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COMPARATIVE GEOCHEMICAL STUDY OF THE 1982 AND 1999 MOUNT CAMEROON VOLCANIC ERUPTIONS, SOUTH-WEST PROVINCE-CAMEROON

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ABSTRACT

Comparative geochemical study of the 1982 volcanic eruption in Cameroon with the 1999 eruption was carried out to determine if a link exist between the magma compositions of the two eruptions, establish if a common parent magma could be attributed to the two eruptions and interpret their genetic model based on geochemical similarities and differences.

Data for the 1982 eruption were sourced from existing literature/studies, while analysis of rock samples for the 1999 eruption was carried out using X-ray fluorescence spectrometer. Initial screening of the rock samples were employed prior to detailed whole rock analysis.

Interpretation of the results obtained from the geochemical analysis of the 1999 eruption with existing geochemical information on the 1982 eruption revealed that the 1982 and 1999 lavas are alkali basalts. The differentiation index – major oxide plots for K_2O, Na_2O, Al_2O_3, MgO, CaO and TiO_2 for the two eruptions show a strong correlation for K_2O, Na_2O and Al_2O_3 with a general increase in these oxides content with differentiation index. Variation diagrams for selected trace elements Ba, Sr, Zr versus La for the 1982 & 1999 eruptions show a general similarity in variability in Ba, Sr and Zr abundances with increasing differentiation. Co-variation plots for K, Sr and Y reveal that a correlation exists between K and Sr and absent in K, Sr and Y. Spider diagram pattern for the two eruptions (1982 & 1999) shows that the basalts are enriched in incompatible rare earth elements, with a general peak at Nb.

Generally, the above results may probably suggest a common parent magma for the two eruptions.

KEY WORDS: Alkali basalt, Chemical composition, Magma, Mount Cameroon, Volcanic eruption

INTRODUCTION

Mount Cameroon is located on the coast of West Africa, in the southwest of Cameroon, on the coastal belt of the Gulf of Guinea. It lies between Latitude 3°57' – 4°27'N and Longitude 8°58' – 9°24'E, and the highest mountain in Central and West Africa, rising up to 4,095m (Fig. 1). It is part of a chain of volcanic mountains that starts about 100km southwest of Cameroon (Fig. 2) from the Island of Pagalu, Sao Tome, Principe, Bioko, through Kupe, Manengouba, Bambouto, Oku and Nkogam to the Adamawa highlands and ends with the Kapsiki Plateau (Ngonge, 1988; Njonfang et. al., 1992). Mount Cameroon rises abruptly from sea level at the coast to reach the summit about 20km inland. The main Plateau is about 50km long and 35km wide and covering an area of about 1800km^2 running SW – NE (Ngonge, 1988).

Despite the considerable scientific interest that surrounds volcanic eruptions and their effects, coupled with the increasing scientific concern about the origin, nature and sources of magma that causes eruption, there is dearth of scientific writing concerning the geochemistry and petrogenesis of the 1999 volcanic eruption in the Mt. Cameroon. Most of the literature consulted prior to this study dealt with preliminary data evolution and petrographic studies of the eruption. Additionally, some of the existing literature on the geochemistry, petrogenesis, seismicity and palaeomagnetism of the Mt. Cameroon volcanic eruptions include (Fitton et. al., 1983; Fairhead, 1985; Ambeh et. al., 1989; Ubangoh et. al., 1997).

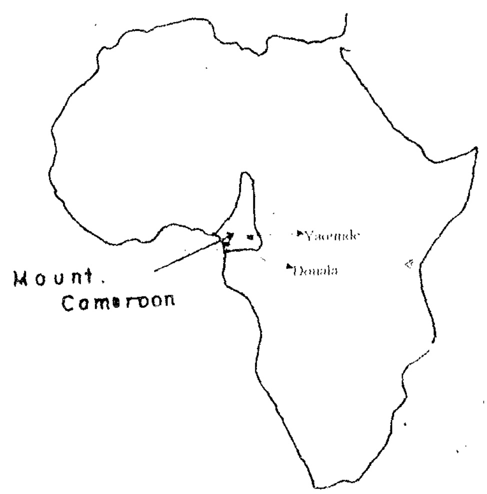

Fig. 1 Location of Mount Cameroon

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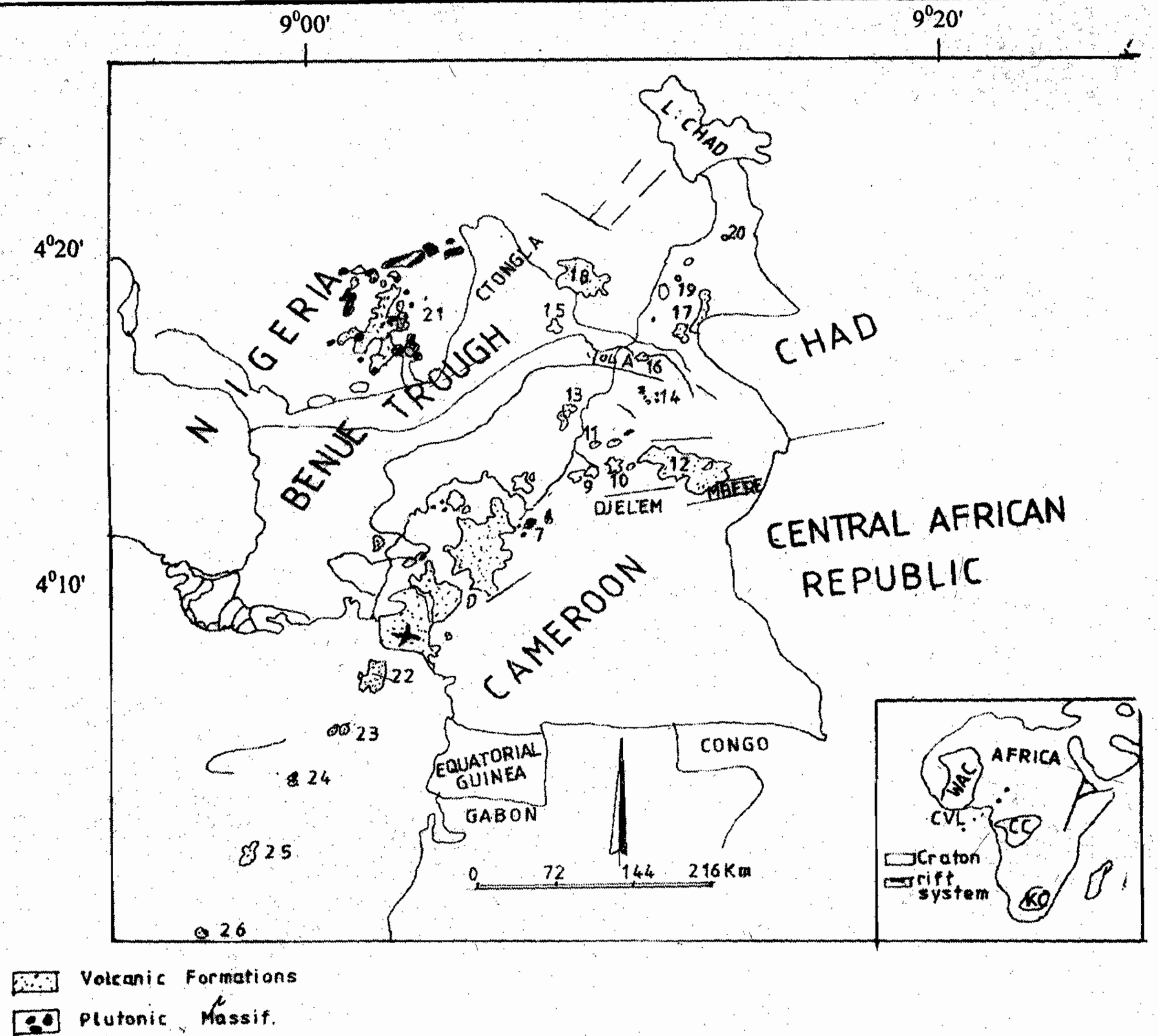


Legend

1. Rumpi mountain
2. Manengouba mountain
3. Mamfe volcanism
4. Mount Bambouto and Bamileke plateau
5. Bamenda-oku mountain
6. Volcanism of the Nyos region
7. Tikar plain plutons
8. Gotel mountain
9. Tchabal mbabo
10. Tignere massif
11. Tchabai Ngandaba
12. Ngoundere plateau
13. Shebshi mountain
14. Poli massif
15. Gombe – Yola
16. Southern Garoua region
17. Mayo louti - lere
18. Damaturu plateau
19. Mandara mount
20. Syenitic massif of mora
21. Jos Plateau
22. Bioko Island
23. Subsurface volcanoe
24. Principe
25. Sao Tome
26. Pagalu

X. Mount Cameroon

Fig. 2. The Cameroon volcanic line

The main objective of this study therefore is to comparatively examine in details the major and trace element data from the 1982 eruption with the 1999 eruption (this study) with a view to establishing a link between the magma compositions of the two eruptions, establish whether a common parent magma could be attributed to the two eruption products and interpret their genetic model based on geochemical similarities and differences.

Geology/ Physiography

The origin of the Cameroon volcanic line has been discussed by many authors. Some people have attributed it to a hotspot due to the deep source character of its magma (Ngonge, 1988; Amboh, 1989) and Moreau et. al., (1987) have proposed that the Cameroon volcanic line is fracture zone. However, this fracture zone model does not offer any explanation for the cause of partial melting in the mantle. Also Fitton et. al., (1983) have proposed that an upwelling asthenospheric hot-zone which was emplaced underneath the Benue trough, but became displaced relative to the lithosphere by the rotation of the African plate, and has been located beneath the Cameroon line and the Gulf of Guinea may have originated the volcanic line. The general view for the origin of Cameroon volcanic line till date has been that of closed spaced hot spots (Zogning, 1997).

Tectonically, the crystalline basement of the Cameroon volcanic line, forms part of a mobile belt between West Africa and the Congo cratons (Fig. 2) and comprises Pan African granitic rocks that yielded Middle Proterozoic Nd model ages (Nzenti, 1998). To the north of the trend of the Cameroon volcanic line lies the Benue trough of Nigeria which is a 1000km long depression that extends from the Niger delta to the Chad Basin (Fitton, 1980), and to the south is the Foumban shear zone which is considered to be the continuation of the Pernambuco lineament of Brazil.

Mount Cameroon is a large volcanic horst which belongs to the Cameroon volcanic line and it is one of the largest volcanoes in Africa. It is composed of alkaline basalts and basanites interbedded with small amount of pyroclastic material (Fitton, 1987). The lavas range in composition from almost aphyritic to strongly porphyritic types, Many recent volcanic cones found on the mountain are aligned SW-NE. The oldest basalt of mount Cameroon is assigned an age of 9Ma while the oldest lavas are estimated to be of Upper Miocene age (Fitton, 1987; Lockwood et. al., 1989). Mount Cameroon is the only presently active volcano in the Cameroon volcanic line, with about eight eruptions in the last century (Ubangoh et. al., 1997).

The step-like morphology of an ovoid shaped mount Cameroon (Horst), comprises; the lower flanks at the base and three superimposed plateaus above each, separated from each other by escarpments. They are the hut II Plateau, hut III Plateau and the summit Plateau (Zogning, 1997). Mount Cameroon forms a watershed for some rivers and streams. It has a drainage pattern with main Rivers like River Mame, Limbe River, Ndongo River with a deep gorge, Bimbia River, Yoke River and River Mongo all taking their rise from the top central relief of mount Cameroon and flowing or radiating in different directions (Fig. 3). The surrounding lowlands of mount Cameroon comprise a diverse mosaic of soil types including ferralitic clays formed by the weathering of igneous rocks, ash deposits, deposits of outwashed material from conglomerates of water-worn rocks and flat poorly drained plains of recent alluvium that is sandy or silty in composition (Ngonge, 1988). The vegetation on mount Cameroon is based on two main approaches. The phytogeographic approach, this is related to broad vegetation zones or belts (Ngonge, 1988). The second approach is based on local occurrence of plant communities.

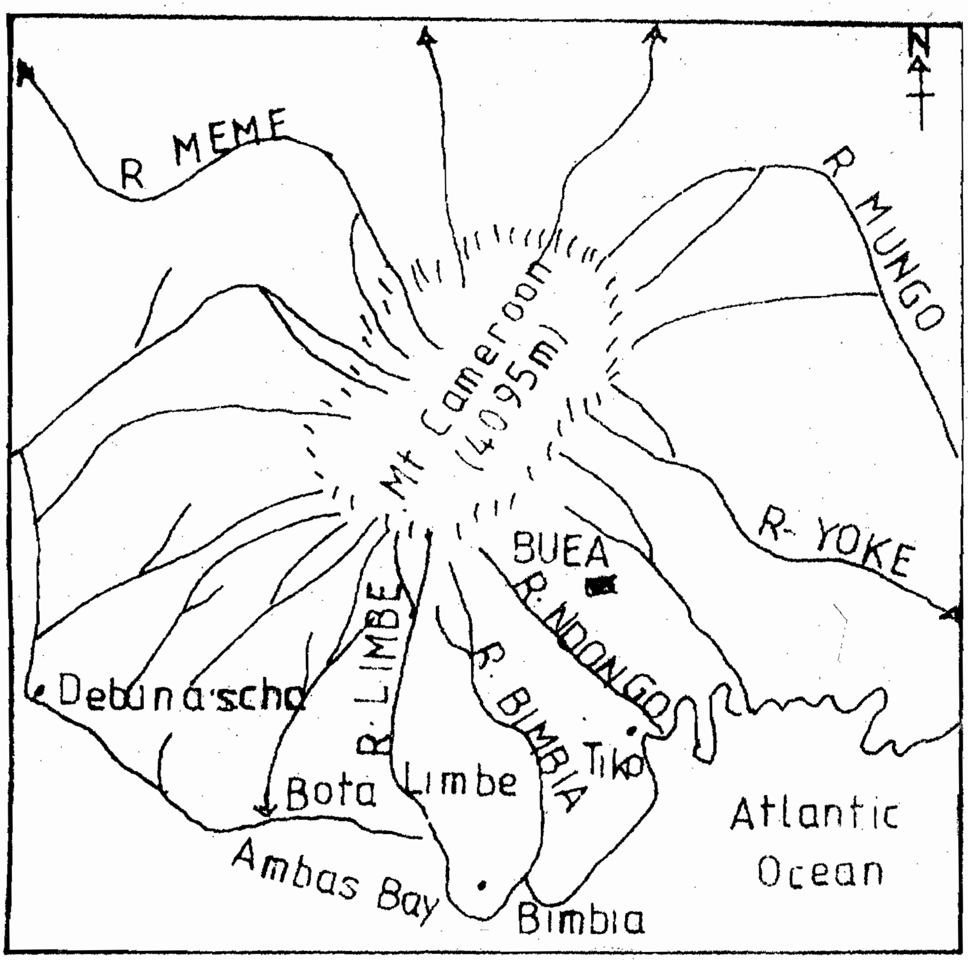


Fig. 3. Mount Cameroon Radial Drainage pattern (After Ngwa, 1978)

Annual mean rainfall decreases in a SW-NE direction of the massif to about 8,650mm at Isongo close to Debundscha (Fig. 4). Short dry season occurs between December and February. However, humidity remains high at 75% - 80% throughout the year (Ngonge, 1988). The persistent cloud cover and mist on mount Cameroon greatly restricts the total number of sunshine hours received per year, which is 900 – 1200hrs at sea level and decreases with altitude.

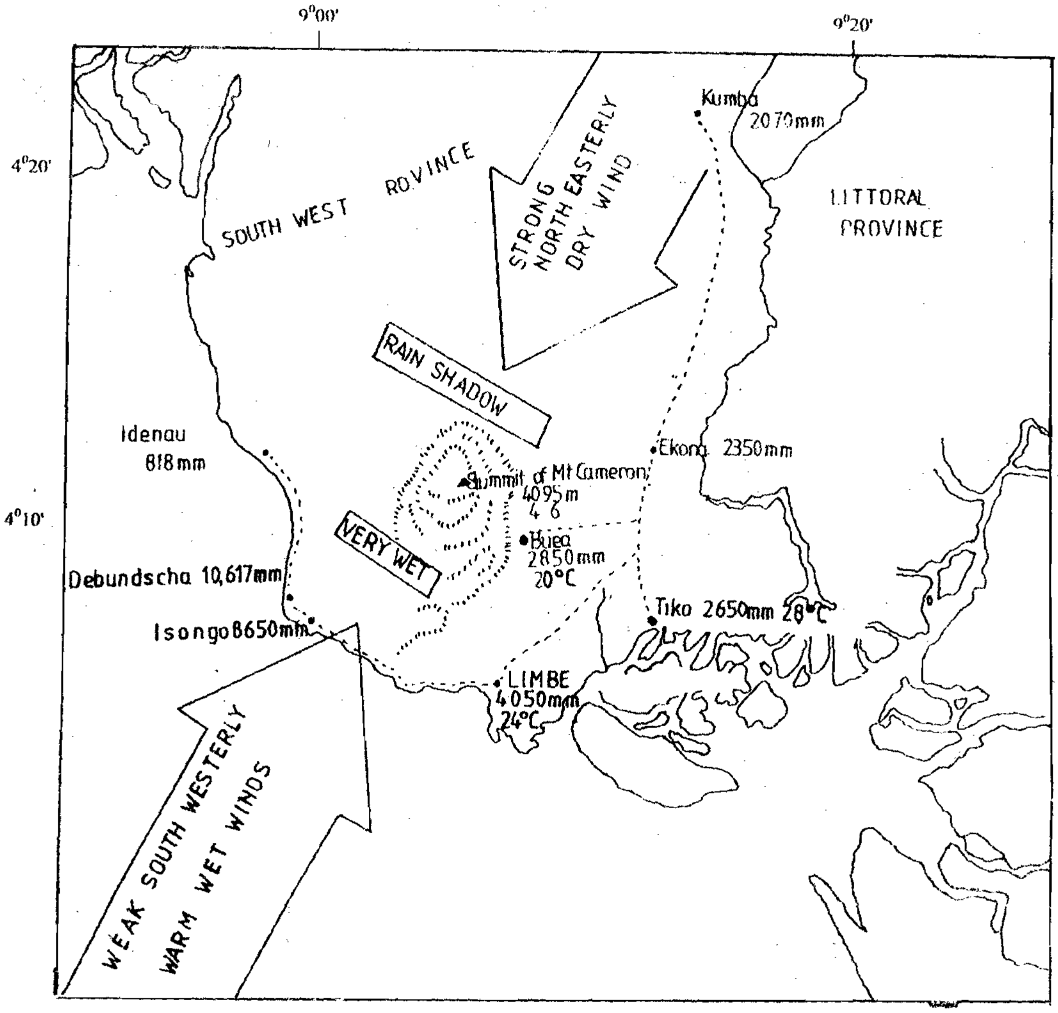
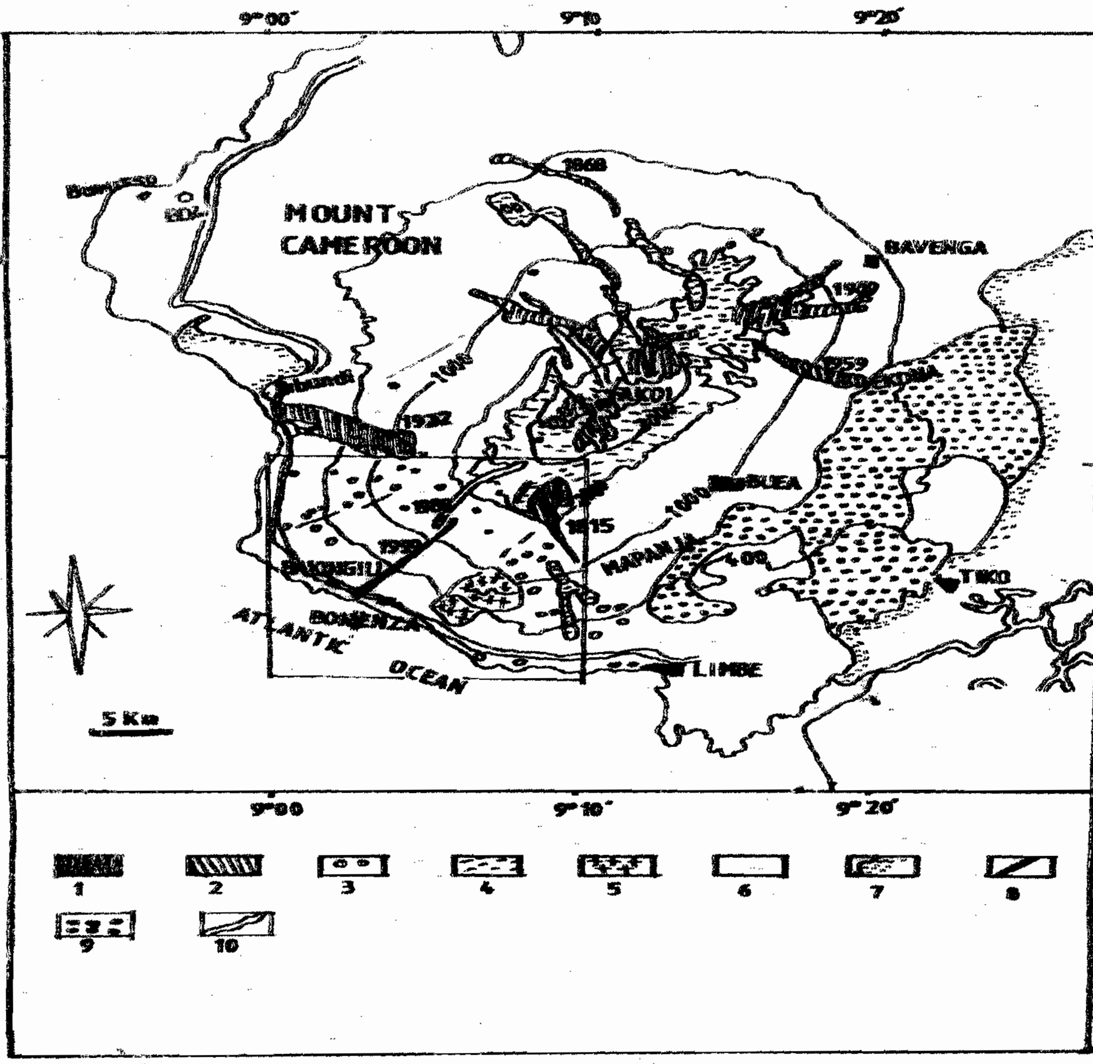


Fig. 4. Climate in the Area of Mount Cameroon (After Ngwa, 1978)

Volcanology of the 1982 and 1999 eruptions

The 1982 mount Cameroon eruption started on October 16, and ended on November 10, 1982. Residents of Buea, approximately 10km SE of the summit were frightened by rumbling sounds and saw red glow on the west flank. Two active fissures were identified, one at 2, 600m altitude and the other 2, 500m altitude (Fig. 5). Steam was emitted at the upper part of the fissure, which began at 2, 600m altitude and ran NNE – SSW, parallel to the general tectonic trend (Fitton et. al., 1983). Basaltic lava from the 2,500m altitude moved down-slope at 20km/hr in a 3m wide flow that reached forested areas. By October 19, the active vent had built a cone 20m high and 50m long and was emitting steam, ash and lava fountains. Volcanic activity fluctuated between October 20 and 22, with periods of vigorous degassing lasting for about 50mins (Fitton et. al., 1983). Short noisy explosions at every 5 – 10 seconds made talking difficult 200m from the crater. By October 24, the lava had moved through dense mountain forest to about 6km from the village of Bakingili on the SW flank. Vent activity continued during October 22 – 30, and was audible 15 – 20 km away. By October 30, the flow was about 200m wide and 20m thick, and its front had apparently stopped at 1,200m above sea level. However, the eruption was reported to be continuing and by November, 7 – 9, it had declined to very sluggish trickle, the eruption apparently ended on November 10, 1982. The total lava output of the 1982 mount Cameroon eruption was estimated at $10^7 m^3$, the eruption plume reached 4000m altitude and total SO_2 output was about 1000 tons/day (Fitton et. al., 1983).

The March 28th- April 17th 1999 eruption in mount Cameroon was felt by the inhabitants and villages/towns along the slopes of the volcano and 70km away from the volcano, in Douala, Mbango, and Kumba. More than 200 seismic events were detected, causing the destruction of many structures particularly buildings and roads, popular among them was the library block of the University of Buea at Molyko, the main block of Bishop Rogan College Soppo, Saint Joseph's College Sasse, and the Presidential Palace in Bokwango. The greatest devastating effects were observed at Poto-poto quarters at Bowango (Lockwood, in Press; Ngwa, 1999). The 1999 eruption took place on two sites along the southern flank of mount Cameroon. The first site is located along a SW – NE trending fissures 500m long and 100m wide at an altitude of 2,650m at latitude 4°9'13"N; and longitude 9°7'46"E. Along this fissure fourteen (14) vents



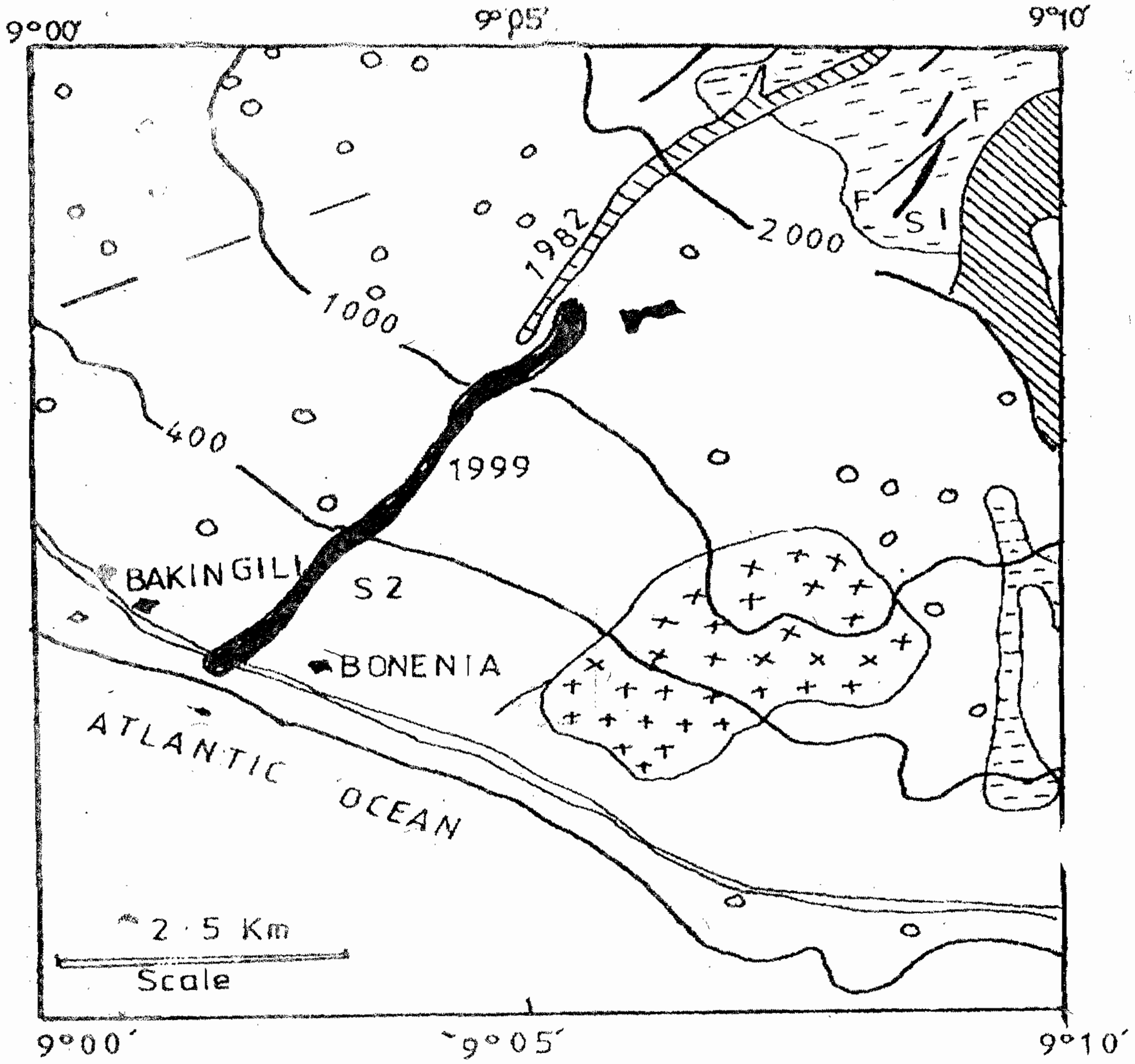
1. The 1999 lava flow
2. Registered historic lava flows
3. Pyroclastic cones
4. Historic lava flows not registered
5. Etindites of Mt. Cameroon
6. Volcanic rocks
7. Limit of sedimentary rocks with occurance of basaltic lava & quarternary alluvia.
8. Faults or open cracks
9. Lahar deposits
10. Bituminous road

Fig. 5. Geological map and historic activity of Mount Cameroon (After Nono et. al., 1994)

were formed by the end of the eruption, some of which are reactivated volcanic cones (Fig. 6). The second site occurred at altitude 1,400m at latitude 4°7'97"N and longitude 9°5'87"E. It is located along a 1.2km, SW – NE trending fissures, with twenty-eight (28) vents identified. The lava flowed in a SSW direction through dense forests towards the coastal village of Bakingili. The Lava flow extended 6 – 7km from its source and stopped approximately 200m from the Atlantic Ocean shoreline after crossing Limbe to Idenau road.

METHODOLOGY

Results of previous studies on the chemical composition of the 1982 eruption in Mount Cameroon were obtained from existing literature/technical papers (Fitton et. al., 1983; Thornton & Tuttle, 1960). However, the results of the 1999 eruption for this study was generated by first embarking on an initial field work between January and February 2000, which consisted of collection of representative samples along the lava flow. Samples were collected at the lava front, and close to the vent (Site 2).



S_1 = Site 1 lava flow
S_2 = Site 2 lava flow
F------F = fracture along which volcanic cones are located during the 1999 eruption

Fig. 6. Location of the cones and lava flow area of the 1999 eruption (After Wandji et. al., 2000 in Ngwa, 1999)

Preliminary geochemical studies on representative samples were carried out at the Petrology workshop/laboratory of the Department of Geology, University of Nigeria, Nsukka, prior to detailed bulk rock composition analysis using X-ray Fluorescence Spectrometer at the Institute Isotopengeologie/Mineral. Rohstoffe Sonneggstrasse 5 ETH Zentrum, No F 62 8092 Zurich, Germany.

DISCUSSION OF RESULTS

Chemical composition of rocks from the 1999 eruption (this study) is presented in Tables 1 - 3. Previous study on major element and normative compositions with calculated differentiation indices for the 1982 eruption after Thorton & Tuttle, (1960) compared with this study is presented in Tables 4 - 5. The trace element composition for rocks from the 1982 eruption after Fitton et al., (1983) is in Table 6. The chemical compositions of rocks from the 1999 eruption (this study) are compared with those of similar compositions of the 1982 eruption in the literature, and then interpreted for their appropriate petrogenetic significance.

Table 1. Whole Rock analysis of Basalt Samples (B_1 – B_2) for this study

	B_1	B_1		B_2	B_2	
	Concentration	Limit 1	Limit 2	Concentration	Limit 1	Limit 2
SiO_2	45.34	0.00	1.68	45.66	0.00	1.68
TiO_2	3.12	0.00	0.01	3.12	0.00	0.01
Al_2O_3	15.11	0.00	0.77	15.06	0.00	0.77
Cr_2O_3	0.02	0.00	0.02	0.03	0.00	0.02
Fe_2O_3	12.30	0.00	0.07	12.32	0.00	0.07
FeO	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.19	0.00	0.01	0.20	0.00	0.01
MgO	6.53	0.00	0.34	0.51	0.00	0.34
NiO	0.00	0.00	0.01	0.00	0.00	0.01
CaO	10.71	0.00	0.10	10.71	0.00	0.10
Na_2O	3.87	0.00	1.01	3.88	0.00	1.01
K_2O	1.55	0.00	0.07	1.54	0.00	0.07
P_2O_5	0.68	0.00	0.02	0.67	0.00	0.02
CO_2	0.00	0.00	0.00	0.00	0.00	0.00
H_2O	0.36	0.00	0.00	0.57	0.00	0.00
Total	**99.78**			**94.27**		
Rb	39	3	5	38	3	5
Sr	975	3	8	967	3	8
Ba	514	1	14	501	1	14
Sc	20	0	2	18	0	2
V	326	3	10	291	3	10
Cr	192	8	11	151	8	11
Co	43	3	4	43	3	4
Ni	78	3	4	73	3	4
Cu	81	3	4	80	3	4
Zn	110	2	11	108	2	11
Zr	386	3	7	381	3	7
Nb	107	2	2	105	2	2
Y	43	3	3	41	3	3
La	130	3	8	122	3	8
Ce	208	28	18	216	28	18
Nd	89	17	9	81	17	9
Ga	9	1	3	7	1	3
Pb	10	3	4	4	3	4
Th	13	8	6	0	8	6
U	0	7	1	0	7	1
S	101	11	38	135	11	38
F	132	0	270	15	0	270

Table 2. Whole Rock analysis of Basalt Samples (B_3 – B_4) for this study

	B_3	B_3		B_4	B_4	
	Concentration	Limit 1	Limit 2	Concentration	Limit 1	Limit 2
SiO_2	45.58	0.00	1.68	45.30	0.00	1.68
TiO_2	3.16	0.00	0.01	3.15	0.00	0.01
Al_2O_3	15.12	0.00	0.77	15.09	0.00	0.77
Cr_2O_3	0.02	0.00	0.02	0.03	0.00	0.02
Fe_2O_3	12.31	0.00	0.07	12.40	0.00	0.07
FeO	0.00	0.00	0.00	0.00	0.00	0.00
MnO	0.19	0.00	0.01	0.21	0.00	0.01
MgO	0.53	0.00	0.34	6.52	0.00	0.34
NiO	0.00	0.00	0.01	0.00	0.00	0.01
CaO	10.72	0.00	0.10	10.73	0.00	0.10
Na_2O	3.86	0.00	1.01	3.85	0.00	1.01
K_2O	1.56	0.00	0.07	1.54	0.00	0.07
P_2O_5	0.66	0.00	0.02	0.69	0.00	0.02
CO_2	0.00	0.00	0.00	0.00	0.00	0.00
H_2O	0.46	0.00	0.00	0.50	0.00	0.00
Total	**94.17**			**99.69**		
Rb	37	3	5	40	3	5
Sr	970	3	8	970	3	8
Ba	512	1	14	502	1	14
Sc	19	0	2	19	0	2
V	320	3	10	320	3	10
Cr	190	8	11	190	8	11
Co	44	3	4	44	3	4
Ni	75	3	4	75	3	4
Cu	81	3	4	83	3	4
Zn	109	2	11	111	2	11
Zr	384	3	7	382	3	7
Nb	106	2	2	104	2	2
Y	42	3	3	41	3	3
La	126	3	8	125	3	8
Ce	206	28	18	210	28	18
Nd	88	17	9	86	17	9
Ga	8	1	3	8	1	3
Pb	9	3	4	5	3	4
Th	12	8	6	10	8	6
U	0	7	1	0	7	1
S	100	11	38	130	11	38
F	130	0	270	110	0	270

Table 3. Whole Rock analysis of Basalt Samples (B_5) for this study

	B_5 Concentration	B_5 Limit 1	Limit 2
SiO_2	45.40	0.00	1.68
TiO_2	3.13	0.00	0.01
Al_2O_3	15.07	0.00	0.77
Cr_2O_3	0.02	0.00	0.02
Fe_2O_3	12.31	0.00	0.07
FeO	0.00	0.00	0.00
MnO	0.21	0.00	0.01
MgO	6.51	0.00	0.34
NiO	0.00	0.00	0.01
CaO	10.69	0.00	0.10
Na_2O	3.88	0.00	1.01
K_2O	1.52	0.00	0.07
P_2O_5	0.69	0.00	0.02
CO_2	0.00	0.00	0.00
H_2O	0.39	0.00	0.00
Total	99.82		
Rb	40	3	5
Sr	977	3	8
Ba	507	1	14
Sc	20	0	2
V	290	3	10
Cr	155	8	11
Co	43	3	4
Ni	70	3	4
Cu	81	3	4
Zn	105	2	11
Zr	384	3	7
Nb	107	2	2
Y	43	3	3
La	125	3	8
Ce	210	28	18
Nd	87	17	9
Ga	9	1	3
Pb	6	3	4
Th	10	8	6
U	0	7	1
S	126	11	38
F	128	0	270

Table 4. Results of Analyses for CIPW and differentiation index based on Thornton and Tuttle (1960) for the 1982 & 1999 Cameroon Volcanic Eruption (Source of the 1982 major element data from Fitton et. al., 1983), with results of this study ($B_1 - B_3$)

	1999 Analysis (this study)			1982 Analysis (after Thornton & Tuttle (1960)				
	B_1	B_2	B_3	C_{194}	C_{193}	C_{195}	C_{192}	C_{197}
SiO_2	45.34	45.66	45.58	44.81	44.80	44.87	44.70	44.72
TiO_2	3.12	3.12	3.16	3.40	3.40	3.37	3.39	3.44
Al_2O_3	15.11	15.06	15.12	15.13	15.10	15.14	15.07	15.45
Fe_2O_3	12.30	12.32	12.31	3.32	4.81	3.81	3.84	2.21
FeO	0.00	0.00	0.00	9.14	7.82	8.64	8.70	10.12
MnO	0.19	0.20	0.19	0.20	0.20	0.19	0.20	0.20
MgO	6.53	6.51	6.53	6.01	6.11	6.21	6.02	5.91
CaO	10.71	10.71	10.72	11.92	11.96	11.93	11.86	11.48
Na_2O	3.87	3.88	3.86	3.62	3.66	3.54	3.68	3.94
K_2O	1.55	1.54	1.56	1.28	1.27	1.27	1.31	1.40
P_2O_5	0.68	0.67	0.66	0.55	0.54	0.55	0.56	0.61
H_2O	0.36	0.57	0.46	-	-	-	-	-
CO_2	0.00	0.00	0.00	-	-	-	-	-
TOTAL	**99.76**	**100.14**	**100.15**	**99.37**	**99.67**	**99.52**	**99.34**	**99.48**
Or	9.2	9.1	9.23	7.6	7.5	7.5	7.7	8.3
Ab	23.2	24.6	32.65	10.7	12.3	13.8	13.3	11.3
An	19.2	19.1	19.27	19.2	19.9	19.6	19.7	19.3
Ne	3.5	2.8	-	10.8	10.1	8.7	9.7	11.9
Wo	6.2	7.4	12.56	14.8	15.0	14.3	14.6	13.8
En	5.0	6.1	-	8.5	11.0	8.05	8.1	6.5
Fs	-	-	-	5.5	3.7	4.4	4.6	4.8
En	-	-	-	-	-	-	-	-
Fs	-	-	-	-	-	-	-	-
Fo	10.4	10.9	-	6.8	5.9	8.07	8.3	9.2
Fa	-	-	-	4.9	2.2	4.8	3.6	5.7
Mt	15.8	13.9	-	4.8	5.9	5.5	4.6	3.2
Il	5.4	5.4	-	5.5	5.5	5.4	5.4	5.5
Ap	1.6	1.6	1.55	1.3	1.3	1.3	1.3	1.4
DI	35.9	36.5	41.88	29.1	29.9	30.0	30.7	31.5

Table 5. Results of Analyses for CIPW and differentiation index based on Thornton and Tuttle (196[illegible]) for the 1982 & 1999 Cameroon Volcanic Eruption (Source of the 1982 major element data from Fitton et. al., 1983), with results of this study (B_4 – B_5)

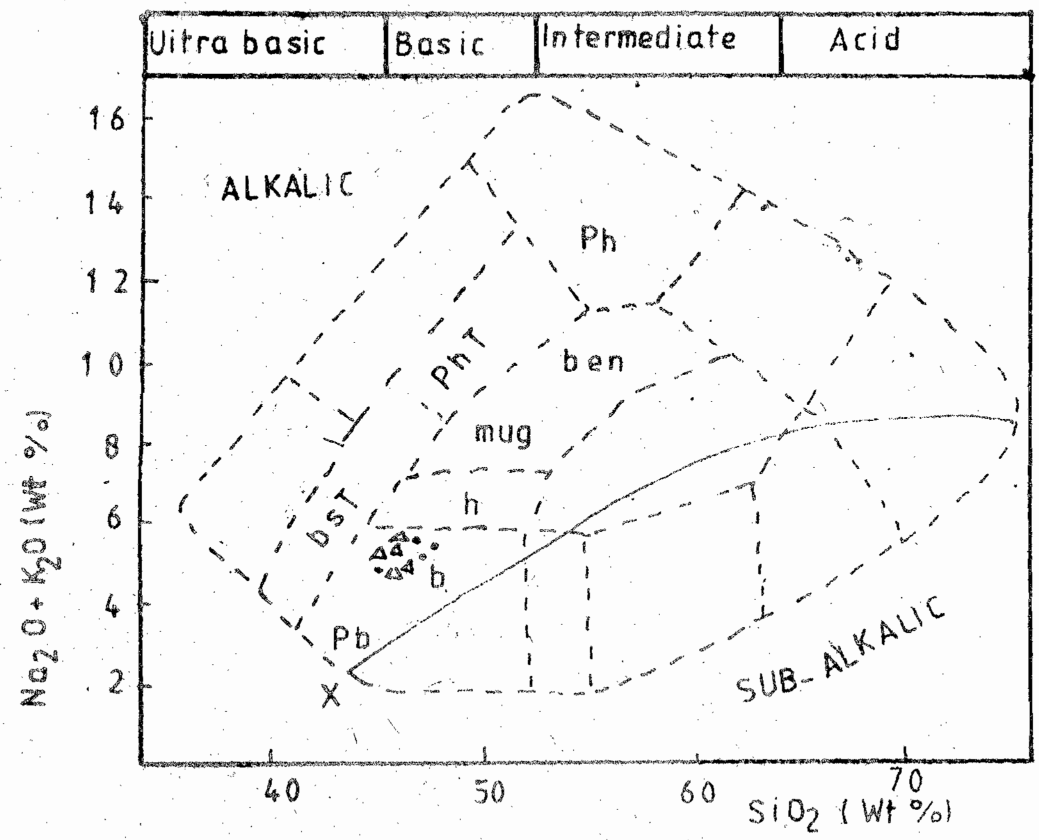
	1999 Analysis (this study)		1982 Analysis (after Thornton & Tuttle (1960)				
	B_4	B_5	C_{194}	C_{193}	C_{195}	C_{192}	C_{197}
SiO_2	45.30	45.40	44.81	44.80	44.87	44.70	44.72
TiO_2	3.15	3.13	3.40	3.40	3.37	3.39	3.44
Al_2O_3	15.09	15.07	15.13	15.10	15.14	15.07	15.45
Fe_2O_3	12.40	12.31	3.32	4.81	3.81	3.84	2.21
FeO	0.00	0.00	9.14	7.82	8.64	8.70	10.12
MnO	0.21	0.21	0.20	0.20	0.19	0.20	0.20
MgO	6.52	6.51	6.01	6.11	6.21	6.02	5.91
CaO	10.73	10.69	11.92	11.96	11.93	11.86	11.48
Na_2O	3.85	3.88	3.62	3.66	3.54	3.68	3.94
K_2O	1.54	1.52	1.28	1.27	1.27	1.31	1.40
P_2O_5	0.69	0.69	0.55	0.54	0.55	0.56	0.61
H_2O	0.50	0.39	-	-	-	-	-
CO_2	0.00	0.00	-	-	-	-	-
TOTAL	**99.98**	**99.8**	**99.37**	**99.67**	**99.52**	**99.34**	**99.48**
Or	9.12	8.99	7.6	7.5	7.5	7.7	8.3
Ab	11.75	16.56	10.7	12.3	13.8	13.3	11.3
An	19.31	19.18	19.2	19.9	19.6	19.7	19.3
Ne	11.27	8.80	10.8	10.1	8.7	9.7	11.9
Wo	12.48	12.45	14.8	15.0	14.3	14.6	13.8
En	10.76	10.73	8.5	11.0	8.05	8.1	6.5
Fs	-	-	5.5	3.7	4.4	4.6	4.8
En	7.87	9.54	-	-	-	-	-
Fs	-	-	-	-	-	-	-
Fo	-	-	6.8	5.9	8.07	8.3	9.2
Fa	-	-	4.9	2.2	4.8	3.6	5.7
Mt	-	-	4.8	5.9	5.5	4.6	3.2
Il	-	-	5.5	5.5	5.4	5.4	5.5
Ap	1.63	1.63	1.3	1.3	1.3	1.3	1.4
DI	32.14	34.35	29.1	29.9	30.0	30.7	31.5

Table 6. Trace Element Result of Analysis for 1982 Eruption (Data Source: Fitton et. al., 1983), with results of this study (B_1 – B_5)

PPM	1982					1999		
	C_{194}	C_{193}	C_{195}	C_{192}	C_{197}	B_1	B_2	B_3
Ni	53	52	54	54	49	78	73	75
Cr	56	56	57	55	39	192	151	190
V	337	345	335	347	336	326	291	320
Sc	27	29	27	27	23	20	18	19
Cu	101	99	101	101	100	81	80	81
Zn	111	102	108	104	117	110	108	109
Sr	886	837	885	871	974	975	967	970
Rb	29	28	29	29	33	39	38	37
Zr	308	298	307	304	335	380	381	384
Nb	72	70	72	73	81	107	10[illegible]	106
Ba	397	414	414	410	443	514	501	512
La	60	61	59	61	66	130	122	126
Ce	129	120	129	124	143	208	216	206
Nd	57	51	55	54	61	89	81	88
Y	29	28	29	29	30	43	41	42
U	1.54	1.56	1.56		1.77	0	0	0
Pb			2.98		3.46	10	4	9

PPM	1982					1999	
	C_{194}	C_{193}	C_{195}	C_{192}	C_{197}	B_4	B_5
Ni	53	52	54	54	49	75	70
Cr	56	56	57	55	39	190	155
V	337	345	335	347	336	320	290
Sc	27	29	27	27	23	19	20
Cu	101	99	101	101	100	83	81
Zn	111	102	108	104	117	111	105
Sr	886	837	885	871	974	970	977
Rb	29	28	29	29	33	40	40
Zr	308	298	307	304	335	382	384
Nb	72	70	72	73	81	104	107
Ba	397	414	414	410	443	502	507
La	60	61	59	61	66	125	125
Ce	129	120	129	124	143	210	210
Nd	57	51	55	54	61	86	87
Y	29	28	29	29	30	41	43
U	1.54	1.56	1.56		1.77	0	0
Pb			2.98		3.46	5	6

Rock nomenclature of 1982 and 1999 lavas was based on the Harker (1904) variation diagram of weight percent $Na_2O + K_2O$ (Total alkali) versus weight percent SiO_2. Cox et al., (1979) chart was used, while the dividing line (X – Y) separating alkalic from sub-alkalic magma series is that of Miyashiro (1970). The 1982 and 1999 rocks are alkali basalts, as they plot within the restricted field of alkali magma series above the "Miyashiro line" (Fig. 7). They range from picrite basalt through basalt to Hawaiites. The basalts are nepheline – normative (2.8 – 12.21%), which is characteristic of alkali magma series. K_2O versus Na_2O



Legend
Pb = picrite basalt
b = basalt
h = hawiite
mug = mugearite
ben = benmorite
bst = basalt + tephrite
pht = phonolite + tephrite
ph = phonolite

Fig. 7. Nomenclature of Basalt from 1982 (Δ) and 1999 (•) (this study) of Mt Cameroon cruptions. (Based on Cox et al., 1979 chart). The dividing line XY between alkalic and sub-alkalic magma series is after Miyashiro (1970)

weight percent plot of Middlemost (1973) shows that the basalts belong to the Na sub-series (Fig. 8). Differentiation index – major oxide diagrams for weight percent K_2O, Na_2O, Al_2O_3, MgO, CaO, and TiO_2 is presented in (Fig. 9). The diagrams show a strong correlation for K_2O, Na_2O and Al_2O_3 with a general increase in these oxides content with differentiation index. The K_2O and Na_2O contents are lowest in the 1982 lava compared to that of the 1999 lava. Also Al_2O_3 contents increase sharply in the 1982 lava than in the 1999 lava. A strong correlation exists for MgO and CaO as shown on the diagram. MgO and CaO decreases sharply from highest in the 1982 lava to the 1999 lava. Generally, the MgO and CaO contents decrease with increasing differentiation index. TiO_2 content shows an inflexion. The variation in major element content can be related to the different degree of fractional crystallization from a common parent magma (Thompson et. al., 1984). The decrease in MgO is linked with olivine fractionation while a decrease in CaO is linked with augite fractionation all of which form a phenocryst phase in these rocks.

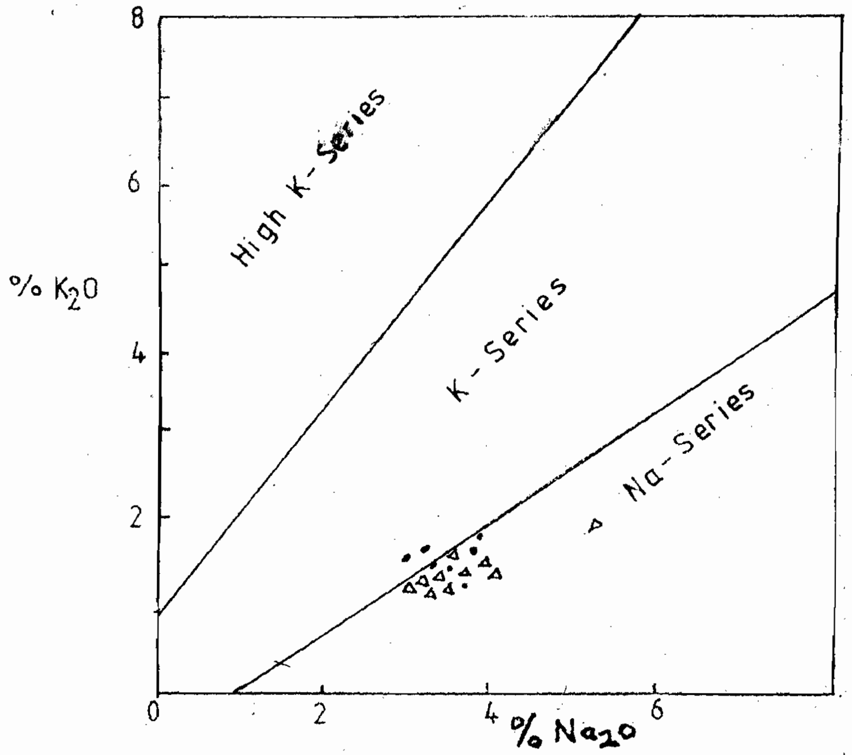


Fig. 8. K_2O Versus Na_2O (wt%) diagram showing sub-division of the 1982 (Δ) and 1999 (•) alkali basalt series (Based on Middlemost, 1973)

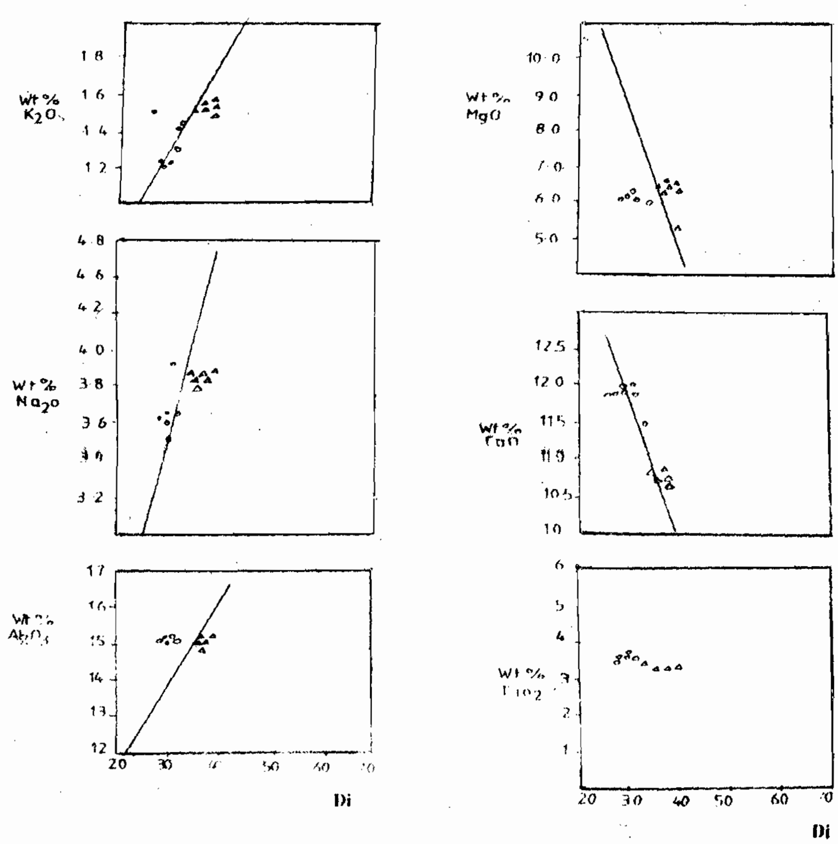


Fig. 9. Major element plot versus differentiation index (Based on Thornton & Tuttle 1960); 1982 (•) and 1999 (Δ)

Three variation diagrams for selected trace elements; Ba, Sr, Zr versus La all in parts per million for the 1982 and 1999 basalts show strong correlation (Fig. 10). A general similarity in variability in Ba, Sr and Zr abundances with increasing differentiation is observed. Similarity in the variability of this nature can be linked with an origin from a common parent magma enriched in incompatible trace elements (Hall, 1967; Allegre et. al., 1977). Co-variation plots for K (wt%), Sr (ppm) and Y(ppm) versus SiO_2 (wt%) as fractionation index for the 1982 and 1999 basalts show that a correlation exists between K and Sr but absent between K, Sr and Y (Fig. 11). This is evident in a fall in 'Y', coinciding with increasing K, Sr and SiO_2. The 'Y' fall can be linked with buffering during the separation of progressively greater amount of residual garnet at depth (Hall, 1967; Allegre et. al., 1977; Thompson et. al., 1984). The behaviour of Sr as an incompatible element (paralleling K) rules out significantly low pressure fractionation, since plagioclase is a phenocryst phase in these rocks. The observed co-variation invokes a deep process close to the magma source at depth below 100km in the mantle.

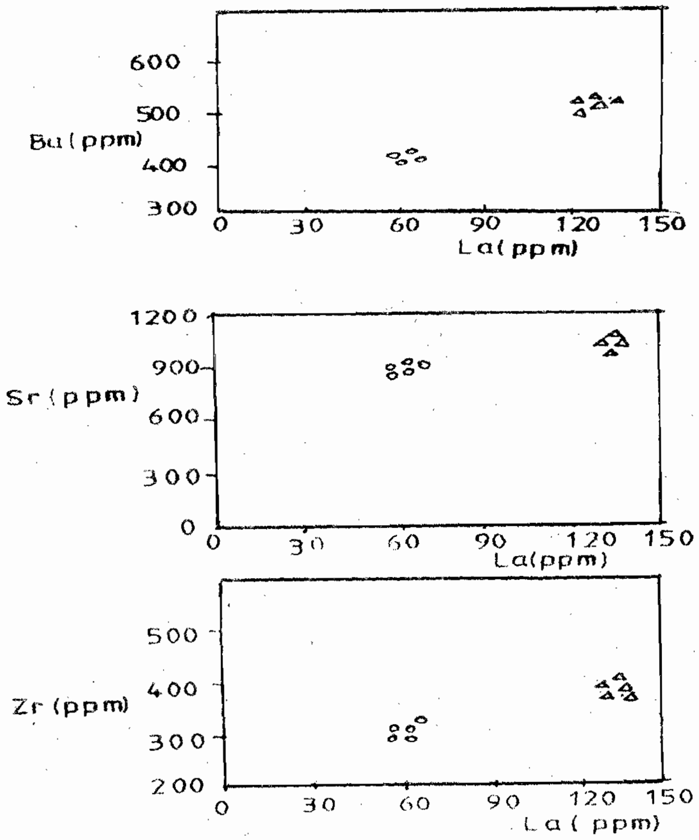


Fig. 10. Ba, Sr, Zr versus La plots for the 1982 (•) and 1999 (A) Mt Cameroon eruptions

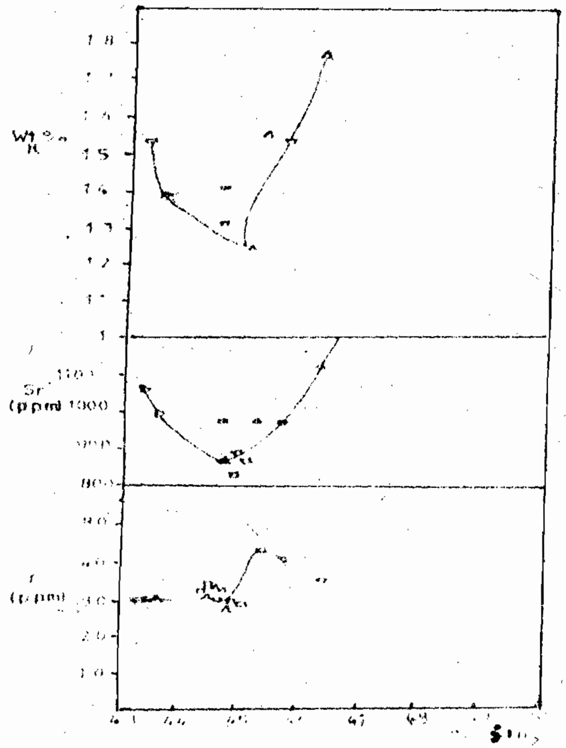


Fig. 11. Co-variation plot of K, Sr and Y with SiO_2 for the 1982 (•) and 1999 (A) basalts (Picrites, Alkali basalt and Hawaiites)

Two dimensional Zr – K variation plot (Fig. 12) to test for compatibility with a mixing hypothesis and to identify the end-members show a clearly defined straight or mixing line along which a linear array of the 1999 and 1982 lavas plot. Spiderdiagram pattern for the 1982 and 1999 basalts that have been chondrite-normalized according to Thompson et al. (1984) is presented in (Fig. 13). The normalized constant used is given in (Table 7). All the basalts show clear enrichment in incompatible rare earth elements, with a general peak at Nb. This suggests an incompatible rare earth element enriched mantle source for these basalts (Puchelt & Emmermann, 1976; Bowden, 1985; Parsons et. al., 1986). The decreased enrichment of 'Y' relative to the light rare earth element (LREE) in these basalts suggests the presence of residual garnet in the source. The characteristic troughs at Ba and Sr result from fractional crystallization of plagioclase (Allegre et al., 1977). The basalts are considered low strontium basalts (LSrB) due to their negative Sr and P spikes. The spiderdiagram pattern also invokes a low degree (2%) differential partial melting of a garnet peridotite mantle material rich in incompatible trace element.

CONCLUSION

This study has provided an insight into the geochemical compositions of the 1999 mount Cameroon volcanic eruptions. Comparative interpretations of the results obtained from the geochemical analysis of the 1999 eruption with existing geochemical information on the 1982 eruption has shown that lavas of the two eruptions are alkali basalts. K_2O versus Na_2O weight percent plot shows that the basalts belong to the Na sub-series. A strong correlation exists for K_2O, Na_2O & Al_2O_3 in the two separate eruptions (1982 & 1999). However, TiO_2 content shows an inflexion. Trace element plots of Ba, Sr and Zr versus La also show strong correlation with a general similarity in variability in Ba, Sr and Zr abundances. This may probably suggest an origin from a common parent magma enriched in incompatible trace elements. Also the spiderdiagram pattern suggests a low degree differential partial melting of a garnet peridotite mantle material which is also rich in incompatible trace elements.

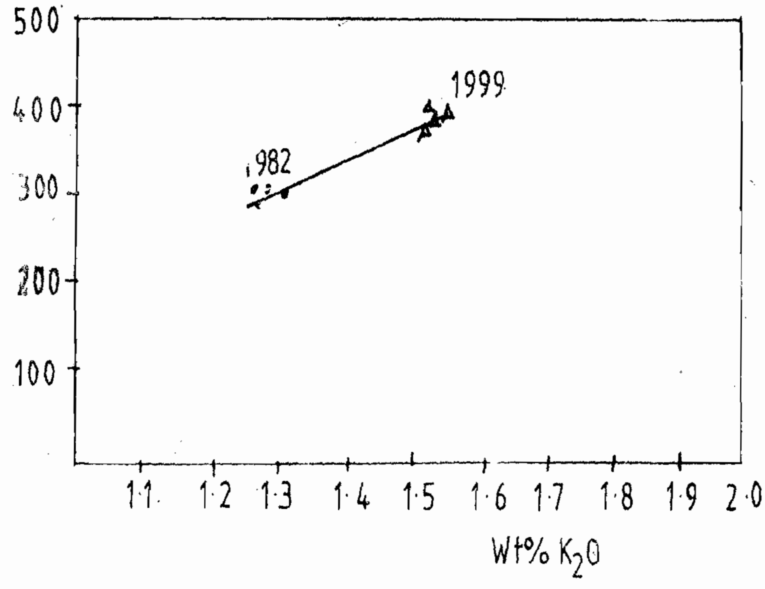


Fig. 12. Zr – K variation plot for 1999 samples (Δ) and 1982 (•)

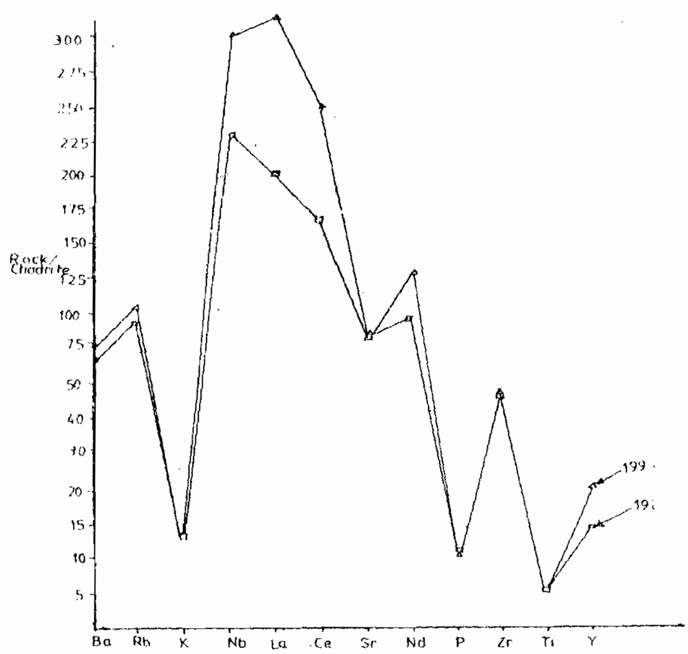


Fig. 13. Spiderdiagram pattern for 1982 (□) and 1999 (Δ) basalt

Table. 7. Normalized constants used for the Spiderdiagram pattern (based on Thompson et. al., 1984)

Element	Normalized Constants
Ba	6.9
Rb	0.35
K	120
Nb	0.35
La	0.328
Ce	0.865
Sr	11.8
Nd	0.63
P	46
Zr	6.84
Ti	620
Y	2.0

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REFERENCES

Allegre, J. C I., Treuil, M., Minster, J.E., Minster, B. and Albarede, F. 1977. Systematic use of trace element in igneous process. Part 1: fractional crystallization processes in volcanic suites. Contributions Mineralogy Petrology 50: 57-75.

Ambeh, W.B., Fairhead, J.D., Franus, D.J. Nnange, J.M. and Djallo S. 1989. Seismicity of Mt. Cameroon Region, West African Journal of African Earth Sciences. Vol.9 Pp-7.

Amboh, W.B., 1989. Siesmicity and Seismological studies of Mount Cameroon, Cameroon, Cameroon West Africa. Ph.D thesis 28p. University of Leads UK (impubl).

Bowden, P., 1985. The geochemistry and mineralization of alkaline ring complexes in Africa (a review). Journal African Earth Sciences 3: 17-39.

Cox, K. G., Bell, J. D. and Pankhurst, R. J., 1979.The interpretation of igneous rocks. George Allen & Unwin, London 450pp.

Fairhead, J. D., 1985. Preliminary study of the Seismicity Associated with the Cameroon Volcanic province during the volcanic Eruption in 1982. Journal of African Earth Science vol. 3: 197-301.

Fitton, J.G. 1980. The Benue trough and Cameroon Line - a migrating rift system in West Africa. Earth Planetary Science Letters 51: 132-138.

Fitton, J. G., Kilburn C.R.J., Thirlwall, M.F. and Hughes, D.J. 1983. The 1982 Eruption of Mt. Cameroon, West Africa. Nature 306, pp.104-105

Fitton, J. G., 1987. The Cameroon Line, West Africa: A comparison between oceanic and contimental alkaline volcanism. In: Alkaline Igneous rock (Edited by Fitton, J.G and Upton, B.C.G.) Geological Society Special Publ. 30: .273-291.

Hall, A. 1967. The Variation of some trace element in the Rosses granite complex, Donegal. Geol. Mag. V.104: 99-109.

Harker, A., 1904. The Tertiary Igneous of Skye, Mem. Geol.Surv. UK 481pp

Lockwood, J.P., (in press). The 1999 Mt. Cameroon volcanic eruption.

Lockwood, J.P. and Rubin, M., 1989. Origin and age of the Lake Nyos Maar, Cameroon. Journal Volcanology Geothermal Research 39, 117-124.

Middlemost E.A.K 1973. Evolution of Volcanic islands. Lithos b123-32.

Miyashiro, A., Shid F. and Ewing, M. 1970. crystallization and Differentiation in Abyssal Tholeiites and Gabbros from Mid Ocean Ridges, E.P.S.L.7: 361-5

Moreau, C., Regnoult, J. M., Deruelle, B. and Robineau, B. 1987. A new tectonic model for the Cameroon line, Central Africa. Tectonophysics 139, 317-334.

Ngonge, E. D., 1988. A geological study of the anorogenic complex of Guenfalabo (an example of a complete series) in the West Adamawa Highlands, Cameroon. These Doctorat 3eme cycle 163p. University Yaounde, Cameroon (unpublished).

Ngwa, J.A. 1978. A new geography of Cameroon. Hongkong: Yu Luen offset.

Ngwa, C.A. 1999. Economic Development of the Ndop Region of Cameroon since 1970. Ph.D thesis, University of Nigeria, Nsukka (Unpublished)

Njonfang, E., Kamgang, P., Ghogomu, T.R. and Tchoua, F.M. 1992. The geochemical characteristics of some plutonic-volcanic complexes along the Southern part of the Cameroon line. Journal African Earth Sciences 14: 255-266.

Nono, A., Deruelle, B., Demaiffe, D. and Kambou, R., 1994. Tchabal Nganha volcano in Adamawa (Cameroon): petrology of a continental alkaline lava series. Journal Volcanology Geothermal Research 60, 147-178.

Nzenti, J.P., 1998. Neoproterozoic alkaline meta-igneous rocks from the Pan-African North Equatorial Fold Belt (Yaounde, Cameroon): biotites and magnetite rich pyroxenites. Journal of African Earth Vol. 26, No.1 pp.37-47.

Parsons, I., Brown, W.L. and Jacquemin, H. 1986. Mineral chemistry and crystallization of the Mboutou layered gabbro-syenite-granite complex,North Cameroon. Journal Petrology 27: 1305-1329.

Puchelt, H. and Emmermann, R., 1976. Bearing of rare earth patterns of apatites from igneous and metamorphic rocks. Earth Planetary Science Letters 31, 279-286.

Thompson, R.N Marrison, M.A; Hendry, G.L and Parry S.J., 1984. An Assessment of the relative roles of crust and mantle in Magma Gneiss: an elemental approach, Phil. Trans. Roy. Soc. Lond. A310, 549 - 90.

Thorton, C.P. and Tuttle, O.F. 1960. Chemistry of Igneous rocks Differentiation index A.J.S 258, 664-84.

Ubangoh, R.U, Ateba, B, Ayonghe, S.N. and Ekodeck, G.E. 1997. Earthquake Swarms of Mt. Cameroon, West Africa. Journal of African Earth Sciences, 24(4): 413-424

Zogning, P., Giresse, P, Maley, J. and Gadel, P., 1997. The late Holocene Palaeoenvironment in the lake Njupi area, West Cameroon: Implications regarding the history of Lake Nyos. Journal of African Earth Sciences. 24(3) :285-300.