The Role of Beach Profile Configuration in the Discrimination Between Differing Depositional Environments Affecting Coarse Clastic Beaches

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ABSTRACT


The role of beach profile configuration in facies modeling of coarse clastic (pebble) beaches is investigated because of the lack of primary sedimentary structures. Classification of 402 profiles gathered from two South Wales' beaches is undertaken using a graphical standardization procedure which gives rise to 10 morphological types. A one-dimensional expression is derived for each profile using the concepts of hypsographic curves and hypsometric integrals. The resulting 402 integrals are subjected to a non-parametric test which confirms that the methodology can distinguish between concave and linear profile macro-forms, both with and without berm development, at the 99.9% confidence level.

The importance of berm development and position in relation to differing nearshore depositional environments is indicated by previously published work. Use is made of this information in applying the above methodology to elucidate beach morphological changes on the two study beaches. A number of original graphical methods are used to identify patterns of morphological change. Although time-related stochastic modeling is not attempted on the data, the methodology is presented as the best means of deriving information for this purpose. As the beach profile provides a fingerprint of previous swash/backwash action, the development of a procedure sensitive enough to take account of berm formation means that an analytical tool is now available which can effectively discriminate between nearshore depositional environments, as a first step towards fuller textural analysis of facies type.

ADDITIONAL INDEX WORDS: Beach profile, berm development, clastic beach, facies modeling, graphical standardization procedure, littoral environment, nearshore depositional environment, South Wales

INTRODUCTION

Modern sedimentological study of littoral environments has centered on the need to identify relevant facies models from the arrangement of nearshore sediments. The first major attempt at facies modeling in a coarse clastic (pebble) beach environment was made by BLUCK (1967). BLUCK (1967) integrated beach processes with sedimentological response to establish facies defined by size/shape distributions, proposing two facies-type models based on incident wave energy (high/low). Since then only ORFORD (1975, 1978) has made substantial progress in this area. In testing BLUCK's thesis of gravel beach zonation, ORFORD (1978) confirmed BLUCK's basic zonal model, but disputed the depositional processes responsible for its formation. ORFORD (1978) observed both on-beach and off-beach sorting under a range of wave conditions. He proposed a three-category classification based on beach profile configuration.

Great potential for facies analysis lies in the area of sediment geometry, which ORFORD (1978) defined at four levels: (1) bulk properties, e.g. porosity, sorting, mean sizes, gross particle morphology; (2) individual particle geometry, which defines the bulk of the inertial qualities of a par-
ticle’s resistance to sediment motion; (3) grain surface characteristics revealed by SEM, and (4) the three-dimensional form of the sediment envelope. ORFORD (1978, p. 63) stressed this aspect of stating, “...beach morphology provides a control on facies type and facies development, such that the need to substantiate facies type by envelope morphology and beach position is crucial in facies analysis,” i.e. large stress is placed on the relationship between morphology and facies type, which is a basic tenet of this paper.

This last aspect is of great importance on coarse clastic beaches where there is a general absence of primary sedimentary structures. It can be related to two major factors of the depositional environment: (1) the hydraulic and energy characteristics prevailing across the swash zone, and (2) the initial morphology and structure of the beach surface.

These two factors are inter-related and changes in one or both can induce changes in the other. Therefore a study of either, or both, is fundamental to the elucidation of morphology and process conditions upon which facies models can be based.

With a study of 291 semi-diurnal sand beach profiles, SONU and van BEEK (1971) proposed a beach-profile transition model. This model was constructed in terms of beach width (S), sediment storage (Q), and surface configuration — a function of height (h), maximum values being subscripted $S_{\text{max}}$, $Q_{\text{max}}$, $h_{\text{max}}$ respectively.

Their basic premise was that the sediment volume contained under a particular profile was a stochastic function of past and present processes and past profiles; as SONU and YOUNG (1970) and SONU and DOLAN (1966). The approach involved the classification of swash zone profile configurations according to two key aspects: (1) the macro-form of the profile, or the shape of the smoothed swash zone trend of the profile (in this context it should be noted that unlike SONU and van BEEK (1971) and ALLEN (1975) who were concerned with sand profiles extending below mean low water springs, only the upper foreshore pebble ridge was investigated), and (2) the absence or presence and position of accretional berms on the macro-form.

According to SONU and van BEEK (1971), three smoothed swash zone profile types occurred: Concave upwards, linear, and convex upwards. The end members in this sequence defined minimum and maximum sediment storage states respectively. SONU and van BEEK (1971, p. 421) stressed the importance of berm position to profile sequence (upper, mid-beach, lower), arguing that this position was indicative of net accretion in the sub aerial profile, “...specific profile curvatures are produced by sediment distribution on the beach face.” They implied that the geometric properties of a beach profile were governed by the distribution of an excessive local sedimentary deposit known as the ‘berm.’

However, these investigations were unable to present a model which accurately distinguished between macro-profiles of a particular type, with and without berm development. In calculating equations in the $Q/S$ plane (SONU and van BEEK, 1971, Figure 5) for each of the three macro-profile types, they seemed to indicate that the development of a berm on any one of these configurations would extend the predictive range of the equation for that configuration. From a theoretical point of view, macro-profiles with berm development should occupy positions in the $Q/S$ plane quite distinctive from that occupied by the same macro-profile types without berm development. Nevertheless, this methodology represented a useful tool for facies analysis and highlighted the need for a rigorous classification approach.

**STUDY AREAS AND DATA ACQUISITION**

Figure 1A shows the location of two beaches along the Glamorgan Heritage Coast on which profile data was amassed between 10/11/77 and 1/4/80. Blue-grey upper Lias limestone forms both beaches, with pebbles of size $-2\Phi$ to $-8\Phi$ predominating. The beach at Nash is backed by a sheer cliff (Figure 1B), while that at Gileston is freestanding (Figure 1C). Nash faces southwest, and has a high energy wave regime; Gileston faces south and is in a low energy area. The dominant wind and waves come from the southwest, and spring tidal range is of the order of 11 m.

Fieldwork commenced in November 1977 when 4 cross-sections were selected at approximately 300 m intervals on each beach (Figures 1B, 1C). In these experiments, 6 temporary cross-sections located 20 m apart were surveyed daily so that a three-dimensional reconstruction of the beach face could be obtained. These studies produced another

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Figure 1 (facing page). Location of Nash and Gileston beaches (1A); Plan of Nash beach (1B); Plan of Gileston beach (1C).
180 profiles. All of these latter profiles were utilized in subsequent analysis because: (1) there were, on many occasions, significant configuration differences between them on any date, particularly in terms of the position and magnitude of berm development, and (2) the daily changes in high-tide level meant that only a proportion of the total cross-section was usually affected by wave action, and only this proportion, which often differed from cross-section, was used in the analysis. The profile data was fed into a DEC 20 computer and all subsequent graphical analysis accomplished with use of a Tektronix Graphics VDU.

**PROFILE CLASSIFICATION**

When an attempt was made to classify profiles according to SONT and van BEEK's (1971) procedure, the fact that beach profiles had $h_{\text{max}}$ values varying between 3-11 m, and $S_{\text{max}}$ values between 15-40 m, meant that an objective visual assessment was difficult. Therefore each individual profile was subjected to standardization based on trigonometric principles.

Figure 2 shows how profile coordinates were recalculated so that the upper beach limit touched the $h$ axis at a value of 5.290 m, and the lower beach limit touched the $S$ axis at a value of 30 m, while the geometric characteristics of the configuration were preserved.

Let $h_{\text{max}}$ and $h_{\text{max}}$ represent the original and recalculated points at which the upper beach limit of a profile touched the $h$ axis respectively, and $S_{\text{max}}$ and $S_{\text{max}}$ represent the original and recalculated points at which the lower limit touched the $S$ axis respec-
Table 1. Numbers of Profiles Resulting From Each of the Four Monitoring Experiments Which Fell Into the Ten Morphological Categories, and Key to Abbreviations Used in Various Figures.

<table>
<thead>
<tr>
<th>BEACH:</th>
<th>INTERVAL:</th>
<th>CCNB</th>
<th>CCUB</th>
<th>CCMB</th>
<th>CCUB</th>
<th>CCCB</th>
<th>LNB</th>
<th>LUB</th>
<th>LMB</th>
<th>LLB</th>
<th>LCB</th>
<th>TOTAL</th>
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<tr>
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<td>c. 2 weeks</td>
<td>30</td>
<td>9</td>
<td>45</td>
<td>0</td>
<td>10</td>
<td>1</td>
<td>0</td>
<td>8</td>
<td>1</td>
<td>0</td>
<td>104</td>
</tr>
<tr>
<td>NASH</td>
<td>c. 2 weeks</td>
<td>20</td>
<td>27</td>
<td>21</td>
<td>7</td>
<td>13</td>
<td>3</td>
<td>15</td>
<td>1</td>
<td>4</td>
<td>1</td>
<td>112</td>
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<tr>
<td>GILESTON</td>
<td>24 hours</td>
<td>32</td>
<td>20</td>
<td>5</td>
<td>3</td>
<td>6</td>
<td>18</td>
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<td>21</td>
<td>11</td>
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**CODE DEFINITION**

- **CCNB**: Concave, no berm.
- **CCUB**: Concave, upper berm.
- **CCMB**: Concave, mid-berm.
- **CCLB**: Concave, lower berm.
- **CCCB**: Concave, composite berm.
- **LNB**: Linear, no berm.
- **LUB**: Linear, upper berm.
- **LMB**: Linear, mid-berm.
- **LLB**: Linear, lower berm.
- **LCB**: Linear, composite berm.
- **K**: Concave, with berm.
- **L**: Linear, with berm.

respectively. Then if $\Phi$ represents the angle between the $S$ axis and the line drawn through the points $h_{\text{max}}$ and $S_{\text{max}}$, the recalculation of each coordinate on the profile ($h_j, S_j$) was undertaken thus:

$$h_j = h_{\text{max}} \left( \frac{S_{\text{max}} \tan \Phi}{h_{\text{max}}} \right)$$

$$S_j = S_{\text{max}} / S_{\text{max}}$$

where $S_{\text{max}}$ and $h_{\text{max}}$ were arbitrarily set at 30 m and 5.29 m respectively (thus the derivation of $\Phi = 10^\circ$). The selection of these values is relatively unimportant when using this methodology. They were chosen to produce profiles with proportions approximately equivalent to the unstandardized sizes. This aided visual assessment during classification. It was then easier to classify sizes objectively.

Table 1 shows how profiles were distributed between 10 configuration types, and it is evident that only concave and linear macro-forms were represented; a result in full agreement with ORFORD’s (1978) work. Similarly, composite berm forms were also observed which represented either ‘step and bar’ profiles formed according to processes proposed by ORFORD (1977), or (more likely) were configurations on which remained the ‘memory’ of previous berm positions together with a contemporary berm. That these profile types were relatively common (12% of total) is probably a function of the large tidal range in the Bristol Channel.

Of crucial significance in the classification procedure was the selection of that proportion of the profile to be examined. For data which was gathered each spring tide, this proportion was considered to be that lying between the ridge crest and its base on the foreshore platform. This presupposed that the whole proportion of the beach face along all 8 cross-sections came under the influence of the waves between each spring tide cycle. The
visual evidence suggested that such an assumption could not always be made (particularly on Gileston beach), but since it had not been possible to keep an exact record of high-tide position prior to surveying, the assumption was nevertheless made. This matter was taken into account when interpreting the results. However, the problem did not arise with data gathered on a daily basis (except for 1 day) since an accurate record was kept of pre-survey high-tide position. Therefore only that proportion of beach which came under the influence of waves during the intervening 24 hour period was examined.

Because of the high porosity of the beach material, swash forces are able to predominate over those of the backwash on pebble beaches (ZENKOVICH, 1967), and material is pushed landwards to rest at a steep angle ($\beta$) where $\beta$ is less than the maximum angle of repose $\theta$.

Ignoring the complications of grain shape and imbrication, the angle $\beta$ for any grade of material at a specific beach position is that at which the force due to gravity ($g$) acting on the material exactly balances net swash forces predominating at that position. The loss of backwash as a result of percolation means that the swash/backwash relative force is greatest in the uppermost zone of wave uprush and the value falls rapidly seawards of this region. For this reason beaches made up of coarse clastic material are more likely to be concave upward in configuration than for example medium sand sized beaches. However, on either beach slope the steepest beach face angle ($\beta$) is observed just below the beach crest (Caldwell, 1982).

Although those profiles which included the beach crest were more likely to be concave in configuration, selected sections of the lower beach portion of other profiles were almost equally likely to fall into either the concave or linear categories. In fact $81\%$ of the 216 profiles gathered at spring tide intervals fell into concave categories, while only $51\%$ of the selected portions of the 186 profiles gathered on a daily basis fell into these categories. This again stressed the care with which any interpretation of results had to be made.

Figure 3 substantiates the accuracy with which profile classification was made. All standardized profiles in each of the ten configuration type categories were used to compute an 'average profile.' Each of these average profiles is plotted in Figure 3 alongside the idealized model for that category with vertical exaggeration.

Standard deviations each side of these average profiles are also shown at 1 m intervals. For all ten categories the agreement with the idealized model is excellent and shows the effectiveness of using a standardized visual format for classification.

**STATISTICAL ANALYSIS**

Profile classification groupings (Table 1) were statistically tested for between-group heterogeneity. ORFORD (1978) in the only previous attempt to classify pebble beach profile configuration, failed to produce significant statistical evidence of the heterogeneity of profile populations in specific categories. He put this down to the fact that "...the ratio of berm material volume to beach material is only small to negligible" on pebble beaches (ORFORD, 1978, p. 309); a matter which the present authors dispute. ORFORD (1978) computed regression lines in the Q/S plane (along the lines proposed by SONU and van BEEK, 1971), and attempted to isolate...
significant differences for the $\beta$ estimates of these lines. He found none and had to subjectively reclassify his profiles as step, bar, and composite (ORFORD, 1978, Figure 10.4) as the basis for his facies model.

Initial $h_{\text{max}}$ and $S_{\text{max}}$ values will determine where resulting $Q$ values will lie in the $Q/S$ plane, and this can make direct comparison between different beach profile data difficult. A method was needed which made profiles independent of their $h_{\text{max}}$ and $S_{\text{max}}$ values. This was accomplished by making use of the concepts of hypsographic curves and hypsometric integrals. Each profile was considered to represent a hypsographic curve from which a hypsometric integral could be derived. The integral was represented by the area of the square of which the $h$ and $S$ axes formed two sides. The integral was expressed as a value between 0 and 1. This value could be derived from the profiles at any time, although it was more easily obtained after graphical standardization when every profile had the same $h_{\text{max}}$ and $S_{\text{max}}$ values. The integral represented a one-dimensional description of the profile configuration.

Figure 4 shows how the integrals for each profile were plotted to identify possible differences between the populations of profiles in each category. The numbers 1 to 10 refer to configuration types A to J shown in Figure 3, while 11 and 12 represent all concave and linear-type profiles containing a berm in any position respectively. In order to establish statistically significant differences between these 12 populations of integrals, an $F$-test was first used to determine equality of variances, and therefore whether a parametric or non-parametric test would be appropriate. It indicated that the assumption of equality of variances could not be guaranteed, although $F$ values often lay close to the borderline of acceptance or rejection. This is explained by re-
ference to Figure 5 which shows how the frequency distributions of the 12 populations often approximated the normal.

Nevertheless, a non-parametric test (the Mann-Whitney U Test) was chosen for testing statistical difference between: (1) concave profiles without a berm and concave profiles with berm(s); (2) linear profiles without a berm and linear profiles with berm(s), and (3) concave profiles with and without berm(s) and linear profiles with and without berm(s).

![Figure 6. Results of Mann-Whitney U Test on Configuration Group Integrals. (Abbreviations CCNB, CCUB etc. refer to configuration types indicated in the key to Table 1. A black circle indicates a significant difference between two populations of integrals as p \leq 0.001. A white circle indicates p \leq 0.01. Key results have been emphasised within a square.]

Key differences are indicated in Figure 6, and were all established at p \leq 0.001 which underlined the effectiveness of the classification. This was therefore strong and convincing evidence that profile morphology could be used to distinguish between facies types provided that evidence was available to explain the genesis of different profile morphologies in depositional terms.

GENETIC IMPLICATIONS OF DIFFERENT PROFILE CONFIGURATIONS

SONU and van BEEK (1971) identified a cyclic transition model which restricted erosion and deposition pathways through certain profile configurations associated with particular wave directions. It is difficult to identify relationships between concave or linear macro-forms and specific wave processes, but the presence or absence of a berm, and its relative position, could be of crucial importance in process categorization, and several authors have linked berm development to nearshore wave conditions. KOMAR (1976) utilized the term 'swell profile' for summer fill, and 'storm profile' for winter cut. KEMP (1961) observed berm-like features developed at the upper and lower beach limits in swell and storm profiles. LEWIS (1931) noticed that beach profiles with an upper berm (step) usually developed due to swell waves, while profiles with lower berms (bars) were formed during storms. However, the lower beach berm (or bar) can become stranded in an ebb tidal cycle because it migrates with tidal translation until reaching the toe of a pebble beach. Its seaward face can then become steepened by spilling breakers giving rise to a major break of slope at the toe. As this appears analogous to a swash reach berm it can create problems in profile type assessment (ORFORD, 1978).

Considerable laboratory and fieldwork has gone into assessing genetic implications of the step/bar profile model. RECTOR (1954), KEMP (1961), IWAGAKI and NODA (1962), SUNAMURA and HORIKAWA (1974) and ORFORD (1978) were all concerned with associating different breaker types with particular profile configurations. Their results show some inconsistency. ORFORD (1977) attempted to establish a logical framework for a facies model by estimating upper and lower breaker steepness boundaries, and using them to test the possibility of associating step and bar profiles with specific ranges of breaker steepness for given shoaling slope angles. This represented a considerable advance because it sought to explain profile morphology and facies type in terms of nearshore wave characteristics.

OBSERVED PEBBLE BEACH MORPHOLOGICAL CHANGES

Having evolved a definitive methodology for the classification of profile configuration, tested its statistical significance and provided some genetic evidence to support its role in facies modelling, this procedure was used to provide information about the morphological changes observed on Gileston and Nash beaches. In order to identify possible patterns in the morphological behavior of the 20 cross-sections monitored, the data were presented in
three forms: (1) three-dimensional diagrams (Figures 7A, 7B, 8A, and 8B); (2) pattern matrices showing the occurrences of the ten configuration types (Figures 9A and 9B), and (3) Morphological time-history diagrams (Figures 10A, 10B, 10C, and 10D). Symbols have been used to represent changes in berm position where they occurred, and these are explained in the key.

Figure 7. Three-dimensional time-lapse record of (7A) cross-section 2 on Gileston beach between 10/11/77 and 19/10/78; the time interval between each profile was approximately two weeks. Three-dimensional reconstruction of (7B) the beach face at Gileston around cross-section 4 on 8/2/80. The six temporary cross-sections are shown, and these were numbered from 1 to 6 starting at the nearest.

A. Gileston Beach

Figure 7A represents a time lapse record of morphological changes observed along beach cross-section 2 (Figure 1C). The time interval between each measured profile is the spring-neap-spring tidal cycle between 10/11/77 and 19/10/78. Two main phases were identified on this beach during the monitoring period: (1) between 10/11/77 and 9/2/78, when a concave profile with no berm development was characteristic of this beach, and (2) between 28/2/78 and 19/10/78, when the general configuration changed to one of concave, mid-berm and concave composite berm for cross-section 1. Cross-section 2 maintained a mid-beach berm (Figure 9A) but showed cyclic linear and concave macro-forms (Figure 10A). Further evidence from the other 2 cross-sections on this beach indicated that the overall morphology was one in which a mid-beach berm developed at around 6.5 m O.D. (Figures 7A and 9A).

With only one exception, 103 profiles showed either no berm development (N = 30), or gave rise to a mid and/or upper beach berm (step profile). The vast majority had concave macro-profiles. Where linear configurations were developed (N = 10) they represented generalized accumulations over the lower beach area. The beach morphology showed stable phases during the generalized ‘winter’ and ‘summer’ seasons.
Figure 9. Pattern matrices for (9A) 'concave, mid-berm' (CCMB) constructed from Gileston beach profile data collected between 10/11/77 and 19/10/78; and (9B) 'concave, upper berm' (CCUB) constructed from Nash beach profile data collected between 11/11/77 and 20/10/78.

When the beach around cross-section 4 (Figure 1C) was examined in detail during a spring-neap-spring tidal cycle (between 2/2/80 and 18/2/80), the 6 temporarily established cross-sections (located approximately 20 m apart) showed little consistency in their configurations on any date. This was probably a result of the low wave-energy levels and lack of any wind/wave pattern observed during the monitoring period. Figure 7B shows a three-dimensional reconstruction of the beach face plotted by using the 6 profiles recorded for 8/2/80. It shows how over even a small area of beach face, profile configuration can vary considerably. Figure 10B shows the morphological time history of temporary cross-section 2 during the monitoring period.

B. Nash Beach

A greater variety of berm positions occurred on this beach, a concave macro-profile dominated with only 24 out of 112 profiles falling into the linear category. There was an overwhelming tendency for beach morphology to have changed between suc cessive survey dates both in terms of the existence and position of beach berms (Figures 8A, 9B, and 10C), making it impossible to characterize beach morphological development along the same lines as at Gileston. This was as a result of: (1) its position in a high energy environment; (2) the fact that the beach is restrained by a cliff-line (Figure 1B) so that it cannot migrate inland (as in the case of Gileston beach) to a position at which increased shoaling distance decreases the level of breaking wave energy levels, and (3) the fact that it is both backed and underlain by an impervious surface which enables water-table levels to rise and thus increase the relative effectiveness of backwash under certain conditions. This is in contrast to Gileston beach which...
allows sea water to drain landwards during spring high-tide phases.

When the beach around cross-section 4 (Figure 1B) was examined in detail during a spring-neap-spring tidal cycle (between 18/3/80 and 1/4/80), the 6 temporarily established cross-sections showed more consistency in terms of shared configurations on any one date. There were several distinct phases observed during the monitoring period. Figure 8B represents a time lapse record of temporary cross-section 4, in which the time interval is 24 hours. Figure 10D provides information about the morphological time-history of the same profile.

These figures exemplify the morphological phase changes from (i) lower beach or no berm development, to (ii) mid-beach accreting berm development during the second half of the tidal cycle (recorded as upper beach berm in Figure 10D because only that portion which has come under the influence of waves was examined), to (iii) storm (bar) configuration on 29/3/80, and finally to (iv) accreting upper beach berm conditions at the end of the cycle. All these changes could be clearly related to changes in the wind and wave field characteristics.

**C. Summary of Field Observations**

Despite the clarity afforded by the classification procedure, results were often complex and lacking any obvious pattern. It was notable that at certain times specific morphological changes could be observed concurrently at a number of beach positions. It was remarkable, however, that at other times even the temporary cross-sections located no more than 20 m apart, showed considerable morphological differences. This underlines the difficulty with which generalized facies models may be applied for a given set of littoral conditions, for it was apparent that localized variations in swash zone hydraulics and/or initial profile morphology and sediment characteristics could give rise to a variety of ultimate beach configurations.

This observation represents a warning against too liberal a spatial interpretation of facies models constructed from individual cross-sectional data (ORFORD, 1978).

**CONCLUSIONS**

Beach facies modeling requires an approach which takes account of the stochastic nature of beach change. One crucial facies attribute which can be used in the resolution of a facies model for coarse clastic (shingle, gravel, pebble) beaches is that of the profile configuration. This characteristic is by its very nature a stochastic phenomenon, as well as providing evidence of changes which form a first-order, non-stationary Markovian process, in the sense that the resulting configuration is partly a function of the preceding profile. This has enabled both theoretical and numerical modeling to be undertaken using this parameter (SONU and YOUNG, 1970; SONU and JAMES, 1973; ORFORD, 1978). While no attempt has been made here to model beach profiles along these lines (because of the relative short sequence of the profile transition pathway, and the fact that the majority of profiles were not gathered in strict semi-diurnal sequence), the proposed methodology represents the best means of providing profile data for this type of statistical modeling.

Using SONU and van BEEK's (1971) approach, initially developed for a micro-tidal sand beach environment, a successful classification system has been established to investigate pebble beach morphological changes. This system distinguishes between different profile configurations with a resolution that has proved significant at \( p \leq 0.001 \). A number of refinements have been made to the original model which should enable a more widespread use to be made of its potential. These are: (1) graphical standardization of profile configuration (Figure 2) which overcomes problems caused by the variance in \( h_{\text{max}} \) and \( S_{\text{max}} \) values for different profiles on different beaches. Such changes are commonplace as a result of tidal and inter or intra-beach variations, and their removal means that a more accurate visual classification can be made on a standardized format, (2) adaption of the concepts of hypsographic curves and hypsometric integrals to beach profiles such that the integral (which is expressed as the area under the curve in proportion to the area of the square of which the h and S axes form two sides), represents a one-dimensional description of the beach configuration and always lies between 0 and 1 (Figure 4), (3) derivation of a 10 category classification system (Figure 3) of particular relevance to the study of coarse clastic beaches, and (4) statistical proof that not only the profile macro-form (concave, linear, and convex), but also the existence or non-existence of a berm can be distinguished in terms of beach sediment storage by using the integral approach (Figure 6 and Table 1).
Evidence strongly suggests that berm development and position can be related to particular swash zone depositional processes. Actual quantitative description of these processes has proved difficult because of the complexity of the hydraulic forces operating in this zone, but the beach profile is shown to provide a fingerprint of previous swash/backwash action. In this sense it can be used as a means of discriminating between the occurrence of different depositional environments and therefore as a tool in the elucidation of differing facies types.

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LITERATURE CITED