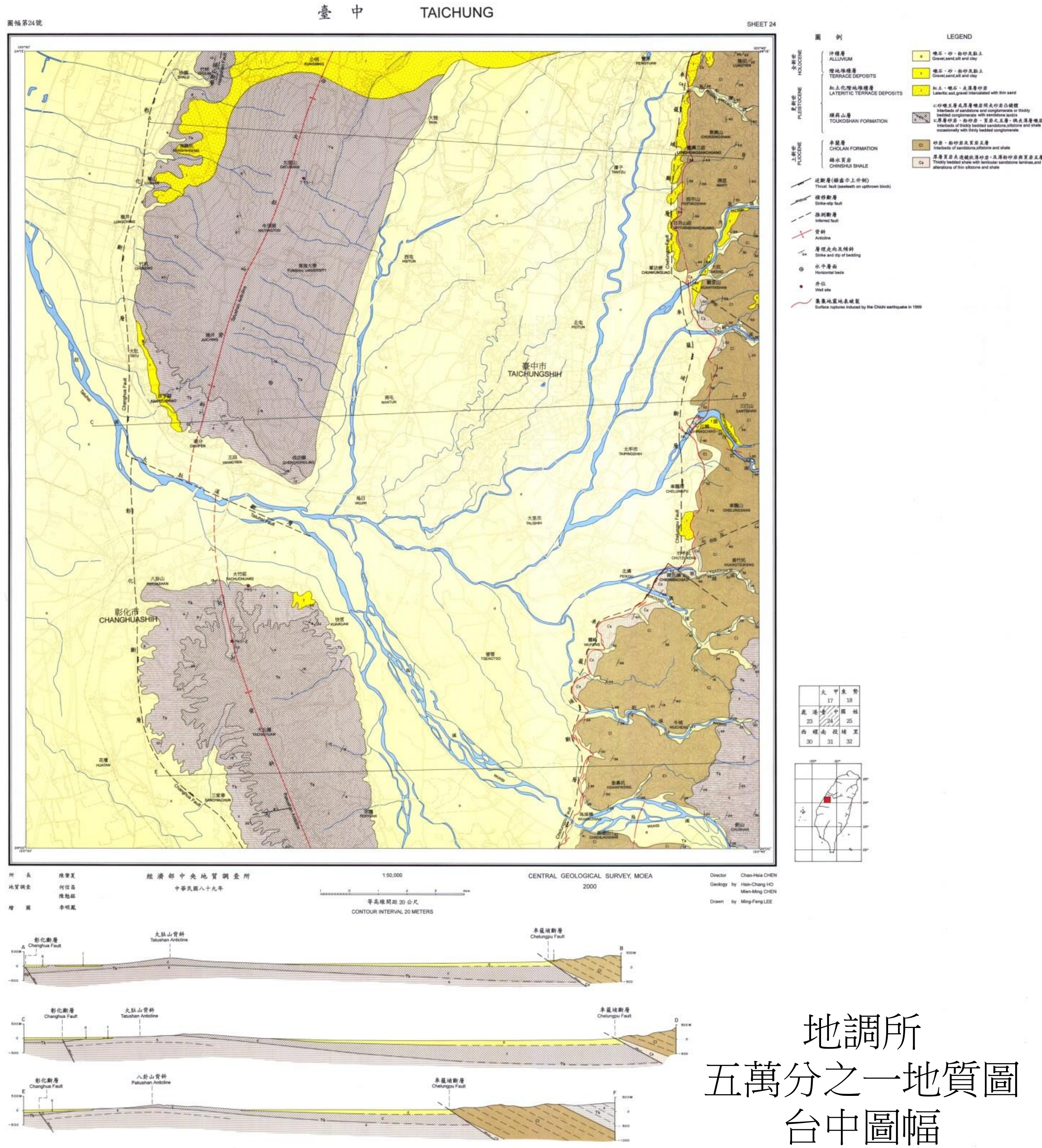
6. 地質圖

6.1 岩層於地形圖上的分布

6.2 地質剖面圖

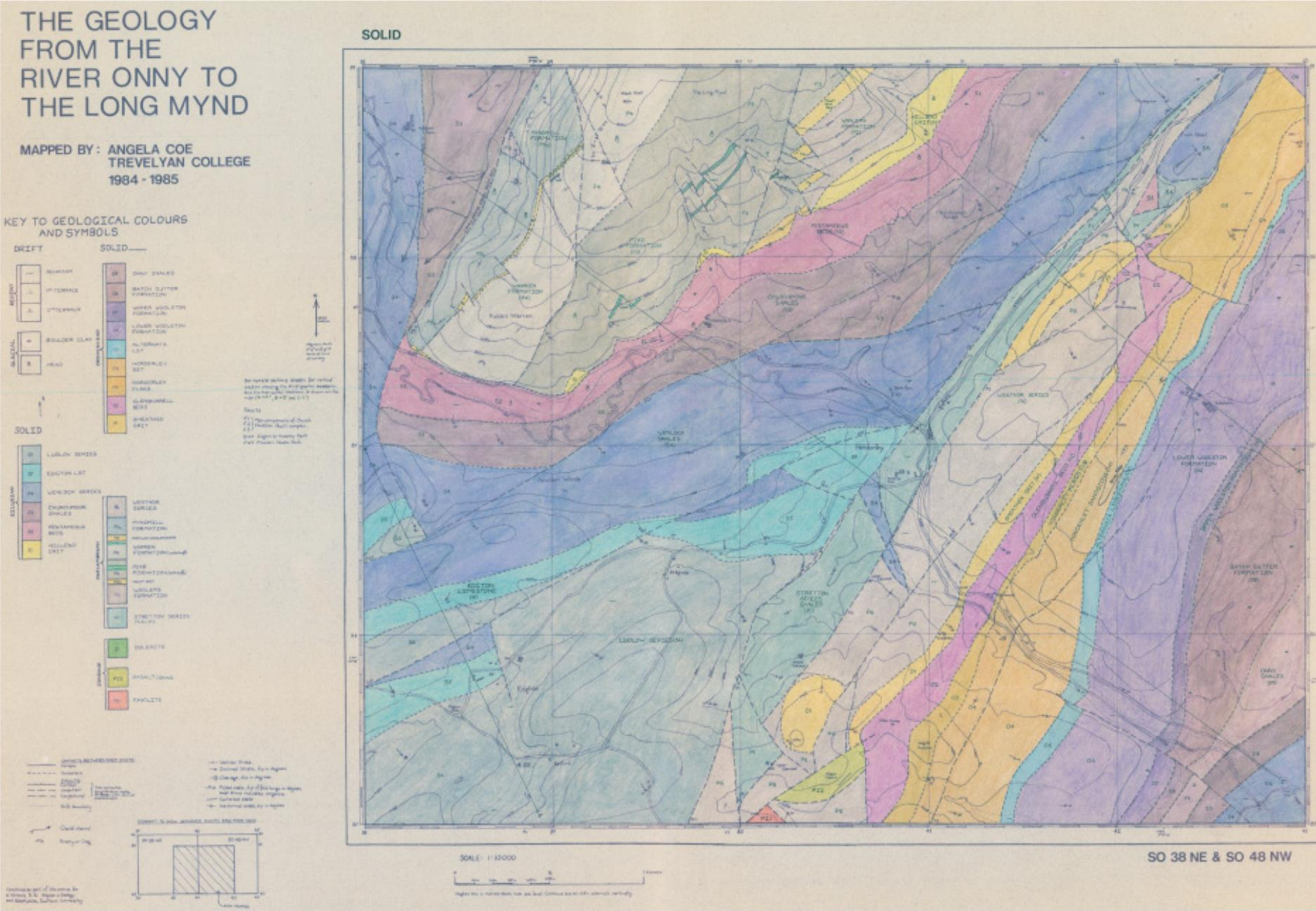
6.3 地質圖判識

A geological shows how geological features (rock units, faults, etc.) are distributed across a region. It is a two-dimensional representation of part of the Earth's surface on top of a topographic base map. Information on the third dimension is incorporated by means of strike and dip symbols and other structural labels. Different rock units are usually shown as different colours (and/or ornaments. Additional information on features such as structure, lithology and stratigraphy is also included, allowing interpretation of the subsurface.



地調所
五萬分之一地質圖
台中圖幅

An example geological map



Coe et al. (2010)

Table 10.9 Additional elements of a final fair copy map.

Element	Comments
Title	Include the name of the area mapped, and indicate any special theme (e.g. ore mineralization)
Scale	As a ratio (e.g. 1:10,000) and in graphical form (e.g. a graduated bar)
N arrow	Indicate true north, and also show relative deviations of grid and magnetic north
Author, date	Include both the date of mapping and of map publication
Sources	Cite the sources of topographic base maps and any additional data used (e.g. previous maps)
Explanation	A detailed legend showing colours, ornaments and letters for units, all symbols, lines, etc., similar to that in Figure 10.6
Stratigraphic column	A vertical section, showing the stratigraphic order and relative thickness of strata
Cross-section(s)	Include one or more horizontal cross-sections, generally along the base, to illustrate the structure of the area

Coe et al. (2010)

Geological maps are made for a variety of reasons and, depending on the region, these are to:

- record the position of particular geological features or exposures;
- help us understand the geological history of a region;
- locate natural resources, and understand the best way to exploit them;
- identify potential hazards (e.g. faults, volcanoes, unstable substrates, hazardous deposits);
- gain insights into the immediate subsurface environment, which governs soils, drainage, agriculture and ecosystems;
- provide a base for constructing a detailed geological cross-section to deduce and visualize strata below ground.

Coe et al. (2010)

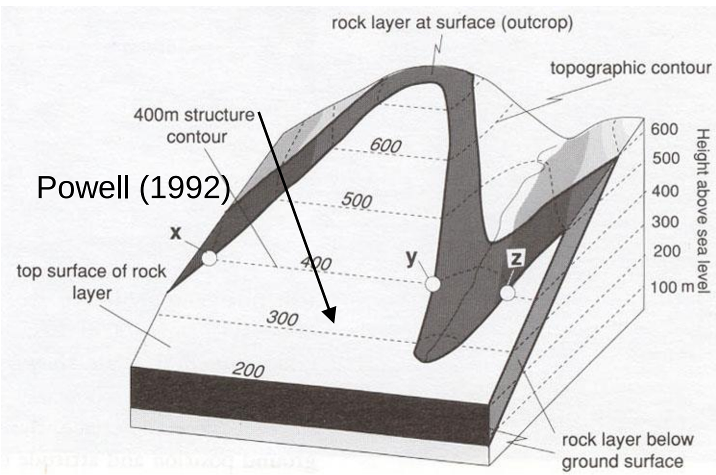
Table 10.5 Information to record on a field map. Level of detail is determined by time allocated and scale of mapping. Conventional symbols used for plotting these data are given in Appendix A10 (Figure A10.3).

Information	**Comments**
Rock exposures	Location: extent if appropriate, nature (e.g. man-made). Brief notes of rock types or facies, and other important information (e.g. fossils, index minerals, structures)
Structural data	Symbols *and* measurements (dip/strike, plunge/trend) for bedding, foliations, lineations, fold axes, joint orientations, etc.
Notebook localities	Clearly label those localities where you have made detailed notes in your book
Specimen localities	Label the locations where samples were taken (rock, fossil, sediment, water, etc.); it is best to link these directly to notebook localities
Photographs, sketches	Label where photographs were taken or field sketches made if not at a notebook locality
Major contacts	Lithological and tectonic: solid where observed, dashed where inferred.
Additional evidence	For example topographic features, drainage, soils, float, vegetation (Figure 10.7a)
Superficial deposits	For example alluvium, glacial/fluvioglacial material, sand, peat, river terraces, etc.
Degree of exposure	Comments on quality and quantity of exposure, weathering, soil cover, etc.
Hazards	Note of hazards not obvious from base map

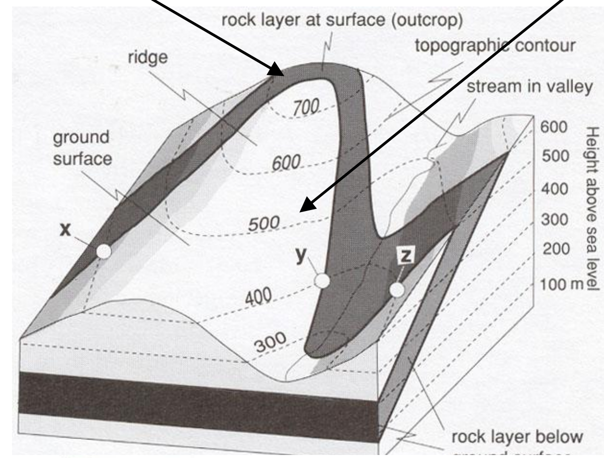
Coe et al. (2010)

6.1 岩層於地形圖上的分布 (Outcrop Patterns)

Structure contour

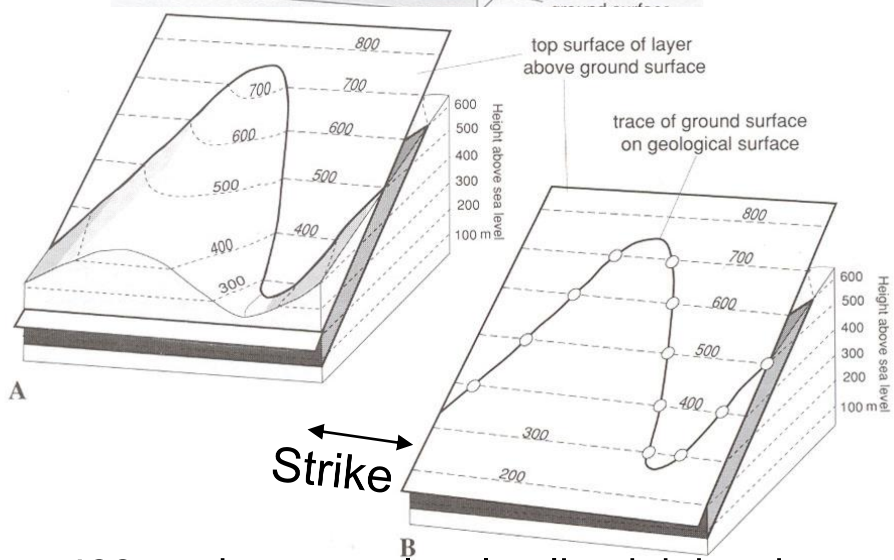


Outcrop pattern shown on topographic contours



Block diagram of an inclined layer of rock

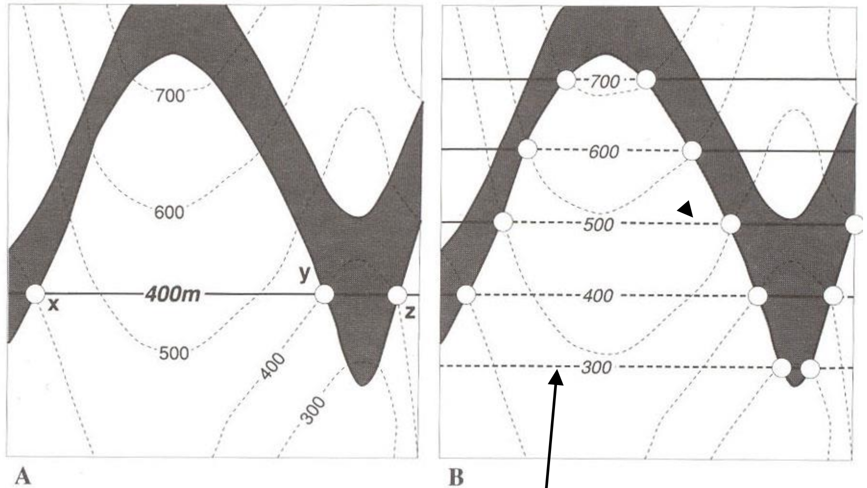
Powell (1992)



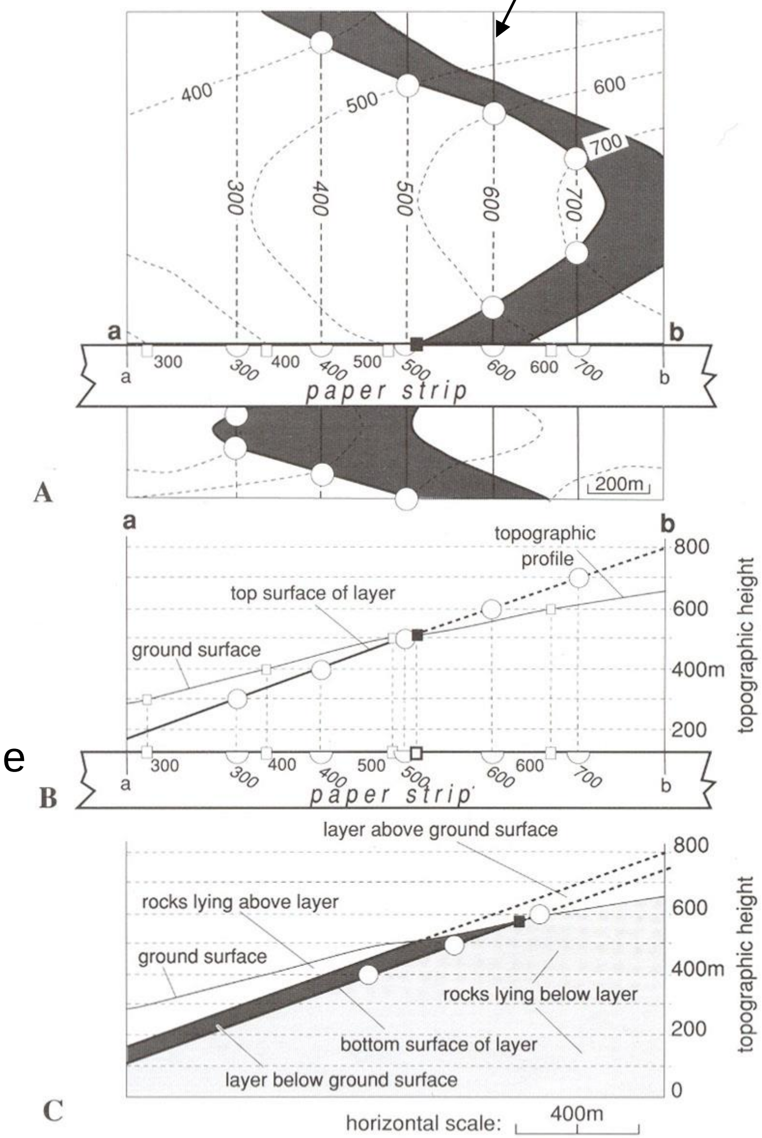
A structure contour is a line of equal elevation drawn on a structural surface; such contours are used to depict the form of the surface. In the simplest case, a structure contour drawn on a planar surface is a straight line and is equivalent to a line of strike (see figures on top and right).

Points x, y, z on the top surface of the layer all lie at 400 m above sea level, a line joining them together will define a 400 m contour on that surface. Lines defined in this way are known as structure contours and are equivalent to topographic contours but drawn on a geological, rather than a land, surface.

Structure contour overlay topographic contours



Solid line indicates eroded strata (on the air)



Dashed line indicates structural plane beneath the ground surface.

The parallelism and even spacing of structural contours indicate that the upper surface of the rock layer is a flat, but inclined, plane and the drop in height towards the bottom of the map shows that the surface is inclined (dips) in this direction.

Constructing a cross section would help to visualize the orientation of the strata (Figures A, B and C shown on right).

Predicting outcrop patterns

A single outcrop at point Z on a structural plane whose dip is 20 due east, construct the outcrop trace of the plane across the map area.

1. Perpendicular to the strike direction establish a vertical section. On this section: (a) Draw a series of horizontal lines spaced at the interval of the topographic contours, and plotted using the map scale. Label each line with its elevation. (b) using these elevation, locate the correct vertical and horizontal position of the outcrop point. (c) Through this outcrop point draw a line in the dip direction inclined downward at the dip angle.

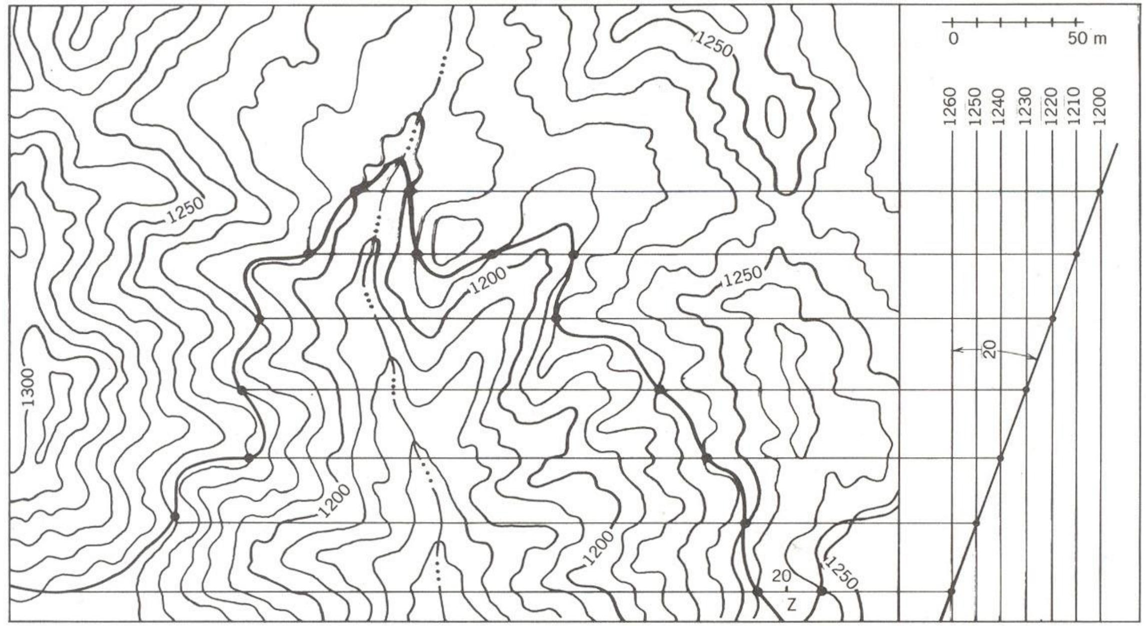


FIGURE 3.8 Outcrop trace of an inclined plane exposed at point Z.

Ragan (1985)

2. Each point where the dip line crosses an elevation line fixes the position of the corresponding structure contour on the structural plane. These contours are projected to the folding line and then back to the map view.

3. Each intersection of a structure contour with its matching topographic contour is an additional outcrop point, and these should be marked distinctly.

4. Complete the outcrop trace by joining successive outcrop points. This trace must cross at and only at these established points. If the contour spacing is wide, the outcrop trace can usually be sketched across the gap.

Finding and tracing contacts between rock units

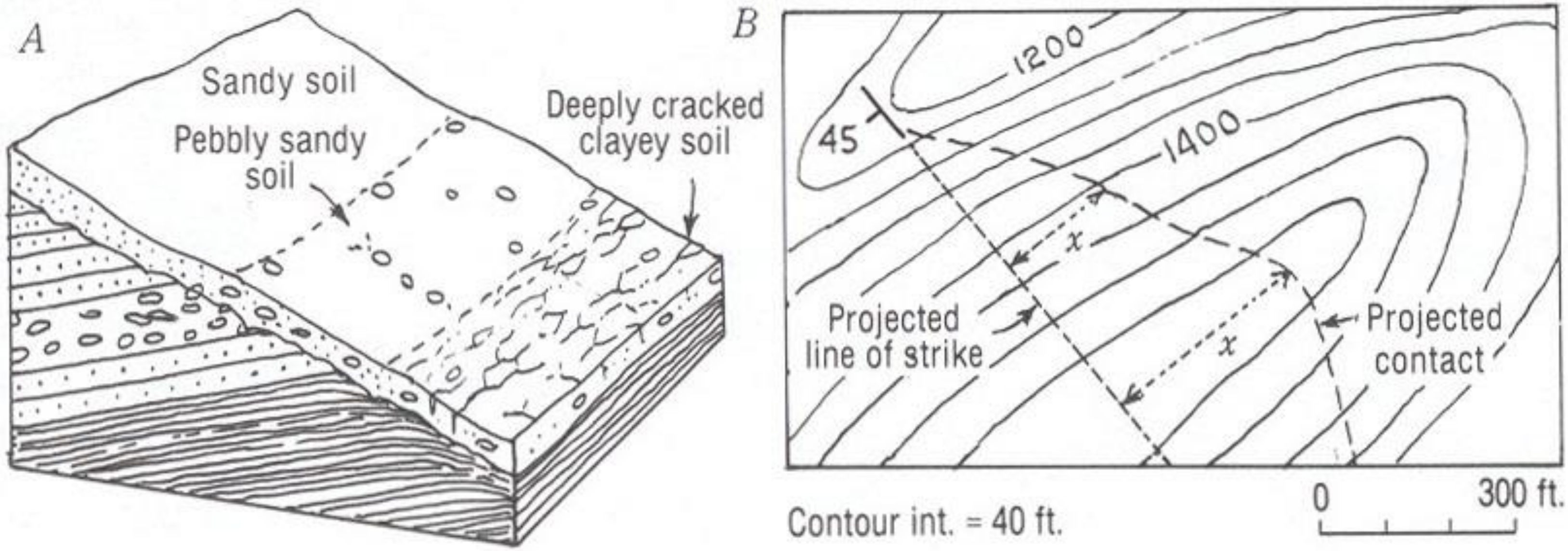


Fig. 5-6. *A*. Using upper limits of pebbles and *(below)* of clay-rich soil to map two contacts. *B*. Strike and dip measured near a contact *(upper left)* are used to project the contact ahead by the relation *x* = *diff. in elevation* ÷ *tan* ∠ *dip*.

Compton (1985)

$$x = \frac{diff.in.elevation}{\tan(bedding.dip)}$$

Determining dip and strike of a structural surface from outcrop patterns

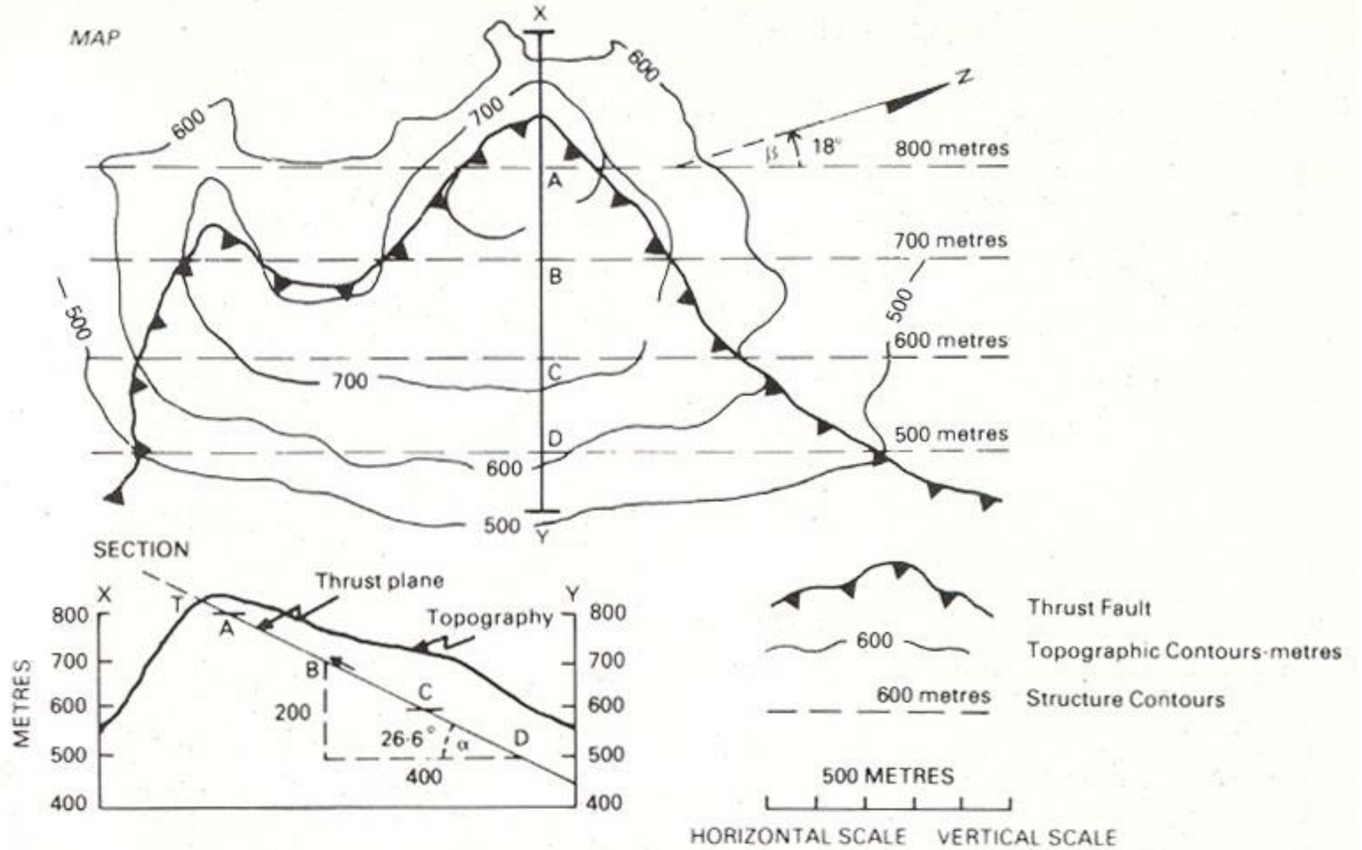


Fig. 9.3 Construction of structure contours and determination of the dip and strike of a planar structure. The map shows the outcrop of a thrust plane in an area of topographic relief. *Structure contours* for the thrust plane are constructed by joining points where the thrust plane intersects a particular topographic contour e.g. 700 metres. The 700 metre structure contour (dashed line) defines the strike of the thrust plane at 700 metres elevation in this area. On the cross-section X-Y the topographic surface is plotted and the outcrop of the thrust plane T is marked. The structure contours for the thrust plane intersect the line of cross section (X-Y) in the points A, B, C, and D and these are plotted on the cross-section to define the thrust plane. The strike of the thrust plane is given by the angle between north and the strike of the structure contours β = 18°, and the dip can be calculated from the cross section – angle of dip = tan 0·5 = 26·6°. Strike of the thrust plane is 018° north east and dip is 26·6° (i.e. 27°) south east.

Outcrop patterns: Exposures in area of topographic relief

Rule of V's

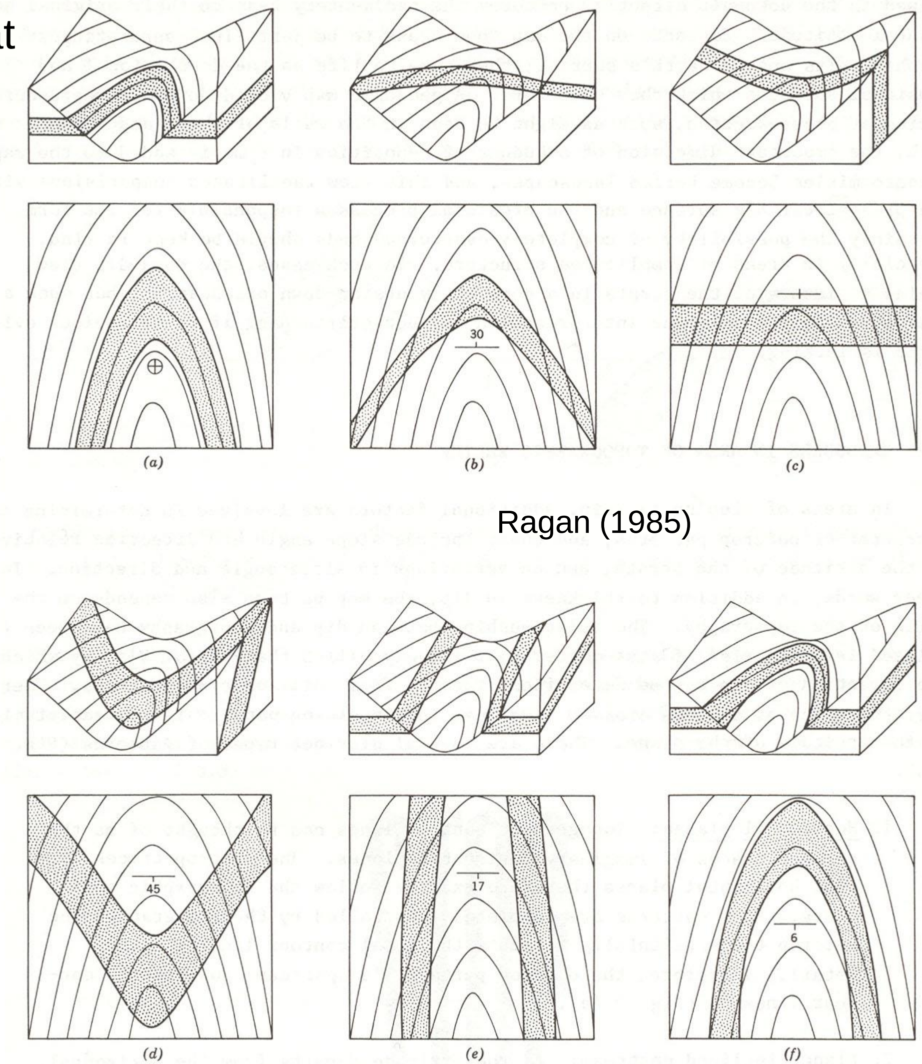
- Horizontal plane: The outcrop pattern follows that of contour. V points upstream, just as the contour lines do.

- Planes inclined upstream: V points upstream.

- Vertical planes: There is no V at all, and thus absolutely no control on the pattern by the topography.

- Planes inclined downstream: There are three cases, depending on the dip angle relative to the stream gradient:

  (1) Dip > valley gradient (d): V points downstream.
  (2) Dip = valley gradient (e): The outcrop will not cross the valley axis, and there is no V.
  (3) Dip < valley gradient (f): V points upstream.



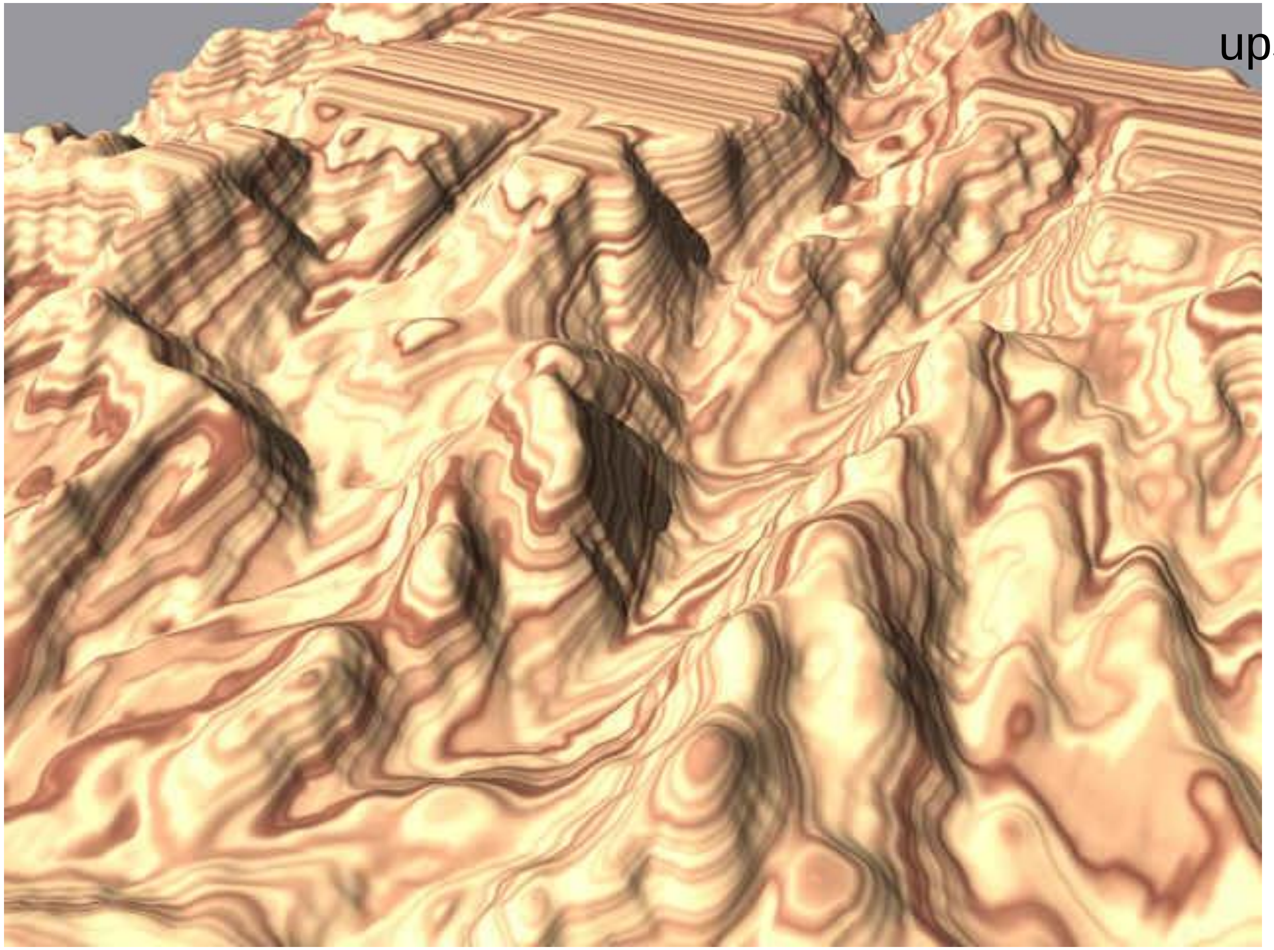
Ragan (1985)

FIGURE 3.4 Outcrop patterns illustrating the rule of V's: (a) horizontal layer; (b) layer dipping upstream; (c) vertical layer; (d) layer dipping downstream; (e) layer and valley axis with equal inclinations; (f) layer dipping downstream at an angle less than valley gradient.

In general case: V尖端指向岩層傾斜方向

20° downstream

(http://www-glg.la.asu.edu/~sreynolds/geologic_scenery/rule_v_20down.jpg)



upstream

Outcrop patterns of folds

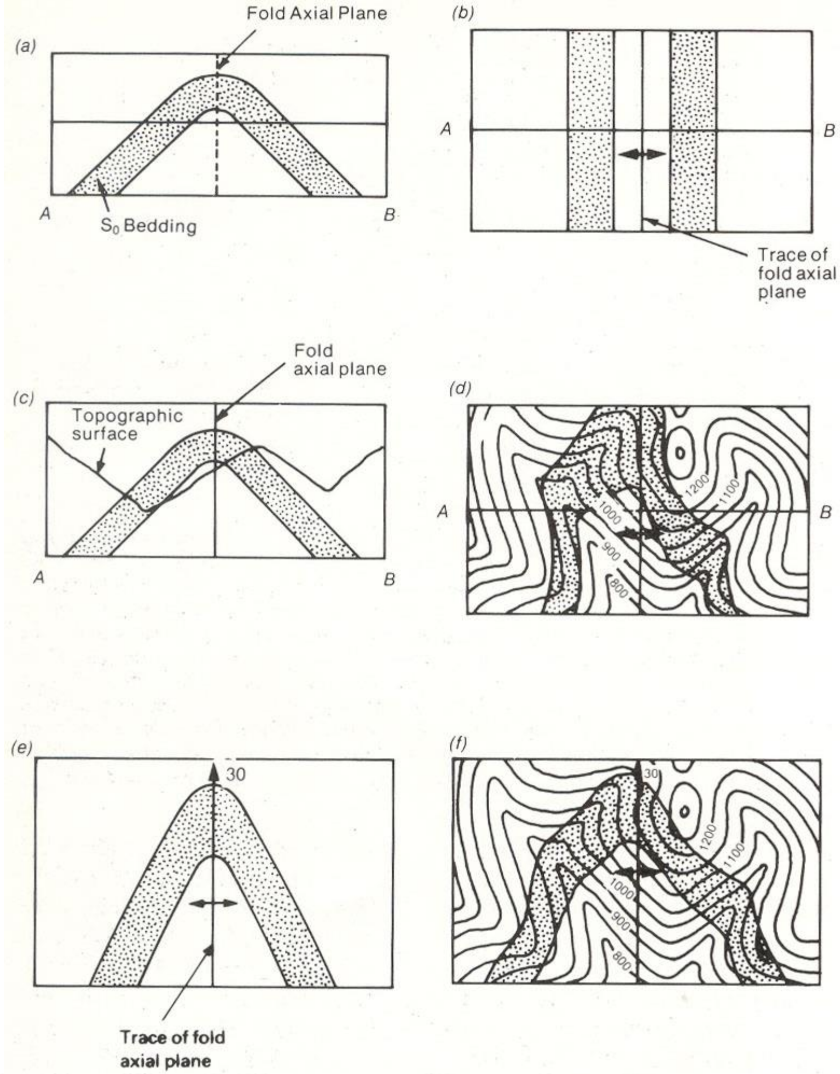
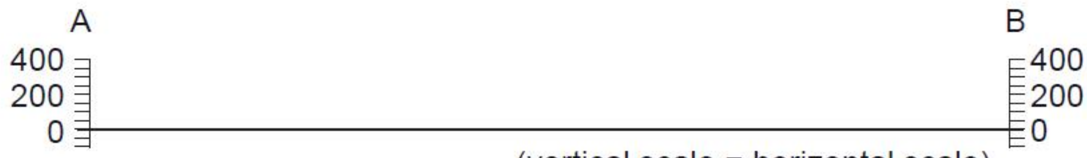


Fig. 9.2 Outcrop patterns of folds, showing the effects of topography on the map patterns: (*a*) horizontal upright fold in the profile plane; (*b*) horizontal upright fold exposed on a horizontal surface; (*c*) horizontal upright fold in cross-section in an area of topographic relief; (*d*) horizontal upright fold exposed in an area of topographic relief; (*e*) plunging upright fold exposed on a horizontal plane surface; (*f*) plunging upright fold exposed in an area of topographic relief. Note the displacement of the fold axial trace upslope from the surface closure on the map. (Adapted from Ragan, 1985 and reproduced with permission.)

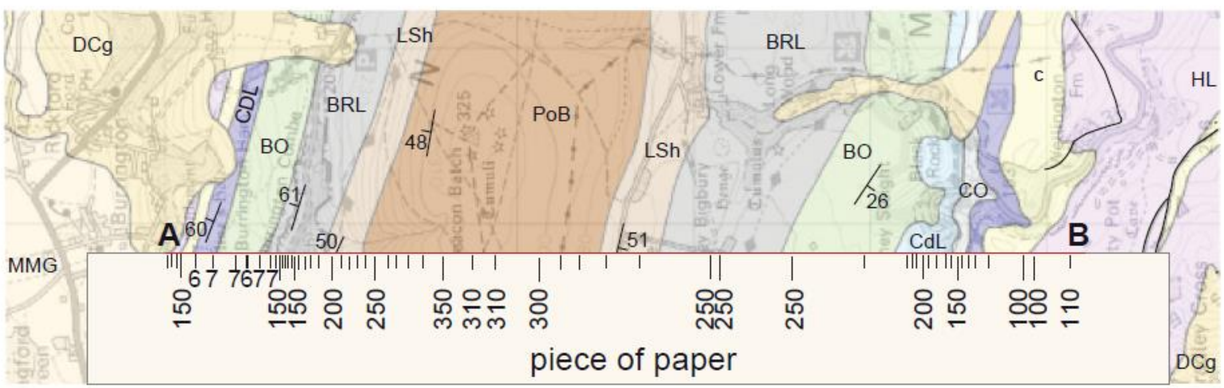
6.2 地質剖面圖

Stages in drawing a geological cross-section



(a)

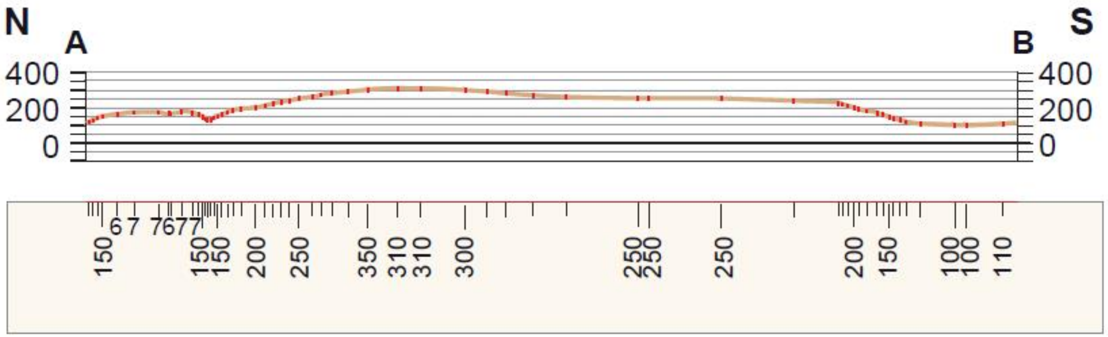
Decide on an appropriate vertical scale for the cross-section. Mark the line of section on the map with a faint line, or mark the end points. On a separate sheet of graph paper, draw a straight horizontal line of the same length, to represent mean sea level (the usual reference datum). Add vertical axes at each end, labelling them with an appropriate scale for the height relative to sea level.



(b)

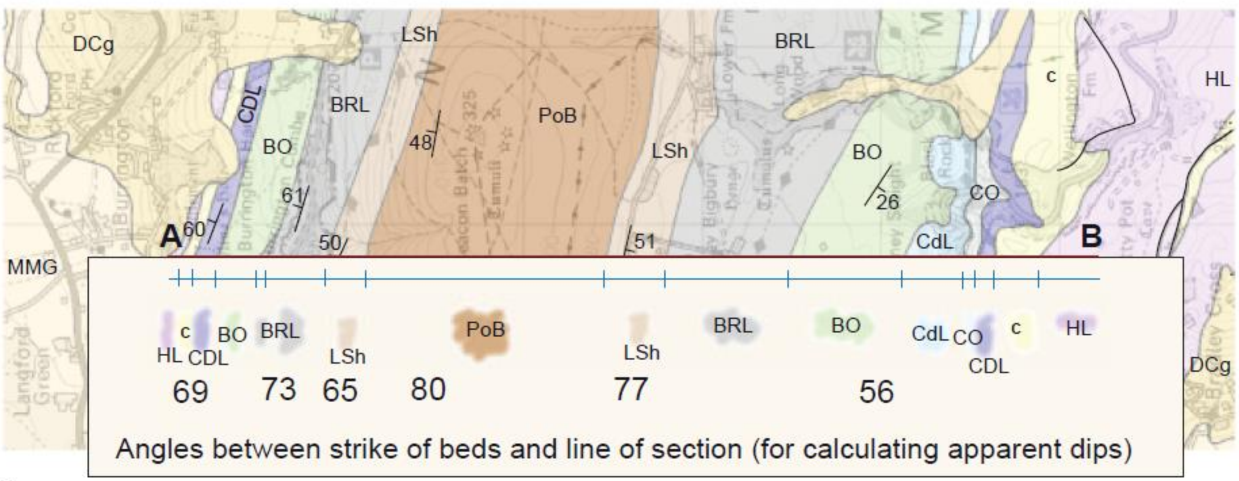
Lay the straight edge of a second sheet of paper along the section line on the map. Mark the end points of the section line on the edge of the paper, and wherever topographic contours cross the section line mark ticks, labelled with the contour height, on the second sheet of paper. (It may help to mark rivers and ridge crests too.)

Coe et al. (2010)



(c)

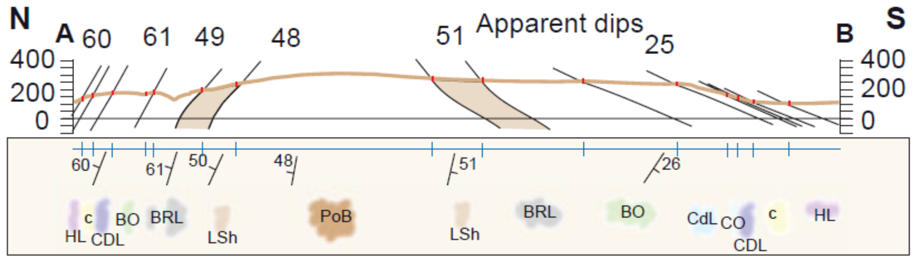
Transfer the contour heights to the graph paper by laying the edge of the paper along the horizontal axis, and marking dots projected up to the correct height all along the cross-section. Join these dots with a smooth curve interpolated between them to produce a topographic profile as a base for your cross-section. Label the end points with a grid or GPS reference, or a compass bearing.



(d)

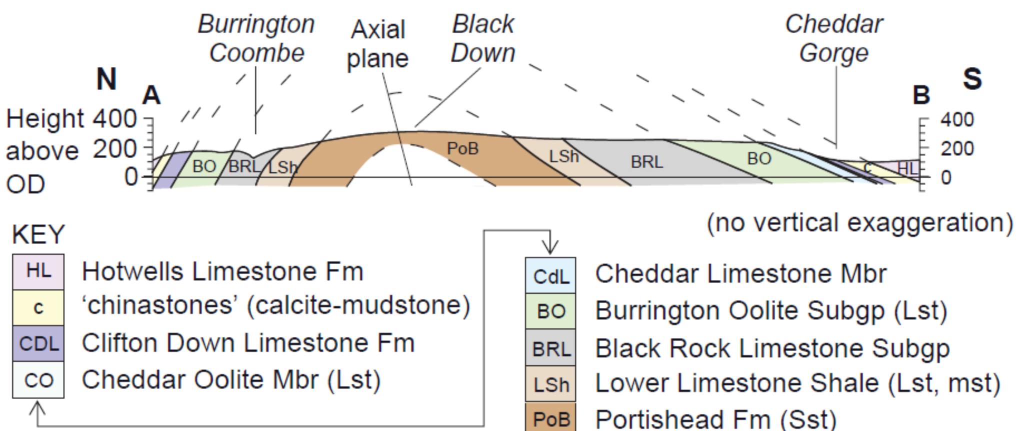
Using a third sheet of paper, transfer geological information such as stratigraphic boundaries, faults and igneous contacts along the line of section from the map to the cross-section in the same way as you did for the contour heights (stage (b)).

Coe et al. (2010)



(e)

Transfer the position of these features directly onto the topographic profile on the graph paper. Dip measurements can also be transferred onto the section. If there are none on the line of section, data lying short distances away from the section line can be projected at right angles onto the line. However, only where strata strike at exactly 90° to the section line can their dip angles be drawn directly onto the cross-section. Dips of strata striking at more oblique angles to the line of section must be corrected to lower values, because in effect the cross-section cuts these strata obliquely, and their dips will hence be apparent dips on the cross-section. The more oblique the strike to the section line, the lower the apparent dip will be. (Appendix 10, Figure A10.1 shows a graph you can use to determine apparent dips.) Draw short lines for the dip data at the correct angle just above the profile initially, as a guide.

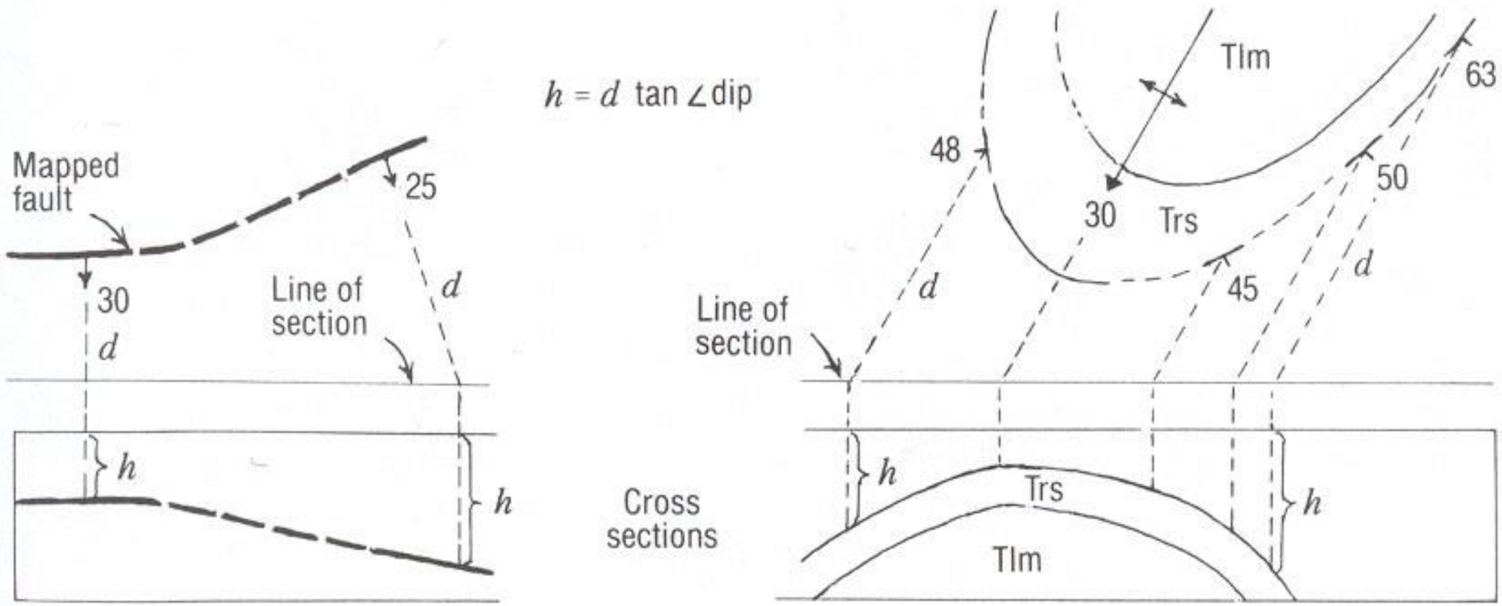


(f)

Choose an important marker horizon or stratigraphic boundary, and draw this across the section, matching its dip to the dip measurements where possible, and interpolating between the different points on intersection with the topography. With this guide to the overall structure, add other unit boundaries in the same way; unless you have evidence for varying strata thickness, draw these parallel to the first horizon. In some cases, you may know or be able to determine the throw on faults, and their attitude; you may also be able to define fold structures. Generally, you will be able to extend your section further below the surface in folded areas; indicate uncertainty with question marks. Finally, add a key to unit colours and other symbols.

Coe et al. (2010)

Project structures outside the section line. Examine the map thoroughly for contacts or other structures that do not project along the surface to the section line but dip or plunge into the section below the ground surface.

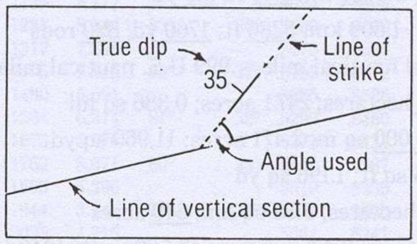


Compton (1985)

Fig. 6-7. Projecting structures that cut across sections beneath the surface, which in the cases shown is a level plain. Depths (h) are calculated by the equation shown. In calculating h for the fold, the angle of plunge is used rather than the angle of dip. For a contact or fault (*left*), the distance d is measured parallel to the local dip, and for a fold (*right*) it is measured parallel to plunge. The apparent dip to be plotted at any point can be read from Appendix 13 or by projecting a number of points and connecting them by a smooth line. If the ground surface is not a level plain, the difference in elevation between the original map point and the point projected to the line of section must be added or subtracted to h.

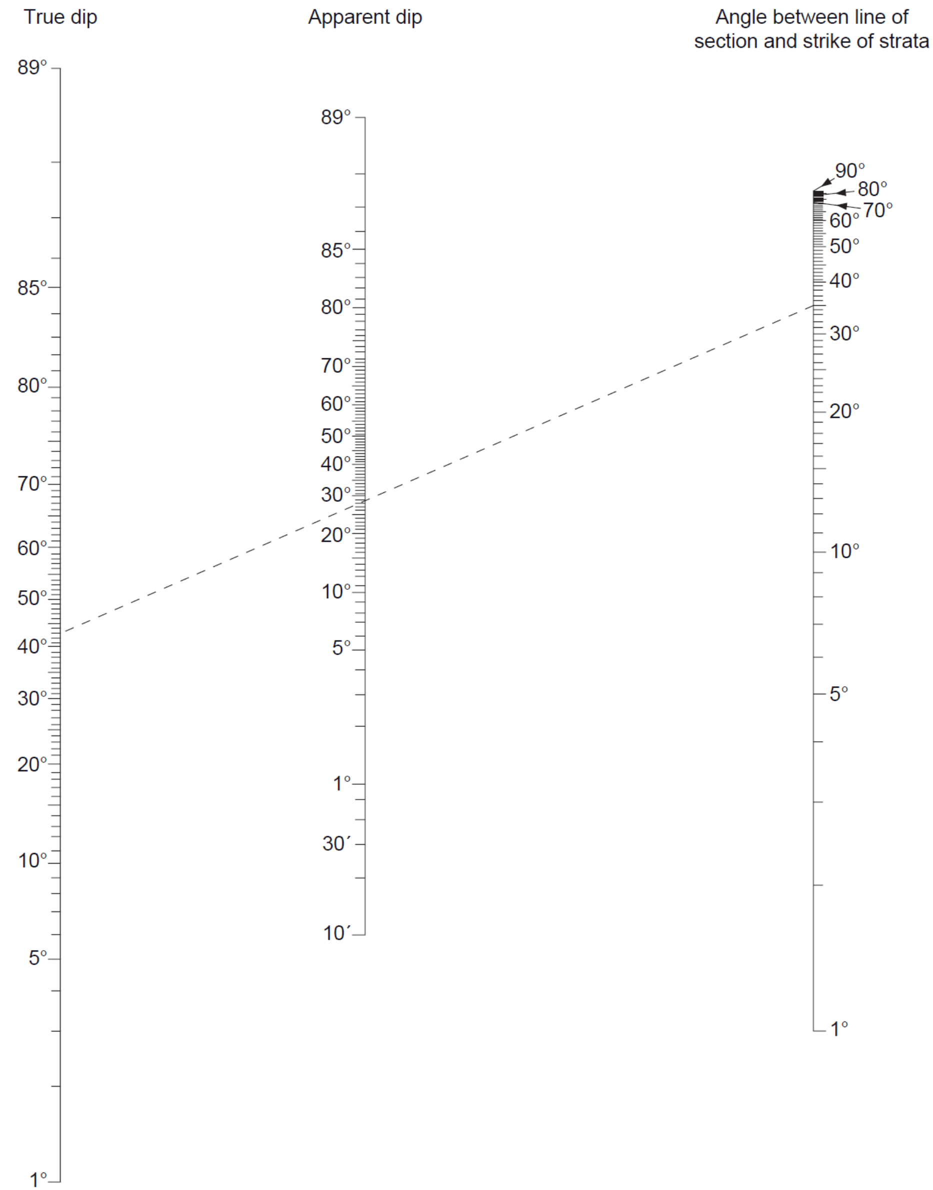
APPENDIX 13: Table for Interconversion of True Dip and Apparent Dip

The true dip of a planar feature is seen in vertical sections oriented perpendicular to the strike of the feature. Vertical sections oriented otherwise show apparent dip. All beds have horizontal apparent dips in any vertical section parallel to their strike, and the apparent dip increases as the acute angle between the vertical section and the strike increases, approaching the true dip as the angle between the section and the strike approach 90°. The values of apparent dip given below correspond to the true dips shown at the left of the table and to the angles between strike and the line of the vertical section shown at the top of the table and in the diagram. The values of apparent dip are rounded to the nearest 0.5° because dips are rarely measured or plotted more precisely.



True dip	ACUTE ANGLE BETWEEN STRIKE AND LINE OF VERTICAL SECTION														
	2.5	5	10	15	20	25	30	35	40	45	50	55	60	65	70	80
5	0.0	0.5	1.0	1.5	2.0	2.0	2.5	3.0	3.0	3.5	4.0	4.0	4.5	4.5	5.0	5.0
10	0.5	1.0	2.0	2.5	3.5	4.0	5.0	6.0	6.5	7.0	8.0	8.0	8.5	9.0	9.5	10.0
15	1.0	1.5	3.0	4.0	5.0	6.5	8.0	9.0	10.0	11.0	11.5	12.5	13.0	13.5	14.0	15.0
20	1.0	2.0	3.5	5.5	7.0	9.0	10.0	12.0	13.0	14.5	15.5	16.5	17.5	18.0	19.0	20.0
25	1.0	2.0	4.5	7.0	9.0	11.0	13.0	15.0	17.0	18.0	20.0	21.0	22.0	23.0	24.0	25.0
30	1.5	3.0	6.0	8.0	11.0	14.0	16.0	18.5	20.5	22.0	24.0	25.0	26.5	27.5	28.5	29.5
35	2.0	3.5	7.0	10.5	13.5	16.5	19.5	22.0	24.0	26.5	28.0	30.0	31.0	32.5	33.5	35.5
40	2.0	4.0	8.0	12.0	16.0	19.5	23.0	26.0	28.5	30.5	33.0	34.0	36.0	37.0	38.5	39.5
45	2.5	5.0	10.0	14.5	19.0	23.0	26.5	30.0	33.0	35.0	37.0	39.0	41.0	42.0	43.0	44.5
50	3.0	6.0	11.5	17.0	22.0	27.0	31.0	34.5	37.5	40.0	42.5	44.0	46.0	47.0	48.0	49.5
55	4.0	7.0	14.0	20.0	26.0	31.0	35.5	39.5	42.5	45.0	47.5	49.5	51.0	52.5	53.5	54.5
60	4.5	8.5	16.5	24.0	30.5	36.0	41.0	45.0	48.0	51.0	53.0	55.0	56.0	57.5	58.5	59.5
65	5.5	10.5	20.5	29.0	36.0	42.0	47.0	51.0	54.0	56.5	58.5	60.0	62.0	63.0	63.5	64.5
70	6.5	13.0	25.5	35.0	43.0	49.0	54.0	57.5	60.5	63.0	64.5	66.0	67.0	68.0	69.0	69.5
75	9.0	18.0	33.0	44.0	52.0	57.5	62.0	65.0	67.5	69.0	70.5	72.0	73.0	73.5	74.0	75.0
80	13.5	26.5	44.5	56.0	63.0	67.5	70.5	73.0	74.5	76.0	77.0	78.0	78.5	79.0	79.5	80.0
85	26.0	45.0	63.5	71.5	75.5	78.0	80.0	81.5	82.0	83.0	83.5	84.0	84.0	84.5	84.5	85.0

Compton (1985)



igure A10.1 Nomogram to determine the apparent dip given the true dip and the angle between the strike nd the line of section. The dashed line illustrates an example: for a true dip of 43° on a cross-section oriented t 35° to the strike of the bedding, the apparent dip on the cross-section would be 28°. (Based on Billings 972.)

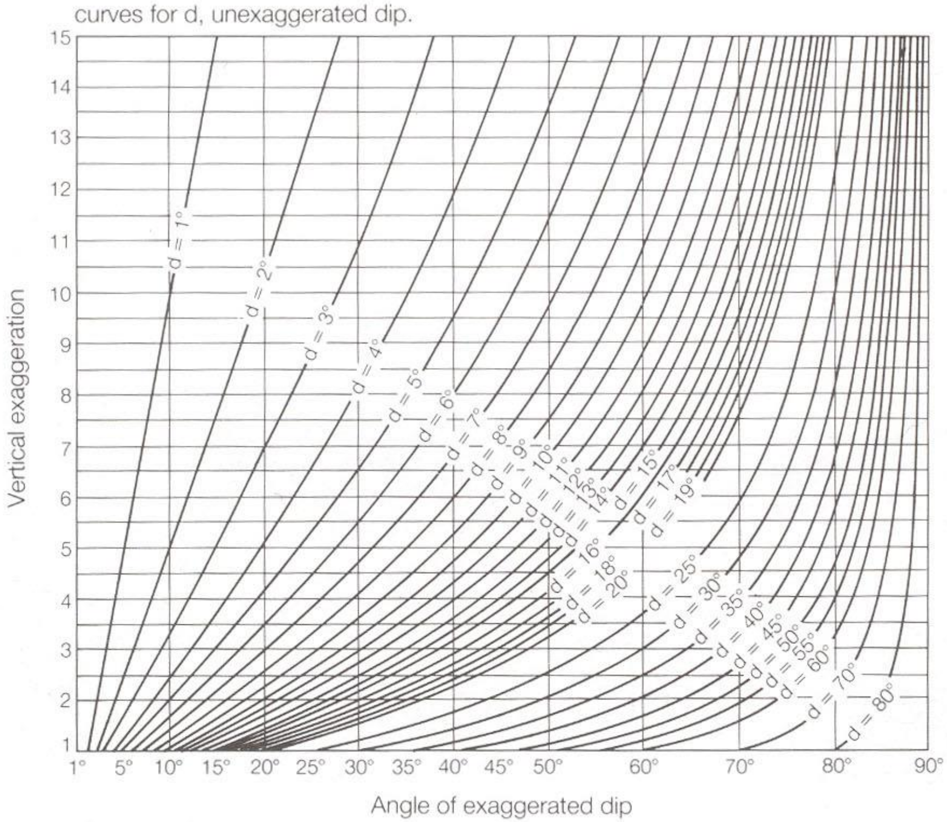
Vertical Exaggeration

In most cases, the horizontal scales of map and section should be the same. If a larger vertical scale is employed it leads to vertical exaggeration. This practice is to show greater detail on the section.

(a) trigonometric relation:

TAN EXAGGERATED DIP = VERTICAL EXAG. × TAN UNEXAG. DIP

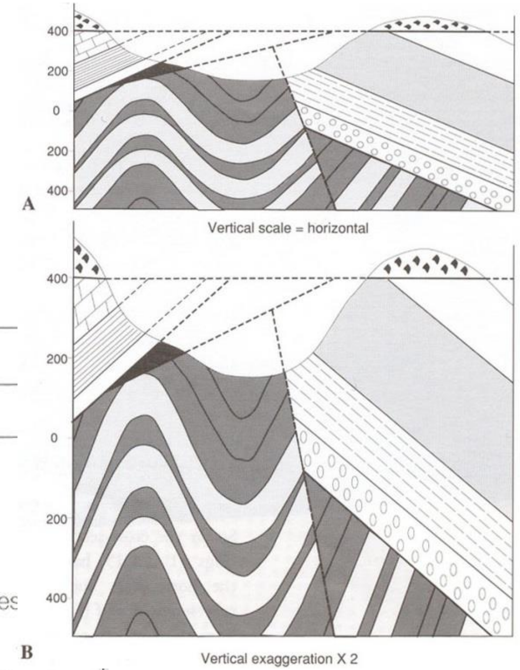
(b) graphical relation:



e.g *to find exag. dip:* select curve of unexag. dip (interpolation between curves necessary at high values). From intersection with horizontal line of appropriate vertical exag., project down to find amount of exag. dip

to find unexag. dip: project upwards from point on horizontal axis of known exag. dip to meet horizontal line of known vertical exag. Interpolate to nearest dip curve to find unexag. dip

Figure 5.3 Trigonometric and graphical relations between vertical exaggerations and dip angles.



Powell (1992)

Maltman, A. (1998) Geological Maps: An introduction, 2nd edition. John Wiley & Sons, 260 pp.

Exposures on horizontal surfaces

Structural planes and topography

Relationship between outcrop width and thickness and dip: (a) with dip constant, outcrop width varies with thickness; (b) with thickness constant, outcrop width varies with dip angle.

The width of the outcrop bands (not true thickness) on a horizontal plane depends on two factors:
the actual thickness of the layers,
the angle of dip of each layer.

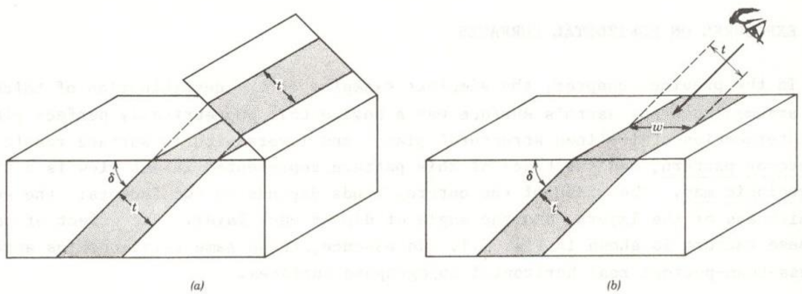


FIGURE 3.2 An auxiliary view showing true thickness: (a) constructed perpendicular to the line of true dip; (b) obtained by down-dip view of the map.

A line of sight inclined to the plane of the outcrop (or map) at the dip angle helps to visualize the true thickness.

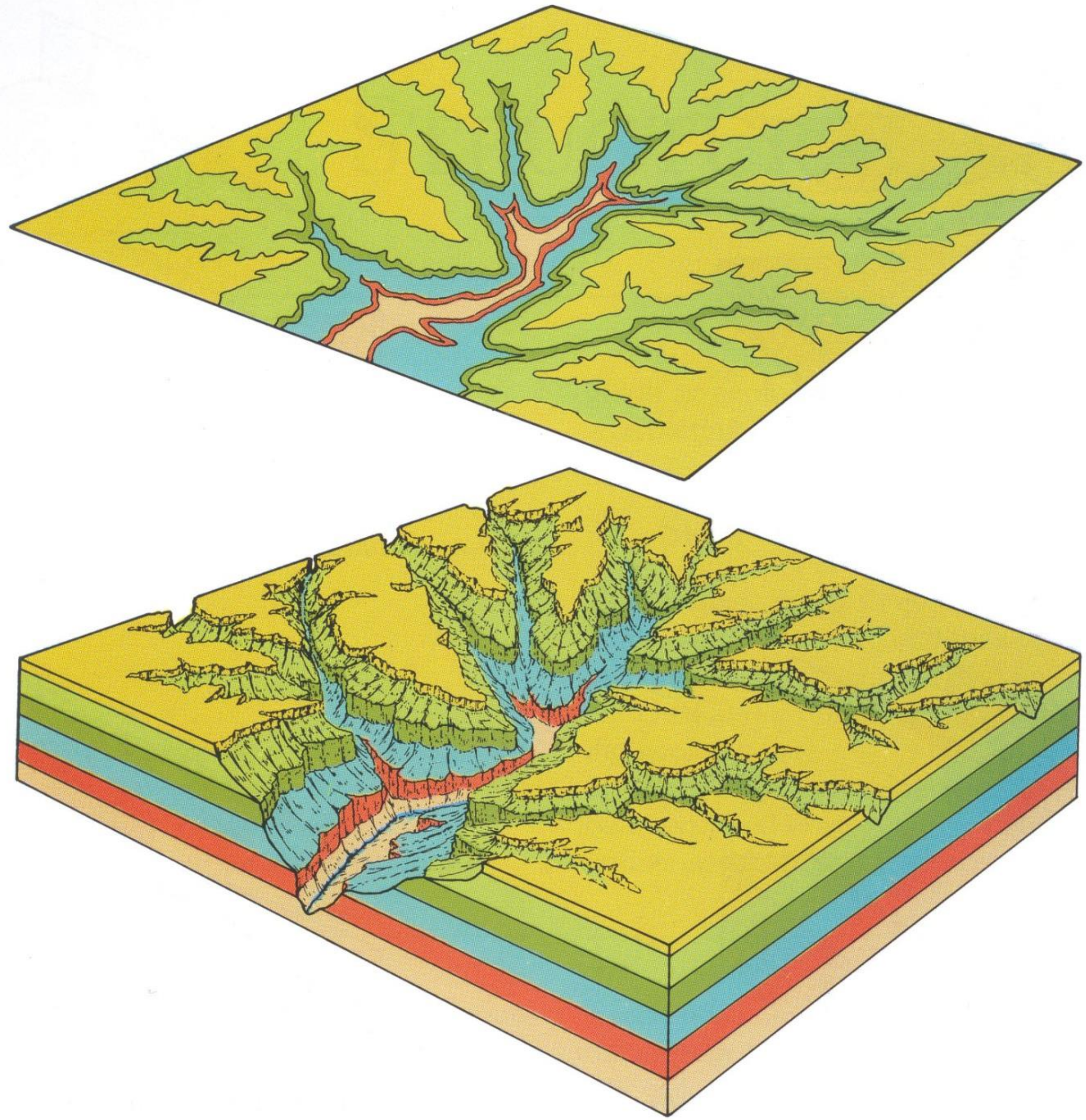


FIGURE 16.3
Outcrop Patterns of Horizontal Strata

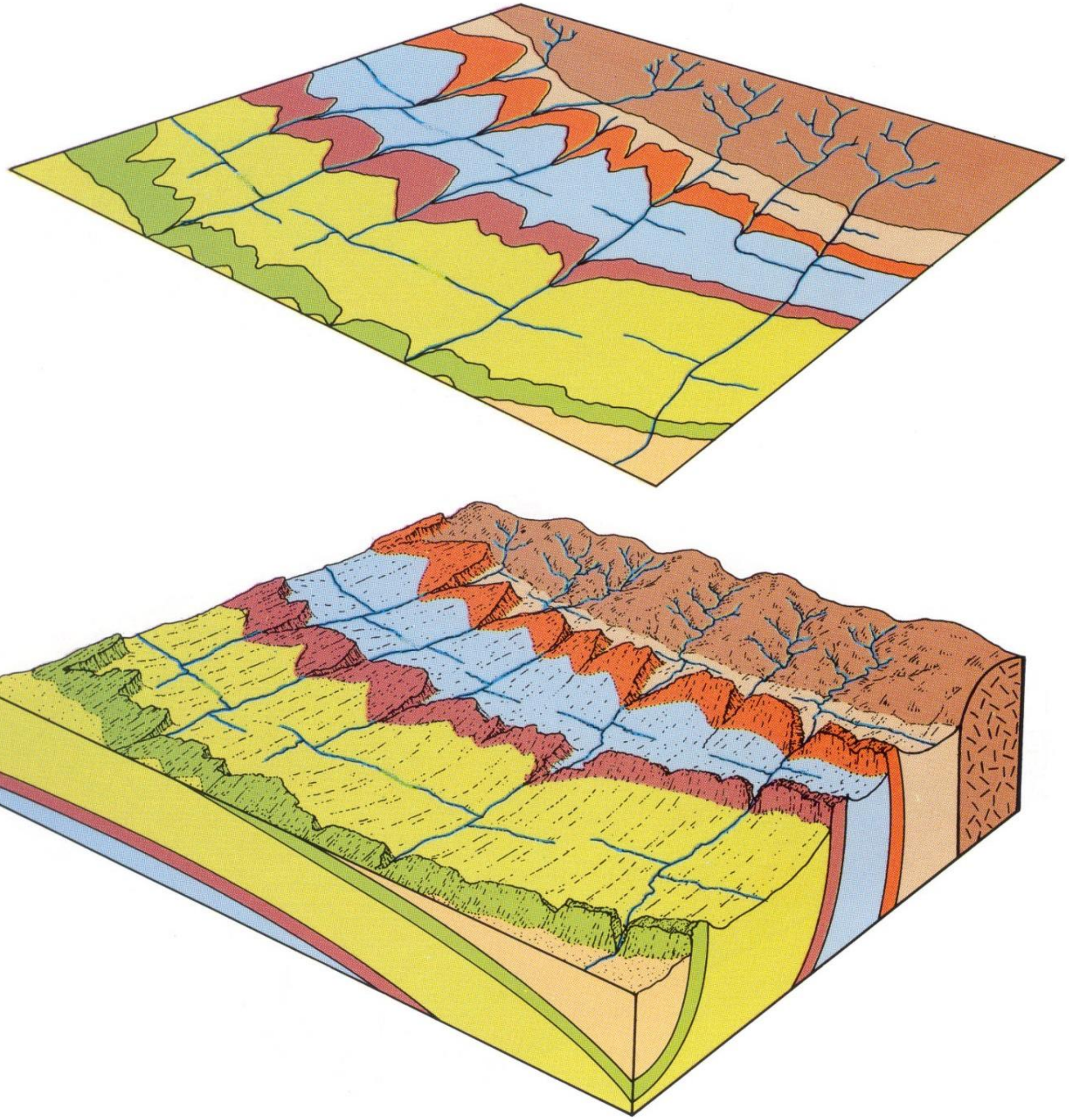


FIGURE 16.4
Outcrop Patterns of Inclined Strata

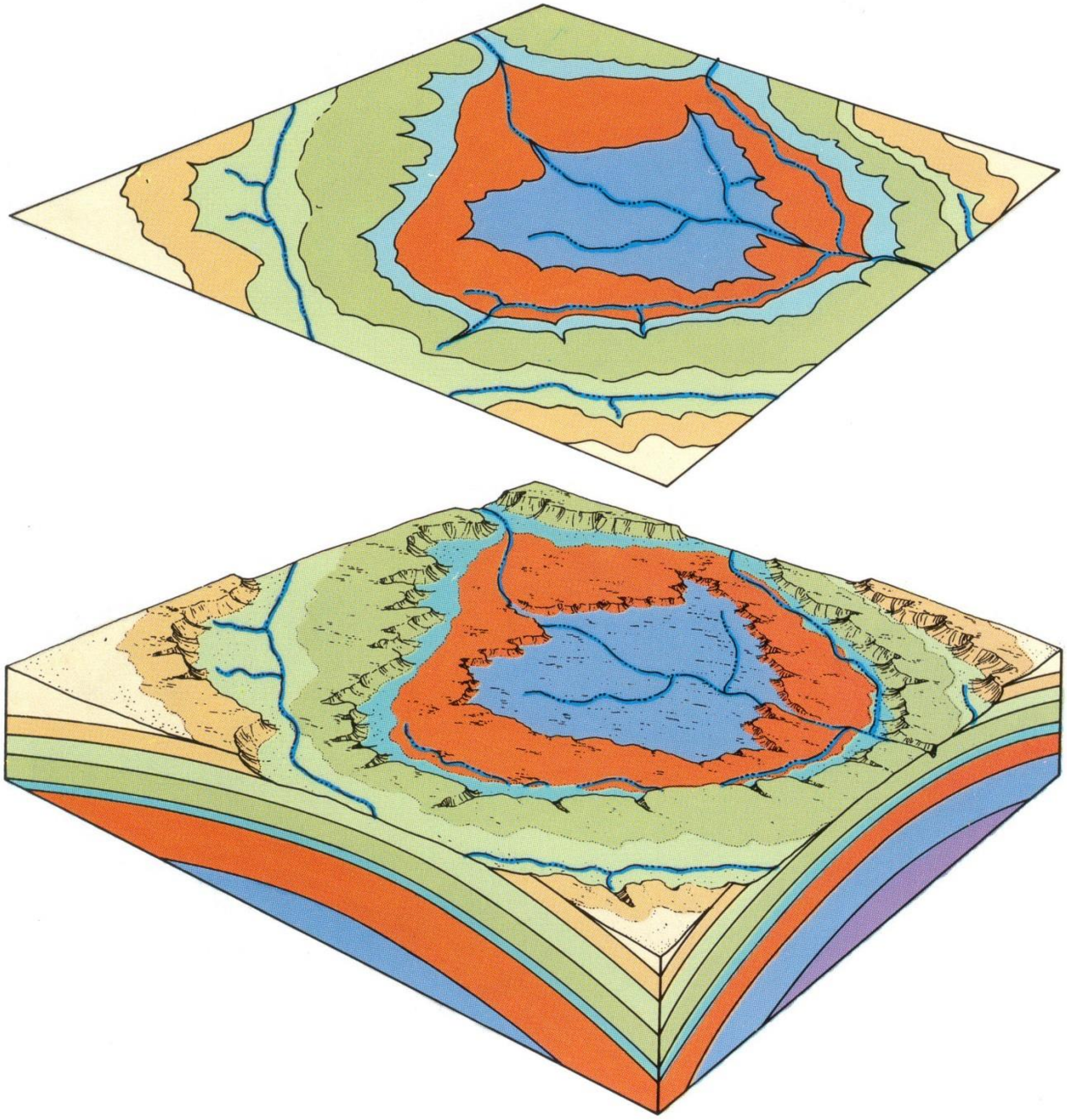


FIGURE 16.5
Outcrop Patterns of a Dome

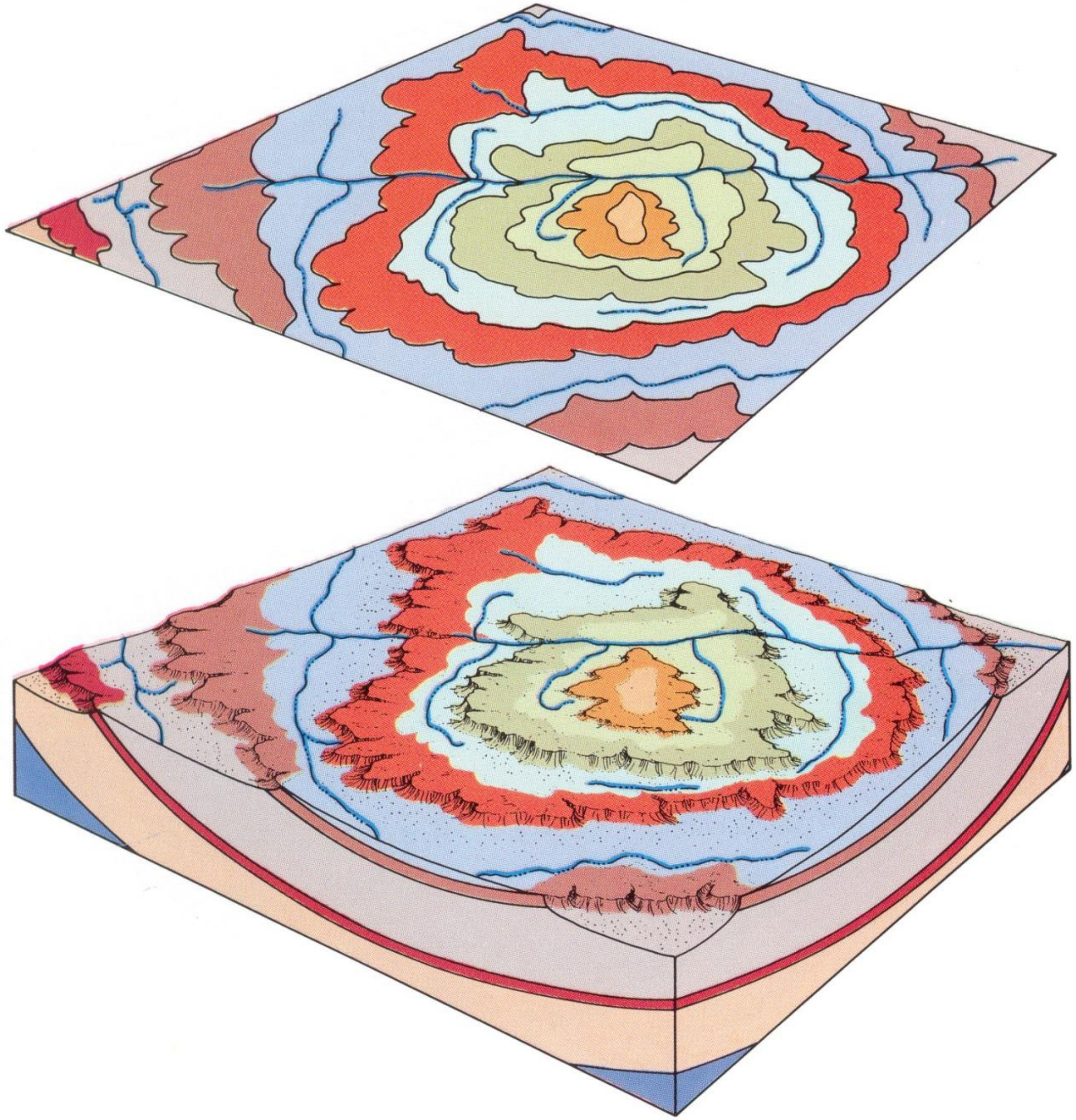


FIGURE 16.6
Outcrop Patterns of a Basin

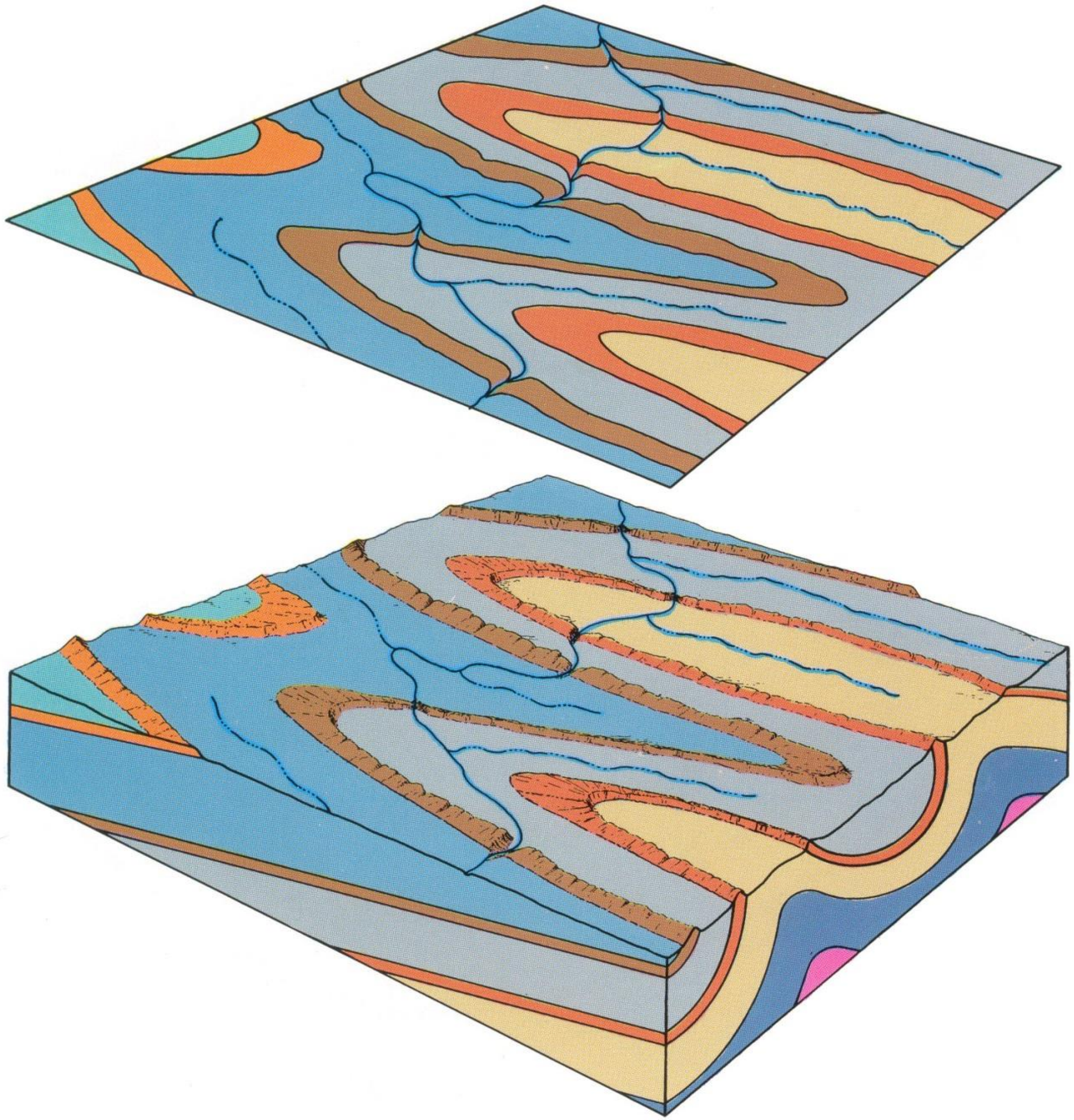


FIGURE 16.7
Outcrop Patterns of Plunging Folds

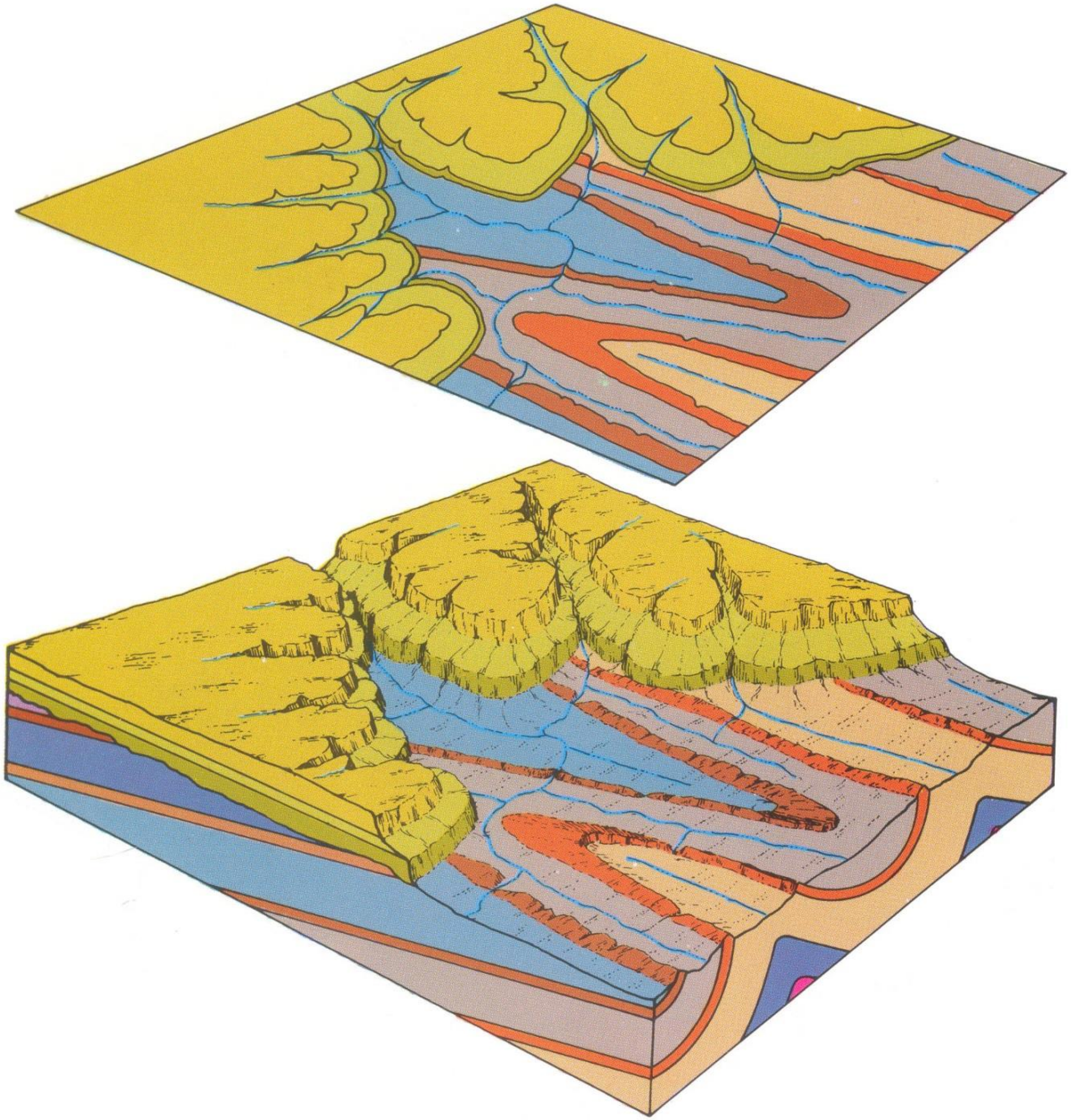


FIGURE 16.8
Outcrop Patterns of an Unconformity

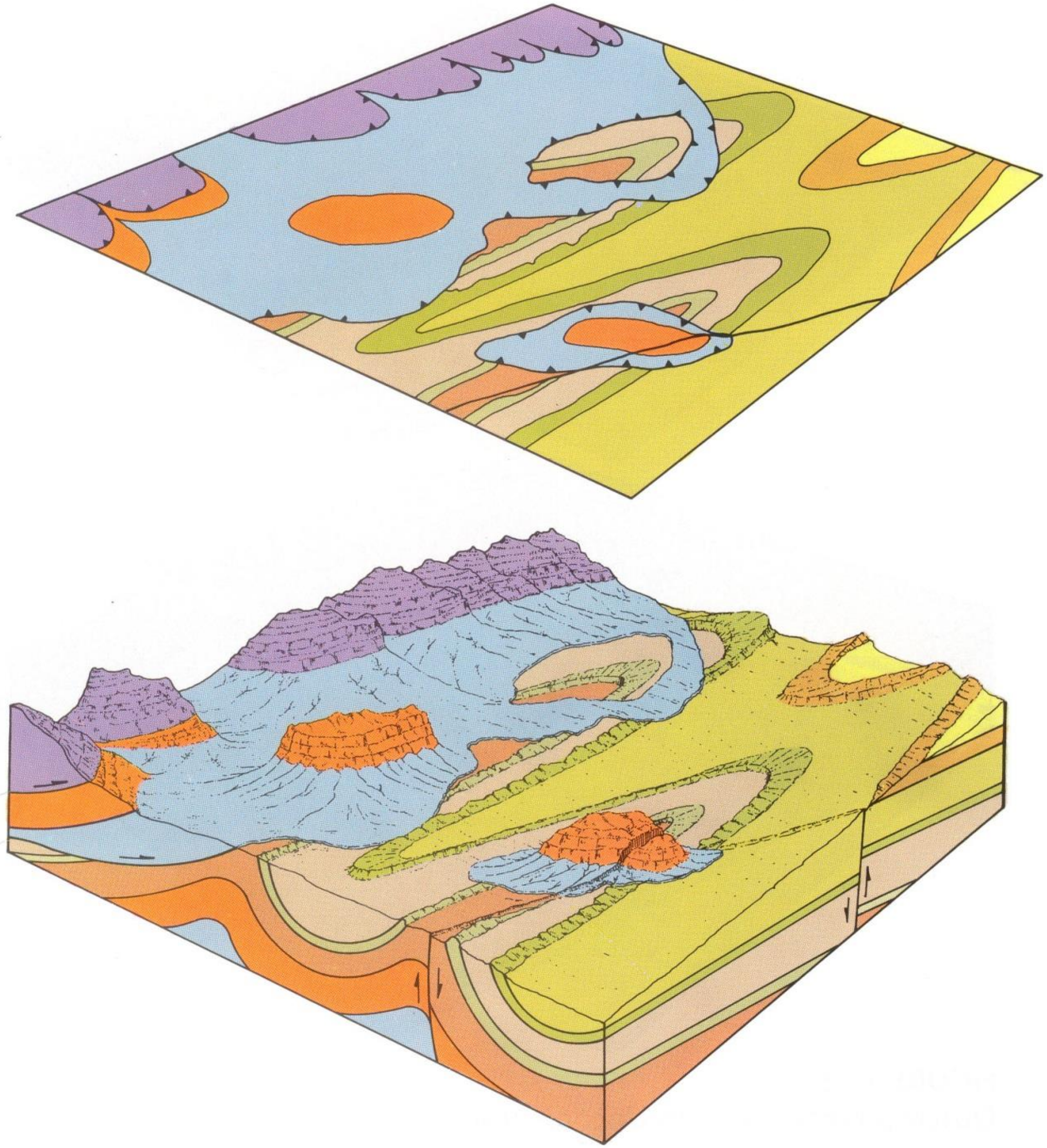


FIGURE 16.9
Outcrop Patterns of Normal and Thrust Faults

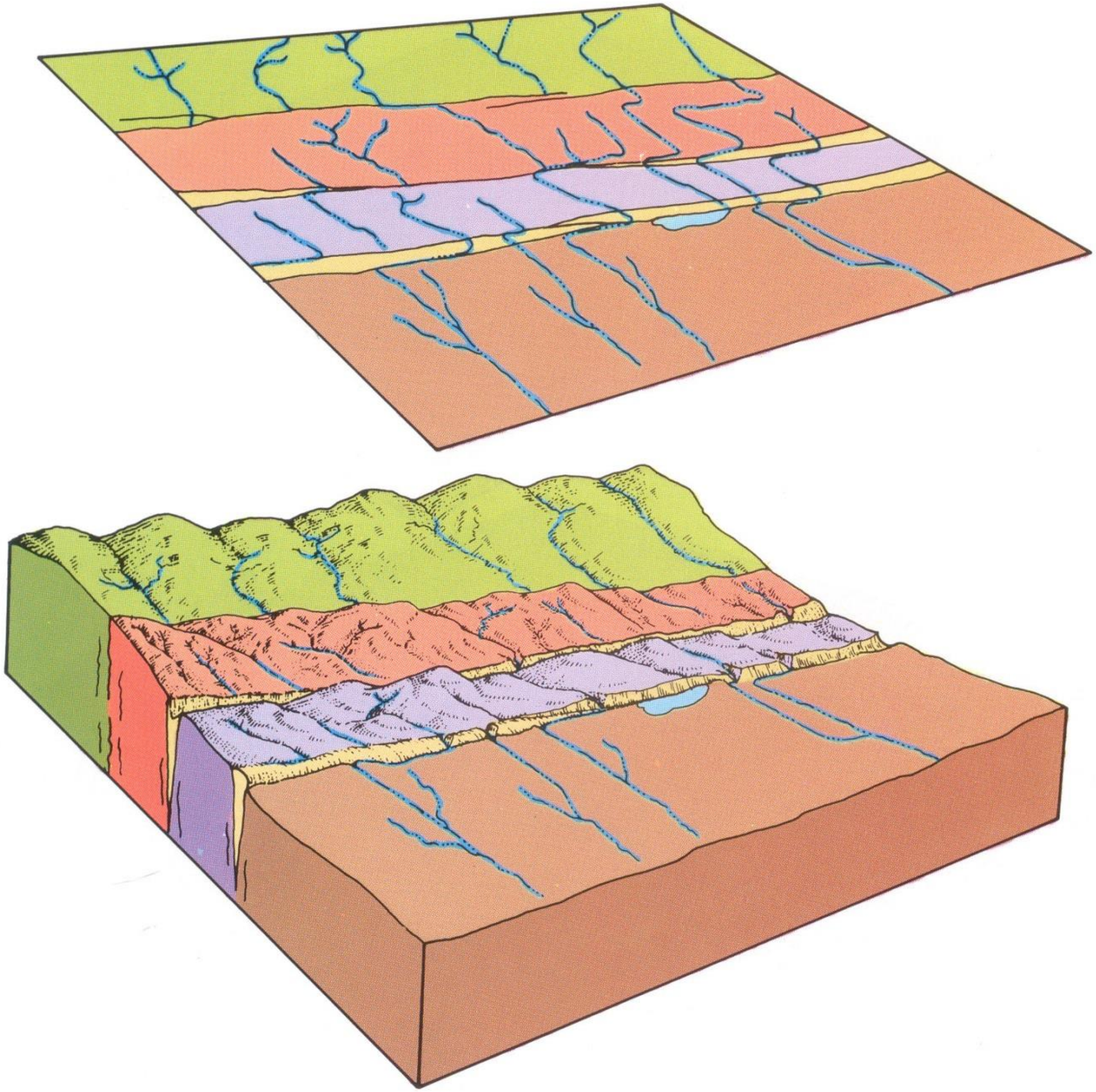


FIGURE 16.10
Outcrop Patterns of Strike-Slip Faults

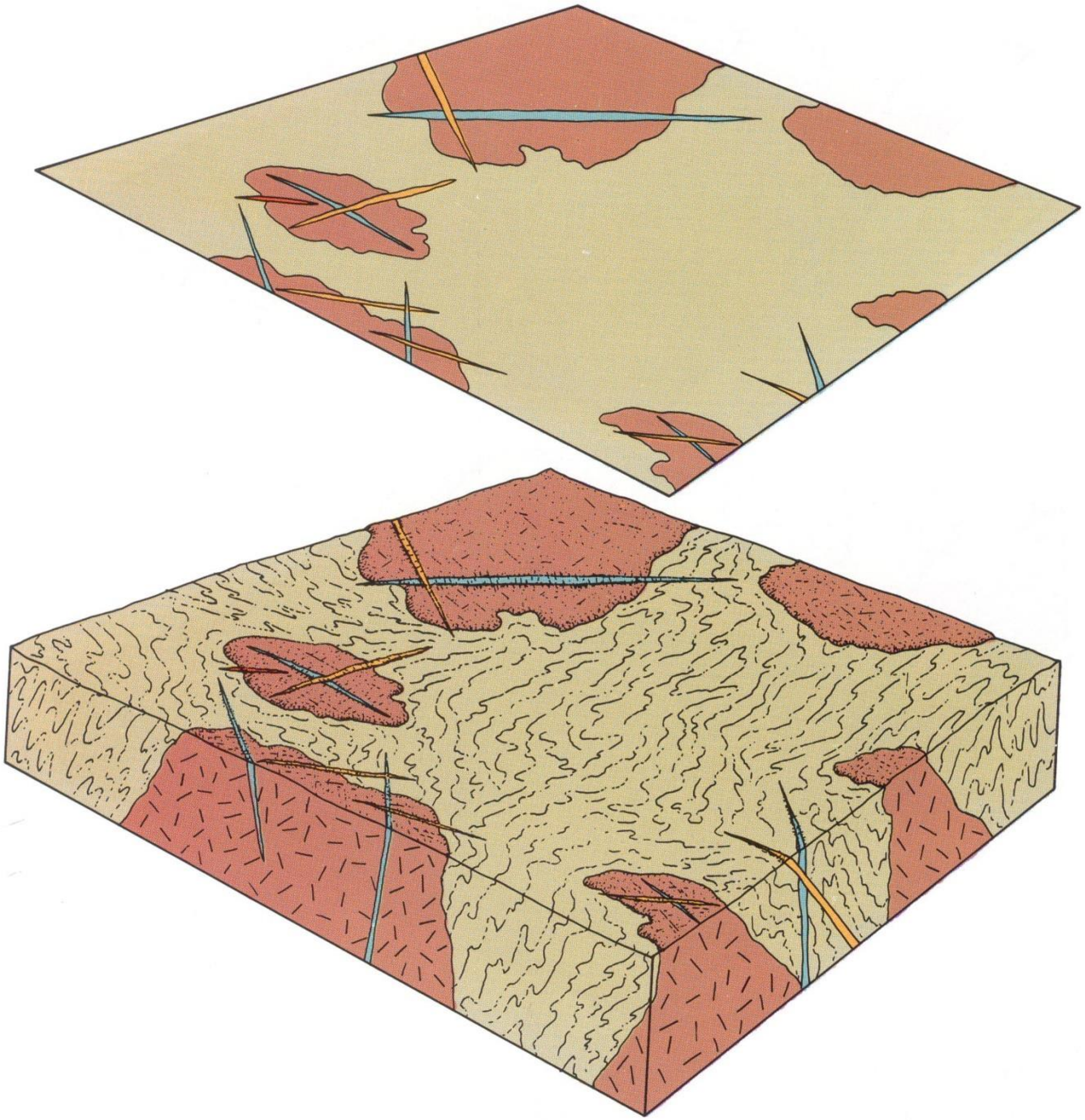


FIGURE 16.11
Outcrop Patterns of Intrusive Rocks

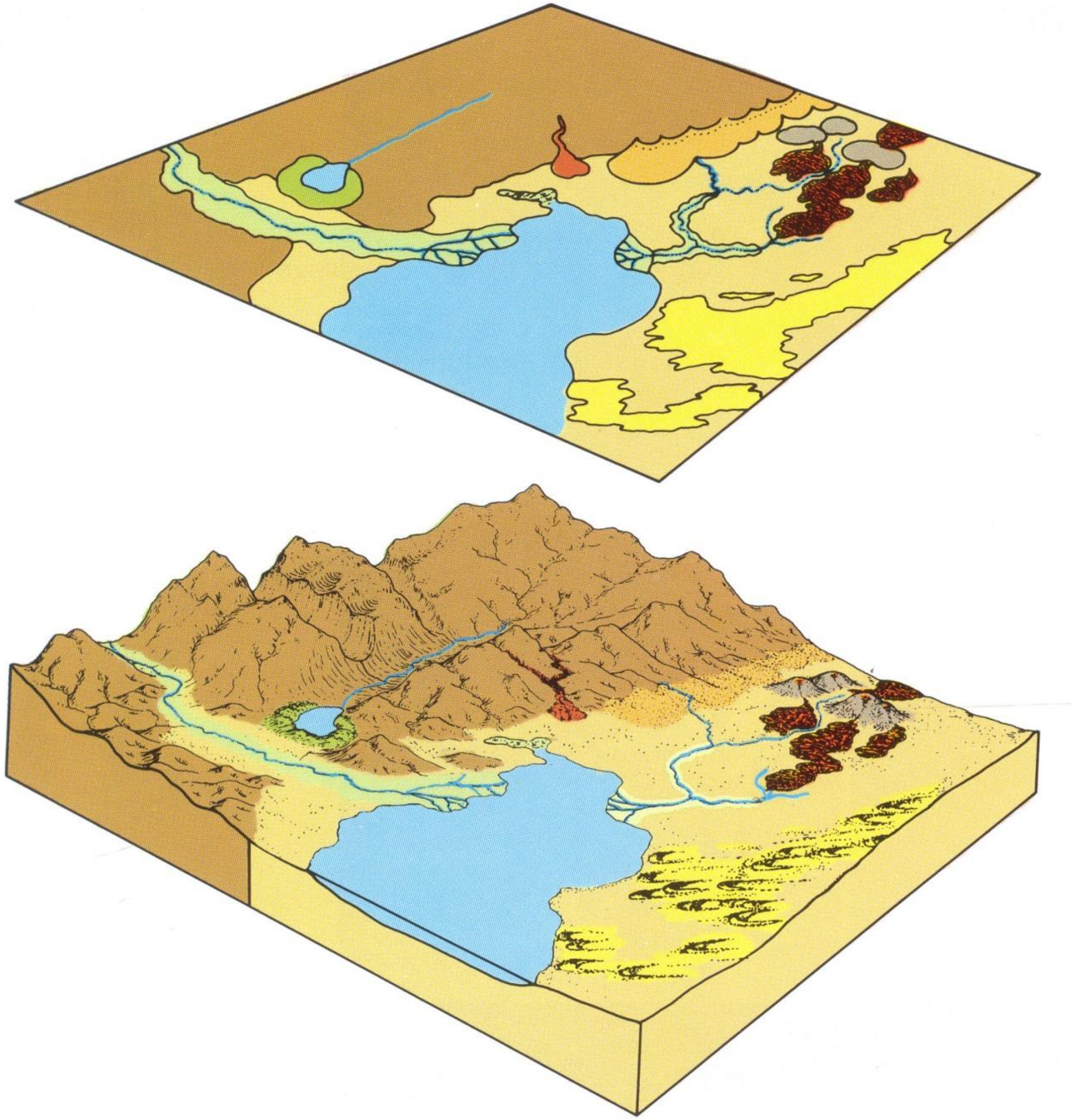


FIGURE 16.12
Outcrop Patterns of Surficial Deposits