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Studies on swash marks and swash angles on texturally, tidally and morphodynamically-distinct beaches

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Abstract

This study evaluates the prospects of a new dimensional attribute of swash marks, herein referred to as swash angle, as a signature of wave-beach interaction. Results from three open Atlantic sea coasts of Nigeria indicate predominantly obtuse swash angle values. Mean swash angle values and the deviation from the mean tend to increase on beaches exhibiting fine grain sizes, elevated tidal ranges and high dissipative process signatures. The converse is the case on the microtidal, coarse-grained reflective beaches. From the obtained results and other published information, it is conceptualized that for a given beach, smaller swash angle mean and deviation would express the potential towards rapid beach mobility. On the contrary, relatively stable beaches typical of the dissipative state would reveal large swash angle and large deviation of the latter.

Introduction

Swash marks (Fig. 1) are seaward-concave, often intersecting microridges on sandy beaches formed in the course of wave swash traversing the beach face. The materials comprising the ridges are commonly a heterogenous combination of sand grains, mica flakes, shelly fragments, wood chips and other forms of organic debris.

The literature contains two mutually-exclusive sets of studies on wave swash phenomenon. The first category examines swash processes in relation to present-day beach and dune dynamics. This is exemplified by Kemp (1960), Waddell (1976), Wright (1981), Guza & Thorton (1982), Short & Hesp (1982) and Overton et al. (1987). In the second category are studies related to the characterization and geological significance of swash marks in environmental interpretation. The reports docu-

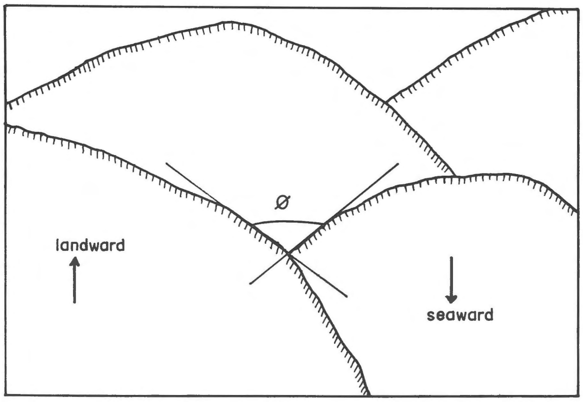

Fig. 1. Schematic diagram of swash marks showing swash angle Ø.

mented by Evans (1938), Emery & Gale (1951), Reineck & Singh (1973) and Sallenger (1981) are illuminating in this respect.

The objectives of this report are to further detail variability in swash mark characteristics from contrasting environments and, ultimately, to assess the prospects of a newly established swash mark characteristic called swash angle as a signature of recent beach dynamics.

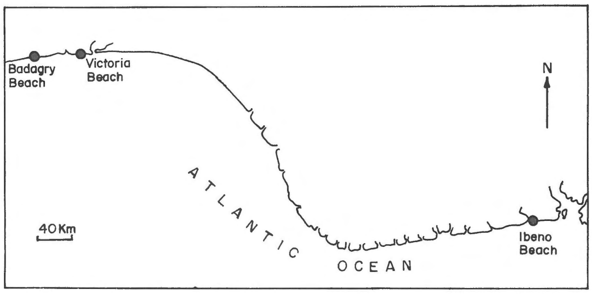

Fig. 2. Outline of the Nigerian coastline showing the locations of Badagry, Victoria and Ibeno Beaches.

Study sites and methods

Swash marks were studied at various times between December, 1984 and December, 1986 on 3 km segments of three Atlantic beaches fringing the Nigerian coast (Fig. 2). Detailed description of the Nigerian beaches, including their morphodynamic characteristics, are contained in Antia (1987a) and Antia & Nyong (1988). The morphodynamic beach states employed in this report are those of Wright & Short (1984). Their three principal beach states (dissipative, intermediate and reflective) are distinguished on the basis of the surf-scaling parameter, ε, of Guza & Inman (1975) and is derived from the relation:

$\varepsilon = H\,(2\pi/T)^2/g\,(\tan \emptyset)^2$ in which H is breaker height (m), T is wave period (seconds), g is acceleration due to gravity, and Ø is beach/surf zone gradient. The end member states, dissipative and reflective, are respectively attained at $\varepsilon > 33$ and $\varepsilon \leq 2.5$.

The relevant characteristics of the Atlantic beaches are as follows:

- Ibeno Beach: mesotidal; fine-grained (1.9–3.0 phi); flat beach face slope (< 8°); typically fluctuates between dissipative and intermediate beach states ($\varepsilon = 15$–55).
- Victoria Beach: microtidal; medium-grained (0.3–2.0 phi); steep beach face slope (7°–14°); varies between reflective and intermediate beach states ($\varepsilon = 0.5$–5).
- Badagry Beach: microtidal; coarse-grained (0.2–1.4 phi); steep beach face slope (8°–16°); generally reflective ($\varepsilon \leq 4$) beach state.

Concurrent measurements were made on swash mark characteristics and beach slope with the aid of a graduated staff, tape, clinometer and stop watch. Swash mark characteristics noted at each of the beaches were spacing (maximum distance between the edges of a single swash at the mid-tide level), length (maximum transhore swash excursion following wave-breaking at shore), swash period and swash angle. The latter, cited from Fig. 1, is the landward-facing angle formed between the tangents drawn along two adjacent swash lines through their point of intersection.

Results and discussion

The mesotidal, fine-grained beach of Ibeno revealed the largest spacing (2.5–6 m), highest period (4.2–13.5 s) and the longest excursion (13–32 m) of swash compared to the medium-coarse grained microtidal counterpart of Victoria and Badagry. Spacing, period and length of swash on these beaches were respectively in the 1.5–4 m, 5–8 s, and 5–6 m range.

The above pattern of variation of swash characteristics are in conformity with the report of Emery & Gale (1951). Because the beaches exhibit comparable wave energy level (moderate-high), disparities in the swash characteristics may relate to the tidal and textural attributes of the beaches. Accounts of Emery & Gale (1951) indicated in particular that the wave filtering effects and the degree of interference between swash and backwash is greater on gentler (fine-grained) beaches than on the steeper, coarse-grained counterpart.

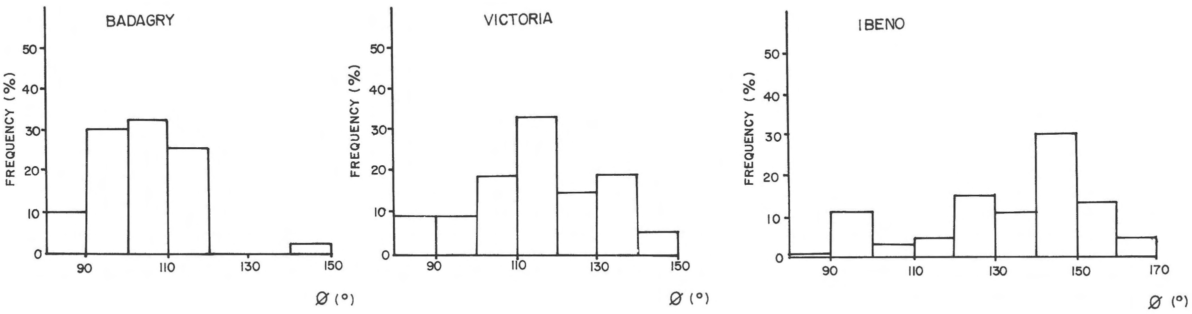

Fig. 3. Histogram of swash mark angles for Badagry, Victoria and Ibeno Beaches.

For the reasons above, swash period is often higher on the former; the swash period on steep beaches reveals a generally high correspondence with the wave period at sea because of negligible backwash-swash interference.

Over 90% of the 119 swash angle measurements made on the beaches revealed obtuse values. It is suggested that obtuse swash angle may be typical of exposed, open sea beaches.

The frequency distribution of swash angles on the beaches shown in Fig. 3 reveals increasing mean and standard deviation of swash angles with fining of beach sediments. The mean, standard deviation and range of swash angles on the beaches were respectively found to be as follows: Ibeno (132°; 21°; 70°–162°); Victoria (113°; 15°; 82°–140°) and Badagry (101°; 13°; 64°–140°). Regression analyses performed between swash angle and beach slope revealed no significant correlations. The coefficient of correlation, r, was − 0.08 at Ibeno, − 0.19 at Victoria and + 0.41 at Badagry.

Results shown in Fig. 3 suggest that the swash angle may serve as a rapid signature of the scale of beach dynamics. The mean and standard deviation of swash angles was found to increase with increasing dissipativeness of the beach. The morphodynamic beach model of Wright & Short (1984) predicts a higher stability of beaches in the dissipative domain. The latter is the end member state of an erosional sequence. On the contrary, the reflective state is more prone to erosion because the associated subharmonic oscillations enhance wave runup and subsequent berm cutting. Recent results of Antia & Nyong (1988) corroborate the above postulates.

Observations at Ibeno indicate, however, that this primarily non-reflective beach may, in the course of rising tide coupled with high breaker condition, temporarily depict reflective process signatures. This is because of the increased beach slope during elevated water condition. A combination of low tide and wave conditions would be less effective in this respect.

The effect of wave period on swash angle is such that the value increases, other variables being uniform, with the onset of short-period waves. This is because of accelerated beach water saturation and enhanced interference between backwash and successive swashes in comparison with long-period waves.

Conclusions

Besides confirming the validity of the previously cited studies on swash marks, this study has attempted to elucidate the potentials of swash angle in environmental interpretation. The close relationship between surf-scale reflectivity parameter and swash angle offers the unique opportunity for a rapid evaluation of morphodynamic beach changes on time-scales of a day or less. In essence, increasing mean and standard deviation of swash angle denote increasing beach dissipativeness. The converse is the case on reflective beaches.

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