6 More about graphs

6.1 Introduction

In one sense geologists frequently have too much data. A field geologist may have a notebook full of dip, strike and location measurements, a geochemist may have analyses of 10 different elements in 100 different rock samples, or a geophysicist may have more than a kilometre of computer tape for every kilometre of a 1000 km seismic survey. In all these cases the problem is the same, the scientist involved must somehow make sense of a mass of data that is far too large to be digested raw. There are three things that can be done about this.

(i) Throw away most of the data. Usually this means ignoring all data which does not fit some preconceived notion. This is very definitely not recommended although it is quite frequently done!

(ii) Perform a statistical analysis. This is the subject of the next chapter.

(iii) Plot the data on a graph which will allow the general properties of the data to be visualized. This is the subject of this chapter.

In fact, although I have separated them here, statistics and graphing are subjects which overlap very significantly.

This chapter deals with graphs in which each data item is plotted as a point on a suitable piece of graph paper. The most common graph of this type has already been used extensively, particularly in Chapter 2. This is the simple x–y graph which has two axes at right angles to each other, representing two different quantities. Figure 6.1, shows such a graph which plots sediment density against depth in a well. Each point represents a specific measurement of depth and density. The remainder of this chapter is about variations upon this simple theme.

6.2 Log-normal and log-log graphs

The use of logarithms, to enable a wide spread of data to be visualized, has already been introduced in Chapter 2. Table 6.1 gives the masses of various modern and extinct animals together with the total areas of the soles of their feet (this is relevant to whether these animals could walk on soft mud without sinking in and can help to indicate the environment in which they lived). This data is plotted on an x–y type graph in Fig. 6.2. Note that all the points except

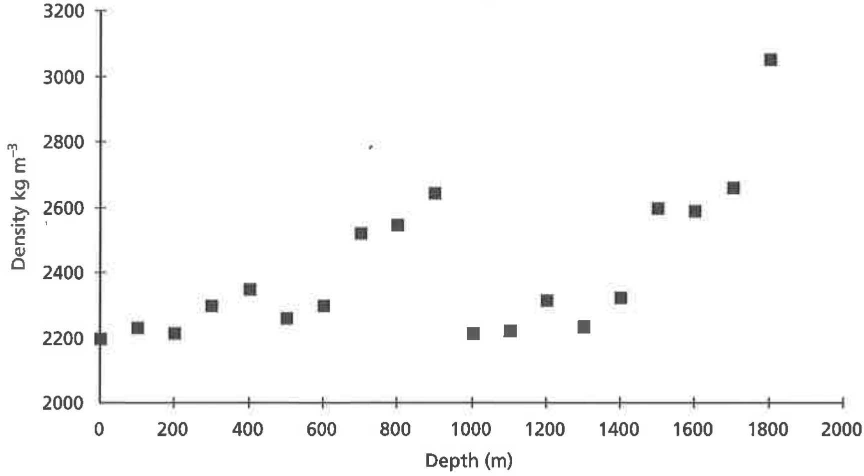

Fig. 6.1 A simple *x–y* plot of sediment density versus depth in a particular well.

Table 6.1 Masses and total foot area for modern and extinct animals. Data taken from Alexander, R. (1989). *Dynamics of Dinosaurs and other Extinct Giants*, Columbia University Press, New York.

Animal	Mass (kg)	Log(mass)	Foot area (m^2)
Apatosaurus	35 000	4.54	1.2
Tyrannosaurus	7000	3.85	0.6
Iguanodon	5000	3.70	0.4
African Elephant	4500	3.65	0.6
Cow	600	2.78	0.04
Human	70	1.85	0.035

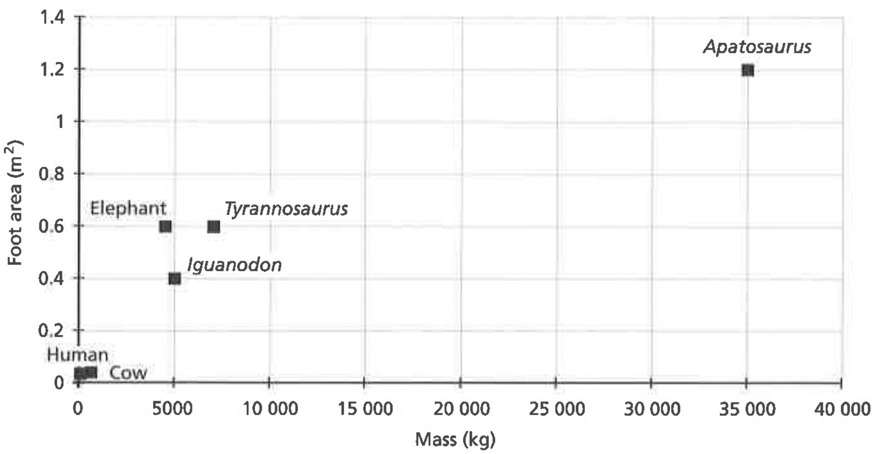

Fig. 6.2 Simple *x–y* plot of the data in Table 6.1. Note that five out of the six data points are squeezed into the leftmost fifth of the graph.

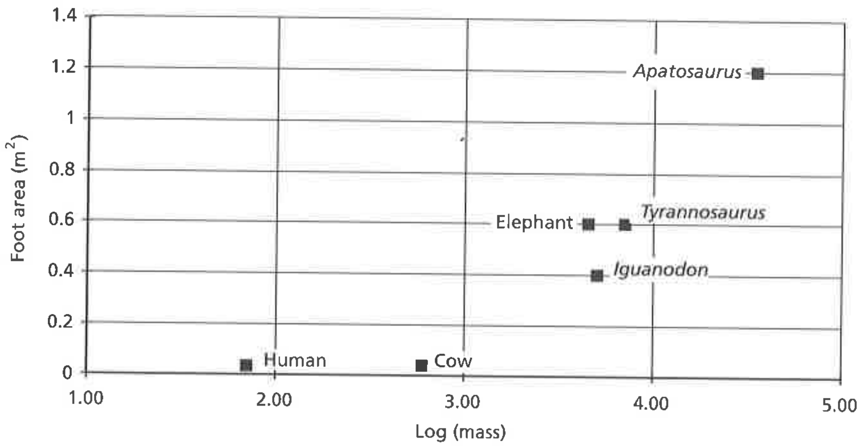

Fig. 6.3 Plot of foot area as a function of logarithm of the mass. Data is now much better spread across the plot.

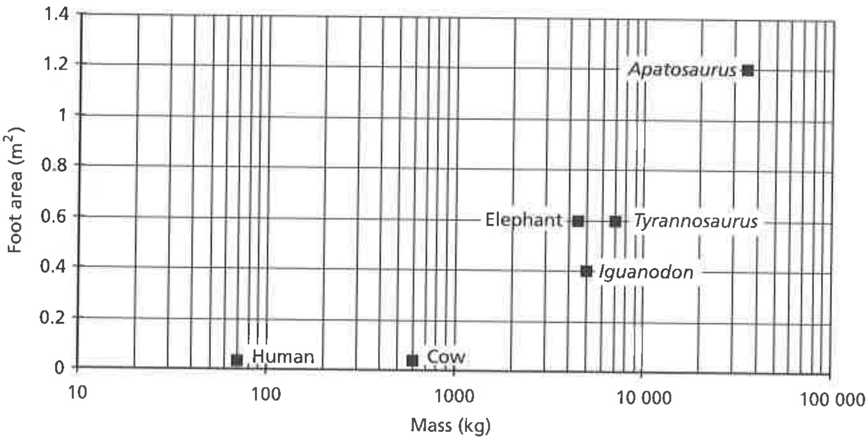

Fig. 6.4 An alternative to Fig. 6.3. Plot the raw data but use a logarithmically scaled axis. The resultant graph is the same shape as before but is easier to read.

one are squeezed into the leftmost fifth of this graph which makes the graph difficult to analyse. A solution to this problem is to plot using the logarithm of the mass instead as discussed in Section 2.8 and the result of doing this is shown in Fig. 6.3.

The problem with Fig. 6.3, however, is that it is now difficult to read off values on the horizontal axis. For example, without looking at Table 6.1, what is the mass of an elephant? You have to read down to the axis (gives 3.65) and then take the inverse logarithm (i.e. mass = $10^{3.65}$ = 4467 kg). This is rather tedious and error prone. An alternative, shown in Fig. 6.4, is to use a logarithmically scaled axis. Note that the distance on the horizontal axis between 100 kg and 1000 kg (a 10-fold increase) is the same as the distance between 10 kg and 100 kg (also a 10-fold increase). The result is a graph

Magnitude	Number per year
8	1
7	18
6	108
5	800
4	6 200
3	49 000
2	300 000

Table 6.2 Average earthquake frequency between 1918 and 1945. Data from Gutenberg, B. and Richter, C.F. (1954). *Seismicity of the Earth and Associated Phenomena*, Princeton University Press, Princeton.

whose shape is identical to that of Fig. 6.3 but from which it is much easier to read the mass of any given animal. Such a graph is known as a **log-normal** plot since one axis (the horizontal one in this case) is scaled logarithmically whilst the other has a normal scale. Note that the grid lines initially go up in multiples of 10 (i.e. the left-most grid line is for 10 kg, the second one for 20 kg etc.) until 100 kg is reached. Then the grid lines go up in multiples of 100 kg (i.e. the next grid line is for a mass of 200 kg) until 1000 kg is reached. Grid lines then increase in multiples of 1000 kg. Hence, the mass of the elephant can be read off the axis as around 4500 kg.

Question 6.1 Table 6.2 gives the average frequency (number per year) of earthquakes of various magnitudes over the period 1918 to 1945.
Using this data:
(i) Plot the frequency as a function of magnitude on normal graph paper. (Frequency should be on the vertical axis.)
(ii) Plot the frequency as a function of magnitude on log-normal graph paper.
(iii) Plot *log*(frequency) against magnitude on normal graph paper. Estimate the constant b in the equation $\log N = k - bM$ where N is frequency, M is magnitude and k is a constant.

It would have been more difficult, although not impossible, to estimate b from the second graph you plotted. Thus, if the main objective is to display the data more clearly, use log-normal graph paper but, if the objective is to estimate a parameter such as b, take logarithms first and plot on normal graph paper.

In Table 6.1, the foot areas are also spread over a rather large range. It might be useful, therefore, to take logarithms of the areas or to use logarithmically scaled axes in both directions. Figure 6.5 is an example of such a **log-log** plot.

Question 6.2 Using Fig. 6.5, what is the mass and total foot area of *Brachiosaurus*?

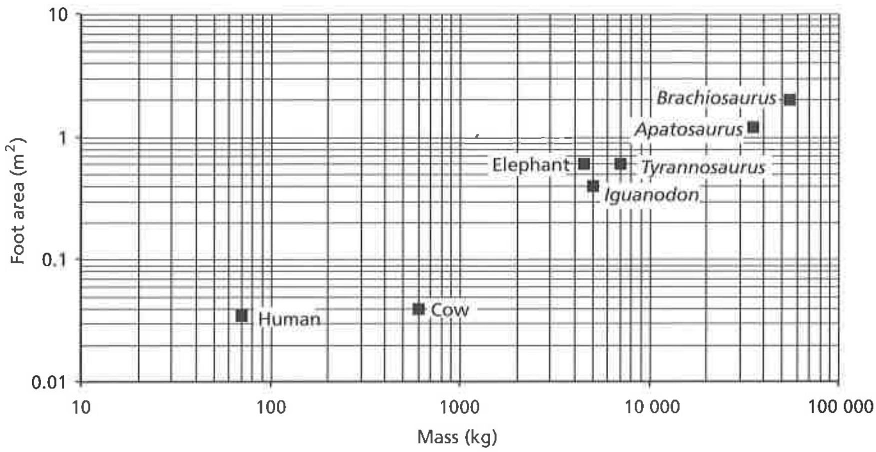

Fig. 6.5 The data from Table 6.1 plotted using logarithmic axes in both directions.

Incidentally, in this example, using a logarithmic scale for the vertical axis has only made a marginal improvement. However, in other cases it will make a much more useful alteration in the distribution of the data across the graph.

6.3 Triangular diagrams

Triangular diagrams can be used whenever you wish to visualize the relative proportions of three components making up a specimen. Common examples are:

(i) The proportions of sand (particles between 2 and 0.063 mm diameter), silt (0.063–0.004 mm) and clay (less than 0.004 mm) in a sedimentary rock;

(ii) An **AFM diagram** which shows the proportions of alkalis, iron and magnesium in a volcanic rock.

Figure 6.6 shows simple cases from the sedimentological example. Point A sits in the corner marked '100% clay' and represents a sediment containing only clay. Similarly, points B and C represent rocks containing exclusively

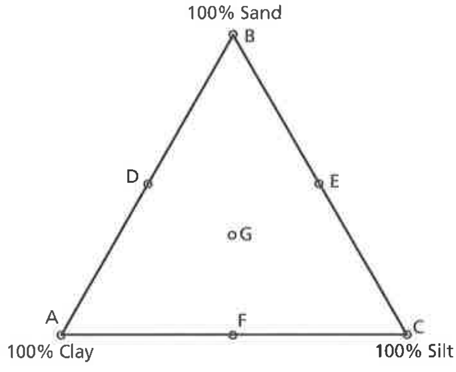

Fig. 6.6 A triangular diagram showing the proportion of clay, sand and silt for seven different sedimentary rock specimens.

sand and silt, respectively. Point D lies half way along a line joining 100% clay to 100% sand. It represents a sediment half of which is clay and half of which is sand. Similarly, point E is a 50 : 50 sand–silt mixture whilst point F is a 50 : 50 clay–silt mixture. Finally, point G is in the centre of the triangle, equidistant from all three edges, and represents a sediment which consists of a 1/3 clay, 1/3 sand and 1/3 silt mixture.

It is also, I think, fairly obvious where to plot a point corresponding to, say, 40% clay and 60% sand and which, therefore, contains no silt. This point will be on the line joining 100% sand to 100% clay and will be 40% of the distance along from sand to clay (or, equivalently, 60% of the distance along from clay to sand), i.e. slightly closer to sand than to clay.

Question 6.3 Plot the 40% clay, 60% sand point onto Fig. 6.6.

These examples are relatively straightforward and it is quite easy to see where on the triangular plot each of these points should go. What about a sediment containing 36% sand, 24% silt and 40% clay? Figure 6.7 illustrates how this

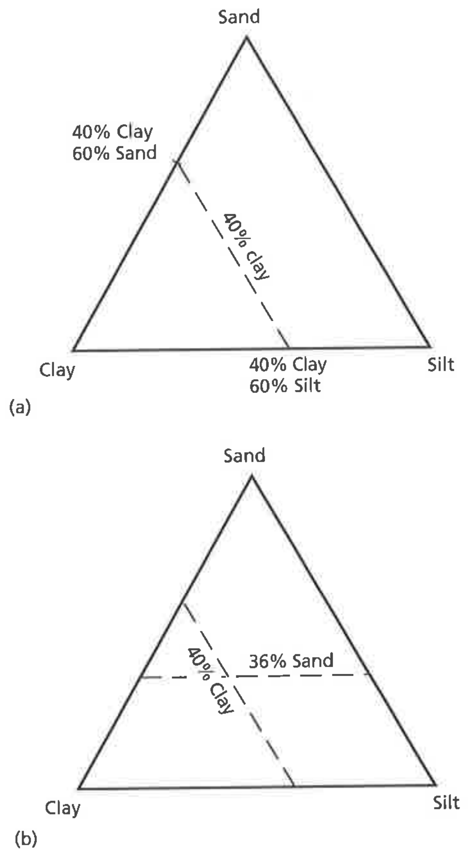

Fig. 6.7 Plotting a point which is 40% clay, 24% silt and 36% sand.

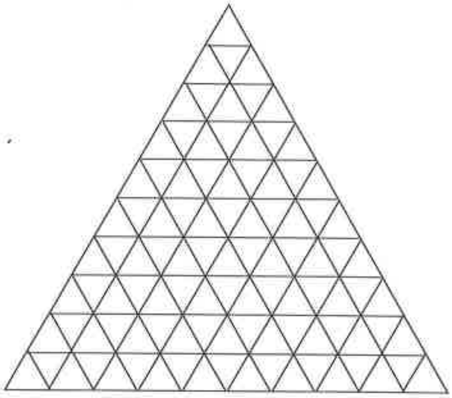

Fig. 6.8 A triangular diagram net. Lines are drawn here at 10% increments although most such graph paper would also have 1% intervals marked.

is done. In Fig. 6.7a, a line has been drawn which connects the 40% clay, 60% sand point to a point representing 40% clay, 60% silt. All points along this line contain 40% clay but have differing amounts of sand and silt making up the remaining 60%. Similarly, Fig. 6.7b shows a line representing all points which have 36% sand. The point where the 40% clay line intersects the 36% sand line is, of course, a point representing a sediment with 36% sand and 40% clay and which must, therefore, be 24% silt.

To assist in accurate plotting of such points, a triangular net similar to that shown in Fig. 6.8 is used. For clarity in this illustration, the lines are drawn at 10% intervals, although these lines will usually be plotted at 1% intervals on most sheets of triangular graph paper.

Question 6.4 Use Fig. 6.8 or some triangular graph paper to plot an AFM diagram as follows.

The left corner of the plot represents 100% ($Na_2O + K_2O$). The right-hand corner represents 100% MgO. The top corner represents 100% ($FeO + Fe_2O_3$). Mark these points on your graph and then plot the following data which is taken from a set of related volcanic rocks.

(i) 10% ($Na_2O + K_2O$), 45% MgO, 45% ($FeO + Fe_2O_3$).
(ii) 10% ($Na_2O + K_2O$), 35% MgO, 55% ($FeO + Fe_2O_3$).
(iii) 10% ($Na_2O + K_2O$), 25% MgO, 65% ($FeO + Fe_2O_3$).
(iv) 12% ($Na_2O + K_2O$), 20% MgO, 68% ($FeO + Fe_2O_3$).
(v) 15% ($Na_2O + K_2O$), 15% MgO, 70% ($FeO + Fe_2O_3$).
(vi) 18% ($Na_2O + K_2O$), 12% MgO, 70% ($FeO + Fe_2O_3$).
(vii) 23% ($Na_2O + K_2O$), 12% MgO, 65% ($FeO + Fe_2O_3$).

A graph such as this can furnish significant information about the evolution of a volcanic rock series. However, the way in which this is done, as well as the details of how to obtain the numbers to plot, is beyond the scope of this book.

Fig. 6.9 Classification of delta types using a triangular diagram.

Before leaving the subject of triangular diagrams, it is worth mentioning that they can be used for classification of geological features if there are three clear **end members** to such a classification scheme. For example, deltas are commonly classified as being dominated by fluvial, wave or tidal processes. However, real deltas are influenced to some extent by all three types of process and will not be accurately represented by a simple threefold classification scheme. The solution is to use a triangular diagram to represent all possible deltas (Fig. 6.9). Real deltas will then fall at some point within the diagram which represents the proportions of fluvial, wave and tidal effects governing the geometry.

6.4 Polar graphs

Some types of data are naturally cyclic. For example, the data in Table 6.3 gives the strength of the non-dipole portion of the Earth's magnetic field at

Table 6.3 Non-dipole magnetic strength (in micro tesla) at various locations around the Earth's equator.

Longitude	Non-dipole strength (μT)
0	17.5
30	13
60	6
90	9.5
120	9.5
150	7
180	4.5
210	3
240	3
270	2
300	5
330	14

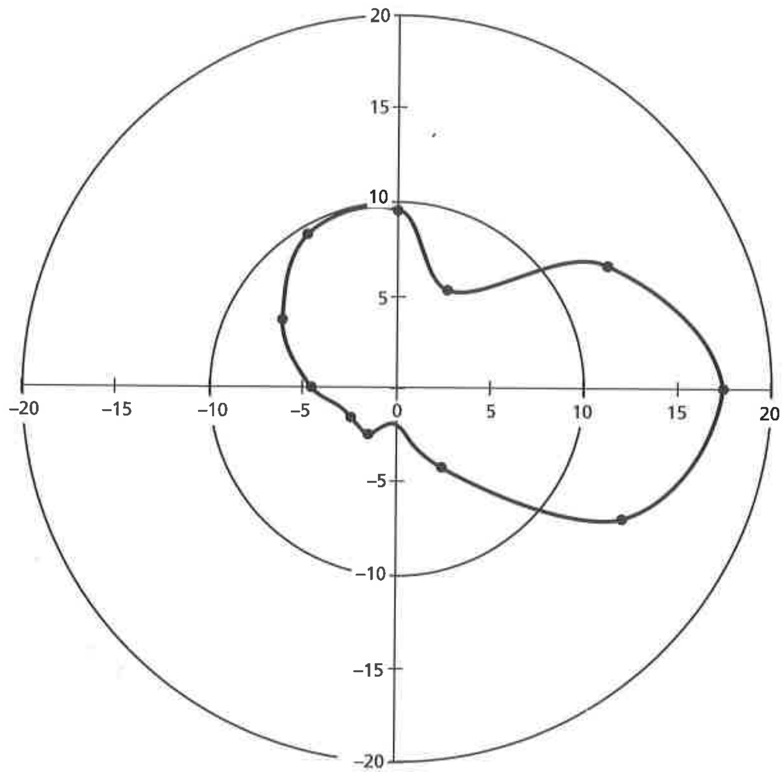

Fig. 6.10 The data from Table 6.3 plotted in polar form.

various locations around the equator (the non-dipole field is that part of the magnetic field which can't be explained as due to a simple bar magnet). Now, the data at a longitude of 330° is only 30° from the data at 0° but, on an x–y plot, it would appear at the opposite end of the graph. Using a polar plot avoids this problem (Fig. 6.10). In the polar plot, the longitude is plotted around the circumference of a circle whilst the field strength is given by the distance from the plot centre (i.e. the stronger the field the further the point is from the centre).

6.5 Equal interval, equal angle and equal area projections of a sphere

This section deals with the problem of plotting data measured on the surface of a sphere onto a flat sheet of paper. This problem occurs, for example, in map making when it is necessary to represent a large portion of the Earth's surface by a map in an atlas. This cannot be done without distortion and there are therefore a large number of different ways of doing this, each of which has advantages and disadvantages. This section will deal with three

Apparent dip	Azimuth
44	11
12	305
31	79
42	2
21	318
34	337
7	112
39	352

Table 6.4 Apparent dip measurements from a single bed at eight different locations. The azimuth gives the directions along which the apparent dips were measured.

very similar methods which are widely used in structural geology, crystallography, earthquake seismology and many other branches of Earth science. These **projections** are useful whenever information about directions in three dimensions is plotted and they enable many, otherwise complex, manipulations to be carried out relatively simply. There are subtle differences between the methods used in different branches of geology but there is a core of ideas and methods which is common throughout. In this section I introduce some of these ideas but, it must be emphasized, application in particular fields has much more extensive uses than those described here. This section is very much a starting point for the more detailed discussions you will meet in specific geological sub-disciplines.

Consider a bed which outcrops at various locations and whose apparent dip has been measured along a different orientation at each of the different locations. Table 6.4 lists such a series of apparent dip measurements together with the directions in which these dips were measured. Is the bed a simple planar dipping one or is the bed folded in some way? If the bed is planar, what is the true dip and dip direction?

Figure 6.11 illustrates the starting point for resolving these issues. This diagram assumes that the bed is indeed a simple dipping planar bed represented by the dipping plane in this figure. The arrows drawn on the plane represent measurements of apparent dip of this surface taken in various orientations. A sphere is drawn with its centre on the plane. The intersection of the plane and sphere is a **great circle**. A great circle is any circle on the surface of a sphere whose centre lies at the centre of the sphere. Thus, the equator and lines of longitude on the Earth's surface are great circles but lines of latitude are not. The individual apparent dip measurements start at the centre of the sphere and intersect the sphere at points on the great circle. If you think of the sphere as having lines of latitude and longitude in a similar fashion to the Earth, each point plots at a 'southerly' latitude equal to the apparent dip and at a longitude equal to the azimuth. Thus, if we plot the projection of our dip measurements onto a sphere and if the resulting points lie along a great

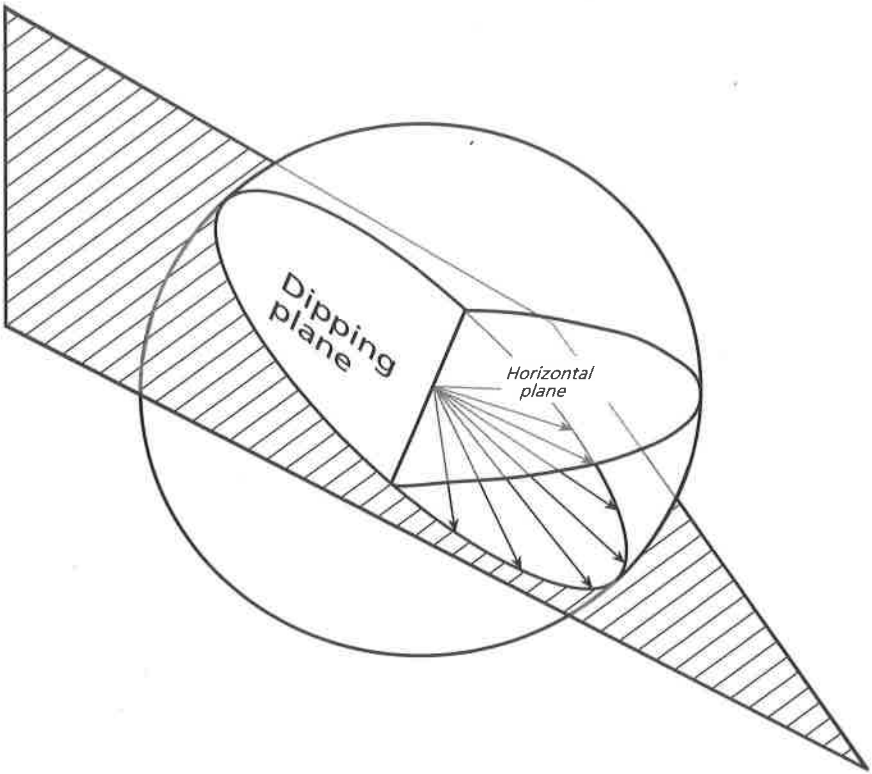

Fig. 6.11 Spherical projection of apparent dip measurements. These will lie along a great circle if the bed is planar.

circle, the measured bed is a simple dipping plane. On the other hand, if this **spherical projection** of the dip measurements is not a great circle, the bed is not planar. Note that, because dips are always measured below the horizontal, only half of all possible orientations are represented. Thus, the spherical projection of the dip data should actually define a semicircle (i.e. the lower half of the great circle).

The problem now is that plotting and performing measurements on a sphere is not very convenient. A solution would be to plot the data using a projection which represents the surface of the sphere on a flat sheet of graph paper.

A method for doing this, bearing in mind that we only have to deal with the lower hemisphere, is to plot onto polar graph paper. To do this, the azimuth is plotted around the circumference of the plot and distance, r, from the centre of the plot is used to represent dip. There are, however, many ways of doing this. The simplest is just to let the distance from the plot edge be proportional to the dip. In other words, dip increases linearly from zero at the plot circumference to 90° at the plot centre. Thus, if a point on the plot

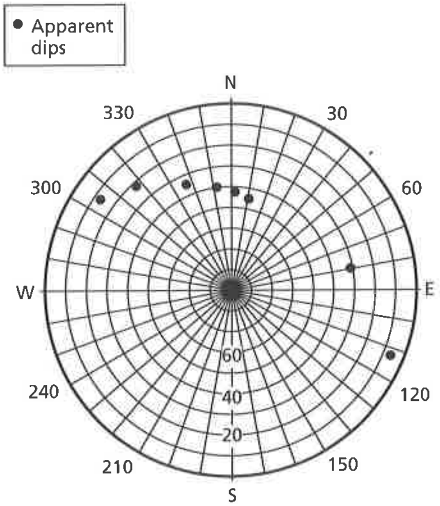

Fig. 6.12 Equal interval polar plot of the data from Table 6.4.

represents a dip of ϕ, the corresponding distance, r, from the plot centre is given by

$$r = R(90 - \phi)/90 \tag{6.1}$$

where R is the plot radius. For example, a dip of 45° would plot at a distance of

$$\begin{aligned} r &= R(90 - 45)/90 \\ &= R/2 \end{aligned}$$

i.e. half way between the plot edge and the plot centre. Similarly, a dip of 0° would be at the plot edge (i.e. $r = R$) and a dip of 90° would be at the graph centre (i.e. $r = 0$).

Question 6.5 Using Eqn. 6.1, calculate how far apart two points with the same azimuth but dips of 10° and 20° are. Assume the graph radius, R, is 90 mm. Repeat this calculation for dips of 70° and 80°.

Using this method for plotting the measurements in Table 6.4 results in Fig. 6.12 and is known as an **equal interval projection**. The data certainly looks as if it might lie along a semicircle but we have the problem that we don't really know whether this is half of a great circle or just some other fairly smooth curve.

Figure 6.13 shows a **stereographic** or **equal angle projection** of the apparent dip data. This is very similar to the equal interval plot (Fig. 6.12) except that the distance between the circles representing dip is not constant. Note, for example, that the distance between the 0° dip and 10° dip circles is greater

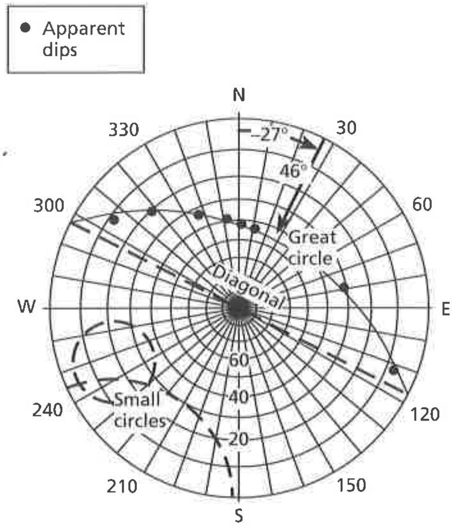

Fig. 6.13 Equal angle (stereographic) projection of the data from Table 6.4. A great circle is also shown which passes close to the apparent dip measurements. Two example small circles are also shown.

than the distance between the 70° dip and 80° dip circles. In this case, the distance from the plot centre is given by

$$r = R \tan[(90 - \phi)/2] \tag{6.2}$$

Thus, a dip of 45° would plot a distance

$$\begin{aligned} r &= R \tan[(90 - 45)/2] \\ &= R \tan(22.5) \\ &= 0.414\, R \end{aligned}$$

which is significantly closer to the centre than half way out (i.e. closer to the centre than in the equal interval plot). Applying Eqn. 6.2 to the cases of zero dip and 90° dip gives a result of $r = R$ and $r = 0$, respectively (the same as for the equal interval plot).

> **Question 6.6** Repeat question 6.5 using Eqn. 6.2. How do these results compare to the equal interval case?

The equal angle projection has two important properties. Firstly, angles measured on the projection are the same as angles on the surface of the sphere. This is particularly useful in crystallography. Secondly, circles drawn on the surface of the sphere project as circles on an equal angle plot and this will be useful for solving our apparent dip problem. Figure 6.13 shows three examples of projections of circles. Two of these are projections of **small circles** (i.e. circles on the surface of a sphere which are not great circles). A great circle is also plotted and is an arc of a circle whose start and end locations define a diagonal to the plot since the two points where it crosses

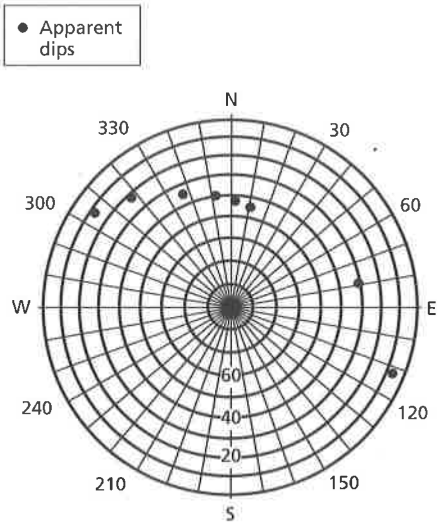

Fig. 6.14 Equal area plot of the data from Table 6.4.

the 0° dip line on the sphere must be opposite each other. In particular, the great circle plotted has been chosen to pass as close as possible through the dip/azimuth data.

This great circle clearly passes quite well through the data points so we can say that the apparent dip measurements are, indeed, taken from a simple planar dipping bed. The true dip and dip direction can also now be found. A dip measurement made in any direction other than the true direction of dip must be smaller than the true dip. Hence, the true dip corresponds to the maximum dip crossed by the great circle. This occurs at the point shown and the true dip and dip direction can be read off as 46° in a direction 27° E of N.

The equal angle projection has the disadvantage that it distorts areas. A figure near the circumference of the plot will plot as an area four times larger than an identical figure at the plot centre. Figure 6.14 shows an **equal area projection** of the apparent dip data. In this case the concentric circles get closer together towards the edge of the plot and r is given by

$$r = \sqrt{2}R \sin[(90 - \phi)/2] \tag{6.3}$$

This time, a dip of 45° will plot at a distance

$$\begin{aligned} r &= \sqrt{2}R \sin[(90 - 45)/2] \\ &= \sqrt{2}R \sin(22.5) \\ &= 0.541R \end{aligned}$$

which is significantly further from the centre than half way out (i.e. further out than in the equal interval plot). Applying Eqn. 6.3 to the cases of zero dip and 90° dip gives a result of $r = R$ and $r = 0$, respectively (the same as for the equal interval plot).

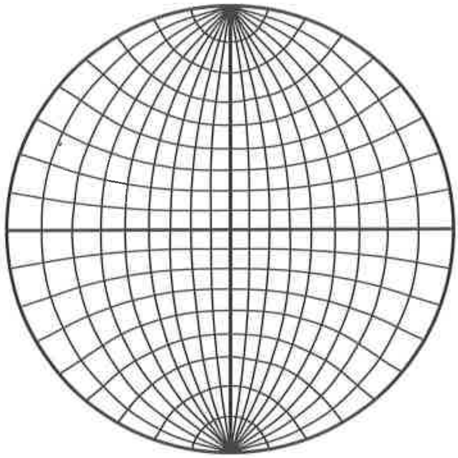

Fig. 6.15 Equatorial net which has great circles and small circles plotted on it.

Question 6.7 Repeat question 6.5 using Eqn. 6.3. This time compare your results to both the equal interval and equal angle plots.

The equal area plot has the property that equal areas on the surface of the sphere project as equal areas on the plot. The disadvantage is that circles and angles are now distorted. The equal area projection is frequently used in structural problems rather than the equal angle projection since the density of plotted points is often important and this is distorted by the equal angle projection.

To make it easier to find great circles (and indeed small circles) on these projections, a slightly different type of display from the polar plots is normally used. These are called **equatorial nets** and are drawn with great circles and small circles already plotted upon them. Figure 6.15 shows the equatorial net for the equal angle case. This is known as a **Wulff net**. The equivalent plots for the equal interval and equal area projections are called **Kavraiskii nets** and **Schmidt nets**, respectively, and have a similar appearance to the Wulff net. In Fig. 6.15, the great circles and small circles cut the vertical and horizontal axes at 10° intervals and cut the circumference of the net at 10° azimuth intervals (these lines will usually be drawn at even finer intervals on these nets).

These nets are extremely useful, but plotting a point on an equatorial net is slightly more involved than on the polar type plots. Plotting the position of data points is normally achieved using an equatorial net mounted on a board with a drawing pin through the centre of the net and into a piece of tracing paper placed over the net. This arrangement allows the tracing paper, upon which the data is plotted, to be rotated above the net. Figure 6.16 (a, b and c) shows how to plot one of the data points from Table 6.4 (dip 31°, azimuth 79°) as follows. Figure 6.16a shows a Wulff net with North marked onto the

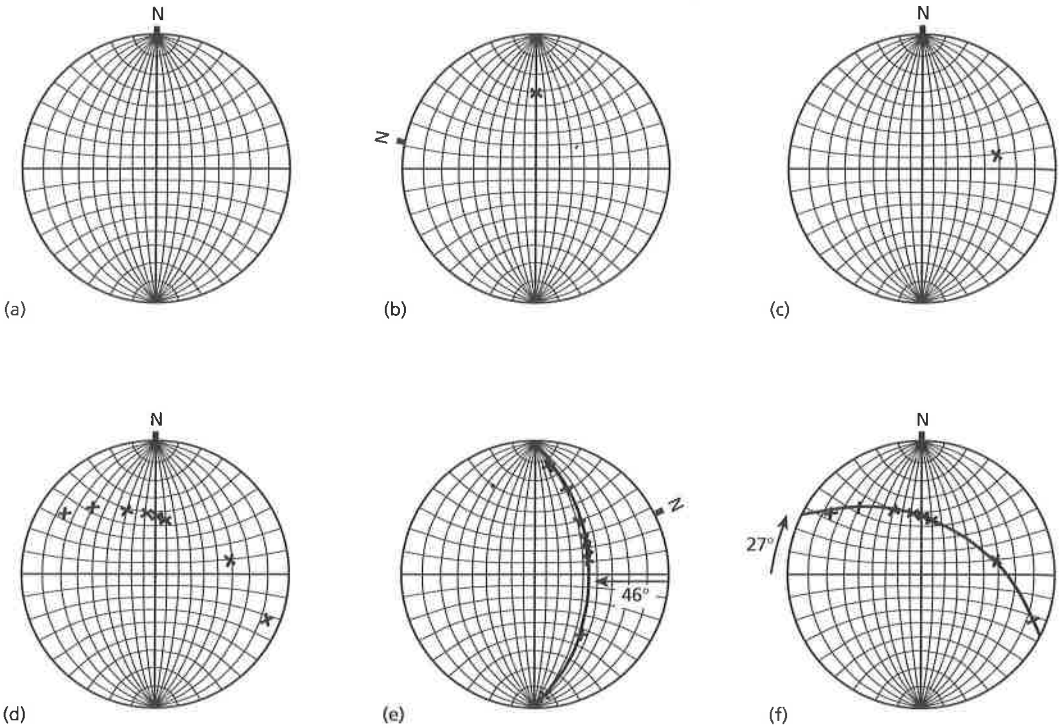

Fig. 6.16 Plotting of the data from Table 6.4 onto an equatorial net.

tracing paper at the top of the net. In Fig. 6.16b the tracing paper is rotated anticlockwise by 79° and the point is plotted 31° down from the top of the net. Rotating the tracing paper so that North is again at the top results in the point being correctly positioned over the net (Fig. 6.16c).

Repeating this procedure for all of the data points from Table 6.4 results in Fig. 6.16d. This figure can then be rotated until the points lie along a great circle (Fig. 6.16e). The distance of this great circle from the plot edge gives the maximum dip value (46°). Finally, rotating the paper again so that North is uppermost results in Fig. 6.16f in which the data and the great circle appear in their correct positions and it can be seen that the dip direction is 27° E of N. Exactly the same set of manipulations can be performed with either the Kavraiskii or the Schmidt nets and, indeed, for many purposes these nets are interchangeable.

The above is only one example of the many problems which these projections can solve. Other examples are: determining the axes of folded structures; determining the earlier orientations of structures which have been multiply deformed; determining detailed earthquake mechanisms; characterizing and identifying crystal structures. This list is very far from being exhaustive. Quite a few of these involve plotting the **poles** of a surface rather than a direction lying on a surface. Poles are outward pointing **normals** to the surface

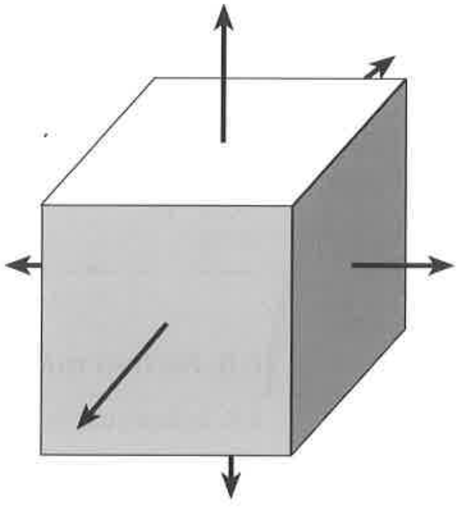

Fig. 6.17 The 6 poles to the faces of a cube.

(i.e. lines at right angles to the surface). In structural geology, downward pointing normals are used instead. Figure 6.17 shows the poles of the surfaces forming a simple cube. As you can see, if this cube has its upper and lower faces horizontal, these poles would plot in a spherical projection with two points at the poles of the sphere and with the remaining four points around the equator.

A small complication with transferring this data to a stereographic (or other) projection is that we have points plotted in both the upper and lower hemispheres whereas a stereographic projection represents only one hemisphere. The solution is to use two projections, one for the upper hemisphere and one for the lower. In practice, both sets of points are plotted on one graph and the difference between them is indicated by using dots for the upper hemisphere points and circles for the lower hemisphere points. Thus, the stereographic projection of the cube poles produces Fig. 6.18.

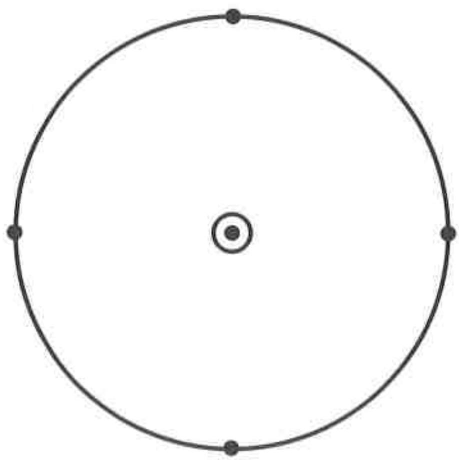

Fig. 6.18 Stereographic projection of the poles from Fig. 6.17. The top and bottom faces plot as the dot and circle, respectively.

Age (My)	Area (10^6 km^2)
> 450	91.1
> 900	50.0
> 1350	35.4
> 1800	26.7
> 2250	7.3
> 2700	1.1

Table 6.5 Area of continental basement which is older than a given age. *Source*: Hurley, P. and Rand, J. (1969). Pre-drift continental nuclei. *Science*, **164**, 1229–42.

6.6 Further questions

6.8 Sedimentary beds, when folded, can have three types of geometry:

(i) Planar (i.e. not folded at all);
(ii) Cylindrical (i.e. folded around one axis, think of a towel hanging over a towel rail);
(iii) Isoclinal (i.e. dome shaped).
In practice, these are the extreme types of fold and real beds are deformed using a combination of these. Thus, for example, a bed might have a very gentle cylindrical fold which can be thought of as a combination of the planar and cylindrical end members. Another bed might be tightly folded around one axis and be gently folded about another axis at right angles (imagine the towel on the towel rail again but this time the rail itself is bent up in the middle). This would be a combination of cylindrical and isoclinal folding. What type of graph would be suitable for illustrating the above concepts?

6.9 Table 6.5 shows the total area of continental crust which is older than a given age. Plot this data in a variety of ways and decide which, you believe, shows the data best.

6.10 Cross-sections through the Earth taken parallel to the equator are, to a good approximation, circular. However, there are small variations due to mountain ranges, ocean basins etc. Imagine such as section taken at a latitude of, say, 30° N. The difference between a circle and the actual section could be tabulated as a function of longitude. What form of plot would be best for displaying such data?

6.11 Consider Fig. 6.19 which shows a planar bed which has been folded about a single axis. Some of the poles to the bedding are also shown and these point in various directions because of the fold.
(i) What form would you expect a spherical projection of the poles to bedding to take?

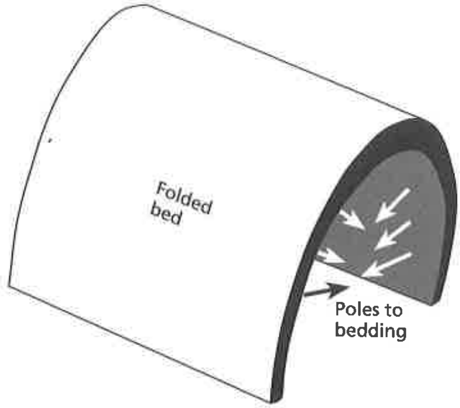

Fig. 6.19 See question 6.11.

(ii) How does the direction and dip of a pole relate to the direction and amount of bed dip at any particular point? For example, if a bed dips towards 30° E of N what direction does the pole point? If the same bed has a dip of 20° what is the dip of the pole?
(iii) Determine the poles resulting from the following bed dip data and plot them onto an equatorial net

Dip (°)	Dip direction (° E of N)
70	182
65	170
25	131
40	70
36	90
70	35
40	40
37	73
37	146

(Data from McClay, K. (1987) *The Mapping of Geological Structures.* John Wiley, Chichester.)
(iv) Is this information consistent with being taken from a bed folded around one axis?

6.12 Consider the following data:

Location	Dip	Strike	%Sand	%Limestone	%Marl	%TOC	Age (Ma)
1	44	11	10	90	0	0.01	42
2	12	305	30	30	40	14	36
3	7	112	60	20	20	1	38
4	31	79	5	5	90	50	32

Sketch the best types of graphs for showing the following. Ensure the graphs have well-labelled axes and that all appropriate data is marked in approximately the right locations.
(i) The dip and strike relationships.
(ii) The %sand, limestone and marl on a single graph.
(iii) The %TOC as a function of age.

6.13 Use spreadsheet *Triangle.xls* to replot the data from question 6.4.

6.14 Use spreadsheet *Polar.xls* to replot the data from question 6.11 using equal-interval, equal-angle and equal-area projections.