

EVOLUTION OF SEDIMENTARY ENVIRONMENTS AND FACIES,
ST LUCIA ESTUARY MOUTH.

by

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ABSTRACT

The St. Lucia Estuary is situated on the subtropical, predominantly microtidal Zululand coast. Modern sedimentary environments within the estuary fall into three categories: (1) barrier environments; (2) abandoned channel environments; and (3) estuarine/lagoonal environments. The barrier-associated environment includes tidal inlet channel, inlet beach face, flood-tidal delta, ebb-tidal delta, spit, backspit and aeolian dune facies. The abandoned channel environment comprises washover fan, tidal creek, tidal creek delta and back-barrier lagoon facies. The estuarine/lagoonal environment includes subtidal estuarine channel, side-attached bar, channel margin, mangrove fringe and channel island facies. Each sedimentary facies is characterised by sedimentary and biogenic structures, grain-size and sedimentary processes. Vertical facies sequences produced by inlet channel migration and lagoonal infilling are sufficiently distinct to be recognized in the geological record and are typical of a prograding shoreline.

INTRODUCTION

Lake St Lucia is situated on the coastal margin of the Zululand Coastal Plain, occupying a position between 27° 52'S to 28° 24'S and 32° 21'E to 32° 34'E (Begg, 1978). Lake St Lucia has a surface area fluctuating between 420 and 215 km² depending on lake levels (Begg, 1978). The lake has a mean depth of less than 1 m.

The 21 km long channel known as The Narrows connects Lake St Lucia with the Indian Ocean. According to Orme (1973) tidal effects penetrate 14 km up the Narrows, but the study area comprises only the first 2.1 km from the sea to Honeymoon Bend. For the purposes of this paper this area will be referred to as "St Lucia Estuary Mouth" (Fig.1).

Hobday (1975) refers to Lake St Lucia as a large saline lagoon, but since the system is semi-closed with an artificially controlled free connection to the sea, Begg (1978) states that the St Lucia system should be referred to as an estuary-linked lake system.

Wallace (1975) states that St Lucia is the largest estuarine system in Africa and it is without doubt the most important in South Africa since it comprises approximately 80% of the total area of the Zululand coastal plain. St Lucia has a reputation, certainly throughout southern Africa, for its fishing and bird life, and is a national asset.

Few reports of sedimentation in tropical areas have been published. Cooper (1988) gives a good account of the sedimentary environments and facies of the Mgeni Estuary, north of Durban. This paper describes the different sedimentary environments of the predominantly microtidal St. Lucia Estuary Mouth, and includes sedimentary and biogenic structures, grain-size analyses and surface features. Observations were made during a spring tidal low period following recommendations by Klein (1977). St. Lucia Estuary Mouth has been subjected to two major floods in the last five years, Cyclone Domoina during February 1984 and the September 1987 cut-off low flood event. Both floods were responsible for removing vast amounts of sediment from the estuary.

Estimates of the St Lucia catchment area vary from 8900 km² to 9065 km² (Begg, 1978). According to The St Lucia Research Series Report No. 1 (1987) the catchment has a mean annual runoff of 287 x 10⁹ m³.

According to Van Heerden and Swart (1986), the catchment has a subtropical coastal and temperate inland climate. Thunderstorms and mid-latitude cyclonic activity are the dominant weather patterns. Rainfall is approximately 1200 mm per annum at St Lucia estuary mouth. Evaporation is the most influential of the natural processes in Lake St Lucia during a dry climatic cycle, and accounts for losses of up to 397 x 10⁹ m³ per annum (Begg, 1978).

The geology of the catchment area ranges from rocks of Swazian age (ca. 3100 Ma.) to unconsolidated Recent sediments. Holocene deposits include extensive beach and dune sands carrying varying proportions of heavy minerals. These deposits occupy a narrow strip adjacent to the present coastline. There is also a widespread deposit of white, wind-blown sand which covers the hills and fills hollows and low-lying areas on the coastal plain (Wolmarans & Du Preez, 1986).

STUDY AREA CHARACTERISTICS

The St Lucia mouth is extremely dynamic. The changing morphology has been clearly depicted by Orme (1975). The estuary mouth is characterised by both a northern spit (extending south from the north bank) and southern spit (Fig.2). These show that longshore drift moves sediment into the estuary mouth from both the south and north. An emergent flood-tidal delta is situated approximately 500 m up the estuary. Casuarina stands are located both north and south of the estuary mouth behind the foredunes. Behind the northern stand of Casuarina an area of low-lying swampland with remnant mangroves and Phragmites is known as Shark Basin. The estuary mouth from Honeymoon Bend to the sea consists of one main channel with a maximum depth of 6 m. The water within the upper channel is confined by steep natural or man-made banks. A 400 m length of the north bank next to Honeymoon Bend has been stabilised by an interlinking concrete mat. Other major man-made structures within the estuary include the dredger and pipeline as well as various remnant concrete blocks left from the

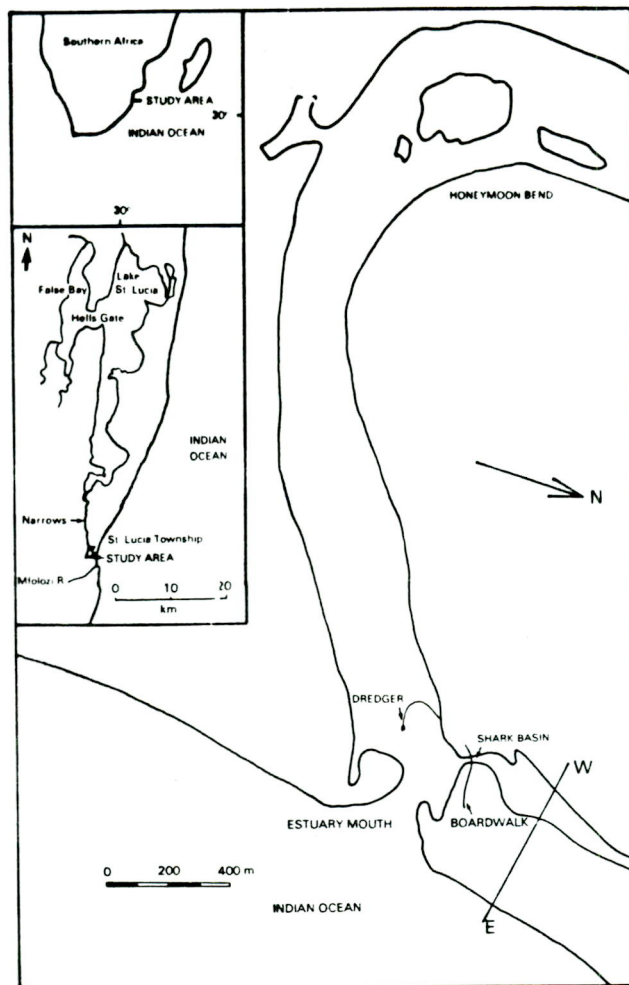


Figure 1. Location of the study area and configuration of the St. Lucia Estuary Mouth, traced from a map made for Natal Parks Board. The mouth shape changes with the seasons.

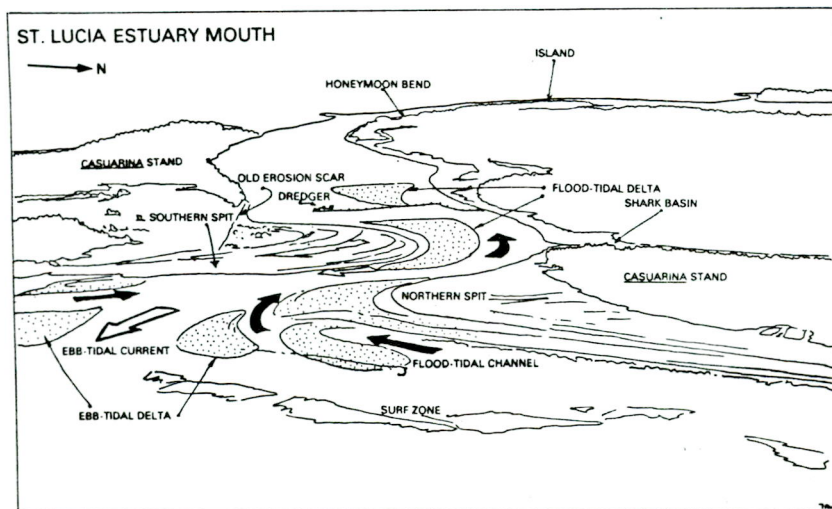


Figure 2. Tracing made from oblique aerial photograph taken by Natal Parks Board showing the configuration of St. Lucia Estuary Mouth and the sand banks constructed by the flood- and ebb-tidal deltas. Photograph by Frank Junor, NPB DATE 1986.

former groyne complex. It is only the lower estuary including Shark Basin that is unconfined, and is thus most susceptible to change. The steep southern bank forms cliffs up to 5 m high especially where, during flood conditions, the water has cut into the old dredger spoil site. Large areas of this dredged spoil are not stabilised and may thus act as a potential sediment source. At Honeymoon Bend, the main channel is split into two by a series of low-lying islands containing oyster beds. These islands are important as they effect the water flow and thus sediment dynamics within the study area.

1. BARRIER-ASSOCIATED SEDIMENTARY ENVIRONMENTS

1.1. Tidal inlet channel

The St. Lucia tidal inlet is commonly 75 m - 150 m wide, and forms the only connection with the sea. The channel bottom comprises coarse sand (99%) with minor gravel (1%). Pebble-sized mudballs eroded from the estuary margins and Shark Basin on the ebb tide were encountered in the channel as well as a variety of marine gastropods and bivalves brought in on the flood tide. Visual observations were limited as it was too dangerous to use SCUBA apparatus due to large shark populations. Aerial photographs indicate both ebb- and flood-orientated sinuous to lunate mega-ripples as well as sand waves. The sand waves have a wavelength of up to 50 m. The tidal inlet splits into two channels in the estuary, one dominated by the ebb current, and the other by the flood (Fig.3). Spring tidal current velocities were measured in the flood-dominated channel with 0.72 m/s recorded for the flood tide and 0.34 m/s for the ebb tidal flow. The tidal channel also splits seaward into ebb and flood-dominated channels.

1.2. Inlet beach face

The inlet beach face is an extensive zone (200 m wide) rimming the inlet channel. Approaching waves are refracted so that the wave front is parallel to the inlet beach face. Marine gastropod and bivalve shells are deposited on the inlet beach face. This environment is inhabited by sparse populations of the burrowing crab *Ocypode*. A number of different tidal and aeolian sedimentary structures were noted in this environment. The interaction of ebb-tidal features and flood-tidal features, plus superimposed aeolian effects, produces a complex set of sedimentary structures. Flood-orientated lunate megaripples with wavelengths of up to 4.5 m and 40 cm amplitude form in an abandoned flood channel zone. In places the lunate megaripple troughs have been completely filled forming trough-cross-bedding. Closer to the main channel, flood-orientated, sinuous to lunate, flat-topped megaripples have smaller secondary flat-topped ripples within the primary ripple trough. The secondary ripple set has a wavelength of 20 cm and an amplitude of 3 cm; they are orientated obliquely to the primary set at an angle of 30°. This combination of two sets of ripples is referred to as a ladderback set (Tankard & Hobday, 1977). A third set of asymmetrical current ripples (wavelength 4 cm and amplitude 0.5 cm) formed 90° to the secondary set. These flat-topped ladderback ripples are typical late-stage emergent runoff tidal features (Klein, 1977). Although often found in intertidal environments (Klein, 1970a; Wunderlich, 1970), ladderback ripples have been recorded from the South African subtidal marine environment by Reddering (1987) and Ramsay *et al.* (1989).

Towards the estuary mouth late-stage-emergence ebb-tidal ladderback megaripples predominate. The seaward orientated primary megaripples have a wavelength of 40 cm and amplitude of 4 cm. The secondary set of ripples have a wavelength of 20 cm and amplitude of 3 cm, and are orientated 90° to the primary set.

During the study a 30 km/h northerly wind occurred, superimposing aeolian bedforms on the estuarine structures. Saltating aeolian sand grains form elongate lineations parallel to the wind direction. Bagnold (1954a) showed that a strong sand-laden wind blowing over a uniform rough surface has a transverse instability, so that sand tends to be deposited in longitudinal ribbons known as sand strips. According to Reineck and Singh (1973) sand strips are typical desert features being found on sand sheets. A combination of rapid sedimentation, high wind velocities, and fairly uniform grain-size of the sand cause deposition of sheet sand with an abundantly developed evenly-laminated sand bedding (Bagnold, 1954a; Glennie, 1970). Thus, although not a desert environment, the inlet beach face does have the basic requirements for sand strips to form. An aeolian slipface of 30° forms where the sand blows over the megaripples. Adhesion ripples form a narrow zone approximately 1.5 m wide adjacent to the estuary. Adhesion ripples have been recorded from sandy beaches and intertidal flats (Van Straaten 1953b; Hunter 1969; Allen 1984). The adhesion ripples form 90° to the dominant wind direction as irregular to regular transverse ridges with a wavelength of 10-15 cm and amplitude of a couple of millimetres. Starved wind ripples of 7 cm wavelength and 0.5 cm amplitude are also formed where dry sand migrates over moist intertidal sediments.

1.3. Flood tidal delta

The St. Lucia flood tidal delta is a prominent feature which contributes most of the marine sediment to the estuary mouth area. When flood tidal currents enter an estuary after surging through the narrow inlet channel much of their energy dissipates and the marine sand which has been transported through the inlet is deposited as a flood tidal delta (Hayes 1975). According to Hayes and Kana, (1976) the three dimensional morphology of flood tidal deltas have been extensively studied. A flood-tidal delta model described by Hayes,

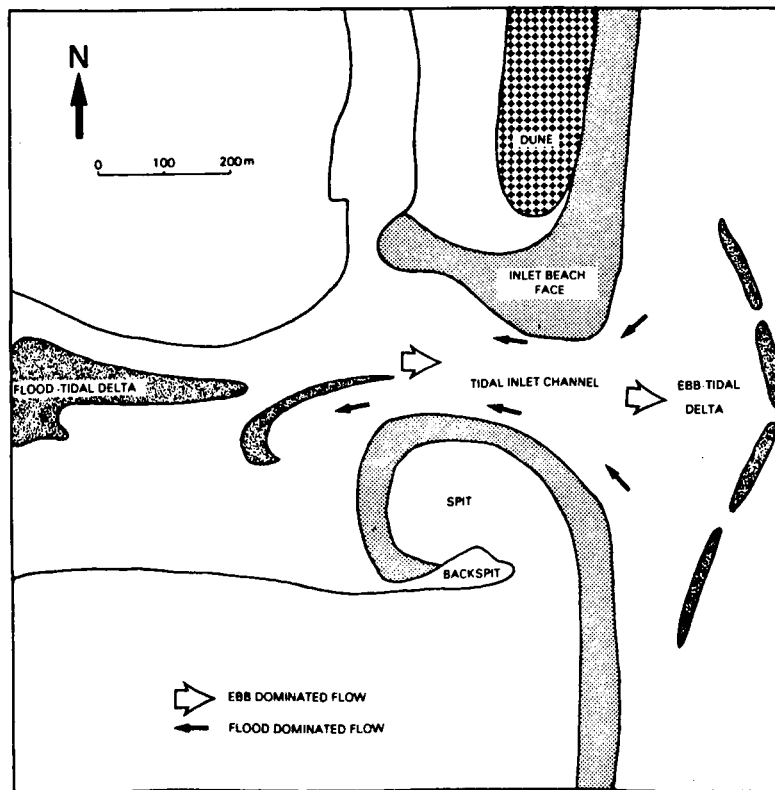


Figure 3. Composite representation of the barrier-associated sedimentary environments of St. Lucia Estuary Mouth.

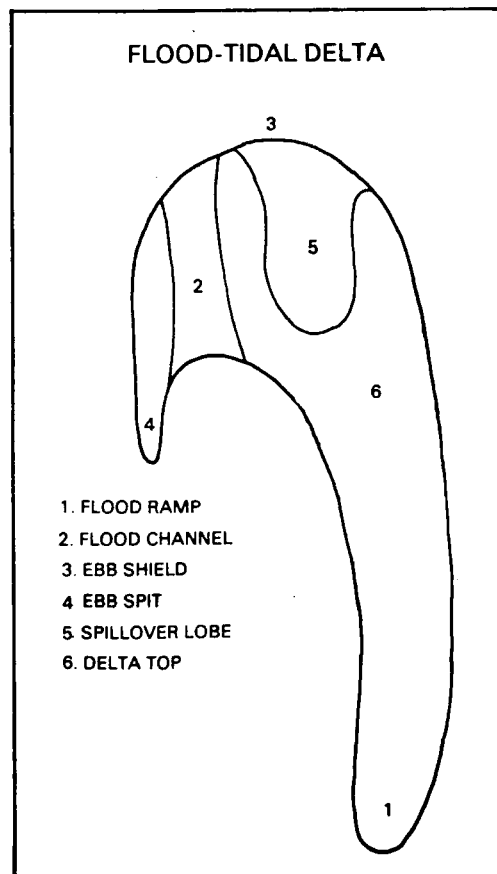


Figure 4. Idealised figure showing the morphology of the flood-tidal delta and its main geomorphic features.

(1980) is characterized by a flood ramp, flood channel, ebb shield, ebb spit, spillover lobe and delta top; similar features are recognized in the St. Lucia Estuary Mouth (Fig.4). During a spring low tide, ebb tidal features dominate the flood tidal deltas. These features include both rhomboidal ripples and megaripples. Aerial photographs show flood-tidal currents moving over the delta forming sinuous and lunate megaripples with a wavelength of several metres. Biogenic structures are absent as the non-cohesive sandy substrate is too unstable for infaunal habitation (Cooper 1988).

1.4. Ebb tidal delta

The St. Lucia estuary mouth is different from most of the other estuaries of Zululand and Natal as it has a distinct ebb-tidal delta. Ebb-tidal deltas are rarely present on this coast due to a high wave energy regime and longshore drift (Cooper 1988). Features present at the St. Lucia estuary mouth resemble those described by Hayes (1980) as being typical of an ebb-tidal delta. The main components of the St. Lucia ebb-tidal delta are the main ebb channel, terminal lobe, swash bars and marginal flood channels (Fig.5). Due to the inaccessibility of the ebb-tidal delta only macro-sedimentary structures traced from aerial photographs were identified. The main ebb channel has both ebb- and flood- orientated rhomboidal megaripples depending on the state of the tides. The emergent swash bars have sinuous flat-topped asymmetrical flood-orientated ripples of 30 cm wavelength and 7 cm amplitude on the landward side. On the seaward side plane beds occur in the swash zone with swash marks forming a primary current lineation (Allen 1964). The sand is coarse-grained and has variety of marine mollusc shells as well as a few discoidal pebbles.

1.5. Spits

St. Lucia estuary is almost completely sealed from the ocean by two spits which are attached to the northern and southern banks. Both spits usually have a lobate upstream curving morphology although during a 3 month period from February 1988 to April 1988 the northern spit took on a long, narrow (60 m long and 10 m wide) shape extending northwest back up the estuary. Van Heerden & Swart (1986) indicate that the southern spit grew after the 1984 floods by southerly waves transporting sediment into the estuary mouth. Growth of the northern spit only commenced after the ebb-tidal delta that was eroded during the September 1987 floods reformed, causing the predominant southerly swell to be refracted around the delta, and enter the estuary from the northeast.

Fig.6 illustrates a section through the southern spit which shows how the spit prograded over a channel deposit with an aeolian deposit on top. The vertical sandy cliff section has a wave-cut swash zone at the high tide level, as well as a similar zone at the low water mark. The channel deposit comprises a medium (1-2 ϕ) to coarse-grained (0-1 ϕ) sand, the spit a fine (2-3 ϕ) to medium-grained sand with a few heavy minerals. The aeolian sand is fine-grained. The spit top is littered with organic debris deposited by the September 1987 flood. On the northern spit the organic debris was stacked and burned as it was unsightly and smelly and this is a recreational beach area. Where this flood deposit was not removed from the southern spit, the plant debris acted as a sediment trap initiating foredune growth. New vegetation growth has helped to stabilize the sand. Littoral processes have deposited the trees parallel to the beach. Tavener-Smith (1982) has recorded similarly orientated fossil logs in the geological record in the Permian Vryheid Formation near Durban. The modern logs are orientated parallel to the waterline and as the spit is curved, almost forming a full circle no dominant log orientation was recorded (Fig.7). Biogenic structures consist of vertebrate and invertebrate trails and tracks and tool marks including grass scratch circles (Allen 1984). Sand strips, current crescents, sand tails and low amplitude asymmetrical wind ripples comprise the aeolian features.

1.6. Backspit

The intertidal and subtidal area behind the spits is known as the backspit region. This expanse is distinguished from the remainder of the facies as it is the only part of the barrier-associated environment which is muddy. The backspit is protected from the main channel by the curved spits so that calm, tranquil conditions prevail, enabling mud to settle from the water column. The intertidal area is dominated by straight to sinuous asymmetrical wave ripples (wavelength 7 cm; amplitude 1 cm). In certain places ladderback ripples may form where water is trapped in the ripple troughs and is moved by wind activity (Land & Hoyt, 1966). Adhesion ripples arise where sand from the supratidal belt is blown over the wet intertidal zone. Biogenic structures include bird footprints, Callianassa burrows and crab (possibly Ocypode) burrows.

1.7. Aeolian dunes

Due to the abundance of Casuarina stands in the study area aeolian dunes are poorly developed on the barrier. Northward along the seaward edge of Shark Basin dunes have been artificially erected to act as a wind break. The dunes are stabilized by vegetation and small blow-outs occur where foot-paths lead to the beach. No washover structures are present but from vibracore data (Wright & Mason, 1989) washovers could have been active in the past before any human interference altered the system. Terrestrial animal tracks and tool marks such as scratch circles made by the wind bending grass over and inscribing a circular pattern on the sand are the only biogenic structures present.

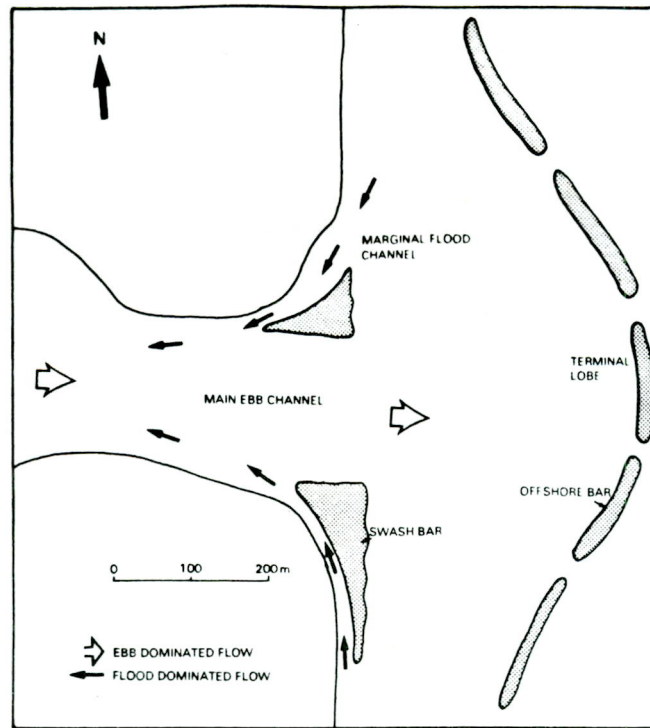


Figure 5. Morphology of the St Lucia ebb-tidal delta showing the position of the ebb and flood channels and the associated sandbanks.

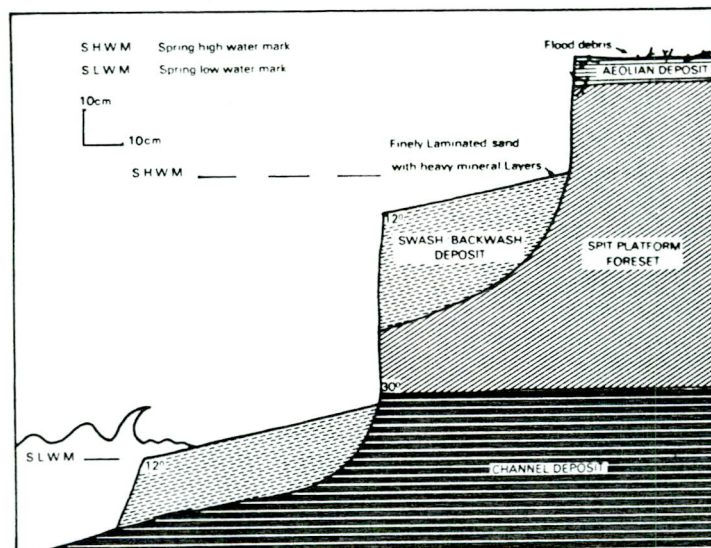


Figure 6. Diagrammatic cross-section showing relationships between the channel, aeolian, swash and spit facies in the southern spit, St Lucia Estuary Mouth.

2. ABANDONED CHANNEL ENVIRONMENT

The "Shark Basin" area represents a former channel of the St. Lucia estuary mouth (Fig.8). Before 1950 the estuary mouth migrated up to 2 km north due to longshore drift and spit formation. During floods the estuary mouth formed in its modern position by breaching the spit. Since human intervention in the late 1950s, various efforts to stabilise the mouth position have failed. In 1969 a groyne complex was constructed to cause scour action at the mouth, and remove the necessity of maintaining a permanent dredging operation. The stabilising of the channel meant that the mouth could no longer migrate north, thus the channel was effectively abandoned: This is "Shark Basin". Since the destruction of the groyne system by Cyclone Doina in 1984 the old channel has been kept open by tidal activity as well as groundwater flow.

* also casuarina, planted
white coral sand

2.1. Washover fan

Pre-1950 aerial photographs indicate a long narrow spit extending north from the south bank. This spit included a number of washover fans which deposited marine sediment into the channel. Active washover fans still enter Shark Basin, forming on a spring high tide, when southeasterly swells enter the mouth depositing medium to coarse sand on the low-lying marshy area as a series of lobes. According to Price (1949), these sand bodies are deposited on the landward side of coastal barriers by strong wave action during storms, but recent observations by the authors along the Zululand coast indicate that these deposits may also form on a spring high tide (Cooper & Mason 1987). Fig.10 shows a lagoon-fill sequence formed by a washover sand unit in the Lower Cretaceous Muddy Sandstone (Davies *et al.* 1971) which is similar to the deposit presently forming in Shark Basin. The washovers that occur in Shark Basin consist of medium to coarse-grained marine sand with a few molluscan fragments. These washovers accumulate over the remains of old mangrove populations. This phenomenon of a fine-grained back-barrier lagoonal sediment being scoured by a marine washover event has been recorded in vibracores taken from Shark Basin (Fig. 9). Internal structures of the washover include parallel lamination with a few heavy mineral layers. Low angle seaward-dipping laminae were attributed to beachface accretion. Asymmetrical sinuous current ripples form on the washover lobes near the sea while straight-crested current ripples form further inland on the washover fan, indicating waning current flow velocities. The washover deposits are subsequently reworked by aeolian processes which redistribute the fine-grained sand fraction over the whole Shark Basin area and leave a coarse lag which camouflages any indication of washover structures. Biogenic structures are rare and consist of a few terrestrial mammal tracks. Wind action around logs deposited during the last floods has formed current crescents.

2.2. Tidal creek

A small tidal creek flows south through Shark Basin entering the main estuary channel. The creek averages 3-5 m wide and 0.8 m deep and is kept open by the tides as well as a groundwater input. Current velocities are low except where the tidal creek enters the main channel. At this point, during spring high tides, the southeasterly swells surge up the creek under the pedestrian boardwalk. It is in this area, where current velocities are at a maximum, that older lagoonal mud deposits which form the channel margins are eroded to form mudballs. The bottom sediments of the creek comprise either medium- to coarse-grained marine sand or lagoonal mud. The tidal creek channel is surrounded by a sparse stand of mangroves including Avicennia marina. Reworking of marine sand within the creek forms intertidal braid bars which prograde downstream towards the main channel. The braid bars have downstream orientated lunate ripples migrating over the bar top. Biogenic structures on the braid bars consist of Uca and polychaete worm burrows and trails as well as pseudofaecal pellets from Uca.

2.3. Tidal creek delta

Where the tidal creek flows into the main channel it forms a delta. The delta surface has a typical fan shape caused by distributary channel bifurcation. Sedimentary structures on the delta include straight-crested flat-topped ripples with a wavelength 20 cm and amplitude 3 cm. These ripples are joined by washout rill structures. According to Reineck and Singh (1973) rill structures are generally associated with a change from subaqueous to subaerial conditions which include a falling water level on intertidal flats. Mud balls derived from the tidal creek and marginal lagoonal mud are common within the troughs of the ripples. The mud balls tend to be spheroidal when they leave the tidal creek but when trapped within a ripple trough they become more elongate possibly due to the swash/backwash action in the intertidal zone. The mud balls also collect an outer armoured crust of sand. The delta comprises thin accumulations of lagoonal mud with remnant mangrove remains overlain by marine sands. Bird footprints and crab feeding trails comprise the biogenic component.

2.4. Back-barrier lagoon

The upper reaches of the tidal creek open into a back-barrier lagoon where strong tidal current effects are negligible. The main depositional mechanism is suspension settling of organic-rich mud. The organic component comprises decaying vegetation including reeds (Phragmites) and mangroves (Avicennia marina). Occasional influxes of estuarine sand and mud enter the lagoon during floods when the whole of Shark Basin is

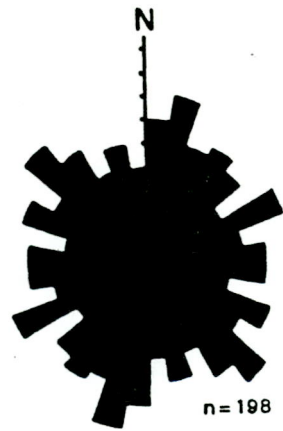


Figure 7. Scalar orientation plot of measurements taken from elongate flood debris deposited on the surface of the southern spit after the September 1987 flood event.

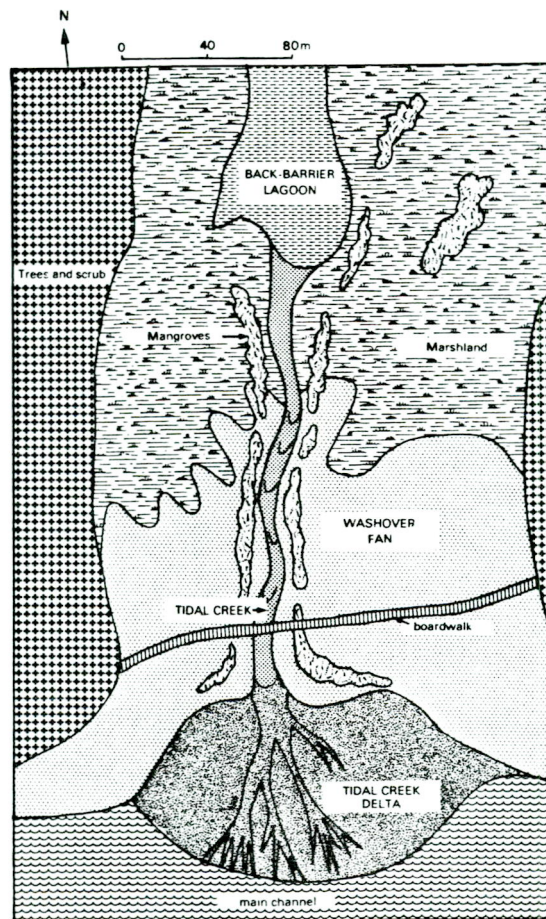


Figure 8. Sedimentary environments of an abandoned channel area behind the northern beach-barrier, Shark Basin, St Lucia Estuary.

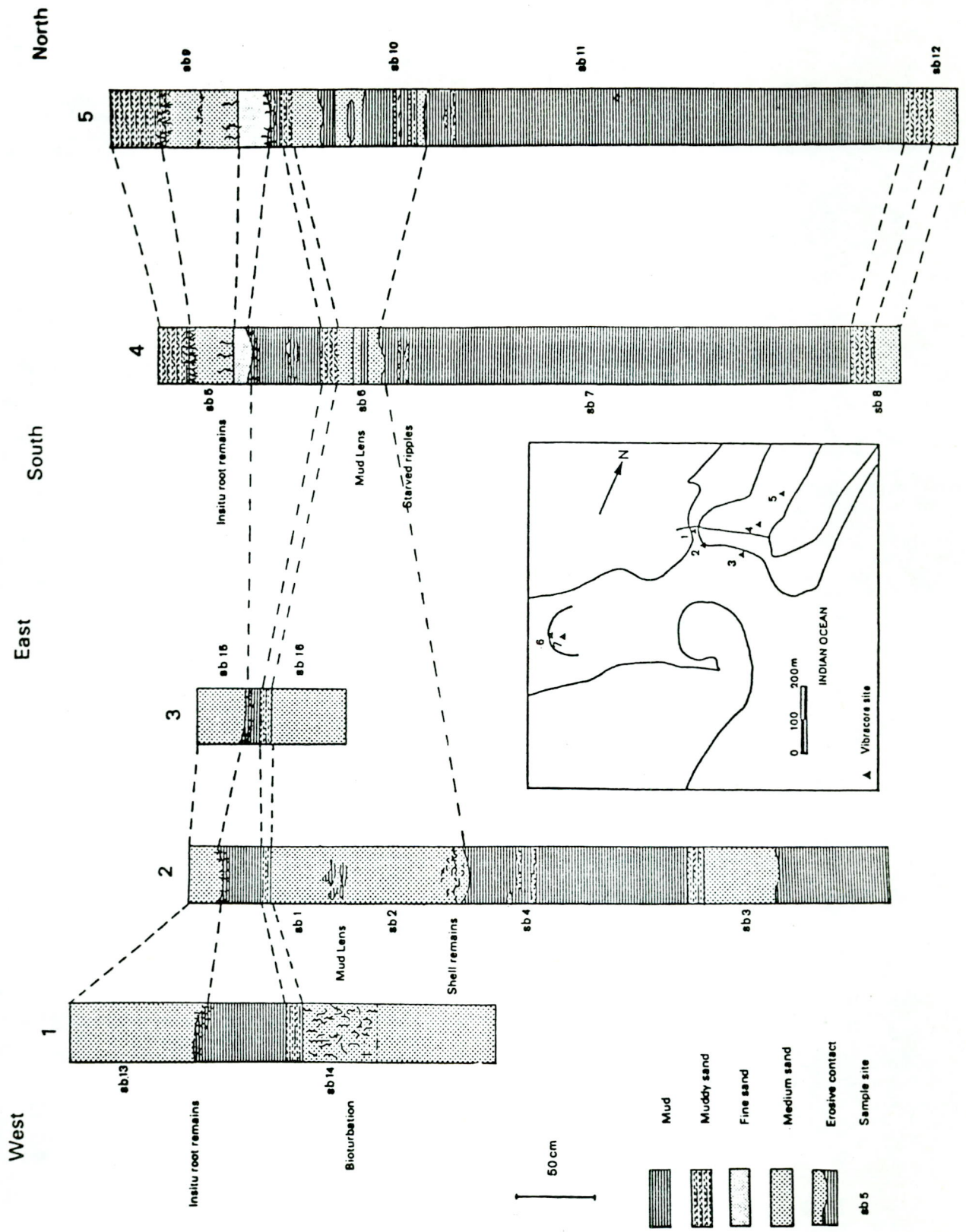


Figure 9. Shark Basin vibracores, the inset map shows the sample points. The Shark Basin successions include washover sand bodies, for example the facies marked sb3, sb14, sb6, sb9 on the vibracore records. The washovers are erosively-based sand bodies resting on muddy lagoonal facies, and overlain by muddy sand. Parts of the succession are bioturbated and contain rootlet beds which represent the mangrove swamp environment.

inundated. During floods large amounts of logs and reeds are normally deposited by the receding waters adding to the organic content. A few Callianassa, Upogebia and polychaete worm burrows occur.

3. ESTUARINE/LAGOONAL ENVIRONMENT

A number of back-barrier and palaeoestuarine deposits have been recognised in the geological record (Bosence 1973; Campbell and Oaks 1973; Hobday and Horne 1977; Tavener-Smith 1982). Five estuarine environments have been recognised in the St. Lucia estuary mouth (Fig.11). The study area from the sea to Honeymoon Bend is dominated by a strong tidal effect with a maximum spring tidal range of 2.26 m at Honeymoon Bend (S.A. Tide Tables, 1988). Visual observations were difficult in this environment due to high water turbidity.

3.1. Subtidal estuarine channel

At the estuary mouth the ebb-dominated subtidal estuarine channel consists of coarse marine sand which is normally associated with a gravel lag. Sand waves of up to 30 m wavelength have been recorded in the ebb channel, 200 m upstream of the estuary mouth. The lower estuary mouth is occupied by marine sand and the middle and upper reaches by estuarine mud and sands. Beyond the furthest marine influence calm conditions prevail enabling mud to settle out. No biogenic structures were recorded as underwater observations were not possible.

3.2. Side-attached bars

A side-attached bar is located where the dredger pipeline reaches the north bank. The pipeline and associated floats are an effective sediment-trapping mechanism, causing a bar to build out from the north bank. The bar consists of fine- to medium-grained marine sand which has been reworked by aeolian processes. A large dredge spoil site located on the north bank next to the dredger pipeline also adds to the sediment input of the bar. Deposits of logs and reeds left by the last flood on the supratidal part of the bar cause deposition and stabilization of the sand. Smaller ebb-orientated side-attached bars form on the spit margins by the ebb tide eroding part of the spit and depositing the sand further downstream.

3.3. Channel margins

The channel margins are fairly steep (10° - 30°) and have been modified by human interference. The intertidal part of the channel margins comprise either older consolidated lagoonal mud or fine- to medium-grained sand which may be either estuarine or marine in origin. The steeper margins occur in the consolidated mud, as they are more resistant to erosion than unconsolidated sand. There is no unconsolidated mud in the intertidal zone as it has been winnowed out. Structures in the sand include a swash lineation and small, asymmetrical, straight-crested wave ripples. Bedding planes in the sand dip gently (10° - 15°) towards the channel centre.

3.4. Mangrove fringe

Only two sparse mangrove communities are found in the study area. They are located at Shark Basin and the south bank of Honeymoon Bend. The Shark Basin mangrove community is struggling for survival as it is continually being buried by marine washover fans. The mangroves consist of Avicennia marina which have the important ability to trap fine sediment with their pneumatophores (Berjak, 1977). The mangrove fauna consist of Uca, Callianassa and polychaete worms all of which have important trace-fossil (ichnofossil) making abilities. According to Cooper (1988) there are a variety of potentially preservable ichnofossils in the mangroves: these are shown in Fig.12. The mangrove stand at Honeymoon Bend is more mature than the one at Shark Basin and is dominated by Avicennia marina with subordinate Bruquiera gymnorhiza. Most of the sediment is organic-rich mud although at Shark Basin a sand fraction is added by marine washover events and floods.

3.5. Channel islands

The two mid-channel islands at Honeymoon Bend are important as they affect the current flow around the bend. The islands comprise estuarine mud and sands that accumulated in the estuary during the late 1950s, due to increased farming activity in the catchment. During the 1960's the estuary was reopened by dredging, but the two islands remained as a spoil pile. The islands have been colonised by oyster beds which have further stabilise them.

DISCUSSION

Fig 13 summarizes the predicted vertical sequence of sedimentary facies at the St. Lucia estuary mouth. The overall facies pattern of a beach or barrier-beach complex is determined by: its long-term response to sea-level fluctuations, subsidence/emergence rates of the depositional area and variation in sediment supply (Dickinson et al, 1972). Although much modified by human activity the sequence shown in Fig 12 is a typical regressive sequence. According to Cooper (1988) the Zululand coast is at present prograding. Van Heerden & Swart (1986) show a seaward migration of the combined Mfolozi River and St. Lucia estuary mouth; having

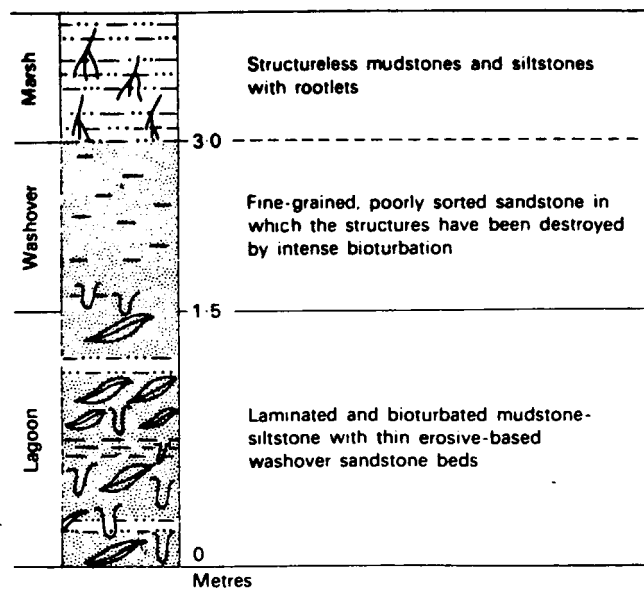


Figure 10. This lagoon-fill sequence from the Lower Cretaceous Muddy Sandstone of the American midwestern seaway includes a washover fan sequence which may be compared with the Recent example from St. Lucia. (After Davies *et. al.*, 1971)

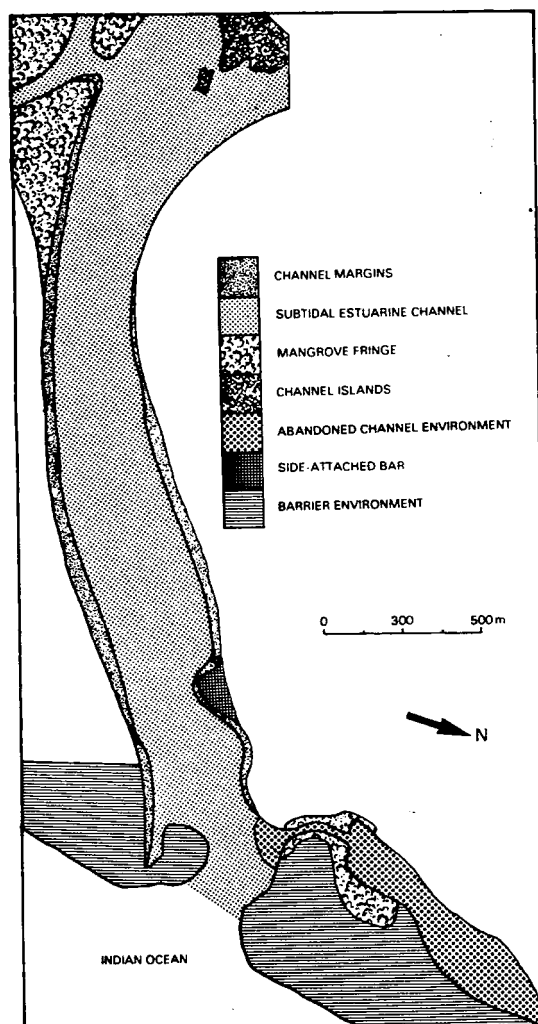


Figure 11. Distribution map of estuarine/lagoonal sedimentary environments of St. Lucia Estuary.

Organism	Nature of trace	Potential ichnofossil
Fiddler crab (<i>Uca</i>)	Vertical burrow, 2-3 cm diameter and up to 10 cm long	<i>Cylindricum</i>
Ghost crab (<i>Ocyrode</i>)	J or Y-shaped burrows, 2-3 cm diameter and up to 50 cm long	<i>Psilonichnus</i>
Marsh crab (<i>Sesarma</i>)	Subhorizontal burrows, 10 cm diameter and up to 100 cm long	not known
Sand prawn (<i>Callinassa</i>)	Complex branching burrow system 1 cm diameter	<i>Thalassinoides</i>
Mud prawn (<i>Upogebia</i>)	Y or U-shaped burrows of 0.1-0.5 mm diameter, commonly 10-12 cm deep	not known
Polychaete worms	Vertical burrows, 0.1-0.5 cm diameter and irregular sinuous surface trails	<i>Skolithos</i> and <i>Helminthopsis</i>

Figure 12. Estuarine trace-making organisms, the traces which they produce, and potential ichnofossils identified in the Mgeni Estuary, Durban. The same animals and traces occur in the St. Lucia system. (After Cooper, 1988)

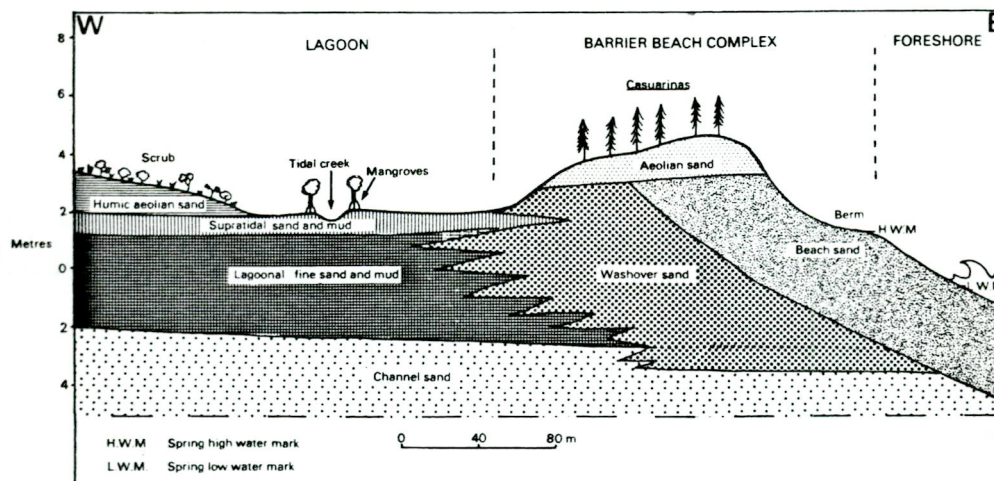


Figure 13. A west-east section through Shark Basin and the barrier-beach complex showing the vertical facies sequence which has been formed by lagoonal infilling and channel migration in a prograding shoreline setting.

prograded approximately 300 m eastward in the past 100 years. Historical records show how estuary mouth conditions have changed through time. Aerial photographs flown in 1937 indicate the Mfolozi River and St. Lucia Estuary Mouth discharging into a large embayment. The bay was separated from the sea by a long barrier-beach complex which had numerous washover fans spilling into the back-barrier lagoon. The tidal inlet channel was deflected up to 2 km north by longshore drift. During floods the Mfolozi River cut a new channel through the barrier. This post-flood response is well-documented by Van Heerden & Swart (1986). Tidal flat deposits with a large benthic infauna were present as well as commercially exploited oyster beds. Historical records (Kriel *et. al.* 1966) indicate that from 1576 to 1927, before intensive farming activity took place in the catchment, the estuary mouth closed for three to four months a year, usually from August to November. At such times of low flow fine-grained sediment would have accumulated within the back-barrier lagoon. The fine-grained succession was interbedded with sandy sediment which had been introduced by occasional washover events. After 1956 increased farming activity and canalization of the Mfolozi River wetlands caused sedimentation which clogged the system and effectively altered the character of the sedimentary environments.

Facies of the barrier-beach and channel environments are mainly medium- to coarse-grained sand with a small terrigenous gravel fraction, whereas the lagoonal deposits comprise fine sand and mud. Similar facies relationships have been recorded by Reinson (1984) from a composite stratigraphic section of the Upper Cretaceous Blood Reserve - St. Mary River Formations, Southern Alberta. Vertical stacking of sequences is caused by inlet channel migration, lagoonal infilling and shoreline retreat. Tidal inlet channel migration occurred until 1969, when the groyne complex was constructed at the estuary mouth effectively stopping any channel migration. Cyclone Domoia destroyed the groyne in 1984 and limited channel migration recommenced. The construction of the groyne isolated Shark Basin from the main channel and lagoonal infilling of this area was greatly accelerated as calm stagnant conditions prevailed. The construction and stabilization of the dune barrier seaward of Shark Basin caused shoreline enhancement. This progradation is also enhanced by the dredge outlet forming a localized prograding beach. The formation of the dune barrier and shoreline retreat has stopped washover fans overtopping the barrier-beach complex. Washover events now only occur when a southeasterly swell enters the estuary mouth on high tide and deposits sand within Shark Basin.

Thus the sedimentary facies present at the St. Lucia Estuary Mouth, although altered by human activity contain evidence of subtropical, wave-dominated conditions on a prograding coastline. Although the estuary is mostly microtidal there is a strong marine sediment influence terminating 900 m up from the mouth. The estuary mouth configuration is controlled by the large southeasterly swell regime of the Zululand coast as well as major floods which periodically flush accumulated sediment from the estuary..

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① How much channel/mouth
migration can we expect?
② Dredge S. Bank sp. 1/2
③ See also 1/2?

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