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EDITORIAL

How does a Barrier Shoreface Respond to a Sea-Level Rise?

According to climatologists the Little Ice Age closed about 150-years ago, and since that time the average temperature of the world's atmosphere has increased owing to natural causes and to the anthropomorphic infusion of greenhouse gases into the atmosphere. Many scientists believe that global warming will continue well into this century. Tidal records collected from around the world and spanning the past few decades show that shorelines in many parts of the world, including the Atlantic and Gulf coasts of the United States, have been subjected to a relative sea-level rise. If global warming continues, it follows that sea level will continue to rise. Studies also show that 70% of the world's sandy shorelines have been eroding during the past few decades (BIRD, 1985) and that includes most of the Atlantic and Gulf barrier shores of the United States (DOLAN *et al.*, 1989). Coastal scientists are now faced with the responsibility of explaining to the public how various components of a barrier will react when subjected to a rise in sea level. Clearly all shores—rocky or sandy—will be inundated. But what else do we tell the public? I suspect that for most coastal scientists the answer is reasonably simple when the question is limited to the subaerial component of a barrier where the littoral drift is not being fed with river-transported sediment. As sea-level rises and the frequency of overwash increases, barriers transgress which means that beaches erode as they are displaced upward and landward. On the other hand when the question is directed to a barrier shoreface, *i.e.* the submarine component of a barrier shore, disagreement and uncertainty abound in the literature. Coastal scientists and engineers can not fully agree on what will happen to a barrier shoreface when subjected to a rise in sea level. In fact, we do not all accept the idea that a rise in sea level causes beach erosion. GALVIN (1990, 2000), based on his forty years of coastal engineering experience, concludes that there is no proof to support this idea. "No place on the sandy ocean shores of the world has been shown to be eroding because of sea level rise" (GALVIN, 1990, p. 32; *personal communication*, 2000). He believes that shorelines used as examples of where erosion has been attributed to a rising water level are in fact eroding because the littoral drift has been interrupted (GALVIN, 1990).

My intuition is that most coastal scientists, after having evaluated the evidence and the discussions in the literature, have concluded that sea-level rise in conjunction with wave action causes beach erosion along barrier shores where the littoral drift is not receiving fluvial sediment. On the other hand, the scientific view on what should happen to a barrier shoreface varies, and these varying views can be subdivided into three theories. First, in order to maintain a beach and shoreface profile at equilibrium in the face of a sea-level rise and with waves breaking closer to a fixed point on a mainland, BRUNN (1962) proposed that sediments must be eroded from a beach and upper shoreface, transported, and deposited on a lower shoreface in order to aggrade the bottom in direct portion to a rise in sea level (Figure 1). Deposition on a lower shoreface extends to the limited water depth of sediment transport, which is about 16–18 m for a hundred year time frame (BRUUN, 1988). This theory does not incorporate overwash as a viable geomorphic process capable of enhancing the rate of beach erosion. In addition a number of publications including SCOR (1991) and DUBOIS (1992) have raised concerns about the assumptions of Bruun's rule and the interpretation of evidence presented in support of the rule. The evidence in question stems from the results of small-scale wave basin experiments (SCHARTZ, 1965, 1967) and field studies (HANDS, E.B., 1976, 1979; ROSEN, 1978). Second, HOYT (1967) postulated that a shoreface transgresses along with the rest of the subaerial component of a barrier shore. In Figure 1 the node separating the zone of erosion from zone of deposition marks the base of a transgressing shoreface profile. Downwilling currents may sweep some shoreface materials seaward of the node (Figure 1) and deposit them on the inner continental shelf (SWIFT, 1975). This second theory does not consider the possibility of aggradation taking place along any part of a shoreface as it transgresses. The third theory combines parts of the first two theories. DUBOIS (1992, 1997) suggested that Bruun's rule might be correct when applied to a nearshore where the bottom slope is gentler than the adjacent shorerise slope. In order for a shore bottom to be elevated in direct proportion to a sea-level rise, the shore bottom must be part of a *self-regulating* system. Such a system may occur in the nearshore. For example, storm waves erode a beach and aggrade a nearshore bottom. Following a storm, swells erode a nearshore and rebuild a beach. However, during times of a water-level rise, not all nearshore sediments are redeposited on a beach; a sediment layer equal to the rise in water level remains on a nearshore bottom (DUBOIS, 1982). In Figure 1, the node is located at the base of the foreshore and the beginning of the nearshore. Beginning at the seaward edge of a nearshore and extending down to the beginning of a ramp, a shorerise profile should transgress along with the subaerial component of a barrier shore. Some sediment residing on the lower shorerise could be swept seaward by downwelling curents and deposited on a ramp, *i.e.* inner continental shelf.

So here we are, nearly 40 years after Brunn first proposed his theory. In my humble opinion, we have not progressed

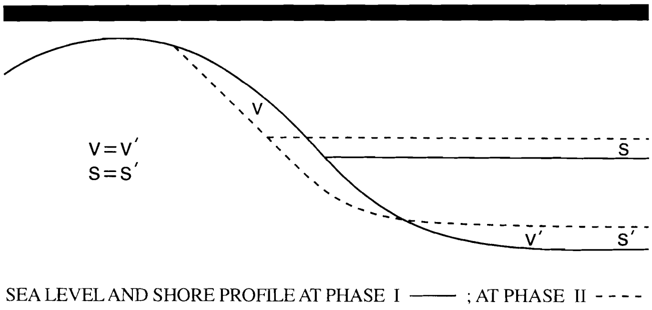

Figure 1. Bruun's rule implies that the sediment volume eroded from a beach and upper shoreface (V) must equal to the sediment volume deposited on the lower shoreface (V′) and that the lower shoreface aggrades in direct proportion (S′) to a rise in sea level (S).

very far. We do not know for sure how a barrier shoreface responds to a rise in sea level. And because of this lack of knowledge, we face two additional problems. First, we can not reasonably predict the rate of beach erosion caused by a given rate of sea-level rise. We have mathematical models (Bruun, 1962; Dubois, 1995) for making such predictions, but we do not know which one—if any—is correct because the assumptions of either model have never been validated. Second, we do not know if a sea-level rise alters the rate of longshore sediment transport. The results of computer models constructed by Berquist and Tanner (1974) suggest that an increase in water level causes the littoral drift to increase, but to the best of my knowledge these models have not been verified. Both of these unsolved problems stem from the simple fact we do not fully understand how a shoreface reacts when sea level is rising. By now we should have conducted controlled studies that would have clearly shown how a shoreface behaves when water-level rises, and from these experiments, we would have gained an understanding of why beach erosion takes place (if it does) and why the littoral drift increases (if it does). And if these changes did occur, we should have proceeded to construct mathematical models capable of reasonably predicting the rates of shoreline erosion and of the littoral drift caused by a given rate of water-level rise taking place in a known wave regime.

If experiments are not already in progress nor on drawing boards, then it is definitely time to begin work on a project that should have been completed years ago. For those who have access to a reasonably large wave basin, consider designing three-dimensional experiments to (1) test the theories that a water-level rise causes beach erosion and increases the rate of the littoral drift, and if the theories are correct, to (2) develop general mathematical models that predict the rate of beach erosion and the increased rate of the littoral drift for a given rate of water-level rise. The following is a very brief and over-simplified description of how three wave-basin experiments might be conducted. The first experiment is designed so that deep-water waves approach a shoreline at an oblique angle and that wave conditions periodically vary between a set of storm waves and a set of swells. Wave parameters within each wave set remain constant from one respective event to the next. The storm waves have dimensional properties that cause beach erosion while swells have wave properties that erode the nearshore and reconstruct the beach. The littoral drift is artificially maintained at a constant rate to prevent the shoreline from retrograding owing to a gradient in the littoral drift. Once a shore profile has achieved equilibrium when no progradation nor retrogradation is recorded from one swell event to the next, water level is made to rise by an amount greater than the largest particle size of beach sediment (Dubois, 1982). If the largest particle size is 0.5 mm, then water level might be increased by 5 mm. Runs of storm and swell events are continued until a beach is back in a equilibrium state from one swell event to the next. Comparing equilibrium profiles before and after a rise in water level should give us a first approximation of how a beach and shoreface respond to a water-level rise for a given texture of shore sediments and a constant set of storm wave and swell properties. This experiment could be repeated by changing the dimensions of one of the independent variables while holding the remaining conditions constant.

For a second experiment, the amount of sediment artificially added to the littoral drift is reduced while wave dimensions established for the first experiment are maintained. In this case once the shoreline is subjected to wave action, erosion should follow owing to a gradient in the littoral drift. With a rise in water level, the rate of shoreline erosion should increase. The second experiment would generally reflect the present day setting of a barrier island shore where river-transported sediment is not added to the littoral drift. When compared to the first experiment, the second experiment should yield a higher beach erosion rate for the same increase in water level. By comparing equilibrium shore profiles constructed by swells before and after a rise in water level, we should gain enough information to be able to formulate a kinematic model that can predict the rate of beach erosion for a rate of water-level rise. It will no doubt take additional research to make this model applicable to complex marine shoreface.

Finally for the third experiment, the amount of sediment added to the littoral drift is increased so that prior to a rise in water level progradation occurs from one swell event to the next. Water level is made to rise and swell profiles are compared. Whether the shoreline erodes may depend on the rate of the littoral drift. If enough sediment is added to the littoral drift, the shoreline should prograde in the face of rising water level.

If wave basins can not be adjusted to meet the aforementioned specifications or are unavailable, then perhaps the experiments could be conducted in a pond or a small lake where the cross-sectional symmetry of sandy shore, wave conditions, littoral drift, and water levels could be artificially controlled.

In conclusion, I believe that there is no other problem facing the community of coastal scientists that is as important as this one. Sea level is rising, sandy barrier shorelines are eroding, and we can not agree on an explanation that describes what is happening to a barrier shoreface. As coastal scientists we have a responsibility to the public and to ourselves to quickly resolve this problem. Hopefully, the results of controlled empirical studies will lead us to unite around one explanation of how a barrier shoreface responds when subjected to a sea-level rise. Of course once we solve this problem, then we face the other problem: How does a barrier shore respond to a sea-level fall?

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