OCEANOLOGICA ACTA 1986 - VOL. 9 - N° 3

Hydrosedimentological processes and soils of the Barito estuary (South Kalimantan, Indonesia)

Indonesia
Barito estuary
Superficial sediment
Hydrodynamics
Soils

Indonésie
Estuaire Barito
Sédiment superficiel
Hydrodynamique
Sols

Ph. BASSOULLET [a], R. DJUWANSAH [b], D. GOULEAU [c], C. MARIUS [d]

[a] Institut Français de Recherche pour l'Exploitation de la Mer (IFREMER), Centre de Brest, B.P. 337, 29273 Brest, France.

[b] Lembaga Geologi dan Pertambangan Nasional (National Institute of Geology and Mining), LIPI (Indonesian Institute of Sciences), Jalan Cisitu, Sangkuriang n° 21/154 D, Bandung, Indonesia.

[c] Université de Nantes, Laboratoire de Géologie Marine, 2, rue de la Houssinière, 44072 Nantes, France.

[d] Université Louis Pasteur, Institut de Géologie, 1, rue Blessig, 67084 Strasbourg, France.

Received 8/3/85, in revised form 4/3/86, accepted 10/3/86,

ABSTRACT

A pluridisciplinary study was carried out in the south-eastern part of Kalimantan (Indonesia) in a deltaic area close to Banjarmasin town.

Upstream from Banjarmasin, Barito river divides into two branches, one of which meets the Kapuas river slightly further to the west, to form the Kapuas Murung estuary.

This programme is designed to increase knowledge about the physical and sedimentological processes, physical and chemical properties of the soils, and hydrological and chemical parameters of the Barito estuary.

Barito estuary was chosen for two main reasons. First, it constitutes an important waterway for the region, on which Banjarmasin harbour is located; second, the management of the sparsely occupied coastal areas is becoming a priority. The transmigration area of Tabunganen, close to the coast (with some saline intrusion problems) is significant in this connection.

The study, some results of which are presented here, is not complete; this is especially due to a lack of data during the rainy season. But its aim is to provide the basis for any future complementary study.

Oceanol. Acta, 1986, **9**, 3, 217-226.

RÉSUMÉ

Les processus hydrosédimentologiques et les sols de l'estuaire du Barito (Sud Kalimantan, Indonésie)

Une étude pluridisciplinaire a été menée dans la partie sud-est de Kalimantan dans une zone deltaïque proche de l'agglomération de Banjarmasin.

En amont de cette ville, le fleuve Barito se sépare en deux bras dont l'un rejoint un fleuve légèrement plus à l'ouest, Kapuas, pour constituer l'estuaire du Kapuas Murung.

Ce programme a pour but de mieux connaître les processus physiques et sédimentologiques, les propriétés physiques et chimiques des sols, les paramètres hydrologiques et chimiques de l'estuaire du Barito. Le choix de l'estuaire du Barito est principalement fondé sur deux raisons. D'une part, il constitue un axe navigable important pour cette région; axe sur lequel est situé le port de Banjarmasin. D'autre part, l'aménagement de zones plus côtières, très peu occupées, devient prioritaire.

L'implantation de la zone de transmigration de Tabunganen, proche de la côte (avec les problèmes d'intrusion saline qui y sont liés) est significative de ce fait.

Cette étude, dont quelques résultats sont présentés ici, n'est pas complète; en particulier par le manque de données en saison des pluies. Mais elle a pour but de définir les bases pour toute étude complémentaire future.

Oceanol. Acta, 1986, **9**, 3, 217-226.

0399-1784/86/03 217 10/$ 3.00/© Gauthier-Villars

INTRODUCTION

Indonesian coastal plains are among the most densely populated regions of the globe. An increased pace of development is foreseeable in connection with plans to develop tidal irrigated rice fields.

As the coastal zone is an area of interaction between the continental and marine environments, any change in this zone might affect both environments in a positive or negative way. Within the framework of French-Indonesian Cooperation in Oceanology, on the theme "Coastal zones management, Barito Research Program", a first piece of pluridisciplinary fieldwork, involving measurements and samplings, was carried out in August 1983 by a team of French and Indonesian scientists.

A location map of the study area is presented in Figures 1 and 2. The study of hydrosedimentological processes covered the Barito estuary from the Serapat canal (15 km north of Banjarmasin) to 5 km offshore from Tanjung Pedadatuan and westwards up to a distance of 10 km from the Barito.

The soil survey covered the area between the Tamban Canal to the north, the Barito River to the east, the shoreline to the south and a line from Kuala Lupak to Tamban Canal to the west.

Due to the poor quality of the geographical maps, only a reconnaissance was possible, although almost all the creeks and canals were surveyed: 40 profiles were observed and 130 samples were taken (Fig. 2).

In the framework of the Transmigration Program, several canals have recently been built, of which the principal is Tabunganen. Barito delta is a swampy delta, mainly reclaimed now for rice cultivation.

Figure 1
Location map of the study area.
Localisation de la zone d'étude.

NATURAL ENVIRONMENT

Geography

The shape of the delta is almost quadrangular, bounded by the parallel Barito and Kapuas Murung rivers which flow from Central Kalimantan to the Java Sea. These rivers are connected by Pulau Petak river as the northern boundary (Fig. 2). Barito river, 650 km in length, is the most important of the South Kalimantan rivers.

Two big canals (Tamban and Serapat) join Kapuas Murung and Barito river.

Climate

With an average annual rainfall of 2823 m at Banjarmasin, the region is characterized as having a "perhumid bioclimate" by Fontanel and Chantefort (1978). This bioclimate, which covers approximately 20% of the Indonesian Archipelago, is marked by abundant precipitation, although the annual total is less than 3000 m. The rainfall is well distributed throughout the year and the monthly amount is mostly above 100 mm (Tab.). However some months may be subhumid, for example in Banjarmasin where August and September receive less than 100 mm. The annual average temperature is 26.8°C.

Geology

According to geological maps (Directorat Geologi Indonesia), the delta lies the southernmost part of a large Quaternary sediment along the southern coast of Kalimantan.

Almost all of the delta has remained up to the present under the influence of tidal fluctuation.

Along riversides and creeks, the marine sediment is covered by fluviatile sediment which physiographically forms river levees and transforms the inner part into a marine sedimentary basin. The upper watershed of the Barito includes two pretertiary formations consisting of schists, grauwackes and sandstones in association with older eruptive rocks (peridotites, gabbros, granits, andesits...).

Vegetation (Fig. 3)

Mangrove forest

One of the main products of this survey was the discovery of a very beautiful *Rhizophora* forest with trees rising to more than 20 m above water level. Two species of *Rhizophora* are represented: *Rhizophora apiculata*

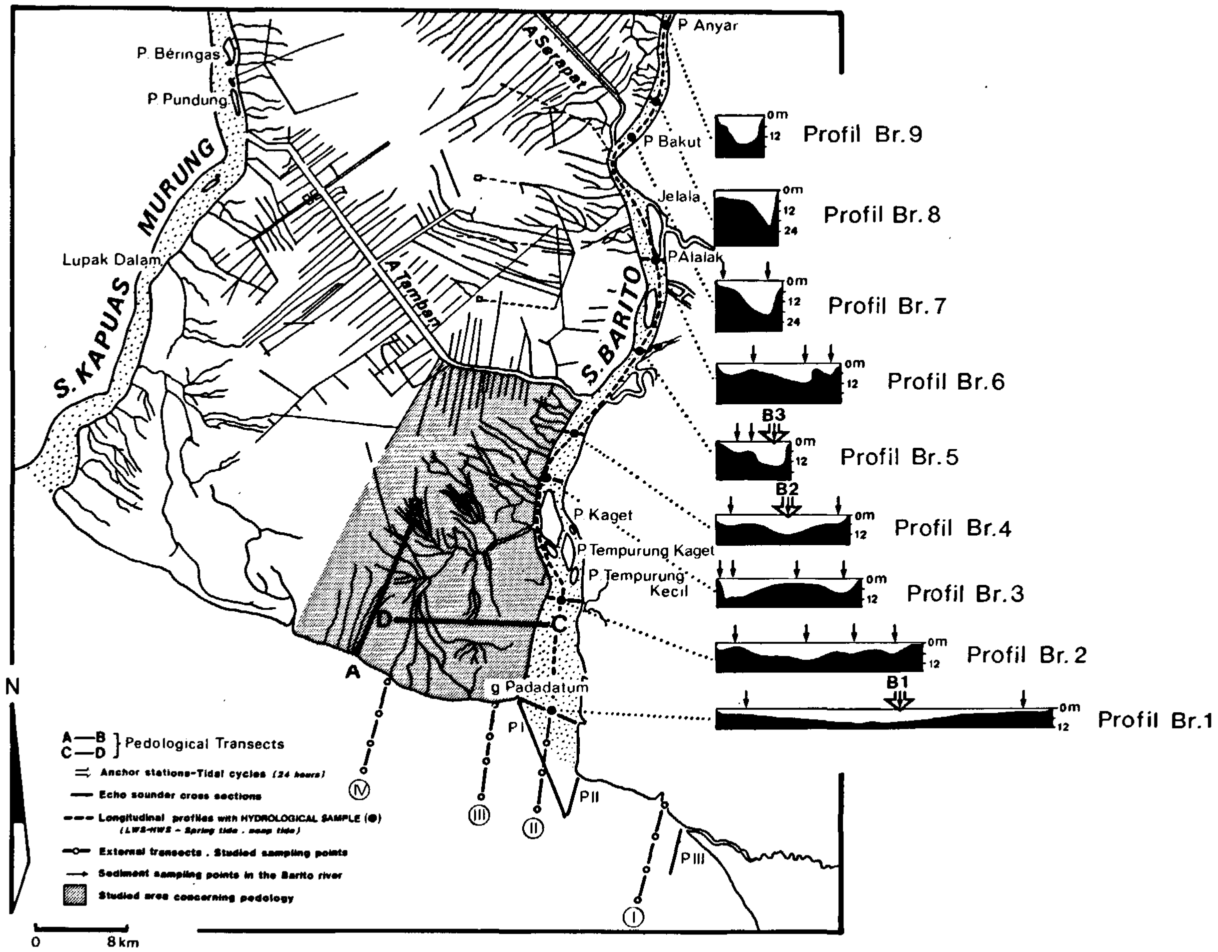


Figure 2
Illustrations: 1) Achrosticum-Rhizophora *association;* 2 *and* 4) Rhizophora; 3) Pandanus - Rhizophora - Melaleuca.

Table
Annual rainfall at Banjarmasin (1931-1960).
Pluviométrie annuelle à Banjarmasin (1931-1960).

Month	J	F	M	A	M	J	J	A	S	O	N	D	TOTAL
Rainfall (mm)	436	298	323	269	206	156	156	98	70	141	273	397	2823
Number of days	21	18	18	16	14	11	10	7	6	9	17	22	169

and *Rhizophora mucronata.* Along the river and on the shoreline, vegetation is mainly represented by *Sonneratia caseolaris,* species throwing out aerial roots like *Avicennia.*

Swamp forest

The natural swamp forest is located near the Rhizophora mangrove forest in Pisak besar river where several species of swamp forest are concentrated including: *Acanthus, Excoecaria agollocha, Cerbera* sp., *Nypa fruticans, Xylocarpus, Pandanus,* as well as several palm trees and mainly *Melaleuca leucadendron* (galam).

Freshwater swamp

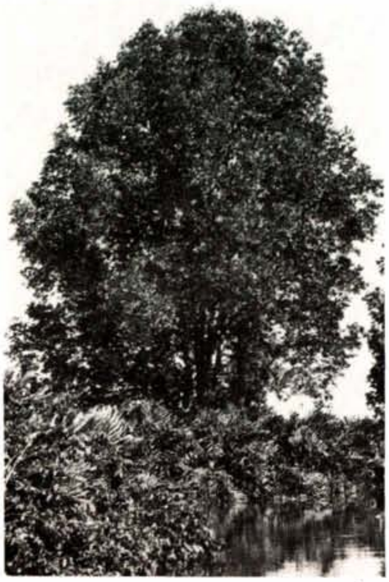
These swamps occupy the largest area of the delta and are generally reclaimed for rice cultivation. Three species are predominant: *Achrosticum aureum, Hibiscus tiliaceus* and *Cyperus rotundus.*

Species either of the mangrove forest or of swamp-forest are often associated with these species, and particularly with *Achrosticum.* The main associations observed are: *Achrosticum-Rhizophora, Achrosticum-Nypa* and *Achrosticum-Melaleuca.*

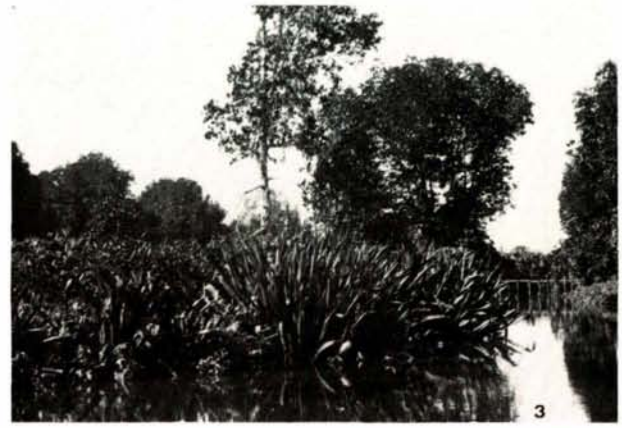
HYDROSEDIMENTOLOGICAL PROCESSES WITHIN THE BARITO ESTUARY

Most of the suspended material coming into the marine environment from the rivers is a fine-grained particulate material, which is responsible for filling inlets of estuaries and for the formation of deltaic complexes. The main processes acting on this particulate material (tidal current and river flow) were investigated.

As is the case with most estuaries included within a deltaic complex, Barito shows at its mouth on the



1



2

4

Figure 3
Situation map of the sampling points (hydrology-sedimentology) and pedological transects.
Localisation des prélèvements hydrologiques, sédimentologiques et coupes pédologiques.

Java Sea an important accretion shoal which requires frequent dredging to maintain a correct navigation channel. The presence of the shoal, continuous silting and a very deep upstream channel confer on the estuary some specific hydro-sedimentological features. The ten-metre isobath is reached between 20 and 60 km from the coastal line of the Pulau Petak delta. Zones in the process of erosion and accretion are described below.

As a preliminary to the hydrodynamic investigation of the Barito estuary, two types of measurements were conducted in August 1983:

— at anchor stations, in spring tide, to establish velocity profiles on a same vertical throughout a tidal cycle (24 hours);

— at nine points distributed along the estuary, in order to obtain a synoptical picture of the estuary in its entirety at a privileged moment of the tide.

The main hydrological parameters studied are: temperature, salinity, pH, dissolved oxygen, dissolved major constituents and their chemical variations in waters (Bassoullet, 1984).

Their dynamic of suspended matters, the mineralogy of the suspended sediments and bottom sediments, and the distribution of the latter within the Barito estuary and at the river mouth were all analysed.

We present here successively the main results relating to the hydrodynamics of the estuary, salinity and water temperature distribution, chemical variations of the dissolved silica in waters and the dynamics of suspended matters.

Hydrodynamics of the estuary

Tide ranges along the south coast of Kalimantan are 0.50 and 2.80 m respectively for neap and spring tide maxima. On this coast, the tide is mixed: diurnal during spring tides and semi-diurnal with very pronounced inequality during neap tides (with secondary high and low tides).

A situation map of the anchor stations (B1 to B3) and sampling points is presented in Figure 3 with bathymetry of nine cross sections.

The diagrams (Fig. 4) show:

- under spring tide and low water level conditions, the ebb duration is twice that of the flood. This ratio is obviously pronounced during the rainy season;
- for similar tidal coefficients, the inlet velocities (and notably ebb velocities) at the B1 station are higher in relation to the other stations. In fact, the maximum of the current velocity distribution is closely related to the topography. At the inlet, water depth is low (5 to 6 m) compared with the channel upstream from Banjarmasin (more than 15 m);
- as in most estuaries, ebb current velocities are higher than flood current velocities.

A point to be made here is that whereas all these mechanisms are very well known in estuaries with semi-diurnal tide, there is very little literature dealing with diurnal tide estuaries.

Current velocity measurements along longitudinal profiles within the estuary at a privileged moment of the tidal cycle show a more pronounced water column stratification during neap tide than during spring tide. This is due to a very pronounced residual circulation and to very slight vertical mixings during neap tide.

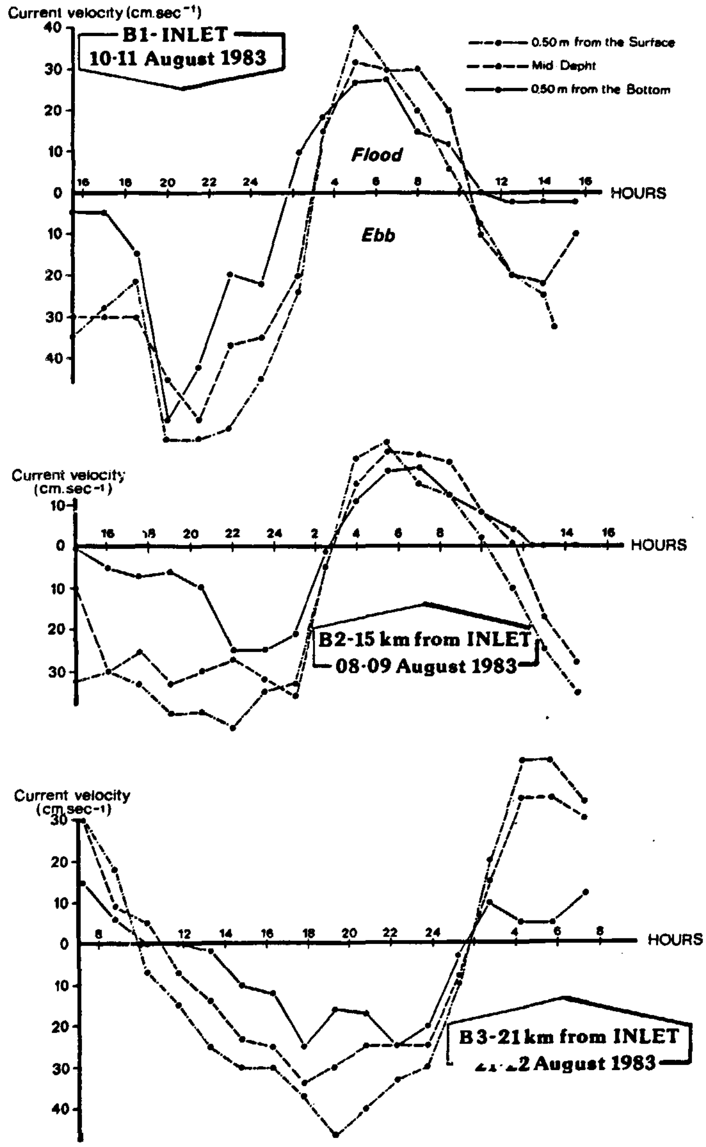


Figure 4

Current velocity measurements during tidal cycles. Spring tides of medium range.

Mesures des vitesses de courant durant des cycles de marée de vive eau moyenne.

Hydrology

The Barito watershed area covers some 45,000 km^2; there are no data relative to Barito river discharge. We have therefore attempted to make estimations from average current velocity measurements at representative sections of the estuary, upstream of the dynamical tide. In the fieldwork, that estimation (realized during the dry season) amounted to between 350-450 m^3/s.

At each anchor station, with a sampling rhythm of 1.30 hour, 17 observations were made at 3 levels: 0.50 m below the surface, mid-depth and 0.50 m from the bottom.

Salinity measurements

At each anchor station, during spring tide

- Station B1:

During the tidal cycle, at the surface, salinity is very reduced, ranging from 0.5 to 3.9. On the bottom, the salinity varies from 1.3 to 31.7. Waters appear to be very stratified (for example, salinity increases from 15 to 27 between 3.0 m and 3.5 m beneath the surface).

The minima and maxima do not correspond with low tide and high tide as well at the surface as at the bottom. It is only at mid-flood that bottom salinity increases again (four hours after low tide).

- Station B2:

At this station, located 15 km landward from B1 station, measurements were made a few days after a lashing rain on the upper watershed. The waters are thus much less salted.

At the surface, water is practically fresh, with salinity ranging from 0.02 to 0.20 during 2/3 of the tidal cycle. On the bottom, water is fresh for more than 1/3 of the tidal cycle.

- Station B3:

This station is located slightly landward from the channel linking Banjarmasin to Barito river in the main navigation channel in front of Banjarmasin harbour.

Here, 65% of the tidal cycle is represented by fresh and brackish waters (<5) on the whole water column.

During instantaneous longitudinal profiles along the estuary

The longitudinal profiles carried out during neap tide (Fig. 2) show:

- that the upper limit on the bottom of salinities higher than 5 is situated in waters between BR5 and BR6 (25 km from inlet) at low tide and between BR6 and BR7 (30 km from inlet) at high tide;

• that stratification is pronounced during neap tide: salinity values are less than 5 at the surface and higher than 30,6 km from the inlet at low water slack tide.

During spring tide, homogenization is much more pronounced and the landward advance of the isohalines is more reduced.

Along the external transects

Four transects of five kilometres each (Fig. 2) were studied during neap tide for salinity distribution at the river mouth and on each side of the Barito inlet (Fig. 5).

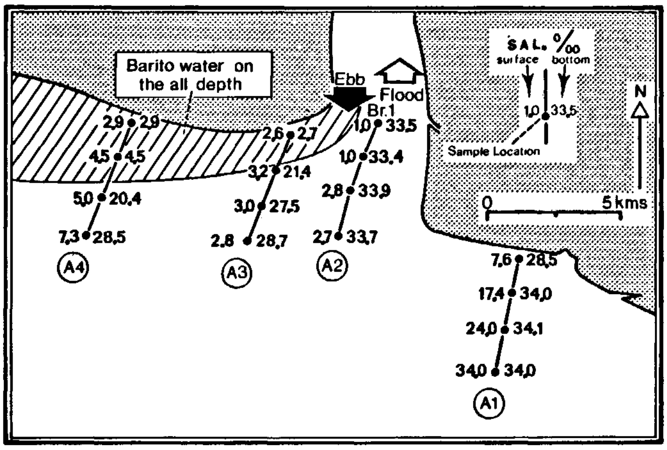


Figure 5

Salinities at the inlet. End of flood during neap tide.

Mesures des salinités à l'embouchure en fin de flot par marée de morte eau.

The evolution of the bathymetry in the area is as follows:

0.4 m to 3.0 m (profile I)

6.0 m to 4.0 m (profile II)

1.5 m to 2.2 m (profile III)

0.4 m to 1.9 m (profile IV)

At the surface at the end of flood:

• the upper salinities are located at the east of the inlet (from 7.6 to 34);

• the lowest salinities are located in front of the inlet (from 1 to 2.8).

On the bottom and despite the low water depth, there are steep salinity gradients (Fig. 5). In the figure, the hachured zone shows Barito waters throughout the water column and reveals the presence of a preferential ebb channel running along the right bank, whereas flood preferentially enters by the left bank.

Relationships between pH and salinity in Barito river

In Barito river, pH ranges from that of freshwater to what is obviously seawater, are from 5.84 to 8.40, *i.e.* more than 2.5 pH units (Fig. 6).

Low pH values are due:

— first, to the pollution linked to industrial activities;

— second, to the nature of the rocks located in the upper watershed.

Temperature variations

Only the distribution of temperatures within the estuary according to a tidal spring tide cycle (from the three stations data) is presented here (Fig. 7).

This figure calls for several remarks:

• Barito estuary is continually homogeneous in temperature near the B2 location. Here it is slightly stratified for three to four hours at the beginning of ebb (temperature differences surface/bottom in the region of one centigrade degree).

• Temperature stratification of the estuary takes place exclusively at the beginning of ebb (mainly at the B3 location) during a period of about four hours. All the observations were made during a relatively low discharge of the river in a spring tide period.

According to the drifts in the Barito estuary and the temperature study, we can obviously determine three water types:

— from marine drifts, with temperatures less than 28°C,

— from river drifts, with temperatures between 29°C and 30°C,

— from channel drifts ("anjirs" and "handils", *e.g.* the Martapura river) with temperatures between 30°C and 32°C.

Study of the dissolved silica variations in the waters

Analyses concern 193 water samples. The diagram (Fig. 8) presents the variations of dissolved silica with chlorosity. Average contents are about 140 µmol/l for fresh waters to 11 µmol/l for sea water (squared correlation coefficient of 0.97 for the equation of the dilution straight line).

In fresh and slightly brackish waters, the numerous low variations in silica concentration (between 120 and

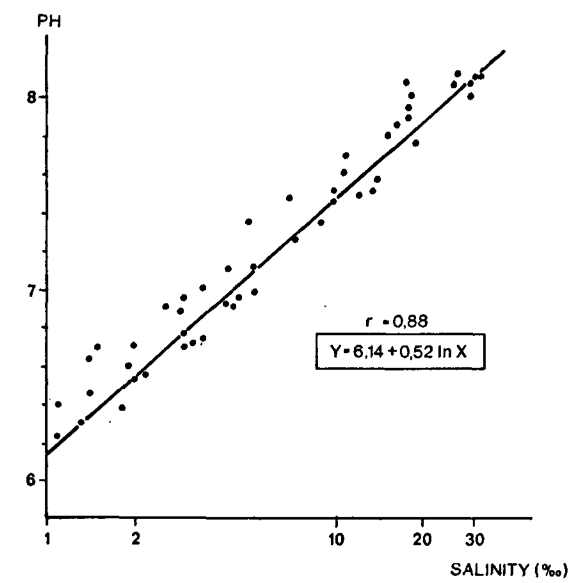


Figure 6

Relationships between pH and salinity in Barito estuary (from headward to seaward).

Relation pH/salinités dans l'estuaire du Barito (de l'amont vers l'aval).

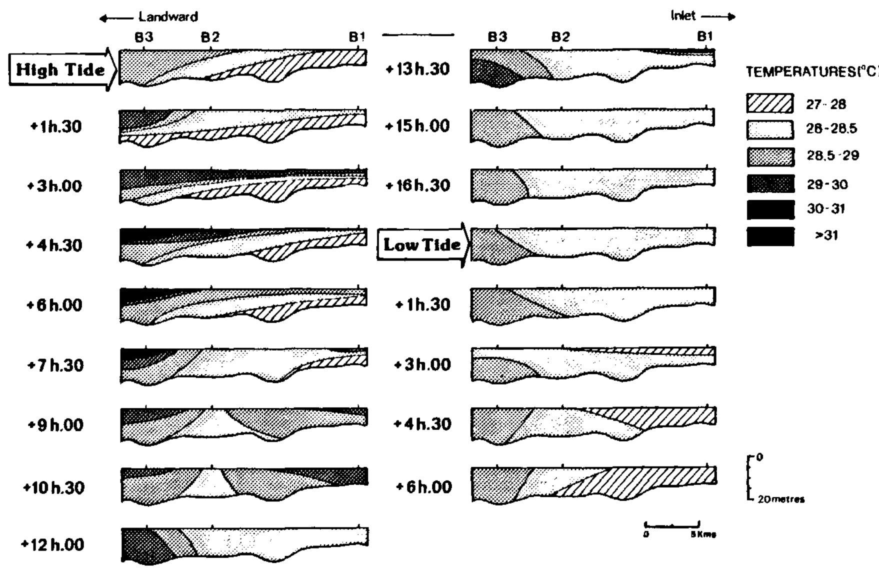


Figure 7
Variations of temperature stratification in the Barito estuary during a tidal cycle (spring tide—low river flow, August 1983).
Variations de la température dans l'estuaire du Barito pendant un cycle de marée (vive eau — étiage, août 1983).

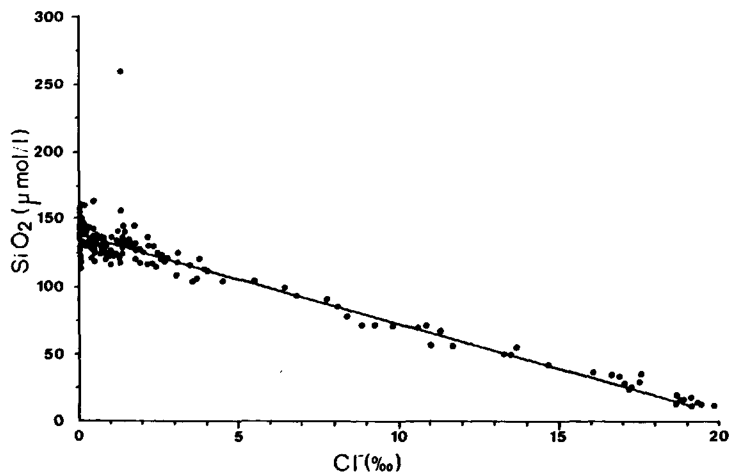


Figure 8
Relationships between dissolved silica and chlorosity from headward to seaward.
Relations silice dissoute/chlorosité de l'amont vers l'aval.

160 µmol/l) indicate a deficit by precipitation, consumption due to phytoplanktonic activity or excess by action of lateral fluxes.

Dynamics of suspended matters in the Barito estuary

Suspended sediments originate for the most part in the weathered basic rocks of the upper basin and constituents of the pretertiary formations: schists, grauwackes (Oertel, 1972; Soil Research Institute, 1973; Hehanussa, 1981).

Crystalline, metamorphic and volcanic rock product clastic materials are transported along the river.

The suspended matter study was carried out during three tidal cycles at a time of spring tides.

A synthesis is provided in Figure 9. Within the estuary, we notice a flood-ebb dissymetry in duration, respectively 1/3-2/3. The dissymetry with curves of current velocities appears upstream 20 km from the inlet.

Flood wave propagation is powerfully inhibited by the sedimentary mouth bar which increases bottom roughness. From the figure we may see that:

- The turbidity is less than 30 mg/l at 3/4 of ebb in the upstream studied zone. Only at the end of ebb are bottom velocities sufficient to drag the sediments and thus to create densities of 100 to 200 mg/l on the bottom.
- The downstream zone is very turbid and stratified at the end of ebb (velocities in order of 60 cm/s) throughout the water column. Contents ranged from 50-100 mg/l at the surface to 300 mg/l on the bottom.

During the rainy season, when leaching landward is very intense, ebb current velocities in the estuary are sufficiently important to induce the migration towards the Barito inlet of a great quantity of sediments carried in suspension. These tend to seal the mouth of the estuary.

The tidal range becomes small relative to the strength of river outflow, as in many tropical estuaries (Wright, 1977).

Some authors (Kendrick, Derbyshire, 1983) have written that from August to November, river flow multiplied by as much as 3.5 the suspension transport.

During the dry season, there is a retention of silt within the estuary. It is very difficult to estimate the annual total of sediments transported in the Barito estuary. Kendrick and Derbyshire indicate an annual load close to 2.5 million m^3.

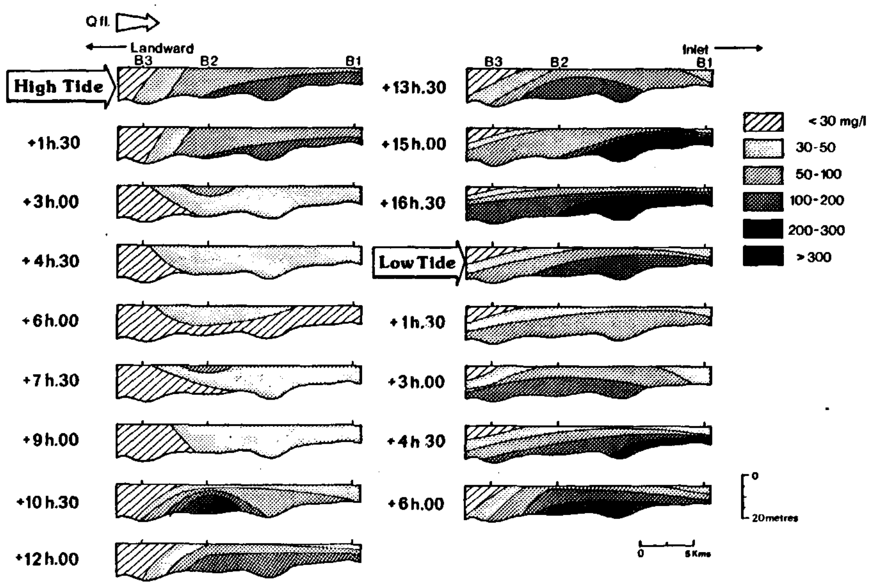


Figure 9
Variations of suspended matters in the Barito estuary during a tidal cycle (spring tide—low river flow, August 1983).
Évolutions des matières en suspension dans l'estuaire du Barito durant un cycle de marée (vive eau — étiage, août 1983).

By way of conclusion, a synthetic map (Fig. 10) of the Barito estuary gives the percentages of distribution of the fraction less than 63 µm.

Four categories are defined with fine elements percentage in the total sediment. Erosive trend zones are marked with a white arrow; zones characterized by accretion phenomena are indicated by a black arrow.

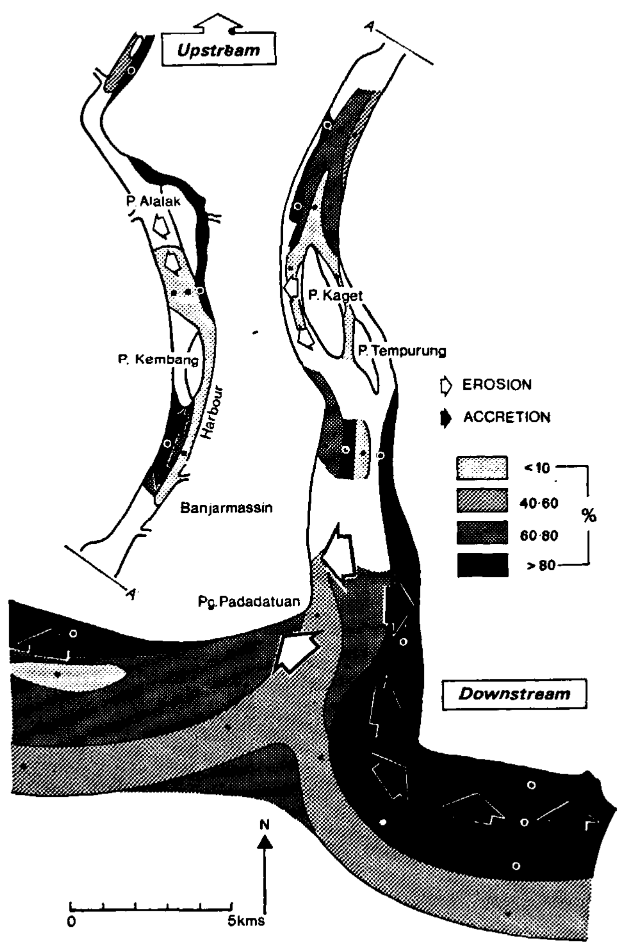


Figure 10
Distribution of the fraction less than 63 µm (%).
Répartition de la fraction fine < 63 µm (%).

THE SOILS

Morphology

Most of the soil profiles are characterized by the presence of a generally fibrous peat, sometimes compounded with wood or leaf residues (Weiss, Da'i, 1974). The peat layer is more or less thick and generally located on the top horizon, rarely at the bottom and sometimes inside the profile (Fig. 11). In fact, it is often a peaty clay horizon with 10 YR 3/1-3/2 colour, rich in fibres and root residue, of half-ripe to ripe consistency, sticky and plastic. Under *Rhizophora* forest, profiles are very much like those we have observed in Senegal (Marius, 1984), homogeneous, very fibrous, with a strong smell of H_2S. At the top horizon, fauna activity is very intense, mainly with crab holes.

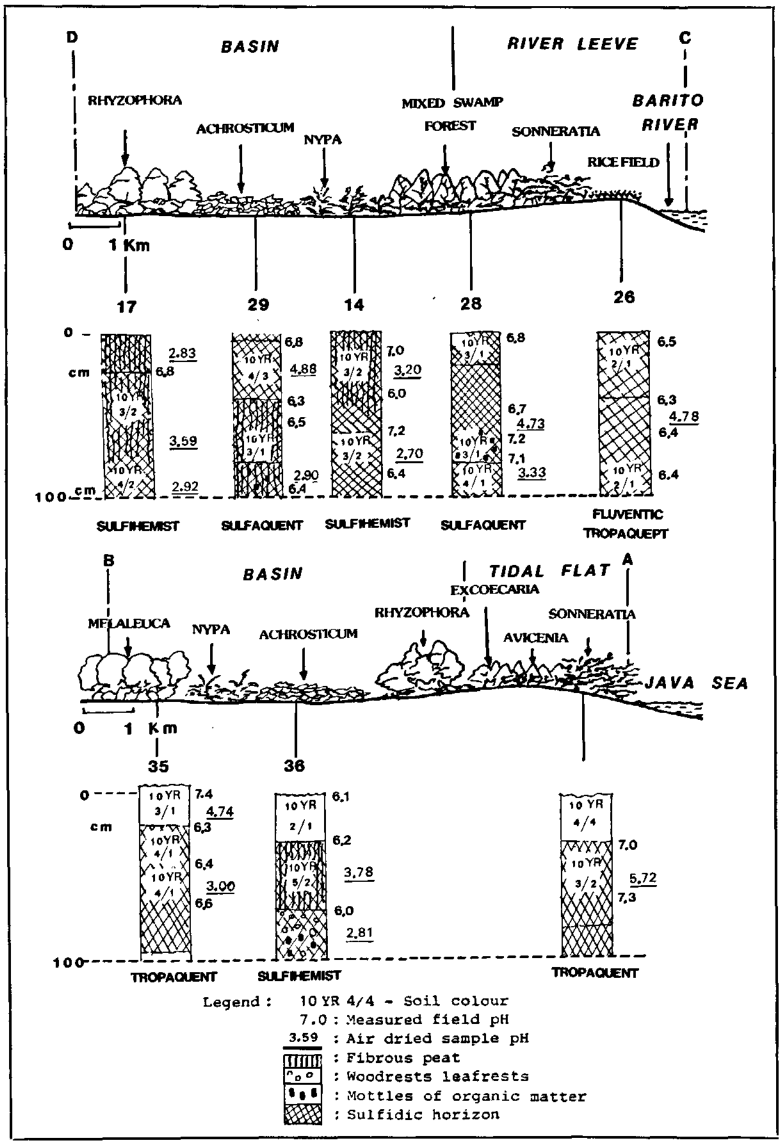
It thus appears that the main morphological characteristic of the soils is a half-ripe to ripe consistency which shows that they are physically developed.

Chemical properties

One of the main characteristics of mangrove soils is a pH which is generally around 6-7 when measured in the field on fresh samples and sometimes acid and lower than 3.5 when measured in dried samples. The difference between the field measured pH and the dry pH is called "potential acidity". This is typical in the case of most of the samples of the soils of the Barito estuary, where the field measured pH is around 6-7 and the air-dried pH is below 3.5, particularly for samples under *Rhizophora*. Most of the profiles are thus "potential acid sulphate soils" or "potential catclays". The potential acidity of these soils is due to accumulation of sulphides mainly in pyritic form. The accumulation of pyrite took place during sedimentation. Sea water sulphates are reduced into sulphides through the influence of sulphate-reducing bacteria contained within the sediment in a reduced environment and with a high content of organic matter. Sulphide reacts with iron from the upper watershed

Figure 11

Two sequences of soil transects (see Fig. 3).
C-D: from the estuary to the central part of the delta.
A-B: from the seashore to the central part of the delta.
Deux séquences de profils pédologiques (*voir* fig. 3) :
(1) de l'estuaire vers la zone centrale du delta;
(2) de la côte vers la zone centrale du delta.



to form pyrite. Under reduced conditions, pyrite is maintained in the soil but when aerated pyrite is oxidised to form iron sulphate, the soil becomes extremely acid with a decline of pH to less than 3.5. Such rapid oxidation will give jarosite $KFe_3(SO_4)_2(OH)_6$, which has a pale yellow colour.

Some 24 water samples were analised and the data show that, except for *Rhizophora* samples, most of the water samples are not saline.

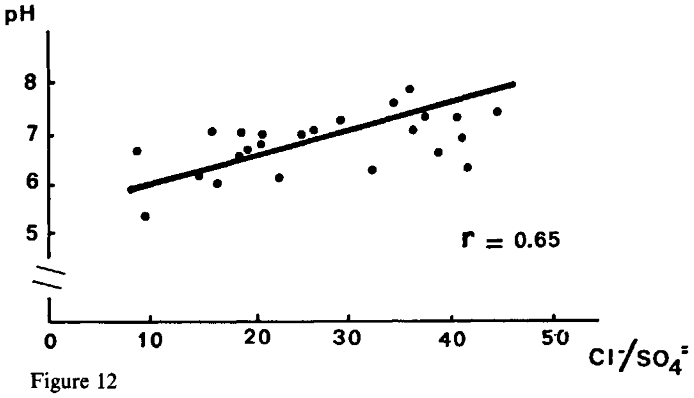


Figure 12

Relationships between pH and Cl^-/SO_4^{2-} ratio of the analysed water samples.
Relations entre pH et rapport Cl^-/SO_4^{2-} des échantillons d'eau analysés.

The water is for the most part composed of sodium chloride. Chloride and sulphate are the main anions; sodium and magnesium are the main cations. In sea water the Cl^-/SO_4^- ratio expressed in mmol/l is approximately 20 and we may note a good correlation between the pH and the Cl^-/SO_4^- ratio (Fig. 12).

As an initial conclusion, it would appear that most of the soils of the surveyed area are potential acid sulphate soils but not saline soils.

Mineralogical properties

All the samples were analised by X-ray diffraction for powder fraction and 77 samples were analysed for the clay fraction.

— quartz, kaolinite, smectite, pyrite, jarosite, feldspar are present in the powder fraction;

— kaolinite and smectite are the two main clayed minerals present in the clayed fraction associated with an interlayered clay.

Classification of the soils

According to the soil taxonomy classification, most of the soils may be described as sulfaquent and sulfihemist when they are peaty. Some profiles are sulfaquept. Non-acid profiles of the river levees are fluventic tropaquept.

LAND USE AND IMPROVEMENT

Rice, the main crop of the surveyed area, is cultivated in permanent flooded conditions during a period of nine months before harvesting and after three successive transplantations. Rice is flooded by non-saline tide water. This method, which is used by local populations to prevent oxidation and acidification of the soils, is well adapted to the soil conditions but permits only one crop per year. Other crops include coconut, banana, citrus, pineapple and cocoa.

Agricultural conditions could be improved by providing for a second crop of rice with short-term varieties, and also by using a separate system for irrigation and drainage.

Associated with agriculture, aquaculture could easily be developed in the area, the mangrove swamps being very rich in fish, prawns and shrimps.

The Rhizophora forest of Pisak besar should be totally protected as a natural forest reserve where tourism might be managed.

CONCLUSIONS

From the sedimentological point of view, during the dry season, the Barito estuary is controlled by tidal currents. There is retention of silts within the estuary. Rather violent winds during monsoon periods are the main cause of a constant redistribution of the fine-grained particulate material at the river mouth. It is to be regretted that data concerning the rainy season are scanty.

The pedological survey carried out to the west of the estuary resulted, *inter alia*, in the discovery of a beautiful mangrove forest. Most of the soils of the surveyed area are potential acid sulphate, rather than saline soils.

REFERENCES

Bassoullet Ph., 1984. Study of the hydrosedimentological processes within Barito estuary, Delta Pulau Petak, Kalimantan, Indonesia, IFREMER, Centre de Brest, 82 p.

Fontanel J., Chantefort A., 1978. Bioclimate of the Indonesian Archipelago, Institut Français de Pondichéry, Travaux de la Section Scientifique et Technique, XVI, 104 p.

Hehanussa P. E., 1981. Basic data from Barito delta, South Kalimantan, Indonesia, L.G.P.N., L.I.P.I., 21 p. (unpublished).

Kendrick M. P., Derbyshire B. V., 1983. Factors affecting the supply and distribution of sediments in some tropical ports, *Can. J. Fish. Aqu. Sci.*, **40**, Suppl. 1, 35-43.

Marius C., 1984. Contribution à l'étude des mangroves du Sénégal et de la Gambie, *Thèse Doct. État, Univ. Louis Pasteur, Strasbourg*, 1984, 309 p.

Oertel G. F., 1972. Sediment transport of estuary entrance shoals and the formation of swash platforms, *J. Sediment. Petrol.*, **42**, 4, 857-863.

Soil Research Institute, Bogor, 1973. Report on soil investigation of the Delta Pulau Petak (South and Central Kalimantan), Ministry of Agriculture, Soil Research Institute, Bogor n° 5-1973, 146 p.

Weiss M., Da'I Y., 1974. Ideas on the genesis and the fertility of regional peat in Indonesia, Congr. I.A.G.I., Bandung, Indonesia.

Wright L. D., 1977. Sediment transport and deposition at river mouths: a synthesis, Doc. n° 70614, *Geol. Soc. Am. Bull.*, **88**, 857-868.