

Tri-plot

An Excel spreadsheet for the preparation of triangular (ternary) diagrams for particle shape and tri-variate data

Documentation

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The latest version of Tri-plot and its associated documentation is always available from <http://www.davidgraham.org.uk>.

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What is Tri-plot?

Tri-plot is a Microsoft® Excel spreadsheet for the preparation of triangular (ternary) diagrams for particle-shape and tri-variate data.

Conventional triangular diagrams are used to represent tri-variate data in which the three variables represent proportions of a whole. In the Earth Sciences, a common application is the representation of the proportions of sand, silt and clay in a sample. Numerous software packages are available for the production of such diagrams.

An alternative type of triangular diagram was proposed by Sneed & Folk (1958) for the representation of particle shape. This scaling of the triangular diagram may also be used to represent sedimentary fabric shape (Benn 1994) and has potential application wherever the relationships between three independent variables are compared. Existing software is unable to plot these diagrams as the parameters on the three axes do not sum to 1.

Tri-plot provides a simple method of producing both conventional and Sneed & Folk triangular diagrams. Because Tri-plot is implemented in Microsoft® Excel, it has a familiar user interface and data can be easily cut-and-pasted into it.

The original version of Tri-plot was described in Graham & Midgley (2000) and is available from the Earth Surface Processes and Landforms resources page on the Wiley Interscience website (<http://www3.interscience.wiley.com/cgi-bin/jabout/2388/OtherResources.html>). Although this version has now been superseded, a condition of use of all versions of Tri-plot is that this work is referenced in any publications that utilise the software.

Requirements

Tri-plot is a Microsoft® Excel workbook and requires Excel to run. It was developed using Microsoft® Excel 97 and 2000 on a PC. It should work with all subsequent versions, but does not work with earlier versions. Compatibility with the Mac is expected, but has not been tested.

Tri-plot has no additional requirements, but a screen resolution of at least 800x600 is recommended. The PDF version of this document requires Acrobat Reader. The latest version is available from <http://www.adobe.com/>.

This documentation assumes that the user has a basic knowledge of Excel, including the charting functions.

Revision history

- v1.2 Additional option added to SHAPE to enable the boundaries of Sneed & Folk's (1958) descriptive shape classes to be plotted.
- v1.3 Additional options added to SHAPE to plot Dobkins & Folk's (1970) oblate-prolate index isolines and Sneed & Folk's (1958) maximum projection sphericity isolines. Error in tick angles along bottom axis corrected. Default maximum number of grains increased to 250. Calculations and input/output sheets combined. Instructions sheet updated.
- v1.4 A table showing the proportion of grains falling into each of the Sneed & Folk descriptive classes added. Minor corrections to documentation.

The Sneed & Folk (1958) diagram

The Sneed & Folk (1958) method of representing particle shape employs a triangular diagram in which ratios of the three orthogonal axes of the particle are plotted. Particles are envisaged as lying in the continuum between blocks (or spheres), slabs (discs, oblate) and rods (prolate) that mark the corners of the diagram (Fig. 1). Although superficially similar in appearance to a conventional triangular diagram, the Sneed & Folk diagram is scaled differently and cannot be plotted using software designed for the production of conventional diagrams.

The conventional and Sneed & Folk scalings of the triangular diagram provide a means of representing fundamentally different things. Conventional diagrams are used to represent the relative proportions of three variables that sum to a whole. The three variables are related in that an increase in one must be reflected in a decrease in one or both of the other two. An example is the relative proportions of gravel, sand and mud in a geological sample. In contrast, the Sneed & Folk scaling enables independent (although related) variables to be plotted. Changes in one variable need not affect the other two. For a particle, the lengths of the three axes (a, b and c) are independent (except that, by definition, $a > b > c$).

This fundamental distinction is reflected in differences in the arrangement of the axes between the two diagrams (Figs. 1 & 2). In addition, the use of ratios in the Sneed & Folk scaling means that the variables do not sum to 1.

For a full discussion of the advantages of using the Sneed & Folk diagram over alternatives for representing particle shape, see Benn & Ballantyne (1993) and the references therein.

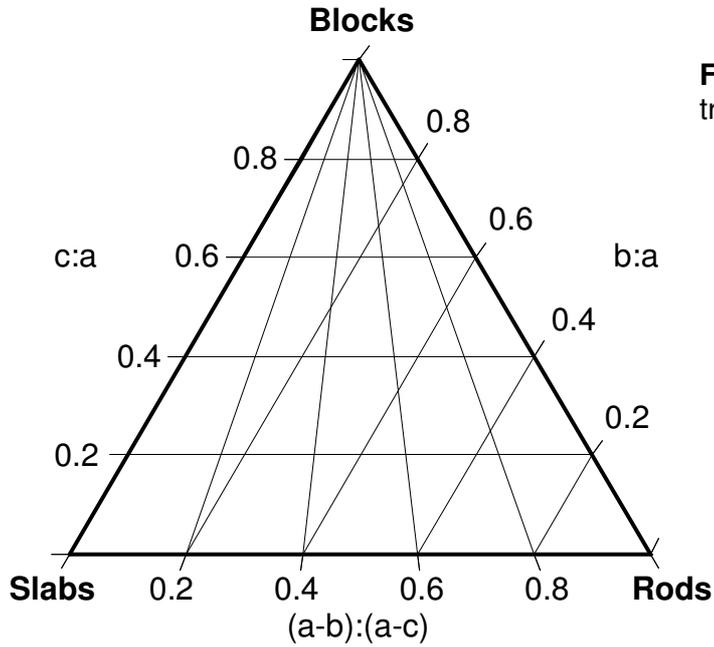


Fig. 1. The Sneed & Folk triangular diagram.

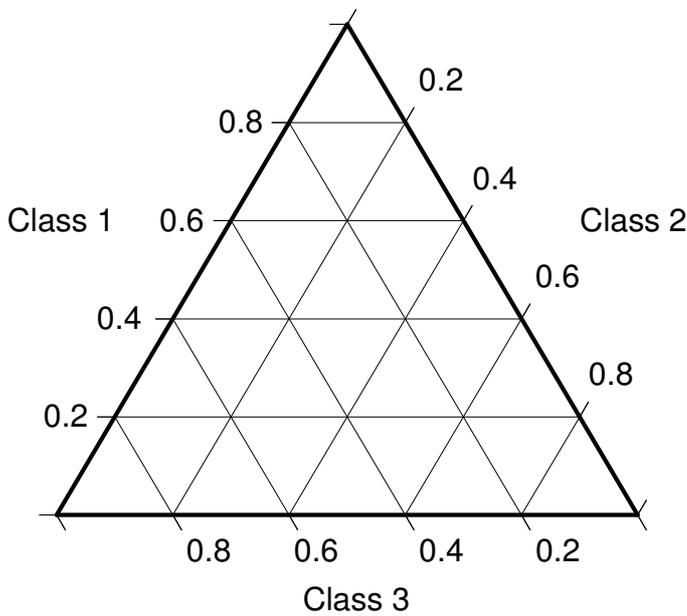


Fig. 2. The conventional triangular diagram. Axes are scaled so they increase in a clockwise direction around the diagram. Points within the diagram represent the relative proportions of three classes and always sum to 1.

Producing triangular diagrams with Tri-plot

The Tri-plot spreadsheet consists of five sheets:

- The first sheet contains instructions and information about Tri-plot.
- The second sheet is for the generation of particle shape (Sneed & Folk) triangular diagrams.
- The third sheet is for the generation of conventional tri-variate triangular diagrams.

To generate shape (Sneed & Folk) triangular diagrams

The second sheet generates particle shape (Sneed & Folk) triangular diagrams. The inputs required are the a-, b- and c-axis lengths of the particles. The "SHAPE" sheet can be accessed using the button on the first sheet or the tab at the bottom of the screen. The sheet contains six areas: the data entry area, the plotting parameters area, the isoline values area, the Sneed & Folk classes area, the triangular diagram itself, and the calculations area. Only the curious, or those who wish to modify the spreadsheet, will need to look at the calculations area.

Data entry area

Type the a-, b- and c-axis dimensions of each clast into the table, or paste them from another spreadsheet. The units of measurement are not important, as long as they are consistent. Error messages are displayed in blue. The triangular diagram will update as data are entered. The data entry area is set up initially to accept data for 250 clasts. Samples of less than 250 clasts do not require the spreadsheet to be altered. Samples of more than 250 clasts require that the spreadsheet be altered (see Advanced operation).

Plotting parameters area

This area defines aspects of how the triangular diagram will appear on the screen and when printed.

The *printer correction* parameter is used to scale the vertical axis of the diagram so the triangle is equilateral. This is necessary because it is not possible to instruct Excel to scale charts. Experiment to obtain satisfactory results on screen and from a printer. Alternatively, the diagram may be scaled using the mouse.

The *tick interval* parameter defines the frequency of tick marks on the axes of the diagram. Acceptable inputs are 0 and from 0.05 to 0.5 but must divide into 1 (i.e. 0.05, 0.1, 0.2, 0.25, 0.5). If 0 is entered, no ticks are plotted. An error message is given if an unacceptable value is entered.

The *tick length* parameter defines the length of tick marks on the axes of the diagram. Acceptable inputs are from 0 to 0.2. An error message is given if an unacceptable value is entered. If 0 is entered, no ticks are plotted.

The *plot C₄₀ line?* parameter determines whether a line is drawn across the diagram to indicate the C₄₀ index value ($c/a=0.4$). This index has been shown to be a useful discriminator of process fields in glacial environments (Benn & Ballantyne 1994). Acceptable inputs are N (line not plotted) and Y (line plotted). Other inputs will result in an error message.

The *left & right axis lines?* parameter determines whether lines are drawn across the diagram from the tick marks on the left and right axes. Acceptable inputs are N (line not plotted) and Y (line plotted). Other inputs will result in an error message. The lines are drawn at the interval specified by the tick interval parameter.

The *bottom axis lines?* parameter determines whether lines are drawn across the diagram from the tick marks on the bottom axis. Acceptable inputs are N (line not plotted) and Y (line plotted). Other inputs will result in an error message. The lines are drawn at the interval specified by the tick interval parameter.

The *bottom axis ticks?* parameter determines whether tick marks are plotted on the bottom axis. Acceptable inputs are N (ticks not plotted) and Y (ticks plotted). Other inputs will result in an error message. The ticks are drawn with the frequency and length specified by the tick interval and tick length parameters.

The *Sneed & Folk classes?* parameter determines whether the boundaries of the particle shape classes defined by Sneed and Folk (1958) are plotted (Fig. 3). Acceptable inputs are N (boundaries not plotted) and Y (boundaries plotted). Other inputs will result in an error message.

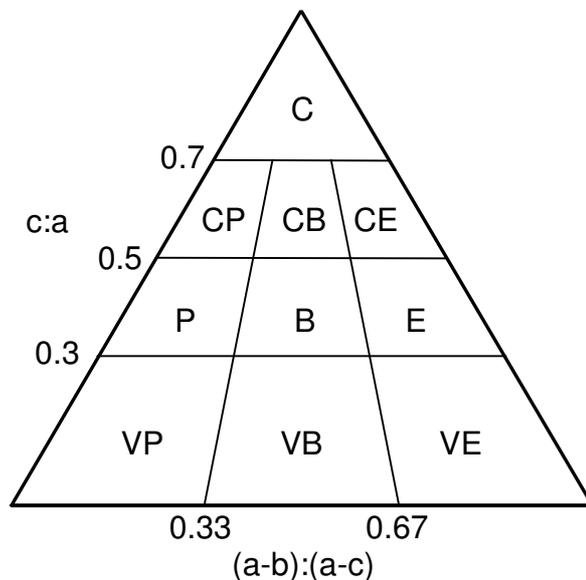


Fig. 3. Descriptive particle shape classes of Sneed & Folk (1958).

C = compact
P = platy
B = bladed
E = elongate
V = very

The *oblate-prolate isolines?* parameter determines whether isolines of the oblate-prolate index of Dobkins & Folk (1970) are plotted (Fig. 4). Acceptable inputs are N (isolines not plotted) and Y (isolines plotted). Other inputs will result in an error message. The values of the isolines plotted are specified in the isoline values area of the sheet.

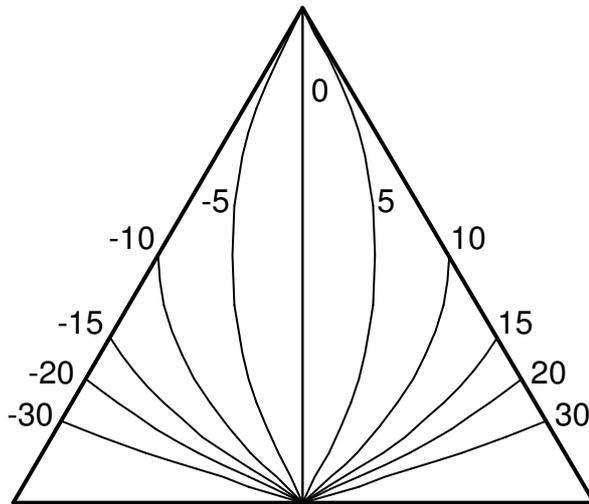


Fig. 4. Isolines of the oblate-prolate index.

$$OPI = \frac{10(a-b/a-c - 0.5)}{c/a}$$

The *max. proj. sphericity isolines?* parameter determines whether isolines of the maximum projection sphericity index of Sneed & Folk (1958) are plotted (Fig. 5). Acceptable inputs are N (isolines not plotted) and Y (isolines plotted). Other inputs will result in an error message. The values of the isolines plotted are specified in the isoline values area of the sheet.

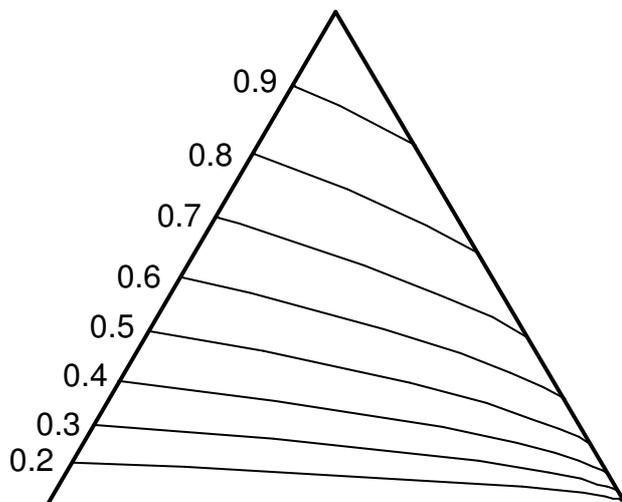


Fig. 5. Isolines of the maximum projection sphericity index.

$$MPS = \sqrt[3]{\frac{c^2}{ab}}$$

Isoline values area

This area provides the opportunity to define which isolines of the oblate-prolate index and the maximum projection sphericity index are plotted on the triangular diagram. Whether the isolines are plotted depends on the appropriate setting in the plotting parameters area. Oblate-prolate index isoline values should be greater than or equal to 0. Negative values (plotting on the left-hand side of the diagram) are calculated automatically. Maximum projection sphericity isoline values should be between 0 and 1.

Sneed & Folk classes area

This area shows the proportion of particles that fall into each of the Sneed & Folk (1958) descriptive shape classes (Fig. 3). Data are presented as raw counts and percentages.

To generate conventional triangular diagrams

The third sheet in the spreadsheet generates standard triangular diagrams, commonly used for the representation of particle size. The "SIZE" sheet can be accessed using the button on the first sheet or the tab at the bottom of the screen.

The procedure for generating a conventional triangular diagram is almost identical to that outlined above. The inputs required are three values representing the proportions of a whole. An example is the proportions of gravel, sand and mud in a geological sample. The values must be entered as a percentage and total 100. An error is given if the data do not sum to 100. The only other significant differences are that the plotting parameters are more limited and there is no isoline values area.

Advanced operation

The following instructions apply to both the Sneed & Folk and conventional diagrams, unless otherwise noted. The instructions apply to Excel 2000 on a PC and may differ slightly for different versions.

Modifying the appearance of the diagram

The triangular diagram itself is a standard Excel XY scatter graph and may be modified to change line thickness, symbols used and so forth. Each aspect of the diagram is saved as a different data series and may be altered in the standard way for Excel charts. The table below lists the data series that comprise the Sneed & Folk chart (those for the conventional diagram are similar but more limited).

| Data series name | Description |
|----------------------|--|
| User data | User entered data |
| Triangle outline | Defines the triangle |
| Left ticks | Ticks on the left (c/a) axis |
| Right ticks | Ticks on the right (b/a) axis |
| C40 line | Defines the line where $c/a = 0.4$ |
| Left axis lines | Extension of left axis ticks across diagram |
| Right axis lines | Extension of right axis ticks across diagram |
| Bottom axis lines | Extension of bottom axis ticks across diagram |
| Bottom ticks | Ticks on the bottom $((a-b)/(a-b))$ axis |
| Sneed and Folk lines | Boundaries of Sneed and Folk (1958) particle shape classes |
| OPI isolines - RHS | Isolines of the oblate-prolate index on the right of the diagram |
| OPI isolines - LHS | Isolines of the oblate-prolate index on the left of the diagram |
| MPS isolines | Isolines of the maximum projection sphericity |

To change the line thickness, colour etc.

Right click on the object you wish to modify in the chart.

1. Select "Format data series".
2. Select the "Patterns" tab.
3. Change the line and marker properties as desired.
4. Click "OK"

To plot multiple data series on one diagram

It is sometimes useful to plot more than one set of data on a single diagram.

1. Enter all of the data in the usual way. You may enter descriptive text to help differentiate between different datasets in the "error messages" column.

Leaving a blank row between each dataset will make the remainder of the process easier.

2. If more than 250 particles need to be plotted see “increasing the number of particles” below.
3. Right click on the chart and select “Source data”.
4. Modify the text in the “Name” box to represent the first dataset.
5. Click on the icon to the right of the “X values” box.
6. Select the range corresponding to the first dataset in column S (for Sneed & Folk shape diagrams; column L for conventional ternary diagrams). Note: column A contains particle numbers corresponding to those on the data-entry sheet. Press “Enter”.
7. Click on the icon to the right of the “Y values” box and select the appropriate range in column T (for Sneed & Folk shape diagrams; column M for conventional ternary diagrams). Press “Enter”.
8. Click “Add” and type text into the “Name” box to represent the next dataset.
9. Select the appropriate data as above.
10. Repeat steps 8 and 9 for each dataset.
11. If desired, change the appearance of each of the new data series as described above.

Increasing the number of particles plotted

The spreadsheet is initially set up to plot 250 particles. This may be increased up to the maximum number of rows permitted by Excel.

1. Enter all of the data.
2. Scroll down to row 257.
3. Copy the contents of columns A to T into the rows below as many times as necessary.
4. Right click on the chart. Select “Source data”.
5. Follow steps 5 to 7 in the previous section to select the entire new data range.
6. Click “OK”.

Plotting several diagrams in a single spreadsheet

It is possible to copy the SHAPE and/or SIZE worksheets so that several triangular diagrams can be plotted in a single workbook. It should be noted that file sizes can become very large if multiple diagrams are created. This may be a problem when diagrams are embedded in other applications (see “Exporting triangular diagrams”).

Worksheets may be copied by selecting “Move or Copy Sheet” from the “Edit” menu. Ensure the “Create a copy” tick box is selected. It is recommended that the new sheet be given an appropriate name (double click on its tab at the bottom of the screen and type the name).

Exporting triangular diagrams

The completed triangular diagram may be exported to an office or graphics application for final presentation and annotation. The simplest way to do this on a PC is using the Windows® clipboard. After clicking on the graph (you must select the edge – “chart area” – not the “plot area”), select “Copy” from the “Edit” menu or press Ctrl-C. Switch to the office or graphics application. Select “Paste Special” from the “Edit” menu. You have a choice between importing as an Excel chart or an enhanced metafile. In general the latter is preferable. If you choose to import the Excel chart you will have a choice between embedding the spreadsheet within the document (the “paste” radio button is selected) or linking to the original spreadsheet (the “paste link” radio button is selected). The table below outlines the merits of each option.

| Embedded Excel chart (“paste” selected) | Linked Excel chart (“paste link” selected) | Enhanced metafile |
|---|--|---|
| + Diagram is editable from within the document | + Diagram is editable within Excel by double clicking in the document | - Diagram is not editable – you must get it right in Excel then copy it |
| | + Changes in the source spreadsheet are automatically reflected in the document | |
| - Excel may automatically re-format the diagram (aspect ratio, text size etc.) | - Excel may automatically re-format the diagram (aspect ratio, text size etc.) | + What you see in the document is what you get in printed output |
| - May result in large file sizes. The entire spreadsheet is included each time a new chart is added to the document | + Increase in document file size is quite small | + Increase in document file size is quite small |
| + Once the diagram is copied to the document, the original spreadsheet can be used to create the next diagram without affecting the first | - You must create a new spreadsheet/worksheet for each diagram as any changes are automatically propagated to the document | + Once the diagram is copied to the document, the original spreadsheet can be modified without affecting the document |

If embedded charts are used, deleting any unused sheets in the Excel workbook before pasting the chart into the document will reduce the file size of the resulting document. Conversely, when multiple diagrams are present in a single workbook, embedding diagrams will result in very large document file sizes.

If you wish to copy the diagram 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.

Alternative applications

In addition to its use for the representation of particle shape, the spreadsheet has the 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 the ratios of eigenvalues (Fig. 6). These diagrams can be plotted using the "SHAPE" sheet 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 is 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 ($S_2:S_1$).

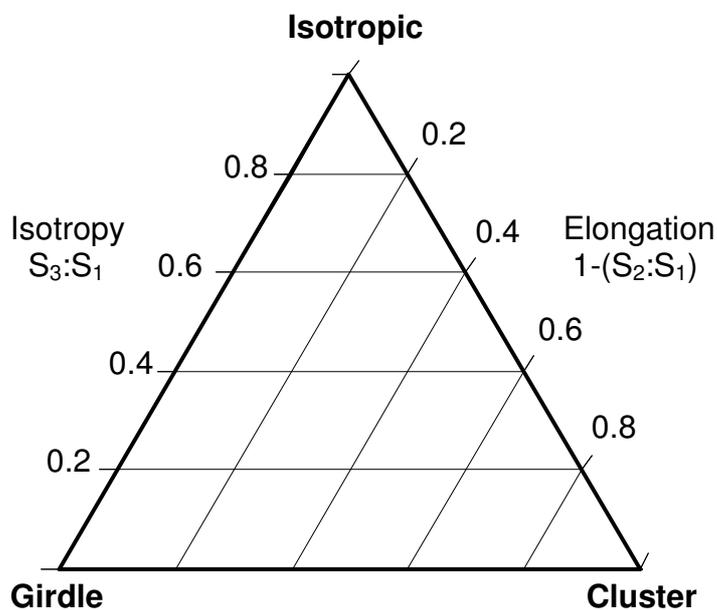


Fig. 6. Triangular eigenvalue plot devised by Benn (1994) for the representation of fabric shape. The three eigenvalues S_1 , S_2 and S_3 represent the degree of clustering around the eigenvectors that describe the orientation of the long axes of the particles within a sample.

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Appendix – Graham & Midgley (2000)

TECHNICAL COMMUNICATION

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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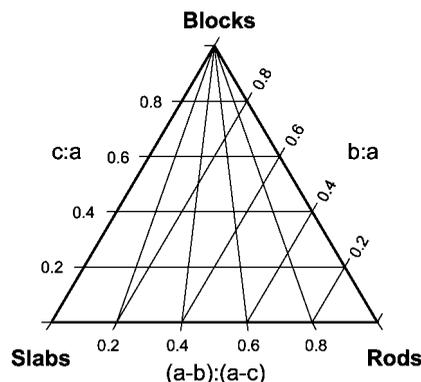


Figure 1. Particle shape (Sneed and Folk) triangular diagram. Letters a, b and c represent the long, intermediate and short orthogonal axes of each particle respectively

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

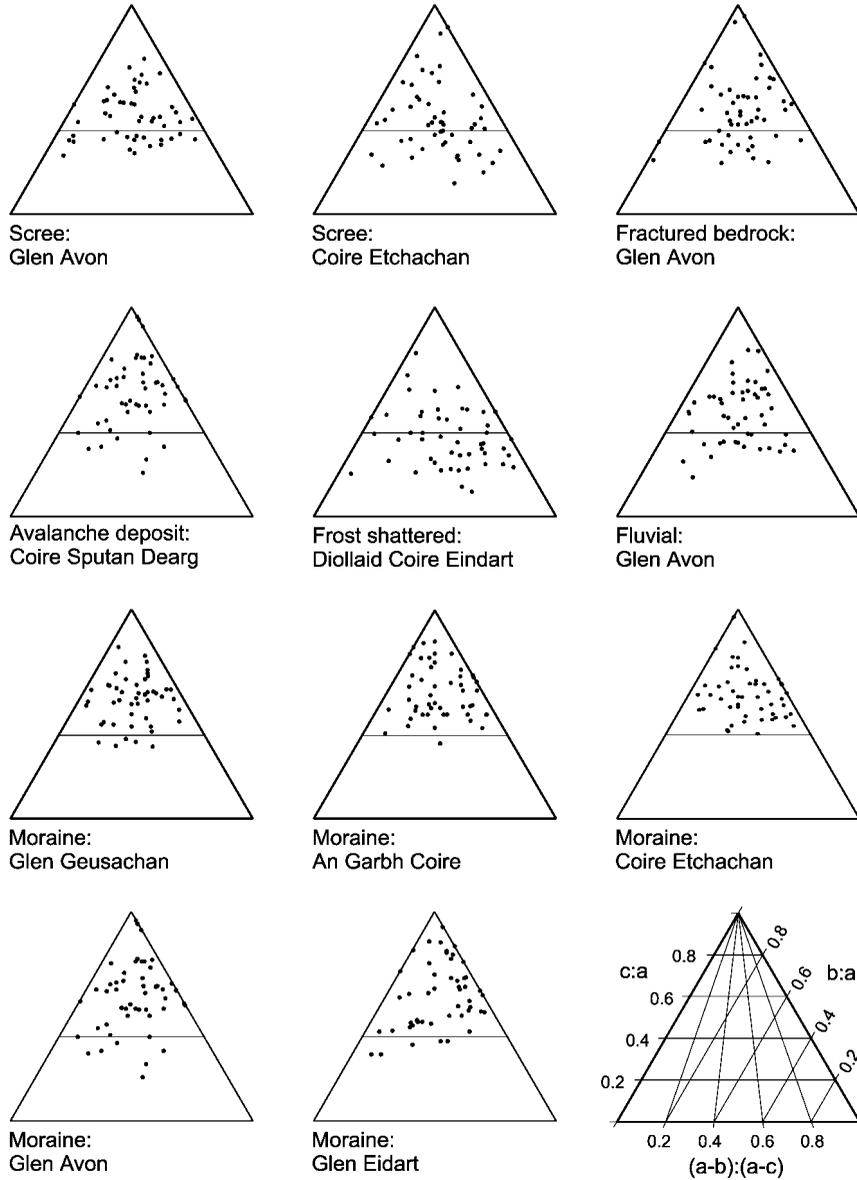


Figure 2. Particle shape (Sneed and Folk) triangular diagrams for clast samples ($n = 50$) of known origin from a number of sites in the Cairngorm Mountains, Scotland

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

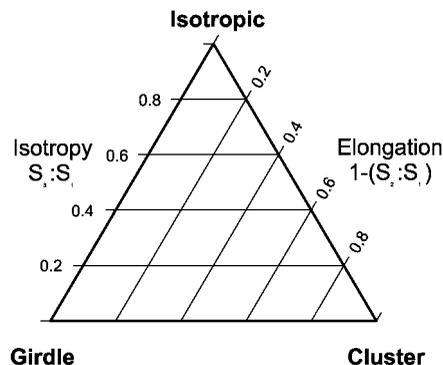


Figure 3. Triangular eigenvalue plot devised by Benn (1994) for the representation of fabric shape. The three eigenvalues S_1 , S_2 and S_3 represent the degree of clustering around the eigenvectors that describe the orientation of the long axes of the particles within a sample

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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