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GRAPHICAL REPRESENTATION OF PARTICLE SHAPE USING TRIANGULAR DIAGRAMS: AN EXCEL SPREADSHEET METHOD

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ABSTRACT

Analysis of the shape of sedimentary particles can provide information about their transport history and aid facies differentiation and the characterization of depositional environments. Triangular (Sneed and Folk) diagrams, employing ratios of the three orthogonal particle axes, have been advocated as the most appropriate method for unbiased presentation of primary particle shape data. A spreadsheet method for the production of these diagrams is described. Clast data-sets from a range of environments are presented using this method. An alternative use of the spreadsheet for the presentation of sedimentary fabric shape is suggested. Copyright © 2000 John Wiley & Sons, Ltd.

KEY WORDS: clast morphological analysis; particle shape; triangular diagram; spreadsheet

INTRODUCTION

The form of sedimentary particles is related to their shape (the relative lengths of each axis), roundness (smoothness or angularity of the edges) and texture (surface roughness) (Benn and Ballantyne, 1993). These characteristics provide a means of differentiating facies, providing clues about the transport history of the sediment, and characterizing depositional environments.

Methods of presenting primary particle shape data have been the subject of heated discussion during recent years, with a variety of schemes being advocated (e.g. Illenberger, 1991, 1992a,b; Benn and Ballantyne, 1992, 1993, 1995; Howard, 1992, 1993; Woronow, 1992; Illenberger and Reddering, 1993; Hofmann, 1994, 1995). These arguments are not repeated here, except to note that each of these schemes have their merits, whilst none are ideal for all situations. To some extent, the precise method of representing particle shape is less important than the adoption of common standards to enable the direct comparison of work undertaken by different researchers. The establishment of a ‘critical mass’ of work using one scheme is probably the key factor that will determine the standard adopted, although different methods will undoubtedly be used by individual workers for particular purposes.

THE SNEED AND FOLK (1958) DIAGRAM

The method of representing particle shape advocated by Benn and Ballantyne (1993) employs a triangular (ternary) diagram in which ratios of the three orthogonal axes of the particle are plotted (Figure 1). Such a method was first proposed by Sneed and Folk (1958), and geometrically equivalent diagrams were presented by Hockey (1970) and Ballantyne (1982). Particles are envisaged as lying in the continuum between blocks (or spheres), slabs (discs, oblate) and rods (prolate) which mark the corners of the diagram (Figure 1). This

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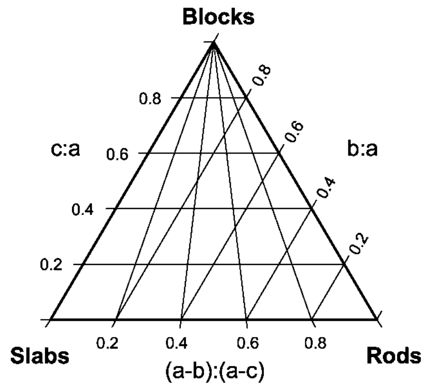

Figure 1. Particle shape (Sneed and Folk) triangular diagram. Letters a, b and c represent the long, intermediate and short orthogonal axes of each particle respectively

method has been adopted by a number of researchers, particularly those working in glacial environments (e.g. Hart, 1995; Bennett *et al.*, 1997), where it has proved useful in discriminating between sediments actively transported in the zone of traction at the glacier bed and passively transported englacially or supraglacially (Bennett *et al.*, 1997). The diagrams have also found use in a number of other fields (e.g. Bertran *et al.*, 1997; Verrecchia *et al.*, 1997; Higgitt and Allison, 1999).

These diagrams have a number of advantages over alternatives (Benn and Ballantyne, 1992, 1993, 1995), most significantly that the ratios vary linearly, resulting in even distribution of particle forms across the diagram without distorting the shape continuum. The diagrams are also easier to understand than alternatives, and the plotted values are easily calculated. It has been demonstrated that the diagram is an effective tool for the identification of useful descriptive indices and analytical methods (Benn and Ballantyne, 1993, 1994).

Many geological and graphing software packages are able to produce triangular diagrams. However, the diagram axes are scaled in either a clockwise or anti-clockwise direction, with each axis representing a portion of a whole unit. Such packages can only be used for plotting diagrams where the position of a point represents the relative proportions of three variables that sum to 1 or 100 per cent. The most common sedimentological application of this type of diagram is the plotting of grain size characteristics such as the proportions of sand, silt and clay in a sample. The axes in the Sneed and Folk diagram are arranged differently from the conventional triangular diagram, and the use of ratios results in the variables not summing to 1. Sneed and Folk diagrams cannot, therefore, be plotted with conventional software. Since hand drawn triangular diagrams are laborious to complete, this paper presents an Excel spreadsheet for their rapid preparation. For completeness, the spreadsheet may also be used to generate conventional triangular diagrams.

TRI-PLOT

TRI-PLOT is available from the Wiley Interscience web site (www.interscience.wiley.com). It has been developed using Microsoft Excel 97 and is known to work with Excel 2000. It is not compatible with earlier versions. The spreadsheet consists of five sheets. The first sheet contains instructions and information about TRI-PLOT. The second and third sheets are used to generate Sneed and Folk diagrams. Data are entered and results presented on the second sheet (SHAPE – Data & results), and calculations take place behind the scenes on the third sheet (SHAPE – Calcs.). The fourth and fifth sheets are used to generate standard triangular diagrams for the representation of particle size. The operation of the spreadsheet is summarized below. Full instructions and details of how to prepare conventional triangular diagrams are contained in the first sheet.

The 'data & results' sheet is divided into three parts: the *data entry* area, the *plotting parameters* area, and the *triangular diagram* itself. The spreadsheet is configured to allow the dimensions of up to 50 particles to be

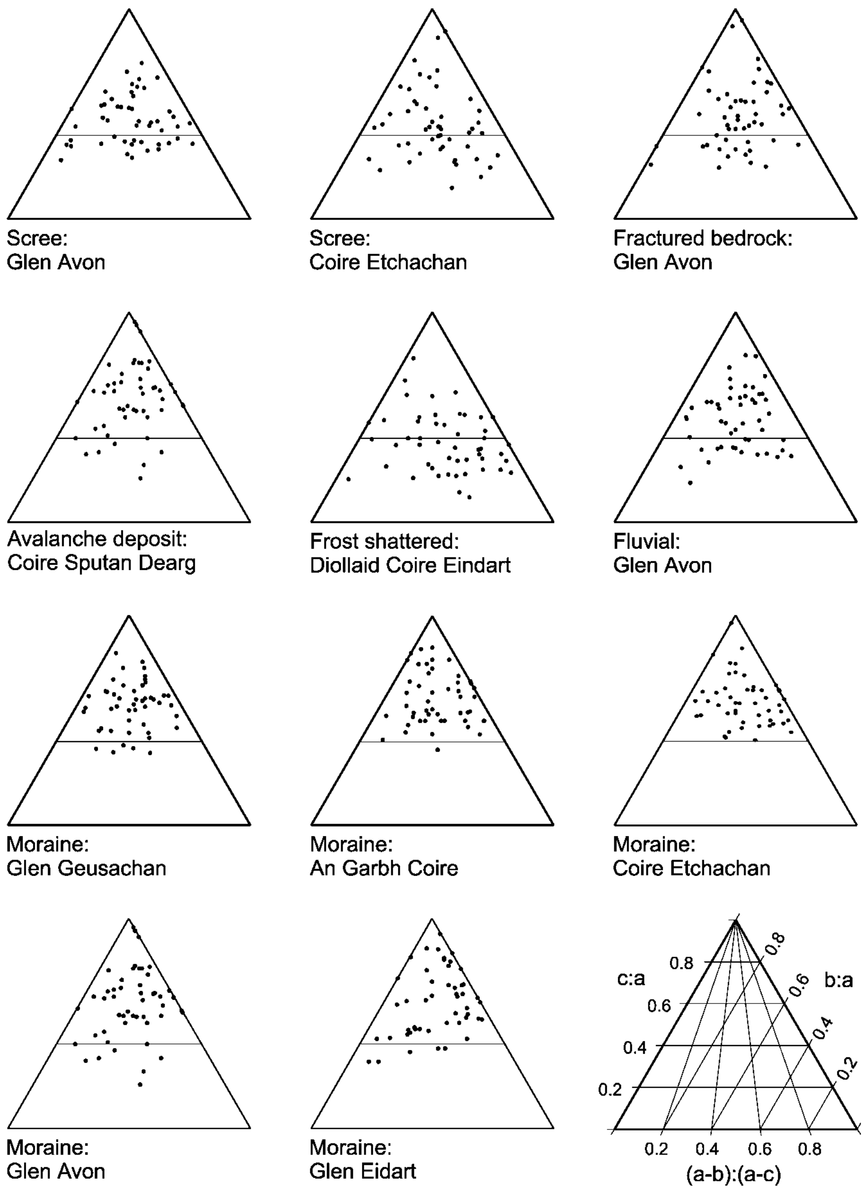

Figure 2. Particle shape (Sneed and Folk) triangular diagrams for clast samples ($n = 50$) of known origin from a number of sites in the Cairngorm Mountains, Scotland

entered without modification. To plot larger samples requires modification of the calculations sheet, as described in the detailed instructions. The triangular diagram is automatically updated as data are entered. The plotting parameters enable the user to change the appearance of the diagram by specifying the frequency and size of tick marks on the axes, and whether the tick marks are extended as lines across the diagram. There is also an option to plot the line where the c:a ratio equals 0·4. This (known as the C40 index) has been shown to be a key parameter in the differentiation of glacial facies (Benn and Ballantyne, 1994).

The triangular diagram is a standard XY scatter graph and may be modified to change parameters such as line thickness, colours and symbols used. Each aspect of the diagram is saved as a different data-series and may be altered in the standard way for Excel charts. A complete list of the data-series is included on the first sheet. Any number of data-sets may be plotted on a single diagram if a new data-series is defined for each and the appropriate part of the calculations sheet extended. The finished diagram can be copied to the clipboard and pasted into office or graphics applications for final presentation and annotation. If copying into another Excel workbook, automatic updating should be set to manual (using the Calculations tab of the Options dialogue box accessible from the Tools menu) to prevent changes in the source spreadsheet being reflected in the copied diagram.

SAMPLE DATA-SETS

An example of the output from the spreadsheet is given in Figure 2. Sample clast data-sets from the Cairngorm Mountains, Scotland, are used to characterize clast samples of identified origin. Each sample set consists of 50 randomly chosen clasts within the small to large pebble classes. These sample data-sets include clasts from scree, fractured and weathered bedrock, avalanche, fluvial and moraine-mound deposits. The lithology of all clasts is Cairngorm Granite, with the exception of the Glen Eidart moraine sample, which is predominantly schist.

ALTERNATIVE APPLICATIONS

In addition to its use for the representation of particle shape, the spreadsheet has potential to be used in other spheres where three independent variables are compared. Benn (1994) proposed a method of representing sedimentary fabric shape on triangular diagrams by plotting indices of fabric isotropy and elongation defined by ratios of eigenvalues (Figure 3). These diagrams can be plotted using the spreadsheet without modification by substituting the eigenvalues in place of particle dimensions. Although the right axis of the fabric shape plots is inverted compared to the particle shape plots, the points are plotted correctly because the elongation index used to scale this axis $(1-(S_2{:}S_1))$ has an inverse relationship to the ratio of the eigenvectors used to plot the points $(S_2{:}S_1)$.

CONCLUSIONS

Benn and Ballantyne (1993) advocated the adoption of Sneed and Folk (1958) triangular diagrams for the presentation of primary particle shape data. Despite some controversy about the relative merits of alternative methods of representing particle shape, Benn and Ballantyne's (1993) recommendation has been widely followed, particularly amongst those working in glacial environments. The spreadsheet presented here

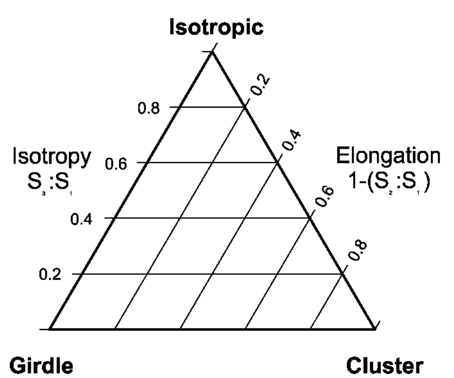

Figure 3. Triangular eigenvalue plot devised by Benn (1994) for the representation of fabric shape. The three eigenvalues S_1, S_2 and S_3 represent the degree of clustering around the eigenvectors that describe the orientation of the long axes of the particles within a sample

provides a rapid means of generating these diagrams electronically. It also has application wherever three independent variables are compared, such as in studies of sedimentary fabric shape.

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