Journal of Coastal Research	SI 39	127 - 131	ICS 2004 (Proceedings)	Brazil	ISSN 0749-0208

Morphologic Evolution of Similar Barrier Islands with Different Coastal Management

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ABSTRACT

ELKO, N. A. and DAVIS, R. A., JR., 2006. Morphologic evolution of similar barrier islands with different coastal management. Journal of Coastal Research, SI 39 (Proceedings of the 8th International Coastal Symposium), 127 - 131. Itajaí, SC, Brazil, ISSN 0749-0208.

The morphologic evolution of two drumstick barriers, Long Key and Caladesi Island, and the interaction with their adjacent updrift tidal inlets, Blind Pass and Dunedin Pass, have been influenced by different coastal management practices over the last century. The barriers, which were morphologically similar in the late 1800's, have developed into two diverse barrier islands because of natural and human-induced changes to the barrier/inlet system. Due to ubiquitous and poorly located development, one of the fastest eroding beaches in Florida now exists on the updrift end of Long Key, whereas minimal human influence has resulted in a relatively pristine state park on Caladesi Island. Despite these differences, both islands are presently transforming from drumstick barriers into wave-dominated barrier islands.

ADDITIONAL INDEX WORDS: *Drumstick barrier islands, mixed-energy, west-central Florida, transgression, progradation, beach ridges, sediment supply, beach nourishment, Caladesi Island, Long Key.*

INTRODUCTION

The west-central Florida coast contains a complex barrier-inlet system bounded to the north and south by marshes and mangrove mangals, respectively. Pinellas County (Figure 1) is located at the north end of this low-energy barrier chain with mean wave heights of about 30 cm and an average tidal range that is less than 1 m (NOAA, 2000). Dunes are also small on this coast, less than 4 m, due to low wind speeds and low sediment supply (DAVIS, 1994). The low wave height and tidal range values result in a mixed-energy coast with some regions displaying classic wave-dominated barriers, with long, narrow islands and few tidal inlets, whereas other areas have short and wide, drumstick islands with closely spaced inlets.

Few tropical storms impact this region due to its sheltered location. The most influential weather events are cold fronts that approach from the northwest during the winter and spring, driving net sediment transport to the south along the west-central Florida coast (DAVIS, 1989a). In Pinellas County, littoral drift diverges at the headland at Indian Rocks Beach (Figure 1).

Drumstick Barrier Model

Drumstick barrier islands typically develop on mixed-energy coasts where a combination of wave and tidal processes shape the coastline (HAYES and KANA, 1976). As opposed to wave-dominated barrier islands, which are relatively long, straight and narrow, mixed-energy barrier islands are short in length typically with one end wider than the other. The shape of these islands has been likened to that of a chicken drumstick (HAYES *et al*., 1974). Such barriers are common and have been studied extensively in Alaska (HAYES *et al*., 1976), Massachusetts (FITZGERALD *et al*., 1989), South Carolina (HAYES and KANA, 1976), Virginia (MCBRIDE and VIDAL, 2001), and the west coast of Florida (DAVIS, 1989b; 1994), as well as along the German Bight of the North Sea (VAN STRAATEN, 1965; FITZGERALD *et al*., 1984).

The coastal processes that shape drumstick barriers depend upon a well-developed ebb-tidal delta associated with the updrift inlet (Figure 2). Waves approaching from the updrift direction are refracted around the ebb delta causing a local reversal in sediment transport near the updrift end of the island. Sediment that becomes trapped by this local reversal is deposited in the lee of the ebb delta in the form of swash bars that slowly migrate onshore. The swash bars fuse with the beach as ridge and runnel systems and over time a prograding beach ridge complex may form. FITZGERALD *et al.* (1984) note that a local sediment transport reversal is not necessary for swash bar attachment. In their model, the ebb delta configuration controls the location of bar attachment that may occur at any distance from the delta.

Features commonly found on the updrift end of a drumstick barrier include (Figure 2): wide accretional beaches, ridge and runnel systems representing the onshore movement of swash bars, and vegetated beach ridges alternating with low-lying wetlands that often contain cat's-eye ponds (HAYES and KANA, 1976).

As a result of the sediment-trapping mechanism at the ebb delta, the downdrift end of the barrier receives little or no sediment from longshore transport and tends to erode. Washover fans, patchy dunes on very narrow beaches, and marsh sediments exposed in the surf zone are common features of the downdrift, transgressive end of a drumstick barrier. The downdrift tip of the island often contains an accretional spit advancing in the direction of net sediment transport and encroaching on the adjacent tidal inlet.

Study Area

Two barrier islands on the west-central coast of Florida, Long Key and Caladesi Island, developed according to this drumstick barrier process-response model. Long Key, a drumstick barrier island in southwestern Pinellas County (Figure 1), was oriented with the wide end of the drumstick to the north due to a local reversal in the southerly littoral drift. Blind Pass, the tidal inlet to the north of Long Key has been heavily armored with jetties and revetments to reduce shoaling and inlet migration.

Caladesi Island, a state park in northwestern Pinellas County, has the wide end of the drumstick barrier to the south (Figure 1) due to a local reversal in the northerly littoral drift. Dunedin Pass was the tidal inlet to the south of the island prior to its closure in 1988. This barrier is one of the few remaining pristine barrier islands on Florida's west coast where the lack of human development has allowed natural morphologic change to occur. No hard structures (e.g. groins, jetties) have been built on the island and the beaches of Caladesi Island have never been nourished. Due to urbanization of Long Key, the present island morphology has been altered from its original drumstick shape; however, Caladesi Island, the pristine barrier, has retained much of its drumstick configuration.

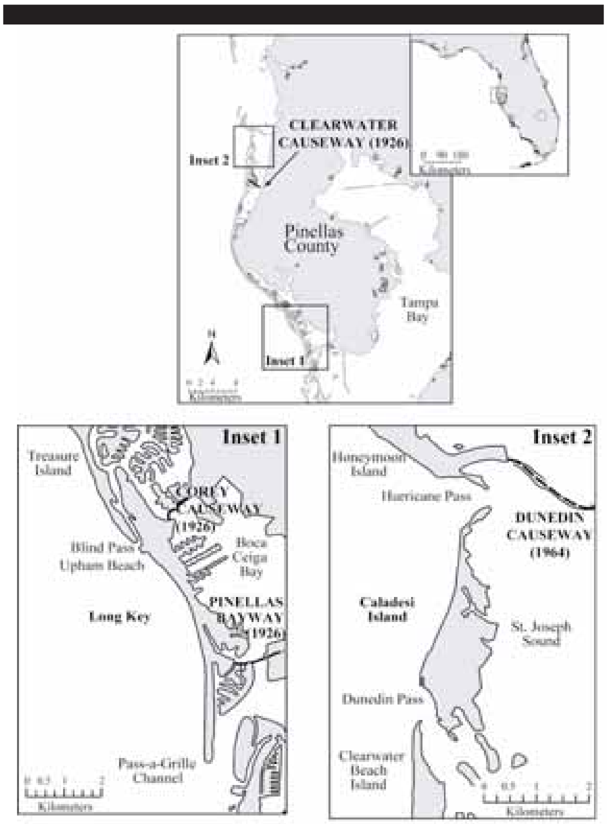

Figure 1. Locations of Long Key and Caladesi Island in Pinellas County illustrated with an early 1970's shoreline. Note the location and year of construction of the causeways.

The present study illustrates two drumstick barriers that evolved into wave-dominated islands despite different natural and anthropogenic modifications. First, we explain the morphologic changes that occurred on the drumstick barriers due to the impacts of hurricanes on the surrounding coastal environment. Then, we discuss anthropogenic modifications to the back-barrier bay environments and to the shoreline of Long Key. Finally, changes in sediment delivery over the last two decades illustrate that both barriers are transforming into wave-dominated systems.

NATURAL EVENTS

Hurricanes that impacted Pinellas County in 1848 and 1921 created new tidal inlets that altered the coastal processes of both Long Key and Caladesi Island. By the time the National Ocean Service (NOS) Historic Topographic Survey Sheets (T-sheets) were published in 1873 (Figure 3), the hurricane of 1848 had already breached John's Pass, the tidal inlet 5 km north of Long Key (Figure 1). The T-sheets depict Long Key with a prograding, triangular-shaped northern end (Figure 3a) whereas Caladesi and Honeymoon Islands were joined as one island called Hog Island, which was prograding on each end, and narrow and transgressive in the mid-section, resembling a double drumstick (Figure 3b). At that time, Blind Pass and Dunedin Pass contained prominent ebb-tidal deltas that refracted wave energy resulting in onshore sediment transport illustrated by attached bars visible along the northern shoreline of Long Key.

The hurricane of 1848 likely initiated the southerly migration of Blind Pass and subsequent erosion of the wide northern end of Long Key. After the hurricane, the cross-sectional area and tidal prism of John's Pass increased and captured a significant portion of the tidal prism of Blind Pass (MEHTA *et al*., 1976). The diminishing tidal prism of Blind Pass did not have sufficient energy to maintain its large ebb delta, which subsequently deteriorated. This instability resulted in the inlet migrating to the south in response to the dominant direction of littoral drift. In 1873, Blind Pass was located nearly 2 km north

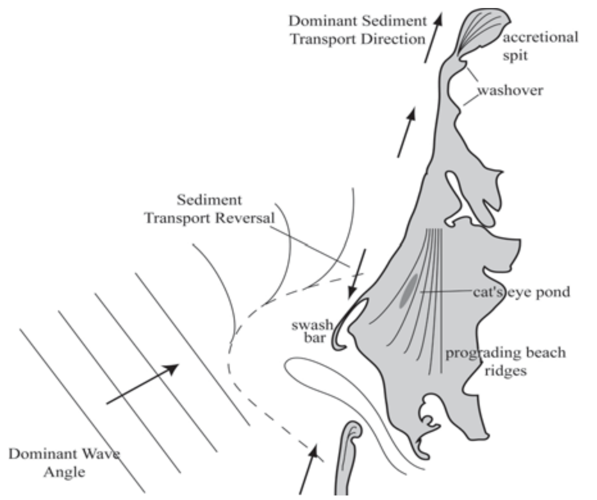

Figure 2. Process-response model and features of a drumstick barrier island (after Hayes and Kana, 1976) illustrated on a 1976 outline of Caladesi Island.

of its present location (compare Figures 1 and 3) and was already migrating to the south at the expense of northern Long Key.

Hog Island remained intact until 1921, when the most significant hurricane on record in Pinellas County breached the barrier in the center. The 3.5 m storm surge from this Category 3 hurricane (WILLIAMS and DUEDALL, 1997) opened Hurricane Pass 3.5 km north of Dunedin Pass (Figure 1). Once Hurricane Pass opened, it began to capture a portion of the tidal prism of Dunedin Pass.

Aerial photographs from 1926 (Figure 4) illustrate the updrift ends of the barriers in two different stages of their post-hurricane evolution. Blind Pass had been migrating to the south and eroding northern Long Key for approximately 75 years, whereas Dunedin Pass and southern Caladesi Island experienced very little morphologic change from 1921 (year of hurricane impact) to 1926.

Blind Pass migrated over 1 km to the south from 1873 to 1926 eroding the elaborate system of beach ridges (Figure 4a); however, sediment was abundant in and around Blind Pass in the form of a reduced ebb delta and a prograding spit on southern Treasure Island. Meanwhile, a complex system of prograding beach ridges continued to form on the south end of Caladesi Island from the onshore transport of large swash bars at Dunedin (Big) Pass (Figure 4b).

HUMAN INFLUENCE

Causeway building that began in Boca Ciega Bay in 1926 (Figure 1) and dredge-and-fill construction during the construction boom that began in the mid-1950s further reduced the tidal prisms and accelerated the deterioration of Blind Pass and Dunedin Pass (DAVIS and BARNARD, 2000).

Throughout Pinellas County, dredged sediment from the back-barrier environment was mounded to create subaerial land upon which causeways and homes were built. Dredge-and-fill construction (compare Figure 1 and Figure 3) reduced the surface area of the back-barrier bays that supplied the tidal inlets, thereby reducing their tidal prisms. The causeways, which connected the barrier islands to the mainland, compartmentalized the back-barrier bays and limited open circulation of tidal flow further reducing tidal prisms.

In the study area, causeway construction caused inlet instability from 1926 to 1964. Blind Pass was already decreasing in width and migrating to the south as a result of the creation of John's Pass in 1848. Construction of Corey Causeway and the Pinellas Bayway in 1926 (Figure 1) contributed to the decreasing tidal prism of Blind Pass, accelerating the southerly migration of the inlet. Meanwhile, Dunedin Pass also became unstable in the 1920's due to the combined effects of the 1921 hurricane and the completion of

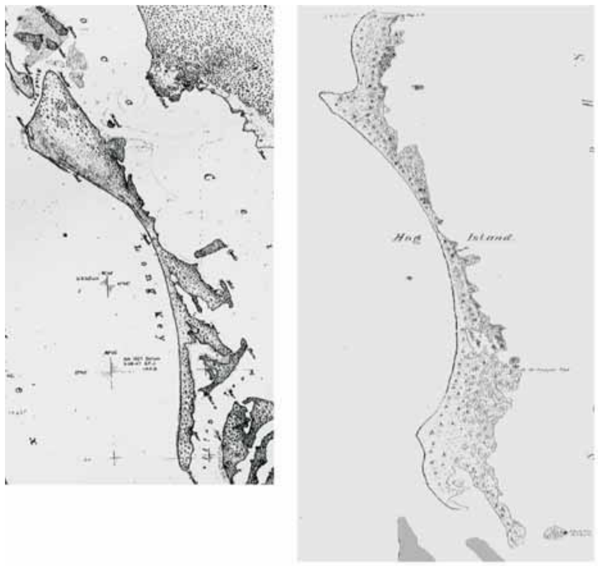

Figure 3. Portions of the NOS Historic Topographic Survey Sheets (T-sheets) of a) Long Key and b) Caladesi Island from 1873.

Clearwater Causeway in 1926 (Figure 1). Dunedin Pass began migrating to the north in response to the dominant direction of littoral drift in this area. The completion of Dunedin Causeway in 1964 (Figure 1) constricted circulation in northern St. Joseph Sound (LYNCH-BLOSSE and DAVIS, 1977) and further contributed to the instability of Dunedin Pass. DAVIS and BARNARD (2000) provide a detailed description of inlet instabilities that resulted from anthropogenic changes to the back-barrier bays in this region.

SHORELINE CHANGES

Long Key

As mentioned above, the instability of Blind Pass resulted in loss of the ebb tidal delta and migration to the south. To prevent further southerly migration of the inlet, the first of many stabilizing structures was built on northern Long Key in 1937 when a 27-m rock-pile jetty (Figure 5a) was constructed on the south side of Blind Pass (MEHTA *et al.,* 1976). This beach was privately owned at the time by William W. Upham, but was donated to local government in a possible act of foresight in 1954, and is now called Upham Beach (HEADRICK, 1999).

Poorly-located construction that occurred during the 1960's has caused the chronic erosion that vexes Upham Beach today. Condominiums were built on the dry beach, seaward of the dunes, and a seawall was constructed at the shoreline (Figure 5). Due to this construction, erosion problems were imminent. Many structures were built on Upham Beach in an attempt to stabilize Blind Pass, creating a continuous line of seawalls, revetments, and jetties around the inlet (Figure 6). The jetty on the north side of Blind Pass was extended to mitigate the inlet shoaling; however, the jetty trapped most of the southerly longshore transport, exacerbating the erosion problem on Upham Beach. The southern jetty was also extended and a breakwater was added, but Blind Pass continued to shoal due to low-energy tidal flows in the inlet and Upham Beach continued to erode. Although the ubiquitous structures in this region have stabilized the position Blind Pass, they have resulted in the most rapidly eroding nourished beach in Florida (DIXON and PILKEY, 1989) and the most highly modified inlet along Florida's west coast (DAVIS and BARNARD, 2000).

Caladesi Island

Concurrent with the construction on Upham Beach, processes that generate and maintain drumstick barriers continued on Caladesi Island (Figure 7). The southern (updrift)

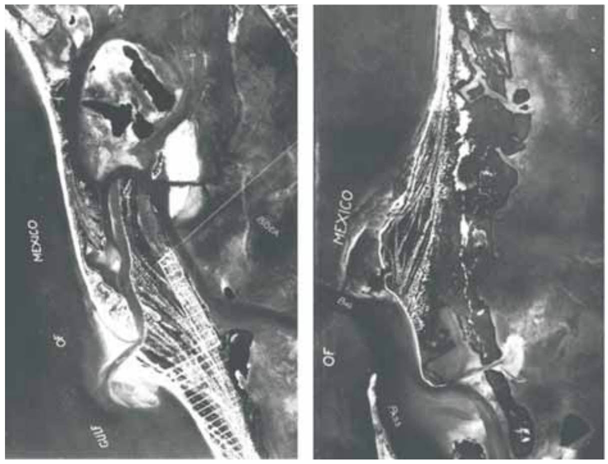

Figure 4. 1926 aerial photographs of a) northern Long Key showing northwest-southeast trending beach ridges and the reduced ebb-delta of Blind Pass, and b) southern Caladesi Island showing north-south trending beach ridges adjacent to Dunedin (Big) Pass and large swash bars migrating onshore.

end of the island continued to prograde as swash bars were transported onshore. The shoreline on the north side of Dunedin Pass eroded as the channel migrated to the north, and as the spit on northern Clearwater Beach Island extended over 1 km to the north.

The northern (downdrift) end of the island was sediment starved because of the sediment trapping mechanism in place at Dunedin Pass at the southern end. Erosion and washover processes have dominated this narrow, low-lying area at least since the first navigational charts were published in the late 1800's. Except for the northern tip of the island, which was a recurved spit, beach processes on the north end were characteristic of a transgressive barrier island.

During major storms, scarce beach sediments were often removed from the foreshore and deposited in washover fans creating erosional scarps and exposing layers of mangrove peat in the intertidal zone. The peat beds originally formed in the mangrove complexes on the landward side of the island and were transgressed by washover deposits then exposed by the eroding shoreline. In the past, these resistant layers created steep scarps and large alongshore instabilities sometimes with 30-m offsets in the shoreline on either side of the peat outcrops (DAVIS *et al*., 1985). After separating from Honeymoon Island in 1921 until the 1980's, Caladesi Island shifted to the north and rotated clockwise about 20º (LYNCH-BLOSSE and DAVIS, 1977).

By 1982, Dunedin Pass had narrowed to 100 m and shoaled to a depth of 2 m, exposing the ebb delta at low tide (USACE, 1977). In 1985, the demise of Dunedin Pass was made certain when 2.5-m waves from the southwest generated by the passage of Hurricane Elena (WILLIAMS and DUEDALL, 1997) eroded the

Figure 5. Blind Pass and northern Long Key (Upham Beach) in a) 1957 and b) 1965 (note the structures built on the beach).

Figure 6. Blind Pass and Upham Beach in 1989 depicting the stabilization of Blind Pass, the southern migration of the inlet, and the development of the back-barrier bay.

Figure 7. Caladesi Island in 1976 with a prograding south end with attaching swash bars, a transgressing north end, and a recurved spit on the extreme north end.

ebb delta. The hurricane also indirectly opened north and south Willy's Cuts, two small tidal inlets that formed due to the erosion of the narrow northern end of Caladesi Island. South Willy's Cut shoaled as North Willy's Cut developed rapidly, capturing most of the remaining tidal prism of Dunedin Pass (DAVIS *et al*., 1989). Much of the sediment that previously bypassed Dunedin Pass and supplied Caladesi Island was then transported into the pass. The channel mouth began to shoal rapidly and closed completely in 1988, joining Caladesi and Clearwater Beach Islands (Figure 8).

CHANGES IN SEDIMENT DELIVERY

Long Key

Despite continued efforts to stabilize the northern end of Long Key, the erosional nature of this part of the island dominates. Nourishment projects were constructed on Upham Beach in 1975, 1980, 1986, 1991, 1996, and 2000. The nourishments create a 150-m wide perturbation in the shoreline (Figure 9a) that "spreads out" rapidly. The beach has routinely eroded to its pre-nourished position within two to three years (ELKO, 1999).

Pass-a-Grille Beach, on southern Long Key, was last nourished in 1992. Since that time, beach performance has been stable (Figure 9b) in large part due to a steady sediment supply that has been eroded from Upham Beach and transported to the south. The beaches of central and southern Long Key have benefited from this downdrift transport of nourished material over at least the last decade. As a result of this influx of sediment, southern Long Key has transformed from a transgressive to a stable beach.

The source of nourished sediment for many of the nourishment projects was dredged material from Blind Pass. Nourishing Upham Beach with sediment from Blind Pass acts as an alternate form of inlet sediment bypassing that might occur naturally without the presence of long jetties. If the north jetty was removed and/or dredging operations ceased, Blind Pass would likely shoal and close, straightening this increasingly wave-dominated coastline. Unfortunately, this previously progradational region is experiencing erosion problems due to poorly located construction and the lack of sediment influx from the north.

Caladesi Island

Drastic changes in sediment delivery have taken place in the last 25 years on Caladesi Island (Figure 10). Presently, the shoreline along southern Caladesi Island is straight and representative of a wave-dominated barrier island (Figure 8). Sediment that was previously trapped by Dunedin Pass now bypasses the inlet and supplies the northern end of Caladesi Island. Addition of sediment to the inlet via washover occurs during winter storms.

After the closure of Dunedin Pass, the northern, transgressive end of Caladesi Island defied its history and began to accrete (Figure 10a). Eroded tree stumps that represent a long history of erosion are still present in the backbeach, whereas ridge-and-runnel systems transport sediment onshore. Central Caladesi Island has also been accreting (Figure 10b). Although sand dunes are quite modest on Caladesi Island, dunes along the central and northern portions of the barrier have been recently accumulating sediment. Southern Caladesi Island prograded considerably from 1974 until the closure of Dunedin Pass, after which this region began to erode (Figure 10c).

Conversion from accretion to transgression on the southern end and the opposite pattern on the northern end supports the notion that Caladesi Island is changing from a mixed-energy barrier into a wave-dominated barrier.

CONCLUSIONS

Morphologic changes to Long Key and Caladesi Island over the last century were initiated by natural events that altered the tidal regimes of their adjacent tidal inlets. The deterioration of Blind Pass and Dunedin Pass was initiated by the effects of the hurricanes of 1848 and 1921, respectively, and then accelerated by anthropogenic influences. Large ebb-tidal deltas eroded as a result of inlet deterioration, thereby removing the sediment sinks that caused the updrift ends of the barriers to prograde. Construction of hard structures stabilized Blind Pass, whereas Dunedin Pass was left to shoal and close naturally.

The shoreline of both barriers appears to be tending toward a straight configuration, as the islands transform from drumstick barriers with prograding updrift ends and eroding downdrift ends into wave-dominated barriers with the opposite erosion/accretion pattern. The main difference between the

Figure 8. Southern Caladesi Island in 1992 after the closure of Dunedin Pass. Washover deposits are visible in the pass.

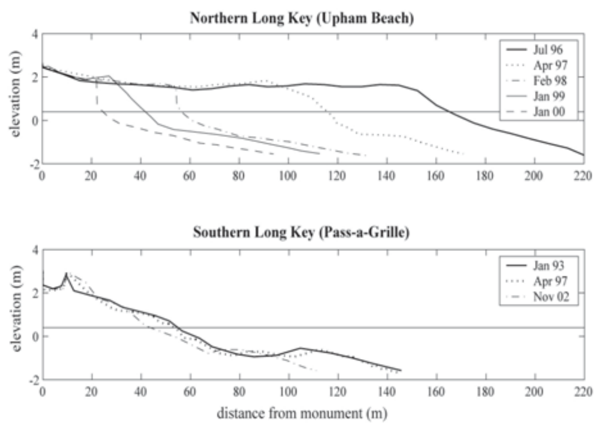

Figure 9. Beach profiles from a) Northern Long Key illustrating the rapid erosion of sediment after the 1996 nourishment project, and b) Southern Long Key illustrating stable beach

present configurations is the long jetties and bulkhead-style seawalls on northern Long Key that have prevented nature from creating shoreline morphology similar to southern Caladesi Island.

ACKNOWLEDGEMENTS

Funding for this project was provided by the Pinellas County Public Works Department as a portion of the primary author's M.S. research. Members of the Coastal Research Laboratory of the University of South Florida surveyed the beach profiles.

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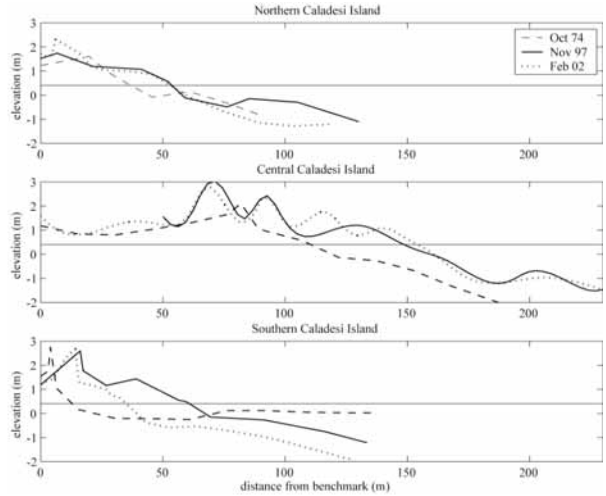

Figure 10. Beach profiles from Caladesi Island illustrating the transformation from a) and b) transgression to accretion, and c) progradation to erosion.

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