

# Sedimentary Dynamics of the Sands of the Cover Formation in the Batéké Plateaus (Republic of Congo): Paleoenvironmental Implications

Otongo Judicaël<sup>1,2,3</sup>, Ngakosso Ngolo Jude Nogelvi<sup>1,3</sup>, Elenka Hilaire<sup>1,3</sup>

<sup>1</sup>Geosciences Laboratory, Doctoral Training Department, Faculty of Science and Technology, Marien Ngouabi University, Brazzaville, Republic of Congo

<sup>2</sup>Natural Sciences Program, Higher Normal School, Marien Ngouabi University, Brazzaville, Republic of Congo

<sup>3</sup>Geological and Mining Research Center, Brazzaville, Republic of Congo

Email: juniorjoviale@gmail.com, hilaire\_elenga@yahoo.fr

**How to cite this paper:** Judicaël, O., Nogelvi, N. N. J., & Hilaire, E. (2024). Sedimentary Dynamics of the Sands of the Cover Formation in the Batéké Plateaus (Republic of Congo): Paleoenvironmental Implications. *Journal of Geoscience and Environment Protection*, 12, 321-346.

<https://doi.org/10.4236/gep.2024.1210018>

**Received:** September 3, 2024

**Accepted:** October 28, 2024

**Published:** October 31, 2024

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## Abstract

The depositional environment of the sands of the cover formation is discussed. This study aims to determine the paleoenvironments of deposition of the sands of the cover formation in the Batéké Plateaus by studying sedimentary dynamics based on the description of lithological facies in the field and granulometric analyses in the laboratory. In the field, six (6) lithostratigraphic logs were surveyed and 42 sand samples were taken for laboratory analysis. In the laboratory, the samples underwent granulometric, sieving and sedimentometry analyses, after washing with running water using a 63 µm sieve. These analyses made it possible to determine the granulometric classes of the samples. The sieving results allowed to determine the granulometric parameters (mean, standard deviation, mode, median, skewness, flattening or kurtosis) using the method of moments with the software “Gradistat V.8”, granulometric parameters with which the granulometric facies, the mode of transport and the deposition environment were determined using the diagrams. Morphoscopy made it possible to determine the form and aspect of the surface of the quartz grains constituting these sands. Granulometric analyses show that these silty-clay or clayey-silty sands are fine sands and rarely medium sands, moderately to well sorted and rarely well sorted. The dominant granulometric facies is hyperbolic (sigmoid), with parabolic facies being rare. The primary mode of transport of these sands is saltation, which dominates rolling. The dispersion of points in the diagrams shows that these sands originate from two depositional environments: aeolian and fluvial. Morphoscopic analysis reveals the presence of clean rounded matt grains (RM), dirty rounded matt grains (RS), shiny blunt grains

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(EL) and shiny rounded grains (RL). The rounded matt grains exhibit several impact marks. The presence of dirty rounded grains with a ferruginous cement on their surface indicates that these sands have been reworked. These sands have undergone two types of transport, first by wind (aeolian environment) and then by water (fluvial environment).

## Keywords

Sands, Lithology, Granulometric Analyzes, Morphoscopy, Deposit Environment, Batéké Plateaus

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## 1. Introduction

The cover formation consists of ochre sands that overlie a large part of the ancient geological formations in the Republic of Congo. It spans a significant portion of the west-Central Africa region, referred to as the Atlantic (including Gabon, the Democratic Republic of Congo, Cameroon, the Central African Republic, and the Republic of Congo) (Segalen, 1969) and Linol (2012). This formation has been the subject of several studies. In the Batéké Plateaus, the works of (Cosson, 1955; Le Maréchal, 1966; Dadet, 1969; Desthieux et al., 1993) suggest that this formation corresponds to the lithological level Ba2, the ultimate stage of the Batéké Plateaus series. The aspects concerning the paleoenvironmental interpretation of the cover formation are controversial in the Central Atlantic African sub-region. In Gabon, the work of (Thiéblemont, 2013) attributes a wind origin to this training and determined a Holocene age, from 3000 to 2000 years B.P., and determined a Holocene age, from 3000 to 2000 years B.P., <sup>14</sup>carbon dating of coals. This age is contemporary with the arid climate phase experienced by the Congo basin. In Congo, (Cosson, 1955; Le Maréchal, 1966; Dadet, 1969; Desthieux et al., 1993; Bauer et al., 2015; Callec et al., 2015; Miyouna et al., 2016; Miyouna et al., 2019) support the aeolian origin of these formations, whereas Ngakosso Ngolo et al. (2021) concluded a fluvial origin in the Chaillu Massif sector. In the Democratic Republic of Congo, the works of Cahen et al. (1946); Cahen and Lepersonne (1952); and Cahen (1954) equate the cover formation with the Kalahari of Southern Africa. In the Batéké Plateaus, only Le Maréchal (1966) suggested a dual shaping, first aeolian and then aqueous, for the cover formation sands based on morphoscopic study. Additionally, De Ploey et al. (1968) in the Democratic Republic of Congo assert that the deposits of ochre sands can be linked to both aeolian and alluvial processes, and Lepersonne (1978) favors a fluvial environment for the deposition of ochre sands. According to Guillocheau et al. (2015), the questions of the age and paleoenvironmental context of the ochre sands remain unresolved, and the age and origin found in Gabon by Thiéblemont (2013) should be considered for this region due to multiple observations that challenge the generalization of these conclusions. This study contributes to the understanding of the depositional paleoenvironments of the cover formation in the Batéké Plateaus. This study aims to

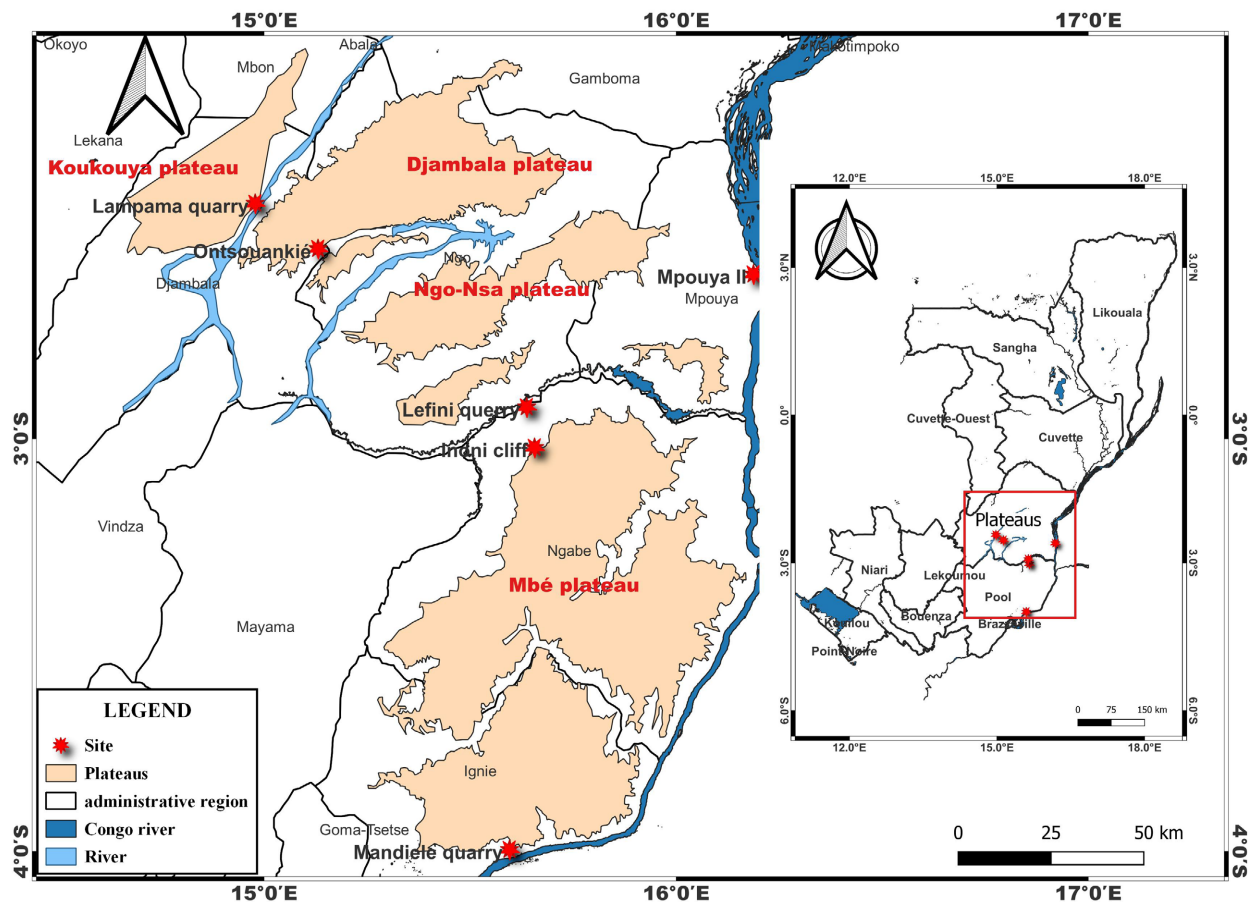
determine the paleoenvironments to deposit the coverage formation in the Batéké plateaus by lithological descriptions, granulometric analyzes (sieving and sedimentometry) allowing the determination of the granulometric parameters from which the transport dynamics are determined, and by the microscopic observations.

## 2. Material and Methods

### 2.1. Study Area

The Batéké Plateaus are a geomorphological unit located between the 2<sup>nd</sup> and 4<sup>th</sup> degrees of South latitude, north of Brazzaville, and occupy the central part of the country (Congo).

The unit consists of four plateaus: the Koukouya Plateau, the Djambala Plateau, the Ngo-Nsa Plateau, and the Mbé Plateau (**Figure 1**). The various plateaus are separated by very deep incisions occupied by rivers flowing NE-SW. The Batéké Plateaus cover approximately 13,000 km<sup>2</sup>, with the Mbé Plateau being the largest at 7500 km<sup>2</sup>. The whole structure exhibits a slight NW-SE dip (Cosson, 1955; Le Maréchal, 1966; Dadet, 1969). The cover formation (formerly called Ba2), formed of ochre sands, is the ultimate term of Batéké plateaus. Thus, these sands are the material for our present study.



**Figure 1.** Map of the study area and location of sampling sites (Bauer et al., 2015; Callec et al., 2015).

## 2.2. Methodology

To this end, six (06) lithological logs were created, and forty-two (42) samples were collected for laboratory analysis. Granulometric analysis was conducted through sieving and sedimentometry. This analysis determines the different granulometric classes contained in the collected samples. The procedure involved weighing 200 g of the sample, washing it with running water using a 0.63  $\mu\text{m}$  sieve, and then drying it in an oven. The fine fraction, less than 0.63  $\mu\text{m}$ , was used for sedimentometric study using the hydrometer method. For the coarse fraction, 100 g of sand was poured onto the top of a column of 6 sieves, following the Udden-Wentworth (US Standard) progression, where each main class corresponds to a diameter that is double or half of the neighboring class, with the base class being 2 mm. The column is placed on a sieve that will vibrate it at a known frequency, for a time of 10 minutes at 50 vibrations (Fournier et al., 2012). The reject of each sieve is then poured into a capsule to be weighed. The percentage of each particle size class and the cumulative numbers are determined using Excel. The particle size distribution parameters are determined by the software "Gradistat V.8" (Blott & Pye, 2001), using the method of moments recommended nowadays by Mercier (2013) and the method of Folk and Ward (1957).

The results of the sedimentometry allowed for the plotting of textural ternary diagram SSA (Sand - Silt - Clay) according to the model of Assale and Aka (2019), and those of the coarse granulometric allowed for the plotting of the cumulative curves, with the main facies determined using Tricart method (Tricart, 1965). The mode of transport is determined by the CM diagram of Passega (1957) and the deposition environments by the dispersion diagrams of Friedman (1967) and Moiola and Weiser (1968).

The morphoscopic study was conducted with the 250  $\mu\text{m}$  fraction using a binocular loupe, according to Pettijohn method (Pettijohn, 1975) in Chamley and Deconinck (2011), based on grain shape, and Cailleux method (Cailleux, 1947), and based on the aspect or texture of quartz grains.

## 3. Results

### 3.1. Logs Description




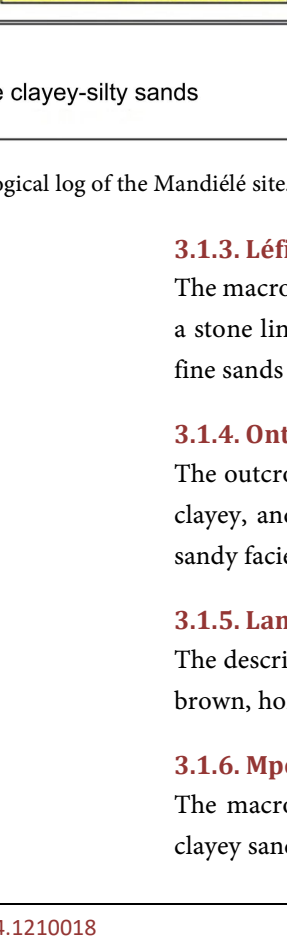

The macroscopic description of the lithofacies was supplemented by sedimentometric results and some granulometric parameters.

#### 3.1.1. Mandiélé Site




The macroscopic description of the lithological log at the Mandiélé site shows fine silty sands 1 cm thick, fine silty-clayey sands about 8 cm thick, topped by a level of fine clayey-silty sands 1.5 cm thick (Figure 2).

#### 3.1.2. Inoni Site

The log of the Inoni quarry shows fine clayey-silty sands about 4.5 cm thick resting on a layer of fine bedded sands, separated by a discontinuous and sinuous stone line (Figure 3).

Depth(cm)	Lithology	Description	Asymmetry	Grading
0		Fine clayey -silty sands yellow ochre	Asymmetrical towards the coarse	Well graded
50				
100		Fine silty-clayey sands yellow ochre	Symmetrical	Fairly well graded
150				
200				
250				
300				
350				
400				
450				
500				
550				
600		Fine silty sands ochre yellow	Asymmetrical towards the coarse	Well graded
650				
700		Fine silty-clayey sands yellow ochre	Symmetrical	Fairly well graded
750				
800				
850				
900				
950				
1000		Fine silty sands ochre yellow	Asymmetrical towards the coarse	Well graded
1050				
1100				
1150				
1150				

Legend		
 Fine clayey-silty sands	 Fine silty-clayey sands	 Fine silty sands

**Figure 2.** Lithological log of the Mandiélé site.

### 3.1.3. Léfini Site

The macroscopic description of the section of the Léfini quarry reveals fine sands, a stone line intercalated between these sandy layers, and a layer of ochre yellow fine sands over a layer of clayey-silty sands (**Figure 4**).

### 3.1.4. Ontsouankié Site

The outcrop at the Ontsouankié quarry shows an alternation of fine sands, silty-clayey, and clayey-silty sands, with a stone line about 2 m thick separating the sandy facies, which rests on weathered sandstones (**Figure 5**).

### 3.1.5. Lampama Site

The description of the log from the Lampama site shows medium-sized, ochre to brown, homogeneous sands (**Figure 6**).

### 3.1.6. Mpouya II Site

The macroscopic description of the outcrop at the Mpouya II site shows silty-clayey sands separating two layers of clayey-silty sands. The entire unit rests on a

stone line (Figure 7).

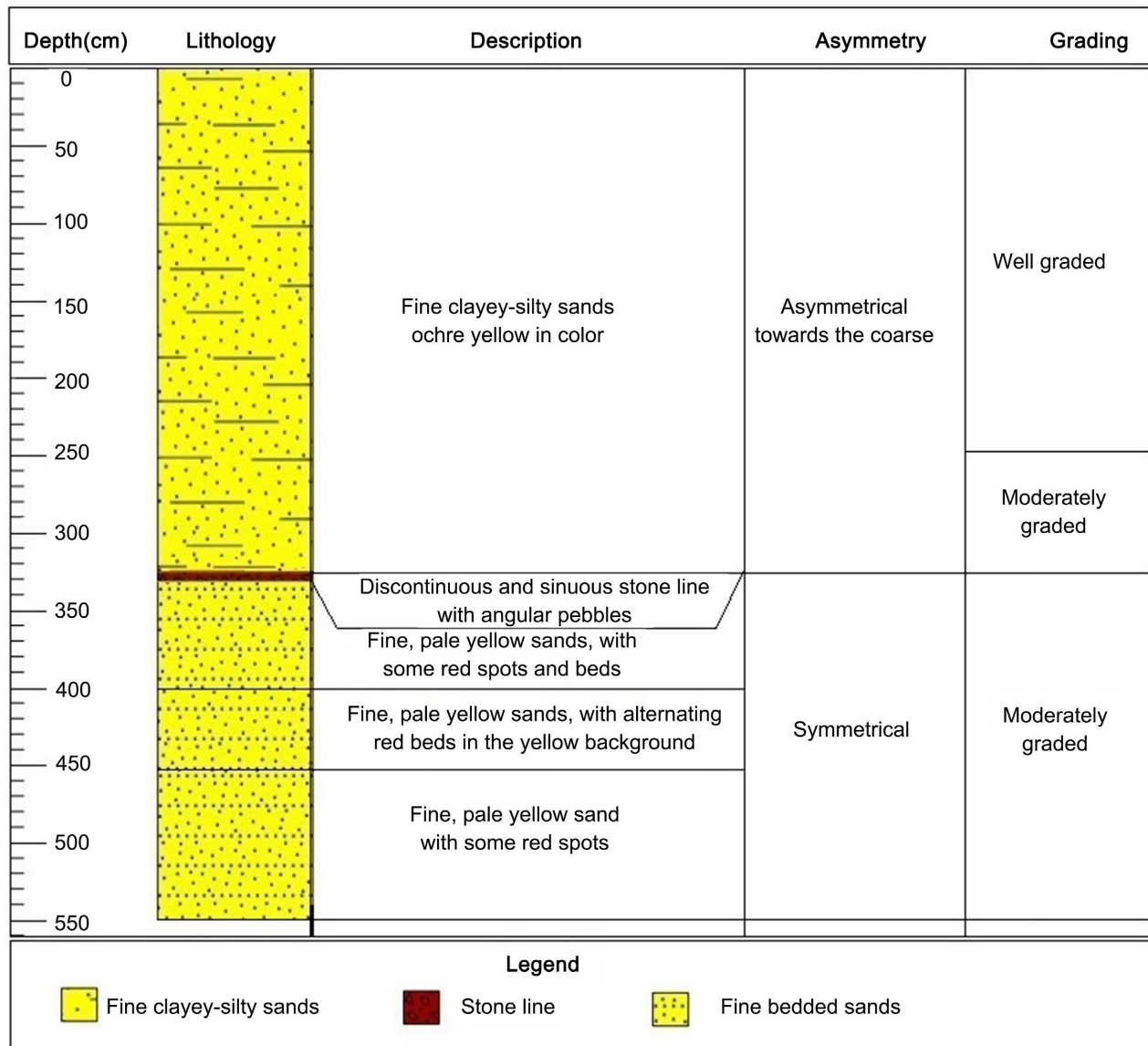


Figure 3. Lithological log of the Inoni site.

### 3.2. Textural Analysis

After sieving and sedimentometry, the results obtained made it possible to represent the ternary diagram of the different particle size fractions using the Sigmaplot 12.0 software, according to the models of Assale and Aka (2019).

The different particle size classes present in the samples sands, silts and clays. Sand is the major component with approximately 75.73% and 24.27% for the matrix, (with 12.90% of silts and 11.37% of clays). The analysis of the different particle size fractions on the 42 samples gives 30.95% of sands sensu stricto, 2.38% of silty sands, 33.33% of silty-clayey sands and 33.33% of clayey-silty sands. Their representation indicates 66.67% of sands and 33.33% for silts and clays, in the SSA

diagram, “Sand”, “Silt” and “Clay” (Figure 8).

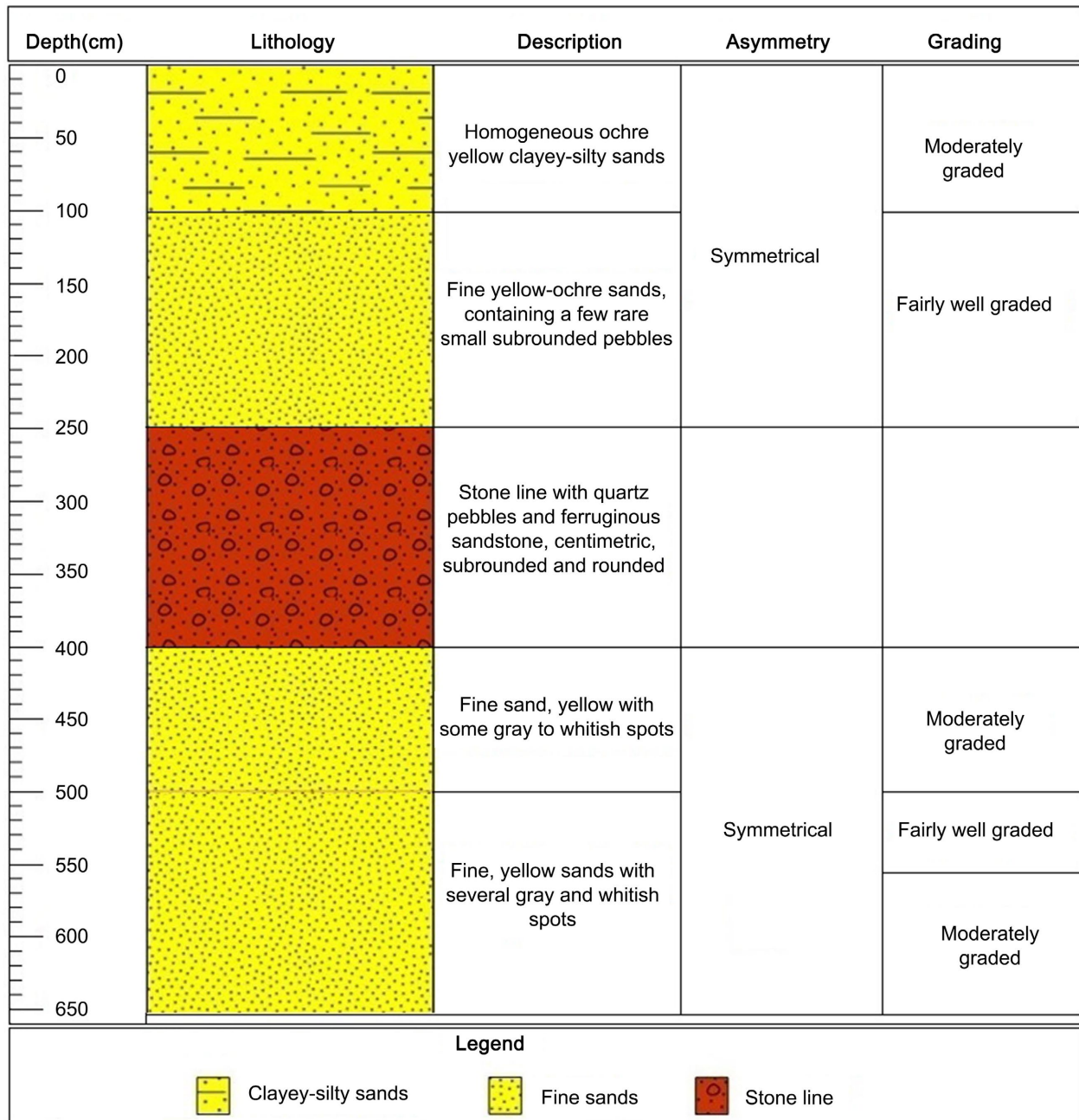


Figure 4. Lithological log of the Léfini site.

### 3.3. Granulometric Parameters

The granulometric parameters of the coverage of the coverage by study site are summarized by histograms (Figure 9) and in detail, see the table in the appendix.

The sands of the Batéké Plateaus exhibit two size types: fine sands with mean values ranging from  $2 \Phi < Mz < 3 \Phi$ , and medium sands with mean values between  $1 \Phi < Mz < 2 \Phi$ . Fine sands are predominant (35 samples), while medium sands

(05 samples) are rare and only found in Lampama (Plateau Koukouya).

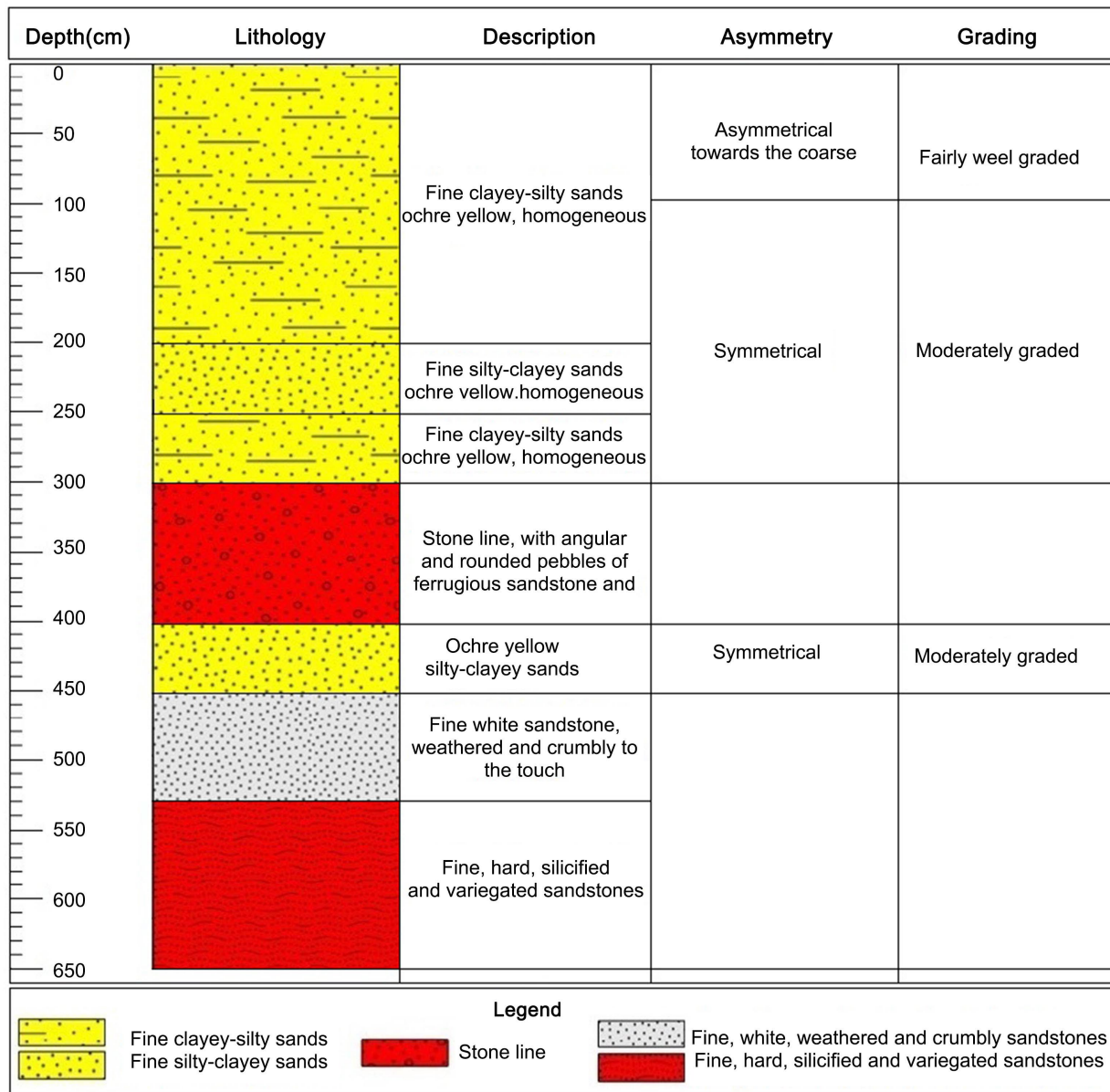
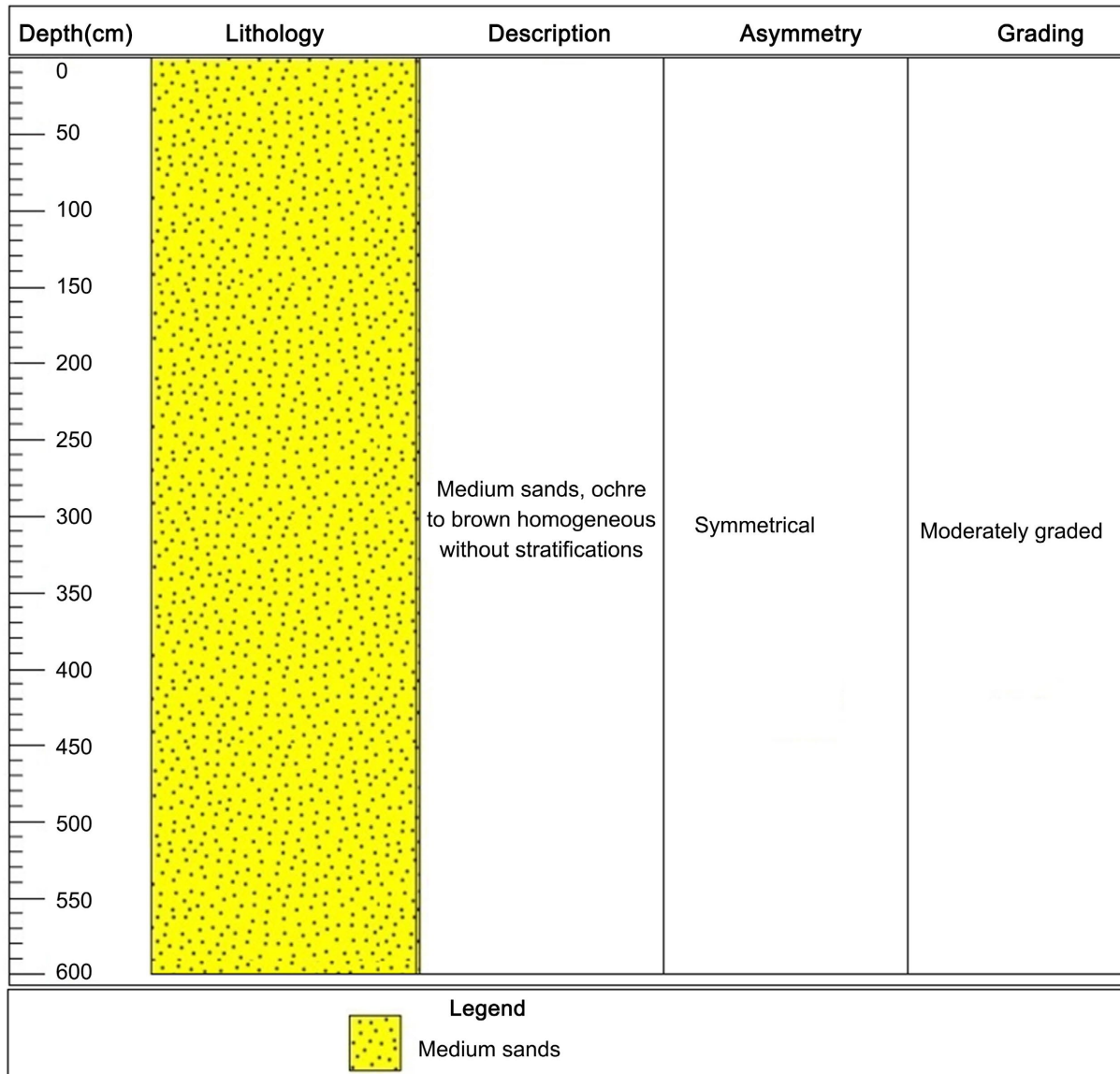


Figure 5. Lithological log of the Ontsouankié site.

Three grading types are defined for the sands of the cover formation in the Batéké Plateaus: well graded ( $0.35 < \sigma_{\phi} < 0.50$ ), fairly well-graded ( $0.50 < \sigma_{\phi} < 0.70$ ), and moderately graded ( $0.70 < \sigma_{\phi} < 1.00$ ). Fairly well-graded (18 samples) and moderately graded sands (17 samples) are predominant than well graded sands (07 samples).

The sands of the cover formation in the Batéké Plateaus exhibit three types of asymmetries:

- symmetrical ( $-0.43 < Sk_{\phi} < +0.43$ ): the curve is normal, with fine and coarse particles symmetrically graded on either side of the mean.



**Figure 6.** Lithological log of the Lampama site.

- asymmetrical towards coarse particles ( $-0.43 < Sk\phi < -1.30$ ): the coarse fraction is predominant and better graded.

- highly asymmetrical towards coarse particles ( $Sk\phi < -1.30$ ): the coarse fraction is highly predominant and better graded.

These sands are largely symmetrical (28 samples), and asymmetrical towards coarse particles (13 samples) and very rarely very asymmetrical towards the coarse particles, and they are unimodal with two values,  $2.5 \phi$  (36 samples) and  $1.5 \phi$  (06 samples).

The frequency curves of the sands (**Figure 10**) of the cover formation have four types of flattening according to the kurtosis values, they are platykurtic (extended curves), mesokurtic (normal curves), leptokurtic (pointed curves) and very leptokurtic (very pointed curves). The frequency curves in order of importance are

mesokurtic (21 samples), leptokurtic (17 samples), very leptokurtic (03 samples) and platikurtic (01 sample).

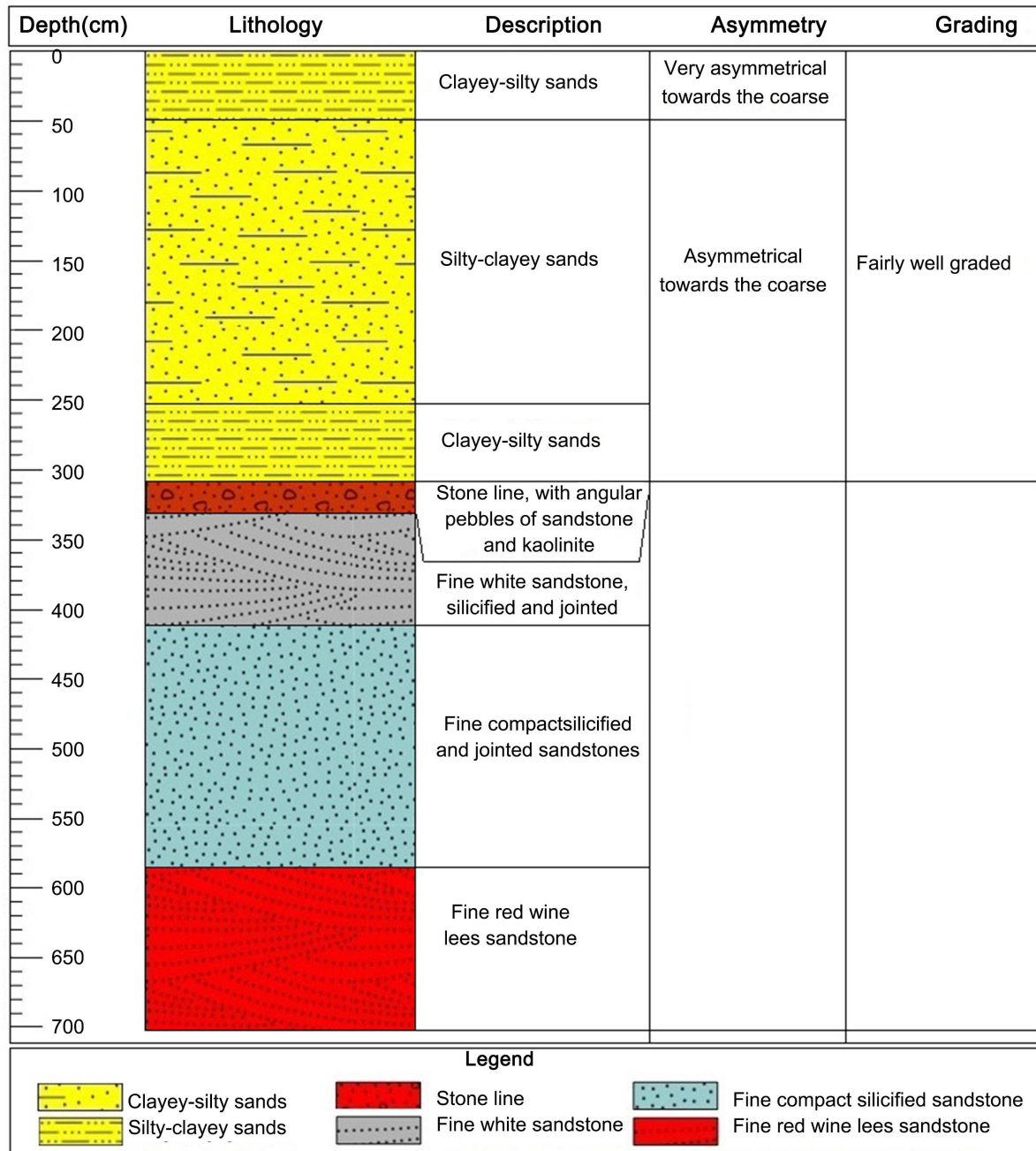
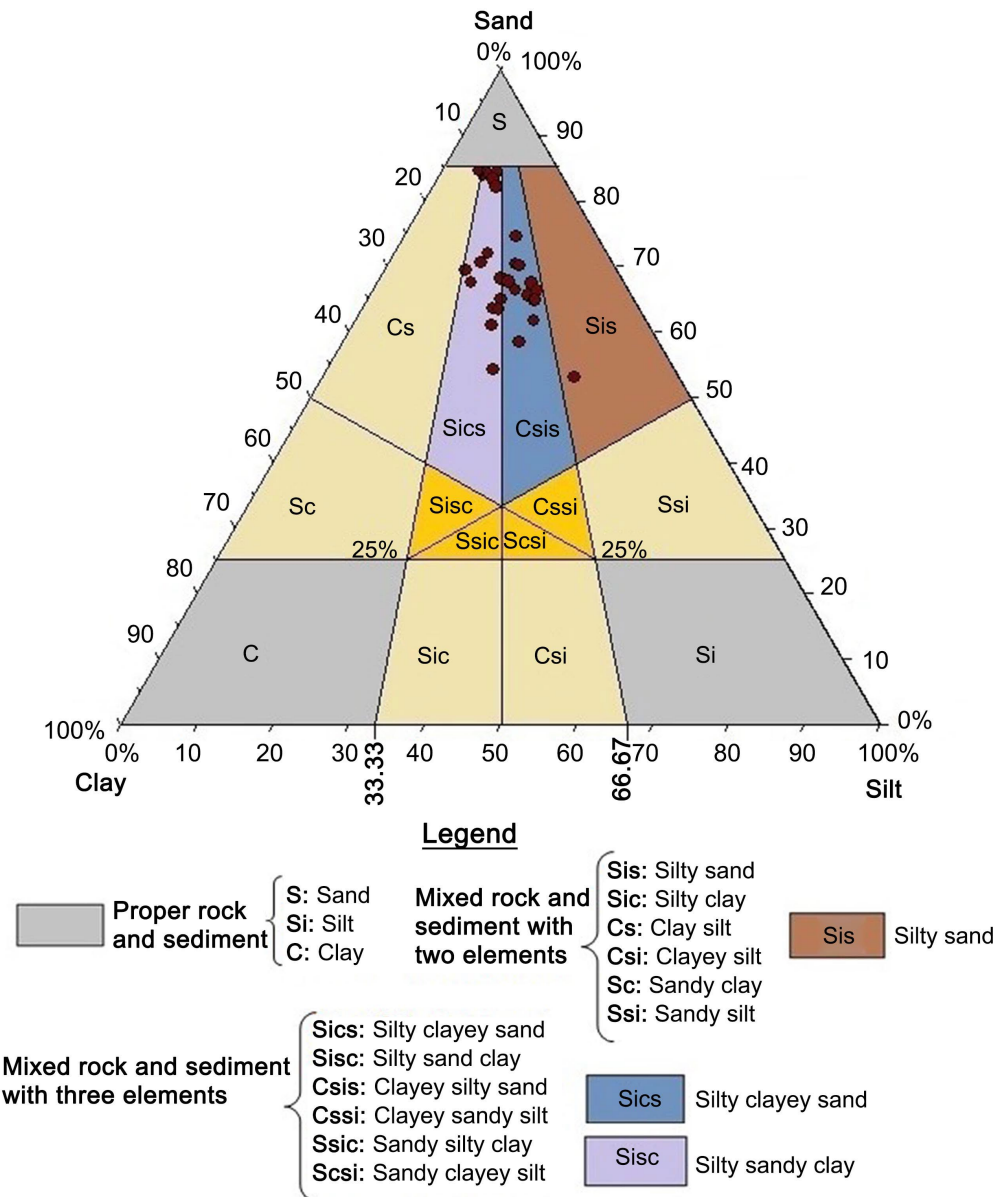


Figure 7. Lithological log of the Mpouya II site.

### 3.4. Granulometric Facies

The sands of the cover formation in the Batéké Plateaus have two types of granulometric facies: The hyperbolic facies or sigmoid facies (S shaped with a regular slope) present in five out of six sites, and the parabolic facies for the Mpouya II sands (Figure 11).



**Figure 8.** Ternary textural diagram SSA (Sand-Silt-Clay) of the sands of the Plateaus.

### 3.5. Mode of Transport of the Sands

The Passega diagram shows that almost all sands in the Batéké Plateaus occupy the RQ and QP segments (Figure 12). Thus, these sands are transported by saltation (RQ) and saltation and rolling (QP) (Passega, 1957).

### 3.6. Depositional Environment

The depositional environment of the sands of the cover formation is determined by the dispersion of points using the Friedman (1967) Sk-So diagram (Figure 13) and the Moiola and Weisser (1968) Sk-Md diagram (Figure 14).

The dispersion of points on the Friedman (1967) Sk-So diagrams (Figure 13) and the discrimination on the Moiola and Weisser (1968) Sk-Md diagram (Figure

14) allowed the determination of two types of depositional environments for the cover formation sands in the Batéké Plateaus: a dune environment (aeolian dune) and a fluvial environment.

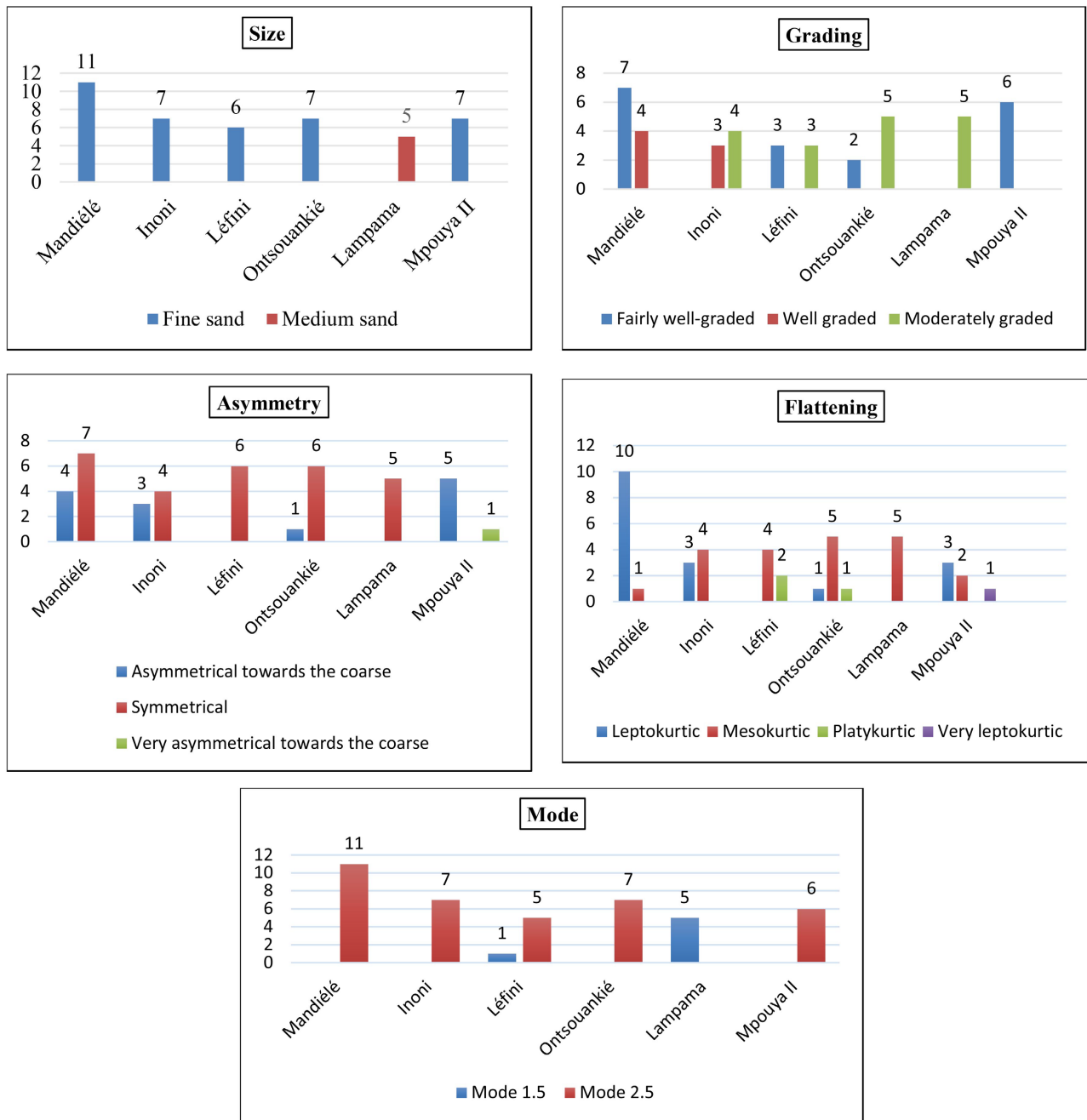
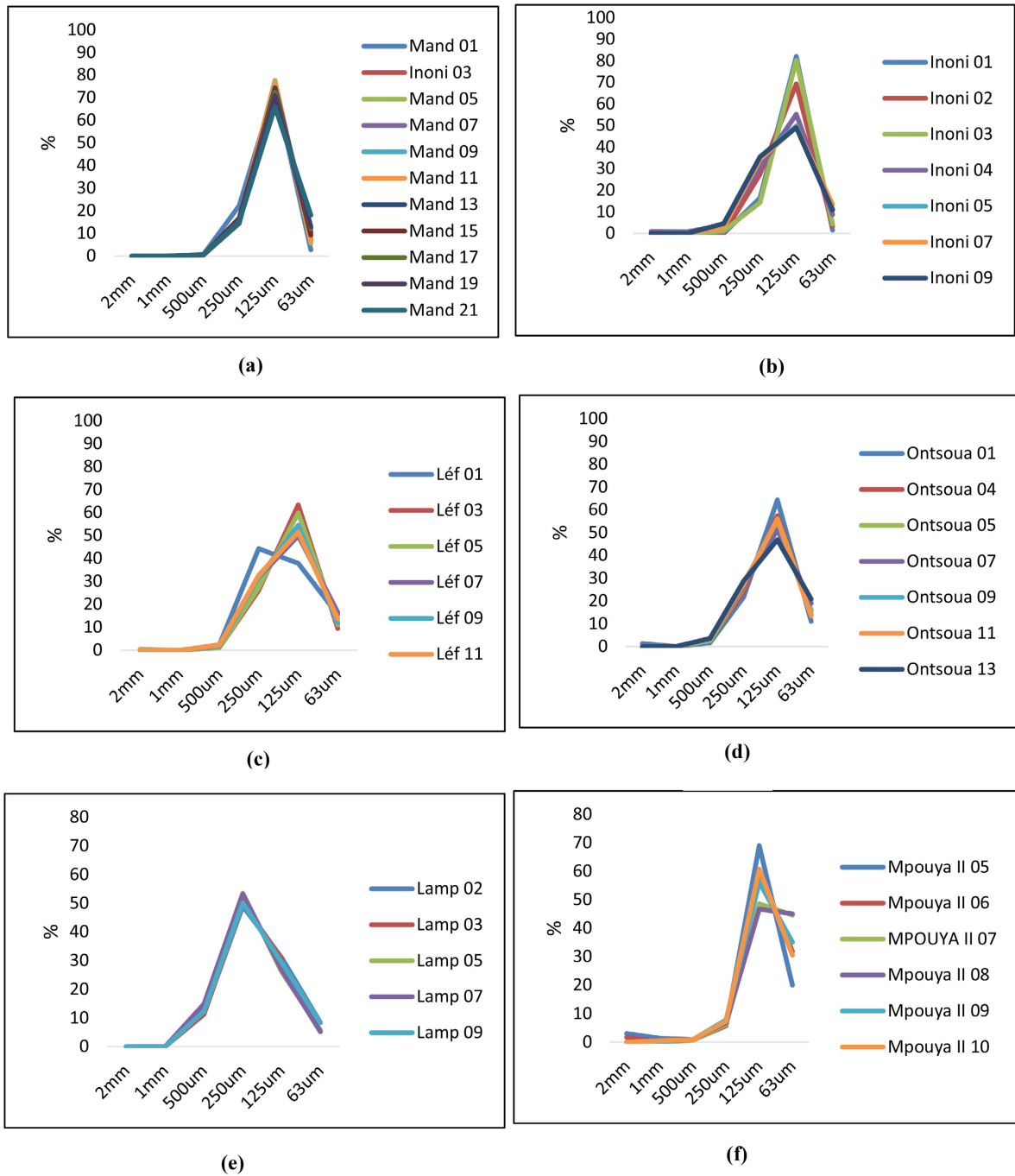


Figure 9. Granulometric parameters of the sands of the cover formation by study site.

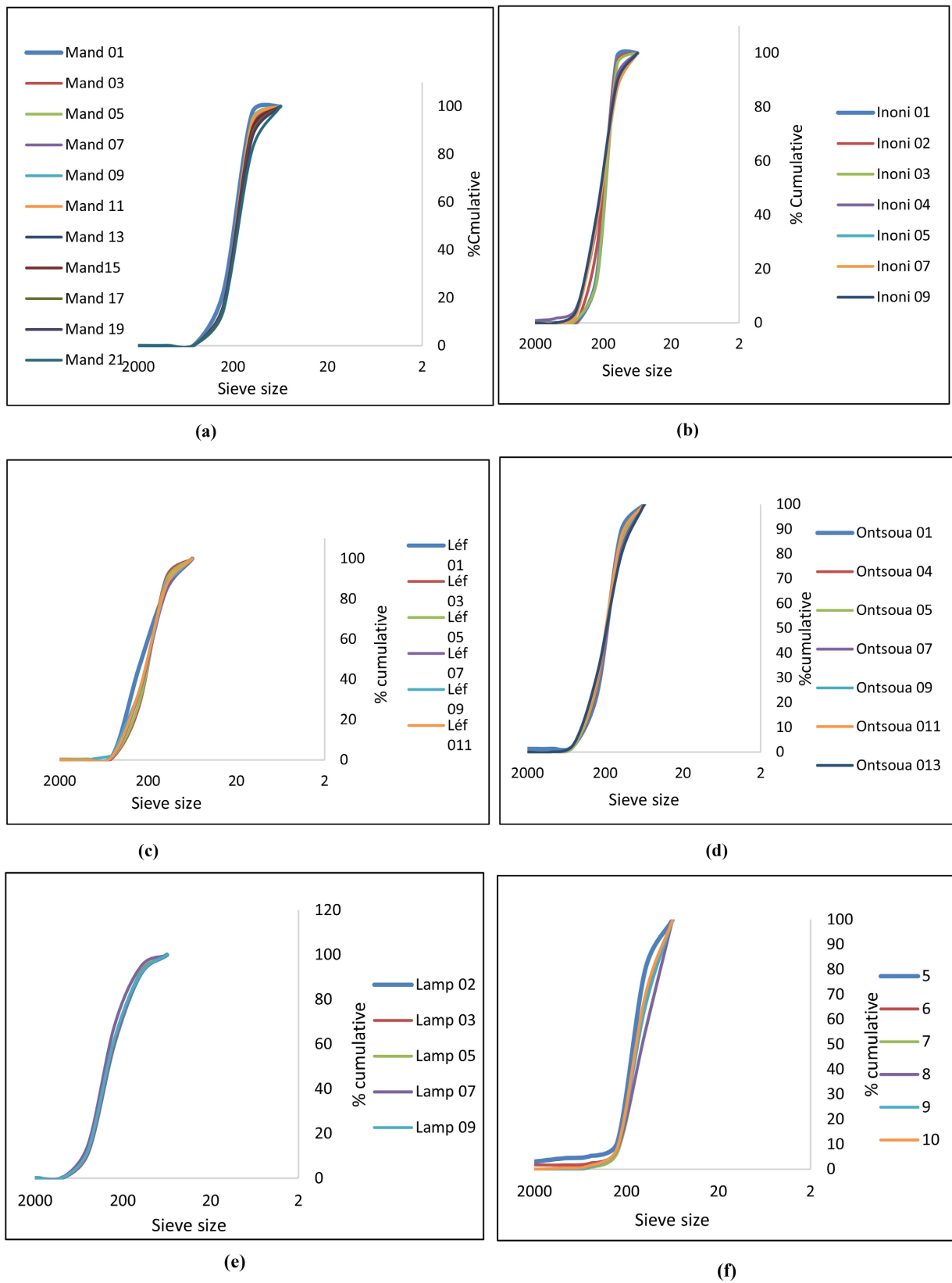
### 3.7. Morphoscopy

The morphoscopic study of quartz grains reveals that most grains are rounded with high sphericity. Regarding the surface aspect of quartz grains, results show that most grains are round, matt, and clean. These grains exhibit several impact

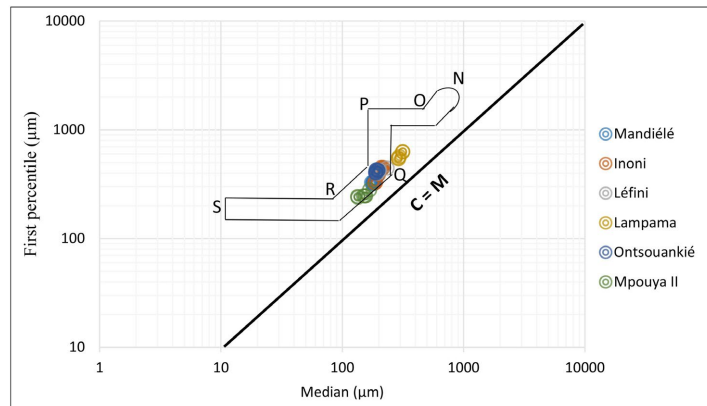
marks. The presence of many broken quartz grains is noted. Of the 1050 grains analyzed, 46.10% are round, matt, and clean (RM); 28.60% are round, matt, and dirty (RS); 12.87% are shiny blunted (EL); and 12.47% are shiny, round (RL). Dirty, round, matt grains have a ferruginous cement on their surface. Round, matt grains (both clean and dirty) show several impact marks on their surface and are larger than the shiny blunted ones, which are sub-rounded (**Figure 15**).



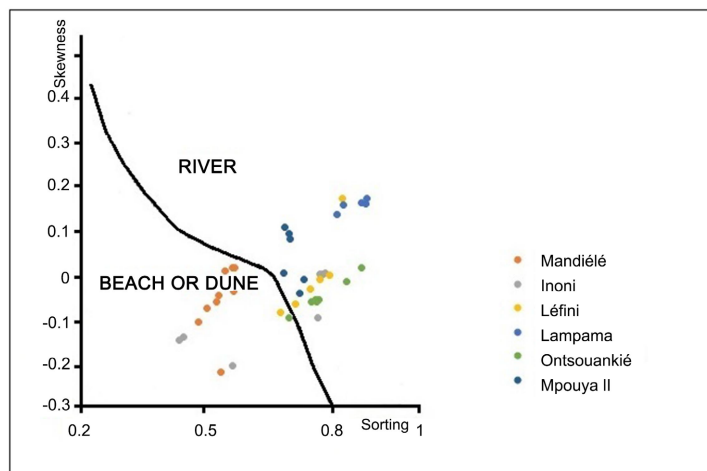
**Figure 10.** Different frequency curves of cover formation sands: (a): Mandiélé; (b): Inoni; (c): Léfini; (d): Ontsouankié; (e): Lampama; (f): Mpouya II.



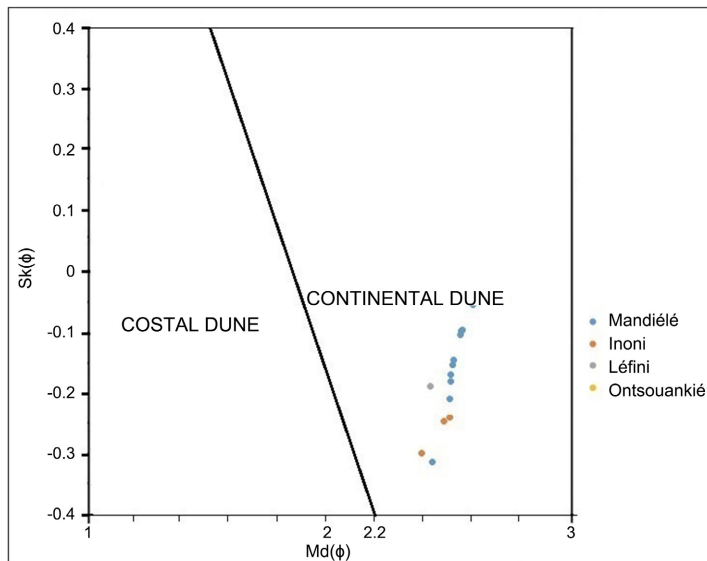
**Figure 11.** (a)-(d) Cumulative curves of the cover formation sands: (a): Mandiélé; (b): Inoni; (c): Léfini; (d): Ontsouankié. (e)-(f) Cumulative curves of the cover formation sands: (e): Lampama; (f): Mpouya II.



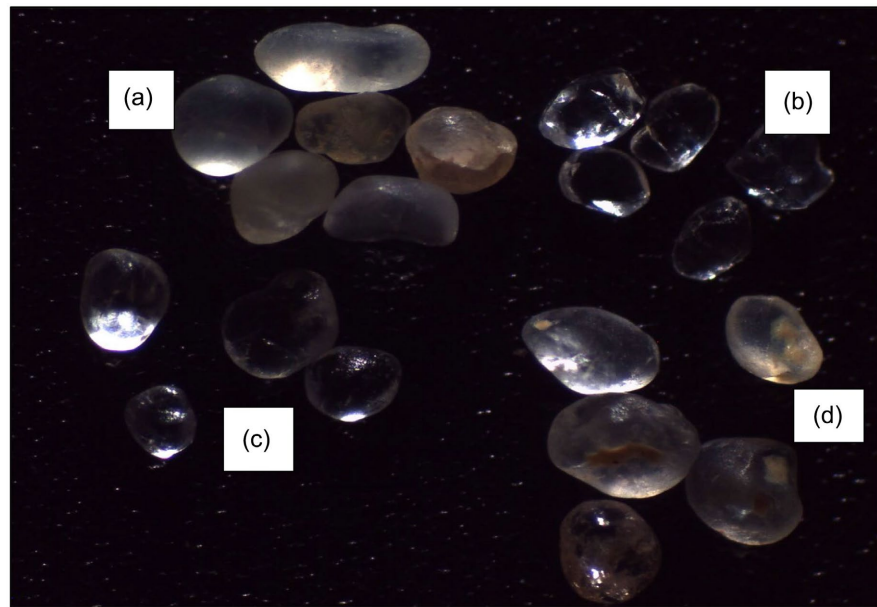
**Figure 12.** C/M diagram of *Passega (1957)* for the cover formation sands in the Batéké Plateaus.



**Figure 13.** Dispersion of the sands of the cover formation in the Batéké Plateaus on the *Friedman (1967)* Sk-So diagram.



**Figure 14.** Discrimination of sands on the Sk-Md diagram by *Moiola and Weisser (1968)*.



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**Figure 15.** Different shapes and textures of quartz grains in sands. (a) Clean, matt rounded grains (RM); (b) Shiny blunt grains (EL); (c) Shiny rounded grains (RL); (d) Dirty matt rounded grains (RS).

#### 4. Discussion

The lithological analysis of the sands from the cover formation in the Batéké Plateaus shows a succession of elementary sequences consisting of fine sands, rarely medium-sized (Lampama), sometimes silty in certain areas (Mandiélé, Ontsouankié, Mpouya II), or fine sands that are occasionally clayey, intercalated with a polygenic stone line. Such a succession indicates, according to [Cojan and Maurice \(2013\)](#) and [Chamley and Deconinck \(2011\)](#), a fluvial-type sedimentation. Gravelly layers correspond to flood events, while fine silty and occasionally clayey layers, and represent sedimentation by settling during low flow periods. The highly variable thickness of the elementary sequences suggests that the floods had varying durations and intensities.

The results of the grain size (sieving and sedimentometry) give approximately 75.73% and 24.27% for the mud, 12.90% silts and 11.37%. They are comparable to those [Le Maréchal \(1966\)](#) for which the fine fraction (silts and clays) is less than 20%, while it is around 24.27%. This slight difference can be explained by increase in the content of clays following the polyphasic alteration affecting these materials ([Bauer et al., 2015](#); [Callec et al., 2015](#)).

The particle size parameters vary depending on the study site, within the same log and from one plateau to another. The sands of the cover formation in the Batéké Plateaus are predominantly fine and sometimes medium (Lampama site). This evolution of the size is from the Lampama site located on the highest Koukouya Plateau, because all the plateaus are inclined slightly NW-SE, is consistent

with the assertions of Chamley and Deconinck (2011) on the evolution of the granulometric parameters for the samples of a series or of the same sedimentary level which says that “the elements transported by a watercourse, the size decreases and the better the gradind”. These sands are fairly well classified, moderately classified and poorly classified. The grading of these sands does not obey the assertions of Chamley and Deconinck. This variable behavior of the average suggests a sedimentation in several phases. These sands are mostly symmetrical and asymmetrical towards the coarse particles. These sands are unimodal.

These granulometric parameters vary from one site to another in a regular manner. Such an evolution of the granulometric parameters favors, according to Chamley and Deconinck (2011) and Cojan and Renard (2013), a mixture of allochthonous sediments with the autochthonous sediments which would be deposited in a calm environment.

With kurtosis values ( $K\phi < 3$ ), the flattening indicates the presence of distribution tails, that's to say the excess of fines or coarses. Such a distribution was interpreted by Mercier (2013) as characteristic of a deposit that took place in several phases. This characteristic is observable on all the study sites of these sands.

The cumulative curves of the sands from the sites studied have a sigmoidal (hyperbolic) shape, which defines a homogeneous sedimentary stock (Tricart, 1965). This shape also indicates sedimentation resulting from a variation in the competence of the transport current, indicating a progressive reduction in the energy of the transport agent (Tricart, 1965; Rivière, 1977; Saaidi, 1991). The predominance of fine silty sands and sometimes clayey sands also justifies the hyperbolic shape of the cumulative curves. Indeed, this shape characterizes facies justifying sedimentation by settling (Fournier et al., 2012). The parabolic shape of certain cumulative curves at the Mpouya II site characterizes sediments where the proportion increases exponentially with size, corresponding to deposition conditions in a relatively fast current. Coarse particles are excessively suspended and deposit in greater abundance (Fournier et al., 2012); this is confirmed by the predominance of the coarse fraction in these deposits. According to Atoui and Brahim (2009), the parabolic facies indicates a heterogeneity of the sandy stock corresponding to sedimentation by excess load.

These results are comparable to those of Le Maréchal (1966) and Miyouna et al. (2019), but there are some differences. Le Maréchal (1966) only found fine and well-sorted sands, while we obtained fine sands with coarse sand layers that appear rudimentary; the latter are fairly to moderately sorted. The cumulative curves are mostly sigmoid, dominating over those of the parabolic facies. However, Le Maréchal (1966) did not find the hyperbolic facies. This may be explained by the very small number of samples analyzed by this author. As for Miyouna et al. (2019), the cumulative curves of the sands from the southern part of Brazzaville show the same shape. Furthermore, the shape of the cumulative curves is comparable to those obtained by Ngakosso Ngolo et al. (2021) for the superficial formations in Chaillu (Mossendjo sector).

The primary mode of transport is saltation (segment QR), while rolling (segment QP) concerns only a small amount of sediments (**Figure 12**). According to Hajek et al. (2010), rolling transport pertains to sediments with a high mode and positive skewness. This is the case for the sands of Lampama and some sandy fractions of Léfini, which exhibit these characteristics.

The dispersion of points on the Sk-So diagrams of Friedman (1967) (**Figure 13**) and Sk-Md of Moiola and Weiser (1968) (**Figure 14**) shows that these sands have two types of paleoenvironmental deposition: aeolian and fluvial.

The morphoscopic study reveals four types of grains: clean matte rounds (RM), dirty matte rounds (RS), shiny blunt (EL) and shiny rounds (RL). The matte round grains show several marks of shock, which characterize an aeolian transport (Richot & Cailleux, 1971). The shiny blunt grains mark an aqueous transport. These results are comparable with those of Le Maréchal (1966). The dirty matt round grains (RS) wear ferruginous cement on their surface, sometimes coated on certain shiny blunt grains. This suggests that these sands have been redesigned (Guilcher, 1945; Ritchot & Cailleux, 1971; Girolimetto, 1982). The shiny blunt grains characterize a wet phase of the evolution of sediment. These results show that these sands have undergone transport in two phases, the first wind phase and the second aqueous. This result is close to those obtained by Ngakosso Ngolo (2022) on the superficial formations of the Congolese bowl in the Republic of Congo. Thus, these sands are deposited in two paleoenvironments, aeolian environment and fluvial environment.

## 5. Conclusion

The study of the sedimentary dynamics of the sands of the cover formation in the Batéké Plateaus, based on a descriptive study of lithofacies in the field and granulometric analyses in the laboratory, shows that this formation is structured by a succession of elementary sequences of fine sands, rarely medium, sometimes silty in certain areas, or by fine sands with occasional clay intercalated by a polygenic stone-line. These sands are fairly well sorted to moderately sorted and poorly sorted. They are symmetrical and this asymmetry tends towards coarse grain. The cumulative curves are sigmoidal or S-shaped, and there are few parabolic curves. The primary mode of transport for these sands is saltation, while few sediments are transported by rolling. The dispersion of a number of parameters using Sk-So and Sk-Md diagrams enabled us to determine two depositional palaeoenvironments, aeolian and fluvial. The Morphoscopy of the quartz grains in these sands reveals rounded matt grains (both clean and dirty) transported by the wind, shiny grains (blunt and rounded) typical of aqueous transport, and many broken grains, indicating a complex transport process by the wind and then by water. This study shows that the sands of the cover formation in the Batéké Plateaus are not exclusively of eolian origin, as suggested by previous studies.

Although this study shows that the deposit was done in two paleoenvironments, it would be even better if we managed to date this training to better understand

and timed the sediment deposit phases, wind and fluvial, in evolution paleoclimatic of the Congo basin. The Holocene age, 3.000 - 2.500 B.P., determined in Gabon, corresponding to the arid climate period would be marked at least with a wet episode well circumscribed in time.

### Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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## Appendix

**Table A1.** Granulometric parameters of cover formation sand in the Batéké plateaus.

Sample number	Granulometric indices	METHOD OF MOMENTS		Description
		Arithmetic (mm)	Logarithmic ( $\phi$ )	
Mand 1	Mean	230.6	2.910	Fine sand
	Sorting	91.68	0.484	Well graded
	Skewness	1.958	-0.838	Symmetrical
	Kurtosis	8.66	3.972	Leptokurtic
Mand 2	Mean	214.4	2.398	Fine sand
	Sorting	85.42	0.497	Well graded
	Skewness	2.100	-0.460	Asymmetrical towards the coarse
	Kurtosis	10.08	4.562	Leptokurtic
Mand 3	Mean	215.2	2.386	Fine sand
	Sorting	83.55	0.474	Well graded
	Skewness	2.238	-0.626	Asymmetrical towards the coarse
	Kurtosis	10.82	4.935	Leptokurtic
Mand 4	Mean	213.4	2.405	Fine sand
	Sorting	85.45	0.501	Fairly well graded
	Skewness	2.103	-0.427	Asymmetrical towards the coarse
	Kurtosis	10.17	4.536	Leptokurtic
Mand 5	Mean	208.0	2.455	Fine sand
	Sorting	87.43	0.540	Fairly well graded
	Skewness	1.988	-0.233	Symmetrical
	Kurtosis	9.769	4.020	Leptokurtic
Mand 6	Mean	214.4	2.394	Fine sand
	Sorting	84.18	0.484	Well graded
	Skewness	2.190	-0.541	Asymmetrical towards the coarse
	Kurtosis	10.61	4.795	Leptokurtic
Mand 7	Mean	207.5	2.450	Fine sand
	Sorting	84.79	0.517	Fairly well graded
	Skewness	2.157	-0.297	Symmetrical
	Kurtosis	10.90	4.438	Leptokurtic
Mand 8	Mean	213.6	2.413	Fine sand
	Sorting	89.04	0.526	Fairly well graded
	Skewness	2.070	-0.354	Symmetrical
	Kurtosis	10.04	4.253	Leptokurtic

## Continued

Mand 9	Mean	207.2	2.459	Fine sand
	Sorting	86.61	0.535	Fairly well graded
	Skewness	2.042	-0.241	Symmetrical
	Kurtosis	10.16	4.117	Leptokurtic
Mand 10	Mean	207.4	2.463	Fine sand
	Sorting	88.35	0.551	Fairly well graded
	Skewness	1.940	-0.208	Symmetrical
	Kurtosis	9.485	3.868	Leptokurtic
Mand 11	Mean	202.6	2.515	Fine sand
	Sorting	93.05	0.597	Fairly well graded
	Skewness	1.918	-0.186	Symmetrical
	Kurtosis	9.417	3.381	Mesokurtic
Inoni 1	Mean	216.9	2.350	Fine sand
	Sorting	71.05	0.396	Well graded
	Skewness	1.675	-1.220	Asymmetrical towards the coarse
	Kurtosis	4.188	4.552	Leptokurtic
Inoni 2	Mean	236.1	2.257	Fine sand
	Sorting	87.11	0.497	Well graded
	Skewness	0.857	-0.395	Symmetrical
	Kurtosis	2.072	2.737	Mesokurtic
Inoni 3	Mean	216.6	2.377	Fine sand
	Sorting	89.81	0.464	Well graded
	Skewness	2.963	-1.085	Asymmetrical towards the coarse
	Kurtosis	15.28	6.250	Leptokurtic
Inoni 4	Mean	266.3	2.161	Fine sand
	Sorting	176.1	0.743	Moderately graded
	Skewness	3.410	-0.652	Asymmetrical towards the coarse
	Kurtosis	21.46	3.982	Leptokurtic
Inoni 5	Mean	262.7	2.189	Fine sand
	Sorting	136.6	0.712	Moderately graded
	Skewness	1.459	-0.042	Symmetrical
	Kurtosis	6.030	2.692	Mesokurtic
Inoni 5	Mean	262.7	2.189	Fine sand
	Sorting	136.6	0.712	Moderately graded
	Skewness	1.459	-0.042	Symmetrical
	Kurtosis	6.030	2.692	Mesokurtic

## Continued

Inoni 6	Mean	255.8	2.232	Fine sand
	Sorting	133.7	0.722	Moderately graded
	Skewness	1.423	-0.018	Symmetrical
	Kurtosis	6.026	2.596	Mesokurtic
Inoni 7	Mean	269.4	2.162	Fine sand
	Sorting	145.2	0.728	Moderately graded
	Skewness	1.504	-0.094	Symmetrical
	Kurtosis	5.830	2.719	Mesokurtic
Léfini 1	Mean	269.5	2.163	Fine sand
	Sorting	133.3	0.760	Moderately graded
	Skewness	0.900	0.318	Symmetrical
	Kurtosis	4.737	2.274	Platykurtic
Léfini 2	Mean	233.8	2.311	Fine sand
	Sorting	106.5	0.602	Fairly well graded
	Skewness	1.598	-0.201	Symmetrical
	Kurtosis	7.193	3.174	Mesokurtic
Léfini 3	Mean	233.6	2.303	Fine sand
	Sorting	110.2	0.649	Fairly well graded
	Skewness	1.397	-0.272	Symmetrical
	Kurtosis	6.482	3.377	Mesokurtic
Léfini 4	Mean	241.9	2.309	Fine sand
	Sorting	124.1	0.719	Moderately graded
	Skewness	1.318	0.003	Symmetrical
	Kurtosis	5.877	2.456	Platykurtic
Léfini 5	Mean	246.7	2.264	Fine sand
	Sorting	122.3	0.677	Fairly well graded
	Skewness	1.462	-0.064	Symmetrical
	Kurtosis	6.436	2.752	Mesokurtic
Léfini 6	Mean	248.3	2.266	Fine sand
	Sorting	126.3	0.704	Moderately graded
	Skewness	1.404	-0.021	Symmetrical
	Kurtosis	6.151	2.611	Mesokurtic
Lampama 1	Mean	336.5	1.863	Medium sand
	Sorting ( $\sigma_{\phi}$ ):	179.9	0.794	Moderately graded
	Skewness	1.026	0.262	Symmetrical
	Kurtosis	3.656	2.663	Mesokurtic

## Continued

Lampama 2	Mean	336.8	1.856	Medium sand
	Sorting	177.7	0.784	Moderately graded
	Skewness	1.032	0.276	Symmetrical
	Kurtosis	3.727	2.707	Mesokurtic
Lampama 3	Mean	364.9	1.729	Medium sand
	Sorting	185.1	0.765	Moderately graded
	Skewness	0.911	0.355	Symmetrical
	Kurtosis	3.235	2.895	Mesokurtic
Lampama 4	Mean	365.8	1.723	Medium sand
	Sorting	185.2	0.757	Moderately graded
	Skewness	0.921	0.317	Symmetrical
	Kurtosis	3.220	2.871	Mesokurtic
Lampama 5	Mean	342.4	1.837	Medium sand
	Sorting	181.7	0.796	Moderately graded
	Skewness	0.988	0.303	Symmetrical
	Kurtosis	3.541	2.699	Mesokurtic
Ontsoua 1	Mean	224.5	2.328	Fine sand
	Sorting	113.0	0.665	Fairly well graded
	Skewness	1.831	-0.704	Asymmetrical towards the coarse
	Kurtosis	8.590	4.439	Leptokurtic
Ontsoua 2	Mean	232.1	2.366	Fine sand
	Sorting	125.9	0.694	Fairly well graded
	Skewness	1.870	-0.272	Symmetrical
	Kurtosis	7.844	3.016	Mesokurtic
Ontsoua 3	Mean	235.5	2.346	Fine sand
	Sorting	126.8	0.699	Moderately graded
	Skewness	1.774	-0.225	Symmetrical
	Kurtosis	7.433	2.906	Mesokurtic
Ontsoua 4	Mean	238.9	2.355	Fine sand
	Sorting	139.3	0.755	Moderately graded
	Skewness	1.747	-0.250	Symmetrical
	Kurtosis	6.857	2.700	Mesokurtic
Ontsoua 5	Mean	245.1	2.294	Fine sand
	Sorting	134.6	0.710	Moderately graded
	Skewness	1.758	-0.241	Symmetrical
	Kurtosis	7.039	2.917	Mesokurtic

## Continued

Ontsoua 6	Mean	245.2	2.292	Fine sand
	Sorting	134.8	0.706	Moderately graded
	Skewness	1.794	-0.267	Symmetrical
	Kurtosis	7.142	2.980	Mesokurtic
Ontsoua 7	Mean	241.9	2.348	Fine sand
	Sorting	142.0	0.782	Moderately graded
	Skewness	1.595	-0.176	Symmetrical
	Kurtosis	6.271	2.459	Platykurtic
Mpouya II 1	Mean	196.0	2.510	Fine sand
	Sorting	173.4	0.773	Fairly well graded
	Skewness	5.818	-1.674	Asymmetrical towards the coarse
	Kurtosis	42.78	7.464	Très leptokurtic
Mpouya II 2	Mean	169.2	2.703	Fine sand
	Sorting	85.39	0.683	Fairly well graded
	Skewness	2.671	-1.129	Asymmetrical towards the coarse
	Kurtosis	17.45	6.091	Leptokurtic
Mpouya II 3	Mean	160.8	2.870	Fine sand
	Sorting	85.37	0.625	Fairly well graded
	Skewness	2.779	-0.638	Asymmetrical towards the coarse
	Kurtosis	16.43	3.188	Mesokurtic
Mpouya II 4	Mean	169.7	2.847	Fine sand
	Sorting	132.1	0.688	Fairly well graded
	Skewness	6.029	-1.125	Asymmetrical towards the coarse
	Kurtosis	55.10	5.387	Leptokurtic
Mpouya II 5	Mean	174.4	2.753	Fine sand
	Sorting	92.31	0.631	Fairly well graded
	Skewness	2.778	-0.493	Asymmetrical towards the coarse
	Kurtosis	15.71	3.386	Mesokurtic
Mpouya II 6	Mean	184.5	2.696	Fine sand
	Sorting	129.5	0.646	Fairly well graded
	Skewness	6.159	-0.874	Asymmetrical towards the coarse
	Kurtosis	57.30	5.794	Leptokurtic