Chapter 5: Structure Contours for Planar Beds

THE LOCAL orientation of a geological bed or stratum can be represented on geological maps by a strike/dip symbol. A more complete way of representing the shape of complex geological structures is by means of structure contours. Such contours can be constructed using points where topographic contours intersect geological outcrop patterns on the ground surface. The interpretation of structure contours then allows an assessment of the subsurface structure of such areas. Structure contours are used not only to represent the shape of geological surfaces, but also provide a means of inferring the strike and dip of geological formations from maps.

Contents: Structure-contour maps are introduced in section 5-1. The determination of strike and dip from structure-contour maps is outlined in section 5-2. The effect of the topographic relief on the outcrop patterns of planar, inclined layers is illustrated for thin beds in section 5-3 and for thick beds in section 5-4.

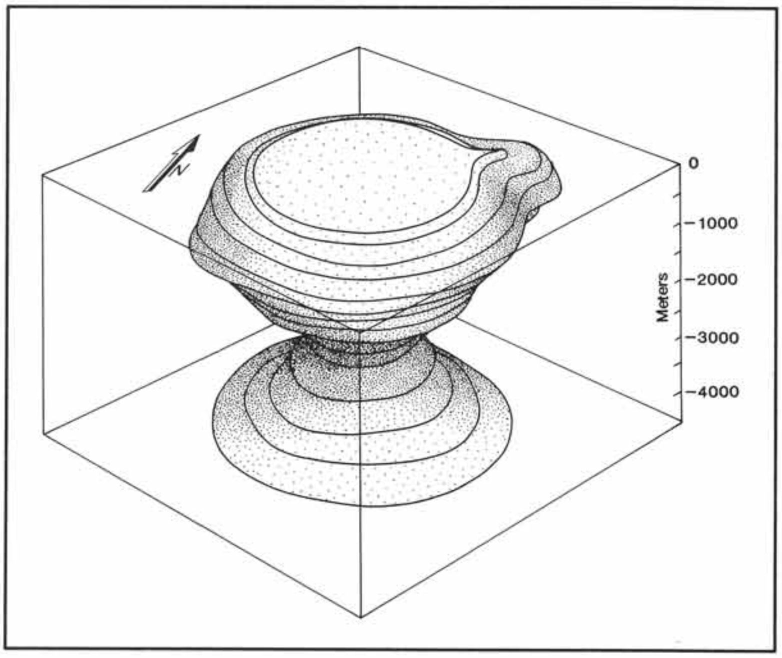


Figure 5-1: *Structure contours on the Hainesville salt stock, USA, in perspective view.*

5-1 Structure-contour maps

The shape of geological structures can be represented by a set of *structure contours*, which are lines or curves connecting points of equal altitude on a specific horizon. Structure contours have properties similar to those of topographic contours. Both sets of contours are used to represent the shape of a particular surface. However, whereas topographic contours are exclusively used to portray the shape of the ground surface, structure contours are employed to illustrate the shape of geological surfaces. Such surfaces may include: bedding planes, fold shapes, fault planes, salt domes, etc. For example, the mushroom shape of a buried salt body can be outlined by structure contours (Fig. 5-1). Structure contours, like topographic contours, commonly form a set of smooth and subparallel curves or lines. Structure contours are straight lines only when the geological surface resembles a flat plane, like an inclined planar bed or a planar fault.

It is often practical to project structure contours on a horizontal map. The spacing of the contour lines in such *structure-contour maps* reflects the gradient of the slope. The closer the contours, the steeper the inclination of the structural surface. Widely spaced contours imply gentle slopes. The difference in elevation between adjacent contours is constant on any given map. Figure 5-2 illustrates a structure-contour map of the top of the Precambrian *basement* of the Michigan Basin. The maximum depth of the basin is four kilometers (12,000 feet).

The contour spacing on different structure-contour maps may be different and is determined by what is convenient for the particular structure displayed. The height or depth of the contours is indicated along them at regular intervals. Figure 5-3 illustrates a structure-contour map for the top of the Precambrian basement of the Arabian plate. The map suggests that the deepest part of the Arabian basin is fifteen kilometers (45,000 feet) below the ground surface.

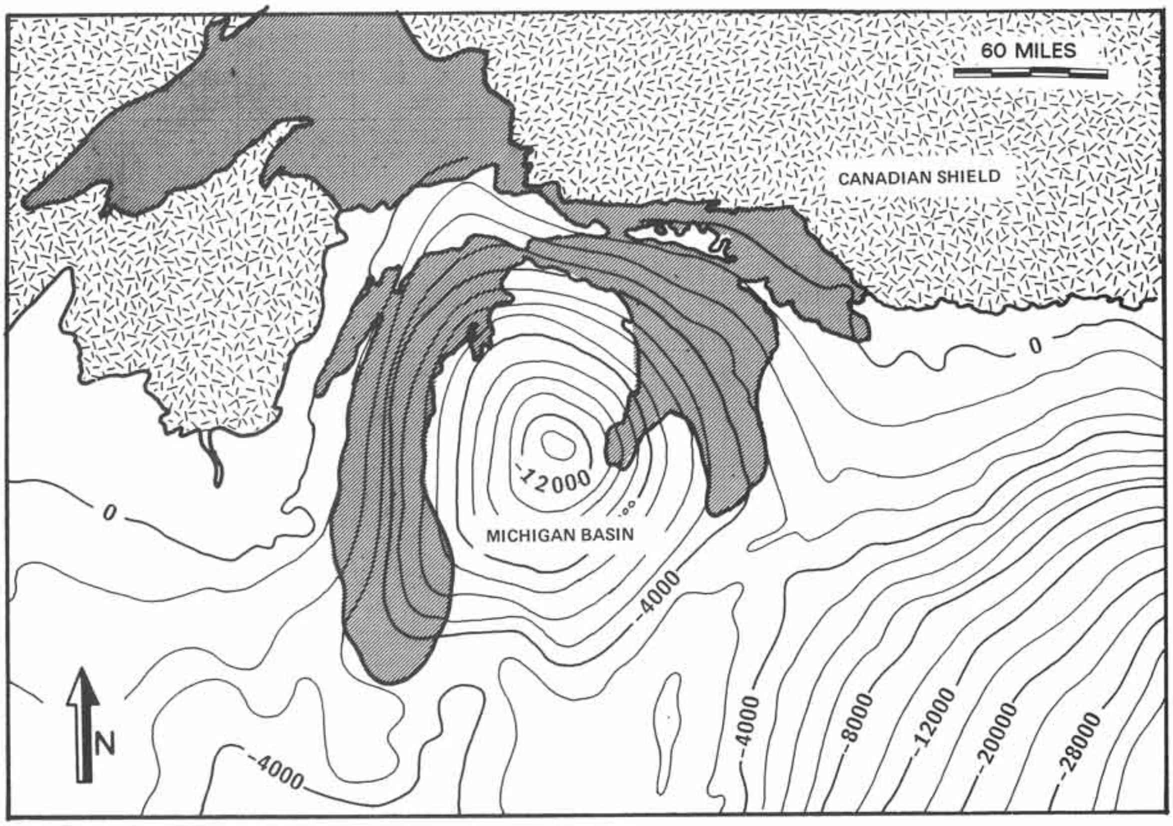


Figure 5-2: *Structure-contour map of the top of the Precambrian basement in the Michigan Basin. Units are in feet.*

☐**Exercise 5-1: a) Examine the map of Figure 5-3, and calculate the average slope of the top of the Precambrian. b) Give the azimuth/dip for the top of the Precambrian basement for the area to the east of its surface outcrop.**

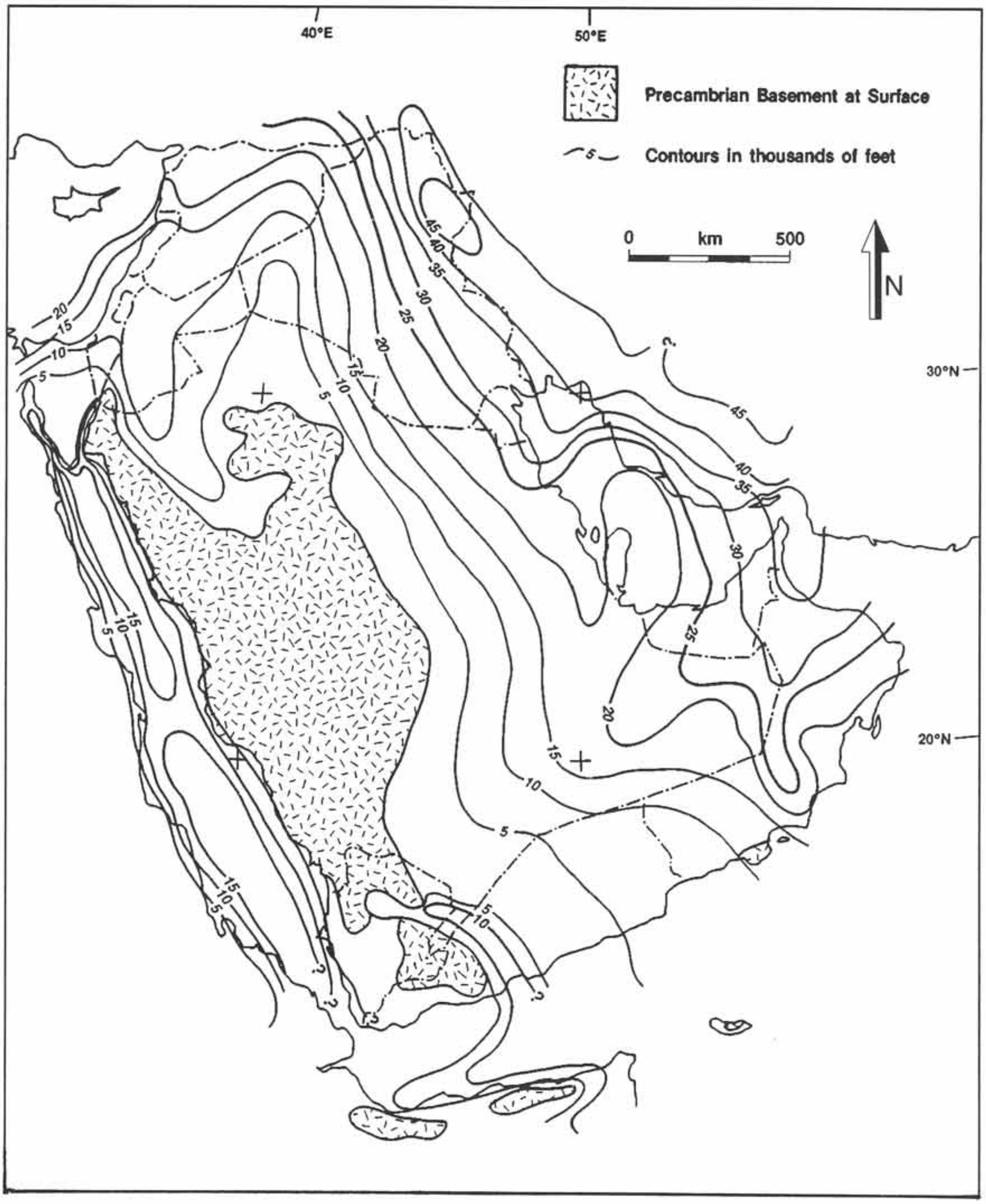


Figure 5-3: *Structure-contour map of the top of the Precambrian basement of the Arabian Peninsula. Contours in thousands of feet below sea level.*

5-2 Strike and dip determination

The structure contours for planar inclined beds are made up of a series of evenly spaced and parallel strike lines (Fig. 5-4). These can be projected orthogonally on the map surface to obtain a structure-contour map. Conversely, it is simple to infer the strike and dip of the original bed from its structure contours. Figure 5-5a shows a structure-contour map. The strike orientation of the bed immediately follows from the trend of the contours, which is parallel to the strike. The dip of the bed, α, can be inferred from the horizontal spacing between the projected contour lines, d, and the contour interval, x, using (Fig. 5-5b):

$$\alpha=\tan^{-1}(x/d) \qquad (5\text{-}1)$$

The map of Figure 5-5a immediately reveals the azimuth/dip of the contoured layer as 270°/45°.

□Exercise 5-2: Figures 5-6a and b are structure-contour maps for the top of a limestone bed. a) Give the azimuth/ dip of the limestone for locations 1 to 4. b) Construct cross-sections along lines A-B and C-D. c) Name the structure seen in the map of Figure 5-6b.

5-3 Outcrop patterns of thin beds

The outcrop pattern of a layer, its structure contours, and the elevation contours have a particular relationship. Figure 5-7a illustrates the outcrop pattern of a very thin limestone layer in a terrain of topographic relief. The map includes three types of contours: elevation contours for the surface topography, structure contours with the elevations of the limestone bed, and the outcrop pattern of the limestone at the ground surface.

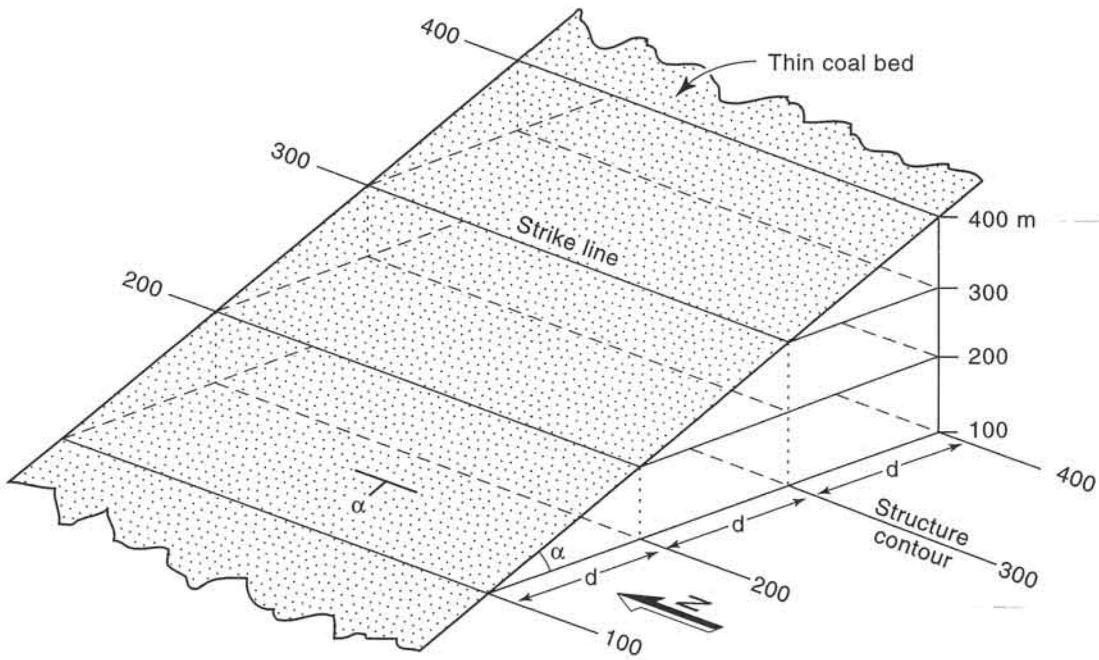


***Figure 5-4:** Structure contours on homoclinal beds are parallel to the strike lines and mark regularly spaced elevations. Orthographic projection of the contours gives a structure-contour map of the coal bed.*

The layer reaches the surface in any location where the topographic contour cuts a structure contour of the same elevation. In other words, the outcrop pattern is the intersection of the structure and the topography as defined by their contours. The implications of this relationship are as follows: (1) Structure contours can be constructed if the outcrop pattern and the topographic contours are known. (2) The outcrop pattern of a geological stratum can be constructed if the structure contours and topographic contours are both known. The concept of point (1) will be practiced in this chapter, and that of point (2) will be examined in more detail in the next chapter.

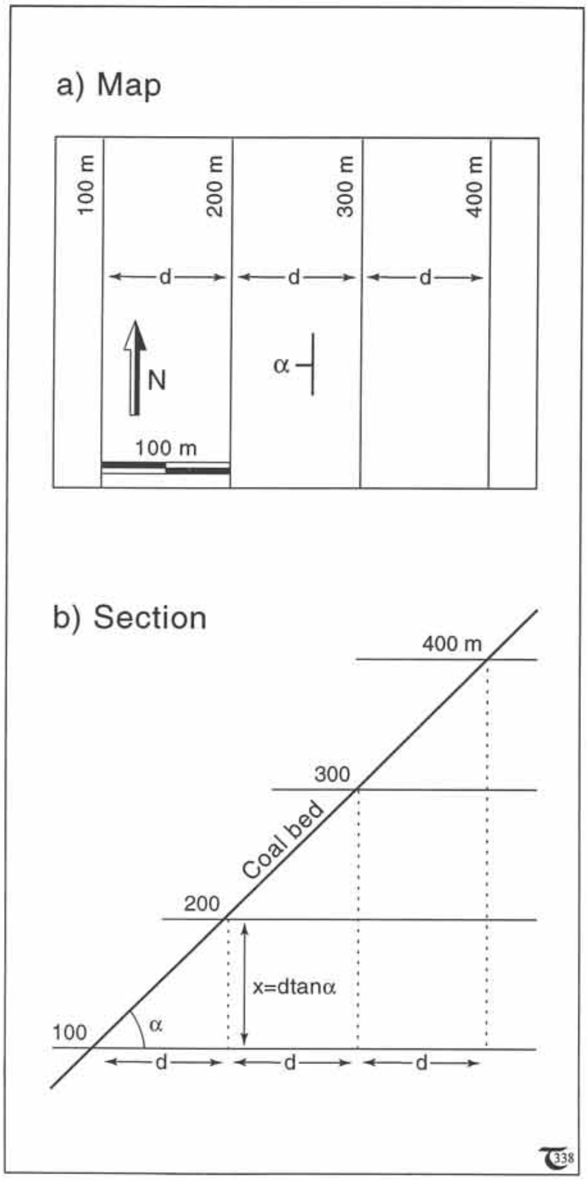


Figure 5-5: *a) Structure-contour map of 100 m intervals. The even spacing indicates a homoclinal bed. b) E-W section across the map of (a). The dip of the bed, α, is given by equation (5-1).*

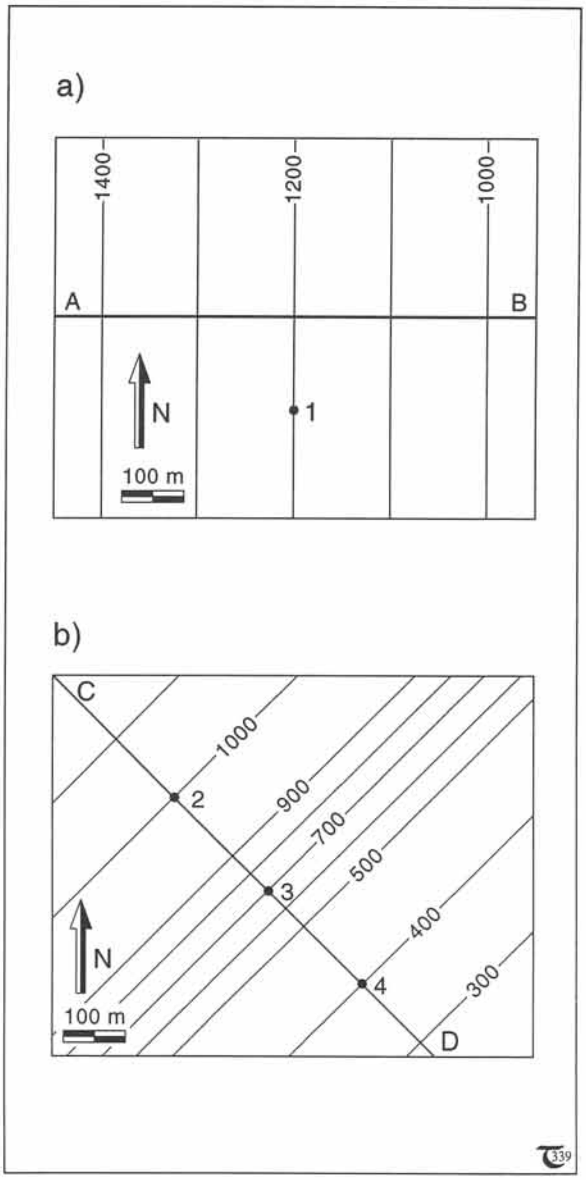


Figure 5-6: *a) & b) Two structure-contour maps, studied in exercise 5-2. Contours are in meters.*

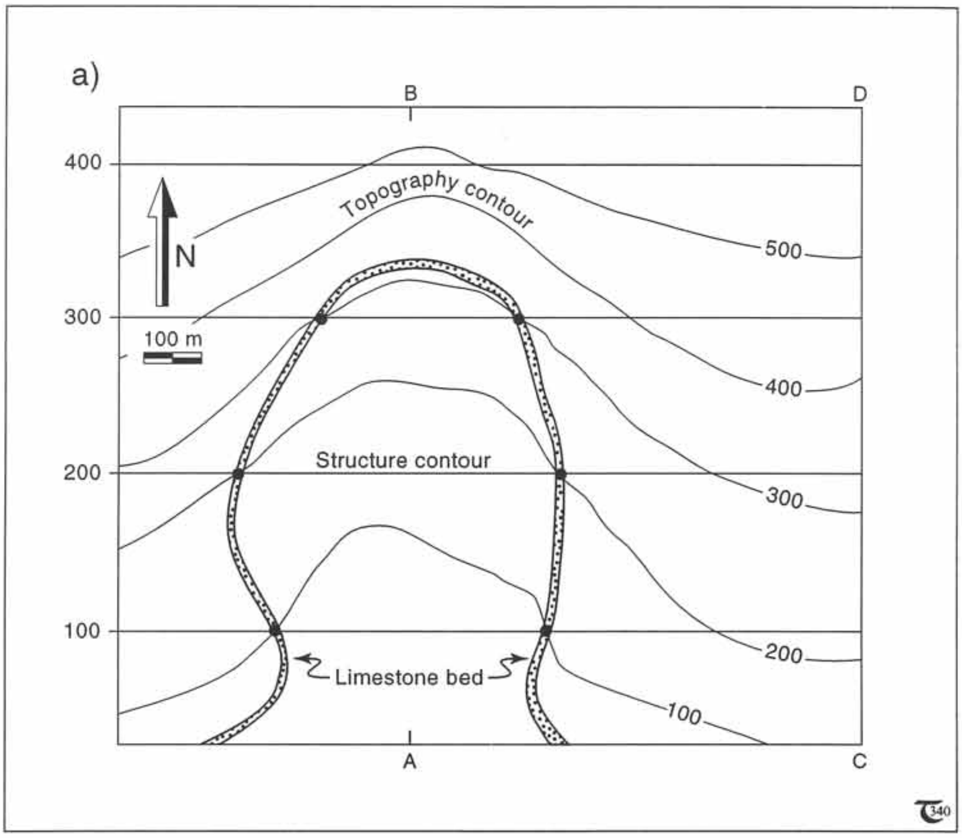


***Figure 5-7a:** Geological map, including three types of contours: elevation contours, structure contours, and contours outlining the outcrop pattern of a limestone bed. Contours are in meters.*

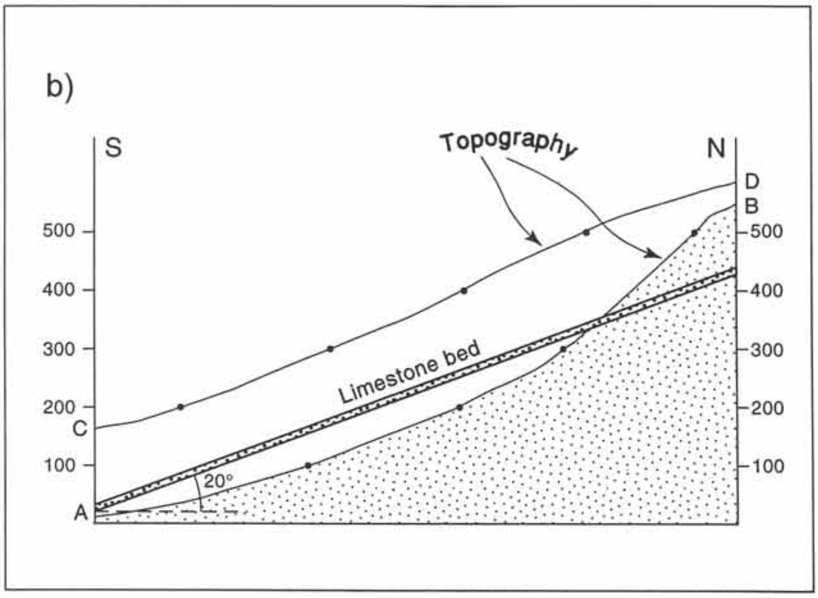


***Figure 5-7b:** Two, superposed cross-sections, A-B and C-D, across the map of Figure 5-7a. Contours are in meters.*

Figure 5-7b shows, in one profile, the cross-sections A-B and C-D across the map of Figure 5-7a. The limestone beds of both sections coincide, but the topography is different. The limestone bed is not seen at the surface along section C-D, because the layer is buried by younger deposits. The layer is visible at the surface in one location along section A-B but has been eroded away in the southern part of the map area. The outcrop-pattern of thin beds, even if homoclinal, may take on an endless variety of shapes, depending on the way the ground surface intersects the bedding plane. Figure 5-8 illustrates a variety of map patterns for a thin coal layer, crossing the same rounded hill for a range of layer dips The strike line is consistently oriented in all map views. The patterns follow the intersection of the structure contours and the topographic surface.

□Exercise 5-3: The rocks on top of the limestone layer of Figure 5-7 contain placer deposits of native gold. Color red the part of the map area where gold can be found. Also, color the gold-bearing rocks in the section.

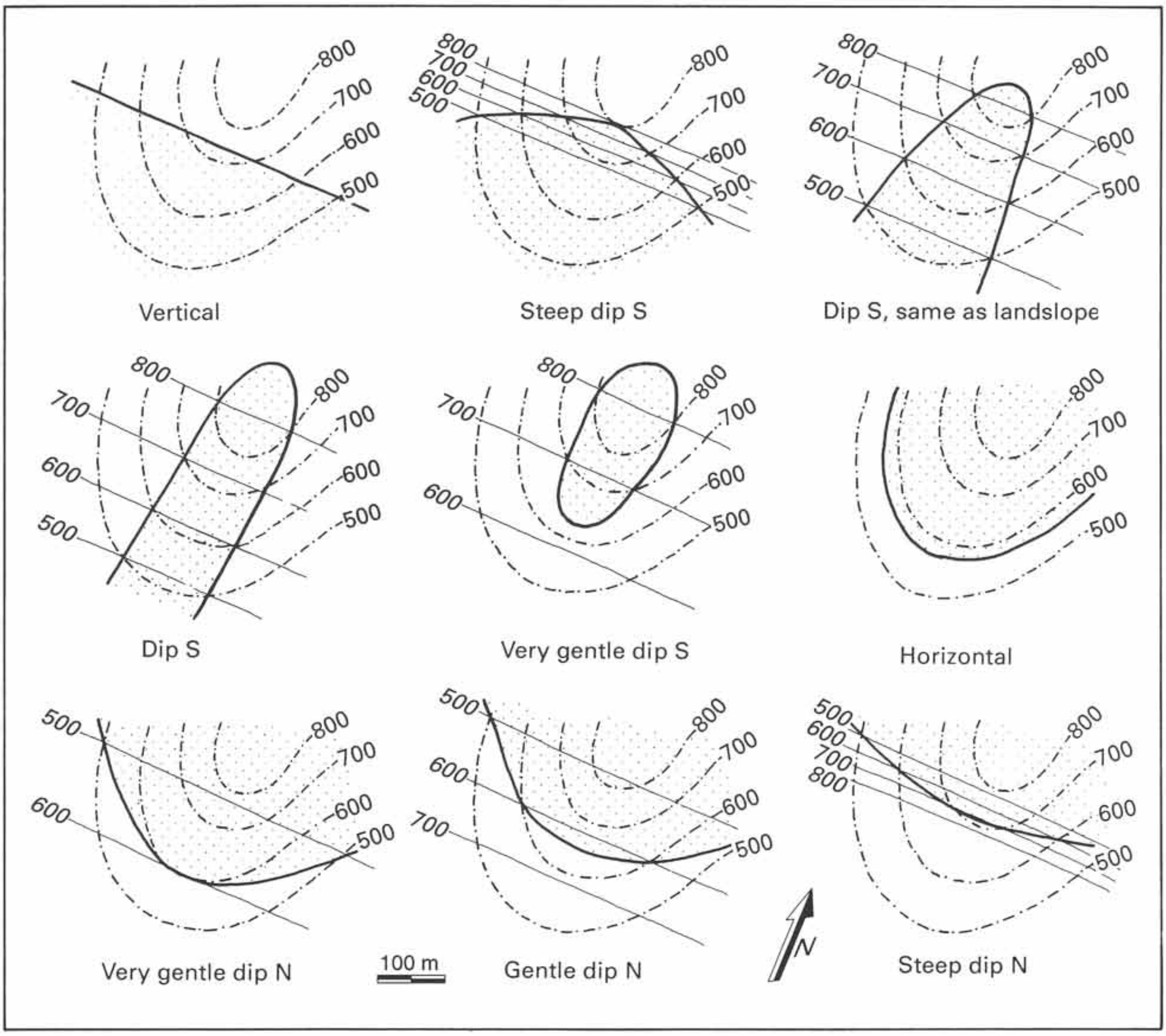


Figure 5-8: *Variety of outcrop patterns, resulting from a homoclinal coal bed with a range of inclinations. The shaded portion of each map indicates the rocks on top of the thin coal bed.*

☐ **Exercise 5-4: The map of Figure 5-9 shows the outcrop pattern of a thin coal bed traced from an orthogonal aerial photograph and transferred to a topographic contour map of the same scale. The vertical lines on the map are structure contours for the coal bed. a) What is the azimuth/dip for the coal bed? b) Construct one W-E cross-section, passing over the two mountain peaks in the map area. Show both the topography and the position of the coal seam. c) Color the parts of the map where the subsurface does not contain coal.**

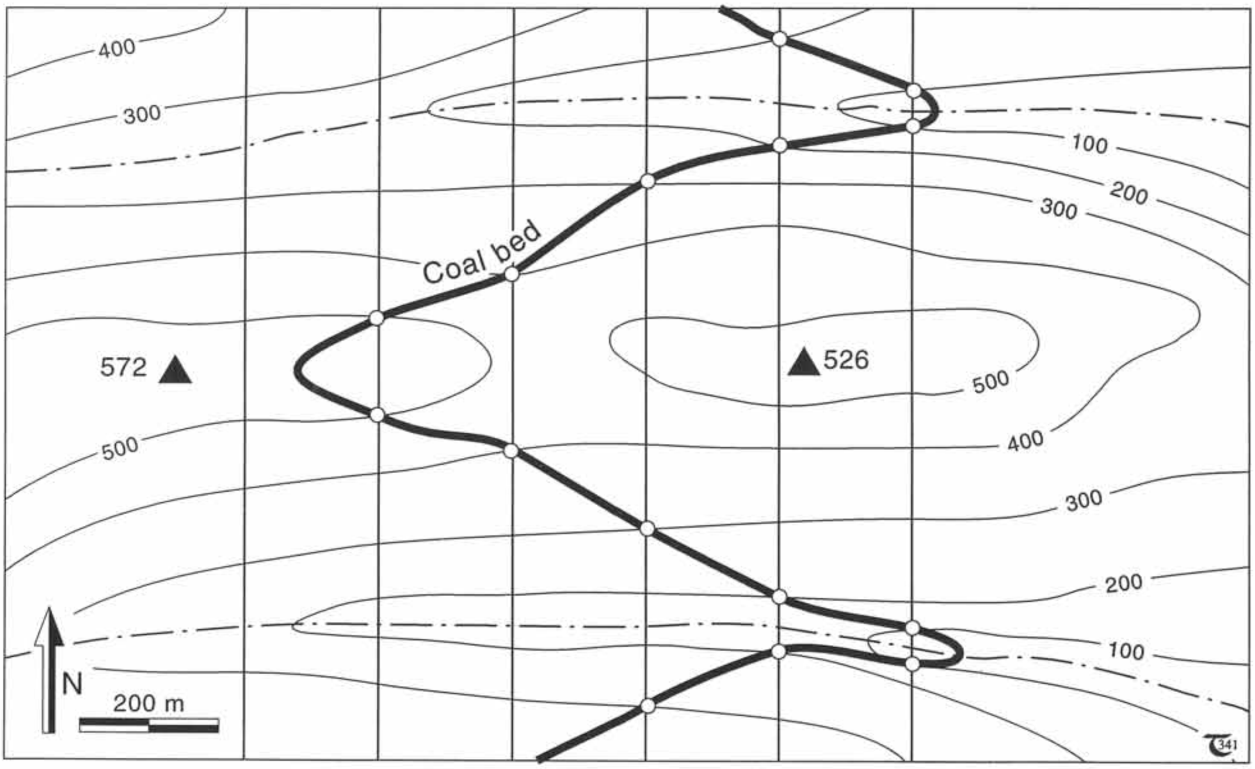


Figure 5-9: Topographic contour map with outcrop pattern of a thin coal bed. See exercise 5-4.

5-4 Outcrop patterns of thick formations

The outcrop patterns of relatively thick beds or entire formations will be affected by the intersection of their top and bottom surfaces with the topography. If the ground surface is flat, the top and bottom planes of a planar, though inclined, bed will appear on the map as a set of parallel lines. Figure 5-10a illustrates a sandstone formation, dipping gently eastward. The structure contours of the top surface and bottom surface of the formation are mapped in Figures 5-10b & c. The outcrop pattern on the flat ground surface is formed by the two traces of the top and bottom surface, which are two lines of constant spacing if topographic relief is negligible (Fig. 5-10d).

Figure 5-10: a) Sandstone formation with structure contours. b) & c) Structure-contour maps for the top and bottom of the sandstone. d) Map pattern of the sandstone.

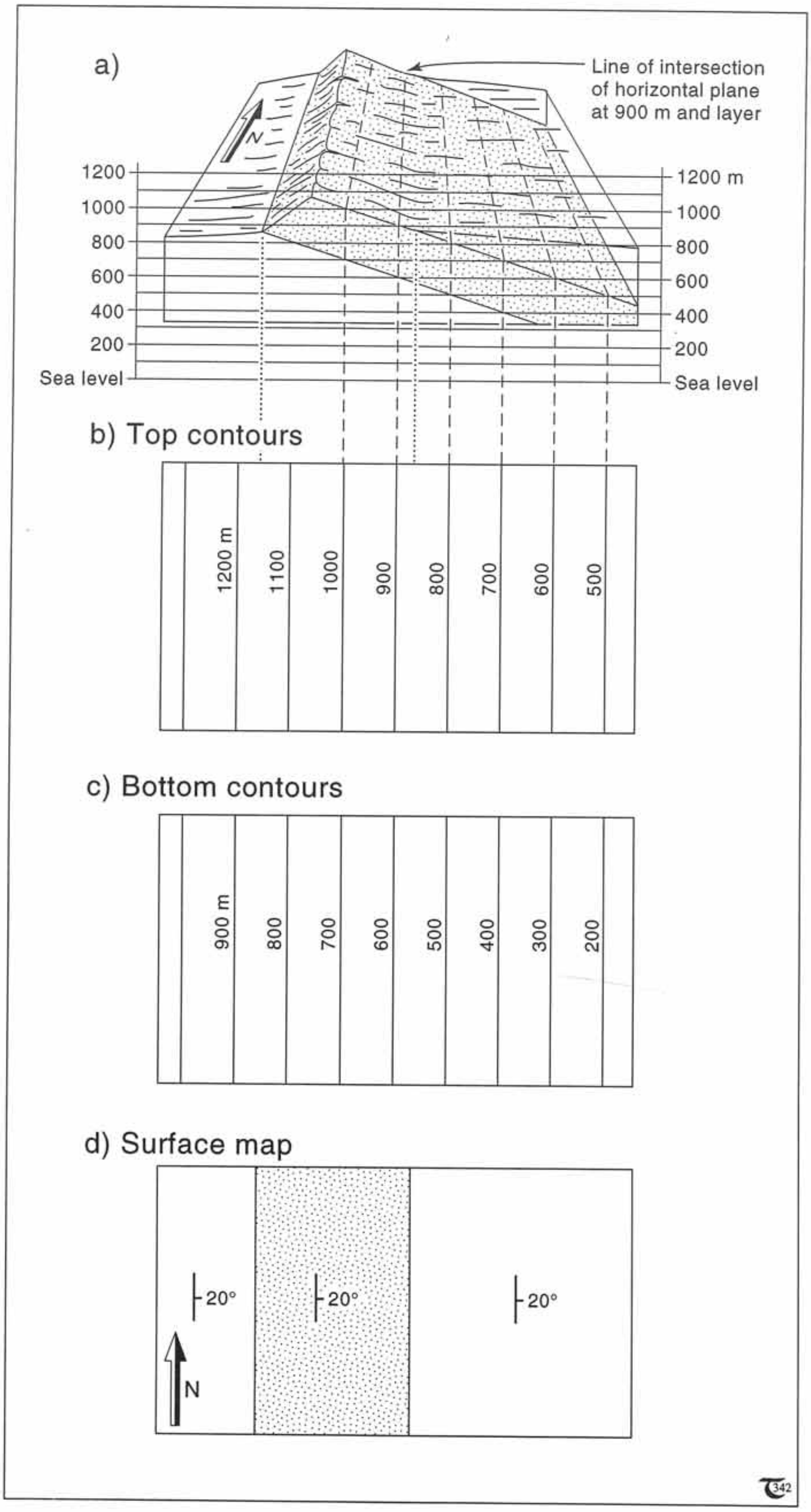


Figure 5-11a shows the outcrop pattern of another sandstone formation, dipping eastward in a terrain of steep topographic relief. The dip of this formation is similar to that occurring in the map of Figure 5-10d. The map pattern of Figure 5-11a is much more complex, solely due to the way in which the eroded topography cuts the bed. The same formation occurs in two different outcrops, disconnected by the erosion surface.

☐Exercise 5-5: a) Construct structure contours for both the top and bottom of the sandstone formation in the map of Figure 5-11a. Use diffferent colors for each set of contours. b) What is its vertical thickness? c) Give the azimuth/dip of the formation. d) What is the true thickness of the sandstone formation? e) Complete the profile of Figure 5-11b by including the topography. f) Color the parts of the map where the subsurface does not contain the sandstone formation.

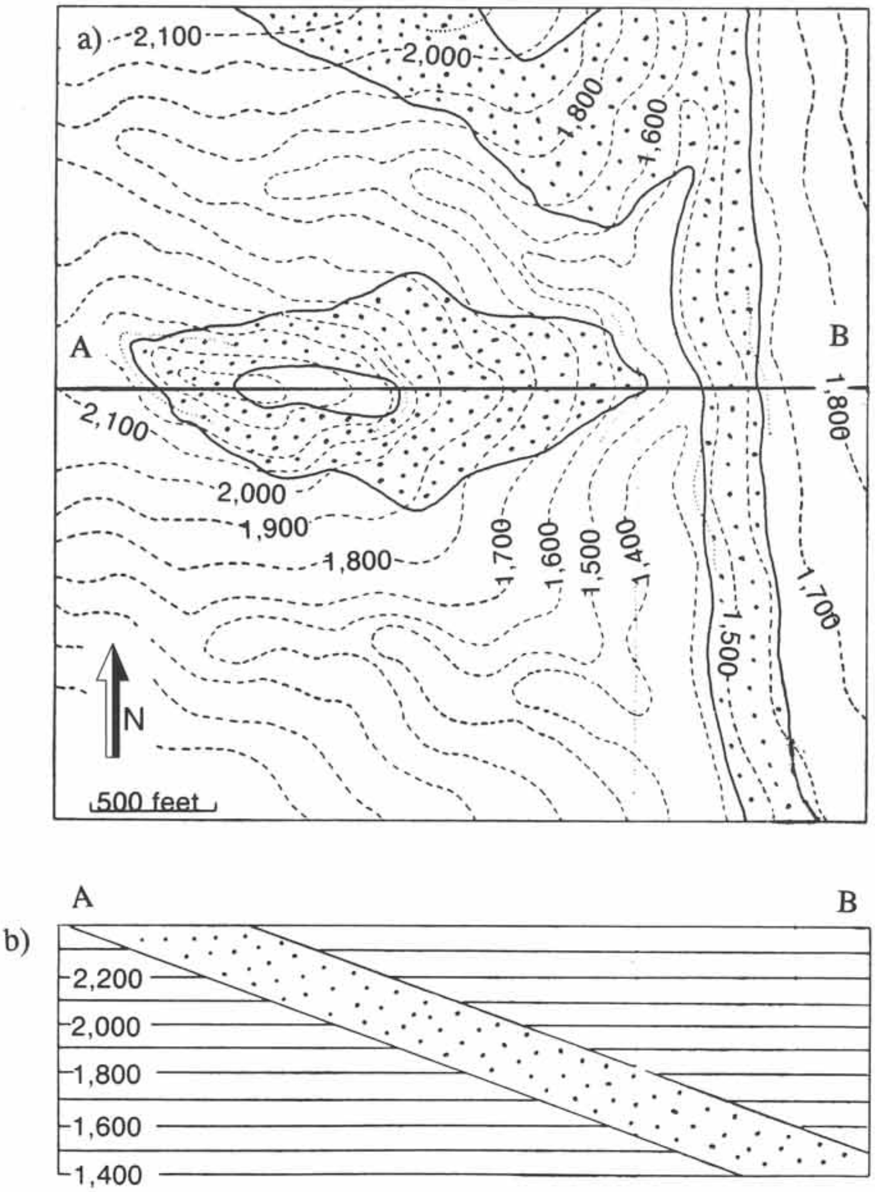
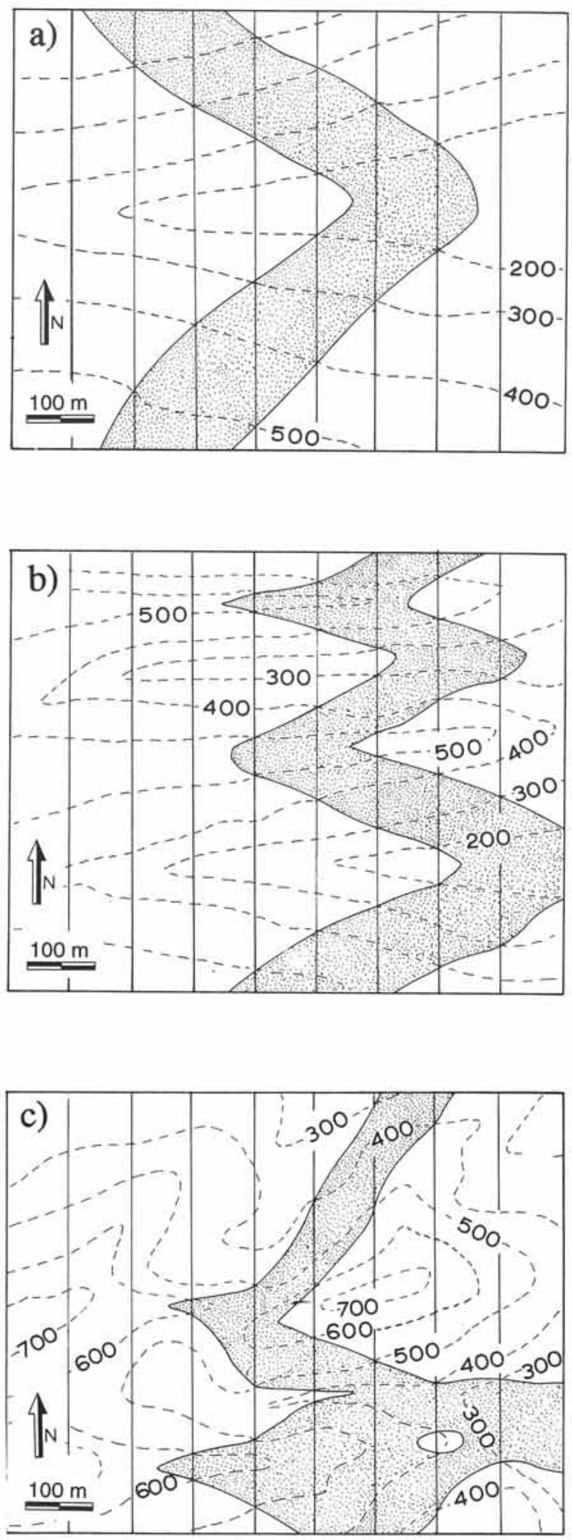


Figure 5-11: *a) Topographic map with outcrop pattern of a thick sandstone bed. b) Cross-section A-B across the map of (a) illustrates a single homoclinal bed. Contours are in feet.*

Figure 5-12: *a) to c) Outcrop patterns of the same sandstone bed dipping homoclinally 45° east. The three maps portray the sandstone bed in terrains of different surface topography.*



Figures 5-12a to c compare the outcrop patterns of a thick sandstone bed of the same thickness and orientation in three different terrains. The different outcrop patterns are solely due to the way in which the eroded ground surface cuts the sandstone bed. The sandstone has a uniform 45° dip towards the east and is not folded or contorted in any way, unlike the suggestive map pattern. Exercises 5-6 through 5-8 illustrate the use of structure contours.

□Exercise 5-6: Refer to the map of Figure 5-13. a) Before constructing structure contours, infer the approximate direction of dip from the V-rule. b) Construct structure contours for both the top and bottom of the sandstone formation. c) Give the azimuth/dip of the formation. d) Construct a profile normal to the strike of the formation across the map area, including the peak in the topography.

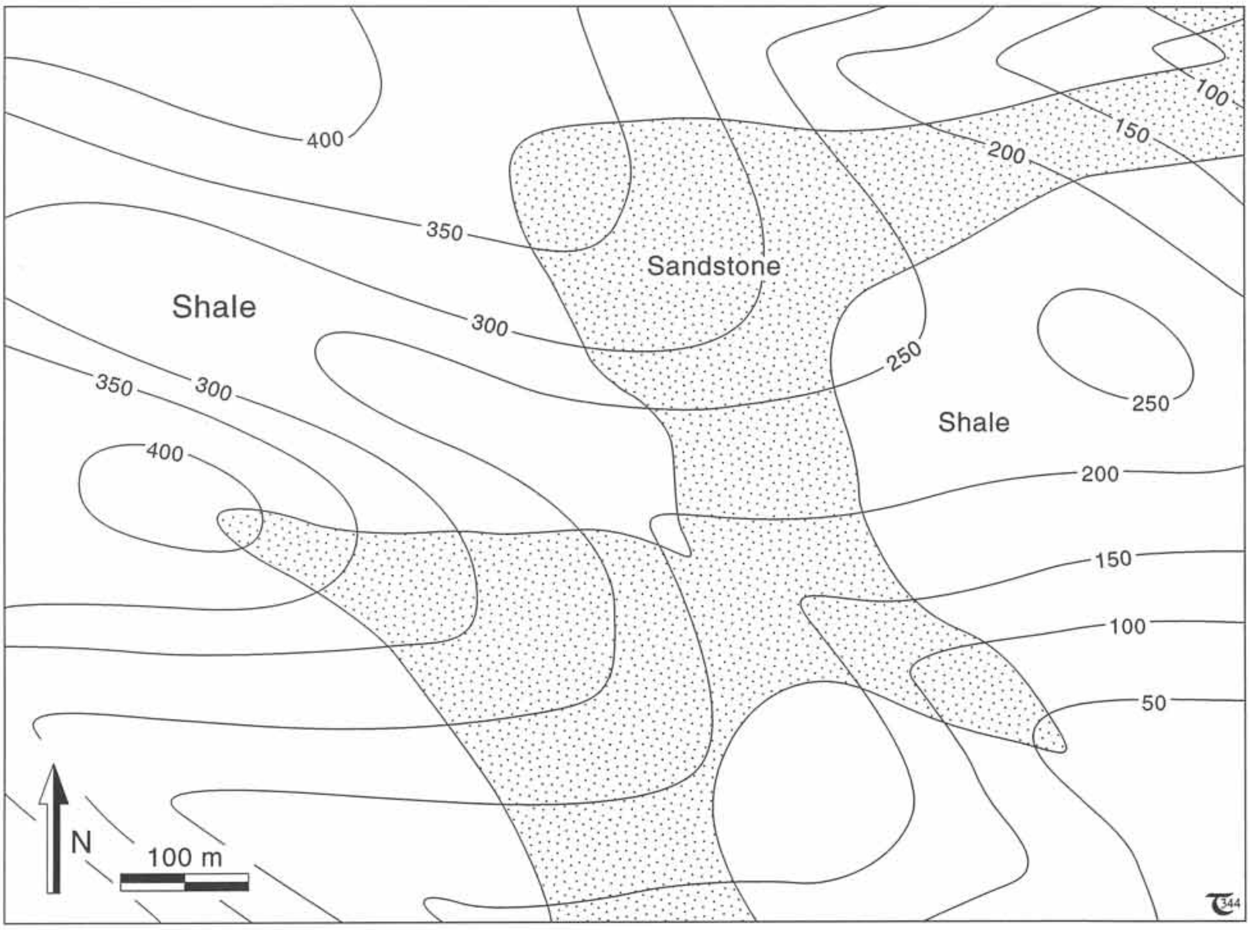


Figure 5-13: *Topographic contour map with outcrop pattern of a thick sandstone formation. See exercise 5-6. Contours are in meters.*

☐**Exercise 5-7: Refer to the geological map of Figure 5-14. a) Use structure contours to construct the exact azimuth/dip of the layers. b) Determine the true or stratigraphic thickness of the indicated sandstone unit. c) Color the part of the map where the subsurface does not contain the sandstone formation.**

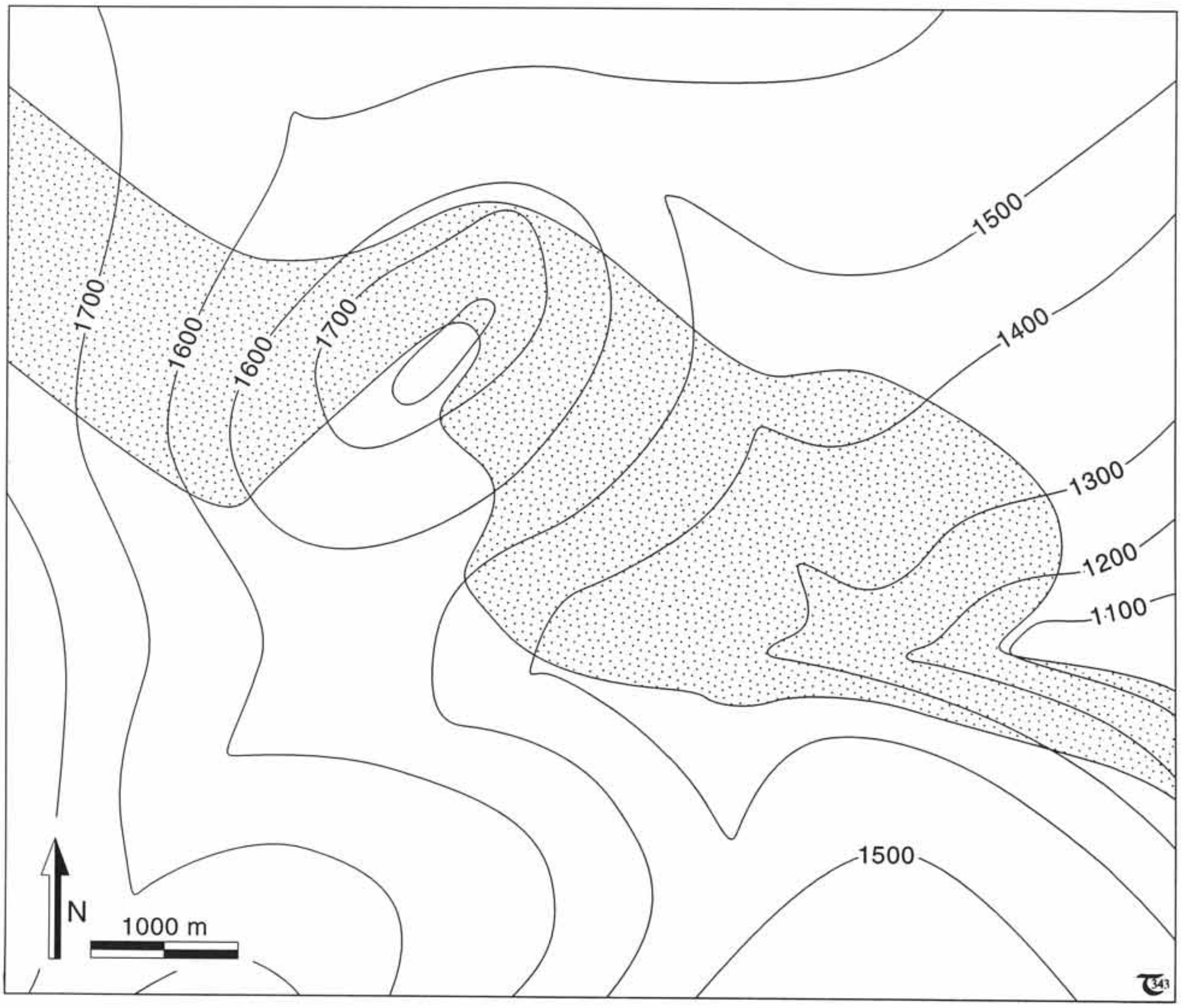


Figure 5-14: *Geological map, showing outcrop pattern of the lithologies on a base map of topographic contours. See exercise 5-7. Contours are in meters.*

□Exercise 5-8: Refer to the geological map of Figure 5-15. a) Before constructing structure contours, infer the approximate direction of dip from the V-rule. What is the youngest bed of the outcrop sequence? b) Use structure contours to construct the exact azimuth/dip of the layers. c) Determine the true or stratigraphic thickness of each layer, and represent the result as a columnar section. d) Complete cross-sections A-B and C-D.

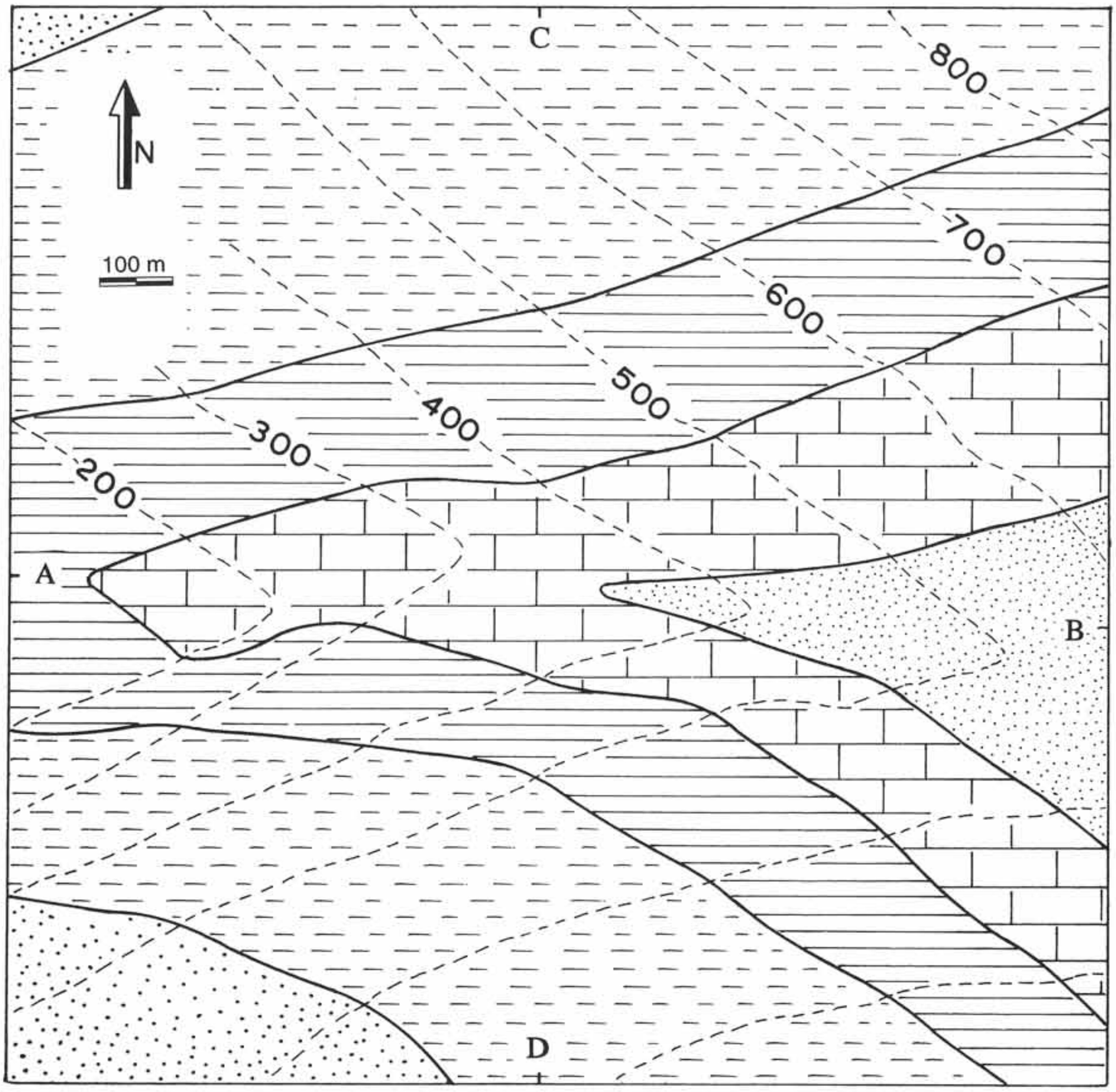


***Figure 5-15:** Geological map, showing outcrop pattern of the lithologies on a base map of topographic contours. See exercise 5-8. Contours are in meters.*