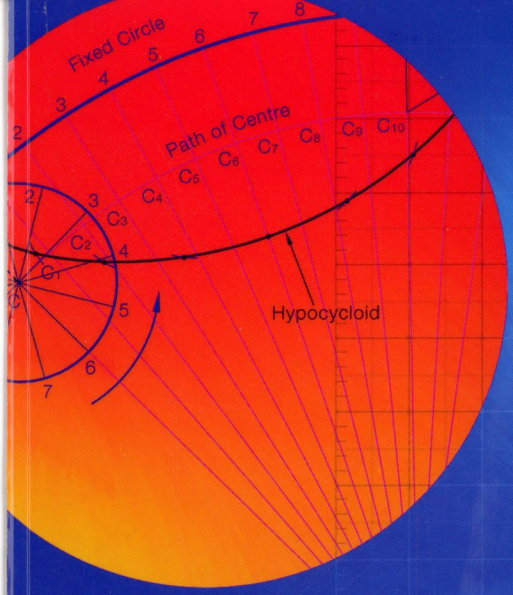
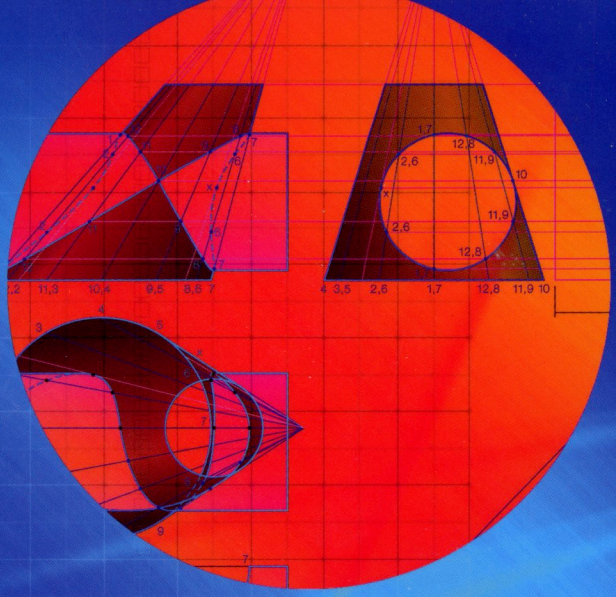
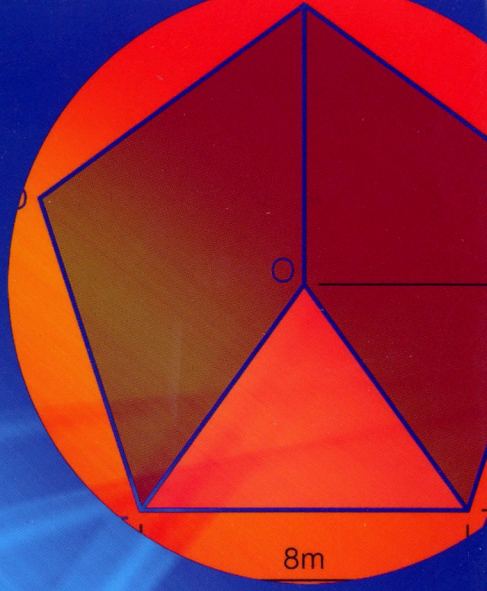
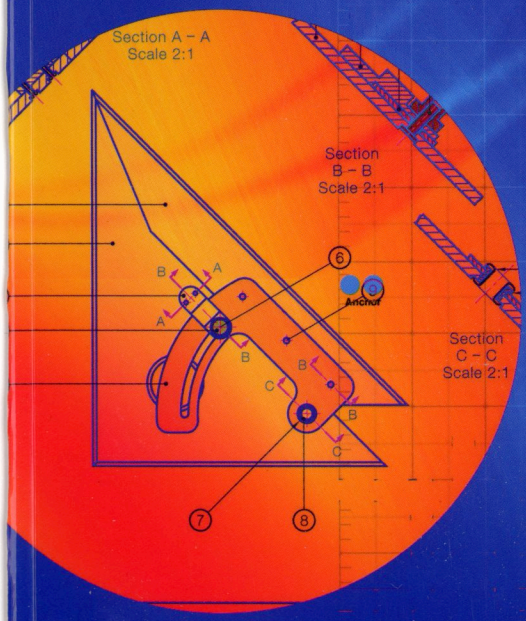


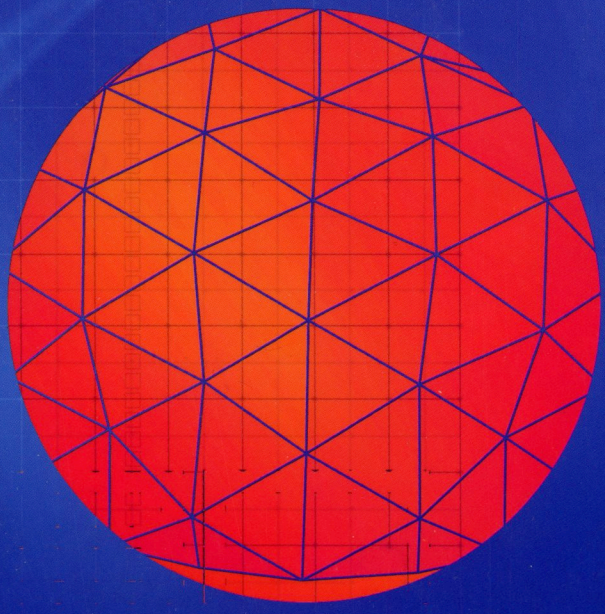


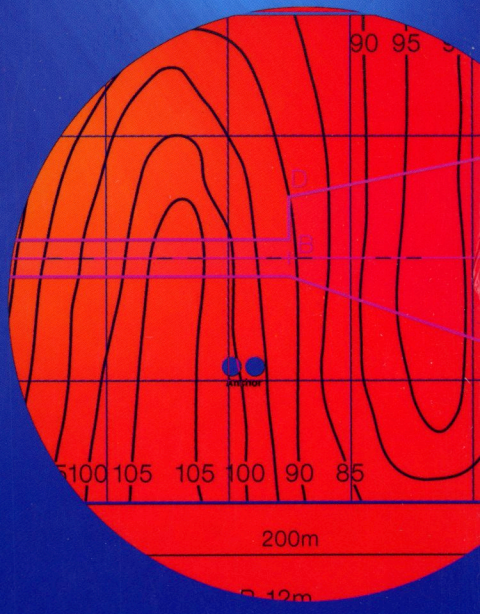


GRAPHICS IN DESIGN & COMMUNICATION 2

CAD AND APPLIED GRAPHICS







DAVID ANDERSON

18 Structural Forms

SYLLABUS OUTLINE

Areas to be studied (in an applied context):

• Structural forms, natural and manufactured. • Singly and doubly ruled surfaces. • The hyperbolic paraboloid as a ruled surface. • *The hyperbolic paraboloid as a surface of translation.* • *Plane directors.* • The hyperboloid of revolution, projections and sections. • Sections through singly and doubly ruled surfaces. • *The geodesic dome of not more than four points of frequency.*

Learning outcomes

Students should be able to:

Higher and Ordinary levels

- Investigate the development of structural forms in a historical context.
- Identify the key structural forms including arches, domes, vaults, frames and surface structures.
- Produce line drawings of the basic structural forms.
- Produce two-dimensional drawings of arches, domes, vaults and surface structures.
- Construct a hyperbolic paraboloid as a ruled surface.
- Determine the true shape of sections through curved surfaces.
- Project views and sections of a hyperboloid of revolution.

Higher level only

- *Relate the key properties of structural forms to their design and construction.*
- *Produce three-dimensional drawings of arches, domes, vaults and surface structures.*
- *Determine plane directors for ruled surfaces, and construct ruled surfaces given plane directors and directrices.*
- *Project views of a hyperbolic paraboloid defined as a surface of translation.*
- *Construct geodesic domes of not more than four points of frequency.*
- *Investigate and represent structural forms as they occur in the environment.*

In this chapter we will be looking at the historical development of some common structural forms including the arch, the dome and the vault. We will then move on to look at some structural forms of special interest, the hyperbolic parabaloid and the hyperboloid of revolution.

Column and Beam

Using columns and beams is the simplest way to make an opening in a wall. The column or post is the vertical member and the beam is the horizontal member. The beam supports the weight (load) above it and its own weight. This weight is then transferred to the columns and from these to the lower structure. This type of construction was used in prehistoric times and is still used in modern day structures.

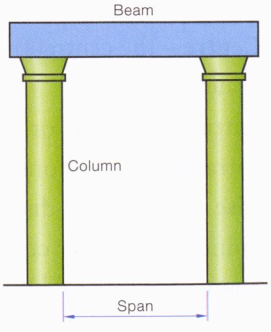


Fig. 18.1

(6) The construction of borehole B is the same. It is bored at an angle of 65° in a north-westerly direction. Draw a line from B at an angle of 65° to the xy line. Where this line meets the xy line at q, project down to a horizontal from B in plan. The constructional borehole is rotated about B into a north-westerly direction and drawn in bold. Find this borehole in elevation.

(7) B_H and B_F have altitudes of 80 m and 45 m respectively. Project these heights onto borehole B in elevation and project to plan.

(8) Join A_H to B_H and also A_F to B_F. The first of these skew lines lies on the headwall and the second on the footwall.

(1) Fig. 19.31 shows that by getting a view showing A_HB_H and A_FB_F appearing as parallel, the strike, dip and thickness of the stratum can be found.
Draw a level line in elevation from one of the points, e.g. A_H From B_H in elevation draw a line parallel to A_FB_F to intersect the level line at O.

(2) From B_H in plan draw a line parallel to A_FB_F. This line intersects the projection line from O in elevation to find point O in plan.

(3) Join O back to A_H. View along A_HO which is the strike. An auxiliary projected in this direction shows the skew lines appearing parallel and thus reveals the thickness and dip of the stratum.

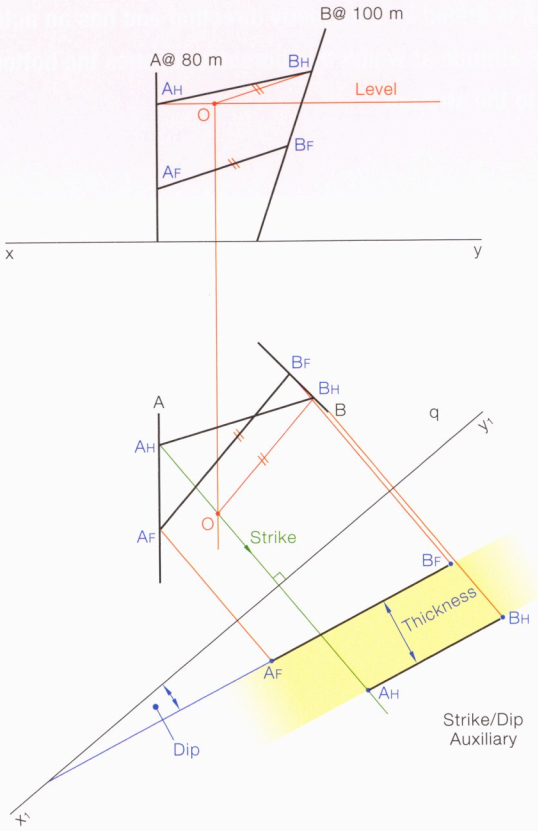
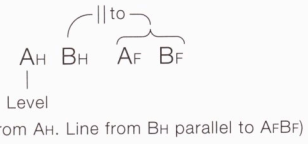


Fig. 19.31



(Level line from AH. Line from BH parallel to AFBF)

On a contour map A and B are two points whose altitudes are 70 m and 90 m respectively. On a map, B is located 90 m south-east of A. A skew borehole at A is drilled in a north-westerly direction in plan and has an actual inclination of 50° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at distances of 35 m and 65 m respectively from A.

A skew borehole at B is drilled in a north-easterly direction in plan and has an actual inclination of 60° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 70 m and 35 m respectively.

(i) Determine the strike, dip and thickness of the stratum.

(ii) A second skew borehole from A is drilled in a southerly direction and has an actual inclination of 60° to the horizontal plane. Determine the altitude at which this borehole touches the bottom surface of the stratum and also the inclination of the borehole to the stratum.

Scale 1:1,000

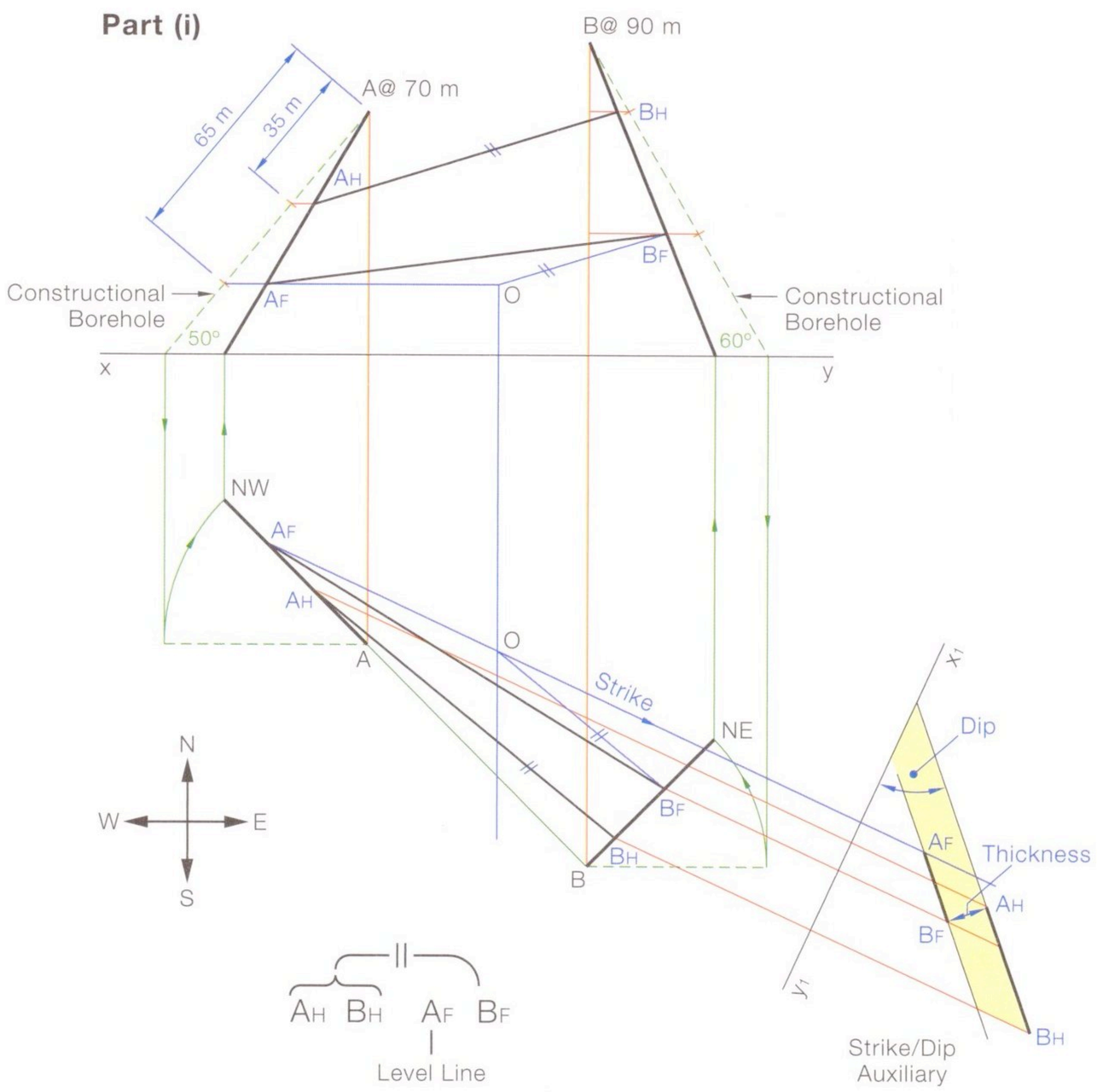


Fig. 19.32

(1) Set up the problem as explained in the previous example. Points A and B are first found in plan. B is 90 m away from A and at a 45° angle in a south-easterly direction.

(2) Project the two points to elevation and at the required elevation.

(3) Draw the borehole A at a 50° angle in elevation, drop it to plan and rotate to a north-westerly direction. Project the rotated borehole to elevation.

(4) This borehole reveals the top and bottom surfaces of the stratum at distances of 35 m and 65 m respectively from A.

These two distances must be measured down from A, along the constructional borehole. This constructional borehole shows true angles and true lengths. As this borehole is rotated into position the points move horizontally thus locating A_H and A_F on the actual borehole. These may be projected down to plan.

(5) Borehole B is found in a similar fashion. The points on the headwall and footwall are given as altitudes. These vertical heights are projected horizontally onto the actual borehole and then down to plan.

(6) A_HB_H and A_FB_F are treated as skew lines. The strike dip and thickness are found as explained in Fig. 19.30.

The second part of the question refers to a new borehole from A, bored in a southerly direction. In order to see this new borehole as a true length and with a true angle, it is viewed perpendicularly. A vertical section is taken along the new borehole to see the position of the stratum at that particular place.

Part (ii)

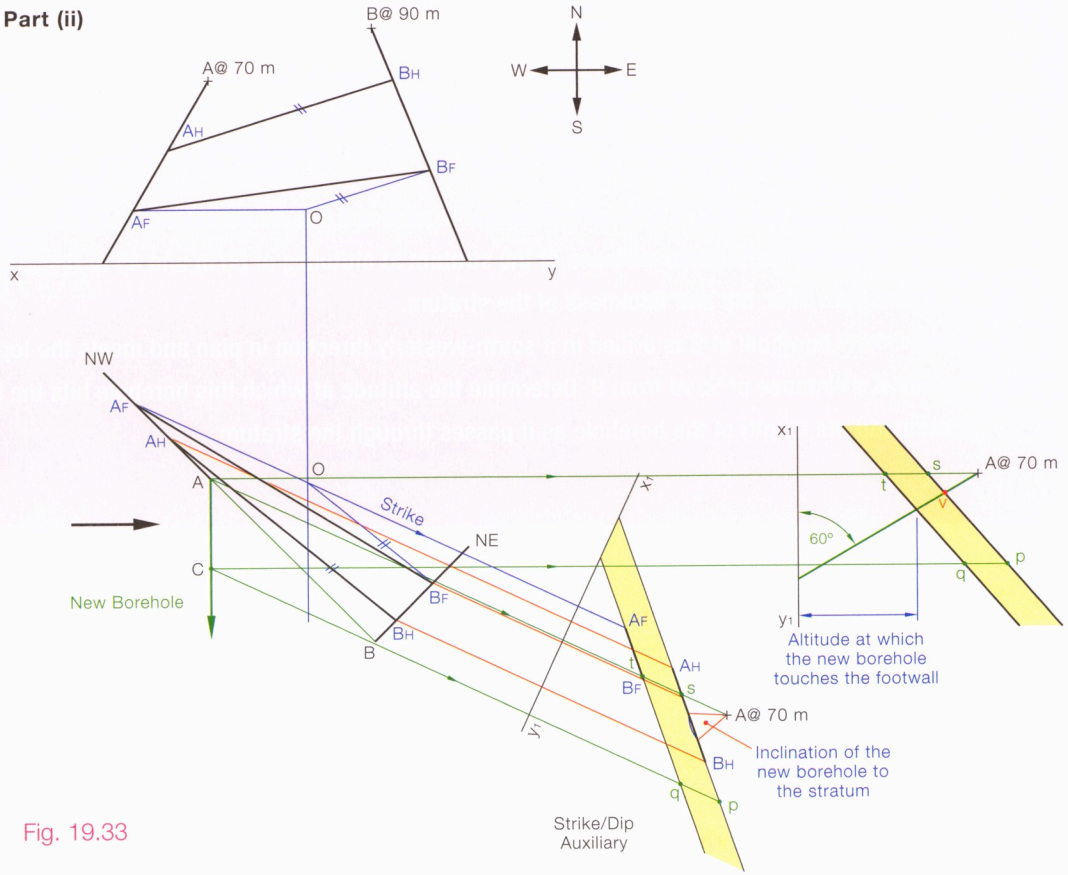


Fig. 19.33

(1) Draw the new borehole from A in plan in a southerly direction.

(2) View perpendicular to this to get the auxiliary view. Point A is projected onto this view to an altitude of 70 m. The borehole is now drawn in the auxiliary making an angle of 60° to the horizontal plane (from question).

(3) The stratum is found by taking a vertical section along the new borehole and projecting it onto the new auxiliary. A vertical borehole is drilled from point A in plan and a second vertical borehole is drilled from a point C anywhere along the new borehole.

(4) **Vertical boreholes will appear perpendicular to the horizontal plane in all elevations.** Draw these vertical boreholes in the new elevation. These two vertical boreholes will hit the stratum at points s, t, p and q (Fig. 19.33). The heights of these four points are found by projecting the same vertical boreholes, A and C, onto the strike/dip auxiliary.

(5) When the points s, t, p and q have been located the vertical section through the stratum can be drawn. The required altitude and inclination can then be clearly seen.

(6) To find the true inclination of the borehole to the stratum, the length Av (which is a true length) is taken on a compass. Use this, as a radius, in the strike/dip auxiliary. With A as centre, scribe an arc to hit the headwall in two places. The inclination of the borehole can then be seen.

On a contour map A and B are two points whose altitudes are 120 m and 100 m respectively. On the map. B is located 95 m north-east of A. A skew borehole at A is drilled in a north-easterly direction in plan and has an actual inclination of 60° to the horizontal plane. It reveals the top and bottom surfaces of a stratum at distances of 45 m and 100 m respectively from A.

A skew borehole at B is drilled in a southerly direction in plan and has an actual inclination of 50° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 60 m and 45 m respectively.

(i) Determine the strike, dip and thickness of the stratum.

(ii) Another skew borehole at B is drilled in a south-westerly direction in plan and meets the top surface of the stratum at a distance of 55 m from B. Determine the altitude at which this borehole hits the bottom surface of the stratum and the length of the borehole as it passes through the stratum.

Scale 1:1,000

(1) Set up A and B in plan and elevation.

(2) Draw the constructional borehole for each point and rotate them into their proper positions.

(3) Locate A_H and A_F noting that the **distances** from A are given. These must be measured **down** from A along the constructional borehole which shows the borehole as a true length.

(4) Locate B_H and B_F by measuring vertical heights above the xy line. Borehole B is in a southerly direction and therefore is only seen as a vertical line in elevation. To find B_H and B_F in plan they must be projected across to the constructional borehole, dropped vertically to plan and rotated into place.

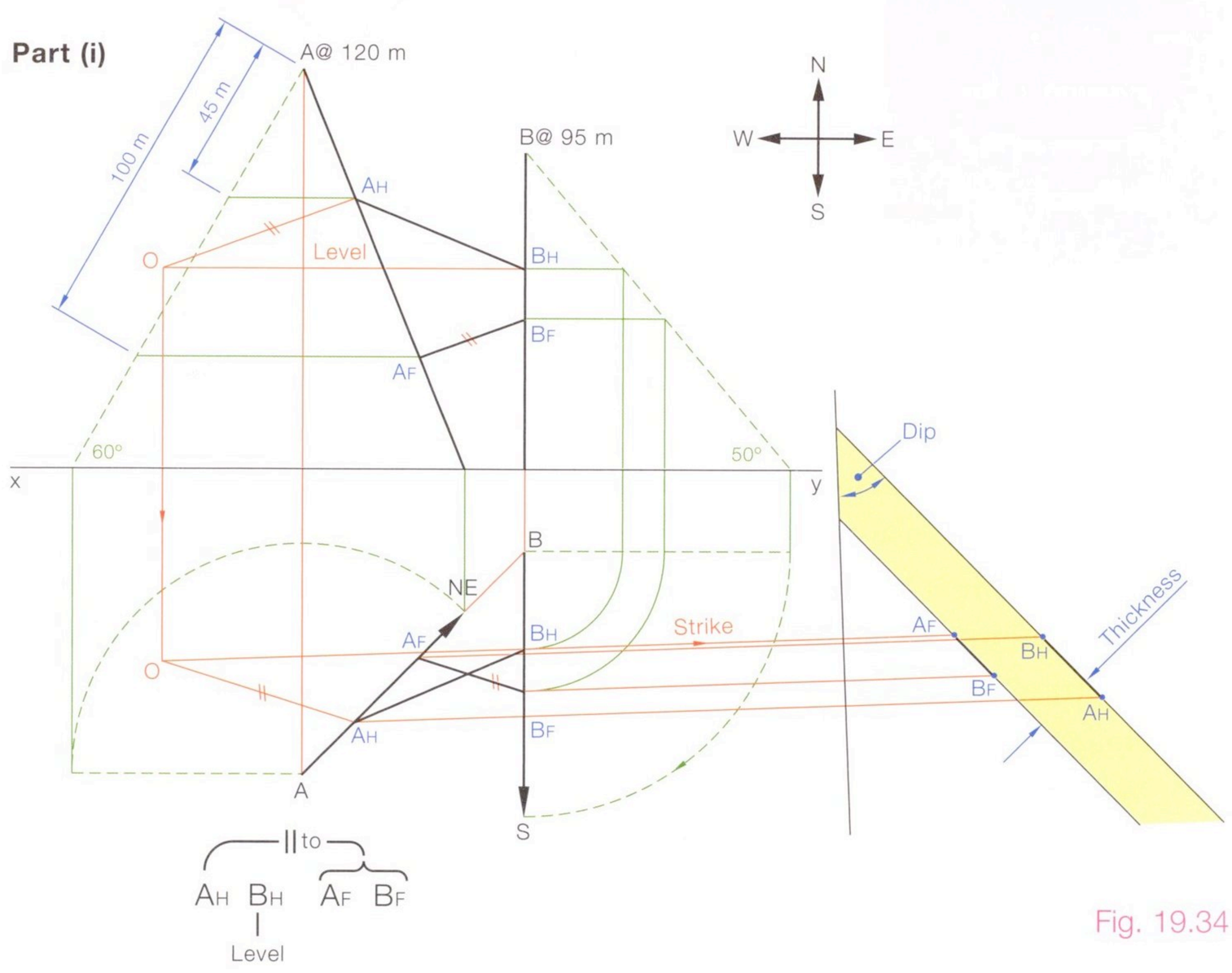


Fig. 19.34

(5) To find the strike, a level line is drawn from one of the points, e.g. B_H. From the other end of this line on the headwall a line is drawn parallel to A_FB_F to intersect the level line at O. Point O is projected to plan and is found exactly by drawing a line from A_H in plan, parallel to A_FB_F in plan. The level line in elevation B_HO, when found in plan, is the strike.

(6) Project the auxiliary and show the dip and thickness of the stratum.

The new borehole is in a south-westerly direction. A vertical section is taken along this borehole and a sectional elevation projected.

Part (ii)

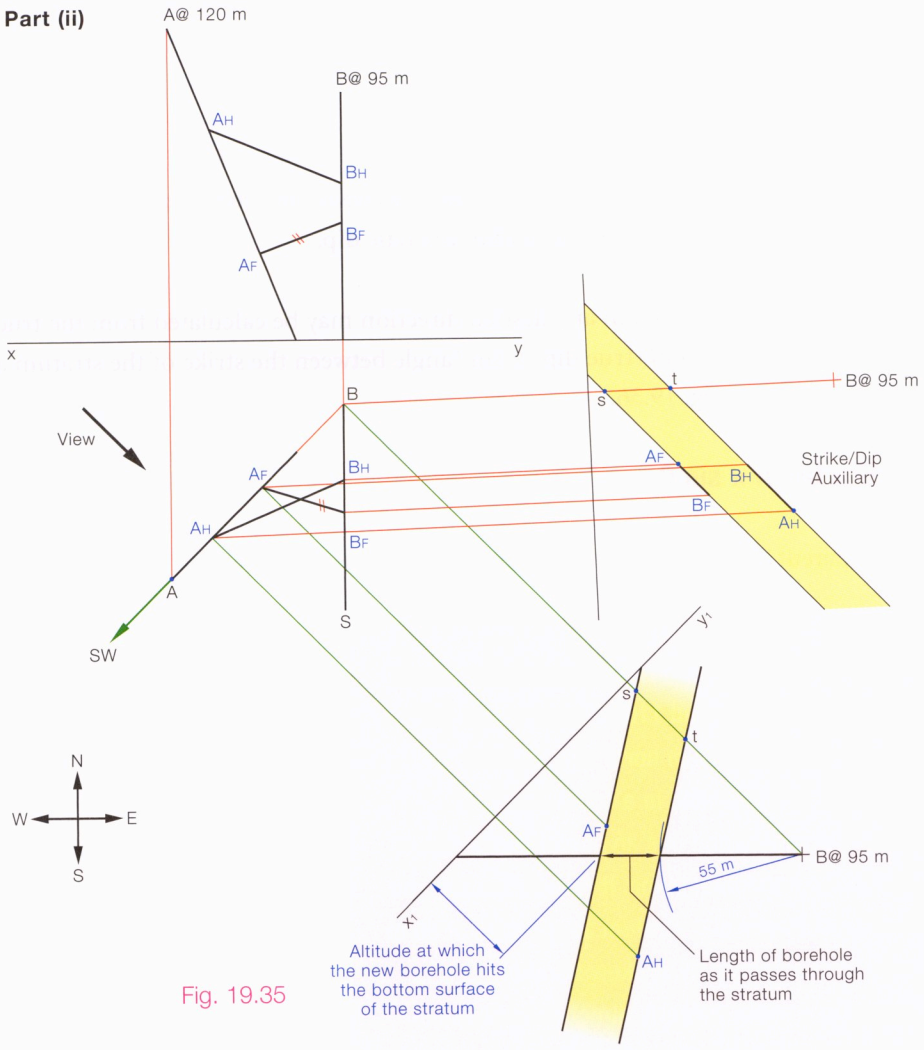


Fig. 19.35

(1) Draw xy parallel to the new borehole.

(2) Project point B onto the new elevation.

(3) The stratum is found. Both A_H and A_F are along the new borehole and can therefore be projected to the new elevation. A further point on the headwall and on the footwall are needed. A vertical borehole is bored at B. Vertical boreholes project perpendicular to the horizontal plane in all elevations. Projected to the strike/dip auxiliary it passes through the stratum at s and t. These two points can now be found in the new auxiliary. Points A_F and s are on the footwall. Points A_H and t are on the headwall.

(4) The new borehole is located by swinging an arc of 55 m length from point B.

(5) The length of the borehole as it passes through the stratum and the altitude at which it hits the bottom surface of the stratum are clearly seen, see Fig. 19.35.

True Dip and Apparent Dip

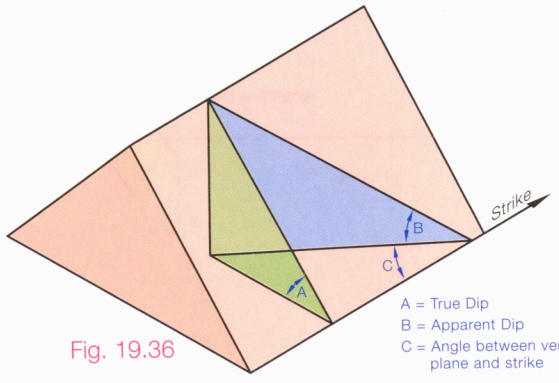


Fig. 19.36

The true dip of a stratum, which is what we have been finding up to this stage, is taken perpendicular to the strike. It can be taken from an edge view of the stratum plane(s) or as a vertical section taken perpendicular to the strike direction. Consider a vertical section taken at a different angle. This will show the layer(s) apparently at a lesser dip. This angle is the apparent dip.

Consider the practical example of a pitched roof. If you walk directly down the roof, taking the shortest route from ridge to

eaves, then that is the steepest slope down the roof. By walking at an angle, the journey will be longer but not as steep. This is the essence of apparent dip. Any plane surface can have only one true dip angle but can have multiple apparent dip angles depending at which angle the section plane is taken.

If a vertical sectional plane is taken perpendicular to the strike of a stratum, then the dip is at its maximum, the true dip of the stratum is found. When the angle between the cross-section and the strike is anything less than 90° then the apparent dip is some value less than the true dip.

The apparent dip of a bed in any desired direction may be calculated from the true dip by the equation:
tan (apparent dip) = tan (true dip) × sin (angle between the strike of the stratum and the direction of the apparent dip)
Referring back to Fig. 19.36.

tan B = tan A × sin C

The apparent dip can also be easily established by graphical means.

HIGHER LEVEL

On a contour map A and B are two points whose altitudes are 85 m and 110 m respectively. On the map, B is located 70 m north of A. A skew borehole at A is drilled in a south-westerly direction in plan and has an actual inclination of 55° to the horizontal plane. It reveals the top and bottom surfaces of a stratum at altitudes of 60 m and 40 m respectively. A skew borehole at B is drilled in a south-easterly direction in plan and has an actual inclination of 60° to the horizontal plane. It reveals the top and bottom surfaces of the stratum at altitudes of 90 m and 10 m respectively.

(i) Determine the strike, dip and thickness of the stratum.

(ii) Determine the apparent dip of the stratum on a vertical section through A that trends in a southerly direction.

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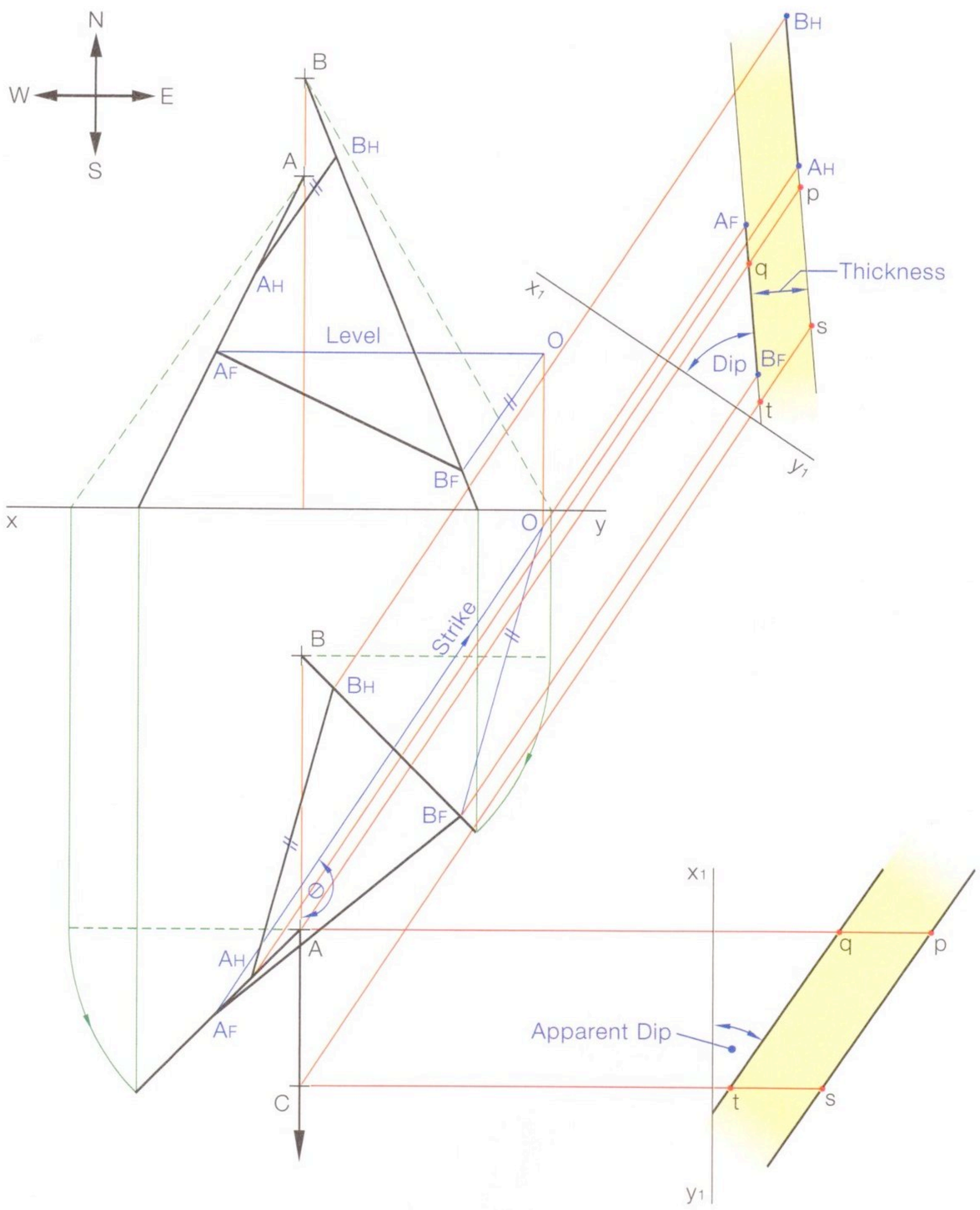

Fig. 19.37

(1) Set up the problem and find the strike, dip and thickness of the stratum in the usual way.

(2) To find the apparent dip, a vertical section is taken in a southerly direction from A. Two vertical boreholes are introduced on this southerly plane, one at A and another at C.