An aid to interpreting multiple frequency distributions in geomorphological field studies

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Introduction

Most geomorphological studies include some consideration of sedimentological properties to clarify or augment morphological data, or as an aid to understanding geomorphological processes. One of the most important aspects of such sedimentological data consists of an assessment of particle size, form, sphericity or roundness, parameters which can be easily established for coarse sediment in the field with the use of visual comparison charts and simple axial measurements. As a consequence the collection of such field data forms an important part of many field work exercises in geomorphological teaching. For ease such data is commonly sampled at a series of points along a transect, for example, across a beach, through a suite of landforms or through sedimentary layers within a section. In our experience, however, the educational benefits of such data collection are often difficult to exploit. This type of raw data is normally presented as a series of frequency bar charts or line graphs arranged along the transect. The visual comparison of these is not easy, nor is the use of more sophisticated techniques such as the analysis of distribution summary statistics always applicable or necessarily desirable. Consequently, it is difficult for students/pupils to established patterns of change along such transects. What is required is a simple graphic tool with which to compare the distributions and pick out the patterns present along the sampled transect.

In this paper we draw attention to a technique, first introduced by Dowling in 1977, for the presentation and comparison of frequency distributions and illustrate its value in studies of particle roundness.

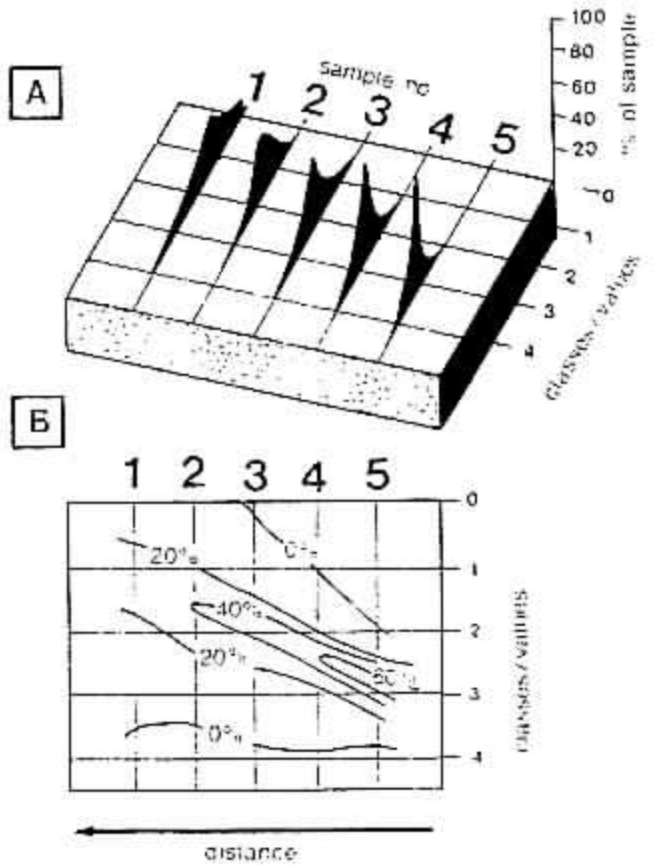


Figure 1 A—Hypothetical frequency distributions for five samples. B—Spectra map of the five frequency distributions (modified from Dowling, 1977).

Spectra Maps

In 1977 Dowling presented a method of visually comparing a series of particle size frequency distributions along a transect (Fig. 1). He called the plot produced a grain size spectra map. Since publication the value of such plots has not received the attention that we feel it deserves.

The spectra map is simply a contour map of the 3-dimensional surface formed when a series of frequency distribution profiles are placed next to one another along a transect (Dowling, 1977)(Fig. 1). It enables the analysis and simultaneous comparison of numerous frequency distributions within a series. Subtle trends and patterns within the data set which may be obscured by simply comparing a summary of each distribution (e. g. mean, range etc.) can be appreciated and presented. Significantly, there is no loss of information with this type of presentation (Dowling, 1977).

Consider Figure 2 which consists of a shore normal beach transect with eight sampling stations along its length. The particle size distributions at each of these stations is summarised by a mean and sorting statistic which illustrates the gross changes in particle size across the beach (Fig. 2A). However, these statistics do not pick out the bimodality present, nor depict the subtle changes in the importance of different size fractions across the beach. More importantly, such statistics are often poorly understood by students/pupils who are much more likely to appreciate the visual or pictorial image of the data provided by a grain size spectra map (Fig. 2C).

The ability of spectra maps to present a large volume of data in a form which is easily appreciated makes the tool also ideal for comparing other types of sedimentological information, such as particle roundness data. This data is normally analysed by comparing a series of bar charts, especially when a visual assessment of particle roundness is used (e. g. Powers, 1953; Krumbein, 1941). Spectra maps have the advantage of allowing a large number of such bar charts to be examined at a glance. The construction of such a spectra map is illustrated in Figure 3. The authors believe that this application is particularly useful as will be illustrated in the following case study.

Case Study: A Small Fluvial Catchment in Mallorca

Ten samples were taken from the bed of an ephemeral stream which drains a small catchment in south east Mallorca (Fig. 4). The particle roundness of each clast within the ten samples was measured using Powers' (1953) visual scale (N=25 to 60). Two additional samples were also obtained, one from an adjacent beach and another from a deposit of valley side colluvium. All the clasts examined were in the range of 20-40

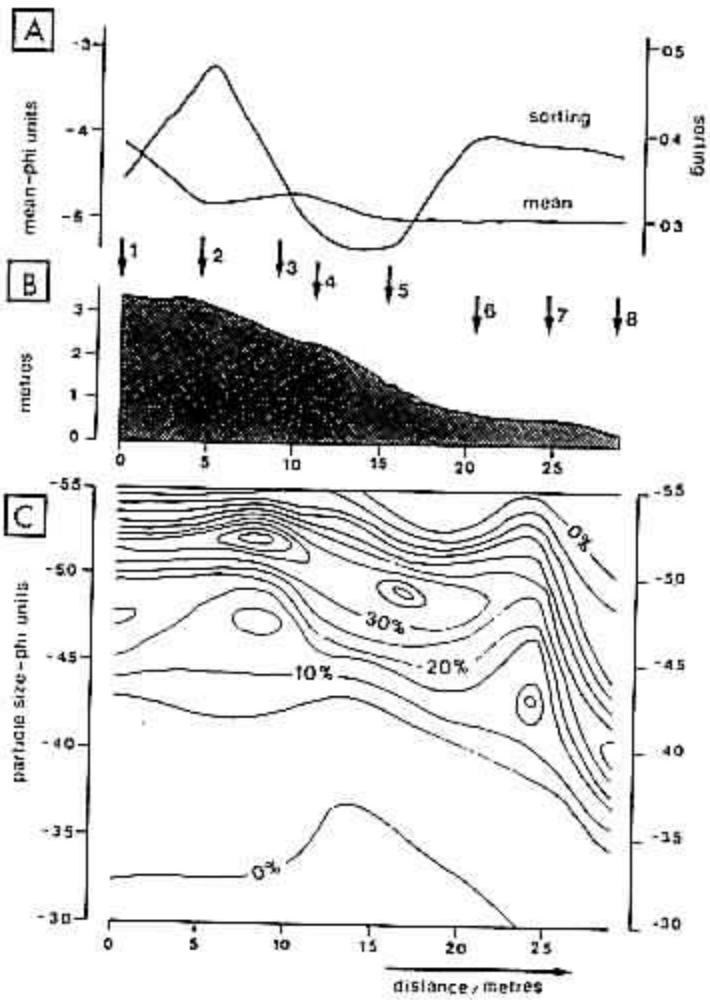


Figure 2 Shore normal beach profile at Dungeness, Kent. A—Variation of mean particle size and sorting across the beach, based on eight samples. B—Beach profile. C—Spectra map of the eight particle size frequency distributions obtained from each samples taken across the beach. The contours are at 5% intervals.

mm in size (a-axis) and of a single lithology. At the time of sampling the river discharge was negligible and had been so for some time. The data are presented in a series of histograms and as a spectra map, to allow more effective comparison (Fig. 4).

The spectra map allows the comparison of all twelve samples and reveals some interesting trends (Fig. 4C). What is very clear from this plot is that roundness data provides strong environmental discrimination between the beach and colluvium environments. The beach sediment (Sample 11) is much more rounded than the sample of valley side colluvium (Sample 12). It is also clear that the pattern of roundness within the channel bed gravels is particularly complex. Analysis of the spectra map suggests that there are two distinct populations of stones within the channel bed: one is an angular population, very similar to the colluvium sample, while the second component is much more rounded. At each point along the river bed the gravel is dominated by one or other of these two populations, with the exception of the bimodal gravel of Sample 10 which contains both in more equal proportions.

An explanation of this pattern is possible if one considers the debris supply within this type of catchment. All the valley floor gravel within the catchment is derived from the valley sides and transported down valley during flood events. At any point along the river bed there are two debris components, that

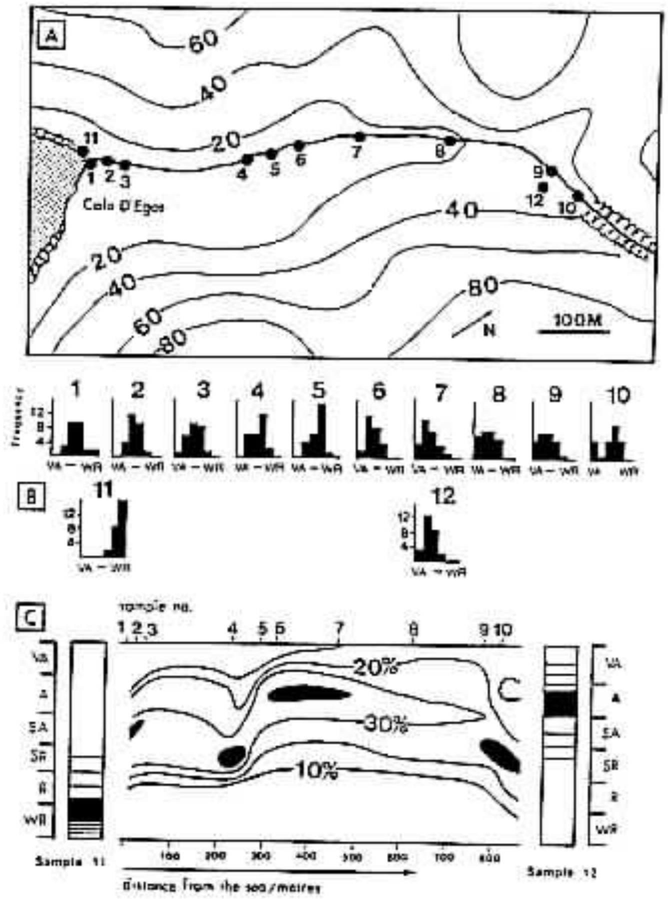
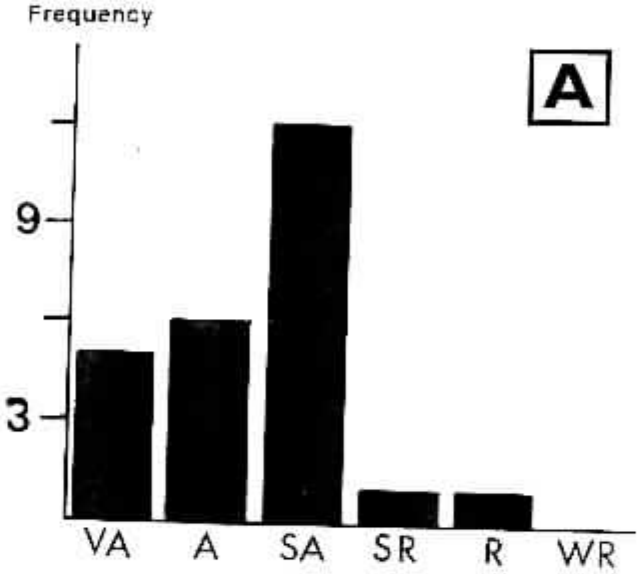


Figure 4 The Cala d'Egos catchment in western Mallorca. A. Map of the catchment showing the twelve sampling stations. B. Frequency distributions of particle roundness for each of the twelve samples [VA=very angular; WR=well rounded]. C. Spectra map of the twelve particle roundness distributions. Sample 12 is shown on the right hand side of the main spectra plot, while sample 11 is shown to the left. The contour are at 5% intervals, while black areas signify areas with a frequency of over 40%.

derived directly from the valley sides (colluvial gravel) and that moved down stream when the river is in flood. The colluvial gravel provides an angular input or stone population whereas the fluvially derived gravel is generally more rounded, having been transported down river. The relative contribution of each of these two populations at any point along the river bed is controlled by the geometry of the valley. At sites where the river bed is overlooked by steep valley sides the supply of colluvium to the channel will be high and the gravel present in the river bed angular, while sites separated from the valley sides by a flood plain will contain only fluvially transported gravel.

Consequently, one would expect the angular samples (2, 3, 6, 7, 8 & 9) in Figure 4 to correspond to valley locations with little or no flood plain and steep valley sides, which is in fact the case. Conversely the rounded samples (1, 4 & 5) correspond to sites were there is a flood plain. The pattern of gravel roundness seems, therefore, at this location to be a function of variations in geometry of the valley. This roundness pattern will be obliterated by large flood events which will transport and mix the stream-worked and colluvial debris. Roundness samples taken immediately after such an event would be more uniform.

These simple patterns are very clearly visualised and appreciated within the spectra map, illustrating its advantage over conventional methods in both analysing and presenting roundness data. The plot draws attention to subtle changes and trends in particle roundness, which in this case are of particular geomorphological interest.



STAGE 1: Bar chart is converted to a continuous line graph

STAGE 2: Frequency values at 3 point intervals are read off the curve and extended downwards on to contour plot axes.

STAGE 3: Isolines are drawn to link the plotted points.

STAGE 4: Isolines are retraced to give smoother contours.

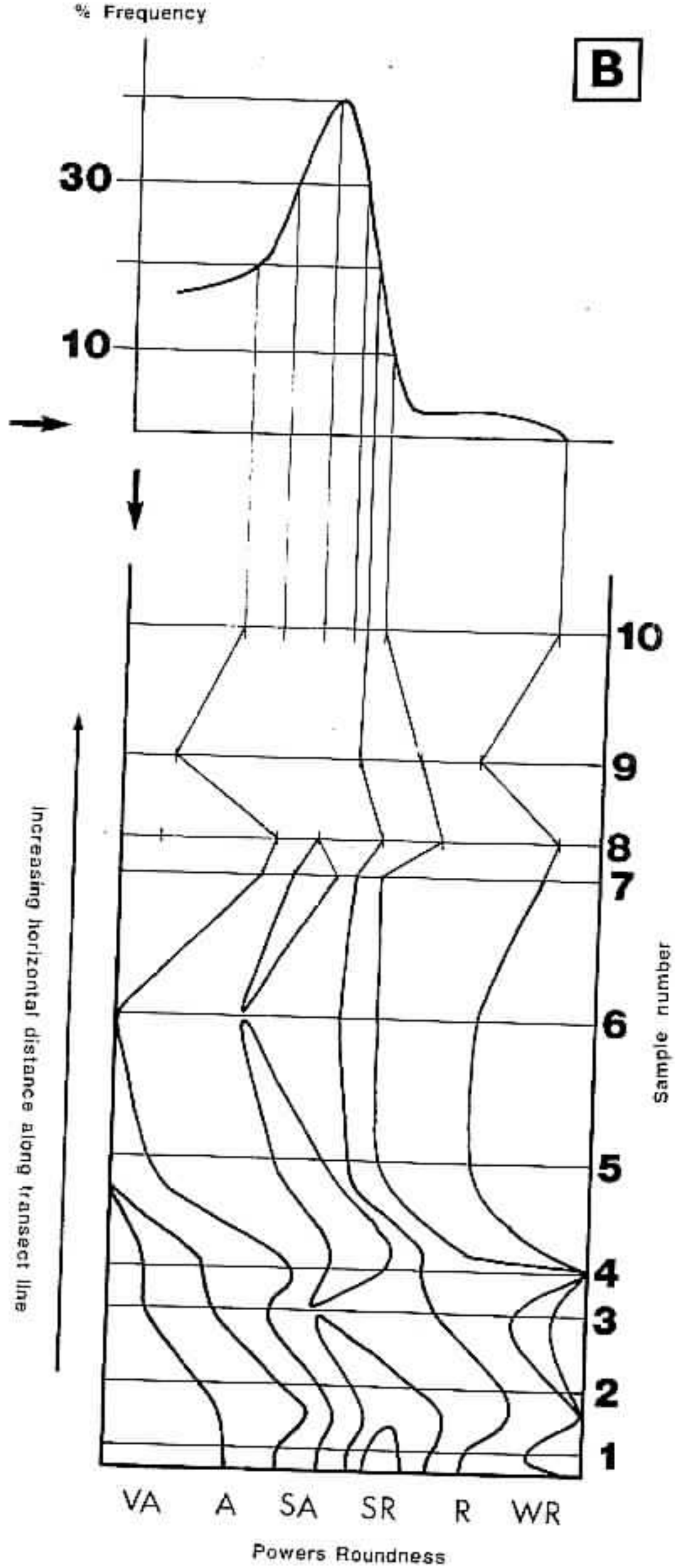


Figure 3 The construction of a spectra map using particle roundness data. A: The initial frequency histogram [VA=very angular; A=angular; SA=sub-angular; SR=sub-rounded; R=rounded; WR=well rounded]. B: Percentage frequency plot of roundness and construction of a spectra map.

Conclusion

Dowling's (1977) spectra plots provide a superior method of visually comparing a series of frequency distributions and are particularly well suited to the analysis of particle roundness data. They are easily constructed by hand and can be used to present a large volume of data quickly. This graphic tool provides an excellent vehicle through which students/pupils can recognise and appreciate subtle variation in the sedimentary properties sampled from a transect across a beach, or through a series of landforms or sedimentary layers.

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