall in a narrow range (0.703198-0.703386) and the $^{143}Nd/^{144}Nd$ ratios also (0.512773-0.512858). These values are similar to those (0.7029-0.7035 and 0.51277-0.51299 respectively) obtained for the basic lavas of the whole CVL by Halliday et al. (1988) and are typical of a mantle origin (Lee et al. 1994). Crustal contamination is negligible. The high $^{206}Pb/^{204}Pb$ ratios are characteristic of the HIMU end-member as pointed out by Halliday et al. (1990).

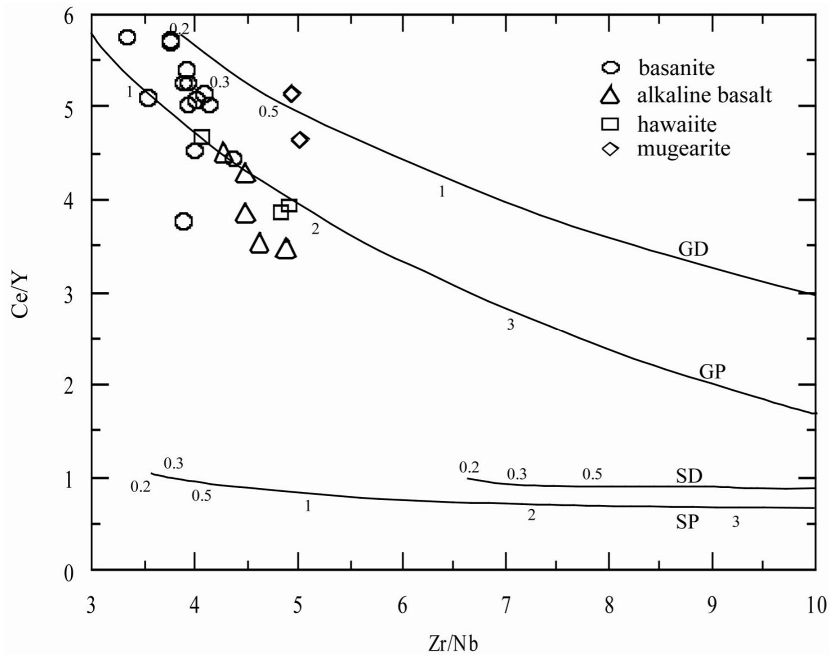


Fig. 8. The Ce/Y *vs.* Zr/Nb (after Hardarson and Fitton 1991) applied to the Mount Cameroun lavas. (GD) depleted garnet lherzolite; (GP) primitive garnet lherzolite; (SD) depleted spinel lherzolite; (SP) primitive spinel lherzolite. Numbers along the curves are percentages of melt

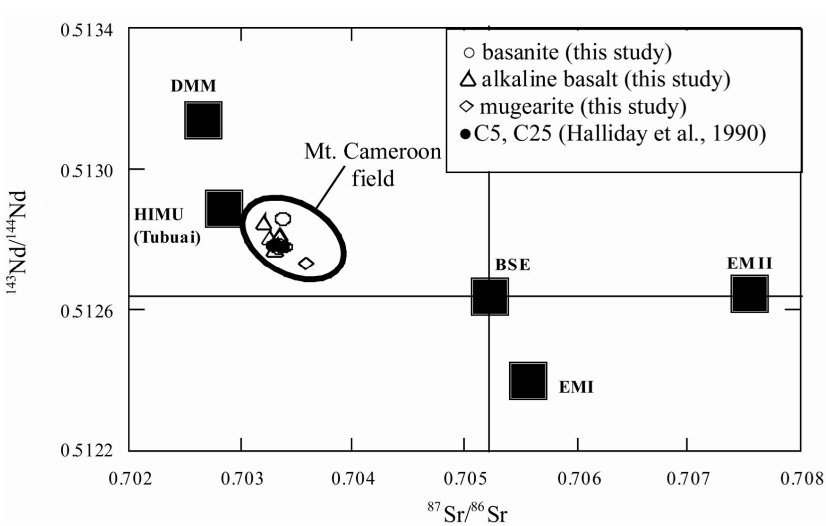


Fig. 9. $^{143}Nd/^{144}Nd$ *vs.* $^{87}Sr/^{86}Sr$ diagram of Mount Cameroon lavas. Depleted-MORB Mantle (DMM), EMI and EMII are from Faure (2001), HIMU from Chauvel et al. (1992), Bulk Silicate Earth (BSE) after Allègre (2005). C5 and C25 samples from Mount Cameroon (Halliday et al., 1990) are represented for comparison

Table 2. ^{40}K–^{40}Ar *ages and radiogenic isotope data. Ages obtained on whole-rock, except TM198, TM600, TM407 obtained on groundmass; samples are located in Wandji et al. (2009). C5 and C25 analyses of the Mount Cameroon are from Halliday et al. (1990) and Lee et al. (1994). nd = not detected, (na) not analysed*

Sample Number and Rock	Locality	Average age ±1σ (Ma) (except Ka)	$^{87}Sr/^{86}Sr$	$^{143}Nd/^{144}Nd$	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{204}Pb$	$^{208}Pb/^{204}Pb$
TM198 basanite	Limbe	29±2 (ka) (2σ)	0.703344	0.512773	20.2130	15.6594	40.1075
TM145 basanite	NE of Limbe	0.00±0.09	na	na	na	na	na
TM190a basanite	NE of Batoke	0.73±0.08	0.703386	0.512776	20.3257	15.6605	40.1562
TM404 basanite	E of Mt. Cameroon	1.34±0.14	0.703371	0.512858	20.3911	15.6544	40.1899
TM413 basanite	E of Mt. Cameroon		0.703339	0.512272	20.3102	15.6581	40.0951
TM600 basanite	W of Mt. Cameroon	0	0.703331	0.512786	18.8270	15.5999	38.6517
TM1 alk. basalt	near Bomana	2.83±0.11	0.703198	0.512851	20.3690	15.6793	40.2093
TM106 alk. basalt	Debundscha Cape	0.77±0.09	0.703260	0.512807	20.3492	15.6560	40.1426
TM402 alk. basalt	E of Mt. Cameroon		0.703331	0.512817	20.3111	15.6571	40.0952
TM530 alk. basalt	W of Mt. Cameroon		0.703292	0.512773	20.1467	15.6496	39.9361
TM532 alk. basalt	W of Mt. Cameroon		0.703328	0.512791	19.4697	15.6263	39.2871
TM407 alk. basalt	near Munyenge	20±3 (ka) (2σ)	na	na	na	na	na
TM272 mugearite	Mt. Cameroon, above 2000 m		0.703579	0.512735	19.3802	15.6649	39.6638
TM190b peridotite	Batoke		0.703402	nd	nd	nd	nd
C25	Mt. Cameroon		0.703350	0.512777			
C5	Mt. Cameroon		0.703280	0.512781			

All these isotopic data confirm the occurrence of a unique mantle source with a HIMU component under the Mount Cameroon.

Conclusions

The Mount Cameroon lavas constitute a slightly differentiated sodic alkaline series ranging from basanites essentially, through alkaline basalts and hawaiites to rare mugearites. The distribution of major and trace elements suggests a fractional crystallization process, with early crystallization of olivine, clinopyroxene and oxides, followed by plagioclase and alkali feldspar. The alteration phenomenon remains weak. Mount Cameroon magmas are formed by partial melting of a mantle plume. They generated from a mixing of melts derived from garnet and spinel lherzolite (Tsafack 2009). The Sr-Nd isotopic compositions show that crustal contamination was negligible during ascent and differentiation of the magma.

Different rare earth ratios as well as isotopic signatures of lavas suggest that the HIMU mantle reservoir was involved in the genesis of the Mount Cameroon magmas. The extended age range, between 2.83 and 0 Ma, confirms that the Mount Cameroon magmatic system was active from Late Pliocene to Present.

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