Morphoscopy of Sandy Sediments in Intertidal Areas along the Gulf of Guinea: A Case Study in Côte d'Ivoire

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Abstract: ***This study focuses on the influence of the transport mode on the shape of sandy sediments along the Ivorian intertidal zone (Assinie: 05°07'45.3''; 003°17'06.3'' to the Ivorian-Liberian border: 04°21'47.8''; 007°31'36.7''). 159 sediment samples were collected and the 630 µm, 250 µm, and 160 µm fractions were taken into account. The granulometric analysis identified two facies' sequences, all with a decreasing grading in the direction of the littoral drift (West-East). The first sequence starts from the Ivorian-Liberian border at Monogaga village (San-Pedro region); and the second from Sassandra town to Assinie town (Ivorian-Ghanaian border). The Ivorian-Liberian border sites contain coarse sediments and the stations in the Monogaga area (San-Pedro region) record medium-sized sediments. However, in Sassandra, the sites show very coarse sediments and those in Assinie show fine sediments. The cumulative semi-logarithmic curves describe sigmoid facies. The main mode of transport of quartz in this study area is by saltation, with a mainly monogenic source. Sediment saltation in the direction of the littoral drift leads to a pronounced polishing of the coarse fractions compared to the fine fractions.***

Keywords: intertidal zone, morphoscopy, granulometry, littoral drift, mode of transport

1. Introduction

The foreshore or intertidal zone is the land covered by the tidal movement. It represents the buffer zone between the sea and the mainland. This area is highly dynamic in sedimentation, due to oceanic sediment reworking, continental inputs, and bio-deposition generated by oysters and mussels. The intertidal zones cover about 18% of the world's ocean surface and contribute significantly to biogeochemical cycles [40]. They are estimated to have a greater diversity than the open ocean or the global terrestrial ecosystem [3], due to their physical, biological, ecological, and hydrodynamic characteristics. Ecological and economic interest in the study of intertidal areas is due to coastal development, increased industrial, agricultural, tourist, and other anthropogenic activities. Considerable changes associated with sea-level variation and hydrodynamic forcing [14] apply pressure to intertidal areas, the most concerning of these being coastal erosion. The scope of understanding of this phenomenon is quite broad and includes in situ sediments. Numerous research has been done on the genesis of intertidal sediments worldwide [17]; [26]; [11]; [27]; [10]; [24]; [28]; [16]; [2], [41], [36]. These studies aimed to understand the parameters influencing sand grain transport and deposition processes. The intertidal zone of Côte d'Ivoire has also attracted the interest of national and international scientists over several decades.

2. Materials and Methods

2.1 Geographic and geological setting of the sampling area

The intertidal zone in Côte d'Ivoire is bordered by the Atlantic Ocean along the Gulf of Guinea. It covers the area from Cap of Palms in the west (Côte d'Ivoire-Liberia border) to Cap of Three Points in the east (Côte d'Ivoire-Ghana border). According to the nature of the rocks in contact with the sea, it has been divided into three morpho-structural zones and grouped into two main parts [32]; [1]. The first part of the intertidal zone consists of two morpho-structural zones: from the Liberian border to Sassandra and from Sassandra to Fresco. This section has a series of rocks that directly connect to the sea and form a rocky coastline. The second part includes the third morpho-structural zone from Fresco to the Ghana border. The lack of consolidated rock structures in this section extends the sandy beaches over several kilometers [32]. The rocks that outcrop over almost the entire Ivorian intertidal complex are those of the continental terminal 'Mio-Pliocene or perhaps the Plio-Quaternary' [15]. The Climate regime of the intertidal zone is equatorial, specifically of the Attieen type. between 100 and 500 mm Annual rainfall is recorded [30]. Small cliffs and creeks make up the western intertidal zone, while the eastern zone has long sandy beaches. Côte d'Ivoire's intertidal zone is the outlet of almost all the country's rivers. Many rivers, lakes, and lagoons constitute the hydrographic network

2.2 Sampling

From February 2020 to November 2021, Sampling was conducted, covering 10 towns along the Ivorian intertidal zone (from Assinie to Tabou) (Figure. 1). The sampling points are from the Cavally River mouth (04-21'47.8'; 007-31.36.7') to the Aby Lagoon mouth (05-07'45.3"; 003-17'06.3"). The sampling point was chosen based on the physical, ecological, and hydrodynamic characteristics. The study area is subject to many activities, including fishing, transport, industry, wildlife, tourism, and agriculture. The area hosts about 30% (7.5 million inhabitants) of the Ivorian population and more than 50% of the country's economic activities (Ports, Airports, Industries, etc.) [9]. A total of 159 sediment samples were collected directly by hand and packed in plastic bags for storage and processing. The samples were taken from a depth of 0-5 cm at mid-tide. The samples were subjected to a conventional treatment (washing, drying, and hydrochloric acid etching) before 100 g were dried in an oven and placed on a column of 16 sieves of AFNOR series. The different fractions were studied in terms of their particle size. The mean, standard deviation, skewness, and acuteness were calculated according to the principle of [5]. The mode of sediment transport was studied according to the principle of [38]; the granulometric facies according to [31]; the source of sediment according to [27] and the morphoscopy of the sediment according to [25]. The sand grains morphoscopy was performed at the Marine Geology and Sedimentology Laboratoryof the University Félix Houphouët Boigny of Cocody (Ivory Coast). One hundred (100) sand grains, with fractions of 630 µm, 250 µm, and 160 µm, were observed and classified according to the shape and aspect of the surface, using a binocular magnifying glass of the Leica binocular loupe connected to a computer containing the LAS EZ software. Easysieve and ArcGIS software were used respectively to determine the sediment quantile values and to map the spatial distribution of the sand grain morphoscopy.

3. Results

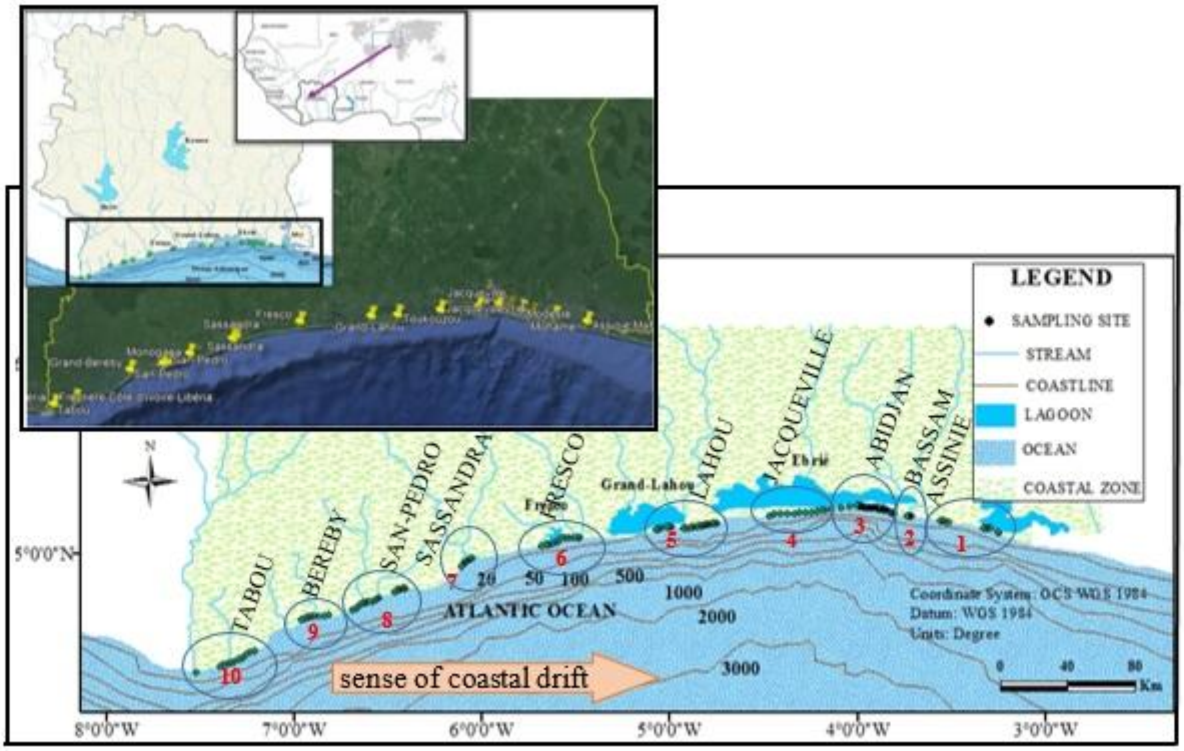

Figure 1: Study area (1: Assinie, 2: Grand-Bassam, 3: Abidjan, 4: Jacqueville, 5: Grand-Lahou, 6: Fresco, 7: Sassandra, 8: San-Pedro, 9: Grand-Béréby et 10: Tabou).

3.1 Granulometric analysis

The granulometry showed a mean value of the grain size (Mz in µm) varying from 191, in the Assinie area to 2217, in the Abidjan area. This reveals a quartz grain size that varies from fine particles to very large particles (gravel). Two different facies sequences, with granulometric sorting, were observed in the study area. The first sequence is from the Côte d'Ivoire-Liberia border (Tabou) and ends in the village of Monogaga in the San-Pedro region. In this area, the grain ranges from 277 to 879µm. This sequence reveals facies made up of decreasing granoclassification ranging from coarse to medium sands. The presence of coarse sands found in the Tabou community could probably be due to the alteration of the rock in situ. The second sequence starts from Sassandra to Assinie. The values observed in this area range from 191 to 2217µm. The facies of this sequence are graded in decreasing order from very coarse to fine sands.

In general, the grain size along the Ivorian intertidal zone is largely dominated by coarse and medium sands and a thin portion of fine sands in the extreme east. This reveals the presence of a marine winnowing of sand grains oriented in the direction of the Ivorian longshore drift current (Figure. 2).

Analysis of the collected sediments indicates a distribution of 6.3% highly graded sand grains ($0.06 \leq \sigma \leq 0.34$ ϕ), 36.5% well-graded sand grains ($0.35 \leq \sigma \leq 0.49$ ϕ), 54.1% moderately graded grains (0.5 ϕ $\leq \sigma \leq$ 0.79 ϕ) and 3.1% poorly graded grains (0.8 ϕ $\leq \sigma \leq$ 0.97 ϕ) (Figure.3). The percentages recorded in the grain distribution show uniformity of grain size. Since more than 97% of the grains are included in the very good to moderate classes. All these sediments describe a sigmoidal (S) type gait, with a steep slope, more or less homogeneous (Figure.4). This reflects depositional facies by gradually decreasing the energy of the marine current [7]. Decreasing current energy shows that the sediments are progressively deposited in the direction of the longshore drift.

These deposits occurred freely in environments with little (very well and well-graded grains of sand), moderate (moderately graded grains), and strong (poorly graded grains) movement. An analysis of the grains shows that more than 73% of the grains in the very well to the well-graded range were in the eastern part of the coastline. This indicates an environment of less turbulent deposition in the east. The sieve diameter histogram versus the proportion of rejects shows an overall unimodal pattern. These sand grains, therefore, come from a monogenic source. However, bimodal curves were observed in some areas such as Grand-Bassam, Sassandra, and San-Pedro. The sand grains from these localities would indicate two sources. (Figure. 5).

Three types of the population are revealed by the logarithmic curve described by the [38] test. The most abundant population is transported by saltation with an average of 93.79% of sand grains. The population whose mode of transport is scavenging has an average proportion of 5.35% and the remaining population with an average of 0.86% moves by the suspension. This analysis shows that saltation is the preferred mode of transport for the sand populations studied (Figure. 6). This transport route is further confirmed by the sigmoidal pattern observed in the analysis of cumulative semi-logarithmic curves [31].

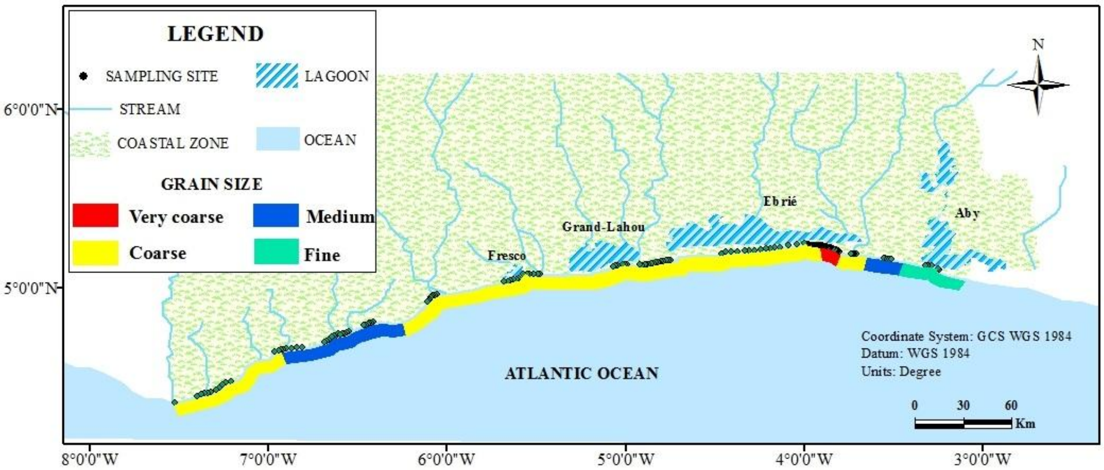

Figure 2 : Spatial distribution of sand size (Very coarse: $Mz \geq 1000 \mu m$, Coarse: $500 \mu m \leq Mz \leq 1000 \mu m$, Medium: $250\ \mu m \leq Mz \leq 500\ \mu m$, Fine: $250 \mu m < Mz$).

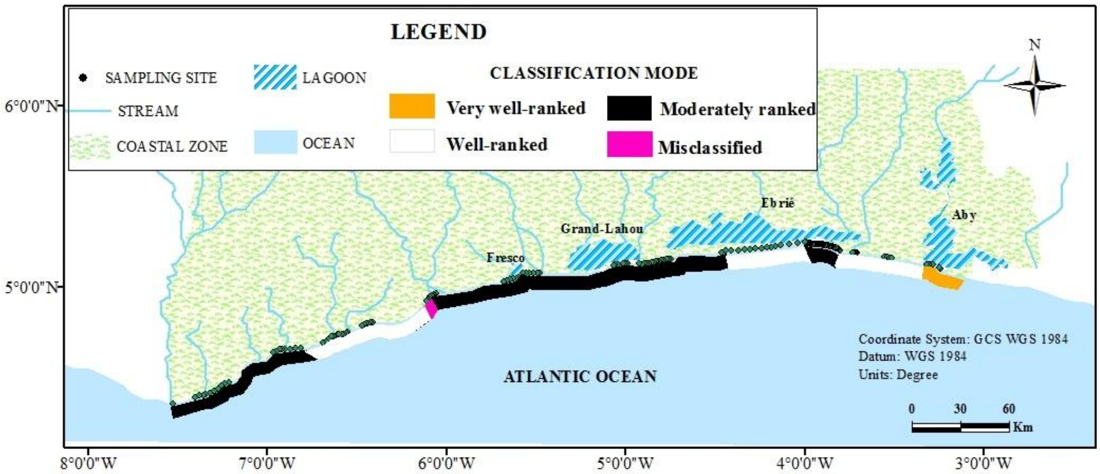

Figure 3: Spatial distribution of sand deposit facies

3.2 Morphoscopic analysis of different fractions of quartz grains

3.2.1 Coarse fraction (630 µm)

The coarse fraction (630 µm) of the quartz, observed under the binocular magnifying glass, shows sub-rounded grains dominating at about 49%, sub-angular at about 32%, rounded at about 14%, and angular at about 5%. The sub-rounded forms are more abundant in the eastern part of the Ivorian intertidal zone, in contrast to the sub-angular forms which are abundant in the western part. Quartz polishing occurred in the direction of the longshore drift. However, weak polishing was observed at the Fresco, Grand-Lahou, and Jacqueville sites (Figure. 7). The presence of sub-angular grains in these sites could indicate a continental input, given the proximity of the mouths of certain rivers and lagoons to the sampling points. This fraction's sands have a predominantly blunt and shiny appearance (83% on average) along the intertidal zone. Unworn grains and less abundant mast grains average 14% and 3%, respectively. The significant presence of a blunt and shiny appearance reflects the long-distance mobility of sand grains in an aqueous medium.

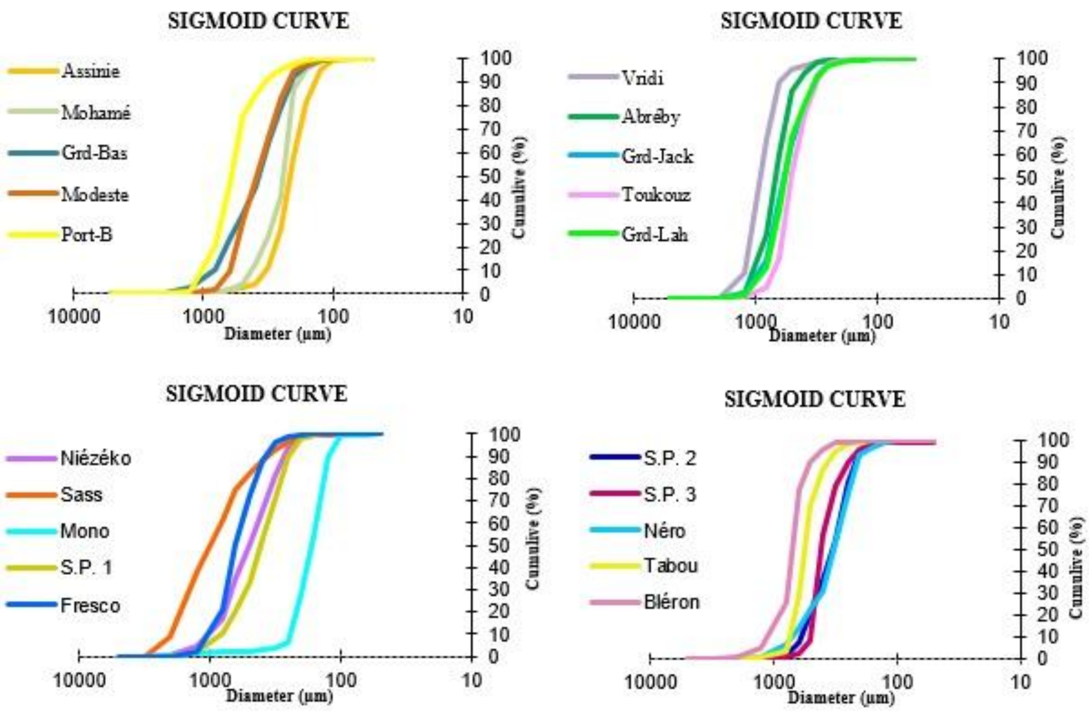

Figure 4: Semi-logarithmic cumulative curves of sands

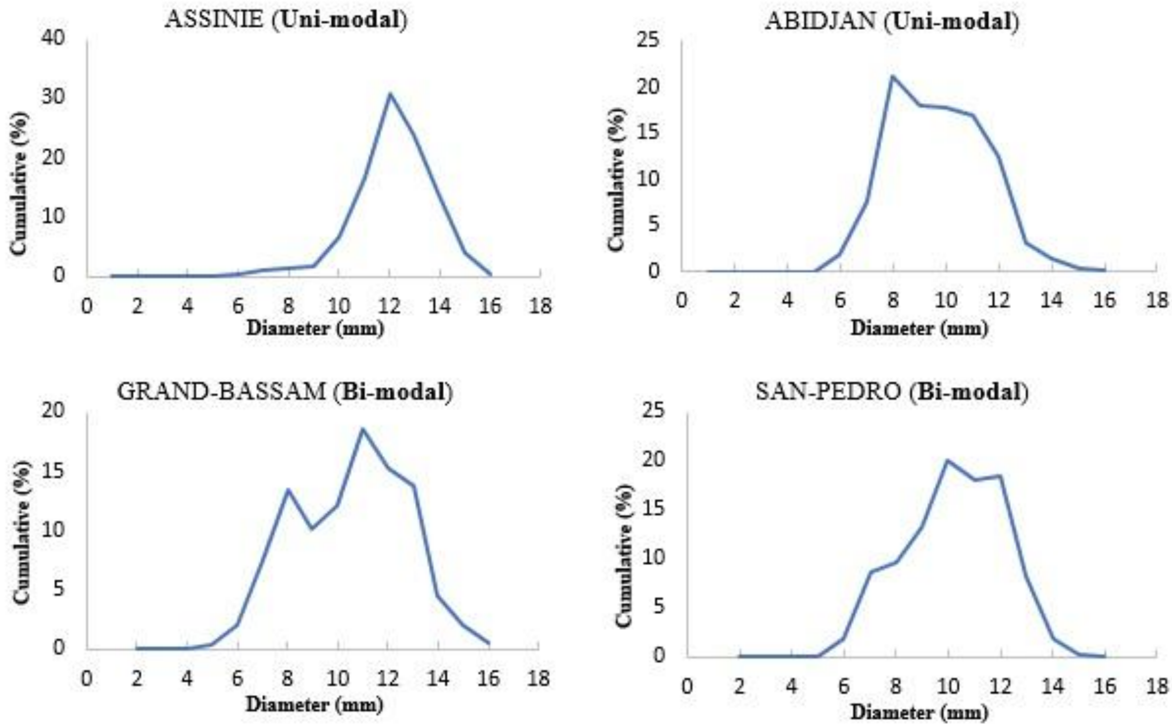

Figure 5: purveyor source of sand

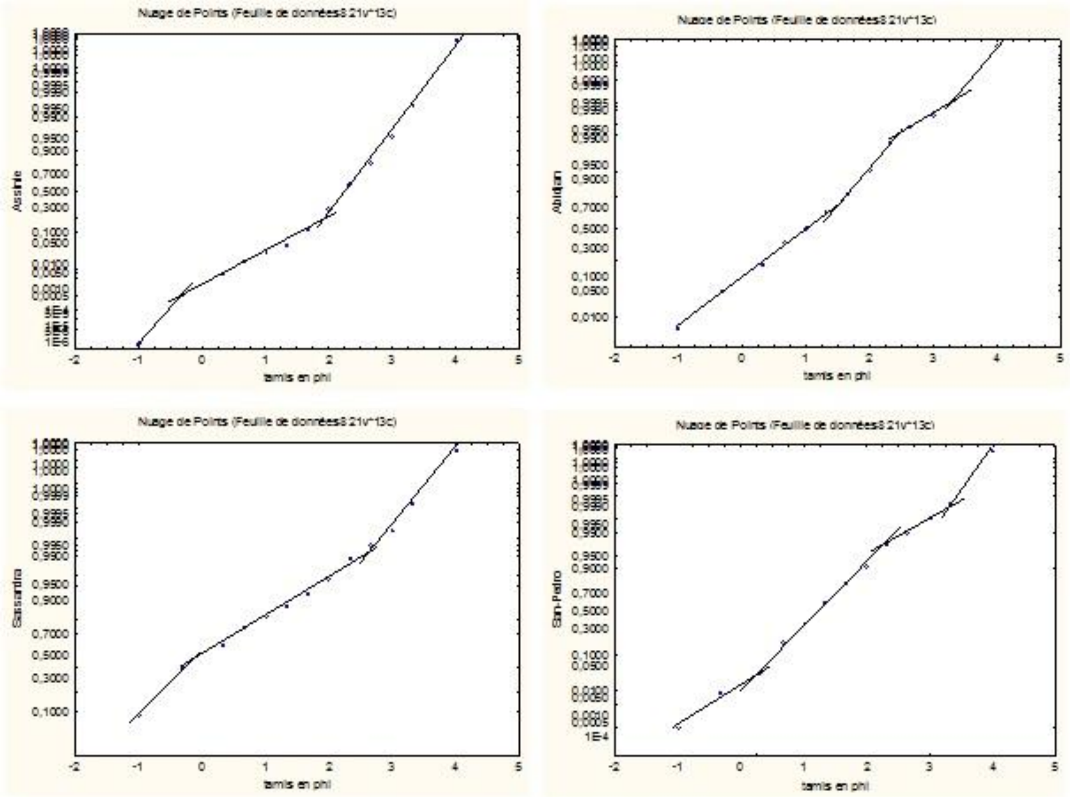

Figure 6: Visher test cumulative curves

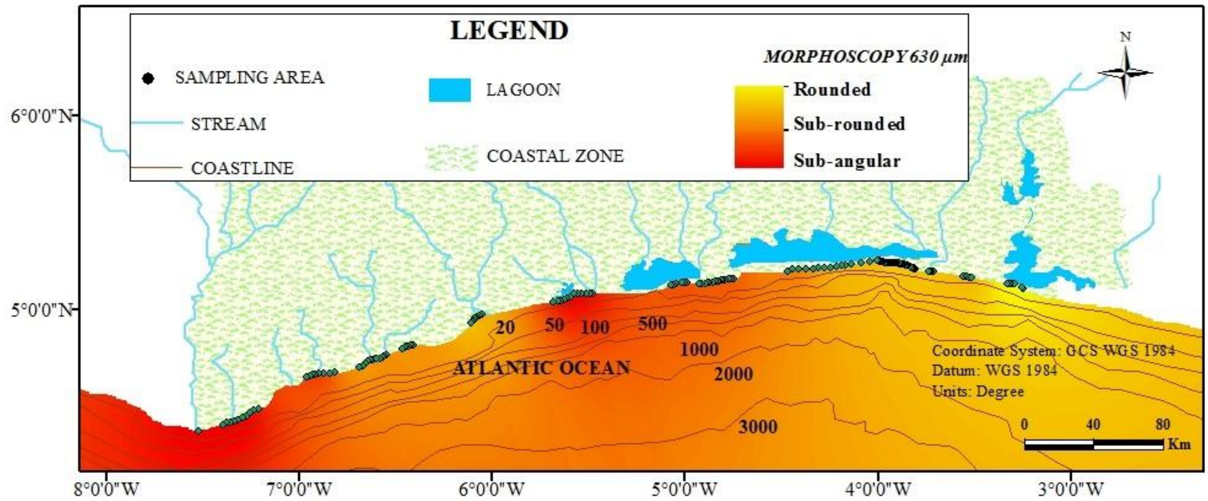

Figure 7: Space morphoscopy of the coarse fraction **(630 µm)** of the Ivoirian coast

3.2.2. Medium fraction (250 µm)

Most of the medium fraction (250 µm) of quartz is made up of sub-rounded grains, with a proportion of 45%. The percentage of this form is reduced by 4 % compared to the above-mentioned coarse fraction. These forms are more abundant in the eastern part than those found in the coarse fraction. There was also a visible decrease in rounded grains, from 14% to 9%. Unlike the rounded and sub-rounded grains, there was a slight increase in the percentage of sub-angular and angular grains from 32% to 36% and from 5% to 10%, respectively. This may be due to the types of transport (saltation). The grains in this case have certainly remained more in the water column.

The result of quartz polishing in the medium fraction is identical to that in the coarse fraction (Figure. 8). Examination of the average fraction shows a predominance of blunt and shiny grains (84% on average) along the intertidal zone; except for the Tabou area which has an abundance of unworn grains. Unworn grains have an average of 11% and masts 5%.

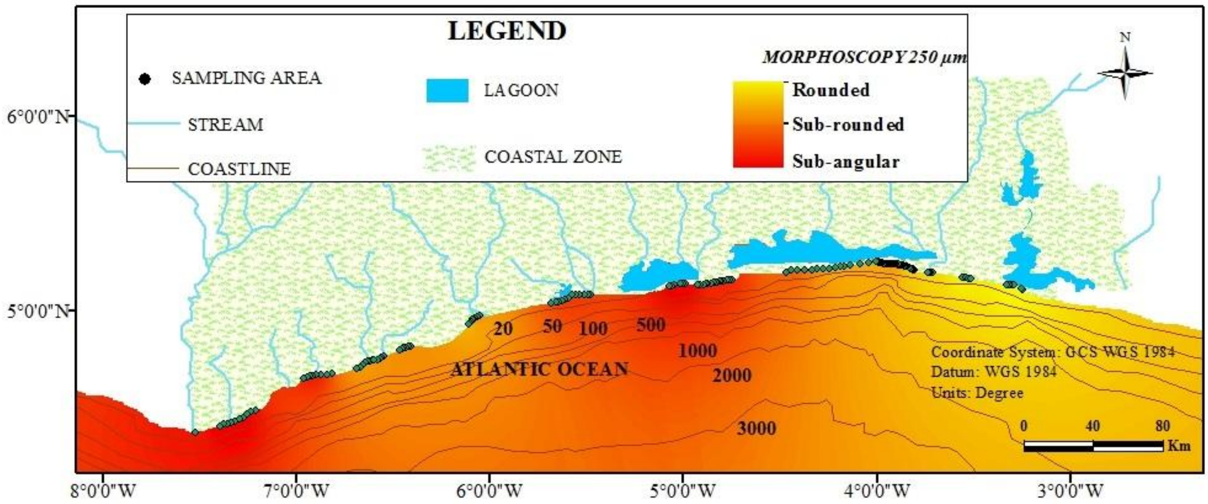

Figure 8: Space morphoscopy of the average fraction **(250 µm)** of the Ivoirian coast

3.2.3. Fine fraction (160 µm)

The grains of the fine fraction (160 µm) revealed a remarkable abundance (47%) of sub-angular quartz over almost the entire intertidal zone, except for some grains in the Sassandra and Jacqueville zone which showed more abundant sub-rounded forms (Figure. 9). This fraction also consists of sub-rounded grains at 26%, angular grains at 23%, and rounded grains at 4%. Sub-angular quartz predominance in this fraction compared to the previous fractions could be due to suspension transport, considering the size of the grains and the energy of the transport agent. Fine fraction grains are 73% blunt-edged quartz, 24% unworn quartz, and 3% mast quartz. This shows that the polishing becomes less pronounced with decreasing grain size (Figure. 10). Except for Abidjan and San Pedro, where unworn grains predominate, blunt and shiny grains were found in the majority of the sample sites. This pattern of unworn grain distribution in the Abidjan area may be the result of the high wave energy associated with the deep underwater morphology. The blunt and shiny appearance found in the town of San Pedro is probably the consequence of the weathering of the rock formations present in the area. From the analysis of the 3 fractions studied, the fine one contains more unworn quartz grains than the larger fractions. This suggests that the smaller the fraction examined, the less blunt the quartz grains.

4. Discussion

Quartz grains collected in the Ivorian intertidal zone, from the Côte d'Ivoire-Liberia border to the town of Assinie, show a granulometry varying from very coarse to fine particles. The two facies sequences found in this study area indicate a decreasing grading from coarse to mid-sized sands for the sequence from the Côte d'Ivoire-Liberia border to the village of Monogaga in the San-Pedro region and from very coarse to fine sands for the sequence from the town of Sassandra to the town of Assinie.

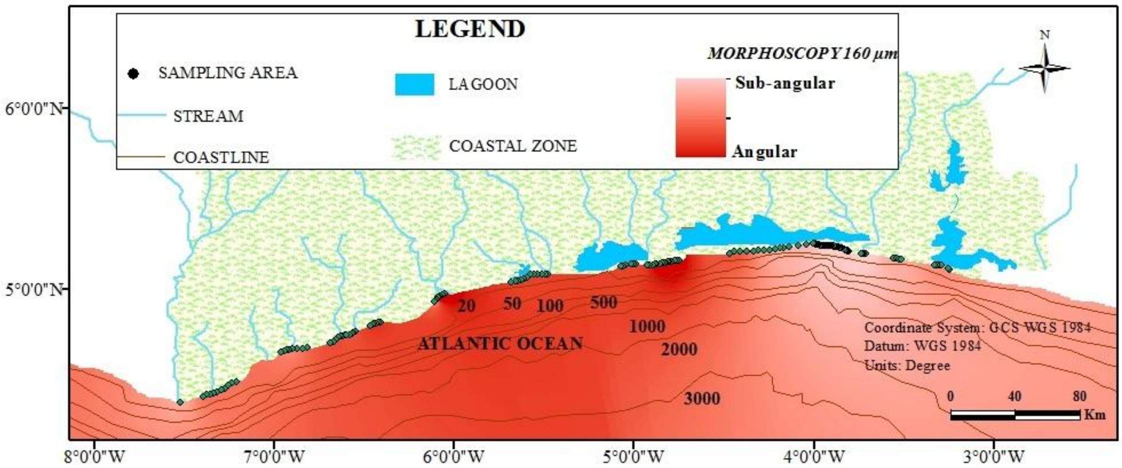

Figure 9: Space morphoscopy of the fine fraction **(160 µm)** of the Ivoirian coast

Many researchers [1]; [42]; [12]; [23]; [35]; [6], [20], [21] had previously described this form of decreasing quartz grain size distribution. These authors worked on fragmentary portions of the Ivorian intertidal zone. Abidjan and Sassandra have the coarsest granulometry. However, according to [29], the coarsest grain size was also found in Abidjan. Their research found a medium grain size in Sassandra. The present work also reveals a medium granulometry in Sassandra. The coarse granulometry in Sassandra in this study could be justified by the smaller sampling intervals in this area.

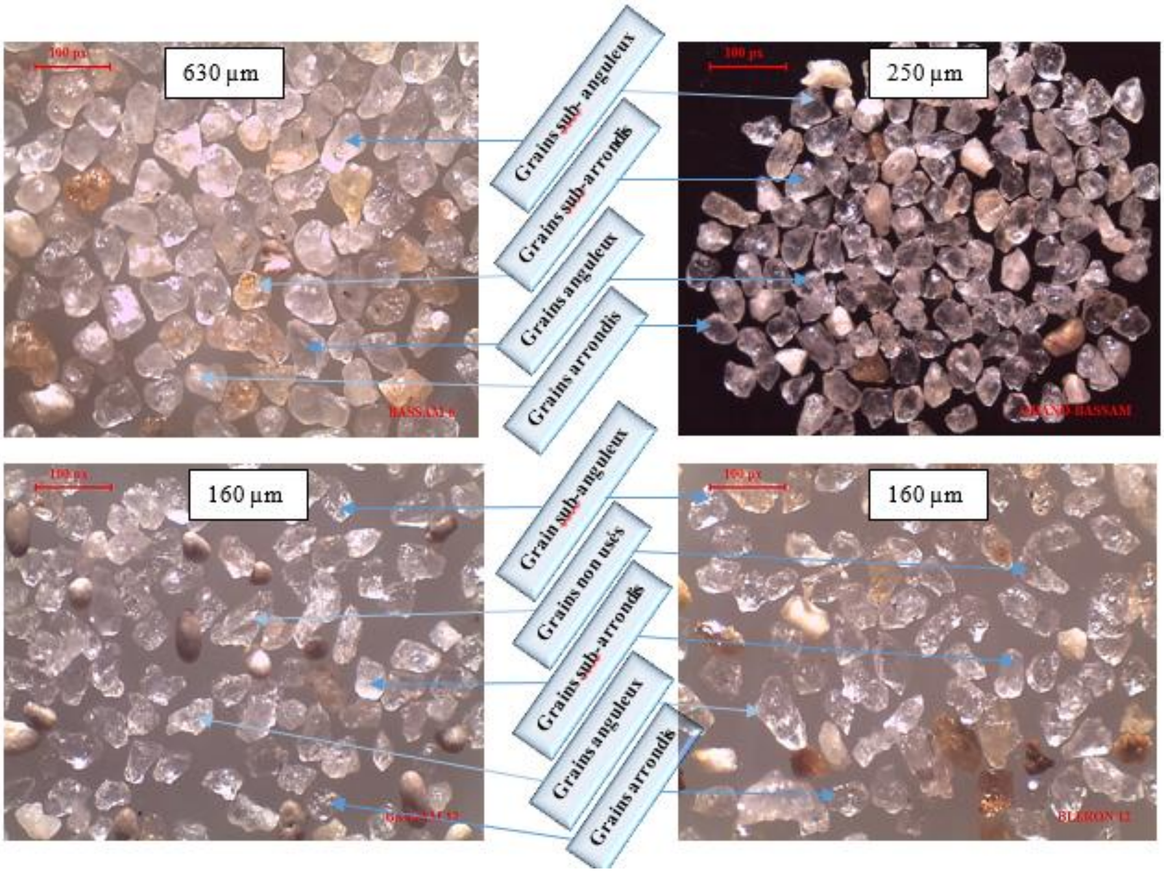

Figure 10: Morphoscopy of quartz grains of different fractions.

A second explanation could be found in the difference in methodology. [29]'s methodology is based on manual calculation from cumulative semi-logarithmic curves, while the present study uses Easysieve software. Furthermore, the peak at Sassandra could be justified by river transport. The Sassandra River allows the deposition of coarse sediments transported from the continent. The same observation has been made at the mouth of the Amazon River by [16]. The weathering of rock formations (cliffs, granite blocks) in situ could also justify this coarse granulometry. In addition, [23] suggest that granitic rocks emerge as shoals at the bottom of the Sassandra River mouth. The particle size distribution along the study area is in the direction of the longshore drift (west-east) as previous research conducted by the authors confirms [33]; [1]; [8]; [39]. [36] research on the Casamance coast (Senegal) confirms the movement of sediments by the longshore drift current. The decrease in medium grain size in the west-east direction on the coast and the sigmoidal shape of the cumulative semi-logarithmic curves indicate a gradual depletion of the energy of the marine current. This West-East direction, which is similar to the littoral drift, reflects a granulometry governed by the littoral drift. Studies by [35] on the thin sandy barrier of Assinie show a decrease in grain size in the west-east direction. This small-scale research corroborates the findings of this study. According to [28] on the surface sediments of the littoral fringe of Sidi Bou Saïd la Goulette, the less agitated an environment is, the better the sediment deposit in the environment is classified. This observation is well illustrated in this study where the East, characterized by a less agitated environment, is full of the best-classified grains. Several studies carried out on the Ivorian coast by Abe [1], [12], [43] and [19], [7], and [20] and [21] based on sedimentological analyses have revealed that the preferred mode of transport of quartz grains in this area is saltation with a predominantly monogenic source. This corresponds with the results collected in this study. A few variations were noted in Grand-Bassam, Sassandra, and San-Pedro where the source is mixed. This diversity of sources may be due to the presence of rivers such as the Comoe River in Grand-Bassam, the Sassandra River in Sassandra, and the San Pedro River in San-Pedro. Based on the analysis of the angular forms encountered at Sassandra concerning the drift, it is clear that the grains are more likely to have a fluviatile origin. This had been demonstrated by [20] and [21] on the origin of coastal sands between Sassandra-Fresco and Fresco-Jacqueville where the source was mainly continental. [23] also indicated a mainly fluvial origin in the coastal sector of Sassandra. Some other authors, such as [4] working on the eastern littoral zone, have concluded that the sediments have a marine origin. These sediments were transported by the westward drift and deposited as the transmission energy decreased. These sediments could be stored on the underwater beach and transported up the foreshore seasonally by frontal swells. Morphoscopic examination of the different granulometric fractions (630 µm, 250 µm, and 160 µm) showed a more pronounced quartz polishing in the west-east direction. This is the direction of the littoral drift. These grains of quartz from the rock weathering in the western part are transported eastwards. This was confirmed by the findings of [34] who indicated that the roundness characteristics of the quartz sands improved considerably as the transport distance increased. Blunt and shiny grains predominate in the coarse fraction (78% on average) and decrease in the medium fraction (75% on average) and the fine fraction (66% on average). The abundance of blunt and shiny grains decreases from coarse to fine, while the abundance of unworn grains decreases from fine to coarse. [26] confirm the abundance of blunt and shiny grains in the coarse fraction, noting that the proportion of blunt and shiny grains is more abundant in the coarse deposits (Îles de la Madeleine, Lachenaie, Sainte-Marthe, etc.) than in the finer estuarine or dune formations. Morphoscopic curves of the coarse fraction of sediments at the base of the Cretaceous in the Maine-et-Loire indicate that the percentage of blunt and shiny grains of size 210 µm decreases rapidly as grain size decreases [17]. Work by [26] on quartz from the Meridional Laurentians in Quebec showed an abundance of unworn grains in the fine fraction. These concluded that the source was nearby. These studies, although similar in result, do not reject the impact of the energy of the environment, which could contribute to a prolonged suspension of the grains resulting in unworn grains in the fine fraction despite having travelled long distances. It has been also reported by [2], in their study of the sediments of the Saïdia coast and the Moulouya estuary (northeast Morocco), that the predominance of unworn sand grains in the western part of the Moulouya estuary is a consequence of the marine erosion of the calcarenite cliffs. Blunt and shiny grains are more abundant in the coarse and medium fractions in this study. This was also revealed by [35], [13], and [20] in the Ivorian coastal zone.

5. Conclusion

The grain size distribution along the intertidal zone reveals two sequences characterized by decreasing grain size in the west-east direction of the littoral drift. The first sequence starts from the Ivorian-Liberian border at the village of Monogaga (San-Pedro region); and the second from the town of Sassandra to the town of Assinie (Ivorian-Ghanaian border). The coarse fraction is the beginning of the first sequence which ends with the medium fraction. The beginning of the second sequence is marked by the very coarse fraction, even gravel, and ends with the fine fraction. The transition from one particle size class to another is fairly regular, especially since the standard deviation analysis places more than 96.9% of the quartz grains in the very well to moderately classified classes.Also, the rather steep slope of the cumulative semi-logarithmic curves shows this homogeneity in the size of the quartz grains. The granulometric sequences are characterised by a pronounced and abundant polishing in the coarse fractions than the fine ones in the direction of the littoral drift. This means that the energy does not promote the deposition of the fine elements that last in the saltation so their fractions are the ones with more angularity.

References

[1] Abé J., 2005. Contribution à la connaissance de la morphologie et de la dynamique sédimentaire du littoral ivoirien (cas du littoral d'Abidjan) essais de modélisation en vue d'une gestion rationnelle. Thèse de Doctorat d'état, 145-159.https://inveniov1.uvci.edu.ci/record/7900

[2] Bellahbib N., Rezqi H., Oujidi M., Bengamra S.,2015. Etude granulométrique et minéralogique des sédiments superficiels du littoral de saïdia et de l'estuaire de la moulouya (Nord-Est du maroc). Larhyss Journal 24, 19-40. http://larhyss.net › ojs › larhyss › article › download

[3] Costanza R, d'Arge R, de Groot R, Farber S, Grasso M, Hannon B, Limburg K, Naeem S, O'Neill RV, Paruelo J, Raskin RG, Sutton P, van den Belt M. 1997. The value of the world's ecosystem services and natural capital. Nature 387: 253-260

[4] Dangui P., Saimon A., Bamba Y., Kesse N., Hauhouot C., Monde S., 2015. Analyse du remaniement sédimentaire dans le cycle intertidal de marée dans le littoral Côte d'Ivoire (golfe de guinée). Bioterre, 15.

[5] Folk R. L. et Ward W. C.,1957: Brazos River bar: a study in the significance of grain size parameters. J. Sedim. Petrol. 27, 3-26. DOI:10.1306/74D70646-2B21-11D7-8648000102C1865D

[6] Gbamble B. Y. A., Yao K. S., Gbegbe M., Konan K. E., Abe J., Monde S., 2016. Variation latérale de faciès granulométrique et du cortège minéralogique du transit lonshore d'Abidjan à Assinie.Bioterre, Rev. Inter. Sci. de la Terre 16, 49-54.http://www.revues-ufhb-ci.org › fichiers

[7] Gbangbot J-M. K, N'Doufou G. H. C., Saimon A. A. M., 2018. Sedimentological characterization of subsurface formations of the tertiary - quaternary in the dabou region (South of Ivory Coast). International Journal of Engineering and Applied Sciences (IJEAS) 5, 86. DOI:10.31873/IJEAS.5.10.22

[8] Hauhouot C., 2010. Le littoral d'Assinie en Côte-d'Ivoire: dynamique côtière et aménagement touristique.Les Cahiers d'Outre-Mer.Revue de géographie de Bordeaux, 305-320. https://doi.org/10.4000/com.6023

[9] INS, 2014. Recensement Général de la Population et de l'Habitat (RGPH-2014), Résultats Globaux. www.ins.ci

[10] Kirk R. M., 1992. Artificial beach growth for breakwater protection at the Port of Timaru, east coast, South Island, New Zealand. Coastal Engineering17, 227-251. https://doi.org/10.1016/0378-3839(92)90053-W

[11] Krinsley, D.H., Doornkamp, J.C., 1973. Atlas of Quartz Sand Surface Textures. Cambridge University Press, 1-91.

[12] Konan K. E., 2012.Etude morpho-dynamique et sensibilité aux événements exceptionnels du cordon littoral sableux ivoirien à l'Est d'Abidjan (Abidjan-Aforenou). Thèse Unique de Doctorat, 729-224.

[13] Konan K. E., N'doufou G. H. C., N'guessan Y A., Koffi K. P. et Bamba S. B., 2018. Contribution des analyses morphoscopique et exoscopique des grains de quartz des plages ivoiriennes à la reconstitution des environnements de dépôts quaternaires. Rev. Ramres 06, 25-28.

[14] Koffi K. P., (2017) -Étude de l'évolution morphosédimentaire du littoral ivoirien: remaniement sédimentaire à l'échelle multi-temporelle. Thèse de Doctorat. Univ. Félix Houphouët Boigny, Abidjan, 321p.

[15] Leneuf N., 1968. Le Continental terminal. Rapp. inéd., 37.

[16] Luglia M., 2014. Caractérisation et facteurs structurants des fonctions microbiennes des sédiments de la zone intertidale en Guyane française : des

vasières estuariennes aux mangroves matures. Thèse de Doctorat, 85.
[17] Louail J., 1969.Etude sédimentologique des sables et graviers de jumelles (maine et loire) origine et mise en place des formations situées à la base du crétacé en maine-et-loire, 71. https://hal-insu.archives-ouvertes.fr/
[18] Migniot C., 1990. Manuel sur l’hydrodynamique sédimentaire et l’érosion et sédimentation du littoral, 159.
[19] N’doufou G. H. C., 2012. Contribution de l’étude morpho sédimentologique et exoscopique à la compréhension de l’évolution du secteur du littoral ivoirien entre Sassandra et Abidjan. Thèse de Doctorat, 193. archives.uvci.edu.ci
[20] N’doufou G. H. C., Konan K. E., Boga A. H., Monde S.et Abe J., 2018. Origine et évolution des quartz du littoral compris entre Fresco et Jacqueville, Côte d’Ivoire. Afrique Science14, 171-180. http://www.afriquescience.info
[21] N’doufou G. H. C., Gbangbot J-M. K. et Saimon A. A. M., 2019. Mineralogical, granulometric and environmental characterization of recent quaternary deposits of beaches between Sassandra and Fresco (Ivory Coast). International Journal of Multidisciplinary Research and Development 6, 44-51.www.allsubjectjournal.com
[22] N’guessan Y.A., Konan K.E., Diangone E., Wango T.E., Affian K., Monde S. et Aka K., 2013. Caractérisation sédimentologique des facies sableux de la lagune potou (littoral de la Côte d’Ivoire). Bioterre, Rev. Inter. Sci. de la Terre13, 53.
[23] N’guessan Y. A., Amani E. M., Koffi B. K. F., Adopo L., Diangone B. E., Monde S. et Kouadio A., 2014. Caractérisation morphologique et sédimentologique de l’embouchure du fleuve Sassandra (Côte d’Ivoire). Afrique Science 10, 277-288.
[24] Paskoff R., 1993. Côtes en danger. "Pratiques de la Géographie" Ed. Masson, 250.
[25] Pryor WA. 1971. Grain shape. In Procedures in Sedimentary Petrology , Carver RE (ed). Wiley: New York; 131–150.
[26] Ritchot G. et Cailleux A., 1971. Taxonomie géomorphologique et morphoscopie de sables au québec méridional. Cahiers de géographie du Québec 15, 423-438. DOI:10.7202/020980ar
[27] Saaidi E., 1991. Traité de sédimentologie. Edition Ellipses,393.
[28] Saidi H., Brahim M. et Gueddari M., 2004.Caractérisation granulométrique et minéralogique des sédiments de surface de la frange littorale sidi bou said - la goulette.Bull. Inst. Natn. Scien. Tech 31, 100-103.
[29] Saimon A. A. M., Konan K. E. et N’ganza K. P. A., 2019.Suivi, observation et disposition des grains de quartz par saison dynamique et par cycle de marée sur les plages du golfe de guinée au niveau d’abidjan (côte d’ivoire).Geo-Eco-Marina; Bucharest, 147-159.
[30] Tape J. G., 2000. Structures spatio-temporelles des peuplements de poisons démersaux du plateau continental de Côte d’Ivoire. Analyse de deux séries de campagnes de chalutage (1978-1986, 1993-1995). Thèse de Doctorat 3ème cycle ; Univ. de Cocody ; UFR Biosciences. 119 p.
[31] Tricart J., 1965. Principes et méthodes de la géomorphologie. Edition Masson, 496.
[32] Tastet J. P., Martin L. et Aka K., 1993. Géologie et Environnement Sédimentaire de lamarge continentale de Côte d'Ivoire in Environnement et Ressources Aquatiques de Côte d'Ivoire. Edition ORSTOM, 23-61.
[33] Tastet J. P., Caillon L., Simon B., 1985. La dynamique sédimentaire littorale devant Abidjan: Impact des aménagements. Contribution à la compréhension des phénomènes d’érosion et de sédimentation, 39.
[34] Timireva S. N. et Velichko A. A., 2006. Depositional environments of the Pleistocene loess-soil series inferred from sand grain morphoscopy—A case study of the East European Plain. ScienceDirect. DOI:10.1016/j.quaint.2005.12.013
[35] Toure M., Kpan B. C., Wango T-E., Monde S. et Dosso S., 2016.Caractérisation pétro-sédimentaire des cordons littoraux fossiles d’Assinie, Côte d’Ivoire. Rev. Ivoir. Sci. Technol 27, 223-236.
[36] Thior M., Sané T., Sy O., Descroix L., Ndiaye L. G., Sambou A. K., Cissokho D. et Solly B., 2019. Caractéristiques granulométriques et dynamique sédimentaire entre les différentes unités géomorphologiques du littoral de la Casamance (Sénégal). Revue Ivoirienne des sciences et technologies33, 189-213. https://hal-normandie-univ.archives-ouvertes.fr/
[37] Varlet F., 1958 - Le régime de l'Atlantique près d'Abidjan (Côte d'Ivoire). Essai d'océanographie littorale. Extrait des Etudes Eburnéennes, 222.
[38] Visher G. S., 1969. Grain size distributions and depositional processes. Jour. Sedim. Petrol., Tulsa 39.
[39] Wognin A. V., Assale F. Y. P., N’Guessan Y. M., Diangone E. T. et Monde S., 2016. Hydrosedimentary characterization and mouth migration process of bandama’s river (Côte d’Ivoire). Int. J. Adv. Res.4, 632-640.
[40] Wollast R., 1991. The Coastal Carbon Cycle : Fluxes, Sources and Sink. In: R. F. Mantoura, J.M. Martin and R. Wollast eds., Ocean Margin Processes in Global change. John Wiley & Sons,Chichester, 1427-1436p.
[41] Woronko B., Zieliński P., Sokołowski R. J., 2015. Climate evolution during the Pleniglacial and Late Glacial as recorded in quartz grain morphoscopy of fluvial to Aeolian successions of the European Sand Belt. Geologic 21, 89-103.DOI: 10.1515/logos–2015-0005
[42] Yao K. S., Abe J., Bamba S. B., Konan K. E. et Aka K., 2010. Dynamique d'un périmètre littoral portuaire : la côte de San-Pédro, Sud-Ouest de la Côte d’Ivoire. Revue Paralia 3,1-12.
[43] Yao K. S., 2012. Etude de la dynamique sédimentaire du littoral occidental ivoirien entre Tabou et Sassandra: Approches morpho-bathymétrique, sédimentologique et exoscopique. Thèse de Doctorat, 187.