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CABO SÃO BRAZ LAGOON (ANGOLA): AN EXAMPLE OF OCEANIC COASTAL EVOLUTION

ABSTRACT: DE PIPPO T., DE ANDRADE H. & FERNANDES A., *Cabo São Braz Lagoon (Angola): an example, of oceanic coastal evolution* (IT ISSN 0391-9838, 1995).

The São Braz Lagoon occupies a triangular bay located immediately to the north of the São Braz promontory, located itself about 200 km south of Luanda (Angola) along the African eastern coast of the Southern Atlantic.

Our investigation demonstrated that the system of spit-bars separating the brackish lagoonal water from the open ocean is a very recent and rapidly evolving feature that first appeared in the seventies. A previous phase of coastline progradation (also ascribed to recent historical times) is shown by traces of an older lagoon, nowadays turned into a small sabka. The Presence, shape and current morphodynamics of the São Braz Lagoon appear clearly controlled by the profile of the coastline (*i.e.* the sharp bend occurring at the promontory) as well as by the SW winds that dominate the region (St. Helen Winds) and the swell phenomena they generate. The resulting northward re-distribution of sediments resulting from sea cliff erosion and fluvial inputs feed the construction of spit bars down-drift of the promontory's head.

Comparison of maps and aerial photos of different ages demonstrated that the present configuration of the lagoonal area is mostly the result of phenomena occurring during the last 20 years, while our repeated surveys indicate that it still suffers appreciable changes from one year to another.

The depositional progradation and progressive closure of the bay that have dominated the recent decades does not represent the continuation of a longer term monotonous morphodynamic tendency. In fact, the morphological evidence we have collected are sufficient to state (notwithstanding the present lack of dates for the older stages of evolution) that the São Braz morphostructural bay has alternatively experienced periods of opening (with destruction of bars and spits and re-activation of the inner sea cliff) and periods of partial or total closure (with creation of lagoons, marshes and sabkas, accompanied by continental re-shaping of the abandoned sea cliffs). Such alternations were probably the consequence of the minor sea level fluctuations that occurred during the second half of the Holocene, but changes of the mean oceanographic conditions induced by climate occurring during the last millennia could also have played a major role.

KEY WORDS: Coastal Lagoons, Geomorphology, Angola.

RIASSUNTO: DE PIPPO T., DE ANDRADE H. & FERNANDES A., *La Laguna di Cabo São Braz Lagoon (Angola): un esempio di evoluzione costiera oceanica.* (IT ISSN 0391-9838, 1995).

La Laguna di Cabo São Braz è ubicata subito a nord dell'omonimo promontorio a circa 200 km a sud di Luanda (capitale dell'Angola) lungo la costa orientale dell'Oceano Atlantico.

Le indagini di geomorfologia costiera e sottomarina eseguite in quest'area hanno consentito di ricostruire l'evoluzione della «*steche*» litoranea ivi esistente e costituita da un sistema di corpi sabbiosi che, legandosi alla costa, separano le acque salmastre della laguna dall'oceano; questo sistema, di età molto recente, presenta una veloce evoluzione a partire dagli anni settanta.

Una precedente fase di progradazione della linea di costa (anch'essa di epoca storica) è testimoniata dalla presenza di un'antica laguna, attualmente allo stadio di «Sabka».

L'esistenza e l'attuale morfodinamica della Laguna di Cabo São Braz è chiaramente controllata dal profilo della costa, dai venti dominanti di SW (venti di S. Elena) e dalle ondate generate da questi ultimi; infatti la ridistribuzione verso nord dei sedimenti provenienti dall'erosione delle falesie e dagli apporti fluviali consente la costruzione dei cordoni sabbiosi a ridosso del Promontorio di S. Braz.

Il confronto di carte topografiche e foto aeree di differenti periodi ha permesso di definire che l'attuale configurazione dell'area è il risultato di fenomeni avvenuti negli ultimi 20 anni, benché indagini ripetute nel tempo abbiano mostrato variazioni apprezzabili da un anno all'altro.

La deposizione dei cordoni sabbiosi e la progressiva chiusura della baia avvenuta nelle ultime decine di anni non rappresenta una tendenza morfodinamica monotona in quanto le evidenze morfologiche sono sufficienti ad affermare che la baia morfostrutturale di São Braz ha sofferto periodi alternati di apertura, con la distruzione delle barre emerse e la riattivazione della falesia interna, e periodi di parziale o totale chiusura con creazione di lagune e sabka e con fenomeni di rimodellamento continentale delle falesie.

Tale evoluzione è probabilmente la conseguenza delle fluttuazioni di piccola entità del livello del mare nella seconda metà dell'Olocene, ma sicuramente hanno avuto un ruolo molto più determinante le variazioni del regime oceanografico medio indotte dal clima nell'ultimo millennio.

TERMINI CHIAVE: Lagune Costiere, Geomorfologia, Angola.

INTRODUCTION

The Angolan section of the South Atlantic coast between Barra do Dande and Cabo São Braz (fig. 1) is characterised by the presence of well formed spit bars at places

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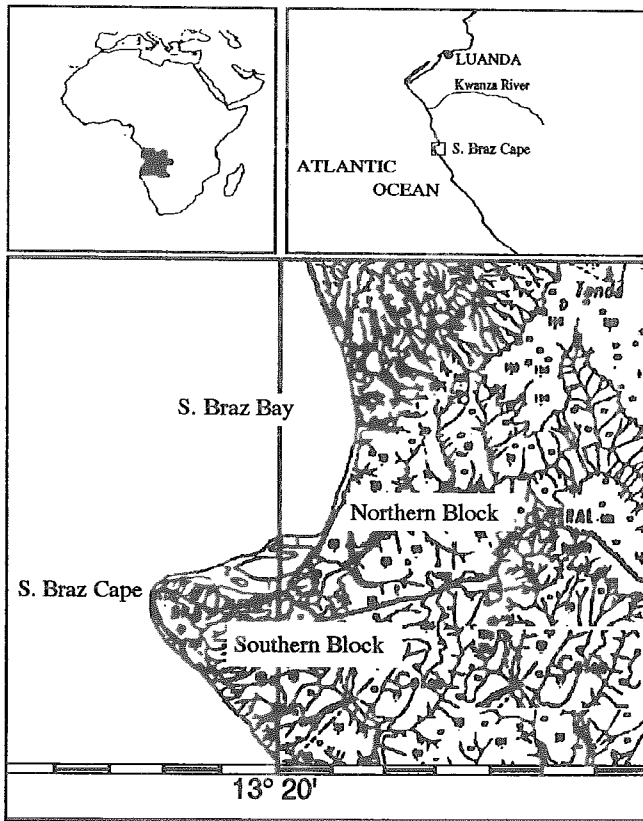


Fig. 1 - Sketches of investigated area.

where the direction of the coast changes. Some of them are of considerable size and are associated with wide lagoons, such as those to be found near Luanda, Mossulo and Cabo São Braz. Research aimed at investigating the genesis and evolution of these three lagoons started in 1990. It involves both Angolan and Italian geologists and geomorphologists, in the framework of a project founded by the «Direzione Generale per la Cooperazione allo Sviluppo» of the «Ministero degli Affari Esteri Italiano».

Studies were carried out with topographic and bathymetric surveys respectively in the emerged areas and in the lagoon. The topographic survey (fig. 2), which related to a spot height present on the top of S. Braz Cape, shows the arrangement of various sandy ridges oriented NNW-SSE near the promontory and W-E in the eastern areas. The survey in the lagoon gave a definition of its maximum depth (- 4 m) and the presence of submerged relict ridges which are oriented with the same trend as the emerged ones.

The lagoon of São Braz has initially received the most attention, because its accelerated dynamics provide an opportunity to understand the factors and mechanisms currently controlling the evolution of these coastal landforms (GUILCHER & *alii*, 1974).

The official cartography of the area, based on aerial photographs of 1975, does not show the present configuration of the bay, but on aerial photos of 1979 (fig. 3) an extensive northwestwards sand ridge is clearly visible departing from Cape São Braz. This was unattached to the opposite coast of the bay, so that a wide open lagoon was present at its rear. Further inland a depressed flat area representing a silted-up older lagoon also appears on these photos.

GEOLOGICAL AND GEOMORPHOLOGICAL SETTING

The São Braz Lagoon represents a stretch of the Angolan coast north of the São Braz promontory and about 200 km south of Luanda. Geologically speaking, the area belongs to the so called Sedimentary Edge of Angola (more precisely to the Kwanza Basin) and extends for 10 km between 9°50' and 10°10' latitude in the South.

The Kwanza basin is the widest of three basins that constitute the Angolan Sedimentary Edge (SCHLUMBERGER, 1991); their genesis, in the lower Cretaceous, was due to the opening of the Southern Atlantic Ocean. The sedimentary sequences that outcrop in the investigated area have a prevailing dip toward SSW and are affected by faults and gentle anticlines with N-S and NE-SW trends. These structures have been ascribed to a saline tectonics generated by evaporitic formations of Aptian age (VERRIER & SA FERNANDEZ, 1978).

The overall geometry of the Angolan coast is strongly linked to the tectono-sedimentary evolution of the western African margin and appears to be defined by the fractures that developed during the Cretaceous-Neogene phases of rifting. Moreover, the coastal outline is locally controlled by fault-lines, showing a NNW-SSE and NE-SW direction, partially inherited from pre-Cambrian phases of continental rise (SIMPSON, 1970; BROGNON, 1970).

Within the investigated area two blocks having different lithological and biostratigraphy characteristics come into contact (fig. 4). The northern block exposes an Eocene calcareous succession composed mostly of pelitic sediments of an open sea environment, unconformably covered by Quaternary red sands. The southern block, which is more important as it controls the evolution of the bay, is made up of a Miocene succession of shallow water deposits, essentially marls, followed by gypsum-calcareous layers and finally topped by the above mentioned Quaternary red sands. The Miocene deposits of the southern block unconformably cover the Eocene succession of the northern block along an ancient, buried fault scarp which is now partly re-exhumed by the incision of the ephemeral Rio S. Braz.

The Quaternary red sands are associated with coastal terraces which are to be found on both blocks at almost the same elevation (*i.e.* between 40 and 60 meters a.s.l.).

The two blocks exhibit different characteristics of the hydrographic network because of both the lithological differences. However, on both blocks the drainage network appears clearly influenced by structural lines. On the southern block the network has a higher density with a

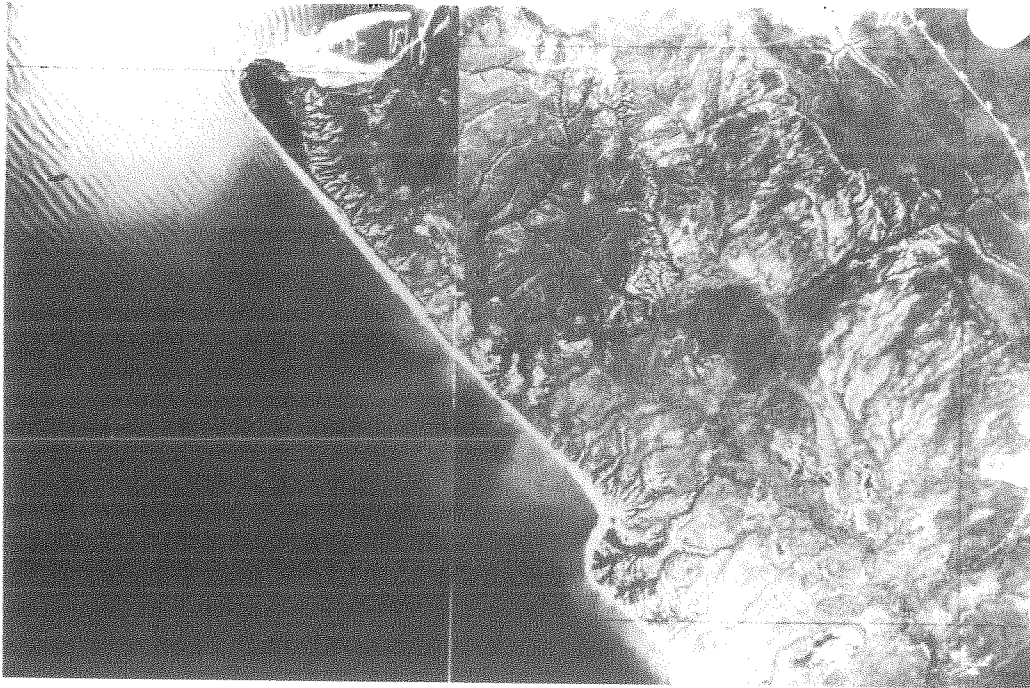


FIG. 3 - Aerial photo of 1979. In the upper part, the more external spit not linked to the coast, the open lagoon and inland the small evaporitic basins (sabka) are all visible.

FIG. 4 - Contact between the Eocenic succession of the northern block (to the left of photo) and Miocenic deposits of the southern block.

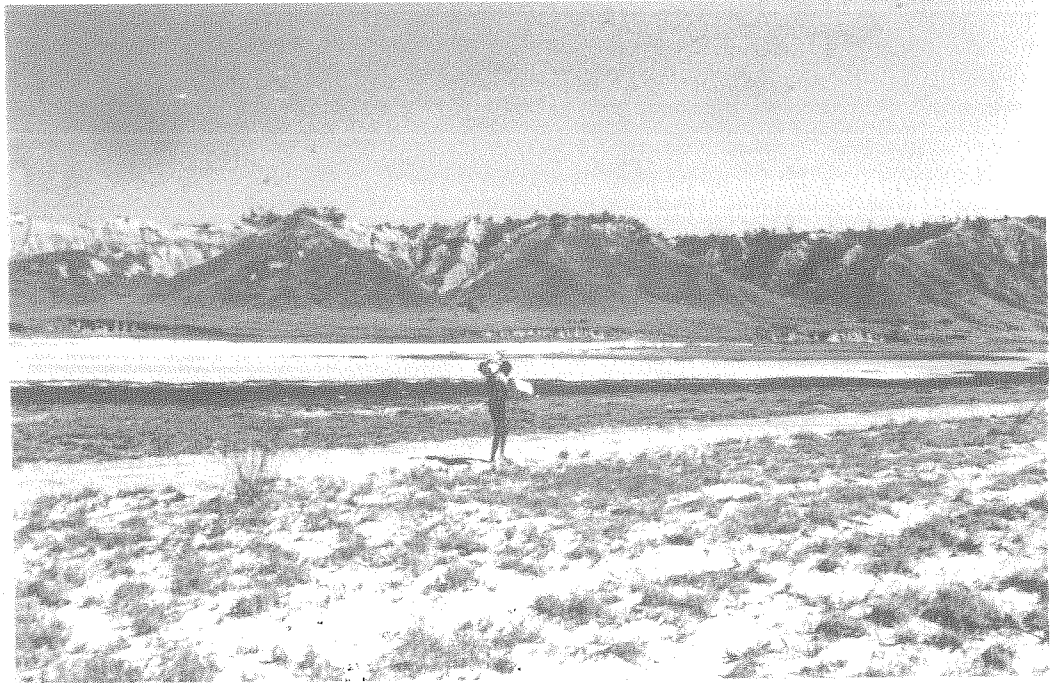


coastline has a NW-SE trend whereas to the north it is W-E oriented. The latter one is characterized by numerous orders of sandy spits. These are due to the wave expansion close to the promontory that permits the deposition of materials supplied by the river eroded from the southern cliffs, transported northward by longitudinal currents (DANIEUX, 1985) and by the Benguela Current (HART & CURIE, 1960). The most ancient spit separates an earlier la-

goon, now a sabka, from the present lagoon, which is itself separated from the Atlantic Ocean by more recent and external spits (fig. 7).

A topographic and geomorphological survey was carried out in the area of the São Braz Lagoon that allowed the detailed mapping of the sandy ridges in the area. The most ancient ridges, which are close to the S. Braz promontory, show a NW-SE trend linked to the coast, all

FIG. 5 - Southern sea-cliff: the different gradient of the upper and lower part of the slope as well as the scarplet few meter high at its base are visible.



with the same direction, spits of intermediate age show a E-W trend oceanward and turn in a NW-SE direction nearer the coast. The most recent spits have the same E-W trend for their full extent.

It is possible to reconstruct their trend through bathimetric surveys carried out in the present lagoon. These investigations showed a maximum depth of four meters and several ancient spits, which have been eroded and submerged. They are related, especially in the central part of the area, to the emerged sandy ridges and represent their natural protraction as far as the currently protected structural cliff (fig. 8).

GEOMORPHOLOGICAL EVOLUTION

In the formation and evolution of the sandy ridges the orientation of the cliffs forming the São Braz promontory, and the span of coast immediately north of it is extremely important. The coastal outline, the inland and sea-cliffs morphology and the results of topographic and bathimetric investigation give an evolutionary pattern of the area.

During a period when the sea level was at almost the same position as today, and the system of spits had not yet formed, marine abrasion modelled a broad platform in the northern area of the S. Braz promontory.

Due to a following regression the abrasion surface emerged at least partly and the sea-cliff become inactive and underwent a process of slope replacement. A new transgression submerged again the outer portion of the ancient abrasion surface and cut a micro cliff not more than 2 m high at the base of the replacement slope. During these events the cliffs at the north of the bay were subject

ed to rapid wave erosion and retreat, which resulted in the formation of a narrow platform at the base of the fault-line scarp, exhumed and reworked by the waves.

When these geomorphological features evolved, the oceanic and climatic conditions controlled the formation of the earliest spits close to the head of the promontory. This was due to local wave diffraction and expansion with deposition of sands transported northwards by longshore currents. These sands are presumably supplied partly by the erosion of the cliffs forming the coast in the south of São Braz and partly by the discharge of rivers (Rio Cubal, Rio Longa etc.).

The spits originated on the shallow platform previously modelled close to the promontory, and developed with an E-W trend until they linked to the coast, forming a primitive lagoon. The process continued over time with the formation of several sandy ridges which have moved the original linking point northwards in a series of large cusps which were formed on the seaward littoral spit. During storm events the sea penetrated through wide cuts in the sandy bodies supplying the lagoon, and at the same time eroded the internal spits in several points.

The remains of these sand bodies were recognised in a bathimetric survey of the lagoon. It was possible to reconstruct the original pattern of the various spits which are nowadays partly eroded and submerged, and the emerged portions, which are covered by halophyte vegetation.

As the growth of new spits moved the lagoon northwards, the inner areas were transformed into small evaporitic basins gradually filled with clastic and salt deposits. The speed of formation of spits in the S. Braz area is high since the morphology of the coastal area appears radically different on maps and aerial photos at

FIG. 6 - Northern sea-cliff subjected to rapid retreat where there are several truncated hanging valleys.



FIG. 7 - São Braz Lagoon; the photo shows the older lagoon, now a sabka, and the present lagoon separate from the ocean by a more recent spit.



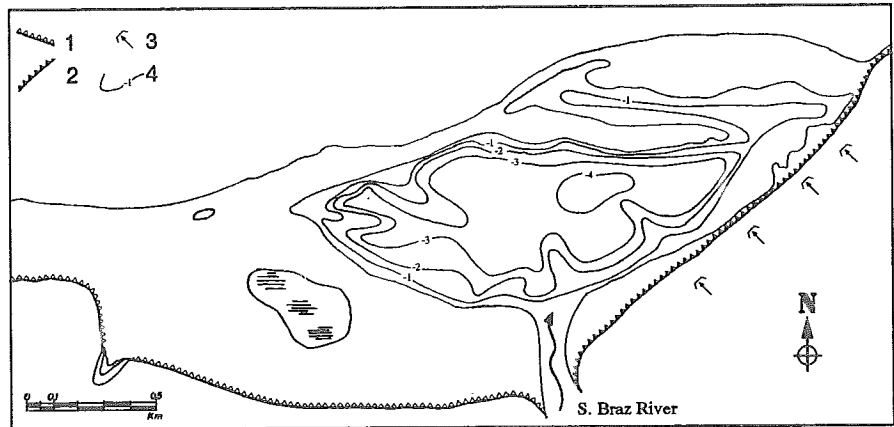
different times. The rapidity of change is also confirmed by direct observations carried out during the last 4 years.

The start of the formation of the S. Braz Lagoon is probably very recent, since the slight sea level fluctuations resulting in a suitable bed morphology are most likely to be ascribed to the late Holocene.

This chronological hypothesis is also supported by the

fact that the first half of Holocene, like the last millennia of the Upper Pleistocene, was characterised by a rapid transgression (of about 10 mm per year and more). This probably produced a continued and marked retreat of coastal cliffs (the first and main phase of sea cliff retreat creating the embayment of São Braz) and did not allow the formation of a broad platform altimetrically close enough

FIG. 8 - Bathimetric reconstruction of São Braz lagoon. 1) Scarp subject to slope replacement, 2) Inactive sea-cliff, 3) Truncated valleys, 4) Isobathimetric lines.



to the present zero. The latter, which is a prerequisite condition for the construction of bars and lagoons, may have started forming only after the end of the most rapid phase of the post-glacial transgression (about 7000 years ago) and it may have become wide and shallow enough later (probably one or more thousand years after that date).

CONCLUSIONS

Investigations carried out on the São Braz Lagoon demonstrate a spit-bars system separating a brackish lagoon from the open ocean. The geomorphological evolution of the investigated area, which is located about 200 Km south of Luanda immediately north of the São Braz promontory, was started by sea-level fluctuations that modelled the sea-bottom until the Late Holocene.

An older lagoon, at present a small sabka, indicates a first phase of coastline progradation. Before the identification of the system of spit-bars, the area was presumably characterised by an open coastal platform, limited inland by a sea cliff now forming the landward margin of the sabka basin. This sea-cliff is affected at present by a phase of slope replacement, northward, the sea-cliff, controlled by a structural feature, plunges directly into the sea. This latter is subjected to active retreat by wave erosion. This is shown by several hanging valleys close to the upper edge of the cliff.

Today the morphodynamics of the São Braz Lagoon is controlled by the coastline orientation as well as by the prevailing wind, and by the swell it generates. This process

has resulted in the construction of a spit system downdrift of the promontory.

The trend of the reconstruction of the spits trend has been possible through topographic and bathymetric surveys which have demonstrated the presence of several ancient sandy ridges which have been eroded and submerged and are clearly related to the trend of emergent spits. The evolution of the area is a consequence of the minor sea level fluctuations which occurred during the second half of the Holocene, but a major role could be ascribed to changes in the oceanographic conditions occurring during the last millennia, which were climatically induced.

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