

## SEDIMENTATION AT THE MOUTH OF THE SÃO FRANCISCO RIVER (BRAZIL)

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### RESUMO

O material fino transportado em suspensão pelo rio São Francisco constitui a principal fonte de sedimentos da área. A desagregação bloquímica dos depósitos de algas calcárias representa uma fonte secundária. O mapa de distribuição do teor de carbonato de cálcio mostra igualmente a influência marinha na composição dos sedimentos.

O sistema de correntes e a distribuição da salinidade determinam a existência e a repartição dos sedimentos em frente à foz do rio São Francisco.

### INTRODUCTION

In recent papers Cavalcanti & others (1967) and Mabesoone & Tinoco (1967) discuss the oceanography and sediment of the shelf of the coast of Alagoas and Sergipe in Northeastern Brazil. Their description includes the topography of the shelf, the temperature and salinity of the waters, currents and sediment distribution, and thus provides an excellent base for more detailed studies of the so-called São Francisco river facies.

The investigation presented here is principally concerned with the areal sediment distribution of the São Francisco River mouth and the suspended matter transported by this river.

As has been shown by Cavalcanti & others (1967), the muddy bottom of the São Francisco influence area permits a commercial exploration of the fishery. With this purpose the vessel Ilha de Itamaracá I, under the supervision of Aldemir Barros of the Divisão de Recursos Pesqueiros (SUDENE), sampled the area for a more detailed study of shrimps and fishes, from January to March, 1967.

The location of the area has been presented in figure 1. The region was sampled at intervals of 2 1/2 miles between each station and a total of 72 samples was taken with a dredge. The muddy sediment has been studied in the laboratory with the usual sedimentological methods. Calcium carbonate content was determined for the mud fraction of the sediments only. The information relating to monthly resultant surface currents, shown in the lower right hand corner of the figure 1, was compiled from the Hydrographic Office of the U. S. Navy. The direction and the length of the arrow are proportional of the mean direction and force of the surface current for the month under average normal conditions.

The author wishes to express his sincere appreciation to Al-demir Barros, for having sent the material for this study. Thanks are also due to director of the Grupo de Irrigação do São Francisco for the datas concerning to the São Francisco river.

*Oceanographic data.* — Coastal seawaters are markedly affected by local influences, such as the temperature, salinity and currents which vary during the different seasons. The rainfall along the coast occurs almost exclusively during the winter (April-July) with the winds blowing from SE, and during the dry season generally from NE.

The temperature and salinity of the surface waters are relatively constant, except at the river mouth where the influence of the fresh and warm waters of the São Francisco is clearly shown, decreasing the salinity near its mouth up to 10-15 miles away from the coast. At 25 m depth, in front of the river mouth the temperature is somewhat low (24°C) and increases seaward till 26° C. Also at same depth a certain discontinuity in salinity occurs. This could be explained by the presence of a costal upwelling that brings up cold deeper waters through the canyon as can be seen from the maps of T°C, S°/oo (Cavalcanti & others, 1967).

The superficial current pattern of this area is known only in a general way and no direct current measurements were made there. The fig. 1, inset, shows the sets of littoral drift patterns, parallel to the coast, in roughly opposite directions. The surface current coincides with the dominant wind directions. The main drift is south-southwest during september to march and northward in Abril to August. Strong tidal characteristics are evident in the surface current, which seems to be influenced also by prevailing northeasterly winds.

*São Francisco River.* — The São Francisco River with .... 2,700 km in length and a basin slightly more than 631.000 km<sup>2</sup> is number 31 on the world list of river-basin by areas. The upper

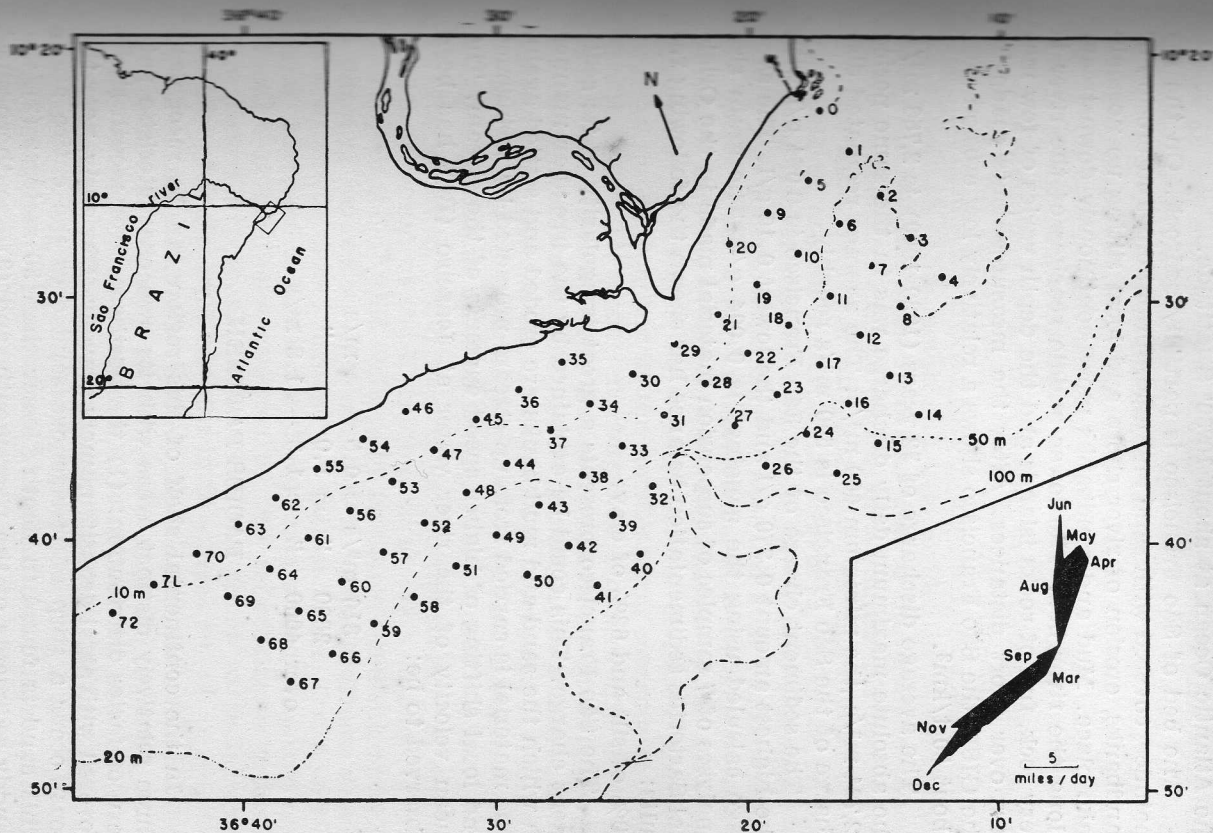


Fig. 1 — Situation of the investigated area and sampling localities.  
 Situação da área estudada com as estações de amostras.



basin is located in the tropical humid region. Part of the middle basin and the entire lower middle basin belong to the so-called "drought polygon", the semiarid area of the Northeast, before the river flows acrosses the humid coast strip and enters the Atlantic Ocean at about 10°30' S latitude.

The bed of São Francisco is partially bedrock. On the remainder, covered with sand and mud, formations and erosion of sandbanks, erosion of river shore and local silting up normally take place. Mud and sandbanks move continuously downstream along the river bed. The lower middle reaches of the river is very rock, full of rocks islands and the depth varies of few meters over short distances. After the measurements made by the GISF, the São Francisco shows a relatively low erosion rate, about 50 t/km<sup>2</sup>.

The average discharge of 32 years (1929-1960) is 2,756 m<sup>3</sup>/s, the absolute maximum daily discharge was in the same period 12,724 m<sup>3</sup>/s, the minimum 609 m<sup>3</sup>/s. The average regulated discharge of the São Francisco is 500 m<sup>3</sup>/s roughly.

The sediment charge of the São Francisco is 0.064 g/l with the highest amount 0.270 g/l and the lowest 0.10 g/l. The average calculated using the gaugings is 0.094 g/l. The grain size analyses of 7 samples of suspension material made in the Original Sartorius sedimentation balance has shown the following results:

30% of silt and 62% of clay.

The São Francisco presents a great irregularity of its sediment charge. This could be explained by the irregular manner in which the sand and mud banks are eroded and settled again. The material is carried from up-stream promoted by turbulence and local shifting of higher speed currents of the stream. The mean velocity of the river water at Joazeiro (Ba) has been observed to be:

816 m <sup>3</sup> /s	= 0.5	m/s
2800 "	= 1.0	"
over 4000 "	= 1.3 — 1.8	m/s

#### FACIES PATTERN

In the continental shelf of this region can be recognized three relatively distinct areas with its own characteristic pattern of facies distribution: (1) the northern river mouth shelf, covered with algal deposits namely gravelly. Obviously, near the coast occur a stirp of terrigenous sand over the entire area. This sand is found in depth lesser than 30 meters; (2) the muddy sediments of the river mouth, and (3) southern shelf shows a mixture of terrigenous, algal and biotrititic facies of

sandy texture. The term *facies* used here is the sence used by van Andel's (1960).

In the present study only the muddy sediments of the river mouth will be considered. The regional distribution of modern facies at the mouth is presented in figure 2. This map was constructed based on the grain size only and using the same terminology adopted by Mabesoone & Tinoco, (1967). The areal distribution presented by the referred authors is very simple and seems not to represent the real distribution of the muddy sediments, at São Francisco River.

The sediments of the river mouth were distinguished in two types: (1) the very silty-clay, and (2) the silty-clay. The first type that covers the greater part of the shelf, occupies a central band in front of its mouth and it is divided in two branches, being the SW the most important due to the main longshore current. The modal mixtures characteristic of this facies are: 2.3% of sand, 30.4% of silty and 67.2% of clay size particles. The bulk of organic material has shown 33.4% of bryozoans, 42.8% of lamellibranches and 23.8% of diferent fragments of shells. Its faunistic assemblage is poor and little variated either in number of species or in individuals. The calcium carbonate content is zero. The second type is represented by the silty-clay sediments, occuring in the central part of the area, near the head of the canyon and at the northeastern, covering the biotrititic sand. Its modal characteristic mixtures are: 0.6% of sand, 17.8% silt and 81.4% of clay. The calcinum carbonate content varying between 0 to 5%. Very rich fauna either in individuals or in species, consisting of 46.5% bryozoans, 11.7% gastropods, 1.5% lamellibranches, 20.3% foraminifera and 20% of different fragments of shells.

Van Straaten (1960) has explained the scarcity of animal remains in front of the Rhône mouth as (1) a dilution of the quantity of the organic remains by inorganic sediment, and (2) a direct or indirect adverse effect of the rapid sediment supply at shelf on the development of the bottom fauna. On the other hand, Sheppard & Lankford (1959) have stated that the destruction of the fauna occurred by the deflocculation process. The second hypothesis of van Straaten seems to explain the scarcity of the animal remains in this area.

The most striking fact about the São Francisco River facies as a whole is the great abundance of clay size material. Most of the "clays" contain between 12 to 20% of silt size particles. Van Straaten (1959) has mentioned that in tidal and marsh sediments in the Netherlands a silt ratio of 33% is normal, and that the higher percentages are atributed to the degree of flocculation in scarcely brackish waters. The low salinity allows the finer sediments to others regions, i. e, the more argillaceous

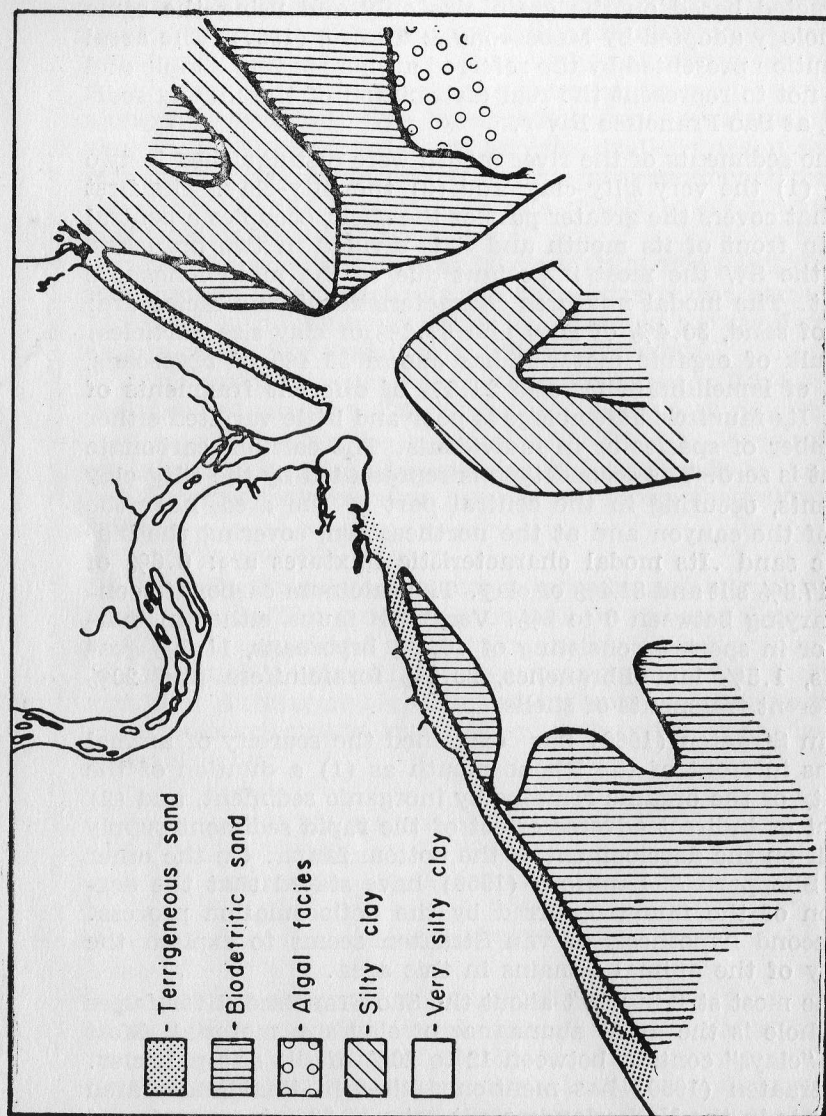


Fig. 2 — Areal distribution of sediment based on grain size composition  
Distribuição superficial dos sedimentos segundo a composição granulométrica.

deposits representing the higher salinities and the silty deposits, the lesser salinity waters. An interesting feature of the sediment distribution in this area is the close correlation between the silty-clay material and the salinity distribution of the waters. Perhaps some features of the near surface distribution of the water properties correspond to the distribution of sediments properties, such as, grain size the shallower parts of the shelf (Gross, 1966).

*Sources and movement of sediments.* — The fine sediments transported by the São Francisco River undoubtedly the major source of sediments in this area. The erosion of the coasts and the biochemical disaggregation of the algal deposits are also sources of sediments. The fine sediments either at north or at south of the river mouth presented a  $\text{CaCO}_3$  content varying from 1 to 5% and the highest values are restricted to the northeastern of the area (fig. 3). This implies that the total fine material is not only derived from the river, but a small quantity of it comes from longshore or offshore sources, e. g., the algal deposits. This is further documented by visual observations on the nature the coarse carbonate fraction.

When at sea, sediments are dispersed by currents, according to the general current pattern of the area. Rip current transports, of course, sediments from the littoral into deeper waters and tidal currents disperse them at steep angles to the coast. Near the shore the suspended sediment transported by the river is dispersed by the littoral drift parallel to the coast in roughly opposite directions, and farther out, by the Brazil Current. The sediments transported by the river flows seaward over the shelf and is separated in two branches of very silty-clay with a central patch of silty-clay material in front of its mouth. In the canyon, at considerable depths, the sediment is a mixture thoroughly of organic fragment with material transported by the river.

The grain size distribution is consistent with a main southward movement along the shelf of modern sediment from the river. The dominance of the São Francisco River as the most important source, explains the relative simplicity of the facies distribution and its close correlation with the general current pattern over the area. The fresh river water causes a decrease in salinity that has a strong influence on the sedimentation in this area. Very silty-clay facies occurs chiefly in the area of low salinity, whereas in the remainder the sediments are silty clay or clayey. The sedimentation of the studied shelf area is dominantly terrigenous, because of the influence of the São Francisco River and the absence of barriers or sediment traps near the continental margins. The area of coarse calca-



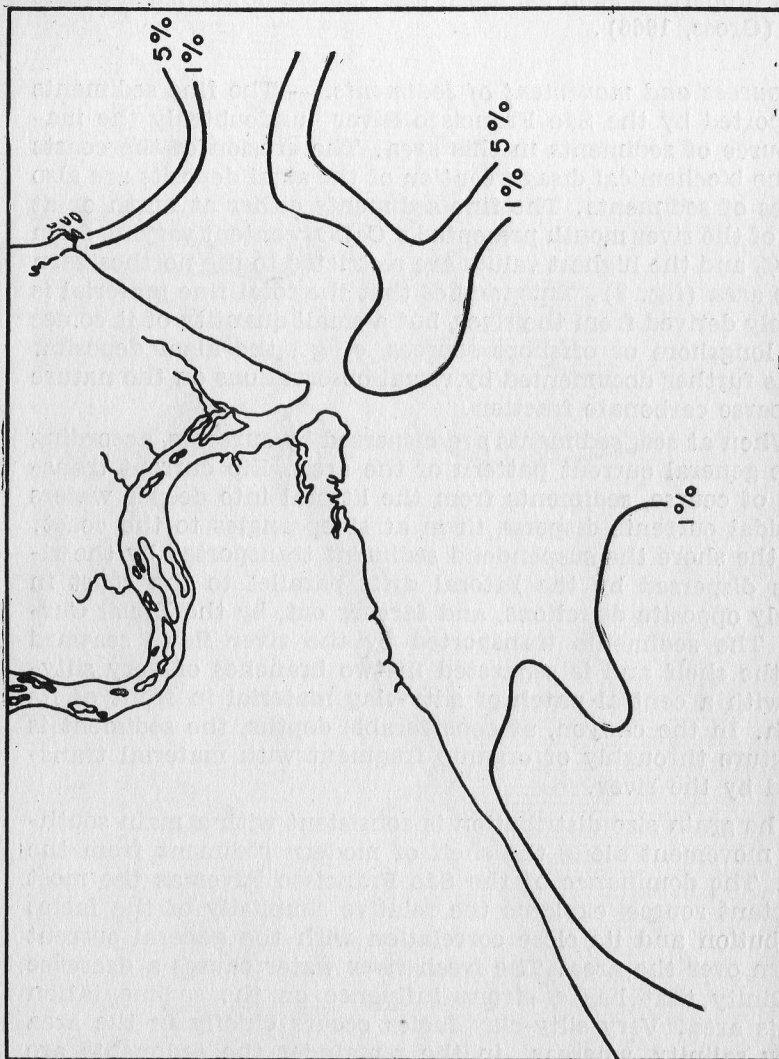


Fig. 3 — Map showing the distribution of the calcium carbonate content of the bottom sediments.  
Mapa mostrando a distribuição do conteúdo de carbonato de cálcio nos sedimentos do fundo.

reous bottom off the river mouth reflects very low rates of present day terrigenous sedimentation. However, the area of the sand size material off the mouth of the São Francisco River shows a rate of sedimentation relatively high

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