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Barrier-Island Progradation and Holocene Sea-Level History in Southwest Florida

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ABSTRACT

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Holocene barrier islands in Lee County, Florida, are composed of beach ridges organized into distinct, unconformable sets bounded by erosion surfaces. These beach-ridge sets are further differentiated on the basis of average elevation. Low sets are about 3-feet and high sets are about 6-feet above local mean sea-level. Beach ridges are composed exclusively of swash-zone deposits that consist of seaward-dipping, planar laminae. This marine origin is further documented by the uniform elevation and the regular, curvilinear geometry of individual beach-ridge crests. The oldest preserved beach-ridge sets in this region were deposited approximately 3000 BP. Elevationally distinct and geographically adjacent beach-ridge sets of apparently identical ages record a major fluctuation in sea-level (rise or fall) and/or wave-energy (increase or decrease). The date of this fluctuation is within the 200- to 400-year counting-error margin for the analyzed marine shells below which the radiocarbon technique cannot resolve differences. The geographic extent and lateral continuity of the low beach-ridge sets in this low-energy, micro-tidal region argue that the primary component of these fluctuations was a change in sea level rather than wave energy. Low beach-ridge sets are as geographically widespread and laterally continuous as are the high ones. Just the opposite situation would be predicted if the low sets were formed during decreased wave energy alone: wave refraction would be increased and result in an even more complex pattern of littoral drift. The more complex this pattern, the shorter the length of any given littoral-drift cell and, consequently, of beach-ridge sets. Five such fluctuations have been identified in these islands: (1) a rise of 4- to 6-feet at 2000 BP, (2) a fall of 3- to 5-feet at 1500 BP, (3) a rise of of 2- to 3-feet at 1100 BP, (4) a fall of about 2-feet at 500 BP, and (5) a rise over the past hundred or so years. The 500-year cyclicity is only apparent and reflects the precision of estimating differences in depositional ages of clastic deposits by radiocarbon-dating their constituent shell clasts. Each of these fluctuations resulted in barrier-island progradation or creation. Sand was supplied by erosion of the nearshore region and existing barrier islands. Each fluctuation had an initial depositional phase followed by an erosional phase as the supply rate fell below a critical threshold. A decrease in sand-supply rate reflects a source depletion and/or a redirection of the transport path.

INTRODUCTION

Two distinct Holocene sea-level histories have been developed from data collected in the southeastern United States. Studies utilizing intertidal peat deposits typically conclude a uniform, asymptotic rise to present-day position (SPACKMAN *et al.*, 1966; SCHOLL *et al.*, 1967, 1969; DAVIES, 1980; ROBBIN, 1984) although COLQUHOUN *et al.* (1980) infer a fluctuating rise from marsh peats and shell middens in South Carolina. Studies of barrier island deposits, on the other hand, indicate that over the past 3000 to 5000 years sea level has fluctuated both above and below its present position (LIND, 1969; MISSIMER, 1973; STAPOR, 1975; STAPOR AND MATHEWS, 1983). This contradiction is in all likelihood only apparent given the following: (1) the radiocarbon dating technique can resolve differences only on the order of 200 to 400 years given typical counting error estimates of 100 to 200 years, and (2) the elevational bias introduced by the basic sampling of these two depositional environments. Peats are sampled at depth by means of coring; barrier island deposits are typically sampled within 1.5 m of their respective surfaces, which are usually no lower than the uppermost portion of the local tidal range. Thus, there is a built-in bias for peats to preferentially record lower, and the barrier islands to record higher, sea-level posi-

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tions. Furthermore, peats formed during lowstands may be preferentially preserved because emergence would tend to destroy peats formed during highstands (FAIRBRIDGE, 1974). Combining these two data sets produces a sea-level history for the southeastern United States over the past 3000 to 5000 years consistent with all of the pertinent data available: a history characterized by fluctuations both above and below present-day position rather than by a uniform, asymptotic rise. The purpose of this paper is to document this fluctuating sea-level history and its effect on the initiation and subsequent progradation of barrier islands in southwest Florida.

Holocene barrier islands found in the Lee County region of southwest Florida are composed of beach ridges organized into distinct, unconformable sets. This indicates that these islands have experienced a complex history of repeated periods of alternating deposition and erosion. The beach ridges are composed of quartz sand that contains an average 20 per cent by weight mollusk shells (SILBERMAN, 1979; NEALE, 1980). These islands composed of multiple beach-ridge sets that contain relatively abundant, preserved, datable materials and that formed in a microtidal, low wave-energy environment present an excellent opportunity to examine the relationship between sea-level and coastal progradation.

GEOLOGIC AND OCEANOGRAPHIC SETTING

The Holocene barriers of Lee County, Florida, are perched on the seaward edge of a Pleistocene sand sheet that is subaerially exposed along the mainland shore of Pine Island Sound. Shell beds of probable Sangamon age (D.F. BELKNAP, *personal communication)* underlie Pine Island (Figure 1) at depths less than 6-feet below sea level. Dunes of probable late Pleistocene age are found within Pine Island Sound, Useppa Island (Figure 1); the age assignment is based on the dark yellow color of the quartz sand, an indication of protracted weathering. Neither of the two rivers entering the Gulf of Mexico in this region transport sand across their estuaries (HUANG AND GOODELL, 1967); nearshore erosion of Pleistocene and earlier Holocene coastal deposits has provided the sand to build these barriers.

The measured significant wave height is 36 cm and the period is 5 seconds in southwest Florida (THOMPSON, 1977). These values coupled with the irregular offshore bathymetry results in a complicated wave-refraction pattern and a littoral drift system characterized by short-distance cells (HARVEY, 1979). The tidal range is only 80 cm (U.S. Department of Commerce, 1980); however, the ratio between tidal prism and wave energy is sufficiently large that ebb-tidal deltas predominate at the major inlets (Figure 1).

RADIOCARBON DATING

All radiocarbon dates in this study are presented as uncorrected ^{14}C-years BP with BP referring to Before Present or 1950. Dates are based on a ^{14}C half-life of 5570 years using 0.95 NBS oxalic acid as the modern standard. The outer 30% to 50% of each individual shell was leached in order to minimize the effects of recrystallization. For this reason sampling was biased toward the largest, most robust specimens available.

Given the susceptibility of shells to mechanical abrasion (FORCE, 1969), the shell population mode of any clastic deposit should be recently dead shells, the age of which equals the age of deposition. However, where rivers supply sediment to fill estuaries instead of delivering it directly to the open ocean, prograding coastal deposits are supplied from the reworking of nearby, older deposits. This situation has characterized much of the southeastern United States' Atlantic and Gulf of Mexico shorelines for the past 3000 to 5000 years. Thus, mollusk shells contained within these southwest Florida barrier islands are clasts potentially derived from sources other than recently dead organisms and, as such, can be expected to have a variety of radiometric ages. The sampling scheme used in this study minimizes isotopic contamination but in doing so maximizes the potential for selecting reworked, older shells.

In order to identify reworked shells and to evaluate their importance a suite of shells was dated at each sampling site. At all sites but one (site 1 on La Costa Island, Figure 2) a spectrum of significantly different shell dates was obtained, a confirmation that shells were reworked during the deposition of these beach

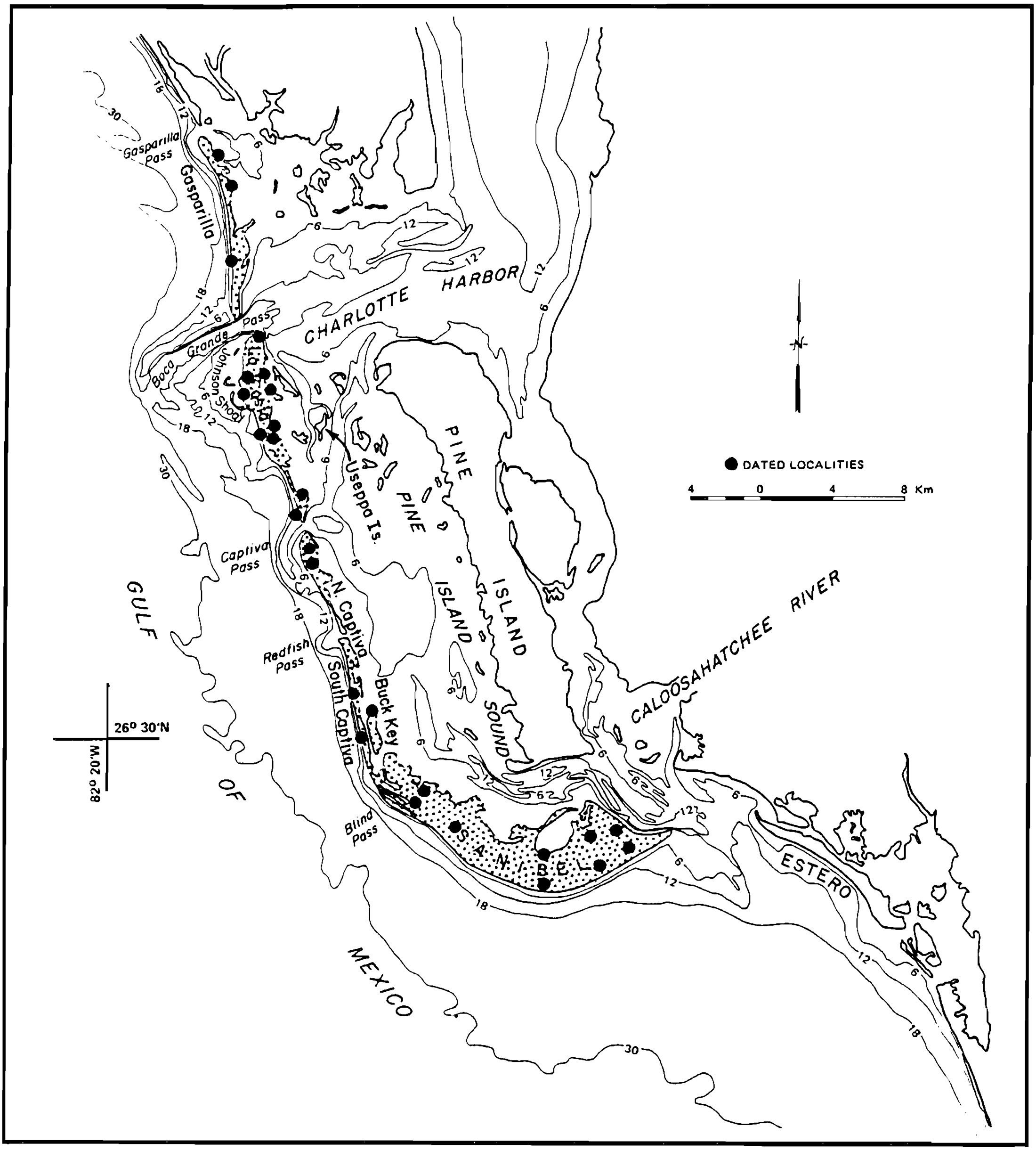


Figure 1. Location map of the Lee County, Florida, barrier islands studied in this investigation. The Holocene barriers are (from north to south): Gasparilla, La Costa, North Captiva, South Captiva, Buck Key, and Sanibel. The black circles locate beach ridges where suites of mollusk shells were collected and radiocarbon dated.

ridges. The presence of numerous reworked shells indicates that their source beds were in close geographic and topographic proximity. The youngest age can be a reasonable estimate of the age of deposition if and only if there is a cluster of overlapping ages at the younger end of a range, essentially those shells with ages no older than the 2 sigma counting error of the

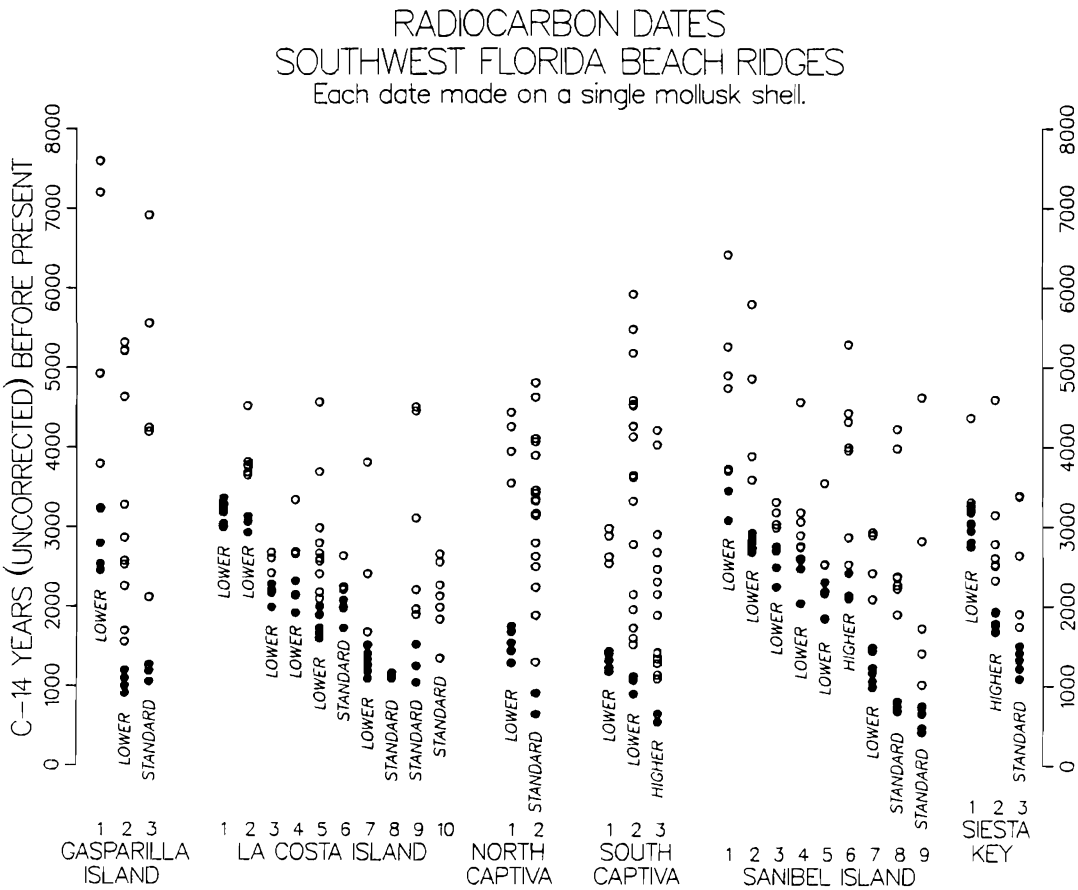


Figure 2. Radiocarbon dates of individual mollusk shells used to determine the age of sampled beach-ridge sets in southwest Florida. Sites on individual islands are arranged with the oldest site being Number 1, based on the truncation relationships among the various beach-ridge sets. The filled circles indicate those shells that are essentially no older than the youngest shell (within its two sigma counting error) reported at a particular site; the open circles are shells that are significantly older than the youngest shell. The range of shell dates present at these localities demonstrates the importance of reworked, older shells. The designations LOWER and HIGHER refer to the elevation of a particular beach-ridge set compared to the STANDARD elevation of historic beach ridges produced over the past century or so.

youngest shell (the filled circles in Figure 2). It should be emphasized that even given the presence of reworked shells at these sites, younger beach-ridge sets (based on truncation relationships) clearly have sequentially younger estimates of depositional age, *i.e.*, La Costa and Sanibel Islands in Figure 2.

BEACH-RIDGE GEOMORPHOLOGY AND SEA LEVEL

Beach ridges that make up these prograding Holocene barrier islands are not the washover products of single, or multiple, large storms nor are they formed by eolian activity. These ridges have smooth, regular, curvilinear crest lines (Figures 3 and 4). They are composed of laminae characteristic of the foreshore or swash zone—planar, gently-dipping, seaward inclined laminae—organized into sets separated by truncation surfaces. Even the uppermost portion of the 8- to 10-feet MSL Wulfert ridge on Sanibel Island (Figure 5), the highest beach-ridge set in this region, is composed of foreshore laminae (MISSIMER, 1973b). During beach-ridge construction, under both storm and fairweather

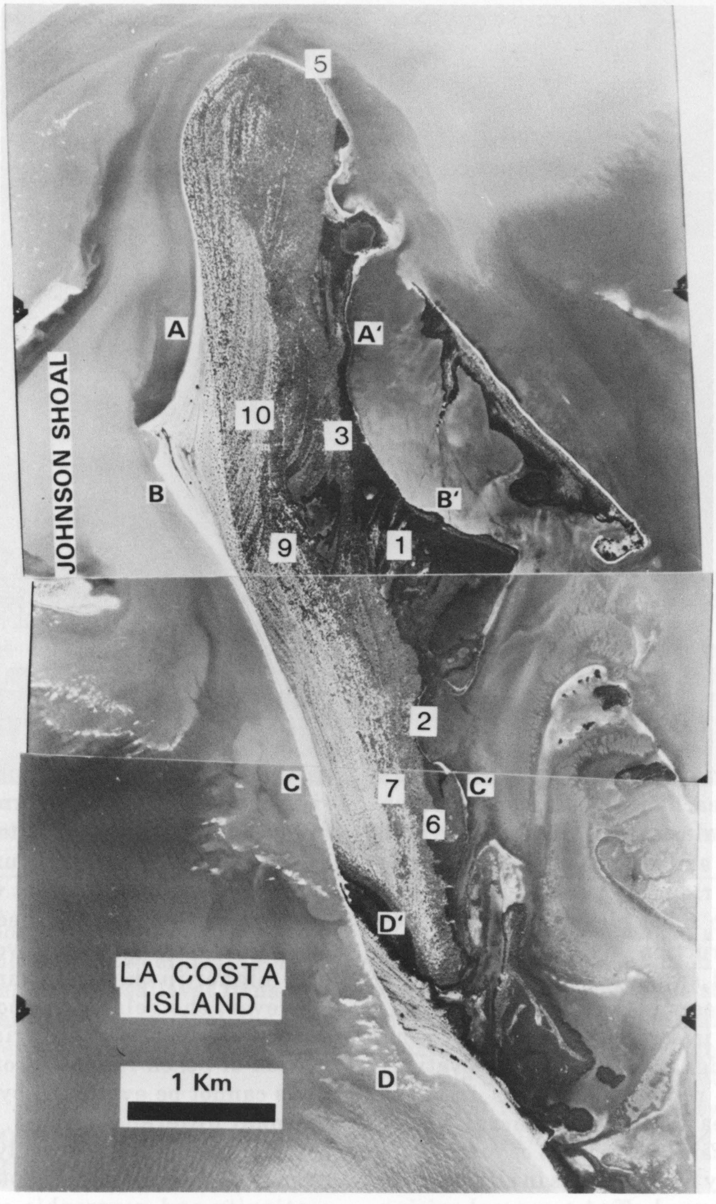


Figure 3. Uncontrolled aerial photo mosaic of La Costa Island, Lee County, Florida from 1953 U.S. Department of Agriculture photography. Shells were collected for radiocarbon dating from the numbered localities; topographic profiles were constructed along the lettered lines from commercial photo-topographic maps (Figure 9). Observe the linear, subparallel, and continuous beach ridges and how they group into discrete sets separated by erosion or truncation surfaces. Furthermore note the general absence of dune blowouts and/or overwash channels throughout this island. La Costa sites 4 and 8 as well as profile EE′ (Figure 8) are not shown on this mosaic.

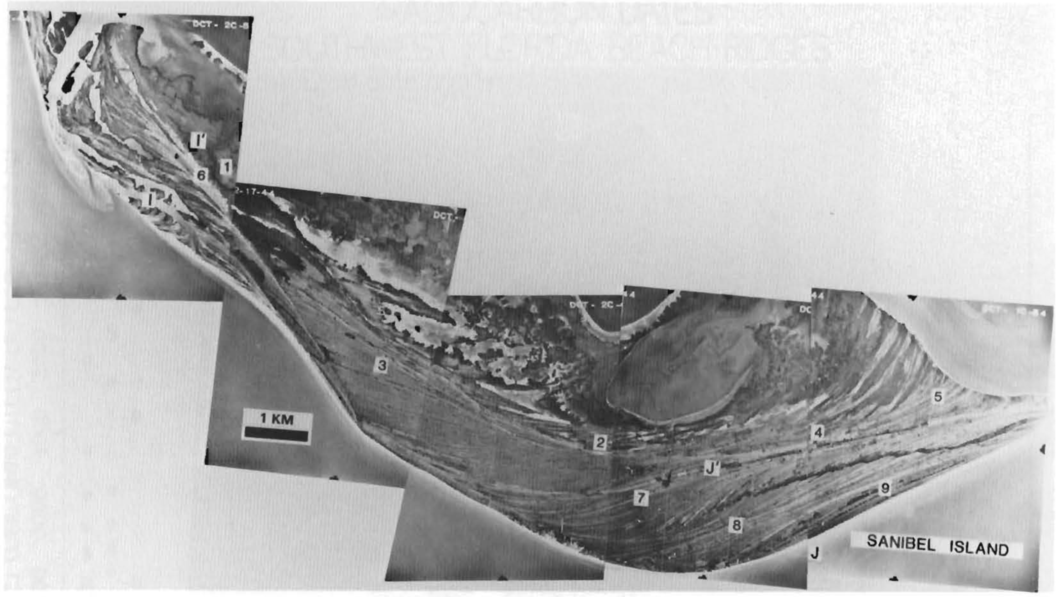


Figure 4. Uncontrolled aerial photo mosaic of Sanibel Island, Lee County, Florida, made from 1944 U.S. Department of Agriculture aerial photography. Shells were collected for radiocarbon dating from the numbered sites; topographic profiles were constructed along lines II' and JJ' from commercial photo-topographic maps with a 1-foot contour interval (Figure 9). Beach-ridge sets 2 through 7 are low in elevation, less than 4-feet MSL, whereas sets 8 and 9 are noticeably higher, 5- to 7-feet MSL (Figure 12). The low ridges are as geographically widespread and continuous as the high ridges, an observation that strongly suggests that the height difference is mainly a function of sea level rather than wave-energy.

conditions, waves essentially rush-up the gently inclined beach face that extends well up into the supratidal zone; the higher the waves the higher they are able to rush-up and the taller the beach ridge will be. Washover and eolian deposition have played minimal roles during the construction of these beach ridges. Rather, repeated swash-zone deposition over years to tens of years is the major mechanism.

Barrier islands in southwest Florida are composed of beach-ridge sets of differing elevations (Figure 6) that record variations in wave energy and/or sea level. Wave energy variations on a time-scale of hundreds of years probably result largely from changes in climate that alter storm tracks and effect a general raising or lowering of wave heights. In addition, on low-energy coasts minor changes in mean sea-level may sufficiently alter water depth relative to nearshore wave heights to produce a similar but much more subtle result: higher positions, greater incident energy, and lower positions, lesser incident energy.

The partial covering of beach ridges by mangroves or marsh vegetation implies a sea-level rise subsequent to ridge formation; the intertidal zone now covers deposits of the supratidal zone. Swash-zone bedding found several meters above the maximum level at which it occurs in modern beach ridges (formed within the past 100 years) implies a sea-level position markedly higher in the past than in the present. However, the relative importance of wave-energy versus sea-level variations in the formation of beach-ridge sets of differing elevations cannot be evaluated by considering elevational differences alone. This is because beach-ridge height is directly related to wave energy (TANNER AND STAPOR, 1972). Lateral continuity and geographic extent have to be considered as well. A major reduction in wave energy alone should result in geographically restricted or localized beach-ridge sets reflecting the compartmentalization or disintegration of earlier, higher energy, littoral-drift systems. This would not be expected to result from a minor shift in sea-level position accompanied by only a subtle reduction in wave energy.

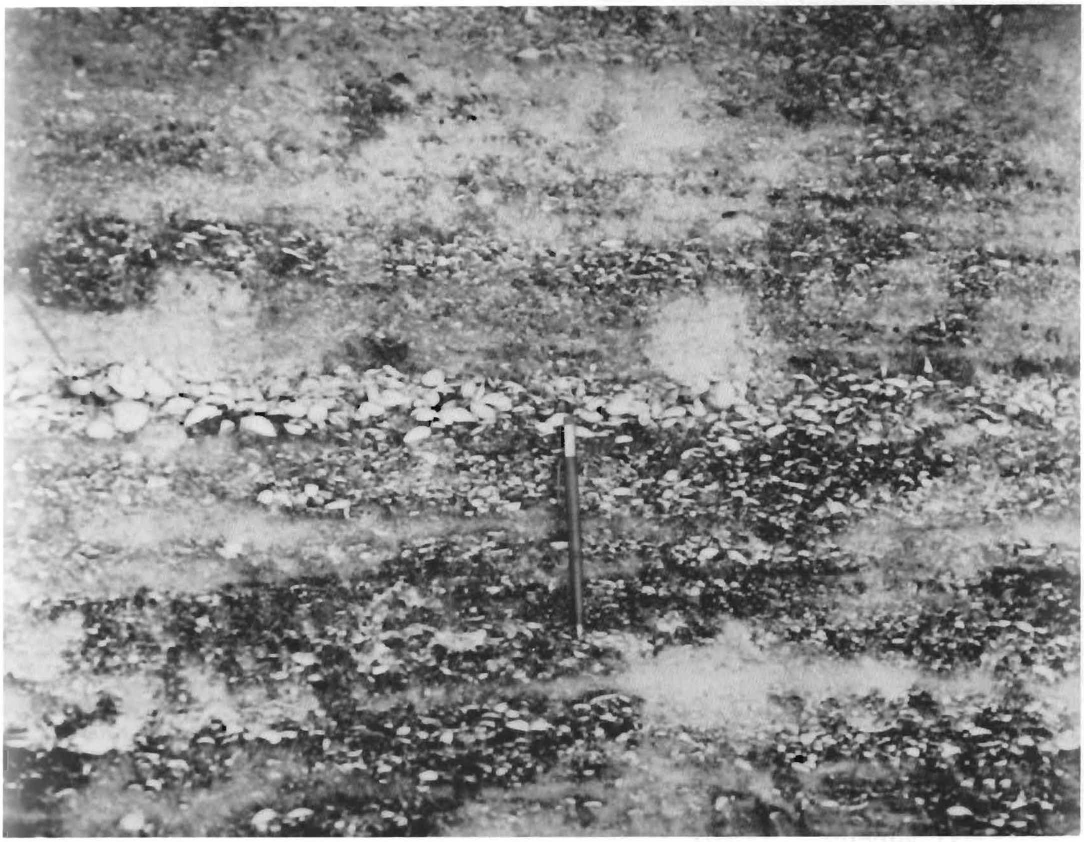


Figure 5. Detailed view of swash-zone bedding in the Wulfert ridge (site 6 of Figures 4, 9, and 12) at an elevation of about 9-feet MSL.

Beach-ridge geomorphology will be used in an attempt to distinguish between whether (1) wave energy changed and sea level remained essentially constant or (2) sea level changed and wave energy experienced only minor modification.

ISLAND GEOMORPHOLOGY AND RADIOCARBON CHRONOLOGY

Seven Holocene barrier islands composed of multiple beach-ridge sets were examined in southwest Florida. Six of these islands are in Lee County: Gasparilla, La Costa, North Captiva, Captiva, Buck Key, and Sanibel (Figure 1). Siesta Key, the seventh, lies 115 km to the north in Sarasota County. Three hundred ten (310) radiocarbon dates determined on individual mollusk shells collected at thirty sites are utilized to date the deposition of specific beach-ridge sets. An informal time-stratigraphic classification has been made in an attempt to segregate deposits of similar ages into regionally mapable units: Sanibel I (3000-2000 BP), Wulfert (2000-1500 BP), Buck Key (1500-1100 BP), La Costa (1100-500 BP), and Sanibel II (500-150 BP).

Gasparilla Island

Three beach-ridge sets comprise the bulk of this island (sets 1, 2, and 3, Figure 7). The marked parallelism of their constituent beach ridges argues for a primary onshore component of sand transport during their construction (STAPOR, 1975). Beach-ridge set 1 was deposited

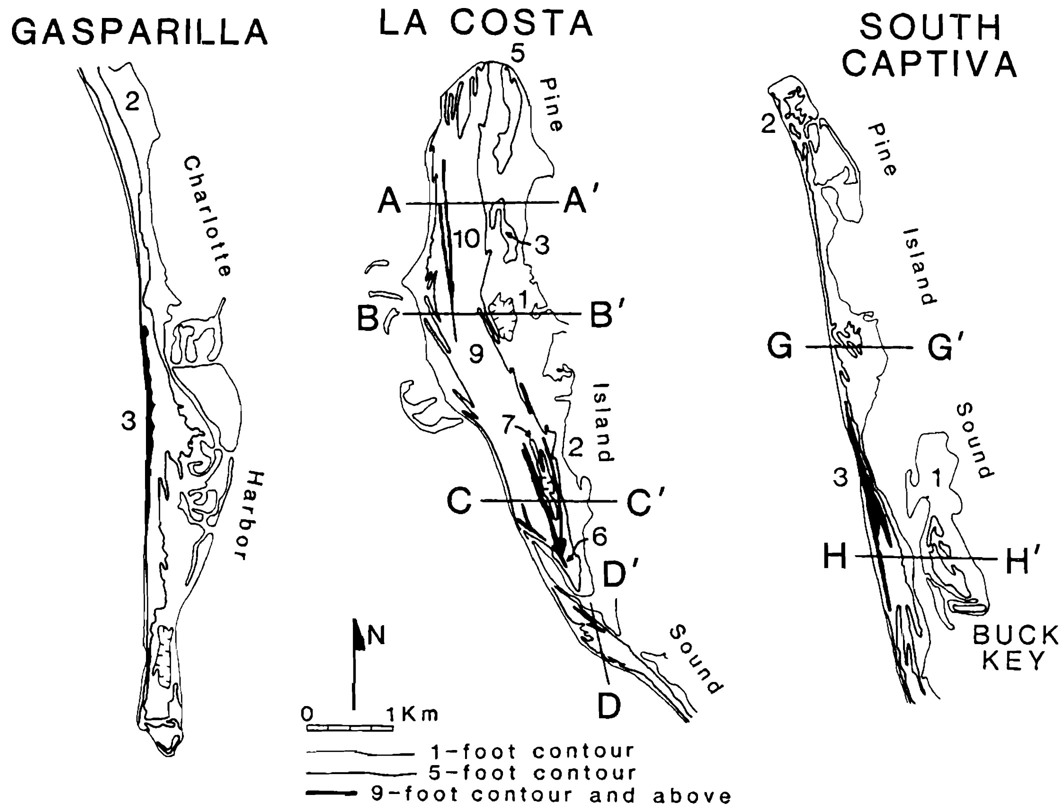


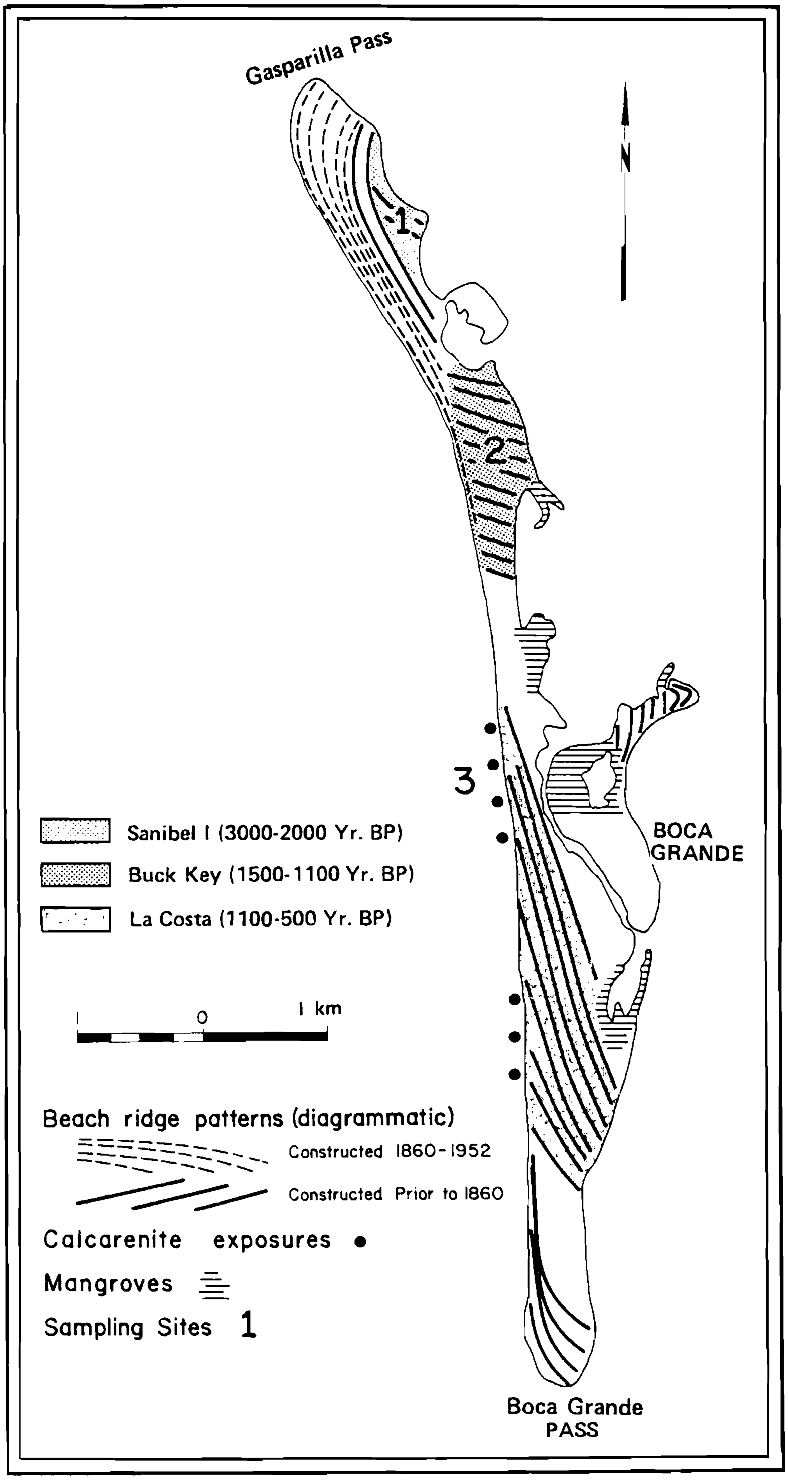
Figure 6. Diagrammatic topographic maps of Gasparilla, La Costa, and South Captiva Islands, Lee County, Florida. These were prepared from commercial photo-topographic maps with a 1-foot contour interval (Hammrick Aerial Surveys, 1981). Topographic profiles are indicated by the lettered lines and beach-ridge set sampling sites for radiometric dating by the numbers. Beach-ridge sets 2 and 3 on Gasparilla are clearly at different elevations with the former having crest elevations well below 5-feet MSL and the latter having crest elevations primarily above 5-feet MSL. On La Costa Island the two oldest beach-ridge sets (sites 1 and 2) are again clearly low in elevation while sets 6, 9, and 10 are clearly high. Set 7, found in a depression contour, is low. The beach-ridge set crossed by profile DD′ formed over the past century or so and can be used as a standard to relate past sea levels to beach-ridge elevation. On South Captiva Island the two older beach-ridge sets 1 and 2 are clearly low while the youngest set (3) is high in elevation.

2400 BP based on a cluster of overlapping ages at the younger end of the 5200-year range of dates (Figure 2). Ridges of this set are partially covered with mangroves and lie within 2-feet of MSL. Set 1 is assigned to the informal time-stratigraphic unit Sanibel I (3000-2000 BP).

Beach-ridge set 2 was deposited about 1000 BP based on a cluster of overlapping ages at the younger end of the 4200-year range (Figure 2). Elevations for set 2 ridges range between 2- and 4-feet MSL (HAMRICK AERIAL SURVEYS, 1981). This set is assigned to the informal time-stratigraphic unit Buck Key (1500-1100 BP).

Lithified calcarenites exposed in a wave-cut cliff (Figure 7) provided shells at beach-ridge set 3. This set was deposited 1000 BP based on a cluster of overlapping ages at the younger end of a 6000-year range of ages (Figure 2). Set 3 lies generally above the 5-foot contour which

Figure 7 (Facing page). The radiocarbon chronology of beach-ridge sets preserved on Gasparilla Island, Lee County, Florida. Beach-ridge patterns are diagrammatic within the various sets and were mapped from 1944 U.S. Department of Agriculture aerial photography. The designations Sanibel I, Buck Key, and La Costa are informal time-stratigraphic units. A generalized topographic map of Gasparilla is presented in Figure 6.


Gasparilla Pass
N
1
2
3
BOCA GRANDE
Sanibel I (3000-2000 Yr. BP)
Buck Key (1500-1100 Yr. BP)
La Costa (1100-500 Yr. BP)
1 0 1 km
Beach ridge patterns (diagrammatic)
Constructed 1860-1952
Constructed Prior to 1860
Calcarenite exposures
Mangroves
Sampling Sites 1
Boca Grande PASS

outlines its individual beach ridges. The north-south alignment of set 3 ridges indicates a pronounced change in shoreline orientation from the east-west ridges of sets 2 and 1. A sea-level rise or increase in wave energy occurred about 1100 BP, immediately prior to the deposition of beach-ridge set 3. This is inferred from (1) the elevated position of set 3 relative to set 2 and (2) that within the resolution of radiocarbon dating the adjacent parts of these two sets are contemporaneous. Set 3 is assigned to the informal time-stratigraphic unit La Costa (1100-500 BP).

The beach-ridge sets present on Gasparilla Island indicate intermittent, southward progradation from about 2400 BP to some time since 1000 BP when bidirectional, northward as well as southward, accretion began. Sand transport during the deposition of these beach-ridge sets probably had a significant onshore component. A marked sea-level rise or increase in wave energy occurred at about 1100 BP prior to construction of beach-ridge set 3. The presence of shell clasts 7600-3000 BP in age indicates that nearby, older Holocene coastal deposits, no younger than 3000 BP, were reworked during the deposition of these beach-ridge sets.

La Costa Island

Thirteen beach-ridge sets are present on La Costa Island (Figures 3 and 8). Eleven are located on that part of the island immediately landward of Johnson Shoal; two sets are present at the southern tip of the island adjacent to Captiva Pass.

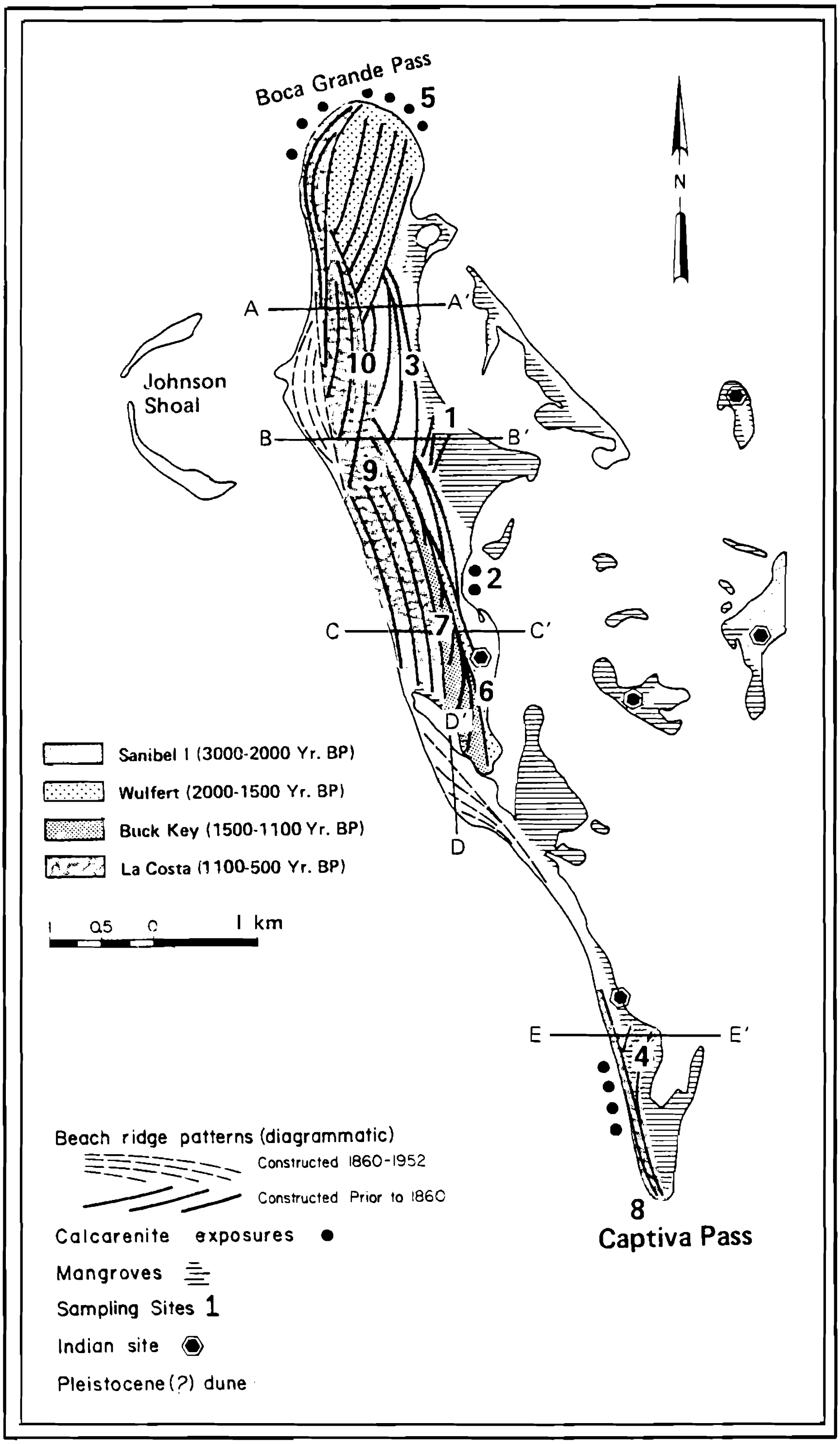
Beach-ridge sets 1-3 are the oldest sets present on La Costa "proper," based on truncating relationships. The writers consider these ridges to have been formed facing the open Gulf of Mexico by swash-zone deposition and not as washover deposits from Pine Island Sound, as interpreted by HERWITZ (1977) and HARVEY (1976). Beach-ridge set 1, the oldest, was deposited 3000 BP (Figure 2). The very small range in ages indicates minimal reworking. Beach-ridge set 2, the next oldest, was also deposited 3000 BP (Figure 2), based on the cluster of overlapping ages at the younger end of the 1500-year range of dates. The synchrony with set 1 deposition is only apparent and reflects the 150-300 year precision of radiocarbon dating. Beach-ridge set 3 was deposited about 2000 BP based on the cluster of ages at the younger end of the 700-year range of dates (Figure 2). Beach ridges making up these sets reach elevations of 3- to 5-feet MSL (sections AA′ and BB′, Figure 9). Sets 1-3 are assigned to the informal time-stratigraphic unit Sanibel I (3000-2000 BP).

Beach-ridge set 5 was deposited approximately 1700 BP on the basis of the cluster of overlapping ages at the younger end of the 3000-year range of dates (Figure 2). Articulated *Spisula raveneli* collected at this set have a 900-year range of ages. Storms scouring a long-existing sand shoal could supply articulated mollusks of differing ages for incorporation into prograding beach ridges. These dates are an indication not only of the age of Johnson Shoal but also of its importance as a sediment source for La Costa Island. Set 5 ridges have elevations ranging up to 8 feet with average elevations between 5- to 6-feet MSL (HAMRICK AERIAL SURVEYS, 1981). The parallel pattern of these beach ridges argues for direct onshore transport during their deposition.

Beach-ridge set 6 was deposited 1700 BP (Figure 2) based on a cluster of overlapping ages at the younger end of the 900-year range of dates. This set reaches elevations of 7- to 9-feet MSL (section CC′, Figure 9). Sets 5 and 6 are assigned to the informal time-stratigraphic unit Wulfert (2000-1500 BP). A sea-level rise or increase in wave energy occurred between the deposition of the Sanibel I sets (1-3) and these Wulfert sets, based on their difference in elevation.

Beach-ridge set 7 was deposited 1100 BP (Figure 2) based on the cluster of overlapping ages at the younger end of the 2800-year range of ages. These ridges have maximum elevations of 4-feet MSL (section CC′, Figure 9). There was a fall in sea level or a decrease in wave energy prior to the construction of this set based on its lower elevation relative to that of sets 5 and 6. Set 7 beach ridges are assigned to the informal

Figure 8 (Facing page). The radiocarbon chronology of beach-ridge sets present on La Costa Island, Lee County, Florida. Beach-ridge patterns are diagrammatic within the various sets and were mapped from 1944 U.S. Department of Agriculture aerial photography. Topographic cross-sections AA′ through EE′ made from Hammrick Aerial Surveys (1981) photo-topographic maps with a 1-foot contour interval, are presented in Figure 9. The designations Sanibel I, Wulfert, Buck Key, and La Costa are informal time-stratigraphic units. A generalized topographic map of La Costa Island is present in Figure 6.


Boca Grande Pass
5
N
A
A'
Johnson Shoal
10
3
1
B
B'
9
2
C
C'
7
6
D'
D
Sanibel I (3000-2000 Yr. BP)
Wulfert (2000-1500 Yr. BP)
Buck Key (1500-1100 Yr. BP)
La Costa (1100-500 Yr. BP)
1 0.5 0 1 km
E
E'
4
Beach ridge patterns (diagrammatic)
Constructed 1860-1952
Constructed Prior to 1860
Calcarenite exposures
Mangroves
Sampling Sites 1
Indian site
Pleistocene(?) dune
8
Captiva Pass

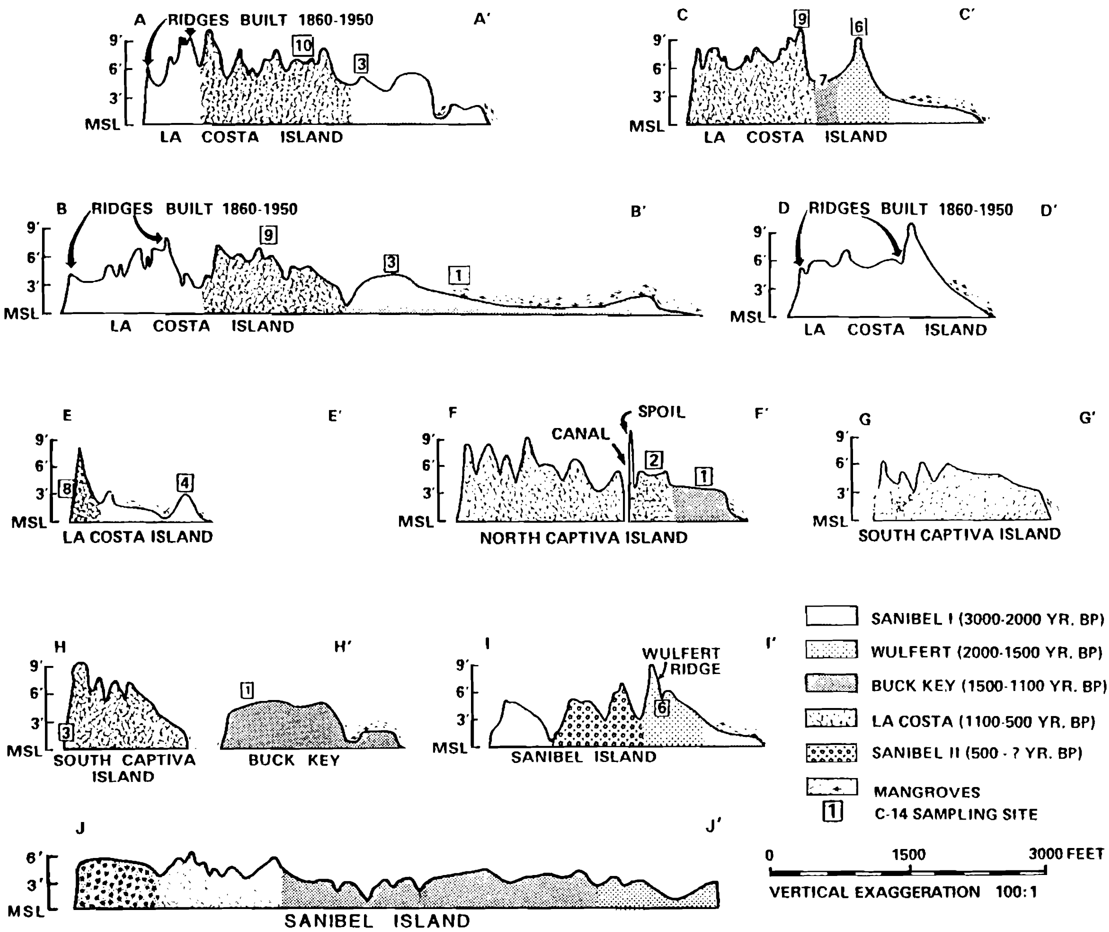


Figure 9. Topographic cross-sections of islands in Lee County, Florida constructed from Hammrick Aerial Surveys (1981) and Bosworth Aerial Surveys (1976) photo-topographic maps with a 1-foot contour interval. The Gulf of Mexico is to the left and Pine Island Sound is to the right on each profile. The locations of these sections are shown in Figures 7, 8, 10, 11, and 12.

time-stratigraphic unit Buck Key (1500-1100 BP).

Beach-ridge set 9 was deposited 1000 BP (Figure 2) based on an overlapping cluster at the younger end of the 3500-year range of dates. The parallel beach-ridge pattern indicates direct onshore transport. Set 10 truncates set 9 and thus is younger (Figure 8). Because there is no cluster of overlapping dates at the younger end of the set 10 range, its youngest date, 1300 BP, is only a maximum estimate of depositional age (Figure 2). The ridges of sets 9 and 10 reach elevations of 6- to 8-feet above MSL (sections AA′ and BB′, Figure 9). A sea-level rise or increase in wave energy occurred prior to deposition of sets 9 and 10 based on their higher elevation relative to that of set 7. Sets 9 and 10 are assigned to the informal time-stratigraphic unit La Costa (1100-500 BP).

The southern third of La Costa Island was added to La Costa "proper" by the filling of two passes: Murdock Bayou landward of beach-ridge set DD′ and an unnamed pass immediately northward of beach-ridge set 8 (HERWITZ, 1977; HARVEY, 1979). Beach-ridge set 4, the oldest set preserved on this part of La Costa, was constructed about 2000 BP (Figure 2), based on the cluster of ages at the younger end of the

1400-year range. Ridges reach an elevation of 3-feet MSL (section EE', Figure 9). This set represents the northern spit-like tip of a barrier that extended into and across (?) what is now Captiva Pass. Set 4 is assigned to the informal time-stratigraphic unit Sanibel I (3000-2000 BP).

Beach-ridge set 8 was formed 1100 BP (Figure 2). It is the remnant of a set that also extended into and perhaps across what is now Captiva Pass, an indication that this pass was cut subsequent to 1000 BP. These ridges have elevations of 7- and 8-feet MSL (section EE', Figure 9). A rise in sea level or increase in wave energy occurred between the deposition of sets 4 and 8 based on their difference in elevation. Beach-ridge set 8 is used to define the informal time-stratigraphic unit La Costa, those beach ridges constructed 1100-500 BP.

The beach-ridge sets of La Costa Island indicate a history of alternating deposition and erosion with sediment being supplied by direct onshore and as well as littoral transport. Johnson Shoal appears to have existed throughout the 3000-year history of this island. Three major fluctuations in sea level or wave energy are suggested by juxtaposed beach-ridge sets of differing elevations: (1) a rise-increase at about 2000 BP prior to the deposition of sets 5 and 6, (2) a fall-decrease subsequent to 1700 BP (beach-ridge set 6) and prior to 1100 BP (beach-ridge set 7), and (3) a rise-increase at about 1100 BP prior to the deposition of sets 8-10.

North Captiva Island

Two beach-ridge sets make up the progradational portion of North Captiva Island (Figure 10). The remainder of the island is narrow and eroding with washover fans projecting eastward into Pine Island Sound. Set 1, the older, is very small in areal extent and rather narrow, essentially an erosional remnant. It has an average elevation of slightly over 3-feet MSL (section FF', Figure 9). It was deposited approximately 1300 BP (Figure 2) as indicated by a cluster of overlapping ages at the younger end of the 3000-year range of dates. This set that originally extended to the north across the area that is now Captiva Pass is assigned to the informal time-stratigraphic unit Buck Key (1500-1100 BP).

Beach-ridge set 2 makes up the bulk of the North Captiva beach-ridge plain. Ridges are 5- to 6-feet MSL in average elevation (section FF', Figure 9) and form a cuspate-headland pattern that suggests tombolo-like growth toward the Captiva Pass ebbtidal delta. Deposition of this set began no earlier than 600 BP, a maximum estimate as there are only two overlapping ages at the younger end of the 4200-year range (Figure 2). Reworking is a very important factor at this locality and can be recognized in the articulated as well as the disarticulated specimens. There was a sea-level rise or increase in wave energy prior to the deposition of set 2, given the difference in elevation between these adjacent sets. Beach-ridge set 2 is assigned to the informal time-stratigraphic unit La Costa (1100-500 BP).

Captiva Pass was cut before the deposition of set 2, sometime between 1300 and 600 BP. The 2000 BP set 4 of the adjacent southern tip of La Costa Island (Figure 8) and the 1300 BP set 1 of North Captiva demonstrate that islands existed in this location prior to the cutting of Captiva Pass. Reworked shells found at these sites adjacent to captiva Pass indicate that Holocene coastal deposition in this immediate vicinity dates to 4800 BP, although no deposits older than 2000 BP have as yet been identified.

Buck Key

This small, low-lying island is east of South Captiva Island across the 200-m wide Roosevelt Channel (Figure 11). A complex history of episodic deposition and erosion can be inferred from the occurrence of at least five distinct beach-ridge sets. Beach ridges average between 3- to 4-feet MSL in elevation (section HH', Figure 9). Deposition of set 1, one of the younger beach-ridge sets preserved on Buck Key (Figure 11), occurred 1200 BP based on the cluster of overlapping dates at the younger end of the 1800-year range (Figure 2, site 1 of South Captiva). Shells from deposits up to 3000 BP were reworked during the formation of this beach-ridge set. Shell middens and burial mounds found on Buck Key date to 1000 years BP (Marquardt, W.H., *written communication*). These beach-ridge sets are used to define the informal time-stratigraphic unit Buck Key, those beach ridges deposited 1500-1100 BP.

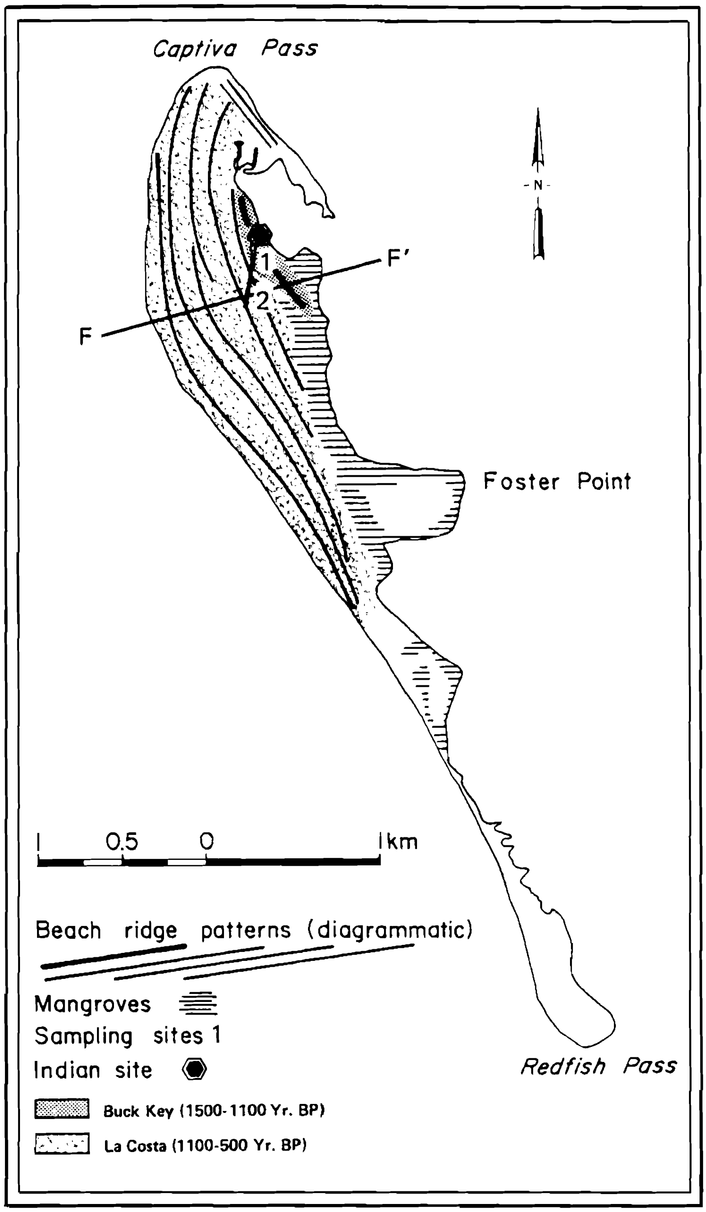


Figure 10. The radiocarbon chronology of beach-ridge sets present on North Captiva Island, Lee County, Florida. Beach-ridge patterns are diagrammatic within the various sets and were mapped from 1944 U.S. Department of Agriculture aerial photography. Topographic cross-section FF' was made from a Hammrick Aerial Surveys (1981) photo-topographic map with a 1-foot contour interval (Figure 9). The designations Buck Key and La Costa are informal time-stratigraphic units.

South Captiva Island

This relatively narrow barrier island consists of two major beach-ridge sets (Figure 11). Set 2, the northernmost and older, contains parallel, spit-type beach ridges indicative of direct

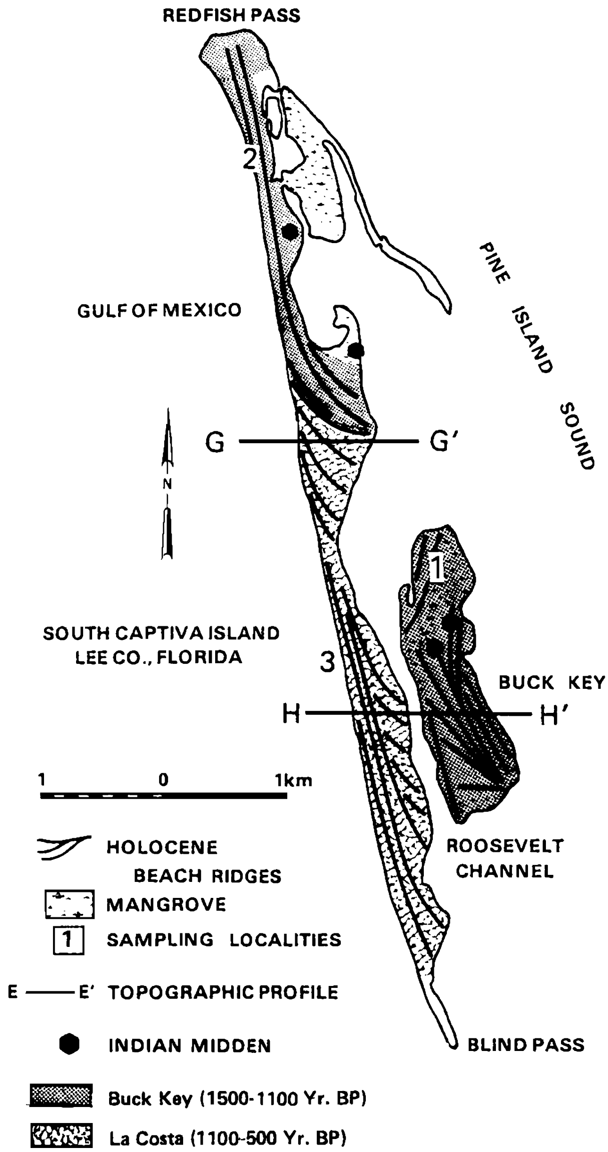


Figure 11. The radiocarbon chronology of beach-ridge sets present on Buck Key and South Captiva Islands, Lee County, Florida. Beach-ridge patterns are diagrammatic within the various sets and were mapped from 1944 U.S. Department of Agriculture aerial photography. Topographic cross-sections GG' and HH' were made from Hammrick Aerial Surveys (1981) photo-topographic maps with a 1-foot contour interval (Figure 9). The designations Buck Key and La Costa are informal time-stratigraphic units. A generalized topographic map of Buck Key and South Captiva is presented in Figure 6.

onshore sediment transport in addition to southward longshore transport. These ridges have elevations below 5-feet MSL (Figure 6). Deposition occurred approximately 1000 years BP based on the cluster of overlapping ages at the younger end of the 5000-year range (Figure 2). A 1000 BP aboriginal shell midden (Calvert *et al.*, 1978) located in the southeastern corner of this set (Figure 11) is consistent with this estimate for the age of deposition. Set 2 is assigned to the informal time-stratigraphic unit Buck Key (1500-1100 BP).

Set 3 contains three groups of spit-type beach ridges that record episodic, southward migration. These ridges have average elevations of 5- to 7-feet MSL (sections GG′ and HH′, Figure 9). Deposition occurred no earlier than 600 BP (Figure 2), a maximum estimate based on a cluster of two overlapping dates at the younger end of the 3600-year range. Set 3 is assigned to the informal time-stratigraphic unit La Costa (1100-500 BP). There was a rise in sea level or increase in wave energy between the deposition of sets 2 and 3, based on their difference in elevation.

Sanibel Island

Sanibel is the largest Holocene barrier island in southwest Florida and also one of the lowest, mostly being about 3-feet MSL. Sanibel Island beach ridges are orientated east-west; only those ridges adjacent to Blind Pass have the northwest-southeast orientation characteristic of beach ridges present on all other barrier islands in southwest Florida. At least 14 separate beach-ridge sets, segregated by surfaces of erosional truncation, are present on Sanibel (Figures 4 and 12).

Beach-ridge set 1 contains the oldest preserved beach ridges on the island (Figure 12). It was deposited about 3000 BP; there is a cluster of only two overlapping ages at the younger end of the 3400-year range of dates, but definitely prior to 2700 BP, the age of set 2, the next youngest (Figures 2 and 12). This age for set 2 is well defined by a cluster of dates at the younger end of a 3000-year range. Beach-ridge sets 3 and 4 were deposited 2200 BP and 2000 BP respectively based on clusters at the younger ends of their reported ranges. Set 5 which clearly truncates set 4 was deposited 1800 BP.

Beach-ridge sets 1,2, 4, and 5 are partially covered with mangroves and are located well within the uppermost portion of the present-day intertidal zone. Beach-ridge set 3 is largely covered with fresh-water marsh vegetation. These sets have maximum elevations between 2- to 3-feet MSL (profile JJ′, Figure 9); however, they are geographically widespread, contain laterally continuous beach-ridge patterns, and make up 40-45% of Sanibel Island. Beach-ridge sets 1 through 5 are used to define the informal time-stratigraphic unit Sanibel I, those beach ridges deposited between 3000 and 2000 BP. This is the oldest unit preserved on Holocene barrier islands in southwest Florida.

Beach-ridge set 6, the Wulfert Ridge, was deposited 2100 BP (Figure 2). The cluster of overlapping dates at the younger end of the 3300-year range confirms the 2100 BP age reported by Missimer (1973). Swash-zone laminae occur at elevations of 8- to 10-feet MSL (profile II′, Figure 9), 3-4 feet above beach-ridge crests formed over the past 100 years and 6-8 feet above the Sanibel I ridges. A rise in sea level or an increase in wave energy occurred subsequent to Sanibel I deposition and prior to deposition of set 6. This beach-ridge set is used to define the informal time-stratigraphic unit Wulfert, those beach ridges deposited during the period 2000-1500 BP. It represents the highest sea level or wave energy recognized in the Holocene barrier islands of southwest Florida.

Beach-ridge set 7 was deposited 1100 BP (Figure 2) as indicated by the cluster of overlapping dates at the younger end of the 2000-year range. These low-lying ridges, elevations of less than 3-feet MSL, are largely covered by fresh-water marsh vegetation. This set is geographically widespread and is composed of laterally continuous beach-ridges, Figures 4 and 12. A fall in sea level or a decrease in wave energy occurred subsequent to set 6 deposition and prior to that of set 7 based on their difference in elevation. Set 7 is assigned to the informal time-stratigraphic unit Buck Key (1500–1100 BP).

Beach ridge set 8 was deposited 700 BP, Figure 2. There is a cluster of overlapping dates at the younger end of the 3500-year range. These beach ridges rise to nearly 7-feet MSL and are the highest elevation on Sanibel Island outside of the Wulfert Ridge, set 6. A rise in sea level or increase in wave energy occurred subsequent to set 7 deposition and prior to the deposition of set 8 beach ridges, given the 4-foot difference in crest elevation. Set 8 is assigned to the informatl time-stratigraphic unit La Costa (1100-500 BP).

Beach-ridge set 9 was deposited prior to 400 BP (Figure 2) and subsequent to 700 BP (the

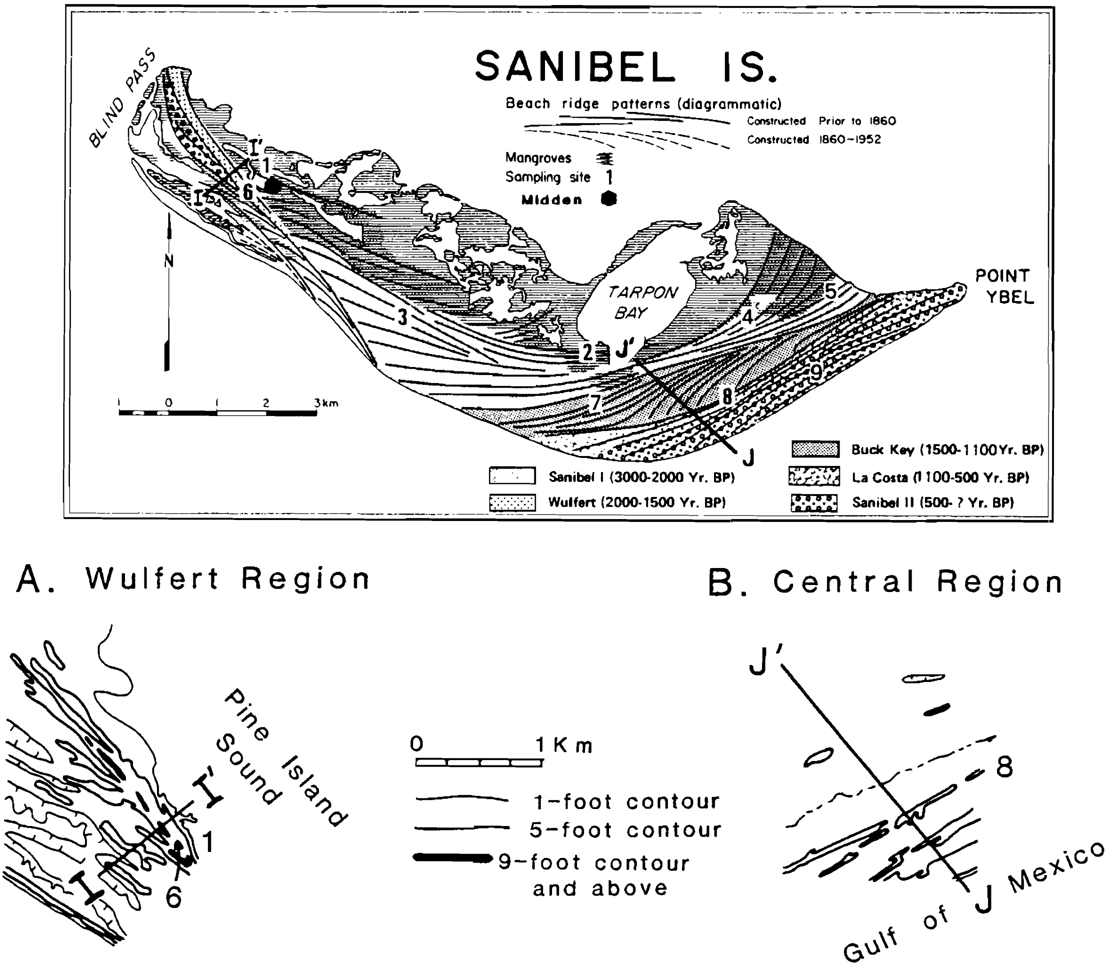


Figure 12. The radiocarbon chronology of beach-ridge sets present on Sanibel Island, Lee County, Florida. Beach-ridge patterns are diagrammatic within the various sets and were mapped from 1944 U.S. Department of Agriculture aerial photography. Inserts A and B are diagrammatic topographic maps abstracted from Bosworth Aerial Surveys (1976) 1-foot photo-topographic maps. Topographic profiles II′ and JJ′ are presented in Figure 9. Note the low-lying nature of much of interior Sanibel and the anomalously high elevation of the Wulfert region. The designations Sanibel I, Wulfert, Buck Key, La Costa, and Sanibel II are informal time-stratigraphic units.

age of set 8). Reworking of older shells is important at this site; however, there is a cluster of overlapping dates at the younger end of the 4200-year range. The parallel beach-ridge pattern argues that sand was primarily transported directly onshore during the construction of this set. These ridges have maximum elevations of 4- to 5-feet MSL and thus infer a sea-level fall or wave-energy decrease from that of set 8. Beach-ridge set 9 is used to define the informal time-stratigraphic unit Sanibel II, those beach ridges deposited subsequent to 500 BP and prior to the period covered by historic maps.

Beach-ridge sets on Sanibel Island record a complex history of intermittent deposition. Six distinct progradational units composed of one or more beach-ridge sets are present on this island and are separated from each other by surfaces of erosional truncation. The oldest such unit, Sanibel I, is 3000-2000 BP and the youngest, spits that migrated across Blind Pass from South Captiva, has been deposited during the past 125 years. Five fluctuations in sea level or wave energy can be inferred from the occurrence of elevationally distinct and geographically juxtaposed beach-ridge sets: (1) a rise-increase at about 2000 BP subsequent to deposition of sets 1-5 and prior to set 6, (2) a fall-decrease between 2000-1100, BP, subsequent to set 6 and prior to set 7 deposition, (3) a rise-increase subsequent to 1100 BP (set 7) and prior to 700 BP (set 8), (4) a fall-decrease between 700-400 BP, subsequent to set 8 and prior to set 9, and (5) the rise-increase during the past 100 or so years subsequent to set 9 deposition.

Siesta Key

Siesta Key is a Holocene barrier island located in Sarasota County, Florida, 115 km north of the Lee County barriers. It is over 2 kilometers wide adjacent to Big Sarasota Pass and tapers southward to less than 750 meters in a distance of approximately 4 kilometers, a classic "drumstick" barrier island of Hayes (1976), Figure 13. A calcarenite outcrop near the middle of Siesta Key (locality 2, Figure 13) forms a headland, Point-of-Rocks, extending several hundred meters out into the Gulf of Mexico.

The oldest beach-ridge set dated on Siesta Key is adjacent to Little Sarasota Bay, locality 1 in Figure 13, and was deposited approximately 3000 years BP, based on the cluster of ages at the younger end of a 1500 year range (Figure 2). These ridges are parallel and gently concave seaward, an indication of direct onshore sediment transport. Crest elevations are less than 5-feet MSL on the USGS topographic map. This set is assigned to the informal time-stratigraphic unit Sanibel I (3000-2000 years BP).

The original topography of Siesta Key has been greatly modified by housing construction. The beach-ridge patterns shown in Figure 12 were mapped from 1948 aerial photography. However, the Point-of-Rocks beach-ridge set sampled at locality 2 is essentially undisturbed, no canals cross it and contour lines describing its topography are concordant with the geometry depicted on the 1948 aerial photography. This set rises to elevations between 10- and 15-feet MSL and forms the highest natural portion of Siesta Key. This "high" beach-ridge set was deposited about 1700 BP (Figure 2) based on a cluster of dates at the younger end of a 3000-year range. This set is assigned to the time-stratigraphic unit Wulfert (2000-1500 BP). A rise in sea level or an increase in wave energy occurred prior to the deposition of the Point-of-Rocks beach ridges, based on their elevated position relative to the adjacent Sanibel I ridges.

The beach-ridge set sampled at locality 3 was deposited 1100 BP (Figure 2) based on a cluster of overlapping dates at the younger end of the 2400-year range. Ridges within this set are outlined by the 5-foot contour line shown on the USGS topographic map. These ridges are distinctly lower than those of the Point-of-Rocks set and are essentially equal in elevation to the historic ridges. Thus there has been a reduction in sea-level position and/or wave energy from conditions existing during deposition of the Point-of-Rocks set. Set 3 is assigned to the La Costa time-stratigraphic unit (1100-500 BP).

It should be noted that the bulk of Siesta Key consists of beach ridges deposited subsequent to the set sampled at site 3, the unpatterned area seaward of sets 3 and 1 in Figure 13. These ridges "V" to the southeast, reflecting southeasterly sediment transport that terminates well before reaching Point-of-Rocks, a rather short distance (Figure 13). In addition, they are located on the southeastern margin of the Big Sarasota Pass ebb-tidal delta and represent the subaerial portion of that growing sand body. Deposition of this beach-ridge set began no earlier than 1000 years ago, a date that is also the maximum age of the ebb-tidal delta.

DISCUSSION

The presence of shell clasts 7600-3000 BP in age indicates that nearby, older Holocene coastal deposits, no younger than 3000 BP, were reworked during the deposition of beach-ridge sets on these southwest Florida barrier islands. However, coastal deposits older than 3000 BP at or within 1 to 3 meters of present MSL have not as yet been identified in this part of southwest Florida. Nor should their existance be expected according to the widely accepted southwest Florida sea-level curves

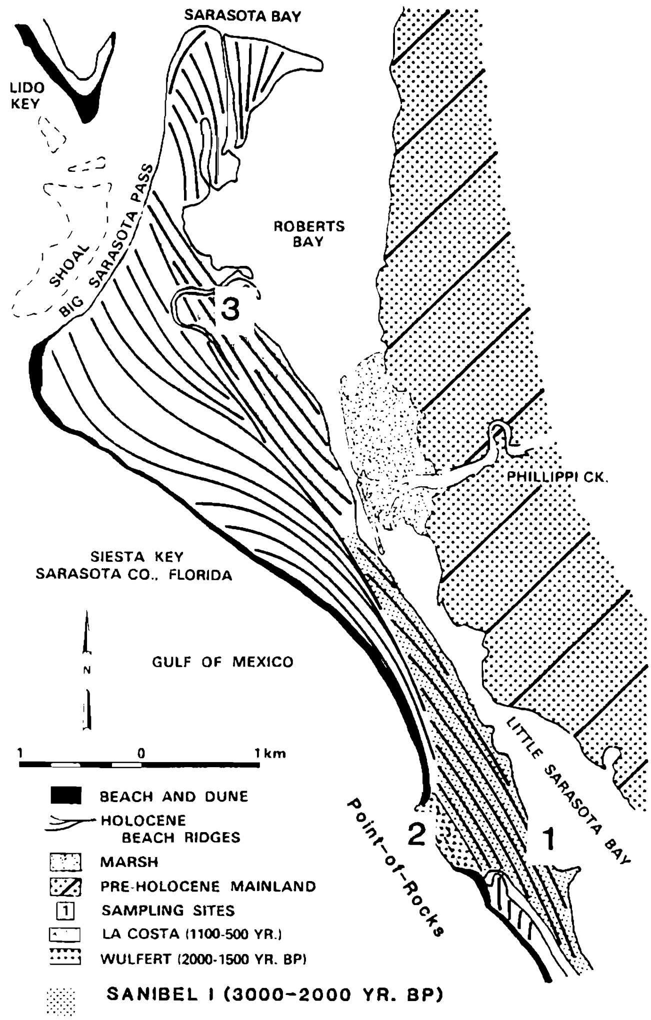


Figure 13. The radiocarbon chronology of beach-ridge sets present on Siesta Key, Sarasota County, Florida. Beach-ridge patterns are diagrammatic within the various sets and were mapped from 1948 U.S. Department of Agriculture aerial photography. The designations Sanibel I, Wulfert and La Costa are informal time-stratigraphic units developed for the southwest Florida barrier islands.

based on intertidal peats that place MSL between −20 and −4 meters over the period 7600–4000 BP, see WIDMER (1988) for extensive review. It is interesting to note that the New Orleans, Louisiana, bar and shoal deposit with a maximum elevation of + 0.5 meters MSL has been dated at about 5000 BP by OTVOS (1978). An aboriginal shell midden on nearby Useppa Island (Figure 1) has yielded nearshore marine and estuarine shells that date back to 5600 years BP (MARQUARDT, in press). Another such shell midden at Horr's Island, approximately 100 km to the south in Collier County, Florida, has also produced similar shells with dates that range back to 6300 years BP (RUSSO, 1991). The New Orleans bar and shoal deposit and these two archeologic sites strongly suggest if not confirm the close geographic and topographic proximity of sea level during this time interval and support the previous existance of the much older coastal deposits hypothesized by these older reworked shells (Figure 2). Furthermore, these geologic and archaeologic deposits call into question the pre-3000 BP portions of southwest Florida sea-level curves determined from intertidal peats.

Holocene beach-ridge sets in southwest Florida are either "high" or "low" with respect to elevation. Crest elevations of the "high" sets are typically 5- to 6-feet MSL with the exception of the Sanibel Island Wulfert set that reaches 10-feet MSL and the Siesta Key Point-of-Rocks set that rises between 10- and 15-feet MSL. Crest elevations of the "low" sets are typically 2- to 3-feet MSL and, in addition, are partially covered with mangroves and/or freshwater marsh vegetation. Beach ridges formed facing the open Gulf of Mexico during the past 100 years have crest elevations of about 5-feet MSL. Because these beach ridges are made up solely of swash-zone deposits, this difference in crest elevation reflects a change in sea-level position or wave energy.

Beach-ridge elevation is a function not only of sea-level position but also wave height (TANNER and STAPOR, 1972); larger waves build higher ridges and vice versa. The geomorphology of the "high" and "low" sets cannot be accurately compared because the swales of the latter have been masked and/or modified by mangrove and freshwater-marsh deposits. Such a comparison, if possible, could determine if wave height had varied between the two sets, based on the premise that ridge relief, the difference between crest and swale elevations, should be uniform for a particular wave climate. However, as this cannot be done a more indirect argument must be advanced. A marked reduction in wave height will tend to increase wave refraction and that will make littoral-drift patterns more complex and individual drift-cells shorter in length. A reduction in drift-cell length should favor the deposition of shorter length beach-ridges of reduced geographic extent. Thus a change in wave energy alone should be reflected in a pronounced difference in the lateral continuity and geographic extent of beach-ridge sets. However, a change in sea-level position alone should not markedly affect either beach-ridge continuity or geographic extent.

The "low" beach-ridge sets present on Sanibel Island, where preservation has been maximized, have considerable lateral continuity and geographic extent (Figures 4 and 12). They are just as continuous and widespread, if not more so, as are the "high" sets. Wave energy can then be inferred to have been no lower during deposition of the "low" sets than it was during construction of the "high" sets. This strongly suggests, if not demonstrates, that contemporan eous "low" sets throughout southwest Florida were formed during times of lower sea level rather than periods of noticeably reduced wave energy.

The timing of the various sea-level fluctuations represented in these beach-ridge sets can be estimated in the following manner. Beach-ridge sets that are geographically adjacent, of different elevation, and the same radiocarbon age, mark a sea-level fluctuation. The sets' synchrony is only apparent and reflects the ability of the radiocarbon technique, as applied to these shells, to resolve only differences greater than or equal to 200-400 years, based on the respective counting errors. This level of resolution also masks the timing of the sea-level fluctuation. The difference in crest elevations provides a maximum estimate of the magnitude of the sea-level fluctuation. Five such fluctuations can be identified in these southwest Florida islands using this method, Figure 14.

The oldest recorded fluctuation occurred about 2000 BP between the deposition of the Sanibel I and Wulfert beach-ridge sets. Sea level may have risen by as much as 4- to 6-feet judging by the difference in elevation of these ridges. Deposition of the Wulfert sets occurred while Holocene sea level was at one of its highest positions. An elevated scarp and terrace cut by wave action some time during this period has been recognized in South Carolina (STAPOR AND MATHEWS, 1983).

Archaeologic data provide an independent confirmation of this particular sea-level rise: (1) encrusting, high-salinity, mollusks from pile-molds that today occur 50 cm above MHW in the low salinity headwaters of the Charlotte Harbor estuary (Solana site near Punta Gorda, WIDMER, 1986); and (2) discrete layers within oyster-shell middens containing abundant high salinity mollusks indicative of periods of elevated salinity in the adjacent brackish estuary (Big Mound Key and Cash Mound sites of the lower Charlotte Harbor estuary, WALKER, in press). Radiocarbon dates made on mollusks at

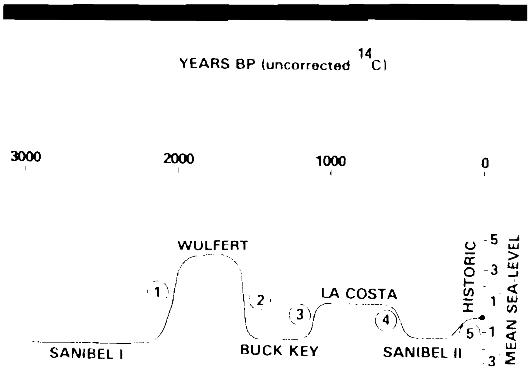


Figure 14. A mean sea-level curve for southwest Florida based on the geochronology, geomorphology, and elevation of beach-ridge sets making up the southwest Florida barrier islands. Sea-level fluctuations 1, 3, and 4 are based on the occurrence of geographically juxtaposed and elevationally distinct beach-ridge sets of the same apparent radiocarbon age. The precise timing of fluctuation 2 is unknown because no Wulfert and Buck Key beach-ridge sets of the same apparent radiocarbon age have as yet been identified. Fluctuation 5 is assumed to be the rise monitored by historic mareograph data. Although the oldest preserved beach-ridge set is only 3000 BP, the presence of reworked shells argues that sea level had reached and stabilized near its present-day position 5000-6000 BP.

the Solana site indicate that sea level was at a higher-than-present position 1600 years BP; dates made at the Cash Mound site indicate a similar age for the layer containing the high salinity mollusks. In addition, preliminary data from the Wightman site on Sanibel Island (FRADKIN, 1976) suggest that a 2000 to 1600 year BP oyster reef locally covers the Holocene beach-ridge substrate. The oyster reef is approximately 10-20 cm above present-day MSL. A similar situation exists at the Onion Key site in the Everglades National Park where an oyster reef, at an unknown but low elevation (less than 50 cm) above present-day sea level, is interbedded in a shell midden. The underlying midden is at least 2500 years BP and the oldest part of the overlying midden is approximately 1300 years BP (GRIFFIN, 1988). The midden at the Turner River site, Everglades National Park, contains an interbedded marine marl layer, again at an unknown but low elevation above present-day sea level. The oldest part of the overlying midden is about 1400 years BP, the age of the underlying material is not known (Griffin, 1988).

PARKINSON (1989) found no evidence of this or any other higher-than-present, sea-level event in Holocene sediment cores from the Ten Thousand Islands, located approximately 90 kilometers southeast of Sanibel Island. These record a transgressive/regressive couplet deposited over the past 3500 years. This region does not contain beach-ridge sets; mangrove swamps form the shoreline and therefore any peats deposited at higher-than-present sea-level stands should have a very low preservation potential. Furthermore, the subtidal nearshore marine sediments grade offshore into those of the open ocean shoreface across a very gently sloping surface, and the faunas grade from euryhaline to mixed euryhaline/stenohaline. A sea-level rise of a meter or so lasting only several hundred years might well be very difficult to detect given the gradational nature of the gently sloping boundary separating both the sediments and faunas of these adjacent environments.

At about 1500 BP sea level fell by an almost equal amount prior to the deposition of the Buck Key beach-ridge sets. At approximately 1100 BP a rise of no more than 2- or 3-feet returned sea level to very near its present position prior to the deposition of the La Costa beach-ridge sets. At present there are no archeologic data confirming this sea-level rise. A fall occurred at about 500 BP prior to the deposition of the Sanibel II ridges. Over the past 150 years sea level rose to its present position during which the historic beach-ridge sets were deposited. These two most recent fluctuations probably were also in the 1- to 2-feet range.

The data presented in this study demonstrate that Holocene barrier islands in southwest Florida have experienced net seaward progradation over the past 3000 years. However, progradation has been intermittent rather than continuous; coastal erosion interrupted seaward growth. Many of the individual beach-ridge sets making up these prograding barriers record sand transport with a primary onshore component. This situation should be expected given that in southwest Florida sand for coasatal progradation can be derived only from the erosion of pre-existing coastal and nearshore deposits, because any sand coming down present-day rivers is trapped within estuaries and not delivered to the Gulf of Mexico shoreline.

CONCLUSIONS

Geomorphologic and radiocarbon data from southwest Florida prograding barrier islands composed of multiple beach-ridge sets support the following conclusions: (1) Beach ridges making up these islands were deposited almost exclusively by swash action on a foreshore. The internal stratification is planar laminae with a gently seaward dip; washover deposits are extremely rare. In addition, eolian processes played essentially no role in their deposition. These characteristics allow their crest elevations to be estimates of sea-level position. (2) Reworking of older shells into younger deposits is an important factor that can be identified and evaluated by dating a number of individual shells at each sampling site. A cluster of overlapping dates at the younger end of the range provides the best estimate for depositional age. (3) Sea level in southwest Florida had reached to within a meter or so of its present position by 5000 BP and possibly by 6000 BP. Five major fluctuations in sea level have occurred in this region subsequent to 3000 BP: (1) a rise at about 2000 BP, (2) a fall between 2000 and 1100 BP, (3) a rise at about 1100 BP, (4) a fall at about 500 BP, and (5) a rise over the past 150 years. This most recent rise that is occurring at average rates of up to several millimeters per year is well documented by mareograph records (HICKS, 1973). The 500-year spacing of these fluctuations is only apparent and reflects primarily the precision in estimating the age of clastic deposits by radiocarbon-dating their shell clasts. (4) Given the geologic setting of southwest Florida these barrier islands were supplied with sand by the erosion of nearshore and shoreline deposits. Furthermore, these sources were distributed all along the southwest Florida coast with the result that coastal progradation has occurred simultaneously at various sites controlled by the local delivery of sand to the shoreline. It is hypothesized that this delivery is a function of the off-shore equilibrium profile and that is controlled by sea-level position. Fluctuations in sea-level are held to be responsible for resetting this profile and episodically driving sand onshore for island progradation.

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□ RÉSUMÉ □

Les îles-barrière holocènes de Lee County (Floride) sont composées de levées de plage organisées en séries distinctes et non conformes limitées par des surfaces d'érosion. Ces levées de plage ont été différenciées d'après leur élévation moyenne. Les ensembles bas sont à 0,9m au dessus du niveau moyen local de la mer, et les ensembles élévés à 1,8m. Ces levées ne sont composées que de dépôts de la zone de swash qui sont des dépôts laminaires plans, plongeant vers la mer. Cette origine marine est appuyée par l'uniformité et la régularité de leur élévation au dessus du niveau de la mer, comme par la géométrie curvilinéaire de chaque levée. Le plus ancien ensemble de levées de plage conservé par içi a été déposé vers 3000 BP. D'autres ensembles d'élévation distincte, en apparence d'âge identique, et géographiquement adjacents à ces levées témoignent d'une importante fluctuation du niveau de la mer (montée ou baissée) et/ou de l'énergie de la houle (croissance ou décroissance). La date de cette fluctuation s'inscrit dans les 200 à 400 dernières années, compte-tenu de la marge d'erreur pour les coquilles analysées pour lesquelles la méthode du radiocarbone ne fait pas de différences. Dans cette région de faible énergie de la houle et de régime microtidal, l'extension géographique et la continuité latérale des basses levées de plage permet de dire que la composante première de ces fluctuations a été un changement dans le niveau de la mer plutôt que dans l'énergie de la houle. Les basses levées, comme les hautes sont géographiquement dispersées et latéralement continues. On aurait pu prédire une situation toute inverse si les ensembles bas s'étaient formés seulement en phase de décroissance d'énergie de la houle: la réfraction des vagues aurait été accrue et aurait entrainé ıne dérive litorale plus complexe. Plus le réseau en est compliqué, plus la longueur de la cellule de dérive littorale, et donc la ongueur de la levée de plage est courte. On a identifié sur les îles 5 de ces fluctuations: 1) une montée de 1,2m à 1,8m à 2000 BP;

2) une descente de 0,9m à 1,5m à 1500 BP; 3) une nouvelle montée de 0,6m à 0,9m à 1100 BP; 4) une descente d'environ 0,6m à 500 BP et 5) uner montée au cours des 100 dernières années. Le cycle sur 500 ans n'est qu'apparent et reflète la précision des datations au radiocarbone des dépôts clastiques contenant des coquilles. Chacune de ces fluctuations a entraîné la progradation d'une dune barrière ou sa création. L'approvisionnement en sable provient de l'érosion de la région circumlittorale et des îles barrière existantes. Chaque fluctuation a eu une phase initiale de dépôt suivie d'une phase d'érosion à mesure que le volume d'approvisionnement passait en dessous d'une seuil critique. La décroissance de l'apport en sable rend compte de l'apauvrissement de la source et/ou d'une réorientation du champ de transport sédimentaire.—*Catherine Bousquet-Bressolier, Géomorphologie EPHE, Montrouge, France.*

□ ZUSAMMENFASSUNG □

Holozäne Strandwallinseln setzen sich in Lee County, Florida, aus Strandwällen zusammen, die aus deutlich getrennten, durch Erosionsoberflächen begrenzten Gruppen bestehen. Diese sind aufgrund ihrer unterschiedlichen Höhe weiter untergliedert. Niedrige Strandwallgruppen sind etwa 0,90 m, hohe etwa 1,80 m über dem örtlichen Mittelwasser. Die Strandwälle werden ausschließlich von Sedimenten aufgebaut, die durch auflaufende Wellen abgelagert wurden und aus meerwärts einfallender Parallelschichtung bestehen. Ihr mariner Ursprung wird ferner durch die gleichmäßige Höhe und die regelmäßige Geometrie der einzelnen Strandwallscheitel belegt. In dieser Region wurden die ältesten erhaltenen Strandwallgruppen ungefähr 3.000 BP abgelagert. Höhenmäßig unterschiedliche, geographisch benachbarte Gruppen von Strandwällen offenbar gleichen Alters bezeugen eine größere Änderung des Meeresspiegels (Trans- oder Regression) und/oder der Wellenenergie (Zu- oder Abnahme). Das Alter dieser Änderung liegt innerhalb der statistischen Fehlergrenze der Radiokarbondatierungsmethode für die analysierten marinen Muscheln (200 bis 400 Jahre). Die geographische Verbreitung und seitliche Ausdehnung der niedrigen Strandwallgruppen in dieser niedrig-energetischen Region mit nur geringem Tidenhub sprechen dafür, daß der ursprüngliche Grund dieser Schwankungen eher die Veränderung des Meeresspiegels als der Wellenenergie war. Niedrige Strandwallgruppen sind geographisch ebenso verbreitet wie die hohen und haben gleiche seitliche Ausdehnung. Genau das Gegenteil hätte eintreten müssen, wenn die niedrigen Strandwallgenerationen nur aufgrundverminderter Wellenenergie entstanden wären: Die Wellenbrechunghätte sich dann erhöht, was zu einem noch komplizierteren Muster des Küstenlängstransports geführt hätte. Je komplizierter dieses Muster, desto kürzer die Länge des Einflusses des Küstenlängstransports und daher auch der Strandwallgruppen. Fünf derartig belegte Meeresspiegelschwankungen konnten auf diesen Inseln festgestellt werden: (1) ein Anstieg von 1,20 bis 1,80 m um 2.000 BP, (2) ein Absinken um 0,90 bis 1,50 m um 1.500 BP, (3) ein Anstieg von 0,60 bis 0,90 m um 1.100 BP, (4) ein Absinken um etwa 0,60 m um 500 BP und (5) ein erneutes Ansteigen seit etwa hundert Jahren. Der 500 jährige Rhythmus ist nur scheinbar und spiegel die Genauigkeit der Bestimmung unterschiedlicher Ablagerungsalter von klastischen Sedimenten wider, wenn man die in ihnen enthaltenen Muschelbruchstücke mit Hilfe der Radiokarbonmethode datiert. Jede dieser Schwankungen führte zum Anwachsen oder zur Bildung von Strandwallinseln. Der Sand stammte aus der Erosion der küstennahen Zone und von bereits vorhandenen Strandwallinseln. Jede Schwankung hatte anfangs eine Ablagerungsphase, der eine Erosionsphase folgte, wenn die Versorgungsrate unter einen kritischen Grenzwert fiel. Eine Abnahme der Sandversorgung spiegelt eine Erschöpfung der Sandquelle und/oder eine Umlenkung des Transportweges wider.—*Helmut Brückner, Geographisches Institut, Universität Düsseldorf, F.R.G.*

□ RESUMEN □

Las bermas holocenas en Lee County, Florida, se componen de crestones organizados en grupos distintos unos de otros, limitados por superficies de erosión. Estos grupos de crestones se se pueden diferenciar en cuanto a su elevación media. Los grupos más bajos tienen unos 3 pies y los más altos alrededor de 6 pies sobre el nivel medio local del mar. Los crestones se componen exclusivamente de los depósitos de la zona de swash generados por el transporte hacia el mar en capa límite. Su origen marino se refleja en la altura (mantenida constante) y en la geometría regular curva, de cada crestón. El grupo de crestones más antiguo que se conserva en la región fue depositado hace unos 3000 años. Esta diferencia de altura entre grupos de crestones adyacentes y aparentemente de la misma edad refleja una variación importante (ascenso o descenso) del nivel del mar y/o una variación notoria de la energía del oleaje (incremento o disminución). En el cálculo de la decha de estas fluctuaciones existe un margen de error de 200 a 400 años, precisión que el análisis por carbono radiactivo de las conchas no puede superar. La extensión geográfica y la continuidad lateral de los grupos de crestones bajos en esta región de baja energía y pequeña marea apuntan a que la principal causa de estas fluctuaciones es un cambio en el nivel del mar más que variaciones de energía del oleaje. Los grupos de crestones bajos están tan extendidos georgráficamente y son tan continuos lateralmente como los altos. La situación opuesta se hubiese producido si los grupos bajos se hubiesen formado debido solamente a un descenso de la energía del oleaje: la refracción se hubiese incrementado y hubiese resultado un esquema de acumulación litoral más complejo. Cuanto más complejo es este esquema, más cortas son las unidades de transporte litoral y, consecuentemente, más cortos son los grupos de crestones. Se ha identificado cinco fluctuaciones en estas islas: (1) un ascenso de 4-6 pies hace 2000 años, (2) un descenso de 3-5 pies hace 1500 años, (3) un ascenso de 2-3 pies hace 1100 años, (4) un descenso de alrededor de 2 pues hace 500 años y (5) un ascenso en los últimos 100 años. Esta recurrencia de 500 años es solamente aparente y refleja la precisión en la diferenciación de etapas de deposición por medio del análisis por carbono radiactivo de los fragmentos de conchas. Cada una de estas fluctuaciones se traduce en la generación de bermas. La arena proviene de la erosión de zonas costeras cercanas o de bermas preexistentes. Cada fluctuación cuenta con una fase inicial acumulativa seguida por una fase erosiva cuando el aporte desciende por debajo de la un umbral crítico. El descenso del aporte de arena se debe al agotamiento de la fuente de material y/o a un redireccionamiento del sistema de transporte.—*Department of Water Sciences, University of Cantabria, Santander, Spain.*