Revue Paralia, Volume 1 (2008) pp 2.11-2.20
Keywords: River mouth, Estuary, Sediment, Bathymetry, Comoé, Côte d'Ivoire.

Characterization of the sediments and morphology of the Comoé river mouth (Grand-Bassam, Côte d'Ivoire)

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Abstract:
The grain size analysis and the bathymetric surveys carried out between 2005 and 2007, made it possible to characterize the sediments and the morphology of the bottom of the mouth of the River Comoé prone to important morphodynamic modifications. On the beach, the sediments consist mainly in coarse and middle sands whereas in the estuary muddy fine sediments are predominant. The variety of minerals on the beach is more important than what is observed in the estuary.
The annual deposits within the estuary are lower than marine deposits in the near beach region. This study made it possible to carry out the first bathymetric charts of the estuary of the River Comoé.

Received 16 June 2008, accepted 29 December 2008, available online 29 December 2008.
Translated version not certified, published under the responsibility of the article authors.

How to cite the original paper:
ADOPO K.L., KOUASSI K.L., WOGNIN A.V.I., MONDE S., AKA K. (2008). Caractérisation des sédiments et morphologie de l'embouchure du fleuve Comoé (Grand-Bassam, Côte d'Ivoire). *Revue Paralia*, n° 1, pp 2.1–2.10.
DOI: 10.5150/revue-paralia.2008.002 (disponible en ligne – http://www.paralia.fr)

1. Introduction

The estuaries, zones where rivers meet the sea, present a rather complex sediment dynamics (LE NORMANT, 1995; GOUBERT *et al*., 2008; DI MATTEO & MILLI, 2008). This dynamics is characterized by an important deposition of the particles transported by river and marine water. Dynamic deposits modify the morpho-structure of the estuarine landscapes.

In Côte d'Ivoire, the mouths of the large rivers (Comoé, Bandama, Sassandra and Cavally) are affected by a continuously accentuated dynamism which generally results in displacements of the points of junction river-sea (ABE, 1995; WOGNIN *et al*., 2007). The Comoé mouth in Grand-Bassam, is a complex hydrodynamic system influenced by river, Atlantic Ocean, and the Ebrié lagoon. Sediment dynamics is even more spectacular as a consequence of the successive deposits of sediments creating sandy banks which break the natural connexion between river and ocean (KOFFI & ABE, 1991).

The accelerated filling of the mouth produces significant modifications of physicochemical parameters and a fast development of watery plants in the lagoon (SANKARE & ETIEN, 1991; SANKARE *et al*., 1991). Dredging works were carried out to open this mouth which always closed again a few years later (TASTET, 1979; ABE *et al*., 1996). Thus, opening operations were carried out in 1987,1990 and 2005 after the fillings observed in 1975,1989 and 2003 respectively. The closing of this mouth involves perturbations of the estuarine environment. In fact, ABE (1995) indicated that the closing of the mouth of the Comoé river would have important simultaneous consequences on sedimentological (silting), chemical (pollution, desalinisation), ecological and economical (fishing, tourism) parameters.

In spite of the dangers linked to the closing of the mouth of the Comoé river, only a few studies try to explain the hydrodynamic and sedimentological processes which take place in this site (ABE *et al*., 1996; ADOPO *et al*. 2008).

Knowledge of sedimentary dynamics in the estuaries makes it possible to understand the processes of silting and filling in these environments. It also contributes to the comprehension of the physicochemical and biological parameters in these complex environments which involve transit, transfer and storage of sediments (AVOINE *et al*., 1986; SANCHEZ & LEVACHER, 2007; AMEY *et al*., 2007).

The present study aims to characterize the nature of the sediments and the morphology of the mouth of the Comoé river.

2. Situation and methods

2.1. Localization, geological and climatic frame

The estuarine sector of the Comoé river is located in the Eastern part of Ebrié lagoon. It is located between 5°12' and 5°14' North latitude and 3°42' and 3°44' West longitude. This zone constitutes the largest estuary of Côte d'Ivoire (Ivory Coast), (KOFFI & ABE, 1991). The study zone covers the surroundings of Morin island in the North, the bridge of Moossou at the junction of the Comoé river and the Ebrié lagoon, Bouet island and an offshore bar in the South. It includes the Comoé river up to the village of Yaou in the North-East (figure 1).

The estuarine zone of Comoé river drains all the hinterland and covers a surface area of 78000 km².

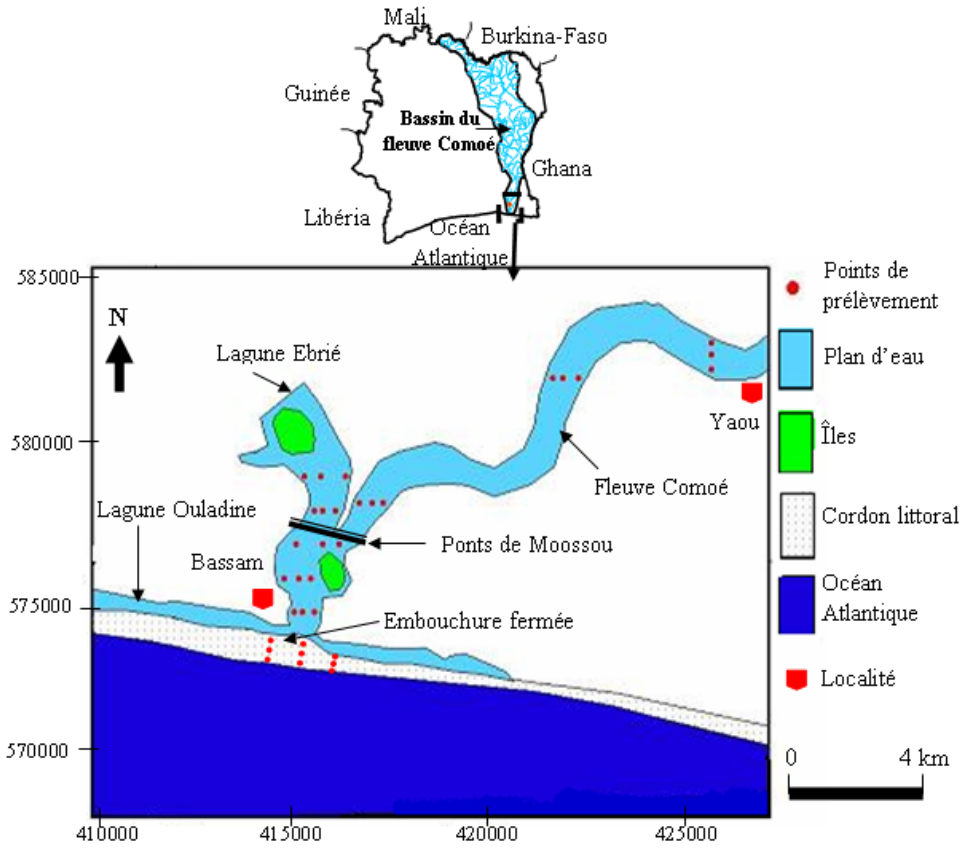


Figure 1. Localization of the estuary of the River Comoé in Grand-Bassam.

2.2. Method of study

In order to determine the granulometric characteristics of sands of the mouth of the Comoé river, 24 samples of sediments were taken over eight radial lines in the estuary (see figure 1) using a Van Veen grab sampler. Nine other sand samples

were also taken close to the mouth over three beach profiles from high, mid and low intertidal zone. The morphology of the beach is relatively monotonous in the vicinities of the mouth. In this study, sediments were analyzed according to a technique described by SAAIDI (1991). The organic matters and shelly debris were eliminated respectively by using hydrogen peroxide solution 30% and hydrochloric acid solution 50%. After separation of the fraction lower than 63 µm, each sand sample was examined through a dry granulometric analysis in a column with 16 sieves (series AFNOR). Sands of the estuary were characterized through the granulometric average (Mz), the skewness (Sk) and the index of classification (So), determined by the methods of FOLK (1974).
The study of the morphology of the bottom of the estuary was performed by means of bathymetric surveys, carried out with a Lowrance echo-sounder, model LMS-160. Four topographical surveys were carried out over an annual seasonal cycle in the vicinities of the mouth in order to determine the quantities of sands deposited or eroded in the beach. The sedimentological and positioning charts were established using software ArcView 3.3 and SURFER 8.2.

3. Results

3.1. Description of the sedimentary facies

The granulometric analysis of surface sediments of the estuary of the River Comoé shows three different lithological sediments. They are sands, fine-grained cohesive sediments and mixed sediments. Cohesive sediments are mainly located in the border banks. Mud is black and very rich in organic matters. Fluid mud has a grey colour and is also rich in organic matters. The mixed sediments consist in muddy sands and sandy muds. Their colour varies from olive black to olive grey. They contain vegetable and shelly debris.
The granulometry study of the sand fraction shows that the grains are ranged from fine to coarse. The granulometric average of sands varies between 67 and 765 µm (table 1). The indexes of classification range between 0.58 and 1.12. This indicates that sands in the estuary range from moderately well-sorted to poorly sorted. The indices of asymmetry (skewness) varies from 0.06 to 0.25 indicating a strong asymmetry towards the small sizes.
In the beach, the grain size of sands increases, as a general rule, from the high intertidal zone (525 µm in average) to the low intertidal zone (918 µm in average). The asymmetry indexes are negative (-0.13) in the high intertidal zone and positive (0.12) in the mid and low intertidal zone. The index of classification is always close to 0.29.

Tableau 1. Granulometry of sands in Comoé river mouth.

		Mean granulometric dimensions (µm)			
		Minimum	*Maximum*	*Average*	*Standard deviation*
Estuary		*67*	*765*	*329*	*231.12*
Beach	*High intertidal zone*	*469*	*708*	*525*	*86.34*
	Mid intertidal zone	*532*	*824*	*756*	*74.57*
	Low intertidal zone	*863*	*1012*	*918*	*62.60*

3.2. Mineralogy of sands

The mineralogical spectrum of sands of the mouth of the Comoé river is characterized by a set of heavy and light minerals.

In the estuary, main heavy minerals found in the sandy fraction are primarily garnet (2%), amphibole (2%), pyroxene (4%), yellow tourmaline (3%) and epidote (2%). Among light minerals, one finds quartz (77%), mica (7%) and feldspar (3%).

Heavy minerals found in the beach sand are composed of amphibole (1%), epidote (3%), leucoxene (3%), siderite (1%), sillimanite (2%), the rutile (4%), chrysoberyl (2%), ilmenite (14%), limonite (4%), monazite (3%), tourmaline (3%), pyroxene (2%), diopside (3%), gold (1%), garnet (3%) and zircon (3%). Quartz is the more abundant light mineral (48%) in the samples.

3.3. Morphology of the bottom of the estuary of the Comoé river

The detailed examination of the bathymetry of the estuary of the Comoé river reveals a relatively complex bottom morphology (figure 2).

The isobaths structures in figure 2 show that the main channel of the river has a NE-SO direction.

Depths decrease from upstream waters towards the mouth of the river. However, the highest depths (14 m) are observed close to the two Moossou bridges. The basin of the estuary presents, as a rule, relatively weak slopes which vary between 0.4 to 2.6%. In the vicinities of the mouth, the general structure of the bottom morphology includes some shallow and depression zones.

The comparison of the bathymetric charts drawn up respectively in 2005 and 2007 made it possible to appreciate the evolutions of the estuary bottoms. It is observed that this estuary is affected by an average thickness deposit of approximately 20 cm over the two years (2005-2007), that is to say, 10 cm over one year.

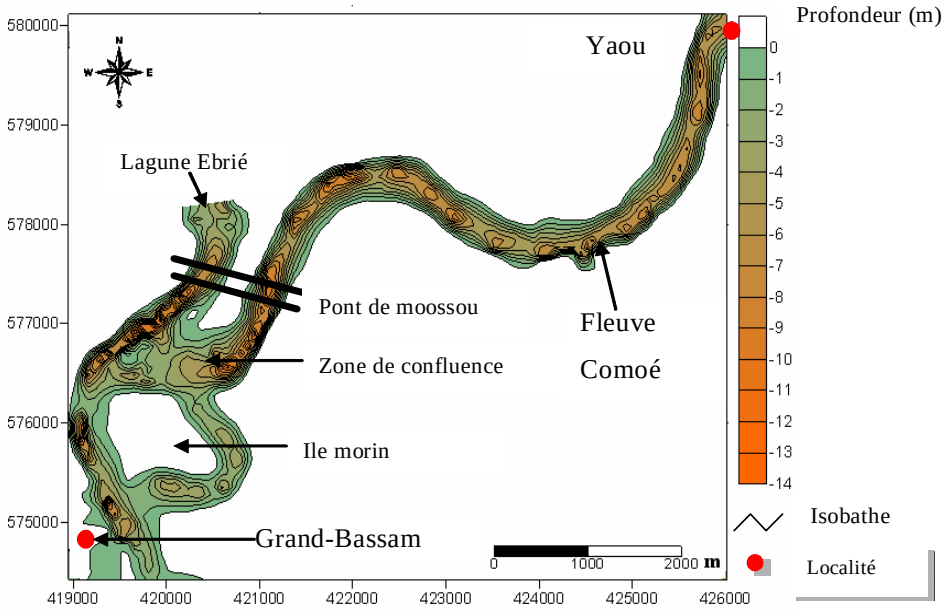
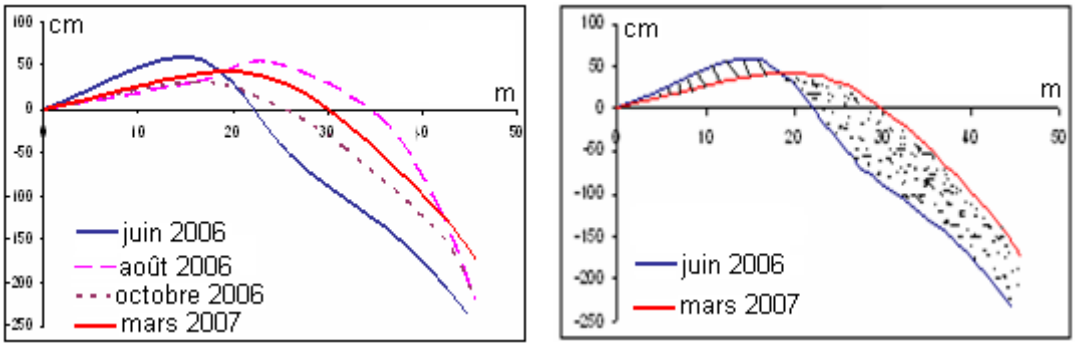


Figure 2. Bathymetry of the estuary of the River Comoé (August 2005).

3.4. Evolution of the beach profiles

Survey of beach profiles over an annual seasonal cycle, made it possible to appreciate the sedimentary movements at the mouth of the Comoé river. In order to allow the comparisons, the profiles on the axis of the mouth appreciably keep the same length during the seasons (figure 3). The more significant morphologic fluctuations in the beach are observed in the low intertidal zone. The comparison of the profiles from June 2006 to March 2007 shows that the high intertidal zone is affected by erosion and the mid and low intertidal zones by deposition. The thicknesses of deposits reach 1 m in some places. The average annual thickness of deposits is about 60 cm.



***a** : Seasonal evolution*

***b** : Evolution between June 2006 and March 2007*

Figure 3. Evolution of the profile of beach in the Comoé river mouth between June 2006 and March 2007.

4. Discussion

The sediments of the estuarine sector close to the mouth of the Comoé river, where this river meets the Ebrié lagoon and Ocean contains cohesive sediments and sands. On the other hand, on near beach, one finds mainly coarse and middle sands.

The mineralogical analysis of sands shows that heavy and light minerals are present in the beach as well as in the estuary. However, one observes a more important specific diversity of minerals in the beach. This fact can be explained by the littoral drift which moves various types of sands from the West towards the East of the Ivory Coast littoral (AKA, 1991). The minerals found in the estuary belong to those described by BROCHE *et al*. (1977) in the upper part of the catchment area of the Comoé river.

The annual thicknesses of deposits (10 cm in average) recorded during this study in the estuary are rather small and can not explain the fast closing of the mouth. These evaluated thicknesses of deposits are in agreement with solid transport in suspension in the Comoé river which is about 72000 tons per year according to ADOPO *et al.* (2008).

On the other hand, sedimentary littoral dynamics is rather significant and causes deposits whose thickness can reach 1 m per year within the region of the Comoé river mouth. This quantity of deposit seems to constitute the main cause of the fast closing of the mouth of this river. It is to be noted that ABE *et al*. (1996) consider that the irregular character of the flows of the Comoé river could explain, partly, this closing. In fact, according to these authors, the significant reduction of river flows during low water periods, in particular during these last decades, limits the penetration of continental water in the ocean. It then creates for itself a barrier which produces the deposits of sediments.

5. Conclusion

The grain size and mineralogical analysis showed that the sediments near the mouth of the Comoé river consist in coarse sands in the beach whilst the estuarine sector contains rather cohesive sediments and muddy sands. The annual thicknesses of deposits in the estuary are less than the marine deposits. The hydrodynamic actions constitute in this context, a determining factor in the control of sediment dynamics.

Research works continue in order to carry out a numeric model for the sedimentation in the estuary of the Comoé river.

6. Acknowledgement
This research was supported by the International Foundation for Science (IFS, Sweden). We sincerely thank this institution for its financial contribution to our work.

7. References
ABE J. (1995). *Etude comparative de la dynamique sédimentaire aux embouchures des fleuves du littoral ivoirien*. Proc. Int. Conf. "Costal change 95" Bordomer-IOC, Bordeaux, pp 347-363.
ABE J., BAKAYORO S., BAMBA S, CISSOKO S. (1996). L'hydrologie de l'estuaire du Comoé à Grand-Bassam (Côte d'Ivoire). *Agronomie Africaine. Journal Ivoirien d'Océanologie et Limnologie*. Vol. 8, n° 3, pp 201-212.
ADOPO K.L., KOUASSI K.L., WOGNIN A.V.-I. (2008). Spatial Distribution and Characterisation of the Sediments of the Estuary of Comoe River (Grand-Bassam, Côte D'ivoire). *European Journal of Scientific Research*, Vol. 20, n° 4, pp 817-827.
AKA K. (1991). *La sédimentation quaternaire sur la marge de la Côte d'Ivoire: Essai de modélisation*. Thèse de Doctorat d'Etat ès Sciences Naturelles, Univ. d'Abidjan, Côte d'Ivoire, n° 146, 320 p.
AMEY K.B., BEDJA K., NEGLO K. (2007). Distribution longitudinale de la granulométrie du sable littorale togolais : grain moyen, sorting index et skewness. *Journal des Sciences pour l'Ingénieur*, n° 8, pp 1-8.
AVOINE J., DUBRULLE L., LARSONNEUR C. (1986). *La dynamique sédimentaire dans les estuaires de la baie de seine – conséquences sur l'environnement*. La Baie de Seine (GRECO-MANCHE) - Université de Caen, IFREMER, Actes de Colloques n° 4, pp 183-192.
BROCHE J., CASSANOVA R., LOUP G. (1977). *Atlas des minéraux en grain, identification par photographies en couleurs*. Société pour le développement minier de la Côte-d'Ivoire, 173 p.
DI MATTEO A., MILLI A. (2008). Morphological, bathymetric and sedimentological surveys used to assess the coastline defensive measures. *Int. J. Environ. Sci. Tech.*, Vol. 5, n° 3, pp 415-424
FOLK R.L. (1974). *Petrology of sedimentary rocks*. Hemphills, Austin, Texas, 182 p.

GOUBERT E., FRENOD E., PEETERS P., THUILLIER P., VESTED H.-J., BERNARD N., VERON V., ALLANO L. (2008). *Caractérisation du fonctionnement hydrosédimentaire de l'estuaire de la Vilaine à partir d'études bathymétriques et altimétriques (Altus).* X^{èmes} Journées Nationales Génie Côtier – Génie Civil, Sophia Antipolis, pp 81-90. Paper available online [URL http://www.paralia.fr/jngcgc/10_08_goubert.pdf]

KOFFI K, ABE J. (1991). Contribution à l'étude des modifications hydro-sédimentaires consécutives à la réouverture artificielle de l'embouchure du Comoé à Grand-Bassam. *Journal Ivoirien d'Océanologie et Limnologie*. Vol. 1, n° 2, pp 47-60.

LE NORMANT C. (1995). *Modélisation numérique tridimensionnelle des processus de transport des sédiments cohésifs en environnement estuarien*. Thèse de doctorat, Institut National Polytechnique de Toulouse ; spécialité physique et chimie de l'environnement. n° 1002, 253 p.

SAAIDI E. (1991). *Traité de sédimentologie. Pétrographie, environnements sédimentaires*. Editions Ellipses, 393 p.

SANCHEZ M., LEVACHER D. (2007). The influence of particle size of the dispersed mineral fraction on the settlement of marine and estuarine muds. *Geo-Marine Letters*, Vol. 27, n° 5, pp 303-313.

SANKARE Y., ETIEN N. (1991). Analyse des effets de l'ouverture du chenal de Grand Bassam (estuaire du fleuve Comoé, Lagune Ebrié) sur la macrofaune benthique lagunaire. *Journal Ivoirien d'Océanologie et Limnologie*, Vol. 1, n° 2, pp 81-90.

SANKARE Y., KOTHIAS A.J.-B., KONAN A.A. (1991). Les effets de la réouverture de l'embouchure du fleuve Comoé sur la végétation littorale lagunaire (Lagune Ebrié – Côte d'Ivoire). *Journal Ivoirien d'Océanologie et Limnologie*, Vol. 1, n° 2, pp 71-79.

TASTET J.P. (1979). *Environnements sédimentaires et structuraux quaternaires du littoral du Golfe de Guinée (Côte d'Ivoire, Togo et Bénin).* Thèse de doctorat, Université de Bordeaux I, n° 621, 175 p.

WOGNIN A.V., MONDE S., AFFIAN K., COULIBALY A., AKA K. (2007). Modèle de circulation des eaux dans l'estuaire du fleuve Bandama en Côte d'Ivoire. *Sud Sciences & Technologies*, n° 15, pp 5-12.