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Quantification of Strain of the Pan-African in Mvog-Betsi Area (Yaoundé Group, Cameroon)

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Abstract: The ductile deformation in the paragneissic bed of Mvog-Betsi in the north-eastern part of Yaounde (Cameroon) appears to be intensive and may be traduced by a high shear rate (more than 10%). Some marker subjects that may quantify this strain are observed. Those are elliptical quartz and feldspar, and folds. The study of elliptical markers shows their preferential orientation. The initial rate R_i of the markers before the strain approaches 3.76, and the harmonic value of R_f is between 1.51 and 1.71. Main orientation $Ø_f$ of strain's ellipse from the direction of stretching in actual position is situated between -10 and -19. The strain's rate R_S is comprised between 1.1 and 1.7. The orientation $Ø_S$ of the strain's ellipse is situated between N10E and N20E. The rate of shortening varies between 20% and 75%.

Keywords: Strain, Method, Rate of Deformation, Yaoundé Group, Cameroon

1. Introduction

The tectonic studies in the migmatites of Yaoundé revealed the tangential nature of Panafrican deformation responsible for the actual regional configuration [1-4]. The formations which are metamorphosed in granulite facies and retromorphosed to green schist facies. The deformation was polyphased. Main orogenic phases of deformation in the studied area are evidenced D_1, D_2, D_3, D_4 and a last post orogenic phase illustrated throw the MORB. The D_1 is characterized by S_1 foliation and sporadic F_1 folds. The most important phase of deformation is the D_2 phase documented by P_2 meso-folds, L_2 lineation, C_2 shear planes, B_2 bounding, S_2 schistosity planes and S_2 foliation planes which transpose S_1 planes to form S_{1-2} composite planes. The D_3 phase is characterized by ductile to brittle fractures. The D_2 phase is responsible of the actual morphostructural configuration of the region. In order to characterize the quantification of this deformation, particular forms of certain deformation minerals took our attention to estimate the ration of the deformation. These deformation minerals premise us to determine the ratio of strain and with some folds we have determinated the percentage of shortening. The presence of sheath folds in the region indicates a high shear ratio. All this informations permit us to estimate the rate of deformation. The results obtained here must be considered as preliminary, which is partly due to the bad conditions of the outcrops.

2. Geological Setting

The North Equatorial Mobile belt includes the Yaoundé region between the West African Craton and the Congo Craton. This mobile belt is extended to the East by the Oubanguide mobile belt of the Central African Republic. Geological studies in the region of Yaoundé have been done by several authors: [3-9]. From petrological studies, it is known that the Yaoundé Group presents rather uniform petrographic enteties which show similar structural evolution. This series is constituted by paraderivated and orthoderivated formations. The paraderivated formation are represented by garnet and kyanite gneisses associated with garnet and plagioclase gneisses, quartzits, garnetits, para-amphibolits, calcsilicat rocks and marbles. Orthoderivated formations are constituted by metadiorit associated with pyroxenis, biotitites and ortho-amphibolits. These rocks have been affected by polyphase deformations associated with migmatisation [3]. They show the retrometamorphic evolution from granulite facies to green schist facies. Calculated temperatures are 650°C and the pressures range from 8 to 9.5 kbars.

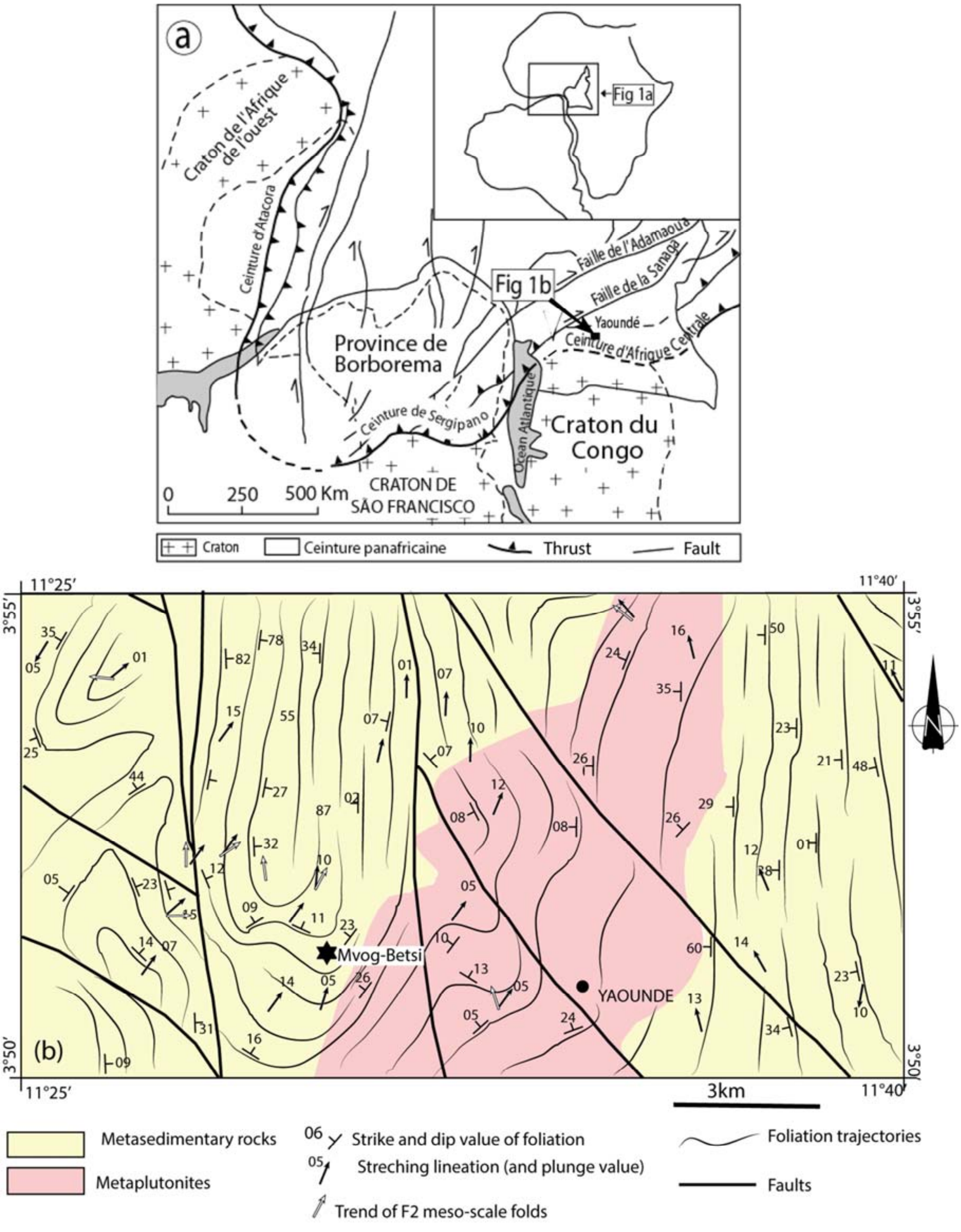

Figure 1. *(a) Pre-drift reconstruction of Pan-African and Brasiliano terranes (modified from [23]). (b) Structural map of Yaoundé (modified afpter [11]).*

Structural studies done shown tangential tectonics, [1] with south vergent thrusting of the Yaoundé Series on the Congo Craton, structural map in Yaoundé region shows the orientation of structures as scales [3] in the studied area (figure 1). That had as consequence a high rate of strain responsible of sheath folds in Mvog-Betsi [4]. That could be appeared during transpression and transtension sinistral shear movement, in the Yaoundé neoproterozoic in south Cameroon [10, 11]. The configuration of some rocks and minerals show some structures of the geometry of deformation which permits to characterize the tangential tectonics responsible of the kinematics of the actual structures and to characterize the strain responsible.

3. Materials and Methods

The material used are compass to define the orientation of long axe of ellipse of the object deformed and the metric object for measurement of the folded objects.

Many makers of deformation ovoid quartz and feldspar eyes (Figure 3B) and folds enable us to make a quantitative study.

Contrary of method of deformation in granular assemblies by [12] on the velocity gradient characteristics, the method here concerns the study of the elliptical markers by the $R_f/Ø_f$ method of [13, 14, 15, 16]. This method is useful for the reconstitution of the initial form of the deformed markers from their finite ellipticity R_f and their orientation $Ø_f$. Note that R_f=L/l; L and l are the lengths of respectively the large and the short axes of the marker; $Ø_f$ is the angle between the large axis and a taken reference direction. In the case of this study, the reference direction is that of the stretching lineation in its actual position, [3,]. A great number of markers of known azimuth have been used. In order to know the initial configuration of these markers before the strain, a set of data (R_f, $Ø_f$) taken on the field have been treated through the THETA program of [17] and the RPHIN program of [18].

A test of symmetry [19] has been realised to see the repartition of markers. A test of the homogeneity of strain has been done through the [20]. The estimation of strain's rate R_S and the orientation $Ø_S$ of the strain's ellipse have been also done through this net. The calculation of the shortening has been realised through two repair levels on the folded objects.

4. Results and Discussions

4.1. Regional Strain Pattern

The tectonic is illustrated by main structural elements. They are S_{1-2} foliation, meso-folds, stretching structures (L_2 lineation; boudins, rods of quartz), shear planes, faults. S_{1-2} is regional. The dip is around 20-25 NNE, (Figure 2a). The lineation are mineral or mechanic (Stretching lineation stria). The stretching lineation is sometime folded. Lineation is on quartzitic material plane S_{0-1-2}, these shows a regional variation, (Figure 2b). In general, we note dispersion of orientation, but a general disposition around the direction N20-N30 with moderate dip to the North. We can also observe another SW-NW orientation which confirms the domings and basins character of the region.

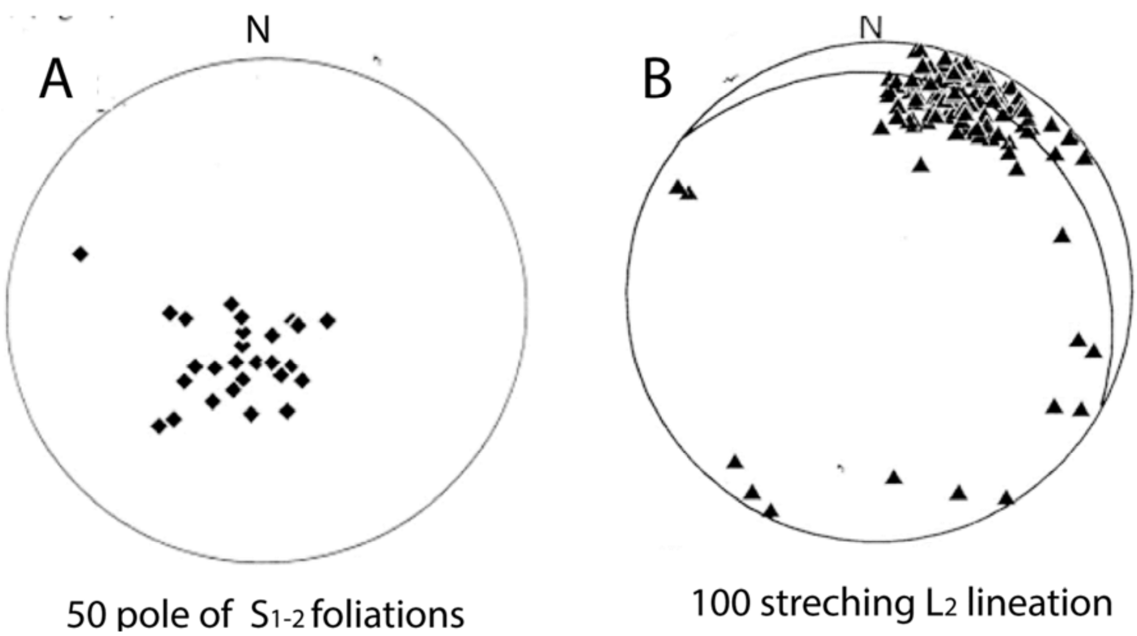

Figure 2. *a) Spatial orientation of sub-horizontal S_{1-2} planes of foliation. b) L_2 stretching lineation in the study area.*

Shearing is the principal mechanism of deformation. The planes are sub-horizontal. We denote the tendency of parallelism between foliation and shear plane. Sheath folds (Figure 3) are the consequence when the shear ratio is high under high temperatures.

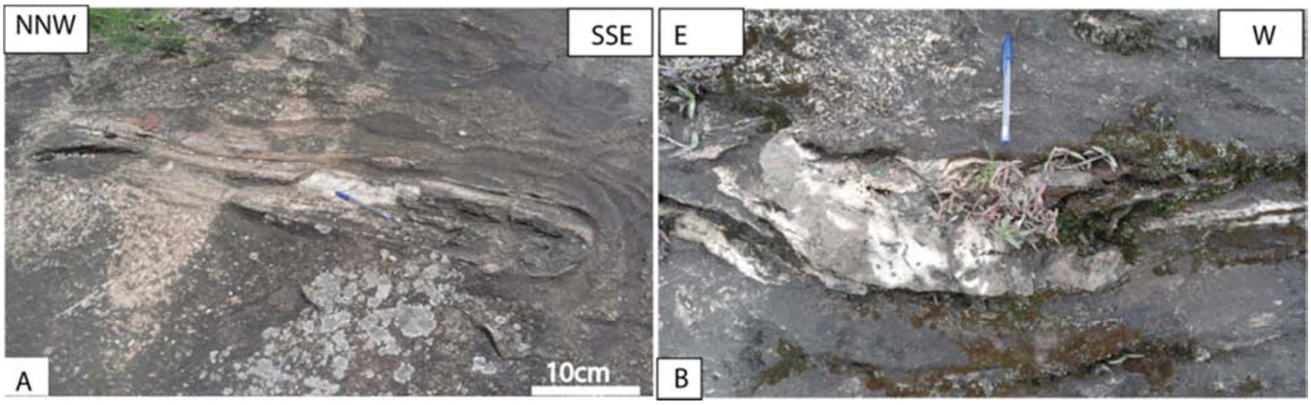

Figure 3. *A) Flatterned sheath fold (A) and Elliptical quartz-feldspath eyes (B) in gneisse in Mvog-Betsi area.*

4.2. Strain Quanfication

The R_i-$Ø_i$ (Figure 4a-e) and R_f-$Ø_f$, (Figure 6 a-e), diagrams have been made on the basis of a set of (R_f, $Ø_f$) data treated through THETA and RPHIN programs. The main value R_i before the strain is 3.76 (Figure 5 a-e). The test of symmetry shows an initial preferential orientation between -90 and 45°. The symmetry index value is between 0.57 and 0.9. The harmonic value of R_f is between 1.51 and 1.71. The mean orientation $Ø_f$ is between -10 and -19 (table 1). The test of homogeneity of the strain (Figure 6 a-e), shows an identical repartition of markers, which means that the strain is homogenous. The strain's rate R_S, deduced from the stereograms, (Figure 7 a-e) is comprised between 1.1 and 1.7.

The ellipse orientation is between N 10 and N 20, (Table 1). The shortening rate is $\varepsilon=(L_0 - L_1)/L_0$ (where L_0 is the length between two repair points before the folding; L_1 is the length between the same points after folding). The shortening rate is ε=20-75%, (table 2).

Table 1. *Results obtained from the program THETA of Peach and Lisle, (1979), and from [21]. N= number of (R_f, $Ø_f$) datas; MR_f= harmonic value of R_f; M $Ø_f$= mean of $Ø_f$; I_{sym}: indice of symmetry; R_S= strain's rate; $Ø_S$= orientation of strain's ellipse; A=Azimut of planes; N= number of datas.*

A	N	Values given by Tetha Program from Lisle 1979			Values of R_S and $Ø_S$ from De Paor (1988)	
		MR_f	$MØ_f$	I_{sym}	R_S	$Ø_S$
N231. 10	50	1.62	-14.1	0.76	1.1	-15
N338. 15	54	1.633	-11.3	0.78	1.2	15
N300. 42	80	1.65	-12.2	0.85	1.2	18
N272. 36	101	1.66	-10.7	0.83	1.2	14
N35. 3	116	1.59	-12.2	0.88	1.3	3

Table 2. *Estimation of shortening rate in Mvog-Betsi area.*

L_0	L_1	ε	L_0	L_1	ε	L_0	L_1	ε	L_0	L_1	ε	L_0	L_1	ε	L_0	L_1	ε
8.8	3.6	59	30	17	43	13	4	68	9	4.3	52	7.1	4.5	37	17	13.5	22
12.7	7	45	11.3	7.4	35	13	10.5	19	7.4	4.8	35	18.8	6	68	8	5	38
20	11	43	15	8	47	15	9	40	6.4	5.4	19	13.7	5.8	58	17	7.5	53
14.8	7	53	36.8	22	40	8	3.6	55	16.5	6.3	62	12	8	33	16	6.1	61
24	10.5	56	24	10.5	56	9.5	5.5	42	7	2.8	60	13.5	9	33	19	9.5	50
10	7	30	9.5	5.1	46	16	7.6	52	11	5.5	50	12	4.4	63	33	13.5	59
11	9.1	19	9.5	3.5	63	18	6.5	64	10	5	50	14	7.8	44	11	7	36
18	10.2	42	23.3	5.4	77	25	14.5	42	9	3.9	57	13.6	8.8	35	24	18.5	23
8	4.1	49	13.5	9	33	17	6	65	77.5	3.1	59	8	3.4	58	10	5	50
9.8	6.1	38	22	13.5	39	12	2.7	78	14.5	9	38	4.4	2.2	50	10	7	30
5.2	3	42	24	15.5	35	38	27	29	15.1	9	40	4.7	2.9	38	16	3.8	76
12.9	5.3	59	5.4	2.1	61	20	5.5	73	8.7	4.3	51	6.1	2.5	59	11	5.2	53

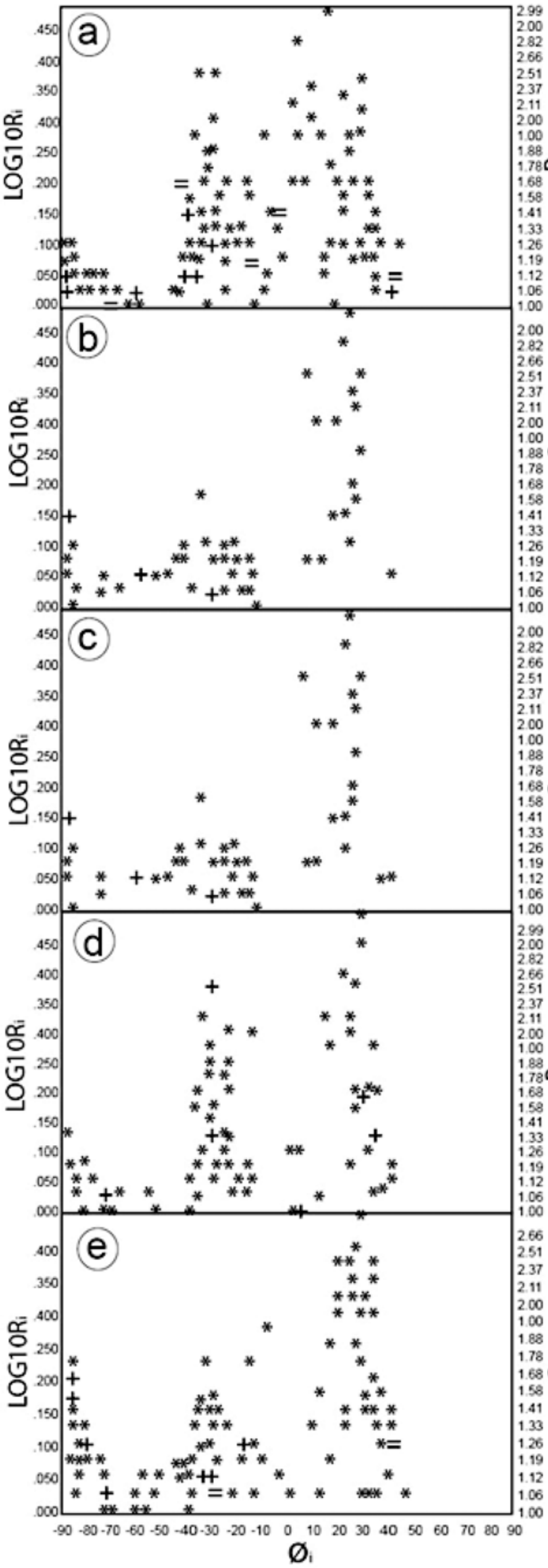

Figure 4. *$R_i/Ø_i$ diagrams of markers taken in several planes of known azimut: a: N35. 3; b: N231. 10; c: N338. 15; d: N300. 42; e: N272. 36.*

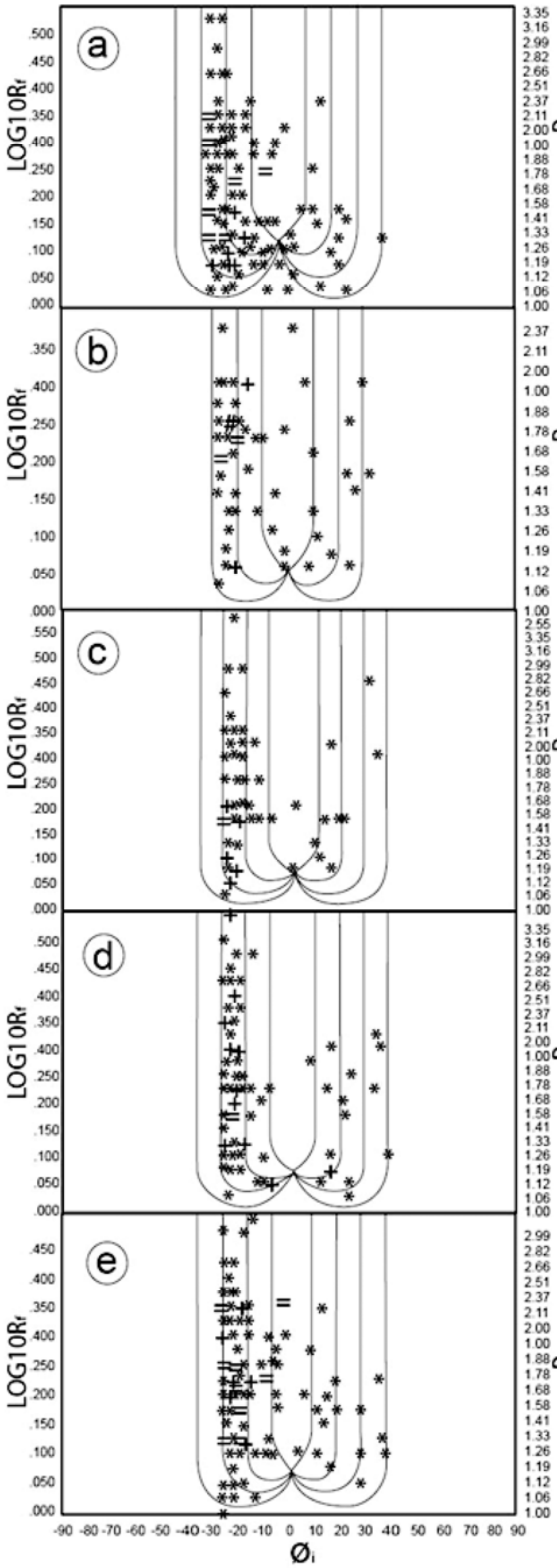

Figure 5. *$R_f/Ø_f$ diagrams of markers taken in several planes of known azimut. a: N35. 3:; b: N231. 10; c: N338. 15; d: N300. 42; e: N272. 36.*

The ductile strain in the Mvog-Betsi area appears is progressive, [3, 21, 22]. A spatial evolution of the stretching lineation shwo that, the $Ø_S$ value (N10°E to N20°E) is similar to the orientation of the stretching lineation in is actual position. The markers should therefore be contemporaneous with the stretching lineation. It means that the deformation ratio estimated from the markers may be that responsible of the lineation. The folds through which estimation of shortening has been done may also be contemporaneous of these structures. The shortening ratio estimated may also at last be the one that prevailed during the deformation responsible of the stretching lineation and the elliptical markers.

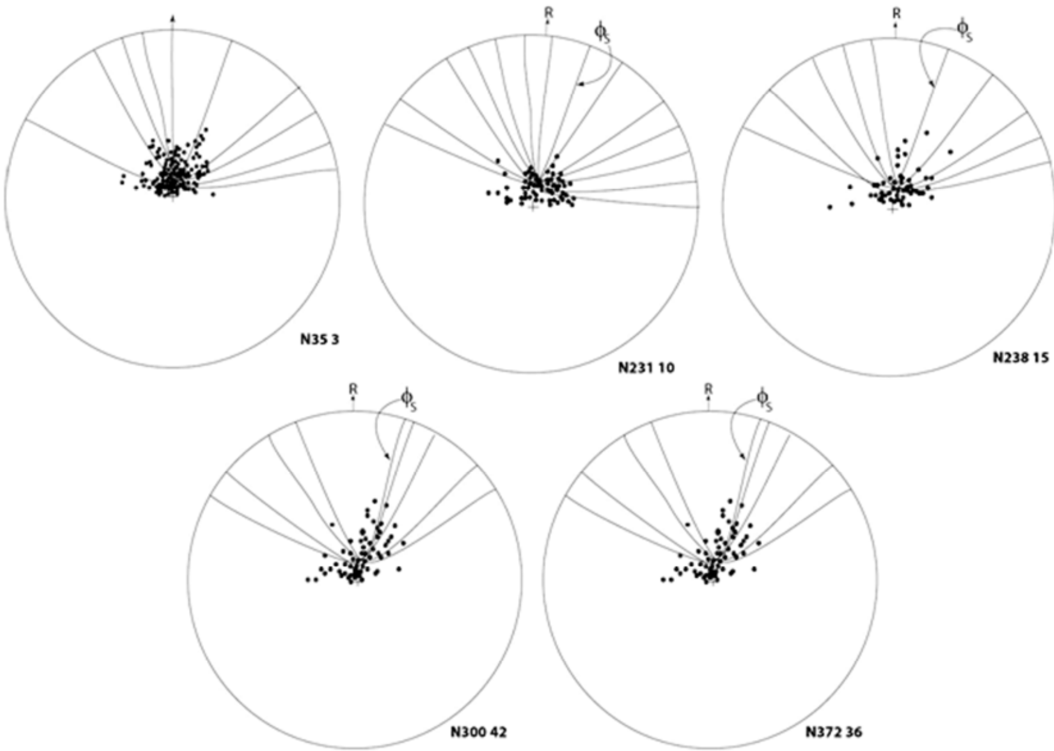

Figure 6. *Test of homogeity of deformation on various planes.*

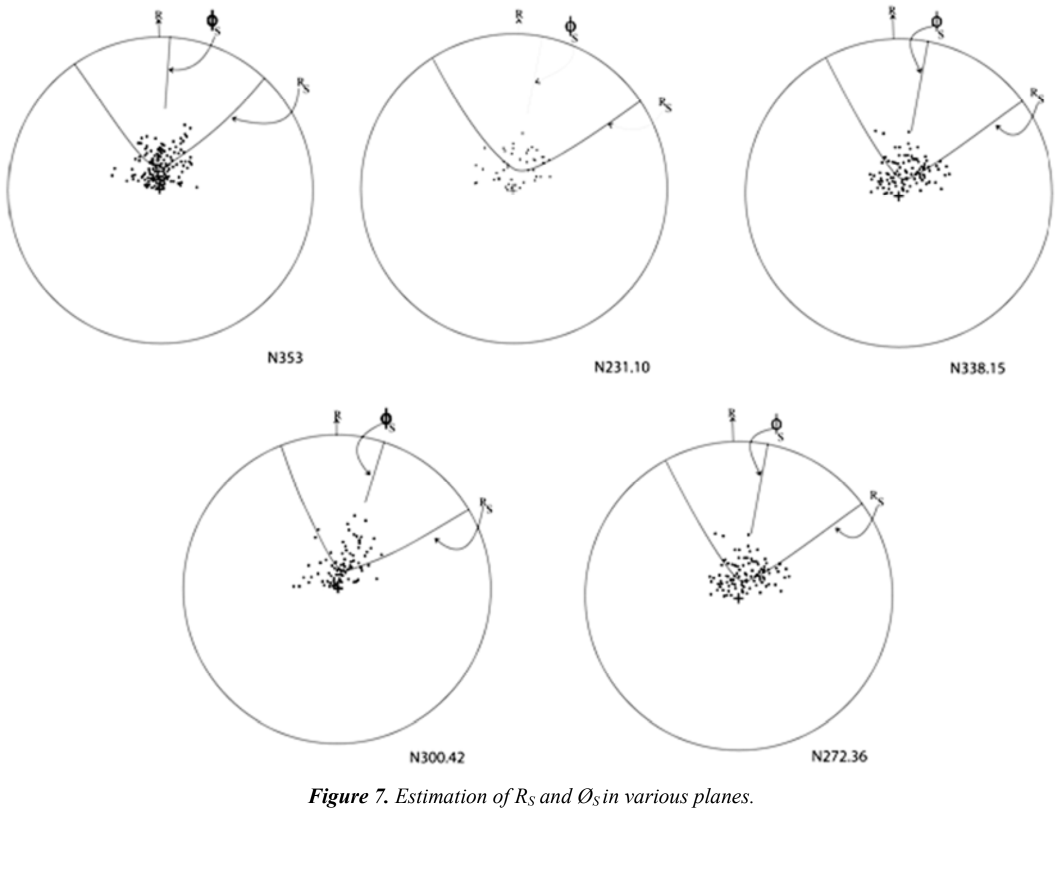

Figure 7. *Estimation of R_S and $Ø_S$ in various planes.*

5. Conclusion

Quantification of the Panafrican strain in the Mvog-Betsi (Yaoundé) area show the strain's rate between 1.1 and 1.7, the rate of shortening varies between 20% and 75%. This first local estimation most considers the conditions of outcrop and the orientation of the plane where the data were taken.

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