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Coastal fieldwork: case study of a particular beach in the UK

Waves are packets of energy that impact upon the coastal environment. Beaches stop these waves and absorb their energy. This is a continual process as the twice-daily rhythm of the tides takes the waves higher or lower on to the beaches. Wave energy is diffused over the vast surface area of the sand grains and sediment which make up a beach. However, bigger waves require greater surface area than smaller waves, whilst larger sediment grains dissipate more energy than smaller grains. Waves are always trying to achieve an equilibrium beach, but due to the rapidly changing environmental conditions the result is dynamic equilibrium. Consequently beach material is rearranged twice each day, leading to significant spatial and temporal changes between high and low water marks and between different beaches. This makes the coastal environment and beaches ideal for investigating the dynamism of physical processes.

Fieldwork alternatives are to investigate a number of different beaches on the same day to analyse spatial variation under the same environmental conditions or to investigate the spatial changes along one particular beach over a period of time, such as a month or a season. Consequently we need to know about:

a) the shape of the beach being studied – beach morphology
b) the sediments on the beach
c) the amount of energy hitting the beach
d) the processes by which sand and other beach materials are being moved.

Beach morphology

A line of transect should be selected from either the top or the base of the cliff to low water mark, as far as safety permits. The height of the cliff can be obtained by geometry (Figure 1a). The beach can be surveyed best using ranging poles, string and a spirit level measuring the rise or fall in millimeters. This should be done over distances of 2 to 10 metres, depending on the obvious surface changes of the beach (Figure 1b). General comments about the morphology of the beach can be added to a recording sheet (Figure 2) for later use when the transect is drawn to scale as a beach profile. The transect is a means of sampling and studying.

Beach sediments

The sorting of sediments on beaches seems to be largely a function of the size and shape of the sediments, because it is these two properties which influence the settling velocity of sediments. This is particularly relevant to pebbles and the ease of rolling of sediments is especially obvious with pebbles in the backwash. The size, shape and sorting characteristics of beach sediments vary according to wave energy conditions, coastline shape and orientation, particle lithology, longshore drift movements and other variables that are rarely constant at one location. Individual particles suffer progressive changes in size and shape due to processes such as abrasion and attrition as they are bumped together by the swash and backwash and solution. It is a case where 'form' may throw light on a process or processes, operating now or in the past. This study relates to processes operating at the time of the survey or at the most only a few weeks prior to it. It is also a study designed to emphasise the critical value of sampling large natural populations in order to identify a pattern of correlation.

Figure 1a: How to measure cliff height

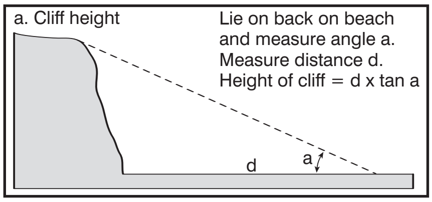
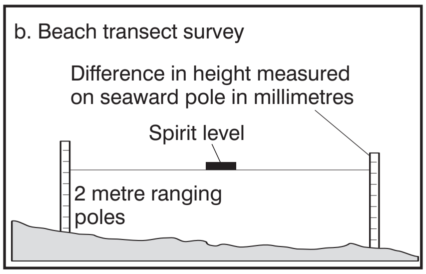


Figure 1b: Beach transect survey



A knowledge of the local geology is required to be able to identify the variety of rock types found on many beaches especially where boulder clay is present. Structure is often crucial to particle shape, with disc-shaped pebbles developing from materials which split mainly along the bedding, lamination or cleavage planes whilst spherical or blocky pebbles are typical of more massive, compact rocks. Discoidal pebbles tend to be concentrated in distinct zones by wave sorting action. Since they have low settling velocity they tend to be pushed further inland and once deposited they are not easily reworked. At the top of the beach, particularly on the storm beach, discoidal pebbles may show

Safety**: Whilst access to a beach can be** easy and the beach environment itself is usually very safe, waves and cliffs can be highly dangerous. Use approved access points to beaches, and avoid climbing up and down cliffs, especially if steep and wet. Check tide times and always work on an outgoing tide. Never enter the sea in dangerous conditions and always conduct coastal studies with at least one colleague.

Figure 2: Beach profile recording sheet

Beach profile recording sheet

Location:________________________ Recorder:____________________

Distance (m)	Rise or fall (+ or -)(mm)	Morphology
1-0	22mm	On top of cliff, 0 is cliff edge
0-4	3500mm	Cliff face
4-10	25mm	Fallen chalk at cliff base, then sandy - sampling point No 1 at 8m
etc.	etc.	etc.

imbrication. Spheres and rod-shaped particles are more readily caught up in backwash and rolled down the beach. Every pebble is a function of lithology, environment and time. Hypotheses relating to this section of work would indicate there are positive relationships between:

a) the intrinsic properties of shape and size of the sediments themselves and their lithologies
b) sediment characteristics (size and shape) and position on the beach slope from which samples have been obtained.

Along the line of the transect at least four sampling points need to be selected (regular or random?). Note the location of these points on your beach profile recording sheet. From the area of each sampling point collect 25 pebbles (using a random numbers table). For each pebble:

a) assess and record the lithology
b) measure and record the prime axes of length (a axis), breadth (b axis) and depth (c axis) of the pebbles from the sampling points (Figure 3a)
c) measure the radius of curvature using the Cailleaux chart (Figure 3b).

In order to gain some insight into the degree of erosion 25 rocks from the cliff face can be extracted and assessed as above. If the cliff material is boulder clay then a larger sample to assess the full range of lithology may be needed. Once statistics have been recorded on the table (Figure 4) the mean size, flatness and roundness can be calculated.

Pie charts can be used for recording lithology. The mean size can be plotted on bar graphs for each sampling point with an overall mean value indicated for each sampling point of 25 pebbles. The value of roundness ranges from 1 for perfectly angular to 1000 for perfectly rounded. For flatness, the flatter the pebble the higher the flatness index with a minimum of 100 relating to a perfectly equi dimensional pebble. Calculating the Zingg form is done by determining for each pebble the b/a and c/b ratios (Figure 5) then plotting all sample values on the chart but using a different colour for each sample point on the entire transect. This is a particularly effective way of displaying results and aids explanation of pebble shape and location.

There is a relationship between permeability, beach angle and sediment size. Sediment size controls beach slope with the steepest slopes on the coarsest beaches. Here, as the sediment coarsens, percolation/infiltration increases so steeper slopes are needed before the swash and backwash are in equilibrium. On sandy beaches there is much less percolation so the backwash is similar in volume to the swash. It is necessary to visit a number of beaches with different sediment sizes on the same day in order to test the hypothesis. At each of the four sampling points beach permeability can be assessed. Water can be poured into a container of known volume and surface area, e.g. 1 litre over $25cm^2$ and then the rate of infiltration timed. This is often extremely rapid on coarse sediment and requires practice. The beach angle also needs measuring. Beach angle can be plotted against average infiltration rate to ascertain what, if any, is the relationship.

At the same four sampling points size of beach material can be assessed. A shovelful of sediment can be sieved through a number of different sized sieves (from garden centres) with the finest material being collected on a sheet of polythene. Each grade of material is weighed in a plastic bag on a spring balance and later calculated as a percentage value.

Figure 3a: Pebble measurements

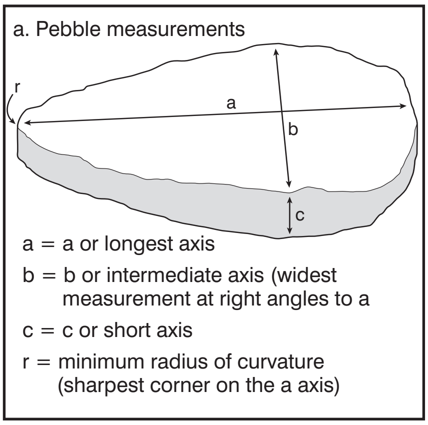
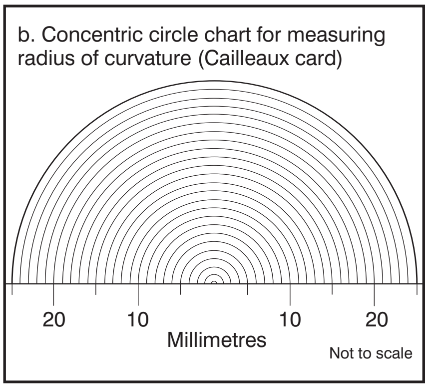


Figure 3b: Concentric circle chart for measuring radius of curvature (Cailleaux card)



Beach angle can be plotted against shingle percentages in order to predict slope steepness. You will have to decide what size of material constitutes shingle; this may depend on your sieve sizes.

Wave energy

Waves are created by the transfer of energy from wind blowing over the

Figure 4: Pebble data and calculations

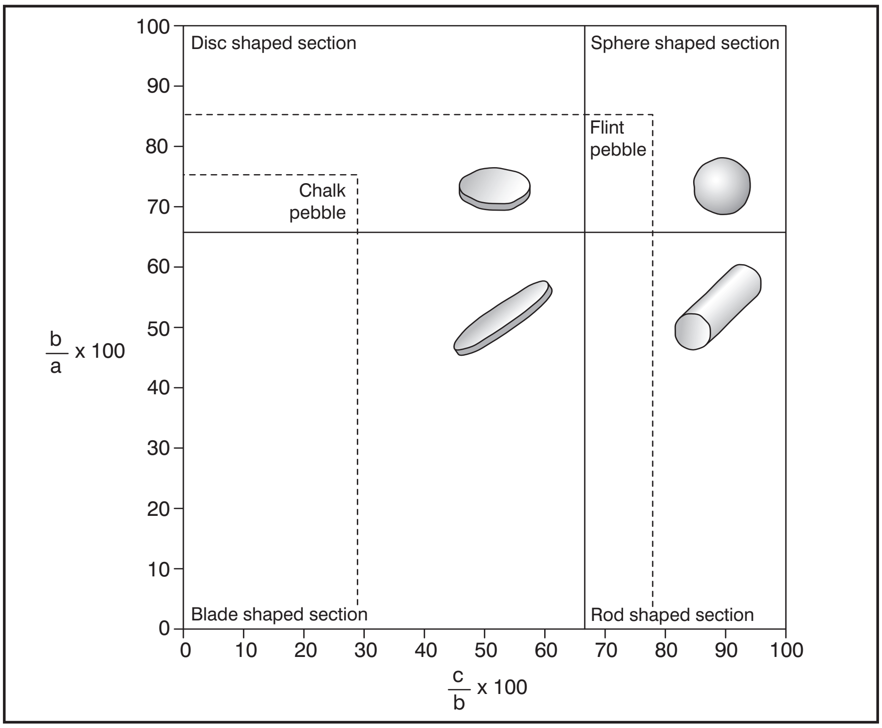
Beech sediment

Location:________________________Recorder:____________________

Pebble	Lithology	a axis mm	b axis mm	c axis mm	Mean size a + b + c ÷ 3	Flatness $\frac{a+b}{2c} \times 100$	rmm	roundness $\frac{2r}{a} \times 1000$	Zingg $\frac{b}{a} \times 100$	form $\frac{c}{b} \times 100$
1	Chalk	85	65	19	169 ÷ 3 = 56.3	395	10	235	76	29
2	Flint	65	55	43	163 ÷ 3 = 54.3	140	5	154	85	78

(each column can be averaged)

Figure 5: Zingg form graph to classify pebbles



Adapted from T. Zingg, W.C. Krumbein, L.L. Sloss, Stratigraphy and Sedimentation, W.H. Freeman & Co, 1963.

surface of the sea and move along the direction of their generation – progressive waves. The energy acquired by the waves depends on the generation and velocity of the wind and the length of the fetch. The energy E of the wave in deep water is the product of the wavelength L and the square of the height H (E is proportional to LH^2). Thus a small increase in wave height will result in a proportionately much larger increase in energy. The ratio between height and length can never exceed 0.14 or one seventh, since the wave will break at this point.

Storms are very important in generating waves, which may then travel very long distances without losing their identity, so the characteristics of waves arriving at any coast are not necessarily connected with local weather. As a wave approaches shallow water, roughly where the depth is half the wavelength, its characteristics begin to change, the circular movement of the water particles becoming elliptical with the long axis parallel to the bottom; the closer to the sea bed, the narrower will be the ellipse. Decrease in water depth leads to a sharp increase in wave height and steepness and when the ratio of water depth to wave height is around 1.3 to 1 the crest rolls forward and over as a breaker.

Breaker type is strongly influenced by beach slope, breaker height, wave period and angle of approach. There are three main wave types (Figure 6a):

1. surging waves that produce net deposition
2. plunging waves producing net beach loss and steep beach profile
3. spilling waves tending to produce deposition at the swash limit but erosion in the mid-beach area; they have a long swash but little backwash, associated with gentle beach gradients.

Wave measurement and analysis is more difficult than some texts suggest. Categorizing a wave into surging, plunging or spilling is not always straightforward and measuring waves is potentially dangerous especially when they obviously contain a lot of energy.

Wave frequency is measured by counting the number of wave crests offshore for one minute and also counting the number of wave crests onshore per minute. Over 13 waves per minute cause destruction, under 13 waves per minute cause construction. Height and depth of waves (Figure 6b) can be measured in relatively calm conditions but when unsafe then a pre measured fixed structure will have to be observed when the tide comes in (Figure 6c). Breaker type can be recorded by observation and also by phase difference i.e. timing the uprush of the wave from break point to the top of the swash in seconds (up to 0.5 for surging, over 0.5 to about 3.0 for plunging and up to 20 for spilling).

Once this observation has been completed, wave length, wave energy and wave steepness can all be calculated (Figure 7). Using this data it is possible to test a number of hypotheses:

- wave period is unaffected by decreasing depth,
- wave length decreases in shallow water,
- energy of a wave is constant,
- wave energy is related to beach angle,
- wave energy is related to sediment size.

Beach sediment movement

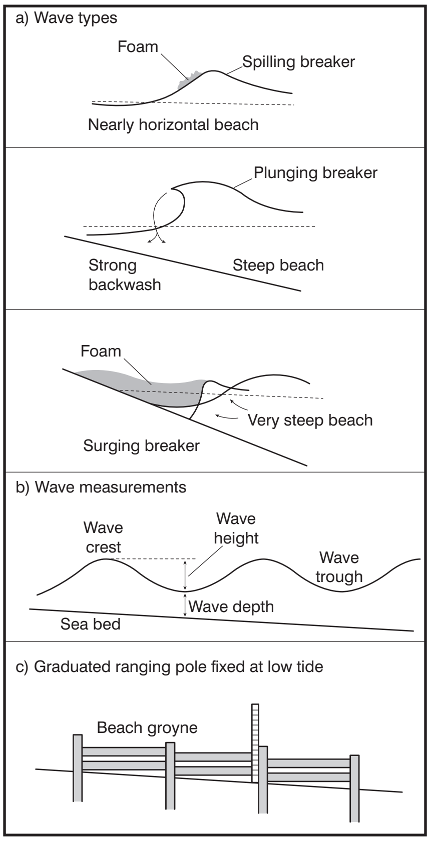
Beach sediment is moved by the energy of the waves. First, measure the wave velocity (if safe) by placing a flow meter (such as a Flowvane) directly into the breaking waves a number of times and record the results. Similarly the swash and backwash velocity can be recorded and averaged. It is then possible to relate these velocities to a variety of sediment movements.

A tin can be set into the beach to act as a sand trap. Over a short period of time the tin will fill with sediment from either the swash or the backwash or both, indicating the beach could be aggrading, degrading or neutral under the wave conditions observed.

Four labelled pebbles of similar size can be selected – one rod, one roller, one blade, one disc (Figure 5) – and their a, b and c axes and radius measured. The pebbles are placed in line below the swash limit and the movement of these pebbles by the waves can be mapped. This will indicate the propensity of pebble type to move in a particular direction, up, down or along the beach, under the conditions of the day.

Over the period of a tide the above experiment can be repeated with each pebble firmly attached to 50 metres of string which is tied to a brick sunk into the sand. The incoming tide over about twelve

Figure 6a: Wave types; b: Wave measurements; c: Graduated ranging pole fixed at low tide



hours should move the pebbles. After the tide retreats, if the pebbles and string can be found then a basic measure of longshore drift can be obtained.

Overall analysis

After processing all field data into meaningful diagrams and statistics comes the most important part of the study. Every map, graph, statistic, sketch etc. must be described and analysed to show what it means. Written comments should concentrate on the ability of qualitative methods to give useful insights into observed relationships and the particular value of quantitative methods to achieve the same or other indications of conditions. Also use your field observations to elaborate on the particular detail you recorded.

This can lead on to more searching questions about the interrelationships between the sediment size and shape, wave energy and sediment movements attempting to seek possible causal relationships and the changes that occur through both space and time. The range of pebble size and standard deviation (dispersion about the mean) can be used. Where numbers and frequencies are concerned the chi squared test is appropriate, e.g.:

- there is no association between location on the coast and pebble size,
- pebbles of different shapes are spread evenly on the beach,
- there is no association between pebble size and lithology.

Data can be correlated using Spearman rank e.g. there is no relationship between beach angle and pebble size. These computations will lead you to investigate possible causal relationships. Throughout the study you are working towards a conclusion about your chosen major hypothesis.

Conclusion

Around the UK the variety of beaches that can be studied will show wide spatial differences and the same locations can show changes through time. The beaches can also be compared to show the range of beach types. Alternatively the aim of your study may be to compare your study beach to a model beach.

Coastal fieldwork described above enables a full investigation of the fieldwork model to be undertaken, i.e. background reading to develop an aim with key questions and overall hypothesis. This is followed by data collection, data representation and data analysis including statistical testing to give an insight into the effect of the processes operating in this dynamic physical environment leading to a conclusion about your overall hypothesis.

The reading, fieldwork techniques, data collected and insights understood can all be brought forward to use in your examination questions, as case studies, as illustrative material, as evidence of practical work and to support theory.

Figure 7: Calculating wave characteristics

Wave study

Location:____________________
Recorder:____________________
Wind direction/force
Tide rising/falling
Angle of wave approach
Average wave frequency per minute offshore
Average wave frequency per minute onshore
Wave period (T) 60 seconds ÷ wave frequency
Height (metres) of breaking wave (H)
Depth (metres) where height taken (D)
Wavelength (L) in deep water = $\frac{1.6 \times 3600}{\text{frequency}^2}$ metres
Wavelength in < 2 metres of water = $\frac{3.1 \times 60\sqrt{\text{water depth (m)}}}{\text{wave frequency}}$
(Alternative formula: $L = 1.56T^2$m)
Wave energy = $740 \times H^2 \times L$ joules/metre/second
Wave type recorded by observation or = $\frac{\text{uprush time}}{\text{wave period}}$
Wave steepness = H ÷ L

Focus Questions

1. Undertake background reading and generate an aim/hypothesis to investigate. Justify the perceived significance of your aim/hypothesis.

2. Compare the contribution of and value of each of the fieldwork techniques towards the whole study in this Geofile.

3. What do you learn from the diagrams in this Geofile that you could not learn from field observation alone?

4. To what extent are the effects of wave energy reflected in beach morphology?