Barrier Island Accretion and Geomorphological Evolution of Keewaydin Island, Collier County, Florida

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INTRODUCTION

Barrier islands are dynamic systems formed by the interaction of wave, wind, and tidal energies that erode, transport, and deposit sediments (Leatherman, 1982). By absorbing the impact of high-energy marine processes, barrier islands reduce erosion of the mainland coast and provide shelter for sensitive coastal habitats. These landforms are vital to the maintenance of many ecosystems, including estuaries and lagoons that support a diverse array of marine flora and fauna. Keewaydin Island, Florida, located on the Gulf of Mexico, between Naples and Marco Island, is just one of many barrier islands that extend down Florida's west coast for about 300 km from Anclote Key in the north to Cape Romano in the south (Fig. 1) (Yale, 1997). This island forms the outermost barrier of the Rookery Bay National Estuarine Research Reserve (RBNERR), located northwest of the Ten Thousand Islands and the Everglades National Park. RBNERR protects one of the largest undisturbed mangrove estuaries in North America. It is therefore critical that we develop an understanding of the geomorphic dynamics of Keewaydin Island. The future growth or demise of this island may have important impacts on Rookery Bay's sensitive mangrove forests, and may also influence human developments on nearby Marco Island.

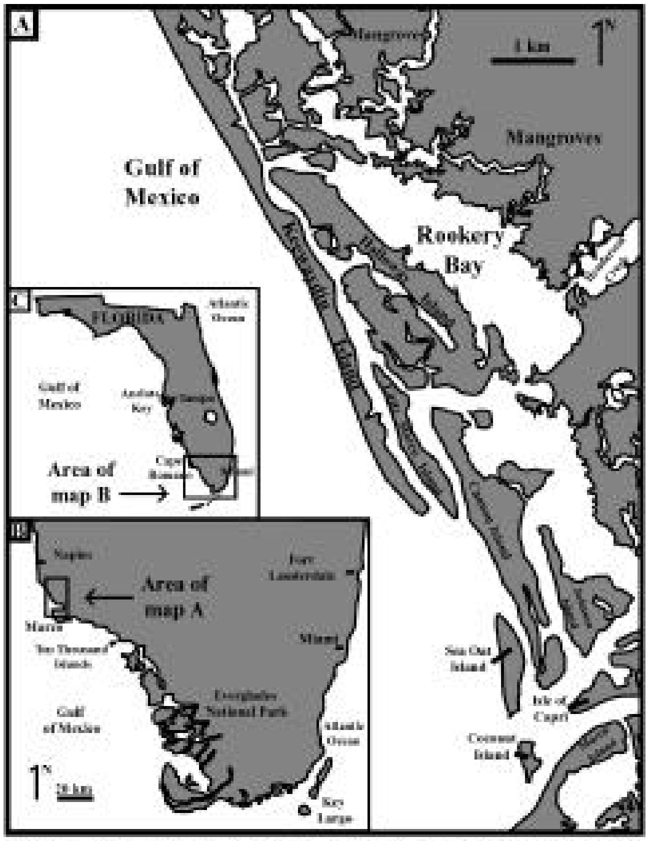


Figure 1. Map of Rookery Bay, Southwest Florida showing Keewaydin Island. (Ten Thousand Islands Fishing and Recreation Map, 1999).

GEOMORPHIC SETTING

Barrier islands are typically elongate, low-lying islands occurring in linear chains parallel to the coastline, with individual islands separated by tidal inlets. Fluctuating marine waters from waves, currents, and storm surges produce gradual changes in island morphology while high magnitude changes occur during major tropical depressions and hurricanes (Leatherman, 1982;

Pekala, 1996). Over a longer time scale, shoreline position, orientation, and length can be affected by variations in sea level, sediment supply, and wave energy (Pekala, 1996). Formation of these islands necessitates 1) an appropriate geomorphic setting, 2) an abundant supply of sediment, and 3) a suite of processes that develop and maintain them (Davis, 1994). A combination of low wave energy, low tidal range, and a wide, gently sloping inner shelf has produced a diverse system of barrier islands along the Gulf Coast of southwest Florida. Wave-dominated barriers originating from spit migration and upward-shoaling are present, a well as drumstick barriers typical of mixed energy settings (Randazzo and Jones, 1997).
Keewaydin Island is an example of a barrier spit, an elongate beach attached at one end to a source of sediment (mainland or large island) and extending into open water (Leatherman, 1982). These spits are formed as longshore currents move sand and gravel down drift. Continual movement of sand along the beach, as well as overwash and wind form an elongate barrier spit.

METHODS

Three principle techniques were used to investigate the process of island accretion: 1) evaluation of the island morphology through topographic profiles, 2) stratigraphic analysis of core samples, and 3) examination of historical aerial photography. This work focused on the area of active accretion near the island's southern tip (Fig. 2).

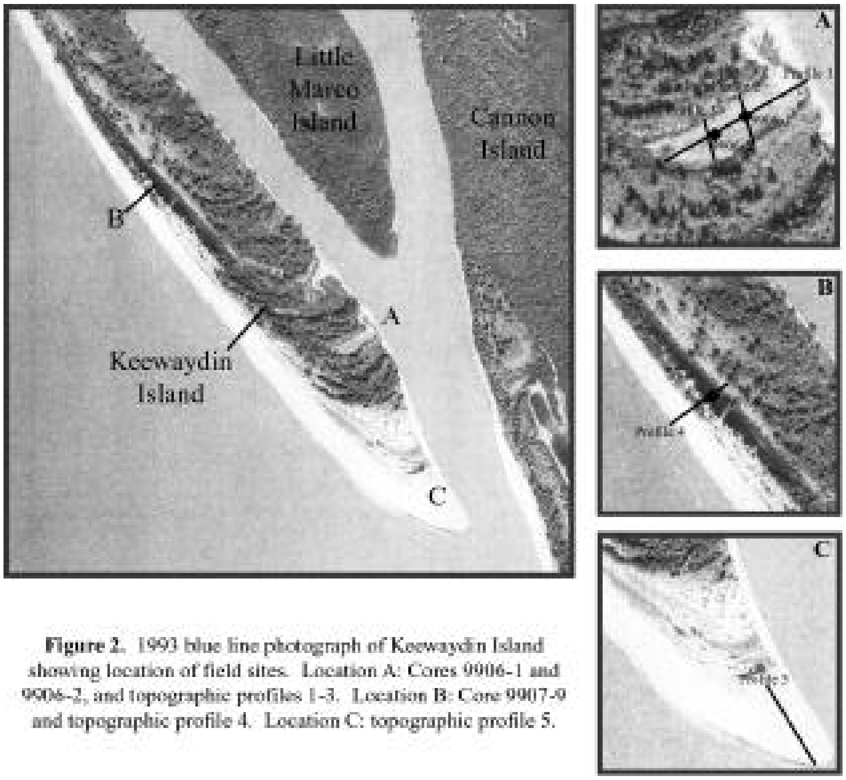
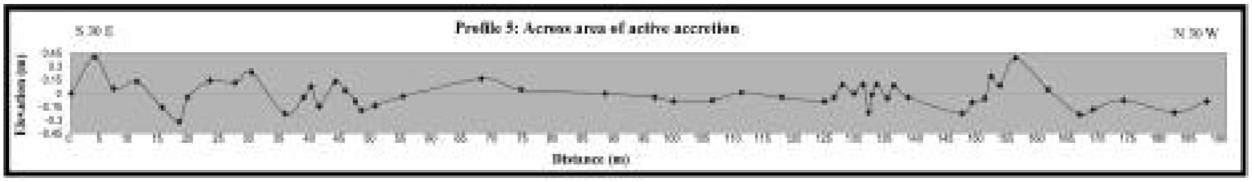


Figure 2. 1993 blue line photograph of Keewaydin Island showing location of field sites. Location A: Cores 9906-1 and 9906-2, and topographic profiles 1-3. Location B: Core 9907-9 and topographic profile 4. Location C: topographic profile 5.

Topographic Profiles. Topographic profiles were measured along five transects oriented both parallel and perpendicular to the island's axis. These profiles reflect the morphologic structure of the island. The sites include: A) a swale on the east side of the island open to tidal flux, B) a



longitudinal pond on the west side of the island closed to tidal influx, and C) a topographic profile across the area of active spit accretion (Figs. 2 and 3).

Core Samples and Stratigraphic Analysis. In conjunction with topographic profiles, core samples were taken at sites A and B (Fig. 2). Coring with two-meter long sections of three-inch diameter aluminum irrigation tubing retrieved a continuous record of near surface sediments. Using adjustable crossbars for leverage, the tube was rapidly pumped up and down to create liquefaction, facilitating sediment penetration. Once the tube was no longer able to penetrate the sediment, we recorded the length of unfilled tube that remained above the ground. This provided an indirect measurement of the depth of penetration. The core was then pulled out of the ground and immediately capped and taped at the bottom to prevent loss of sediment from the bottom. Another section of core was then inserted into the same hole and the same procedure was repeated until no new penetration would occur.

Each core section was cut down the length of both sides with an electric circular saw. The cores were carefully separated into two halves using a knife. One half of the core was immediately photographed for a pictoral log to aid in analysis and interpretation. A stratigraphic log of each core was then completed. Logs include a description of lithologies, grain size distributions, stratigraphic contacts, sedimentary structures, and percentage of shell fragments (Fig. 4).

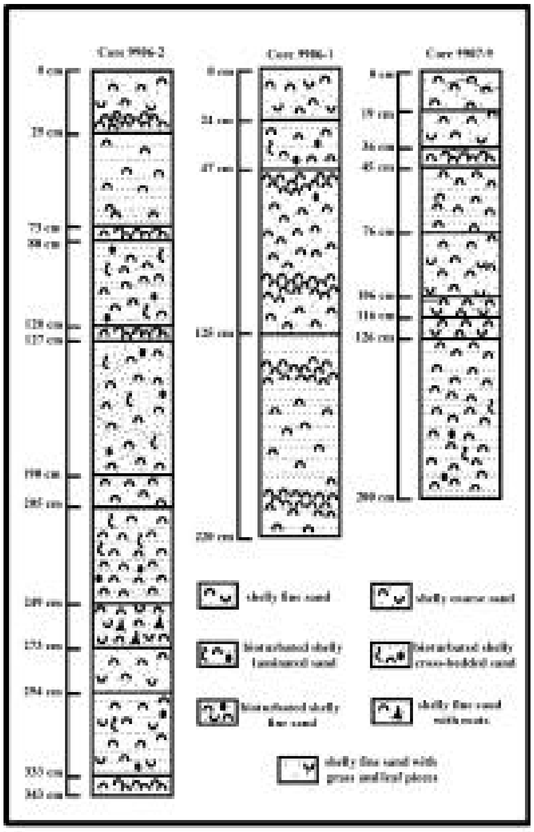
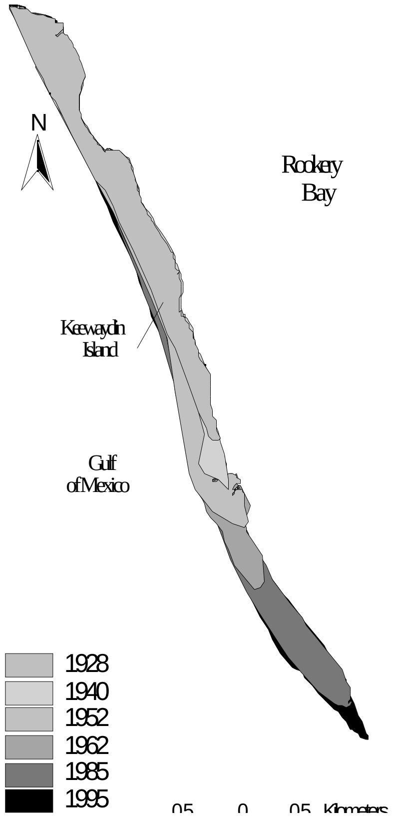


Figure 4. Stratigraphic columns produced from core and pictoral logs. Refer to Fig. 2 for core locations.

Aerial Photograph Analysis. The geomorphic evolution of Keewaydin Island is captured on a sequence of aerial photographs (1928-1995). Photographs of various scales and quality were obtained from RBNERR (1928, 1990, 1995), the Collier County Soil Conservation Service (1940, 1952, 1962), and Indiana University – Purdue University (1992). Blue line aerial photographs were obtained from the Collier County Property Appraisers Office (1975, 1981, 1985, 1989, 1993, 1996).

Due to spatial discrepancies caused by differences in altitude, tilt, focal length, and scale, the aerial photographs were rectified to a known geographic reference system (Leathem et al., 1998). Digital images were created by scanning each photo. These were then corrected using the orthorectification software ERDAS Imagine. Individual photos were rectified to the 1995 USGS Digital Raster Quadrangles provided by RBNERR. This technique necessitates the location of stable control points on both the base map and the air photo. All the photos for a specific year were then stitched together in a mosaic, which produced a complete rectified image for each year. These photo mosaics were then transferred to ArcView, a Geographic Information System (GIS) program, and analyzed to determine the longitudinal growth rate and area change of Keewaydin Island over time. In ArcView, shape files were created for each mosaic and these were then compiled into one document showing the spatial evolution of the island over time (Fig. 5). The changes in length and area of the island for each year were calculated and graphed (Fig. 6).



DISCUSSION AND CONCLUSIONS

Historical aerial photography shows that Keewaydin Island has undergone extensive coast-parallel progradation by way of spit migration. This growth occurs by curvilinear extension of successive sand-spit ribbons around the island tip. Field observations and topographic profiles show that the island’s geomorphology is dominated by alternating beach ridges and swales reflecting pulses of spit accretion (Figs. 2 and 3). These pulses may relate to an annual storm cycle. The ponded longitudinal swale on the seaward side of the island (Location B) may have formed as a result of a spit ribbon detaching from an adjacent or previously deposited beach ridge. Swales oriented perpendicular to the island on the lagoon side (Location A) are a result of curvilinear spit accretion around the island’s tip.

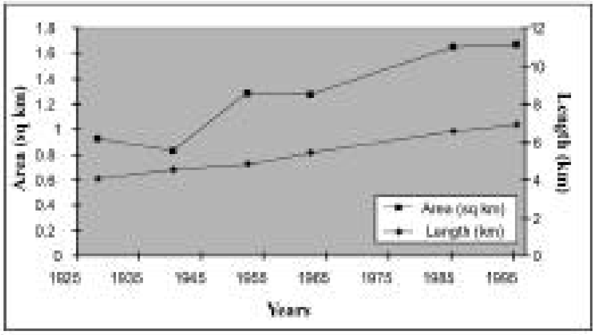


Figure 6. Growth of Keewaydin Island (1928-1996) measured below N2,881,233.45; E421,811.73. Total linear growth of the island ~2.84 km. Total area growth ~.75 (sq km).

The resulting stratigraphic columns provide a record of facies changes associated with barrier island evolution (Fig. 4). Core logs reveal alternating low-energy fine laminated sands and high-energy cross-bedded sands. The presence of unorganized shelly layers may indicate individual storm overwash events. The core logs also show layers with bioturbation and root traces indicative of aerobic conditions needed for marine organisms and periods of minimal sedimentation allowing for establishment of infaunal and plant communities. Rapid growth results in a dynamic succession of geomorphic environments and associated ecological habitats as the island marches southward (Tedesco, 1999).

Spatial analysis of aerial photo mosaics allowed for calculation of average rates of linear growth along the island axis (42.4 m/yr) and growth in total area above sea level (11,200 m^2/yr). While longitudinal coast-parallel growth of the island has progressed at a relatively constant rate through time, the aerial growth has occurred irregularly (Fig. 6). Periods of rapid aerial growth are followed by apparent periods of slow growth or decline that may correspond with the passage of major hurricanes (e.g. the Labor Day hurricane, 1935, and hurricanes Donna 1960 and Andrew 1992). This behavior may reflect the removal of sand to offshore storage during the high-energy storm events. During intervening periods of average wave energy this sediment is gradually returned to the island's longshore drift system. Hence, while hurricanes appear to have little influence on the longitudinal growth rate, they may have significant impacts on offshore/onshore sand movement.

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REFERENCES

Davis, Richard A., Jr., 1994, Other barrier systems of the world: geology of Holocene barrier island systems: New York, Springer-Verlag, p. 435-456.

Leathem, Sean P., Gelfenbaum, Guy, and Brooks, Gregg R., 1998, Photographic analysis of migration of transverse bars off of Anna Maria Island, FL, http://coastal.er.usgs.gov.

Leatherman, Stephen P., 1982, Barrier island handbook: Maryland, University of Maryland, 109 p.

Pekala, John M., 1996. Stratigraphy and geologic history of Anna Maria Island, Manatee County Florida: Master's Thesis, University of South Florida, Tampa, FL.

Randazzo, Anthony F., and Jones, Douglas S. (eds), 1997, The geology of Florida: Gainesville, University Press of Florida, 327 p.

Tedesco, Lenore P., 1999. An introduction to southwest Florida's natural environment: a guide to accompany the 1999 Florida Keck Geology Summer Research Program. (unpublished)

Yale, Kristin E., 1997. Regional stratigraphy and geologic history of barrier islands, west central coast of Florida: Master's Thesis, University of South Florida, Tampa, FL.