2 BASE MAPS AND CARTOGRAPHY

Readers are assumed to have a certain familiarity with standard geographic maps and this chapter simply serves as a reminder of their most relevant and major features. An experienced geologist may often be able to interpret much of the geology of an area from topographic information alone because many landforms are strongly controlled by the geology. Also, without topographic information it may be difficult to assess how much of the geological form seen on the map is the result of the interaction of the geological surfaces with an irregular topography. Before attempting to interpret a geological map several aspects of base maps have to be understood.

2.1 PROJECTION

A fundamental problem for the map-maker relates to the representation of part of the spherical earth on a flat map. This is achieved by projecting from the sphere on to a flat sheet or another surface that can be opened out to lie in a plane, for example, a cone or a cylinder (Figure 2.1). In addition to these fairly direct geometric projections there are a large number of contrived examples derived mathematically. When dealing with large areas (which implies small-scale maps) it is very important to be aware of the properties of various projections and to use them appropriately. The Mollweide projection (mathematical) preserves areal accuracy and would be of use to a geologist measuring the relative areas occupied by different rock types in a particular tectonic zone. The cylindrical Mercator projection preserves directional accuracy and would be used for any comparison of directional properties of structures over a wide area. For maps of tens to hundreds of square kilometres the nature of the projection is not significant and areal or orientation distortion will be slight.

2.1.1 SCALE

This is the ratio of the length of an object measured on the map to its actual length. The simplest way of indicating the scale on the map is by writing it as a **representative fraction** (RF), e.g. 1/63 360. This has several advantages. It has the value of graphically conveying the difference between large-scale maps (1:10 000) and small-scale maps (1:250 000) because $1/10\,000 \gg 1/250\,000$. Because of the seemingly large number involved, calling a 1:250 000 scale map small

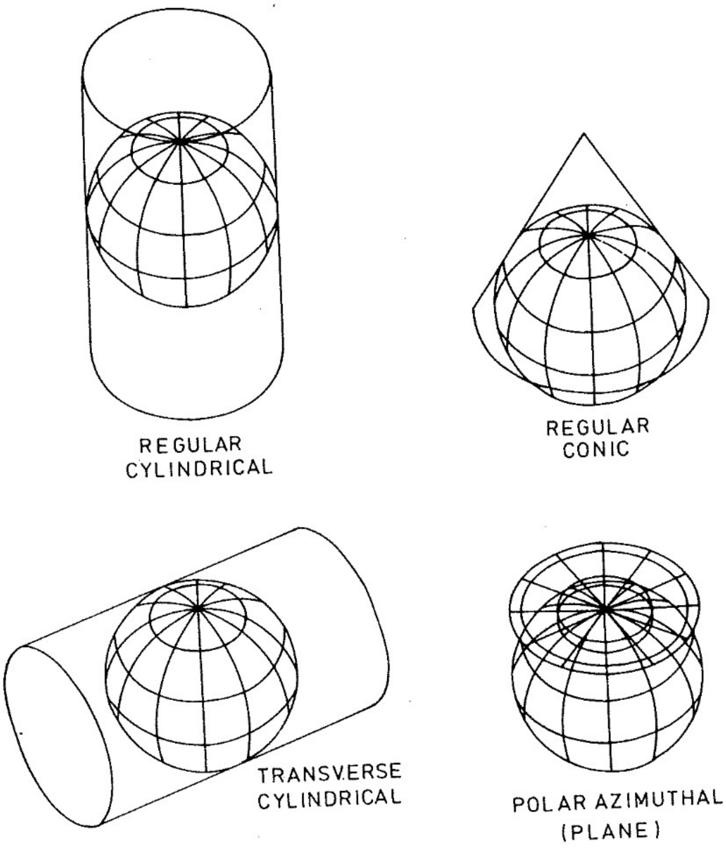

Fig. 2.1 Map projections. The earth's latitude – longitude grid can be projected on to a plane (polar azimuthal), or on to cones (regular conic) and cylinders (regular and transverse cylindrical) that can be cut and flattened out to planes. These are examples of geometric projections but many projections are mathematical to reduce specific distortional effects

scale tends to grate one's sensibilities but this has to be conquered. The method is also international: a person used to the metric system can appreciate the fact that 1/63 360 means 1 cm on the map represents 63 360 cm on the ground (though they may have trouble comprehending why it is used!). A graphic scale, in which a line representing convenient distances is drawn on the map, is useful because it remains true during reduction or enlargement. Descriptive scales, which make statements like 'four inches to one mile' or 'four miles to one inch', tend to be confusing but they are in common use. As international metrication proceeds map publication is being standardized at 1/25 000, 1/50 000, 1/100 000, 1/250 000, etc., scales.

The metric conversion process will cause problems for decades (?) to come because many old maps in imperial units will still be the only ones available for some areas. Whilst there are many conversion tables few give details of the imperial system itself and many modern students simply do not know 12 inches equals 1 foot, 3 feet equals 1 yard, and that 1 mile contains 1 760 yards. Such information is necessary when making constructions on old maps with metric graph paper and rulers or when converting old descriptive scales. Some British maps torment modern students; there are 1:25 000 maps with contours in feet! When centimetre graph paper is used, section drawing can be quite traumatic. In this mixed system, careful sums will lead to a happy ending, e.g. at a scale of 1:25 000 the following identities hold:

1 inch = 25 000 inches
1.54 cm = 2083 feet
1 cm = 820 feet

2.2 MAP REFERENCES

In describing a map it is often necessary to specify the location of a point or a geological feature in an exact way. Likewise, if in a report you read that the gold mine you are interested in is found at a specific location it is convenient to have a quick method of finding the mine on the map. Both cases are satisfied by using a coordinate grid system consisting of a network of equally spaced straight lines superimposed on the map. One coordinate in a west to east direction (left to right) is known as the **northing**: the other is a south to north (bottom to top) coordinate called an **easting** (Figure 2.2). The origin of a grid system is conventionally taken as its most south-western point. A grid reference for a locality should give the number of metres east and north from the origin but in a large country or for a global system this would generate a very big number. Most grids are, therefore, subdivided into 100 km × 100 km squares which are identified on a regular pattern by letters or a combination of letters and numbers which reduces the size of the grid reference. To identify the relevant 100 km^2 grid square requires local knowledge which cannot be provided here. The United States is moving towards widespread application of the Universal Transverse Mercator Grid (Merrill, G. K. 1986, *Geological Society of America, Bulletin*, **97**, 404 – 9). The British National Grid, which follows a Transverse Mercator projection, is explained in outline on most Ordnance Survey maps. One point to note is that eastings on grids rarely parallel true north and angular differences may amount to several degrees.

Once the 100 km^2 square is identified the rest of the grid reference, for a point or small feature, is determined as follows. All values are first read from west to east (easting) and then from south to north (northing). The mnemonic 'read **right, up**' may be useful. Firstly locate the vertical grid line to the left of the point and read the number of the line. Then estimate tenths of the grid spacing to the point (four on Figure 2.2). For the northing locate the horizontal line below the point and read the number of the line. Again estimate tenths from the grid line to the point. This results in a six-figure grid reference which is appropriate for 1 : 50 000 and 1 : 100 000 scale maps giving a precision of ±100 m. A large-scale map (1 : 10 000) can give an eight-figure grid reference (precision ±10 m) where the size of the kilometre grid squares means that they may sensibly be divided into tenths and hundredths. If you mostly use maps of only two or three scales it is well worth the effort of constructing a grid reference reader — a romer — on tracing paper or drafting film. For each scale subdivide kilometric grid squares in tenths and hundredths if appropriate) to give a fast and accurate methods. Reference to 1 × 1 km grid squares is made by quoting the coordinates of its south-west corner (9722 in Figure 2.2). This is useful when locating larger features.

An alternative referencing system, **geographic coordinates**, uses latitude and longitude. On large-scale maps a point may be located to the nearest second giving a

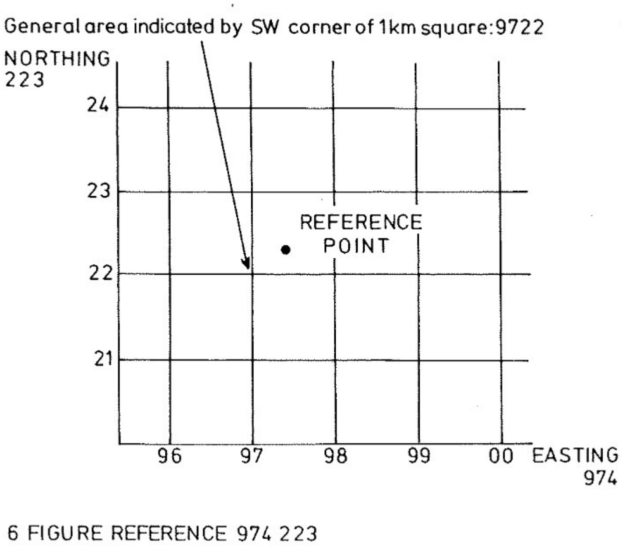

Fig. 2.2 The elements of a grid system. Northings run east – west and eastings run north – south. To give a six-figure grid reference for the point quote the easting immediately to the left (97) and estimate the tenths of the grid spacing to the point (4); the second half is the northing below the point (22) and again the tenths of the grid (3). The complete grid reference is 974223 which is always symmetrical so a full stop, oblique or whatever in the centre is unnecessary. A 1 × 1 km grid square is located by referring to the coordinates of its south-west corner — 9722 in this example

precision of about ± 30 m. By convention, latitude is quoted first then longitude, e.g. 20°46′ 20″ S, 118°48′ 25″ E. (Remember there are 60 seconds in a minute and 60 minutes in a degree.) The latest regional maps (1 : 250 000) of the British Geological Survey use for the offshore regions grid lines based on geographic coordinates and also offshore show the intersections of every 10 × 10 km grid of the Universal Transverse Mercator system. Onshore these maps show the National Grid of Great Britain which, though on a Transverse Mercator projection is differently numbered and located. Also onshore intersections of 10′ × 10′ grid lines of the geographic coordinates are marked. Indexing the variety of grids can be quite an exercise!

2.3 TOPOGRAPHIC MAPS

Relief may be represented in three ways; oblique illumination, hachuring, or contouring. The first two styles are schematic and give no quantitative information which is the reserve of contouring. Oblique illumination and hachuring have sometimes been used as bases for geological maps but rarely with success and hence are not considered further. A topographic contour may be defined as a line joining points of equal elevation on the surface of the ground (Figure 2.3). Elevations are measured above a selected datum plane, usually sea-level. A topographic contour at 100 m may also be thought of as a line of intersection between a horizontal plane at 100 m and the ground surface. Map representations of contours are in fact showing the vertical projections of contours on to a horizontal reference plane and not the actual contours themselves (Figure 2.3). The role of projection in mapping contours

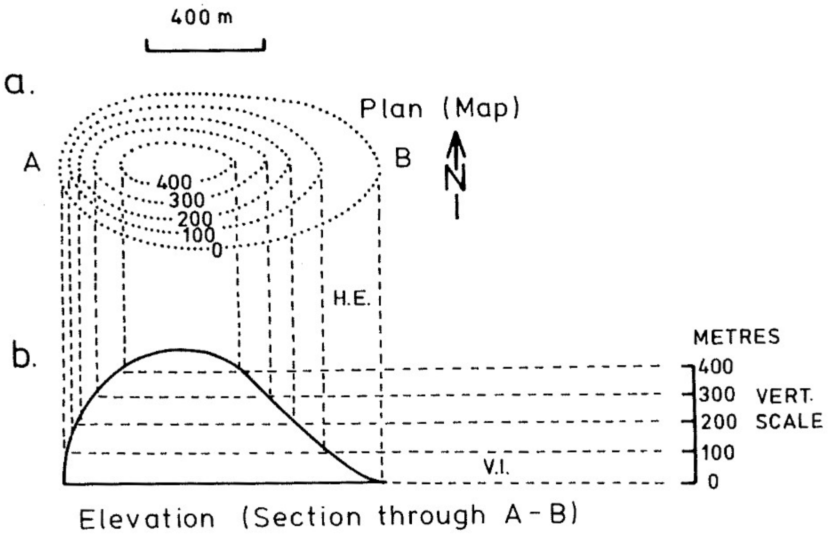

Fig. 2.3 (a) Topographic contours for an island. Readers are expected to be well experienced in interpreting landforms by this method and particularly to appreciate slope variations portrayed. Spacing of contours on the map is the horizontal equivalent (H.E.) which is inversely proportional to slope. (b) A vertical cross-section from A to B on the map. The vertical interval (V.I.) between contours is constant at 100 m. Note the convexity of the western side of the island and how it relates to the contour map pattern

must be kept firmly in mind as it is equally important in interpreting topographic and geological contours.

Contours may be drawn at any constant interval, the vertical distance between two successive contours being known as the **vertical interval** (VI). The latter is commonly multiples of 10, 25, or 100 but as a result of the traumas of conversion from imperial to metric you may come across intervals of 8 m and the like. Another variable is that map-makers may use one interval for lowlands and another for uplands on the same map. It will be assumed that the reader is familiar with interpreting contour patterns in terms of landforms. If not a diversion to an introductory text on map reading or geomorphology is a must. It is absolutely essential that you should be able to view a pattern of contours and quickly see the shape of the land being portrayed and the variation in slopes involved.

2.4 CARTOGRAPHY

In constructing a map or when examining a published map, a certain amount of information must be present for it to be useful as a scientific document. Some optional information may be incorporated depending upon circumstances. In the check list below essential data are marked by an asterisk:

1. **Title.*** The title gives the subject of the map, usually the name of the district and perhaps the type of map (e.g. solid geology, solid and drift, hydrological).
2. **Orientation.*** The direction of true north should be indicated by an arrow. As a matter of convention most maps are drawn so that north is at the top. Magnetic

north is a useful reference in many cases. Mine plans can be very disorientating as their grids commonly relate to the elongation of the deposit and grid north may be many tens of degrees away from true north. On virtually all maps grid north, true north and magnetic north, are in different orientations and the relationships should be studied carefully especially when you are involved in making a map. Also magnetic declination varies with time hence it is important to date the map.

3. **Scale.*** A vital piece of information best shown as a bar.
4. **Legend (key).*** This is an explanation of the symbols and colour scheme used on the map. Different rock types are represented on published maps by colours sometimes backed up by a letter and/or number code. Symbols on geological maps are the source of much anguish. The number of different systems is enormous and even within one country there is no such thing as a standard. The state of disarray is such that groups of related features do not even have the same style of symbols from system to system. The basic message is, treat every new map source warily and analyse their approach to symbology—never assume anything.
5. **Compilation.** It is standard practice to show on the map both the names of the person and organization responsible for compiling the map. In the case of multi-author maps some surveys show on a small index map particular regions covered by each geologist.
6. **Map projection.** Information of this nature is essential for small-scale maps of large areas but of little significance for maps greater than 1:50 000.
7. **Index maps.** This shows the location of the map sheet in relation to a larger more readily recognized region (see Figure 10.30) and is a feature that should be used more often. Many maps show the reference numbers of adjoining maps but this may be of little help if not put into the larger context.
8. **Coordinate system.*** Except for maps of very small areas, all maps should show at least two lines of latitude and longitude though these may be represented by ticks at the margin. A regular grid, taken from the appropriate national grid, is essential for ease of reference to localities (see for example Figure 11.8).
9. **Reliability.** Some idea of the style of mapping should be given. Some maps were completed by sparse ground traverses with much interpretation based on air photographs, whereas others will have involved mapping of every exposure and comprehensive walking of the ground. These differences are most commonly marked on reconnaissance maps by means of reliability diagrams. More detailed maps tend not to have such information and the reader is left to assume the extent of the data base. The rate of mapping is never given though this may vary from over 400 km^2 per week to less than 1 km^2. The reliability of such maps is vastly different.