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CHANGE AT A SHOREFACE SUBMARINE SAND RIDGE

Michael Craghan
Department of Geography
Rutgers University
New Brunswick, N.J. 08903

ABSTRACT: Beach Haven Ridge is one of the ubiquitous ridge forms that exist on the Atlantic continental shelf. The origin of ridges is the subject of numerous hypotheses. It is unresolved what the forming mechanisms may be, or even if the ridges are relict or active features. Investigations at the ridge have determined that sediment sizes change systematically in relation to location. The most dramatic changes occur near the closed contour region of the ridge. Grain size is coarsest on the landward flank, and fines continuously up that flank, over the crest and down the seaward flank. Comparisons of bathymetry recorded in 1991 and 1994 have also shown a change in position of the ridge. The form is apparently moving seaward by erosion of the landward flank, and deposition on the seaward flank.

INTRODUCTION

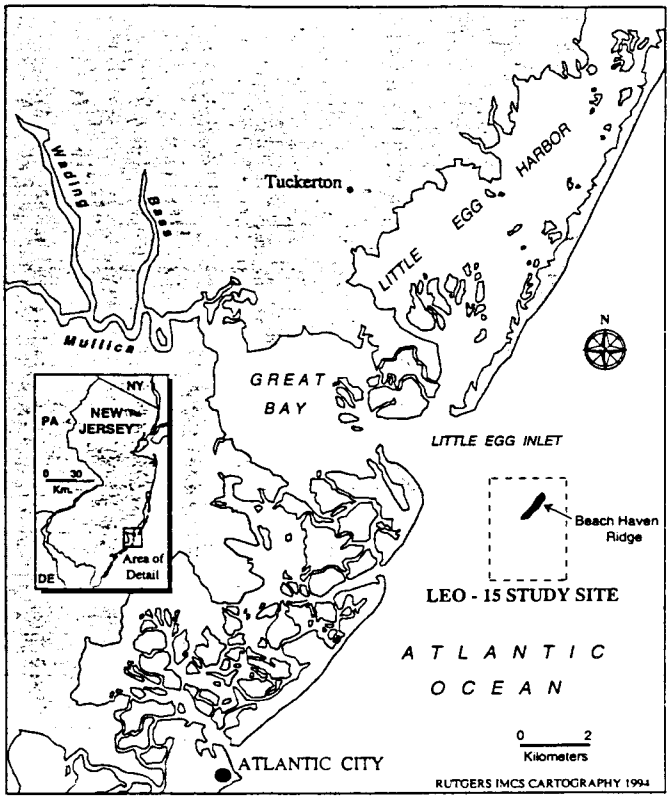
Beach Haven Ridge is a shoreface submarine sand ridge located about 3 kilometers offshore near Tuckerton, N.J. (See Fig. 1). Sand ridges are large scale bottom features on the continental shelf that exist from close to the shoreline out to the shelf edge. Beach Haven Ridge is roughly 1 km wide and several km long. The length of the lowest whole unit closed contour on the ridge is 4.8 km, although the ridge would be considered to be much longer than that. At its highest point there is approximately 6 m of relief to the neighboring seafloor.

Beach Haven Ridge is an element in a whole set of ubiquitous ridges on the Atlantic coasts of North and South America. (Duane et al., 1972; Swift et al., 1978; Hoogendoorn and Dalrymple, 1986; McBride and Moslow, 1991). Ridges exist off of Nova Scotia, and from Long Island south to Florida, as well as off the coasts of Brazil and Argentina. They are correlated with areas of plentiful sandy sediment and especially with inlet and barrier island environments (McBride and Moslow, 1991). Wherever they appear, the ridges exist at an oblique angle to the general shoreline trend. On the east coast of the North America all of the ridges "open" to the north. In the southern hemisphere, all of the ridges "open" to the south. The only exception to this is on the East-West trending Sable Island shelf where the ridges "open" to the west. That contrary pattern is attributed to the dominant storm systems which pass to the north of the island, as opposed to along the rest of North America where storms pass seaward of the shelf. (Hoogendoorn and Dalrymple, 1986)

The ridge is a component of a Rutgers University-NOAA/NURP research site known as LEO-15 (Long-term Ecosystem Observatory-15 meters deep). LEO-15 is a multidisciplinary research area where geographers, oceanographers, biologists, ecologists, and geologists are investigating the modern continental shelf. Eventually the facilities will include terminals on the seafloor capable of handling remotely operated vehicles equipped with special sensing equipment. These nodes will be connected by fiber optics to the Rutgers University Field Station in Tuckerton, and from there, real time data can be sent to the State Aquarium in Camden, the Liberty Science Center in Jersey City, and to the Rutgers Campus in New Brunswick. Current research at the site involves reproduction and

recruitment of surf clams, remote sensing of upwelling events, benthic organisms, and boundary layer sediment transport investigations, among other projects, in addition to the larger scale geomorphological study detailed in this paper.

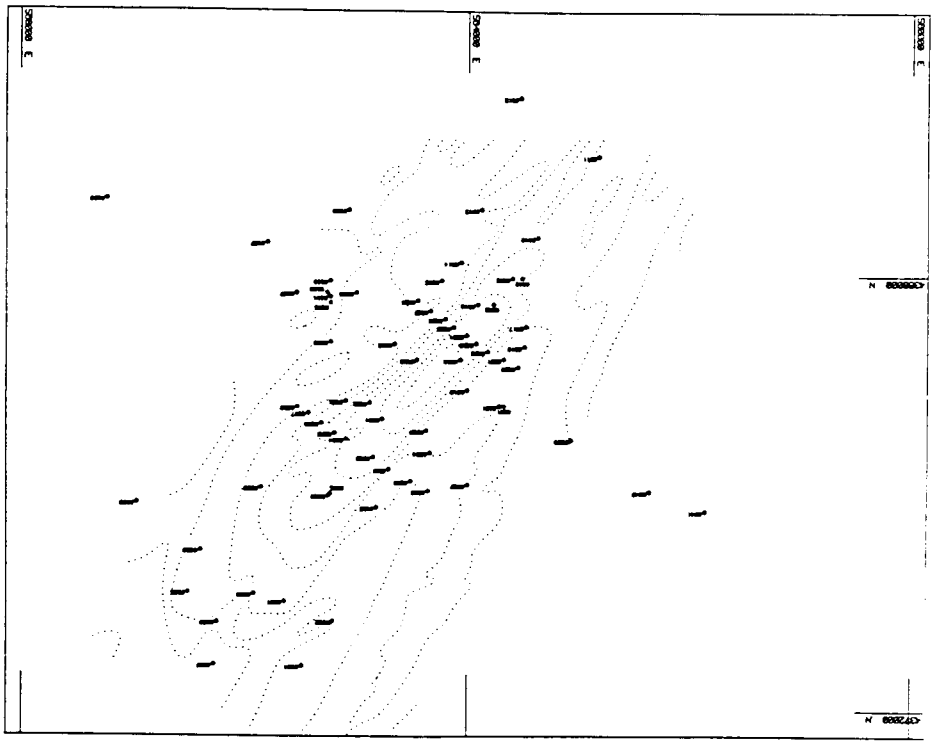
The objectives of this work at Beach Haven Ridge are: 1) Determine if there are any sediment based changes at the ridge; 2) Determine if there are dimensional or positional changes to the ridge; 3) Shed some light on the various origin hypotheses for continental shelf sand ridges; 4) Assess the consequences for humans if there are measurable changes; and 5) Provide support for the other researchers at LEO-15.



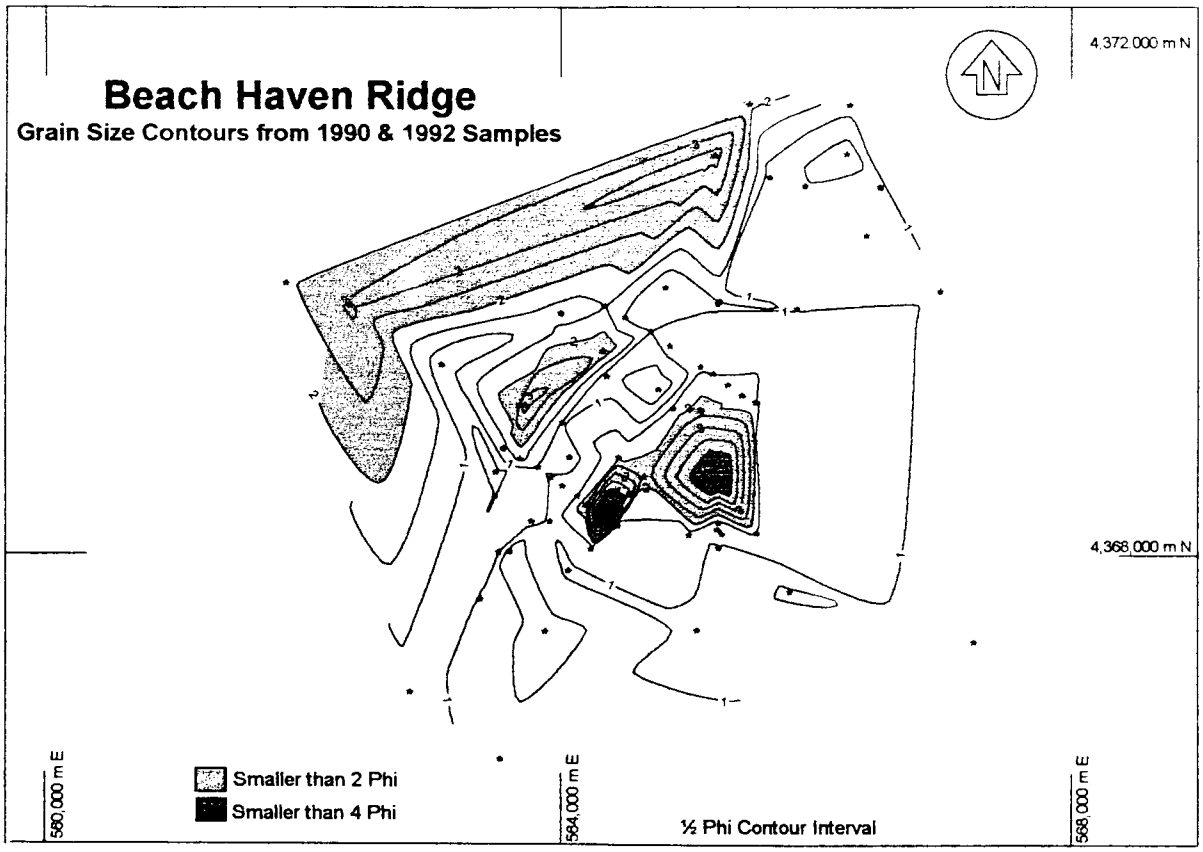
== Figure 1 ==

DISCUSSION

Almost all of the surficial sediment at Beach Haven Ridge is sand (i.e particles between 2 mm and 0.063 mm in size). Grain size analysis of 69 grab samples taken in 1990 and 1992 (See Fig. 2) revealed [illegible] sediment size trends that are related to the ridge form. Most of the samples' mean grain sizes are in the medium to coarse sand sizes (0-2 Phi). There are however three regions with finer grained material. To the west of the ridge area, there is an area of fine grained sediment, but mean sizes are still in the sand range. The other two areas of fine grained sediment are located adjacent to the closed contour area of the ridge. One is landward and one is seaward of this region. The closed contour area is the portion of the ridge that is so distinct from the seafloor that the ridge form has closed bathymetric contours. In other portions of the feature, the ridge is defined by deflections of the seafloor elevation contours. The fine grained zone that is landward of the closed contour area is in the area where the seafloor begins its transition from the gentle continental shelf slope into the landward flank of the ridge. This area is still sandy, but mean grain sizes are in fine and very fine sands. The fine grained zone that is seaward of the closed contour area is at the lower part of the seaward flank, where the ridge is transitioning back into the seafloor. This is the finest grained area of the ridge. It is also the only place where surface sediments have mean grain sizes in the silt ranges (See Fig. 3).



== Figure 2 ==

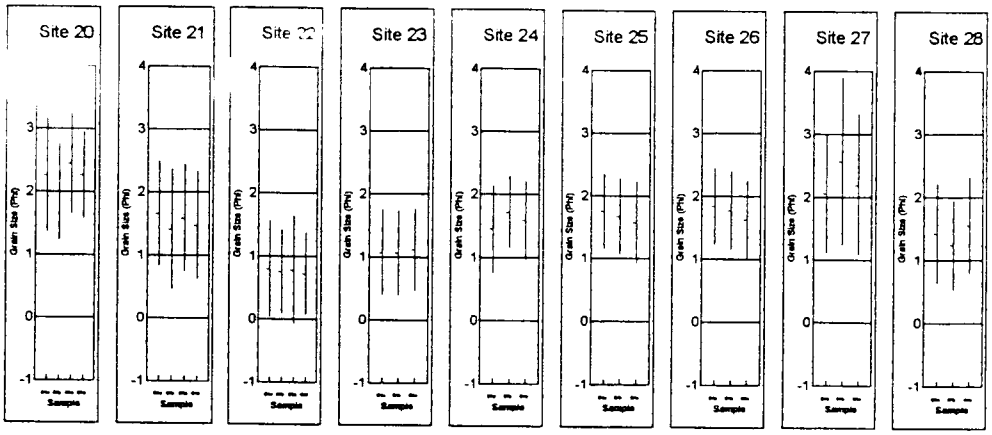


Pattern of mean grain size distribution at Beach Haven Ridge. Note that the areas of finest sediment are adjacent to the closed contour area of the ridge.

== Figure 3 ==

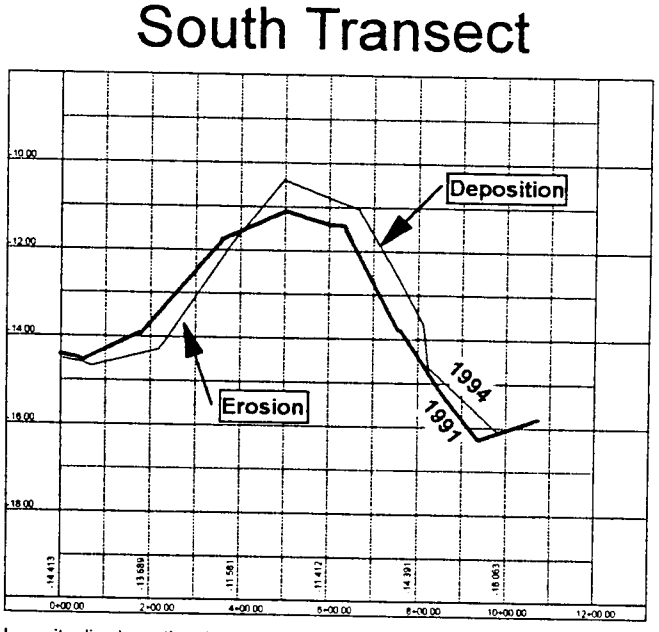
Grain size investigations found the same pattern of sediment distributions found by others working on similar features (Swift and Field, 1981; Stubblefield and Swift, 1981). In general, as one moves landward to seaward over the ridge crest, sediment sizes change systematically. Fine grain sediments are found in the trough before the ridge begins to rise, the coarsest sediments are found at the base of the landward flank, from that point mean grain sizes fine up the landward flank, and continue to fine over the crest and down the seaward flank, until the finest sediments are found at the base of the seaward flank (See Fig. 4). The most variability occurs in the closed contour area, which is the area where the ridge is the most distinct as a feature.

The systematic changes in grain size and, in particular, the distinct changes that occur in the closed contour area suggest that the ridge is reacting to modern continental shelf processes. It is possible that the ridge form may have changed either position or dimensions in response to the severe storm climate of the past three years. In 1991 USGS conducted an intensive investigation of Beach Haven Ridge using side scan sonar (Twichell and Able, 1993). As part of that study an extensive series of Latitude-Longitude-Depth points was collected. In 1994 USGS revisited the site and conducted a follow-up survey. Using the thousands of x,y,z coordinates from 1991 and 1994 it was possible to reconstruct the surface topography of the ridge area for each year. From each of the



Mean grain size along the southern ridge transect shown from landward to seaward Tick marks represent the mean grain size. Whiskers are +/- one standard deviation

== Figure 4 ==

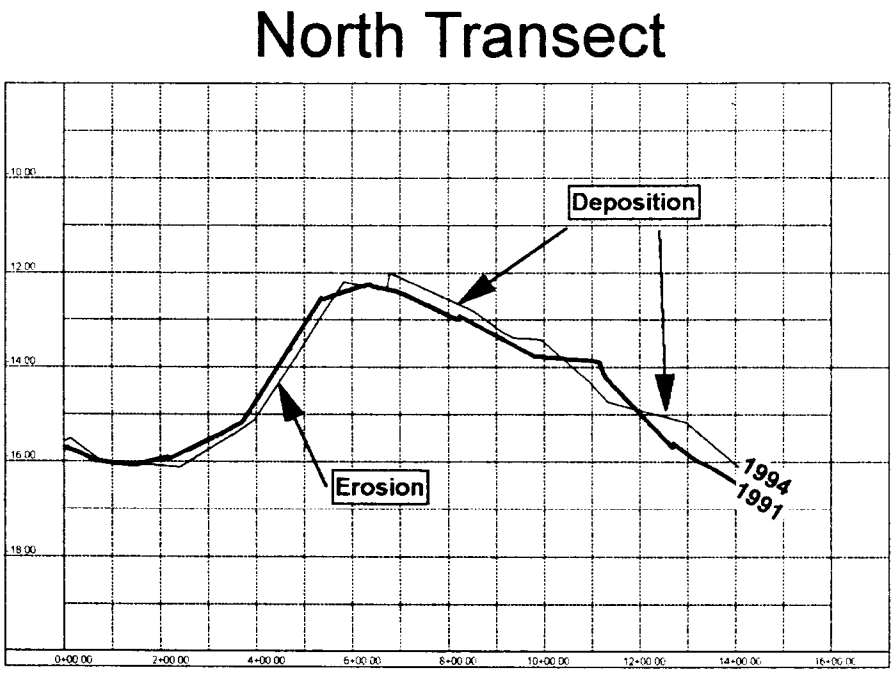


Longitudinal section between 0+00.00 (Site 20) and 10+73.43 (Site 28)

Overlay of 1991 and 1994 profiles from the south ridge transect. The ridge has shifted seaward (to the right) and has also increased in height.

== Figure 5 ==

sampling transects. When placed in horizontal register with each other the southern transect showed erosion of sediment from the landward side and deposition of sediment on the seaward flank. There is also an increase of height on the southern transect (See Fig. 5). When the two northern transects are overlaid, a similar pattern of erosion and deposition is also seen (See Fig. 6). These changes also suggest that the ridge is reacting to modern shelf processes.



Overlay of 1991 and 1994 profiles from the north ridge transect. The ridge has shifted seaward (to the right) by differential erosion and deposition on its flanks.

== Figure 6 ==

The origin of continental shelf sand ridges is still unsettled. There are a number of competing hypotheses. Long period waves propagating from beyond the edge of the continental shelf have been suggested (Boczar-Karakiewicz and Bona, 1986; Boczar-Karakiewicz et al., 1990; Boczar-Karakiewicz et al., 1991). Stubblefield proposes that ridges may be drowned barrier islands that have survived transgression (Stubblefield and Swift, 1981). McBride and Moslow (1991) have noted the high correlation of ridge forms to barrier island shorelines and inlet locations. They suggested that ridges are formed from ebb tide deltas as inlets migrate and barriers retreat. Swift and Field (1981) have suggested that ridges form in response to modern processes and mention shore parallel geostrophic flow caused by storm setup pressure gradients and the coriolis effect as a mechanism that may have

led to ridge formation. The Huthnance models for formation of tidal sand banks (Huthnance 1982a, 1982b) can be modified by using geostrophic flow as a substitute for the dominant tidal current to explain the presence of ridges.

CONCLUSION

The number of large storms within the past few years, the pattern of sediment distribution at the ridge, and the shift in horizontal location revealed by analyzing bathymetric data from 1991 and 1994 all suggest that the ridge is not a relict feature, but is instead reacting to modern processes on the continental shelf.

If the ridge is responding to modern continental shelf processes, then it is most supportive of Swift's geostrophic flow model for the origin of ridges. The long period wave ideas and the edge wave hypotheses do not account for the sediment distribution or dimension changes that have occurred at LEO-15. The idea that barrier islands survived sea level rise suggests that the ridges are relict features, whereas the data from Beach Haven Ridge suggests that they are active. McBride and Moslow's hypothesis is hampered by too many assumptions and also fails to explain the changes taking place at Beach Haven Ridge.

The ridge feature has a definite sedimentological pattern and moves as a feature. There are important implications for humans because of the proximity of these features to the shoreline, and because of proposed uses for them. Because they are near to the shoreline, engineering structures like outfall pipes or communications cables fall across ridge fields. Similarly, ridges have been used as a resource site of sand for beach nourishment processes (Anders and Hansen, 1990). This particular ridge was once the object of intense research in the early 1970's as a site on which to construct an offshore structure. Certainly if one is going to build an offshore nuclear power plant adjacent to a sand ridge, (EG&G, 1973) then it is good to know the ocean bottom is in a dynamic state.

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