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Petrography and Geochemical Features of Dolerites Dykes from Fell (Adamawa Plateau, Cameroon-Central Africa)

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Abstract Dolerite dykes from Fell locality in Southern Adamawa plateau in central Cameroon transect the granitoids of the basement along Pan African cracks of N70 and N135. They are 20 to 30 m in width and stretch on more than 100 m. Petrographical studies show intersertal doleritic texture defined by subhedral to euhedral k-feldspar, plagioclase, clinopyroxene and oxides. ICP-MS and ICP-AES geochemical analyses of Fell dolerites show that they are basalts of continental tholeiite affinity. Studied dolerites are the results of relatively high partial melting of E-MORB mantle source of spinel lherzolite composition. Lavas have evolved through fractional crystallization process coupled with continental crust contamination. Fell dolerites are considered as times markers of a geodynamic even combining limited stretching and tectonic phenomenon, probably the post Pan African relaxation setting.

Keywords: *dolerite, continental tholeiite, pan african, Fell, Adamawa plateau, Cameroon*

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1. Introduction

Fell locality belongs to the Adamawa plateau, a horst shape structure of Pan African granitic basement, in Central Cameroon (Figure 1). The whole structure is part of Adamawa-Yadé domain of Pan African mobile belt which is recently considered as stood out element of Congo Craton after a phase of continental extension at early Archean age [1]. Numerous dolerites dykes transecting the granitic basement of Fell have recently been discovered. Those formations are the least studied magmatic units though they are key structure for geodynamic interpretations [2]. Dolerites dykes are considered worldwide as times markers of geodynamic events and many dykes swarm have been studied in Central Africa especially in Cameroon [3-8] and Chad Republic [9]. Petrological studies of those formations highlight diverse magma processes involved on their petrogenesis and geodynamic implications stay restricted. The main worry on dolerites studies in Central Africa is that researcher's attention has been not drawn early on those materials yet their contribution on geodynamic reconstitution are well-known. This study aims to bring petrography and introductory geochemical data of recently discovered dolerites dykes of Fell locality in South Eastern Adamawa plateau.

2. Geological Setting

The basement of studied area (Fell) in Central Africa (Figure 1A) belongs to the Adamawa-Yadé Domain (AYD) of Pan African fold belt chain of Adamawa plateau (Figure 1B). AYD is composed of abundant plutonic rocks that intruded Palaeoproterozoic gneisses and is cut by the Trans current Central Cameroonian Shear Zone (CCSZ). Fell basement is composed of metaluminous to slightly granitoids of high-K calc-alkaline to shoshonitic suite from rocks of mantle origin, and/or from the remelting of metabasalt or metatonalite [10]. The evolution of Pan African belt is diversely interpreted: (1) Active continental margin-type environment [11], (2) a succession of continent-continent collisions [12] and (3), effects of Eburnian and Pan-African orogenesis [12] are among the scenarios proposed to elucidate the formation of Pan African mobile belt. The pyroxene and amphibole-bearing gneiss located south of Meiganga shows the geochemical characteristics of Archean TTG (tonalite-trondhjemitegranodiorite) with $^{207}Pb/^{206}Pb$ single-zircon evaporation method determinations yielding Late Archean (2.6 Ga) to Palaeoproterozoic (1.7 Ga) ages [13]. Those rocks are affected by four successive deformational phases (D1, D2, D3, and D4) around the Meiganga area [13]. Dolerites dykes are widespread in Fell locality in Southern Adamawa plateau in Central Cameroon. They are never been studied before and their petrological characteristics and geodynamic implication on the evolution of Adamawa-Yadé domain is not yet constrained.

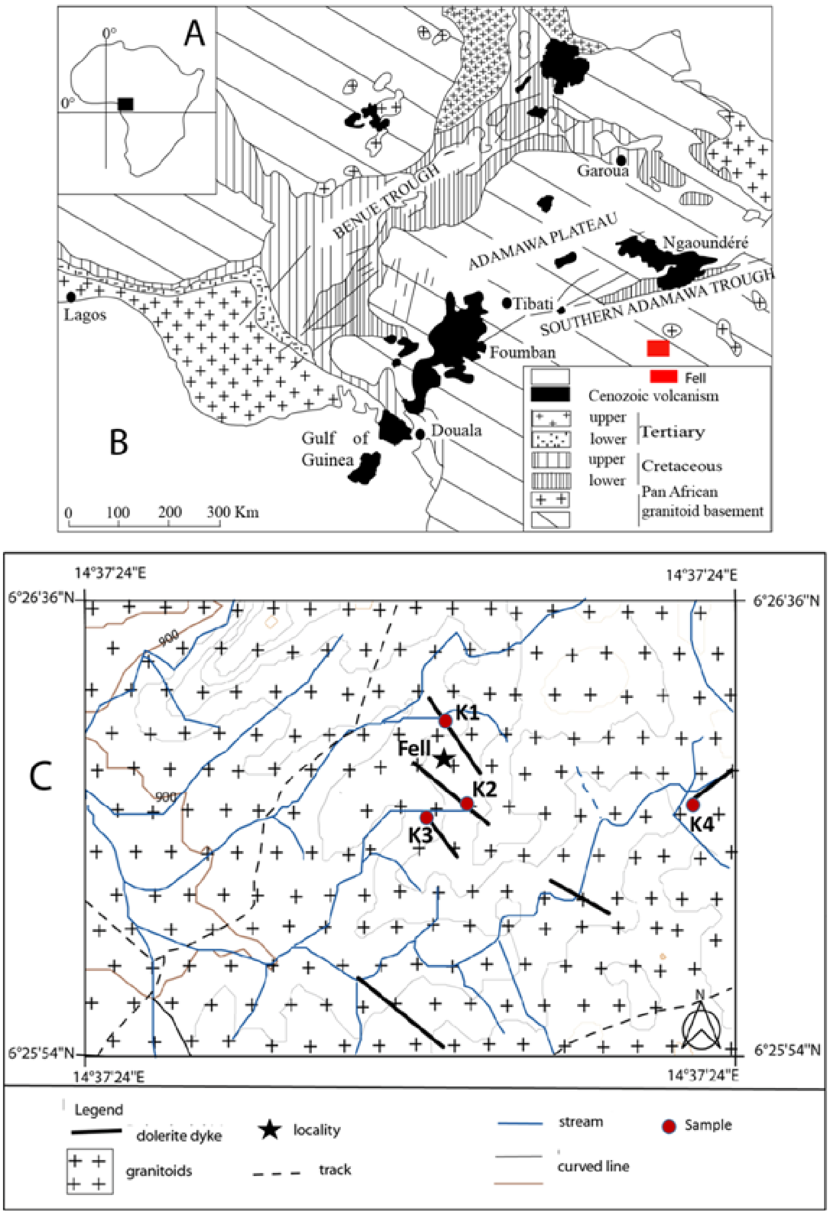

Figure 1. A: Location of Cameroon in Central Africa, B: Geological map of Adamawa plateau after [14], C: Geological sketch map of Fell area

3. Analytical Method

Six thin sections have been made from the selected representative samples at the "Laboratoire de Pétrographie" of the University of Yaoundé 1, Cameroon. ICP-MS and ICP-AES analytical methods have been used to determine major, trace and rare earth elements at ACMEL Analytical Laboratories, Vancouver, British Columbia, Canada. Major and trace elements were carried out from pulps. 0.2 g of rock powder was fused with 1.5 g $LiBO_2$ and then dissolved with 4 acid digestions. Analytical precisions vary from 0.04 to 0.1 % for major elements; from 0.1 to 0.5 ppm for trace elements; and from 0.01 to 0.5 ppm for rare earth elements. Loss On Ignition (LOI) has been determined by weight difference after ignition at 1000 ℃.

4. Results

4.1. Field Work and Petrography

Dolerites dykes occur in Kinta and Barka in Fell locality, and cross cut the local granitic basement along N135 and N70 directions parallel to stream lineaments of studied area (Figure 2A). Kinta dolerites are 50 m width and stretch from to 600 m to 1 km. They are organized in bowls of 30 to 80 cm in diameter along the Kinta stream. Stripping alteration mode is responsible of bowl shape features of outcrops (Figure 2A). Dark greyish matrix (Figure 2B) is covered by thin patina of 12 to 15 cm and contains whitish crystals of alkali feldspars (20% to 25% of volume) plus others blacks phases (pyroxene or oxides), 10% to 12% of volume). Barka dykes (Figure 2D) keep the same direction as those of Kinta village but it outcrops show angular shape of more than 80 cm size. They are 20 to 30m in width and may crop out on more than 1 km. Hand specimen show brownish altered patina and dark greenish coarse matrix with whitish crystals of feldspars and probably pyroxene. Sparkling yellowish crystals of pyrite (< 5% of volume) are present (Figure 2D).

On plate polarized thin section (Figure 3A and Figure 3B), lavas show intersertal doleritic texture and are composed of 30 to 45% sub-hedral to euhedral of 0.5 to 2 mm feldspar phase, containing rare oxides. Plagioclase phases (10 to 15% of volume) are skeletal, clinopyroxene crystal (15 to 25% of volume) show sub-hedral shape and interrelated with those of oxides crystals. Oxides (0.5 mm, 5 to 10% volume) are sub-hedral. Small crystals are frequently stuck on clinopyroxene borders (Figure 3B) or included in plagioclase or feldspar phases.

Figure 2. Representative of Fell dyke outcrop at Kinta stream composed of angular blocks of dolerite lavas (A), containing feldspars and mafic phases in a greenish grey matrix (B) and at Barka along N70 direction (C), containing feldspar and pyrite crystals in dark green matrix (D)

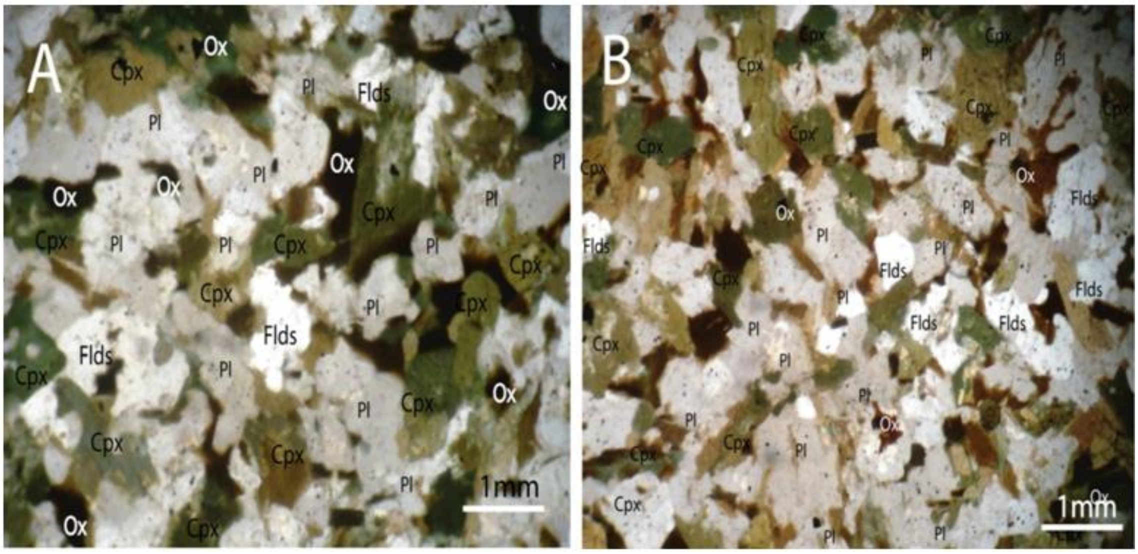

Figure 3. Photomicrographs showing main characteristics of dolerite textures of Fell dolerites

Table 1. Whole rock geochemical analyses of Fell dolerites

locality	Fell				Afikpo	Mbaoussi
Location	basalt	basalt	basalt	basalt	basalt	trachybasalt
sample	K4	K1	K3	K2	86B	D12
SiO_2	48.41	51.36	51.41	51.50	52.06	49.68
TiO_2	2.39	2.73	2.84	2.69	1.54	2.21
Al_2O_3	16.69	14.56	14.31	14.19	15.18	15.65
Fe_2O_3	12.30	12.64	13.02	13.04	3.25	11.38
MnO	0.17	0.18	0.22	0.22	0.16	0.17
MgO	6.48	3.91	3.90	3.94	5.72	4.95
CaO	8.34	6.99	6.58	6.60	8.21	6.39
Na_2O	3.33	2.84	2.68	2.64	3	3.64
K_2O	0.97	1.96	2.23	2.14	0.35	2.22
P_2O_5	0.78	0.87	0.90	0.87	0.13	0.45
LOI	-0.2	1.5	1.5	1.8		
sum	99.72	99.71	99.71	99.72	98.9	99.64
Mg#	48.42	35.54	34.80	35.00	75.82	43.67
Ba (ppm)	565	1092	1083	1075	344	570
Sc	24	23	24	22		
Be	2	5	1	<1		2
Ni	60	40	40	38	53	35
Co	44.0	33.8	36.2	34.2	34	34.2
Cs	3.8	1.6	1.1	0.8		0.3
Cu	30	29	31	31	36	23.6
Cr	5.85	4.095	3.51	4.095	285	27
Ga	17.4	18.7	19.9	20.1		
Hf	4.8	7.7	7.8	8.2	2.2	7.4
Nb	10.5	17.1	17.1	17.6	7	20.2
Rb	15.6	44.3	50.1	48.4	9.8	75.7
Sr	583.3	594.6	551.7	562.0	235	594.8
Ta	0.6	0.8	1.1	1.3	0.36	1.1
Th	1.0	3.5	3.6	3.6	0.9	6.8
U	0.3	0.5	0.8	0.5	0.21	0.9
V	187	197	246	193	200	167
Zn	102	129	131	124	125	
Zr	209.9	346.4	351.1	351.6	78	345.4
Y	32.1	41.6	40.6	42.4	20	36.5
La	28.9	55.4	52.9	54.7	7.15	43
Ce	63.0	116.1	111.2	116.0	102.15	94
Pr	8.03	13.99	13.69	14.23	2.2	11.11
Nd	36.5	56.4	57.6	58.2	10.74	43
Sm	7.34	11.26	11.51	11.53	3.45	9.29
Eu	2.38	3.21	3.19	3.18	1.38	2.19
Gd	7.81	10.62	10.31	10.70	4.53	6.15
Tb	1.07	1.52	1.47	1.53	0.76	1.26
Dy	5.90	8.57	7.68	8.25	4.44	6.77
Ho	1.22	1.59	1.58	1.50	0.86	1.37
Er	3.69	4.31	4.54	4.45	2.33	4.01
Tm	0.48	0.59	0.57	0.57	0.31	0.54
Yb	3.06	3.50	3.80	3.68	1.96	3.73
Lu	0.44	0.56	0.51	0.55	0.237	0.54
Pb					1.7	2
Y/Nb	3.06	2.43	2.37	2.41	2.86	1.81
Nb/Ta	17.50	21.38	15.55	13.54	19.44	18.36
Zr/Nb	19.99	20.26	20.53	19.98	11.14	17.10
Zr/Hf	4.80	7.70	7.80	8.20	2.20	7.40
La/Nb	2.75	3.24	3.09	3.11	1.02	2.13
La/Ta	48.17	69.25	48.09	42.08	19.86	39.09
ΔNb	0.93	1.22	1.25	1.22	0.57	1.44
Ba/Th	565.00	312.00	300.83	298.61	382.22	83.82

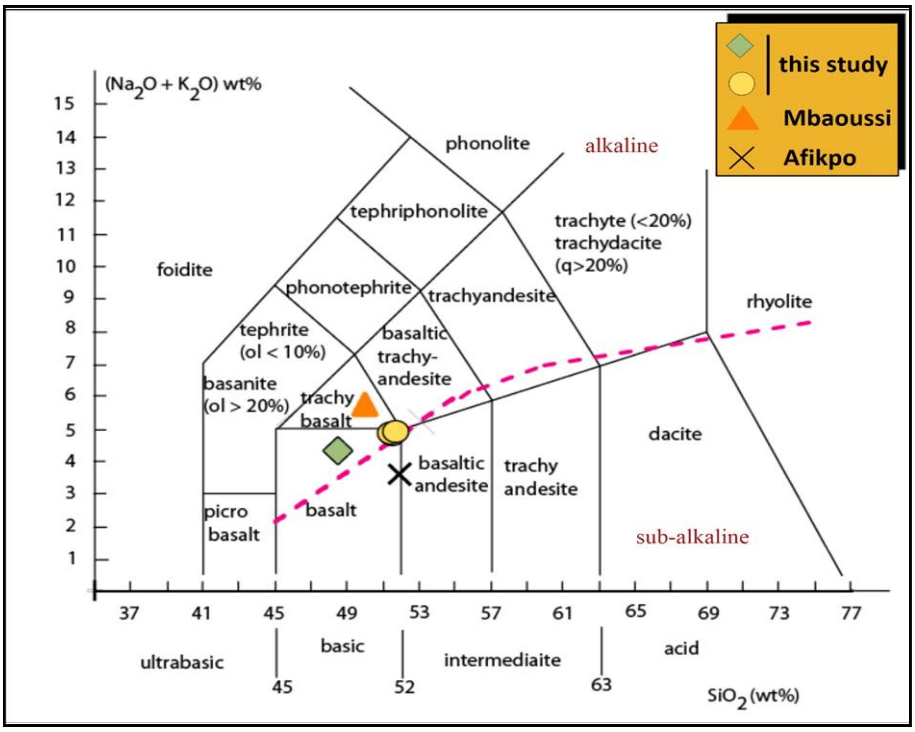

Figure 4. T.A.S. diagram for Fell dolerites after [16]. Pink dashed line separates alkaline and sub alkaline fields after [17]. Analyses recalculated to 100 LOI free

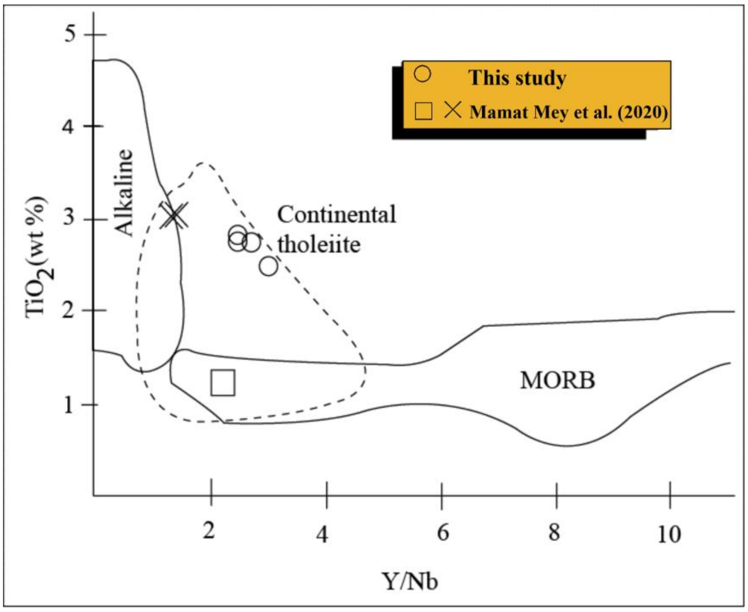

Figure 5. Composition of Fell dolerites plotted in TiO_2 vs Y/Nb diagram after [18]

4.2. Geochemical Characteristics

Geochemical classification of studied dolerites exhibits basaltic composition and some basalts are closed to trachybasalt and basaltic andesite field (Figure 4). Low LOI (< 2% wt.) testifies of non-altered character of the lavas. SiO_2 are between 48.41 and 50.50 wt. %. TiO_2 are relatively high (2.39-2.84 wt. %) and alkali contents are high (4.30-4.91 wt. %). Mg# (=100MgO/40.32/(MgO/40.32+FeOt/71.87)) is low and lay between 34.80 and 48.42. Transitional elements contents Ni (38-60 ppm), Co (33.8-44.0 ppm), Cr (3.51-5.85) Cu (29.0-30.0 ppm), V (187.0-286.0 ppm) and Zn (102.0-131.0 ppm) are low. Alkali and alkali earth elements contents Rb (44.3-50.1 ppm) are low. The lowest values (16.6 ppm) are found in basalt K3. Sr contents (551.7-583.3 ppm) are relatively low while Ba contents (565-1092 ppm) are high. High incompatible elements contents Nb (10.5-17.6 ppm), Ta (0.6-1.3 ppm), Zr (209.9-351.1 ppm), Th (1.0-3.6 ppm), Hf (4.8-8.2 ppm) and Y (32.1-42.4 ppm) are low. Zr/Hf ratios are low in basalt K3 while the values obtained in others basalt are low. Values of Nb/Ta ratios vary between 13.54 and 21.38. Low value is found in basalt K2, closed to trachybasalt lava. Y/Nb ratios are high and lay between 2.4 and 3.05 (Figure 5). In Tb-Th-Ta diagram (Figure 6A), Fell dolerites fall within the continental tholeiite field and within the field (1) of Y-La-Nb diagram (Figure 6B) where they are found in field «D» and one sample in field A of Hf-Th-Ta diagram (Figure 6C). A normalization according to [15] show relatively high contents of incompatible elements which may reach up to 200 times (see Ba) the values of the same elements in the mantle. Negative anomalies are noticed in Th, U, Nb, Ta, P and Ti. Positive anomalies are shown in K and weakly in Y (Figure 7A). Rare earth elements patterns decrease progressively from LREE to HREE without noticeable anomalies (Figure 7B). Values of (Ce/Yb)n ratios of studied dolerites are low (5.3-8.6).

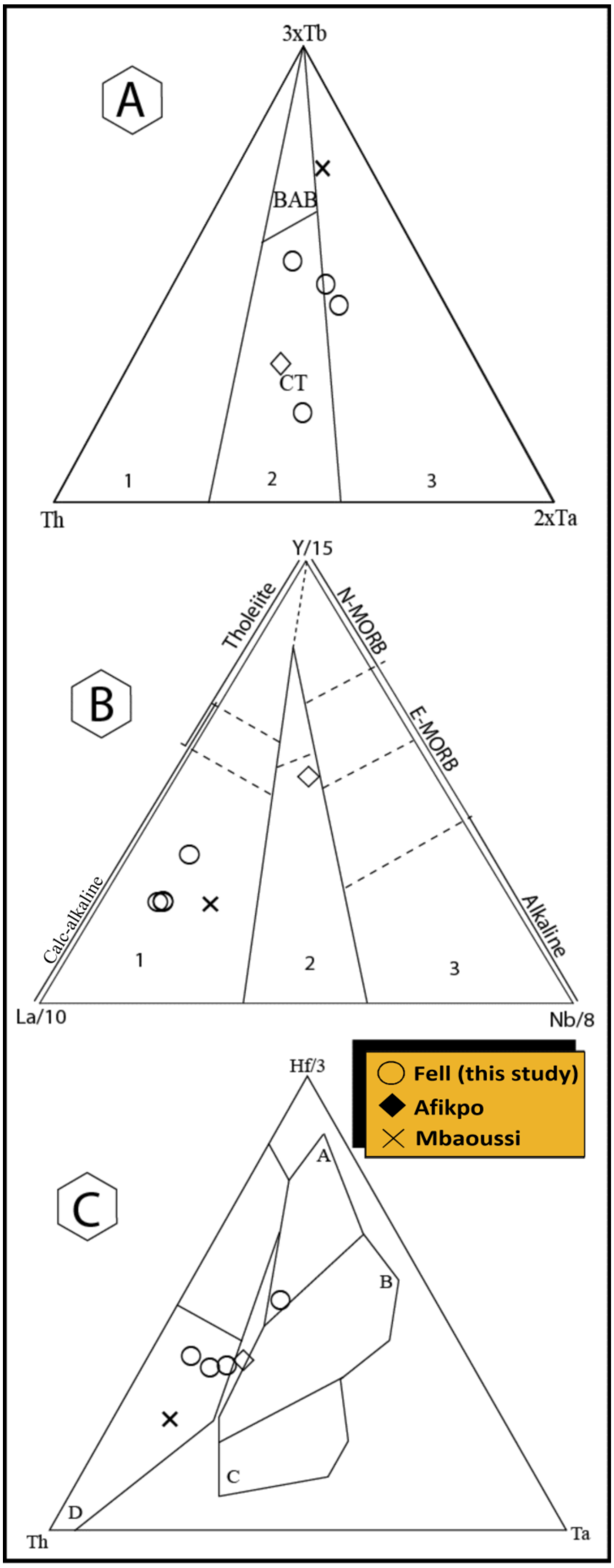

Figure 6. Fell dolerite in triangular diagrams. (A). Tb-Th-Ta triangle after [19], BAB: Back Arc Basin Basalts, CT: Continental Tholeiites; 1. Orogenic Basalts, 2. Continental Tholeiites and Arc Basin Basalts and 3. Non orogenic Basalts. (B): La-Y-Nb [20]: 1: Arcrelated orogenic series, 2: Intermediate domain of continental tholeiites, 3: Anorogenic series of oceanic ridges and intraplate alkaline basalts, (C): Th-Hf-Ta [21]: 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

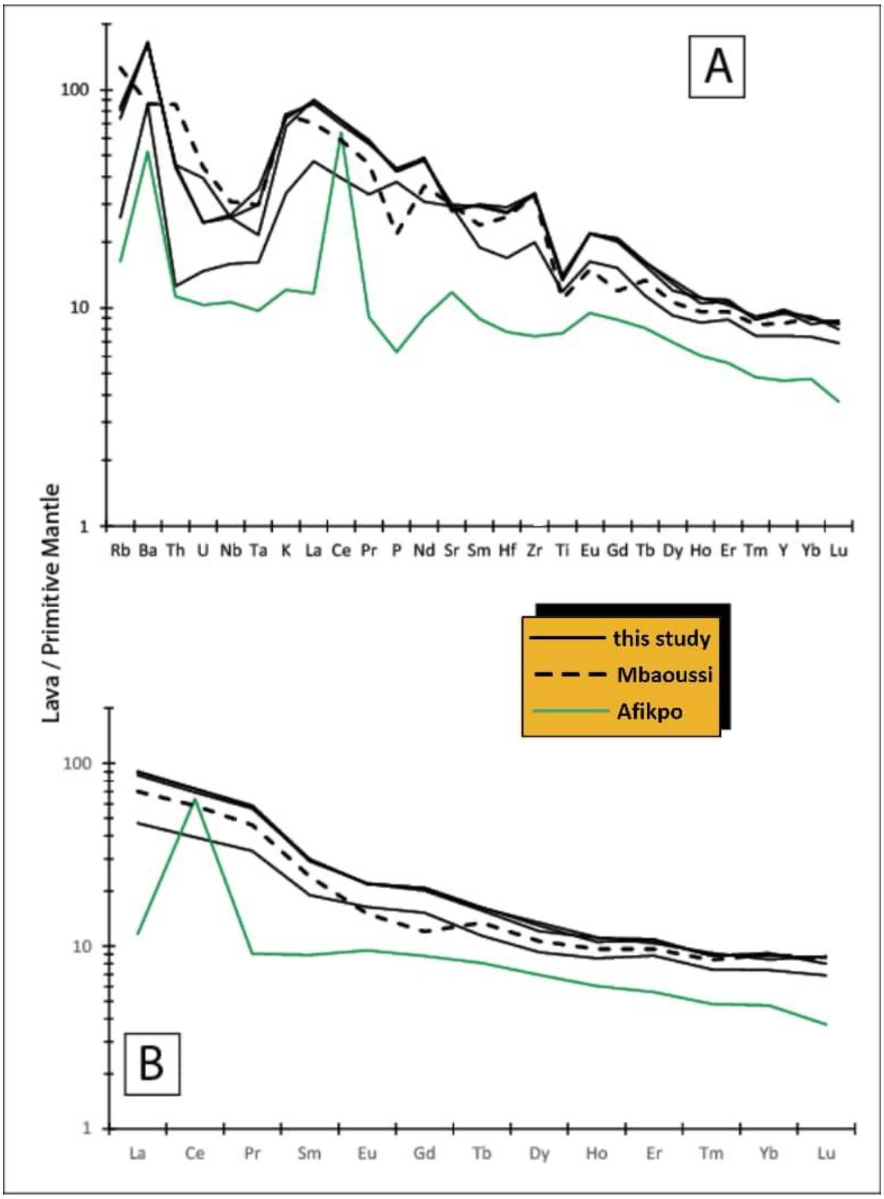

Figure 7. A: Multielements spider diagram (normalization after [15]) and (B) REE of Fell dolerites

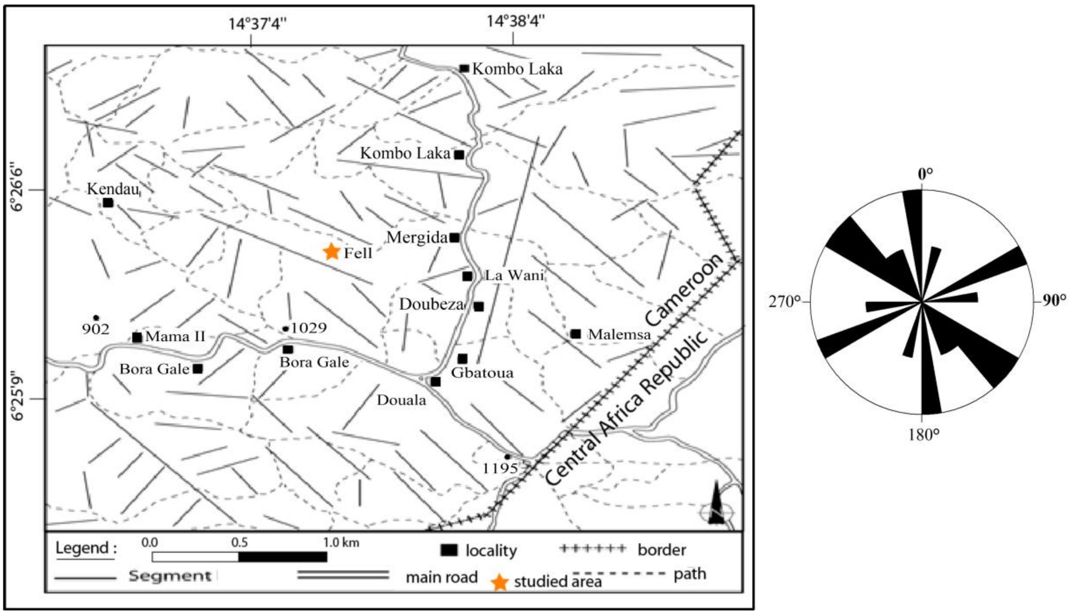

Figure 8. Fracturing map and lineaments strikes of Fell locality

5. Discussions

Dyke swarms are known world-wide as times markers to understand geodynamic processes, particularly for the Precambrian period [2]. In Fell, the locality at south of the Adamawa plateau in Cameroon, dolerites occur as giant dykes cutting the Pan African granitoids of the basement along the N135 direction and few to N70 (Figure 8). Those directions are among of the Precambrian ones which delimit the Adamawa plateau at the North and South [14,22] and are supposed to have been reactivated at Tertiary to be responsible of Adamawa uprising [23]. This may suggest a certain relation between dolerites dykes and local pan African structures as evidenced by quite parallelism between stream segments and N135 and N70 directions of dolerites dykes (Figure 8).

Granitoïds of the Pan African Basement have been dated at 614-619 My [10]. Studied dolerites dykes are thus supposed to be Late Pan African, specially post Pan African and probably have occurred after a phase of tectonic relaxation, invading N70 and N135 cracks. Petrology of Fell dolerites show that lavas are basalts of continental tholeiite affinity as shown on Figure 5 and their Nb, Ta and Ti negative anomalies on Figure 7 [24]. Their alkali contents are high (4.3-4.9 wt. %) and their Mg-number (34.80-48.42) are low, attesting the evolved character of the lavas. Fell dolerites are composed of plagioclase, k-feldspar, oxide and clinopyroxene. The crystallization of those minerals is the strong argument which should be considered to stand behind the Fell dolerites evolution, suggesting the fractional crystallization as the major process of lava differentiation. This assumption is sustained by the very low contents of transitional elements Ni, Co, Cr, compared to those of primitive lavas, directly obtained from lherzolite mantle melting (Ni: ppm, Co: ppm, Cr: ppm, and V: ppm, [25]. Values of La/Ta ratios of Fell dolerites are high (>30), suggesting the contribution of crustal materials on lava genesis so as the La/Nb (>1.5). The relatively constant ratios of Nb/Ta, Zr/Hf and Zr/Nb attest of co-genetic feature of studied lavas and suggest the same source or the same composition of the source for all lavas. This source should have undergone the high melting degree as suggest the low values of Cen/Ybn ratios (5.3-8.2) of studied dolerites. ΔNb value is relatively high and point out the lherzolite mantle as the best candidate of the source composition of studied lavas [26,27]. The figures 7A and 7B show that the patterns of Fell dolerites stand near those of Mbaoussi which are from E-MORB mantle and quite different to those of Afikpo of N-MORB source. Thus, studied dolerites originate from E-MORB mantle of lherzolite composition. Geodynamic setting of studied dolerites is constrained by ternary diagrams (Figure 6). On Tb-Th-Ta diagram (Figure 6A), some studied lavas are within the continental tholeiites domain and that of MORB-OIB and within the orogenic of Y-La-Nb diagram (Figure 6B) while they fall within the arc volcanic domain of Hf-Th-Ta diagram (Figure 6C). Those observations show that studied dolerites are time markers of a geodynamic even combining limited stretching and tectonic phenomenon. The accurate setting should be the post Pan African relaxation which may associate all those events.

6. Conclusion

Dolerites dykes of Fell in Southern Adamawa plateau are continental tholeiites stretching N70 and N135, along the Pan African cracks. They are basalts in composition and show doleritic texture defined by plagioclase, k-feldspar, clinopyroxene and oxides phases. Studied dolerites are considered as times markers of post Pan African tectonic relaxation event. They are the results of the high partial melting degree of the lherzolite mantle source of E-MORB affinity. Fractional crystallization and crustal contamination are main processes behind the petrogenesis of those rocks. Ongoing analyses (isotopes) and geochronological data should improve the petrogenesis processes and geodynamic setting of studied dolerites.

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