The Changing Coastline of the Cedros Peninsula, Trinidad.

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ABSTRACT

The extreme tip of south-western Trinidad at Icacos has been the site of aggressive shoreline erosion and accretion over the past several decades. The effects of erosion are particularly noticeable at Coral Point, Constance Estate and accretion at Punta del Arenal. Anecdotal evidence suggests that the rate of erosion at Coral Point has accelerated over the past three decades. There are few readily identified landmarks of known age making it difficult to measure recession or progradation of the shoreline. The most prominent are the estate buildings at Constance Estate and the base of the navigational beacon beside the beach road leading to Punta del Arenal. Nevertheless, using details of the earliest comprehensive coastal survey map of 1797, the Mallet Map, the Cazabon painting of Columbus Bay dated 1857 showing the Los Gallos rocks, and aerial photography of Icacos Point in 1957 and 1994, it has been possible to estimate rates of erosion and accretion. At Coral Point the rate of recession is approximately 4.3m per year while that of progradation at Punta del Arenal is about 3m per year. Evidence from the Mallet Map, the Cazabon painting and aerial photography indicates extreme change in the Los Gallos rocks over the past 200 years. It is suggested that the apparent acceleration at Constance Estate may be caused by continued natural erosion of the Los Gallos rocks permitting more violent longshore currents in Columbus Bay.

INTRODUCTION

The interaction of the sea with landmasses causes erosion and the rate of erosion of this process is determined partly by the local geology and partly by energy levels of the sea impacting on shore. On rocky shorelines the rate of erosion will be determined by the nature of the rock. Igneous rocks are generally more resistant than metamorphosed sedimentary rocks and these more so than unconsolidated sediments. Wave trains at right angles to beaches tend to build while oblique wave trains tend to induce longshore transport of sand and thus erosion. Other factors including landform, vegetation cover, rivers and bioerosion also influence erosion to one degree or another. Shoreline can also grow where sediments are deposited as in deltas or on beaches where longshore currents decelerate abruptly.

Energy applied to a coastline will be mainly in the form of wave action and nearshore currents. In some circumstances wind action may also determine movements of particulate material. Inflow of rivers will also cause local erosion and accretion near the river mouth, especially where the outflow changes course. The geological nature of the shore and orientation to prevailing wave action and current flow will impart local characteristics, which are short-term equilibria. Finally, it must be noted that the net effect of interaction of ocean and land in most cases must be erosion of the shore.

The coastline of Trinidad and Tobago is as varied as may be found anywhere in the world. While the north and east coasts of Trinidad and the windward and leeward coasts of Tobago are moderately stable, the south coast of Trinidad is visibly unstable and eroding. This is obviously so because the sediments making up the coast are young and unconsolidated while the waters of the Columbus Channel flow continuously to the west, parallel with the shore line. Moreover, the southern anticline (Ministry of Energy and Energy Industries 1998) extends from about Erin Point and undersea through to Galfa Point to the west on the Cedros peninsula. The anticline has been the scene of numerous eruptions of bouffes or mud volcanoes, both on land and undersea. Short-lived offshore islands have been a feature of local conditions with two being recorded in the twentieth century (Weeks 1929; Higgins and Saunders 1967) and one at the birth of the twenty-first.

Although there is visible erosion and accretion offshore in many parts of Trinidad and Tobago, the effects are particularly striking at the tip of the Cedros peninsula at Coral Point and Punta del Arenal. At the former, the shoreline is receding while at the latter, it is growing. Kenny (1995) and de Verteuil (2000), have suggested that the severe erosion at Coral Point has been caused by longshore currents in Columbus Bay flowing to the south-west with the sediments being deposited at Punta del Arenal. Bawan Singh (1997) on the other hand suggests that the phenomenon may have been caused possibly by sea level rise, an effect of global warming, and possibly by seabed subsidence, an effect of petroleum extraction from deeper strata in the general area, both on land and at sea.

Circulation patterns in offshore waters around Trinidad and Tobago are well documented in the scientific literature. Nearshore circulation is not as well known. The islands are under the influence of the South Equatorial Current which runs to the north-west along the north-eastern shoulder of South America. This massive oceanic stream deflects the South American rivers in the same direction. The effects of this are most marked where the inner band of this current, the Guiana Current, meets south-eastern Trinidad where it parts into two streams, one flowing through the Columbus Channel and into the Gulf of Paria, the other flowing to the north and passing through the Galleon's Passage and around the north of Tobago. There is a permanent clockwise gyre in the Gulf of Paria with a residence time estimated to be from seven to ten days. Nearshore currents in the Columbus Channel may be in excess of 2 knots to the west (Admiralty 1965), and this may be enhanced at the ebb tide as well as by wind and wave action. The effect of this is severe erosion and westerly transport of materials along the beach. Indeed, material shed from Red Cliff to the east of Chatham can be traced on the beach to as far west as Islote Point.

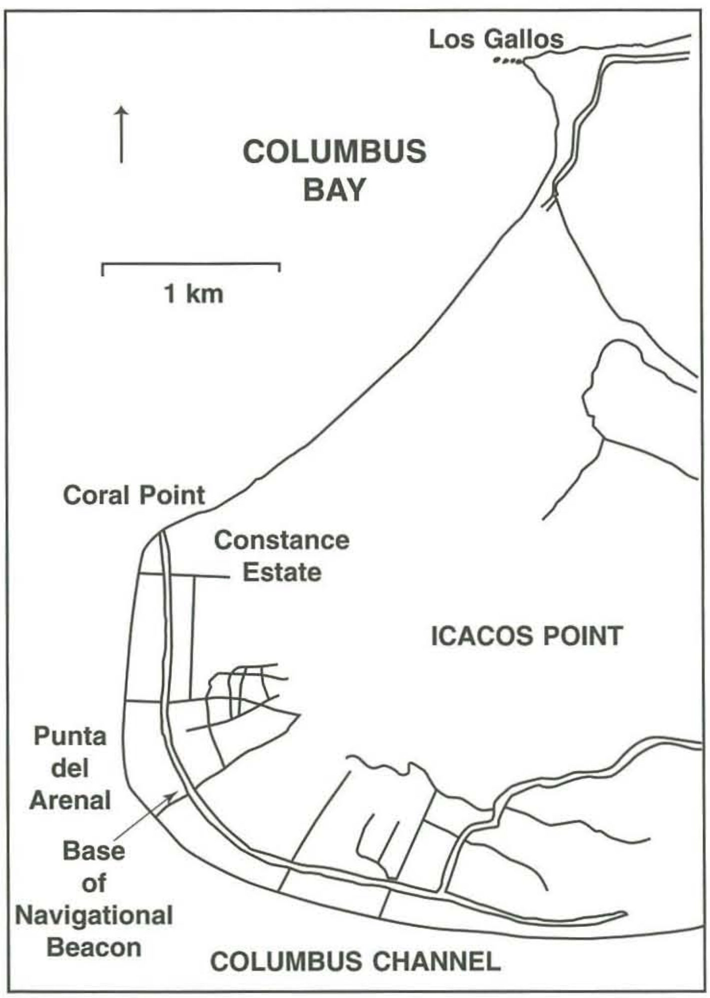

Fig. 1
Topography Icacos Point.

The south coast of Trinidad consists mainly of geologically young unconsolidated sediments and is under severe erosional pressure, while the sea floor in the western part of the Columbus Channel is scoured down to mudstone and rock. To these influences must be added those of tidal currents and wave action.

Perhaps the most important single influence on the shoreline of Trinidad is the Orinoco discharge, for not only does it erode the south coast, but it also delivers sediments to the Gulf of Paria (van Andel and Postma 1954; van Andel and Sachs 1964), and produces a marked annual cycle of falling and rising salinities (Gade 1961). It must be emphasized that the bulk of the discharge of the Orinoco river is to the east and that it has to swing through almost 180 degrees to enter the Gulf of Paria, in which the outer arc of its flow impacts on the south coast of Trinidad.

The Icacos peninsula is of low elevation, mostly below the 25 foot contour, and much of its area is inundated with open herbaceous swamp and mangroves (Figure 1 - Lands and Surveys 1974). The higher elevations are generally devoted to coconut cultivation. Many of the coconut estates are measured in hundreds of hectares. Permanent free standing freshwater is generally absent in the area but boreholes do yield freshwater. Of particular interest is the fact that on the western extremity primary freshwater fish are absent, and there are few amphibian species. Since the end of the last glaciation, sea level has been rising. Given a sea level of about 130m below present levels at the height of the last glacial period and the bathymetry of the Gulf of Paria, Trinidad, and Tobago must have been linked to South America by a land bridge in the south-west and the flow of the Orinoco must have been around the east of Trinidad, and Tobago. Rising sea level would have swamped these bridges, with the Tobago-Trinidad bridge disappearing before the Trinidad-South America bridge. There is now much circumstantial evidence, from oceanic palaeo-reefs in the Gulf of Paria that the Trinidad-South America bridge persisted up to about 500 AD, (Kenny 1995; Chen, Bonair and Kenny [unpublished observations] 1994).

There has been no extended monitoring of coastal changes in the area, the only conventional data being that generated by the Institute of Marine Affairs in the

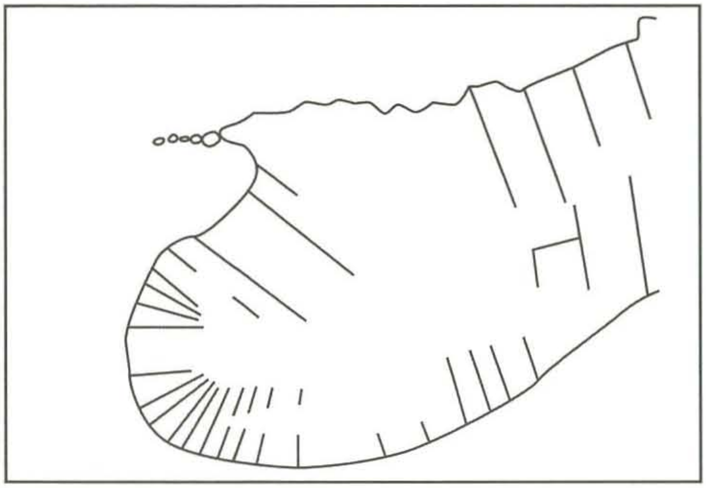

Fig. 2a
Tracing of Mallet Map - 1797.

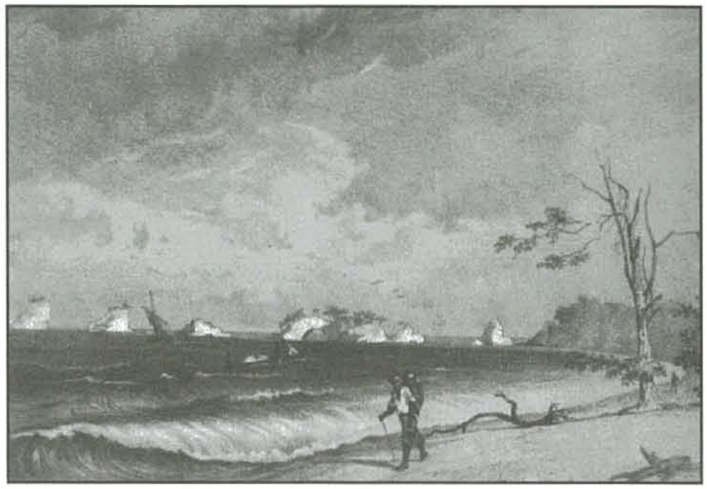

Fig. 2b
Columbus Bay: Cazabon 1857 - Los Gallos in background.

past 20 years. Moreover, unlike many other parts of Trinidad there are no prominent features that could be used as baselines for measurement of recession and progradation of shoreline. It is possible however, on the basis of certain archival records dating back some 200 years and some relatively recent aerial photography, to record the changes and make an approximate measure of the rate of processes. This paper employs the Mallet Map of the coast of Trinidad dated 1797, the Cazabon painting of Columbus Bay dated 1857 and aerial photography dated 1957 and 1994. In addition, certain landmarks in the area are also employed, namely the buildings at Constance Estate, the base of the navigational beacon at the corner of the Icacos Beach Road at Punta del Arenal Road, and the Los Gallos Rocks.

METHODS

Two sets of aerial photographs each covering the Los Gallos area and the tip of Icacos, dated 1957 and 1994, were obtained from the Lands and Surveys Department. For purposes of comparison aerial photography was simply copied to the same scale, reduced to the scale of the topographical sheet, converted to transparencies and overlaid on the existing topographical sheet. (Lands and Surveys 1974), of the area based on 1967 aerial photography.

CONCLUSIONS

The Mallet Map

On the conquest of Trinidad in 1797, Sir Ralph Abercromby commissioned a charting of the coastline and known hinterland. This was done by Captain F. Mallet, Captain of the Surveying Engineers, Faden 1797, in the same year and subsequently modified in 1872 by Sylvestre Devenish, the Surveyor General of the island. Fig. 2a is a tracing of part of a copy of the original map showing the tip of the Cedros peninsula. The picture conveyed of the landform at Los Gallos Point is of a narrow extended peninsula broken by narrow passages into five or six islands.

The Cazabon Painting

The Cazabon painting, (MacLean 1986), (Fig. 2b) done some 60 years after the Mallet map reveals a distinctly different picture. There are seven or possibly eight different islets or sea stacks with the central one being an elongated islet with a prominent sea arch. Of interest too in the painting on the right is an erect, partly dead tree with sparse foliage and exposed buttress roots standing on the beach. While Cazabon may have taken artistic liberties, this latter detail indicates features not unlike that which may be seen today in Columbus Bay suggesting continuous erosion. It must also be noted that the outlines of the two outer islets are comparable with those in contemporary photography.

Aerial Photography

Los Gallos.

1957 aerial photography of the Los Gallos formation (Fig. 3a) shows that while there are six islets, the prominent central one with the sea arch figured by Cazabon in 1857 has disappeared. The 1994 aerial photography (Fig. 3b) shows three notable features. Firstly, two of the islets in the center of the formation have disappeared. Secondly, the extensive sand deposits to the south of the formation have been considerably reduced in extent, perhaps to about one-eighth that in 1957. Thirdly, the beach to the south of the formation visible

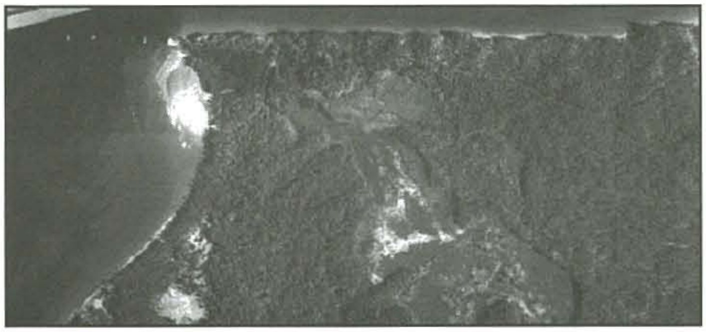

Fig. 3a
Los Gallos 1957 – Note extent of sand deposits to south of the islets.

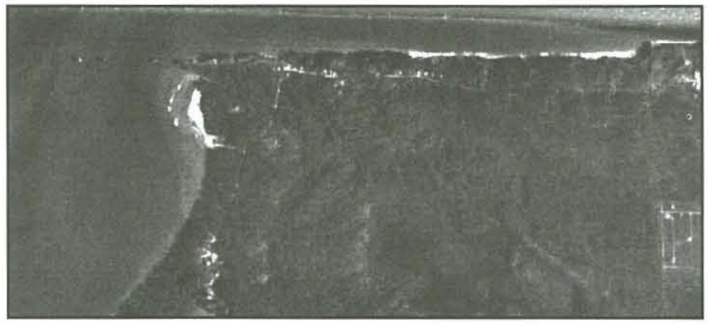

Fig. 3b
Los Gallos 1994 – Note the reduction in size of sand deposits.

in the lower half of the 1957 photograph has disappeared.

Icacos.

The 1957 aerial photography of Icacos (Fig. 4a) covers Columbus Bay, Coral Point where the Constance Estate Buildings are visible and the sweep down around Punta del Arenal to the southern shore of the peninsula. Apart from the extensive clearing of lands on the peninsula, three other noteworthy features are obvious in the 1994 aerial photography (Fig. 4b). Firstly, much of Coral Point and the Constance buildings have disappeared into the sea, including the Icacos Light House, figured in de Verteuil 2000, which for many years stood at the end of the beach road. Secondly, the beach in the southern part of Columbus Bay has been extensively eroded (see also Fig. 5b). Third, and most prominently visible, there has been extensive progradation of the shore at Punta del Arenal (see also Fig. 5a).

A general feature seen in both photographs is the alternate and irregular bands of coconut vegetation and lagoons. This suggests that the area has been growing outward to the west through a series of sand spits formed by westward transport of sediments in the Columbus Channel, enclosing lagoons formed of open sea. These in turn became ponded by beaches in Columbus Bay. Other differently formed, but similar, sand spits may be seen at Nariva and Erin.

In the absence of well documented land marks it is difficult to determine measures of the actual erosion and accretion rates obtaining. It is possible nevertheless that

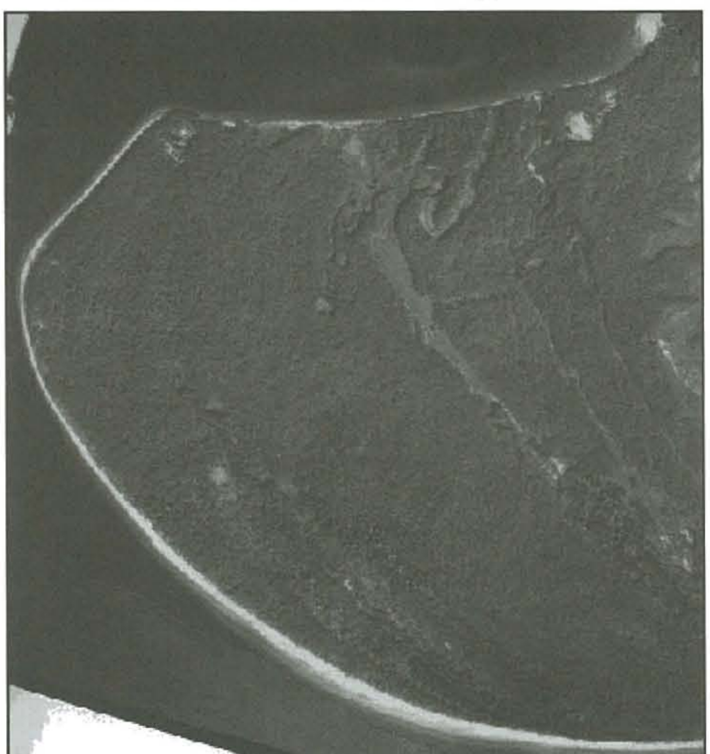

Fig. 4a
Icacos 1957.

Fig. 4b
Icacos 1994 : Note progradation of Punta del Arenal and recession of Coral Point.

Fig. 5a
Beach accretion – Punta del Arenal 1997.

Fig. 5b
Constance Estate, Coral Point 1997.

the rate of recession at one point where there is a good land mark may be measured. Overlaying transparencies of aerial photography at Coral Point and the constancy of the remaining buildings was used as a base to obtain an estimate of shoreline recession at that point. This measures approximately 160m. As the interval between the photography is thirty-seven years the recession rate is about 4.3m per year. The only other markers of note include the beach road leading to Coral Point and the base of a navigational beacon employed for landing at Punta del Arenal. Unfortunately, the aerial photography does not help with the beach road owing to vegetation cover.

The base of the beacon (Fig. 5a) and the anchors for the pole survive and may be seen at the junction of the Beach Road and the Punta del Arenal Road, a few metres diagonally to the north of the junction, amongst the vegetation. From this junction to the edge of the sea is estimated at about 300m (Fig. 5b). Unfortunately it is impossible to date the construction of the beacon. Bearing in mind however that the beacon was used to indicate the landing area amongst a featureless tree line at a time when access to Icacos was by sea, and making a crude estimate of this at late 19th century, and assuming that the beacon was on the shoreline above high water, the accretion rate would work out at approximately three metres per year. This is comparable with the measured erosion rate at Coral Point. That the process of accretion at Punta del Arenal is a longstanding one is attested to in the name given it by Columbus in 1498. Accretion takes place where current slows and the sand is deposited and Punta del Arenal would be the only place in the area where there would be slack water and where it would be suitable for landing.

DISCUSSION

In Trinidad and Tobago the largest coastal influences are the combined South Equatorial/Guiana/Orinoco River discharge currents meeting Trinidad in the southeast and splitting into the two streams. The southern stream passing into the Columbus Channel must change course while being confined to the narrowing channel. Erosion and long shore transport of sediments on the outer side of the bend, the south coast of Trinidad, is inevitable, while deposition on the inner side of the bend, the Venezuelan coast, will take place. To these can be added the local effects of ocean swell and wind driven wave action. These forces have been in operation for several millennia.

Several factors may influence coastal form in and around Trinidad and Tobago. These include tectonic activity, local geology, oceanographic currents, tidal currents, swell and waves, riverine discharge, historical post-glacial sea level rise, and just possibly sea level rise resulting from increased levels of greenhouse gases and consequent accelerated global warming or subsidence from petroleum and natural gas extraction.

One undisputed fact is that there have been profound changes to the Los Gallos formation with the records of the past 200 years showing a pronounced change in physical appearance. Aerial photography confirms that six islets have now been reduced to four. The conclusion is inevitable that these are a product of erosion of the formation. Another inevitable question arises: is the erosion of Coral Point in any way related to changes at Los Gallos? As a working hypothesis it is suggested

Fig. 6a
Base of the Navigational Beacon.

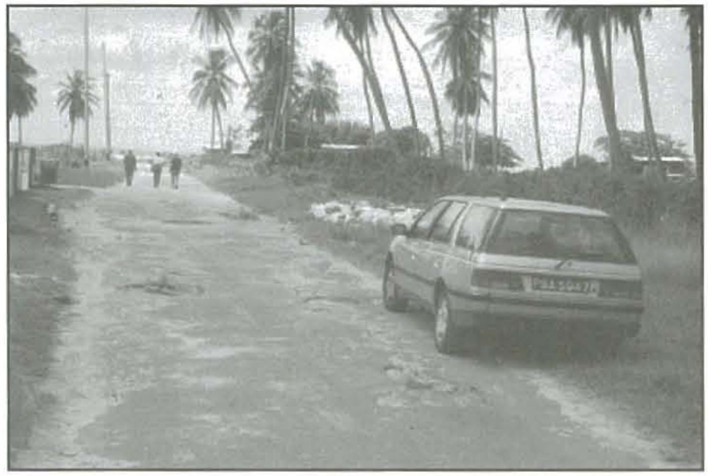

Fig. 6b
Road to Punta del Arenal – the base of the Navigational Beacon is a few metres to the right of the car. Photograph is taken from the junction of the road to Constance and the road to Punta del Arenal. The sea is more than 300 metres away.

that the Los Gallos formation may in fact have served in the past few centuries as an extended groyne, rather like the man-made groynes employed to control longshore erosion of beaches. The Los Gallos formation is sandstone, which in time fractured and was penetrated by the sea in several places. The prevailing southwesterly currents would have eroded these fractures creating the islets recorded by Cazabon, and depositing sand to the south of the islets. This aspect of the hypothesis is supported by huge deposits of sand seen to the south of the islets in the 1957 photography. As erosion of the groyne continued, its protective effects weakened exposing Columbus Bay to the full force of the prevailing currents. The accelerated recession at Coral Point, and indeed Columbus Bay followed. The process resulted in accelerated depositing of sand in the slack water at Punta del Arenal, obvious in the photography.

The Bawan Singh hypothesis suggests that sea level rise and local subsidence may possibly be responsible for accelerated erosion. The hypothesis is based on: a series of beach profiles that have been done at different localities over about seven years; temperature records over a fifty year period; rainfall; surface water temperature; groundwater salinity; and, tidal records. The possible effects of wave activity, nearshore and offshore circulation and local land form have not apparently been considered. Erosion of the shoreline depends on a range of factors and it is clear that if one wishes to explain the phenomena the critical measurements to be made will be the energy applied to the particular coastline. In the absence of application of energy there can be no erosion. If one wishes to study the causes of coastal erosion, beach profiles are simply not enough and it is mandatory that energy levels being applied be considered. Sea level rise will not add any energy; merely apply energy at a different level.

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