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Full Length Research Paper

Evidence of a Miocene volcano-sedimentary lithostratigraphic sequence at Ngwa (Dschang Region, West Cameroon): Preliminary analyses and geodynamic interpretation

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The Ngwa sedimentary sequence is situated on the southern flank of the Bambouto volcano. Analysis of petrography, lithostratigraphy, mineralogy, morphology and morphometry enabled the reconstruction and interpretation of their stratigraphic architecture, depositional and paleogeographic setting, the origin of the sediments and the geological history of this region. The lithostratigraphic sequence of the Ngwa sedimentary deposits reveals two major phases of sedimentation: (i) Conglomerates with pelitic sandstone matrix, pelitic sandstone and carbonaceous clayey shale with lignite intercalations; and (ii) conglomerates and arkosic sandstones. Pebbles from the Ngwa conglomerates are sub-rounded to spherical. The grain size distribution of the sandstones indicates a high amount of very fine clay particles. The sediments of Ngwa are well sorted. The homometrical character of sandstones is related to their fluvial origin. The presence of sillimanite and kyanite testifies to the metamorphic provenance of a part of the Ngwa sediments while the basaltic pebbles indicate the volcanic origin of the other part. During the Miocene, Ngwa area experienced detrital sedimentation with alternation of volcanic phases related to volcanic activity at Mount Bambouto.

Key words: Ngwa, Cameroon, lithofacies, detrital sedimentation, Miocene.

INTRODUCTION

In Cameroon, many studies concerning sedimentary rocks have been carried out, but most of those studies have been dedicated to the coastal sedimentary basins: Kribi/Campo (Belmonte, 1960; Njiké and Eno, 1987; Ngueutchoua, 1996; Angoua, 2006), Douala (Reyre, 1964; Salard-Cheboldaef, 1976, 1977; Njike, 1986; Njike and Eno, 1987; Njike, 2005; Ngoss III et al., 2006) and Rio Del Rey (Njoh, 2007). Those studies also concerns the major intracontinental basins: Mamfe (Njieatih, 1997; Petters et al., 1987; Eyong, 2003), Mbere Djerem (Njike et al., 2000; Tchouatcha et al., 2010), Babouri Figuil (Dejax et al., 1989; Ndjeng, 1998), Mayo Oulo Lere (Brunet et al., 1988; Ndjeng and Brunet, 1998; Hell, 2006), Hamakoussou (MINEF, 1995; Tsafack, 1998) and Logone Birni (Petters, 1979 in Ntep et al., 2000; Allix et al., 1983 in Ntep, 2000). No earlier study noted the presence of sedimentary units higher up in the West Cameroon Highlands. Recently geological surveys of the Dschang region (belonging to the piedmont zone of the southern flank of Bambouto massif) identified fragmental sedimentary lithofacies at Ngwa and enclaves of sedimentary rocks randomly distributed in volcanic complex (Kenfack, 2002; Kwekam, 2005). However, very little is known about the features of these sedimentary rocks including: their age, provenance and a possible relationship with the coastal sedimentary basins deposits of Cameroon. Lithostratigraphic and petrographic investigations of the Ngwa sedimentary rocks presented in this paper were done in order to better understand the provenance of the detrital sediments and their stratigraphic architecture, depositional and palaeogeographic setting and the geological history of

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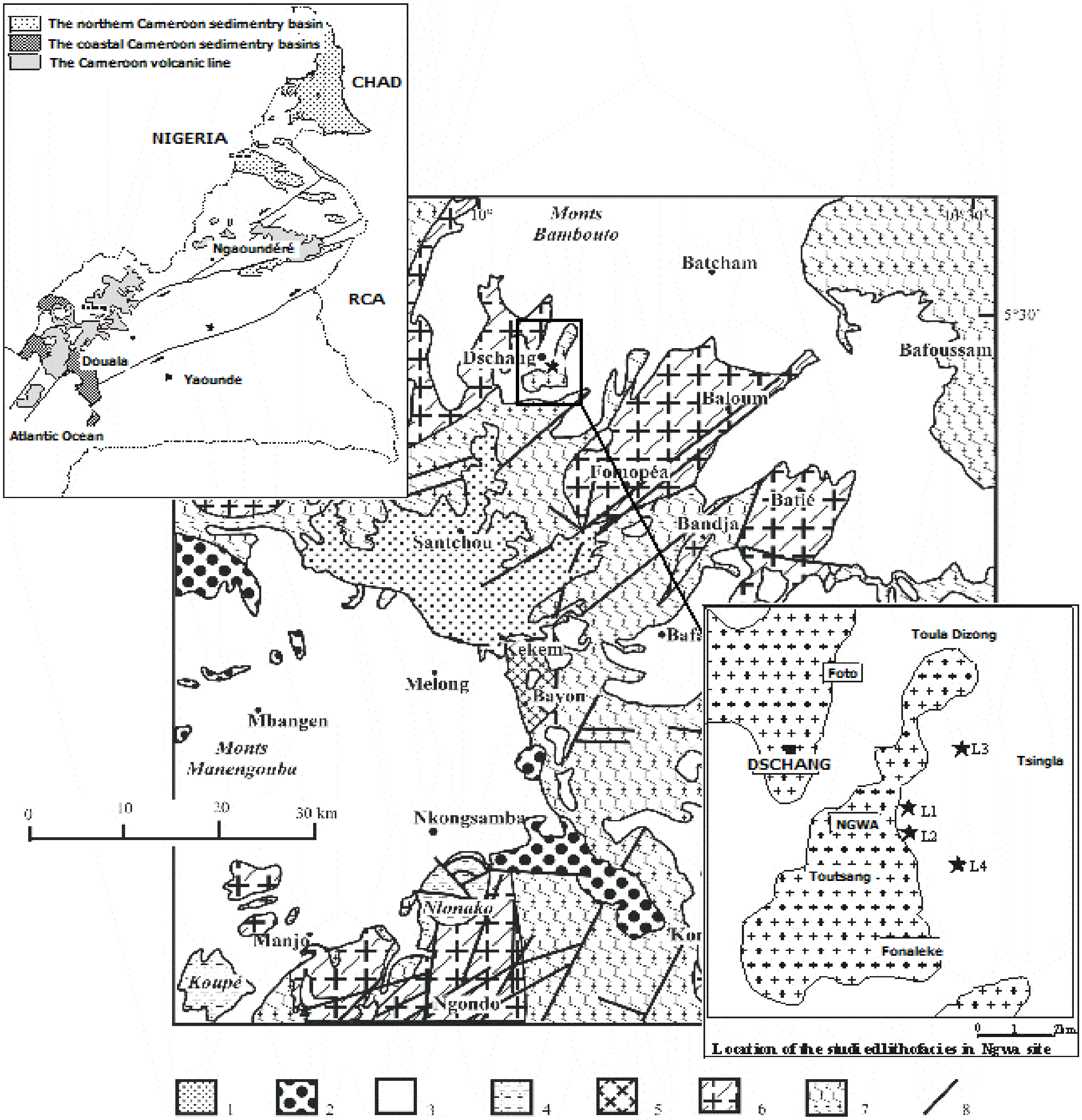

Figure 1. An overview of the geological map of Dschang and the study area (The inset shows the discussed area and location of the four lithofacies).

the region.

REGIONAL SETTING

The study was carried out in the area of Ngwa, a small locality in the eastern part of the Dschang region on the southern slope of Mount Bambouto belonging to the Cameroon volcanic line (CVL) (Figure 1). The CVL represents a 1600 km long chain of Cenozoic volcanic and sub-volcanic complexes that straddles the continent-ocean boundary and extends from the Gulf of Guinea to the interior of the African continent (Marzoli et al., 2000). It constitutes a major tectonic feature in Central Africa characterized by a zone of fault-bounded horsts and grabens that extended in the direction of N30°E. These structures are thought to be induced by a network of combined faults, related to an intra-plate sliding system of high extension (Deruelle et al., 1991). Its continental part is represented by the major volcanic massifs of Mounts Cameroon, Rumpi, Manengouba, Bambouto and Oku and the volcanic necks and plugs of the Kapsiki plateau and Benue Valley (Nono et al., 2004). Mount Bambouto is the third largest volcano of the CVL after Mounts Cameroon and Manengouba (Kagou et al., 2001). The Dschang region, on the southern slope of Mount Bambouto in the West Cameroon Highlands, forms the northern edge of the Mbo plain (Figure 1). It is characterized by various volcanic products covering the basement granitoids (Kwekam, 2005). The Mbo plain is considered to be an eastern extension of the Mamfé basin (Figure 1). The basement rocks in the Dschang region consist of Neoproterozoic granite-gneisses, Late Proterozoic granitoids intruded within the granite-gneisses, and gabbroic dykes that crop out in the two previous units. The gabbroic dykes are generally related to Atlantic rifting. The basement rocks are partly covered by a very thick layer of volcanic deposits derived from Mount Bambouto. Volcanic activity at Mount Bambouto began around 500,000 years ago, originating as a complex sequence of basalt, trachyte and phonolite lava flows and ignimbrites (Tchoua, 1974; Youmen, 1994; Marzoli et al., 2000; Nono et al., 2004; Nkouathio, 2007). In this sequence, trachy-rhyolitic ignimbrites, with a vitroclastic structure containing quartz, alkaline feldspars, hornblende, opaque minerals and various enclaves characterize the initial explosive volcanic phase (Ngountié Dedzo, 2003; Nono et al., 2004). Sandstone and conglomerate are interlayered within the volcanic rocks. The most important sedimentary rocks outcrop is at the Ngwa locality in the eastern part of the Dschang region (Figure 1).

MATERIALS AND METHODS

In order to reconstruct the past sedimentary environment, outcrops were sought in Ngwa and the surrounding areas. After outcrops where found, each of them was localized with a GPS and then, the succession of lithofacies was described from the base to the top of the sequence of each outcrop. The description was essentially based on the lithological characreristic of sediments, their granulometry and the sedimentary structures. This description enabled to establish correlation between outcrops and then draw the synthetic lithostratigraphical sequence of the Ngwa sedimentary deposits. In the laboratory, many sedimentological analysis including morphology, morphometry, granulometry and heavy minerals analysis were carried. Morphology analysis was carried on pebbles according to the works of Cailleux (1942). Morphometry was also carried on pebbles according to the works of Zingg (1935) and Cailleux (1942). Granulometry was conducted using a sieves column of the Saulas scale set up on a vibrator. Heavy minerals were extracted using bromoform from the fine fraction below 250 µm deriving from sieving. The combination of field and laboratory works gave results presented thus.

RESULTS AND INTERPRETATION

Field observations

Lithological characteristics and reconstruction of the lithostratigraphic sequence Ngwa

Four main lithofacies, labelled L1, L2, L3 and L4, were identified at the Ngwa site see black stars in (Figure 1). Lithofacies L1 crops out in the central part of the Ngwa sedimentary basin which is represented by the following lithological succession (Figure 2a). Sedimentary breccia overlying ignimbrite deposit and constituted of poorly sorted quartzite pebbles in sandstone matrix. The sandstone is constituted of angular millimetric grains of quartz which are held firmly by grayish clay matrix. The quartzite pebbles are angular and do not show clear traces of abrasions, evidence of which suggest a proximal position relative to the source and gravity induced transportation under the influence of gravity. The thickness of the bed is about 80 cm.

Above the breccias lies the sandstone. This sandstone bed is similar in all aspects to the sandstone matrix of the underlaying breccia. The thickness of this bed is about 20 cm. The outcrop L1 is limited by more or less weathered volcanic tuff rich in diverse elements such as small wood fragments.

Lithofacies L2 was also described in the central part of the Ngwa area. It shows a succession of sedimentary breccia and pelitic sandstones (Figure 2b). The breccias are composed of pebbles floating in a sandstone matrix. The pebbles are small in size (less than 4 cm in diameter), mainly quartzitic, smooth and well rounded without any preferential orientation. Weak graded bedding of the pebbles was observed near the top of this layer and the grains are held together by a clayey matrix. The thickness of the bed ranges between 20 and 40 cm.

These breccias are overlain by a layer of clayey sandstone which is petrographically very similar to the matrix of the basal breccias. It is constituted of very fine (mostly less than 0.5 mm width) grained quartz held together by grayish clay. The layer is about 75 cm thick and is covered by tuffs.

Lithofacies L3 is located in the NE part of the Ngwa locality (Figure 1). It corresponds to a thick layer of conglomerates about (5 m thick) with intercalation of sandstones (Figure 2c). The conglomerates are made up of pebbles and cobbles with a sandstone matrix (Figure 3). Those clasts varied from 40 to 100 mm in diameter. They are essentially volcanic in origin (basaltic), with a considerable amount of quartzitic pebbles. The clasts are smooth, well rounded, without a preferential orientation. The sandstone matrix contains very abundant fine sand grains of quartz embedded in a clay matrix. The intercalated sandstones have the same petrographic characteristics as the muddy sandstone matrix, but contain no clasts. Their beds are lenticular, over 2 m long and 10 to 30 cm thick.

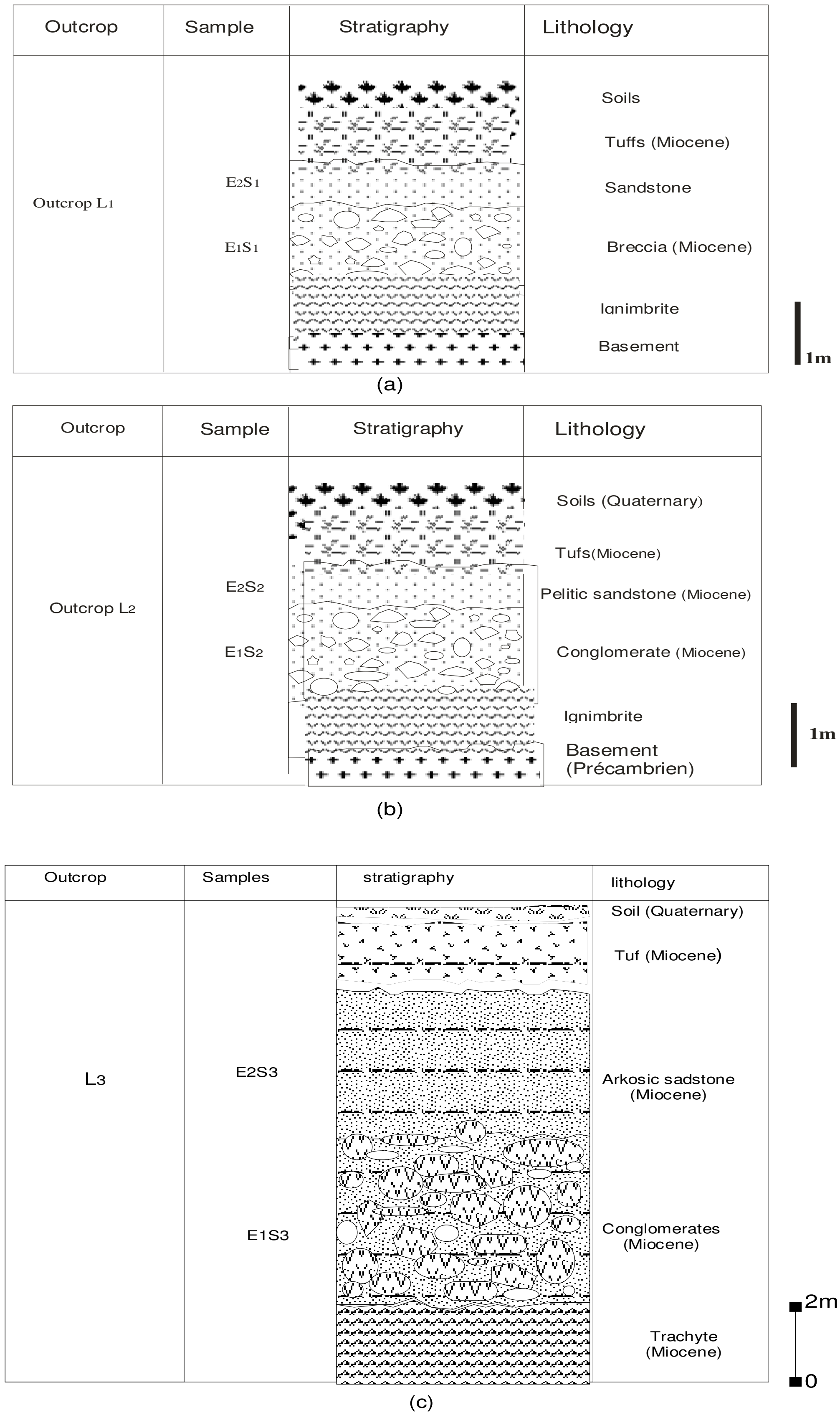

Figure 2. Differents lithofacies of Ngwa formation. . (a) The L1 lithofacies of Ngwa, (b) The L2 lithofacies of Ngwa, (c) The L3 lithofacies of Ngwa.

Figure 3. conglomerates with pelitic sandstone cement in the L3 lithofacies.

Figure 4. carbonaceous clayey shale with slaty cleavage and plants remains in the L4 lithofacies.

The conglomerates of facies L3 are overlain by a micaceous arkosic sandstone layer, whose grains float in a whitish clay matrix. Grains, whose size varies from 1 to 3 mm, are similar to those of the cement of the underlying conglomerate. They are angular and their surfaces are well polished. The thickness of this layer is greater than 4 m. This sandstone is covered by tuffs, which are, in turn, overlain by basalts.

Lithofacies L4 is situated in the SE part of the Ngwa area (Figure 1). It is made up of a 6 m thick layer of carbonaceous shale, (Figure 4). It is petrographically very similar to the carbonaceous clayey shale observed in L2.

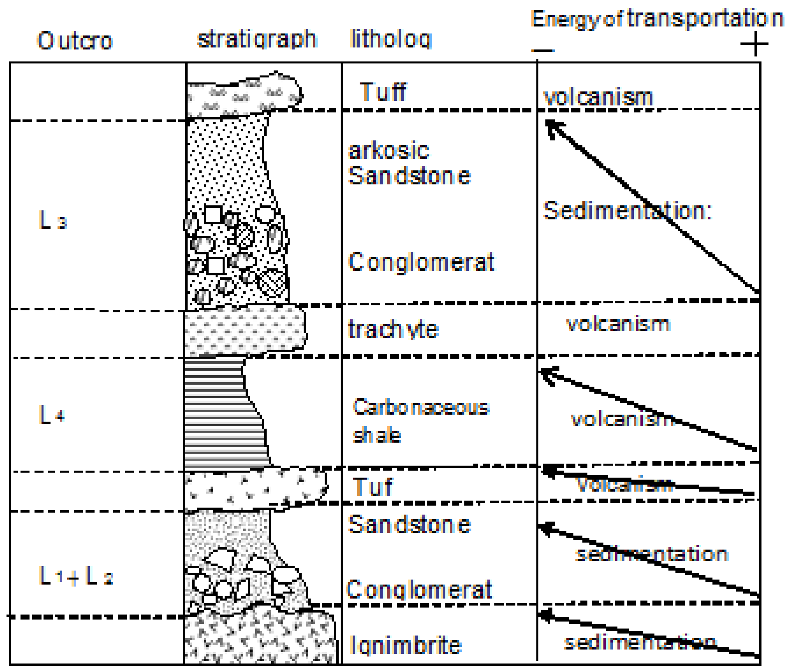

Figure 5. A synthetic lithostratigraphical sequence of the Ngwa sedimentary deposits.

Nevertheless, it is more compact, with slaty cleavage defining sub-horizontal sheets of varied thickness (Figure 4). It contains a high proportion of partially decomposed plants remains and randomly distributed lenses of lignite.

The above descriptions, the altitude relations of the outcrops and the respective contacts between the facies enable them to be correlated and presented as a composite lithologic sequence in the Ngwa area in Figure 5.

This succession highlights the fact that the sedimentary units in the Ngwa area represent positive, lithologic sequences characterized by coarse (pebbles and cobbles) at the bottom of the sequence, which becomes progressively finer and more clayrich upwards (Figure 5). Therefore, in the Ngwa locality, there have probably been two major phases of sedimentation. The first phase led to the deposition of sedimentary breccias and conglomerates with a pelitic sandstone matrix, the overlying clayey sandstone and the carbonaceous clayey shale with lignite intercalations (outcrops L1, L2 and L4). The presence of tuffs between sandstones and clays is due to an interruption of sedimentation by volcanism. The second phase of sedimentation led to the deposition of conglomerates and arkosic sandstones of outcrop L3. The stratigraphic column of the synthetic lithologic sequence (Figure 5) in this environment shows “fining up” sedimentary lithosequence, and consequently highlights the decreasing of the depositional energy upwards (Miall, 1997). The presence of carbonaceous clayey shale suggests that during their formation, reducing or anoxic conditions prevailed in the depositional environment characterizing the standing body water such as lake or swamp (Bandin, 1989; Pederson and Calvert, 1990; Dill et al., 2007; Namik et al., 2007).

Results of laboratory analysis

Morphometry, morphology and grain size distribution of the Ngwa sediments

The morphometric and morphological analysis of the Ngwa sediments refer to the pebbles from the conglomerates, wherever the grain size distribution concerns the sandstones. The main results of the morphometry and morphology studies were analyzed statistically and presented in Tables 1 and 2. From the morphological point of view, 92% of the pebbles and cobbles from the Ngwa conglomerates have the sphericity ranging from 0.47 to 0.96 (Table 1). The most abundant group (20% of particles) has a sphericity between 0.75 and 0.82. The less abundant groups (less than 5% of pebbles each) have a sphericity between 0.33 and 0.47, or between 0.96 and 1.03. The mean sphericity (n_ic_i) is equal to 0.72. Consequently, the pebbles from the Ngwa conglomerates are essentially sub-spherical to spherical. 95% of these pebbles have the flattening index ranging between 1.14 and 3.51, with a mean value (n_ic_i) at 2.22 (Table 2). The morphometric analysis based on the Chamley abacus (1988) (not shown) indicates that

Table 1. Statistical analysis of the pebbles sphericityn_i,: number of variable in class i c_i the mean value of class i.

Classes	n_i	c_i	n_ic_i
0.33-0.40	2	0.36	0.73
0.40-0.47	4	0.43	1.74
0.47-0.54	10	0.50	5.05
0.54-0.61	7	0.57	4.02
0.61-0.68	16	0.64	10.32
0.68-0.75	13	0.71	9.29
0.75-0.82	20	0.78	15.70
0.82-0.89	17	0.85	14.53
0.89-0.96	9	0.92	8.32
0.96-1.03	2	0.99	1.99
Total	100		71.71

Table 2. Statistical analysis of the pebbles flatness n_i: the number of variable in class i; c_i the mean value of class i.

Classes	n_i	c_i	n_ic_i
1.14-1.93	42	1.53	64.47
1.93-2.72	41	2.32	95.32
2.72-3.51	12	3.11	37.38
3.51-4.30	3	3.90	11.71
4.30-5.09	1	4.69	4.69
5.09-5.88	0	5.48	0.00
5.88-6.67	0	6,27	0.00
6.67-7.46	0	7.06	0.00
7.46-8.25	0	7.85	0.00
8.25-9.04	1	8.64	8.64
Total	100		222.23

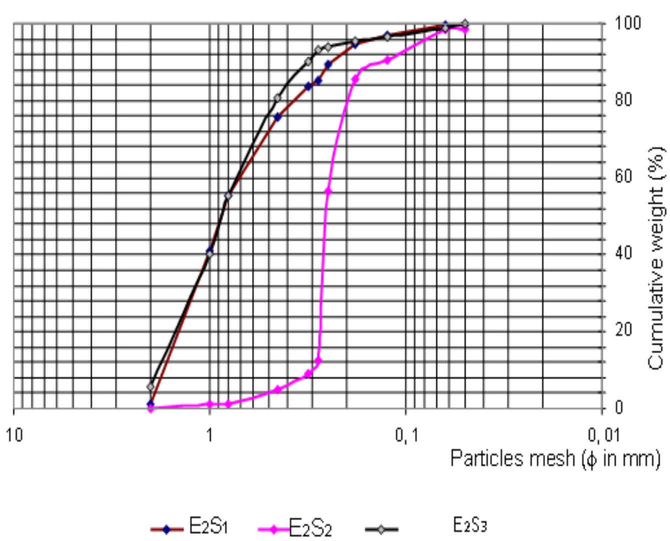

Figure 6. Cumulative curves of the grains size distribution in L1, L2 and L3 lithofacies.

the pebbles of L1 and L2 display rough to slightly rounded surfaces suggesting a short distance of transportation. They derived probably of the erosion of the neighboring basement. Meanwhile the basaltic and quartzitic pebbles and cobbles of L3 are dense and well polished, suggesting long distance of transportation in a high energy medium of fluvial type (Lindsey et al., 2007; Cojan and Renard, 1997).The basaltic cobbles were eroded from the basalts of Mount Bambouto and transported on long distances while the quartzitic pebbles are products of the Precambrian basement complex which have been recycled many times.

The grain size distributions of the Ngwa sandstones are presented in Table 3. The clayey fraction (particles below 50 µm across) represents 30.63% of the sandstone in L1, 63.16% in L2 lithofacies and 20.02% in L3. In L1, the most abundant sand fraction, 69 and 37% of the sandstone, corresponds to the particles between 450 µm and 2 mm in diameter. In L2, it corresponds to particles between 180 and 280 µm representing 72.99% of the sandstones; while in L3 it corresponds to the particles between 450 µm and 2 mm in diameter. These results indicate the presence of a very high amount of very fine clay particles in L2 sandstones which classifies them as wackes. Meanwhile a large amount of sand grains of variable dimensions (from fine to coarse sand) constitute the sandstones in L1 and L3 lithofacies.

The cumulative curves of the grain size distributions show (Figure 6) very steep slope between 0.1 and 0.3 mm in L2 (see the X axis). In L1 and L3, they are more extended and slightly smooth, ranging between 0.1 and 1 mm.The cumulative curve of sample E2S2 have a sigmoid shape, highlighting that the particles from these sandstones were well sorted (S0=1,14) during the depositional process. Accordingly, during a relatively long transportation, these sediments may have been well sorted by a regular flow, probably of fluvial type (Tricart, 1959). Meanwhile for samples E2S1 and E2S3, the cumulative curves are asymmetrical highlighting that those sand are leached deposits, poorly sorted (S0=1, 69 and S0=1, 67) characterized by variations in the speed of energetic flow.

The above results show that all the sandstones are immature (each sample has over 5% of terrigenous clay matrix), poorly sorted (the sorting index for each sample is over 0.5). This indicates the weakness of the current in the depositional environment or rapidity in the depositional process. Sediments have not been subject to input or any mechanical energy after deposition (Robert, 1980). These grains parameters and the presence of carbonaceous clayey shale described above allow concluding that the depositional environment is a confined zone, likely lacustrine, or swampy.

Microscopic examination of heavy minerals from the Ngwa sandstones indicates the presence of about 15% sillimanite, 22% muscovite, 17% biotite, 12% kyanite and 34% of opaque minerals. The presence of sillimanite and

Table 3. Grains size distribution of the Ngwa sandstones mm: grain seizes in millimetres (sieve diameter), W.S: Raw weight of samples retained in each sieve; %S: Weight percent of sample,%C: Cumulative weight percent of sample.

Sieves diameter(mm)	E2S1			E2S2			E2S3		
	W.S	S (%)	C (%)	W.S	S (%)	C (%)	W.S	S (%)	C (%)
2.00	1.6	1.2	1.2	0.0	0.0	0	8.1	5.6	5.6
1.00	55.3	39.9	41.0	0.8	1.1	1.1	50.3	34.5	40.0
0.80	20.1	14.5	55.5	0.6	0.0	1.1	22.0	15.1	55.1
0.45	28.1	20.4	75.8	2.9	3.9	5.1	37.1	25.4	80.5
0.315	11.1	8.0	83.8	3.0	4.1	9.2	14.2	9.7	90.3
0.28	2.2	1.6	85.4	2.5	3.4	12.6	4.3	2.9	93.2
0.25	5.5	3.9	89.3	32.3	43.8	56.4	1.4	0.9	94.1
0.18	7.5	5.4	94.7	21.5	29.2	85.6	2.1	1.4	95.5
0.125	33.1	2.2	96.9	3.7	4.9	90.5	1.8	1.3	96.8
0.063	3.9	2.8	99.9	5.9	8.1	98.6	3.0	2.1	98.9
0.05	0.2	0.0	99.8	0.4	0.0	98.6	1.6	1.1	99.9
Total	138.7	99.9		73.7	98.6		145.9	99.9	

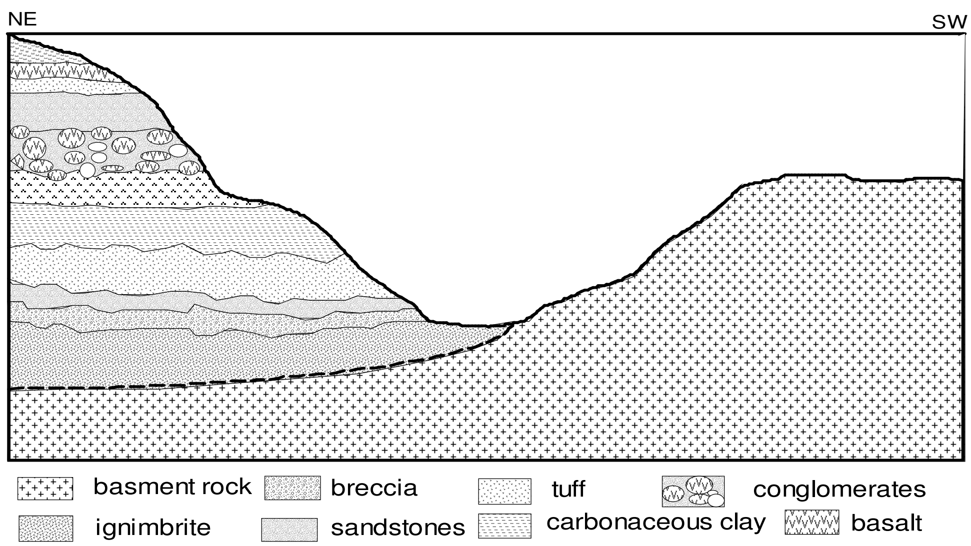

Figure 7. A synthetic sketch of the Ngwa sedimentary deposits.

kyanite points to the metamorphic source of sandstones of the Ngwa sediments (Einsele, 1992). These sediments derived certainly from the erosion of the granitic and metamorphic Precambrian basement complex (Njueya, 2009).

DISCUSSION

Geological history of Ngwa and the surrounding area

After formation of the PanAfrican precambrian basement, the study area was submitted to the influence of the first manifestations of the Bambouto volcanism in the late Tertiary (Miocene: 22 million years) (Youmen, 1994). This volcanism led to the deposition of ignimbrites which occur at the base of the sedimentary sequence, unconformably overlying the Precambrian basement constituted of granite and metamorphic rocks (Kwekam, 2005). The major consequence of the volcanic activity in this area was the obstruction of the river Menoua's bed by the volcanic flow. This led to the creation of a depressive environment with abrupt partition limited at the North-east by the front of the volcanic flow materials and at the South-west by the granito-gneissic basement (Figure 7). The unstable partition of this new depression and it surrounding zones were eroded and some time crumbled under the effects of surface water and gravity. The products of this erosion and crumbling accumulated into the depression and constitute the basal deposits of the microbasin. This is characteristic of the first stages of the filling of a sedimentary basin. They are represented by the breccias and sandstone detritic deposits of outcrops L1 and L2. This phenomenon has been described in the West African coastal sedimentary basins (Njike, 2005). For example, in the Douala sedimentary basin the basal deposits (*Grès de Base*) are products derived from the erosion and crumbling of the abrupt partition of the basin (Njike, 1984).

This first sedimentation episode of the Ngwa basin was interrupted by a second volcanic episode which led to the deposition of tuff observed at the top of sandstones in outcrops L1 and L2. Following the close of this second volcanic event, sedimentation continued with the deposition of lignite clays. At this stage, the energy of transportation of sediments has considerably decreased and the sedimentation conditions are calm. The sedimentary environment is confine implying the partial decomposition of the organic matter. This is characteristic of end of a transgressive sequence of deposition (Cojan and Renard, 1987). The deposition environment is lacustrine and swampy.

The clayey sedimentation episode was followed by another volcanic phase which led to the deposition of trachyte (L3). This volcanism was followed by the recovery of a new transgressive sedimentation phase. It is marks by the deposition of conglomerates and sandstones of outcrop L_3. The nature of pebbles (well polish basaltic and quartzitic pebbles) and their high density suggest the remoteness of their source and the high energy of the river responsible of their transportation. The decrease in particle size from the base to top of the sequence is due to the fact that when the river falls into the lake or the swamp, its energy drop down and the sedimentary particle are deposited in the reverse order of the decrease of their density (Bernard, 1999). The absence of the finest particles (clay) at the top of this new phase of sedimentation can be due to: (i) change in climate which became drier inducing the drying of rivers; (ii) the volcanism which interrupted the sedimentation and it deposits blocked the river trajectory.

The geological history of Ngwa ends with two successive volcanic episodes: the first one displays an explosive character giving rise to the tuffs that overlie the arkosic sandstones and the second one, which is fissural, and resulted in of the basalts that cover the tuffs.

Therefore, the geological history of Ngwa area is constituted by an alternation of volcanic and sedimentation phasis since the Miocene. The ages of the various episodes range between 22 and 15 million years, corresponding respectively to the critical phase of the Bambouto dynamism (Youmen, 1994) (Figure 7).

Conclusions

The studied area presents a diversity of petrographic types. They range from volcanic material to basement rocks through sedimentary deposits. The present work was dedicated to the characterization (petrography, origin and age) of those sedimentary deposits and to establish an eventual relation with the coastal sedimentary basins deposits. It reveals that the Ngwa sedimentary facies are principally detrital, and poorly sorted. They are located in a depression limited by the crystalline relief of the south and west on one hand, and by the volcanic landforms in the North and East on the other hand. The basal deposits of the Ngwa formation are gravelly deposited under the influence of gravity and surface water. The infilling of the basin progressed with the deposition of organic matter rich clays typical of semi-confined zones (lake or swamp). The deposits of the end of infilling consist of distal fluvial deposits. The deposition of those sediments, younger than the basement and contemporaneous to the volcanism is of Tertiary age (Miocene). The process of creation of this sedimentary milieu as described above show that there is no relationship between this deposits and those of the coastal sedimentary basin of Cameroon. Their putting in place is just link to an isolate geological phenomenon occurred in the area.

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