Chapter 4: Representation of relief

Introduction

To this point in our discussion of maps we have been concerned only with their planimetric properties, those relating to the location of features in two-dimensional space. But of course we live in a three-dimensional world and our maps must depict it as such. This is far easier said than done, however, and one of the great cartographic challenges has been to produce maps which not only picture the form of the land but accurately portray it quantitatively as well. Indeed, an ideal solution is yet to be found.

We should define two commonly used topographic terms from the outset. *Altitude* or *elevation* refers to the height of the land surface above some arbitrary datum. In many maps, such as those of the Canadian NTS series, altitude is expressed as the height (once in feet, now in metres) of the land above mean sea-level. *Relief* refers to the *difference* in height between the highest and lowest land surface in a locality. Thus a high plateau may have a high altitude but a low relief. Similarly, coastal mountains may achieve only a modest altitude but may have great relief.

Attempts to solve the problem of representing relief include the following techniques:

1. Pictorial representation
2. Hachures
3. Bench marks and spot heights
4. Contours
5. Layer shading and tinting
6. Hill shading

*Pictorial representation* of the land, as a landscape artist might depict it, was a feature of many early maps. Mountains were painted onto the map and valleys drawn to accommodate rivers. In areas of simple topography the technique can provide an effective general picture of ‘the lay of the land’. In regions of complex topography such as alpine areas, however, the task is overwhelming and the results invariably confusing and certainly obscuring. In any case, the information imparted by this device is purely qualitative; actual altitudes, relief, and slopes have to be derived by eye and imagination, instruments not known for their precision and reliability! The only type of serious mapping in which this technique is used today is marine navigational charts. It is not uncommon, for example, for the approaches to a harbour or a hazard to be shown pictorially or as a silhouette in the margin of the map to assist navigators to identify particular stretches of coastline from offshore. Pictures and silhouettes are not used by themselves, of course, but as information supplementary to other more quantitative descriptions.

*Hachures* represent an early attempt to portray not only the general lay of the land, but more
4.1: The representation of relief by hachuring (Based on an extract from a map in the French 1:80 000 series, type 1889, Service Géographique de l'Armée, Paris).
detailed information on relative slopes as well. They are short parallel lines indicating approximately the
direction of surface-water flow from higher to lower ground. On steep slopes the hachures are closely
spaced (and sometimes thicker) and are placed further apart as the slope lessens to more gentle inclines.
An example of a hachured map is shown in Figure 4.1. Although hachuring can very effectively depict the
major relief features of a region, the technique has several important deficiencies, not the least of which is
that they obscure most other information on the map. Furthermore, they tell us nothing quantitative about
altitude or relief although attempts were made early in this century to standardize the hachure spacing to
reflect slope classes. They are common on 19th century and early 20th century European maps but little
use is made of them on modern maps. Perhaps the one exception is their use in portraying near-vertical
slopes such as those encountered at a waterfall or at the walls of a quarry.

Bench marks and spot heights, by themselves do not convey an impression of the lay of the land
but they may be used very effectively in combination with other methods such as hachuring and
contouring. Bench marks are accurately surveyed permanent markers (usually a brass disk set in
concrete) from which local surveys may originate. In Canada these are installed by Federal or Provincial
surveyors and common locations are bridge abutments, freeway overpasses, telecommunication towers,
railroad tunnel entrances, and so on. They are marked on Canadian topographic maps by a small black
arrow. Spot heights are points on a map for which elevation has been accurately determined. They are
indicated as a dot on the map but they are not monumented or marked on the ground in any way. Their
basic function is to augment the information given by contours.

Contour lines represent imaginary lines on the ground along which all points have the same
elevation. In other words, if you walked along a contour line your path would be perfectly horizontal.
Contours appear on Canadian topographic maps as fine brown lines (unless on the surface of a glacier
where they are blue), with every fifth contour (called index contours) thickened to facilitate reading them.
At various places the contour is broken and its height printed in feet or metres above mean sea level. A
very useful convention to remember is that, on all Canadian maps and on most foreign maps (except
those of the United States), the contour numbers are printed so that they read 'uphill' (the top of the
number is on higher ground than the bottom). This printing convention can be very helpful in determining
the lay of the land in very low-relief terrain where contours are few and far between. On some maps of
flat areas where the index and intermediate contours do not show sufficient detail, auxiliary contours may
be added to the map. These are represented as dashed lines at one half the contour interval of the map;
their accuracy is the same as that for the intermediate and index contours.

Contour accuracy depends on the survey methods used (very accurate ground survey or
somewhat less accurate photogrammetry) and on the slope of the land. In general, a rule of thumb used
by some geographers is to regard the contours on the NTS sheets as accurate to \( \pm \frac{\text{contour interval}}{2} \). In
other words, on a topographic map with a 50 ft (~15 m) contour interval, the actual contour height is
accurate to ± 25 ft (~8 m). This height error translates into a contour position displacement that is a function of the slope of the land and the scale of the map. For example, at a scale of 1: 50,000, an 8 m contour height error on a land surface sloping at 20° would correspond to a horizontal contour displacement of 21 m on the ground or only about 0.4 mm on the map. At a slope of 5°, however, the corresponding contour displacement is 91 m on the ground or about 1.8 mm on the map.

On Canadian maps the contour interval, the height difference between adjacent contours, varies with map scale and terrain type as follows:

<table>
<thead>
<tr>
<th>Type of terrain</th>
<th>Scale of topographic map</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1:25 000</td>
</tr>
<tr>
<td></td>
<td>Metric units (metres) / Imperial units (feet)</td>
</tr>
<tr>
<td>Very flat</td>
<td>2.5 m / 10 ft</td>
</tr>
<tr>
<td>Moderate relief</td>
<td>5 m / 10 ft</td>
</tr>
<tr>
<td>Hilly</td>
<td>10 m / 25 ft</td>
</tr>
<tr>
<td>Mountainous</td>
<td>20 m / not used</td>
</tr>
</tbody>
</table>

The distinct advantage of contours over other devices for representing relief is that they provide comprehensive quantitative information about the surface of the land without cluttering up the map and obscuring other detail. Their weakness is that they do not convey a picture of regional landform as readily as do hachures or pictorial representations. On balance, however, contours are far superior to any alternative relief-display methods, displacing them on all modern maps.

Although contour maps do not readily yield a picture of the lay of the land to the untrained and unpracticed eye, they do come alive for those who have made the effort to learn to 'read' a topographic map. An experienced map reader can pick up any topographic map and quickly translate the contour pattern into a three-dimensional image of the ground with its hills and valleys and ridges and rivers. We may not quite understand how the brain takes such two-dimensional data and turns them into a real landscape in our 'mind's eye', but we do know that most people have the ability to visualize in this way. But like learning any language, it takes practice.

The relation between the contour pattern and landform is illustrated for various features in Figure 4.2. In each case a cross-section A-B has been formed as though a knife had taken a vertical slice through the feature to yield an outline much as the silhouette of the feature would appear against the fading light of dusk. By this means the relation between the slope of the land and the contour spacing on the map may be seen directly. A careful examination of each of the examples and any Canadian NTS sheet will suggest some general rules for contour properties:

(a) Because contours join only points which are the same height above sea level, they can never cross. It is possible, however, that they may touch where the slope is precipitous, as at a near-vertical
cliff. Remember that contours describe the surface form of the land; a cave does not present a contour-crossing condition because there can be only one 'surface'.

(b) Each contour must close so that it is continuous, with neither beginning nor end. This condition may be met on one map or on adjoining sheets, depending on the map scale, contour interval, and the scale of roughness of the land.

(c) Contours tend to parallel adjacent contours. This is another way of stating that, if the contour interval is small enough for a meaningful depiction of the major landform elements, then the slope changes between adjacent contours will be relatively small.

(d) Contours tend to parallel major river courses.

(e) Valleys generally are shown by 'V'-shaped contours with the 'V' always pointing upstream and upslope.

(f) Ridges are shown by 'V'- or 'U'-shaped contours with the 'V' or 'U' always pointing downslope. Ridges described by 'V'-shaped contours are characteristic of glacially eroded alpine areas whereas 'U'-shaped contours describe the more rounded ridges of non-glacial erosion.

(g) Contours generally are depicted as smooth curves.

The contoured landform examples shown below in Figure 4.2 certainly are not exhaustive in their coverage of landform types found in nature but, nevertheless, most landforms include at least several of the elements depicted.

4.2: (on the following pages 43-47): Contour maps of common landform features

A. A straight planar slope
B. A conical hill
C. A concave slope
D. A convex slope
E. A convexo-concave hill
F. A 'V'-shaped valley
G. A 'U'-shaped valley
H. A ridge
I. A saddle
4.2A: A straight planar slope

Perhaps the simplest contour pattern is that describing a sloping planar surface. Because the surface is a plane the contours are straight, parallel, and equidistant. It is a contour map of the surface of a flat board inclined at some angle to the horizontal. Here we see the expression of an important rule: equally spaced contours specify a linear or constant slope.

4.2B: A conical hill

This simple example illustrates as directly as any the relationship between form of the land and the shape of contours describing it. Because the outline or planform of a conical hill is circular the contours form concentric circles. Because the sides of the cone are straight the slope is constant from top to bottom and the contours therefore are spaced equally on the map.
4.2C: A concave slope

A concave-upward surface is one in which the slope steepens from the foot of the incline to the top. This increase in surface slope with elevation is represented by a contour pattern in which the contours become more closely spaced as elevation increases.

4.2D: A convex slope

A convex-upward surface is one in which the slope declines from the foot of the incline to the top. This decrease in surface slope with elevation is represented by a contour pattern in which the contour spacing increases as elevation increases.
4.2 E: Convexo-concave hill

This stylized elliptical convexo-concave hill includes many of the form elements commonly found in natural hills. The lower slopes are gentle and represented by widely spaced contours. As elevation increases the slopes steepen to a maximum in the mid-elevation range (where the contour spacing is at a minimum) and then decline again towards the top of the hill. Thus, slopes on top of this feature also are rather gentle and represented by widely spaced contours. You will note that this hill is asymmetrical in the sense that the rate of slope change with elevation varies from one side of the feature to the other.

4.2 F: A 'V'-shaped valley

Note that the contours representing a 'V'-shaped valley are themselves 'V'-shaped and that the 'V' points upvalley towards the higher elevations. The equidistant contour intersections along the cross-section A-B implies that the valley sides here essentially are straight.
4.2 G: 'U'-shaped valley

Note that the contours representing this 'U'-shaped valley, like those in Figure 4.2F, 'point' upvalley towards the higher elevations. The contour intersections along the cross-section A-B indicate, however, that unlike the 'V'-shaped valley, the valley sides here are concave.

4.2 H: A ridge

In the case of a ridge, the contours 'V' downslope towards lower elevations. The contour pattern for a valley and a ridge are identical and contour heights must be used to distinguish one from the other. Valleys and ridges do not occur in isolation but together form ridge and valley complexes.

4.2 I: A saddle:

Two hills separated by a pass or col constitute a saddle. Note that the volcano on the right is topped by a checked 50-metre depression contour, indicating that the floor of the crater is lower (50m>elevation>40m) than the rim. This contour pattern also indicates that the land in the pass of the saddle must be at an elevation greater than 20 metres but less than 30 metres above sea level.
Layer shading and tinting are used in combination with generalized contours to represent relief on small-scale maps where it is impossible to show individual relief features. Layer shading is designed for use on monochromatic (shades between black and white) maps while tinting can be used on coloured maps. In both cases the elevation range on the map is divided into a limited number of classes, assigned a shade or tint, and mapped as such. Excellent examples of layer tinting can be found in the Canadian sheets of the International Map of the World at the Millionth Scale (IMW). Here land between sea level and the 200 m contour is tinted light green, 200 m-500 m is light buff, 500 m-5000 m is shown by deepening shades of buff and brown in 500 m bands, and land above 5000 m is tinted in deepening shades of purple. Most world atlases are replete with examples of this technique of displaying relief.

4.3: An example of hill shading used to create the illusion of relief on a portion of the British 'Loch Lomond and The Trossachs' Ordnance Survey map.
Hill shading, a technique borrowed from artists, is used to enhance the three-dimensional appearance of a map by creating the illusion of depth. It records the shadows that might fall over an area if it were illuminated by a light in the northwest. Thus the southeast sides of hills, which are away from the light, are darkened, the tops of hills and lower slopes are only lightly shaded, and plains are fully illuminated (unshaded). An excellent example of this technique is provided by the British one inch to the mile 'Loch Lomond and The Trossachs' Ordnance Survey map (Figure 4.3).

We must now leave the theory of representing topography for the moment and spend some more time looking at topographic maps. You will find it useful to obtain a topographic map of your local area and do some translation of contour maps to verbal descriptions of topography, and *vice versa*. In these exercises it is not only important that you appreciate the topographic information stored in the contours, but it also is important that you are able to clearly express in writing the nature of that information. For those of you who are completely new to topographic maps this task may be quite demanding. But you must persevere because the lessons to be learned are fundamentally important.

In the next chapter we will return to the business of contour mapping and examine further the information stored in the contours shown on the Canadian N.T.S. map sheets.