Storm-built sand ridges on the Maryland inner shelf: a preliminary report

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ABSTRACT
Several aspects of the Maryland ridge field are pertinent to the problem of ridge genesis in response to Holocene sea-level rise. There is a systematic morphologic change from shoreface ridges through nearshore ridges to offshore ridges, which reflects the changing hydraulic regime. Grain size is 90° out of phase with topography, so that the coarsest sand lies between the axis of each trough and the adjacent seaward ridge crest, while the finest sand lies between each ridge crest and the axis of the adjacent seaward trough. Finally, analysis over a 43-year period on an outer ridge reveals a systematic pattern of landward flank erosion, seaward flank deposition, and seaward crest migration. These relationships support a model which explains the ridges as consequences of the up-current shift of maximum bottom shear stress with respect to the crests of initial bottom irregularities. The oblique orientation of the ridges with respect to the beach may be at least partly due to the more rapid migration rate of the ridges' inshore ends.

INTRODUCTION
Storm-built sand ridges occur on the Maryland inner continental shelf of the central and southern Atlantic Coast of North America [1], on the eastern Gulf of Mexico coast, on the coast of Buenos Aires Province, Argentina, and on the coast of the East Frisian Islands, North Sea, and probably on other coasts as well [1]. The ridges are up to 10 m high, with crestlines that extend for tens of kilometers. Earlier studies (summarized in [1]) have provided considerable circumstantial evidence, based on classical marine geology field techniques, that the ridges are responses to storm flow, and have provided some constraints that hydrodynamic models of ridge formation must meet. In this note, we present additional geological evidence from the Maryland inner shelf of North America. Our evidence provides further constraints for models of ridge formation and strongly supports one of the existing models. The definitive test of this model will require simultaneous quantitative observations of hydraulic process and substrate response, and remains to be undertaken. However, we believe that the data presented in this note will determine the experimental design for such a study.

Length measurements original to this paper are presented in meters. The National Ocean Survey map is presented in feet because of the excessive labor involved in recontouring the surveys on which it is based.

SAND RIDGE MORPHOLOGY, MARYLAND COAST
A smooth, concave-up shoreface extends from the breakpoint bar down to the inner shelf floor at 15 to 20 m. Slopes range from 1:20 at the bar crest to 1:2000 at the inner shelf floor. The inner shelf floor as far seaward as the 40-m isobath is an undulating surface characterized by sand ridges 2 to 6 km apart, making northward-opening angles of 17 to 35° with the shoreline. Side slopes are generally a degree or less, but relief ranges from 3 to 13 m. The ridges extend into the shoreface, where they locally retain their identity in water as shallow as 3 m.
In this area, morphologic parameters of sand ridges vary in continuous fashion from the shoreface across the inner shelf floor. However, for purposes of discussion, it is convenient to classify ridges as shoreface ridges, nearshore ridges, and offshore ridges. Shoreface ridges are seaward deflections of the contours that define the shoreface (Fig. 1). Nearshore and offshore ridges are designated by closed contours. Nearshore ridges are separated from offshore ridges by the 16-m isobath (50-ft isobath in Fig. 1).

The crestlines of the ridges rise to the southwest. On nearshore and offshore ridges, a "peak" or highest point occurs toward the southern end, after which the crestline drops abruptly to the general level of the shelf floor.

Shoreface ridges as a group are the most symmetrical. However, within this class, there is a tendency for the inshore ends of the ridges to have steeper landward flanks, and the offshore ends to have steeper seaward flanks. Seaward asymmetry increases to 1:2 for nearshore ridges and 1:5 for offshore ridges (Table 1).

Shoreface ridges have the steepest slopes (mean of 1.5°) and mean slopes decrease to 1.0° for nearshore ridges and 0.5° for offshore ridges. However, the southern ends of offshore ridges are locally quite steep (up to 7.0°). Length-to-width ratios decrease from shoreface to offshore ridges and the maximum cross-sectional area increases fivefold.

Both shoreface ridges and nearshore ridges tend to occur in clusters (complexes). They branch repeatedly from south to north, and branch ridges bear second-order ridges on their backs, giving them a "furrowed" appearance. Major swales between subridges tend to be asymmetrical, with steeper seaward than landward sides. In shoreface complexes swales between subridges are as deep as the shelf floor in either side,

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Shoreface Ridge (12 Ridges)</th>
<th>Nearshore Ridge (8 Ridges)</th>
<th>Offshore Ridge (15 Ridges)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Slope</td>
<td>1.5°</td>
<td>1.0°</td>
<td>0.5°</td>
</tr>
<tr>
<td>Steepest slope</td>
<td>2.5°</td>
<td>2.0°</td>
<td>7.0°</td>
</tr>
<tr>
<td>Mean asymmetry (landward slope; seaward slope)</td>
<td>1:1</td>
<td>1:2</td>
<td>1:5</td>
</tr>
<tr>
<td>Mean aspect ratio, (length:width)</td>
<td>9:1</td>
<td>6:1</td>
<td>3:1</td>
</tr>
<tr>
<td>Maximum cross-sectional area in m²</td>
<td>87 x 10</td>
<td>187 x 10</td>
<td>481 x 10</td>
</tr>
</tbody>
</table>