4

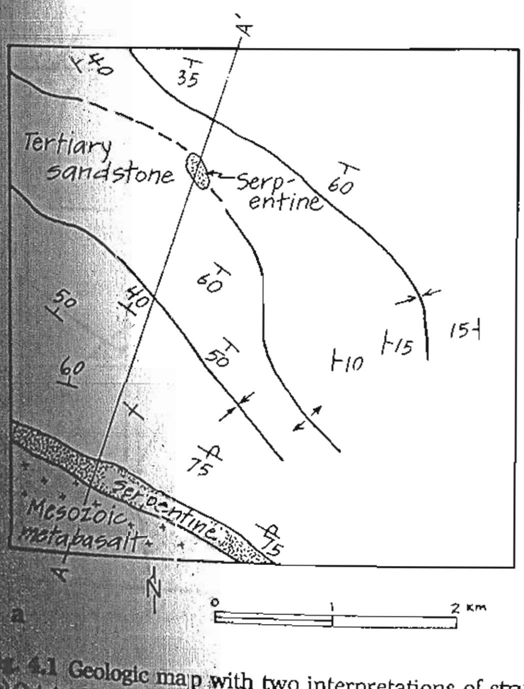
Geologic Structure Sections

OBJECTIVE

Draw geologic structure sections through folded and faulted terrain

A geologic map only shows the geology on the earth's surface. In order to provide a third dimension, it is standard practice to draw one or more *vertical structure sections*. These are vertical cross-sections of the earth showing rock units, folds, and faults. By convention, structure sections are usually drawn with the west on the left. Structure sections oriented exactly north–south are usually drawn with the north on the left.

At best, structure sections are drawn using well logs and geophysical data to supplement the surface information; most structure sections, however, are based solely on the geologic map and the geologist's best guess about how the rocks have been deformed. As such, structure sections must be regarded as interpretations that are subject to change with the appearance of new information. By way of example, examine the geologic map in Fig. 4.1 and the two structure sections based on it.



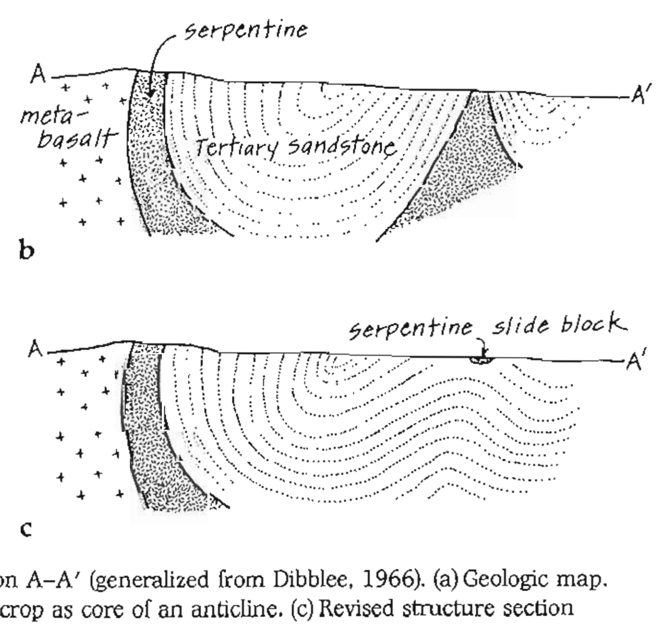


Fig. 4.1 Geologic map with two interpretations of structure section A–A′ (generalized from Dibblee, 1966). (a) Geologic map. (b) Original structure section interpreting northern serpentine outcrop as core of an anticline. (c) Revised structure section interpreting northern serpentine outcrop as a landslide block.

The map shows three groups of rocks: Mesozoic metabasalt, serpentine, and Tertiary sandstone. The serpentine occurs as a continuous band between the metabasalt and the sandstone in the southwestern part of the map and as a small patch within the sandstone in the northern part of the map. The original interpretation (Fig. 4.1b) accounts for the northern outcrop of serpentine as occurring in the core of a partially eroded anticline. Further field work has shown, however, that the northern patch of serpentine is more probably a large landslide block that long ago slid off the southern serpentine mass (Fig. 4.1c). Far from being a trivial difference, these two interpretations imply rather different styles of folding as well as predicting completely different stability and permeability characteristics for the entire length of the anticlinal axial trace.

When you are drawing structure sections remember that it should be geometrically possible to unfold the folds and recover the fault slip in order to reconstruct an earlier, less deformed or undeformed state. In other words, your structure section should be *retrodeformable*. Structure sections in which great care is taken concerning retrodeformation are called *balanced structure sections*. An introduction to the construction and retrodeformation of balanced structure sections is presented in Chapter 15. For many situations, if you make sure that sedimentary units maintain a constant thickness (unless you have evidence to the contrary) and that the hanging walls of faults match the footwalls, you will be on the right track.

Drawing a topographic profile

The first step in constructing a geologic-structure section is drawing a topographic profile along the line of section. Topographic profiles show the relief at the earth's surface along the top of the structure section. Problems 4.1 through 4.3 in this chapter are relatively simple structure sections in which the topographic profile is provided. Problem 4.4 involves the construction of two structure

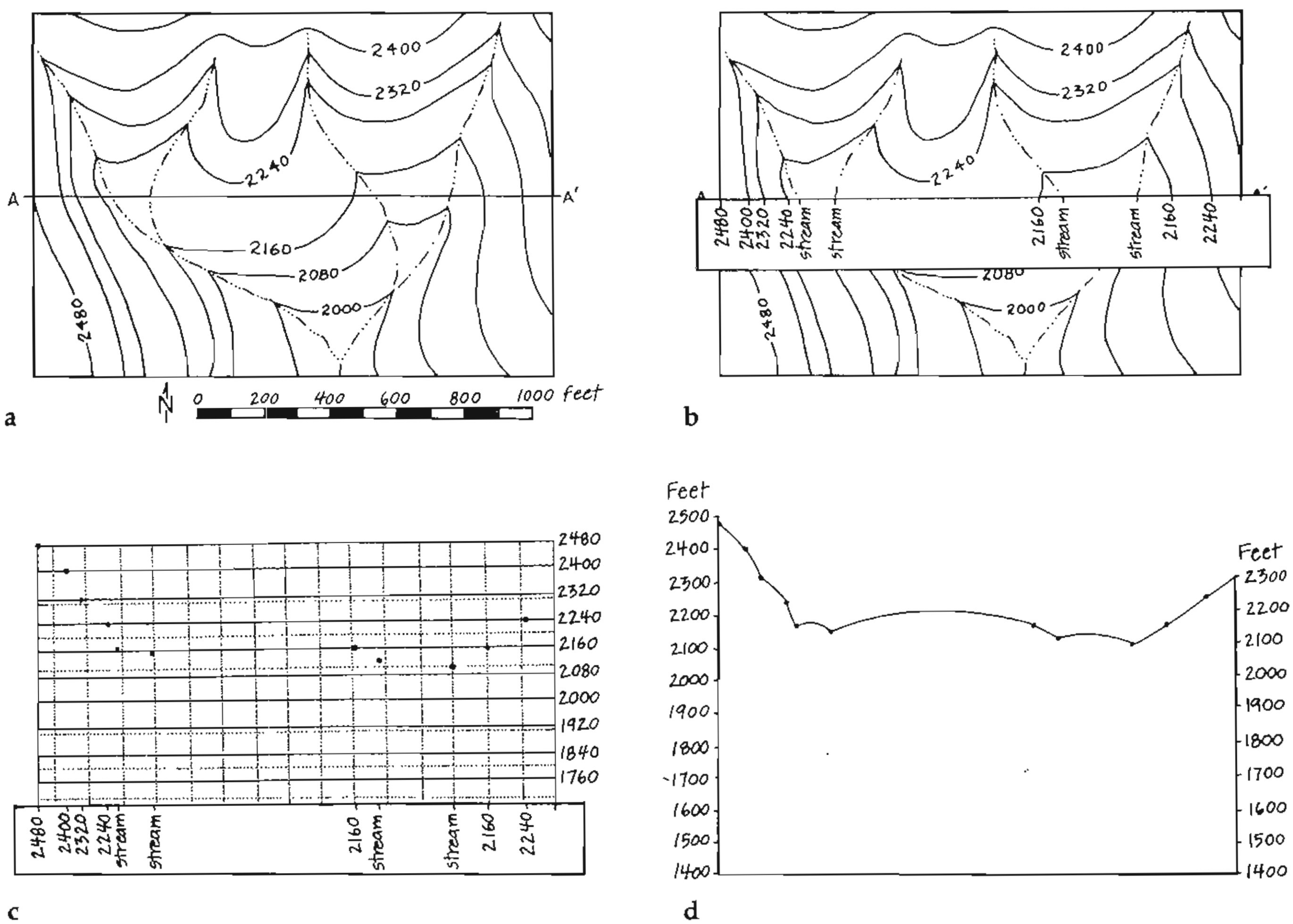


Fig. 4.2 Drawing a topographic profile. (a) Draw section line. (b) Transfer contour crossings, streams, and other features to paper. (c) Plot points on paper onto graph paper. (d) Connect points.

sections on the Bree Creek Quadrangle map, for which you will draw the topographic profiles yourself.

The technique for drawing a topographic profile is as follows.

1 Draw the section line on the map (Fig. 4.2a).

2 Lay the edge of a piece of paper along the section line, and mark and label on the paper each contour, stream, and ridge crest (Fig. 4.2b).

3 Scale off and label the appropriate elevations on a piece of graph paper (Fig. 4.2c). Graph paper with 10 or 20 squares per inch is ideal for 7.5-minute quadrangle maps because the scale is 1 in. to 2000 ft. Notice that the map scales on Figs 4.2a,b are the same as the vertical scale for Figs 4.2c,d. It is very important that the vertical and horizontal scales be the same on almost all structure sections. This is a very common oversight. If the scale of the structure section is not the same as the scale of the map then the dips cannot be drawn at their nominal angle. In the rare case where the vertical scale must be exaggerated to emphasize the topography, the graph in Appendix D must be used to find the corrected dips, and the amount of vertical exaggeration must be clearly labeled on the structure section.

4 Lay the labeled paper on the graph paper and transfer each contour, stream, and ridge crest point to the proper elevation on the graph paper (Fig. 4.2c).

5 Connect the points (Fig. 4.2d).

Structure sections of folded layers

The geometry of folds is discussed in Chapter 6. In this chapter we will be concerned with the mechanics of drawing structure sections through folded beds, not with the mechanics of the folding.

The simplest structure sections to draw are those that are perpendicular to the strike of the bedding. Figure 4.3 shows a geologic map with all beds striking north–south. Section A–A′ is drawn east–west perpendicular to the strike. Each bedding attitude and each contact is merely projected parallel to the fold axis to the topographic profile oriented parallel to the section line. On the topographic profile each measured dip is drawn with the aid of a protractor. Using these dip lines on the topographic profile as guides, contacts are drawn as smooth, parallel lines. Dashed lines are used to show eroded structures. As much depth below the earth's surface as the data allow should be shown.

> **Problem 4.1**
> Draw structure section A–A′ on Fig. 4.5.

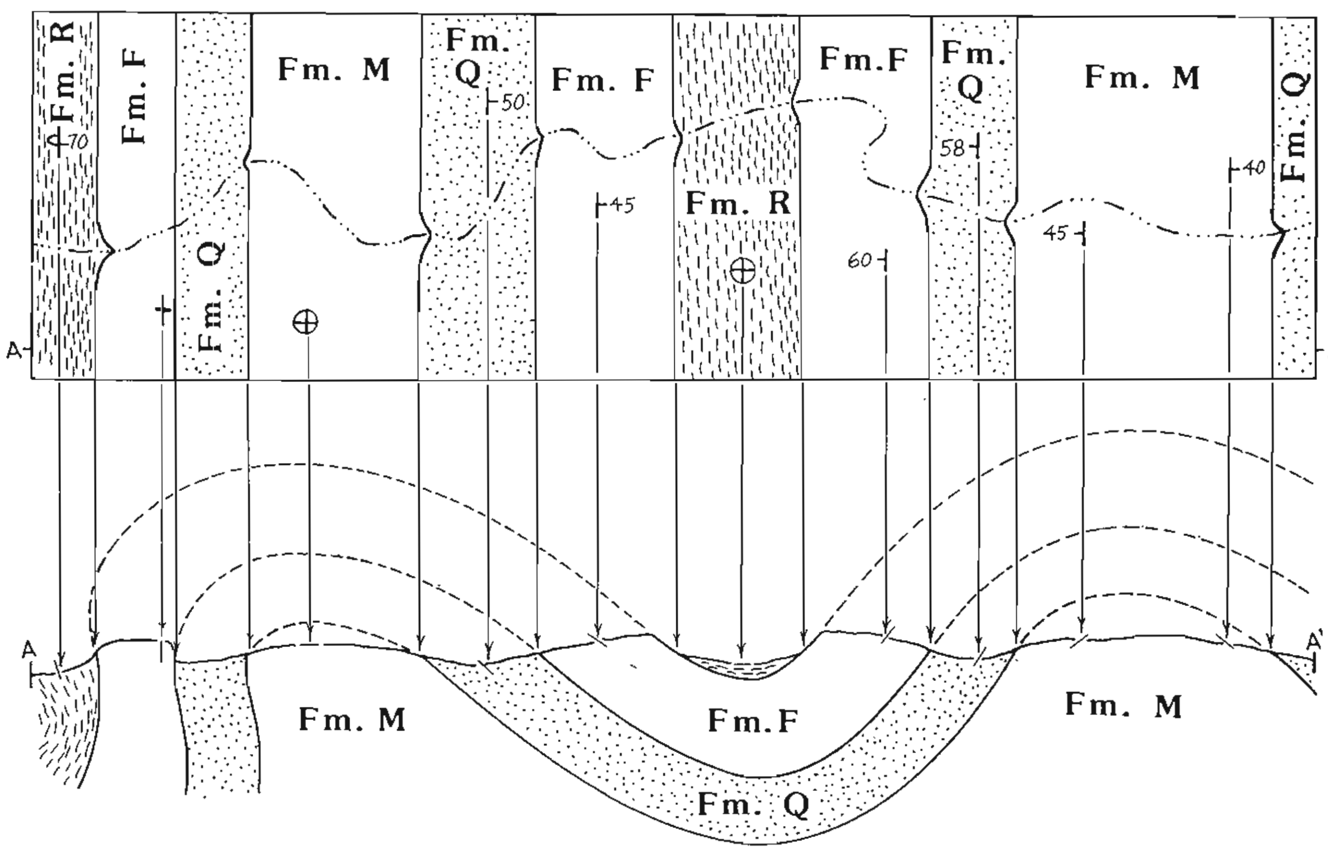


Fig. 4.3 Drawing a structure section perpendicular to strike of bedding. Arrows show transfer of attitudes from map to section.

In very few cases are the strikes of the beds all parallel, as they are in Fig. 4.3. The section line, therefore, rarely can be perpendicular to all of the strikes. When the section line intersects the strike of a plane at an angle other than 90°, the dip of the plane as it appears in the structure section will be an apparent dip. Recall that the apparent dip is always less than the true dip.

The quickest way to determine the correct apparent dip to draw on the structure section is to use the nomogram in Fig. 1.7. Figure 4.4 shows a geologic map in which the strike of formation B has been projected along strike to line X–X′ and then perpendicular to X–X′ to the topographic profile. The angle between the strike and the section line is 35°, the true dip is 43°, and the apparent dip is revealed by the alignment diagram to be 28°, which is the angle drawn on the structure section.

Some rock units have highly variable strikes, and judgment must be exercised in projecting attitudes to the section line. Attitudes close to the section line should be used whenever possible. If the dip is variable, the dip of the contact may have to be taken as the mean of the dips near the section line. The attitudes should be projected parallel to the fold axis, which in the case of plunging folds will not be parallel to the contacts. In all cases, it is important to study the entire geologic map to aid in the construction of structure sections. Critical field relationships that must appear on your structure section may not be exposed along the line of section.

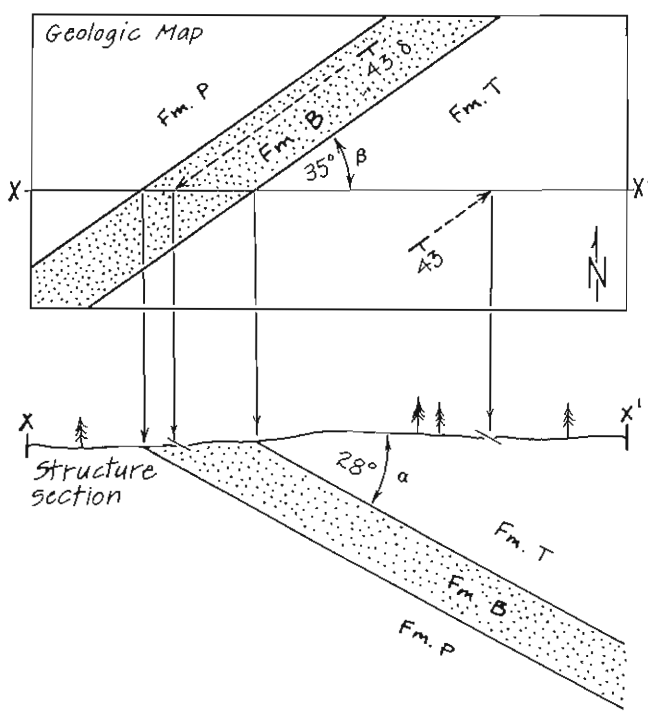


Fig. 4.4 Geologic map and corresponding structure section drawn at an angle to strike. Dip from map becomes apparent dip in section.

The arc method

A more precise, but not necessarily more accurate, technique than freehand sketching for drawing structure sections is called the arc (or Busk) method. It has proved to be particularly useful in terranes of basins and domes where beds have been folded by flexural slip and retain a constant thickness. Such folds are sometimes called *concentric* folds, for reasons that will become clear.

The arc method is based on the following two premises: (1) the transition from one dip to the next is smooth, and (2) bed thickness is constant. "Room problems" (loss of volume) at the cusps of folds are completely ignored, which is why this technique is only appropriate for gently folded layers.

Consider the map and topographic profile in Fig. 4.6a. Each attitude on the map has been projected to the topographic profile. Instead of sketching freehand, however, a drawing compass is used to interpolate dips between measured points. The steps are as follows.

1 With the aid of a protractor draw lines perpendicular to each dip on the topographic profile. Such lines have been drawn in Fig. 4.6b perpendicular to dips a, b, and c. Extend them until they intersect.

2 Each point of intersection of the lines perpendicular to two adjacent dips serves as the center of a set of concentric arcs drawn with a compass. Point 1 on Fig. 4.6b is the center of a set of arcs between the perpendiculars to dips a and b. Point 2 serves as the center from which each arc is continued between the perpendiculars to dips b and c.

3 The process is continued until the structure section is completed. Figure 4.6c shows the completed structure section. Notice that some arcs were drawn with unlikely sharp corners in order for thicknesses to remain constant.

Problem 4.2

An exploratory oil well was drilled at the point shown in Fig. 4.8, and the units encountered are shown on the structure section. The oil-bearing Eagle Bluff Limestone was struck at a depth of 7200 ft. Using the arc method, draw a structure section. Indicate on the map where you, as a consulting geologist, would recommend drilling for oil. How deep do you predict the well will have to be to hit the Eagle Bluff Limestone?

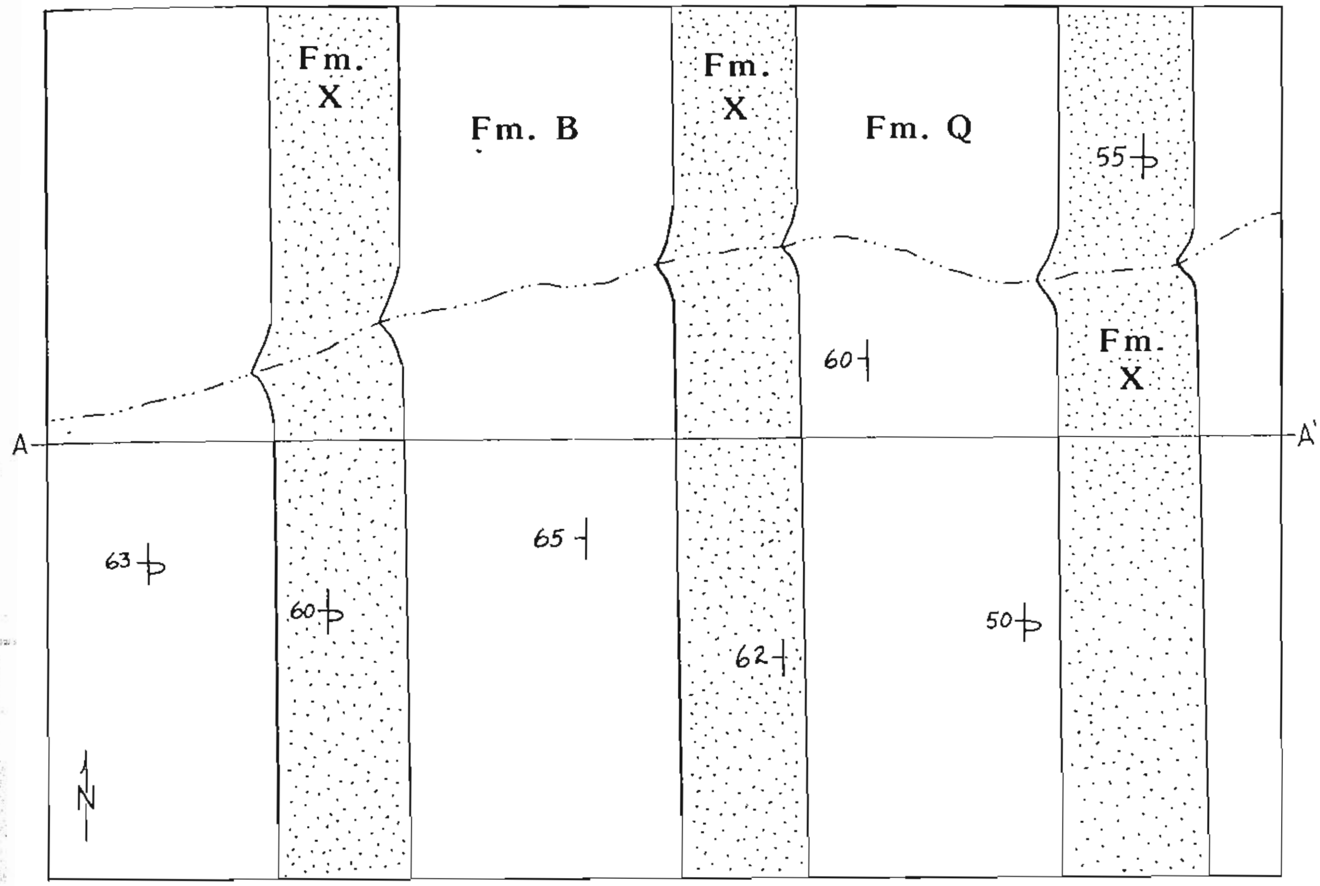


Fig. 4.5 Map and topographic profile for Problem 4.1.

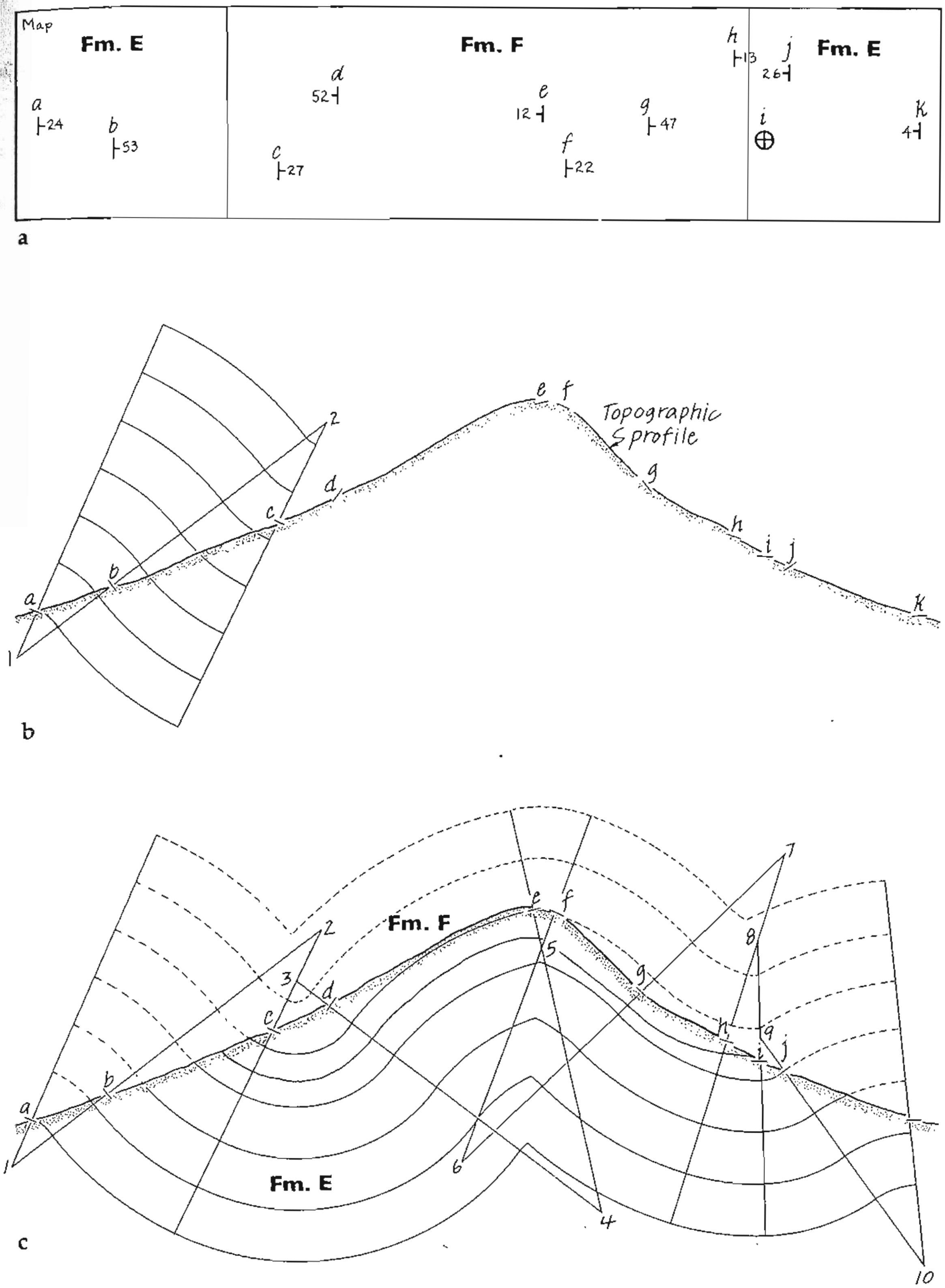


Fig. 4.6 Arc method of drawing structure sections of folded rock layers. (a) Geologic map. (b) Topographic profile with beginning of structure section. (c) Completed structure section.

Structure sections of intrusive bodies

Tabular intrusive bodies, such as dikes and sills, present no special problem. Irregular plutons, however, are problematical because in the absence of drill-hole or geophysical data it is impossible to know the shape of the body in the subsurface. Such plutons are usually drawn somewhat schematically in structure sections, displaying the presumed nature of the body without pretending to show its exact shape. For an example, see Fig. 4.7.

> **Problem 4.3**
> Draw structure section A–A′ in Fig. 4.9. Use freehand sketching rather than the arc method. Determine each apparent dip using either the alignment diagram in Fig. 1.7 or trigonometry.

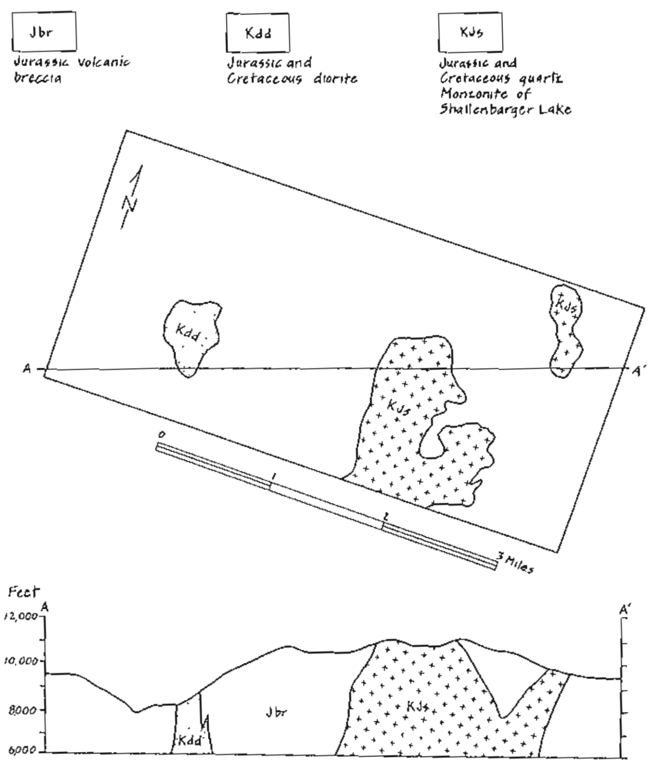


Fig. 4.7 Example of a structure section with intrusive bodies. After Huber and Rinehart (1965).

Structure-section format

Formal structure sections should include the following characteristics:

1 a descriptive title;
2 named geographic and geologic features such as rivers, peaks, faults, and folds should be labeled;
3 the section should be bordered with vertical lines on which elevations are labeled;
4 all rock units should be labeled with appropriate symbols;
5 standard lithologic patterns should be used to indicate rock type (see Compton, 1985, Appendix 8);
6 a legend should be included which identifies symbols and scale;
7 vertical exaggeration, if any, should be indicated, if none indicate "no vertical exaggeration";
8 contacts should be thin dark lines;
9 construction lines should be erased;
10 rock units should be colored as they are on the map.

> **Problem 4.4**
> Draw topographic profiles and structure sections for A–A′ and B–B′ on the Bree Creek Quadrangle map. Draw them as neatly and accurately as possible, and color each unit on the structure sections as it is colored on your map. Because the map shows that the Tertiary section is sitting on Cretaceous crystalline basement, you must show the crystalline basement beneath the Tertiary rocks on your structure sections. These structure sections will later become part of your synthesis of the structural history of the Bree Creek Quadrangle.
>
> Use your thickness measurements from Problems 3.2 and 3.3. Units should maintain a constant thickness in your structure section unless you have good evidence to the contrary.
>
> Remember that structure sections involve a great deal of interpretation and that, until someone drills a hole, there is no correct answer. As in all scientific interpretations, the best is the simplest one that is compatible with the available data. In the northeastern part of the map area, someone did drill holes. Problem 2.2 (Fig. 2.11) involved the drawing of a structure contour map on the upper surface of the Bree Conglomerate. Use your completed structure contour map to determine the depth of the Bree Conglomerate in the eastern half of structure section A–A′.
>
> Be sure that your structure sections have all of the features listed above.

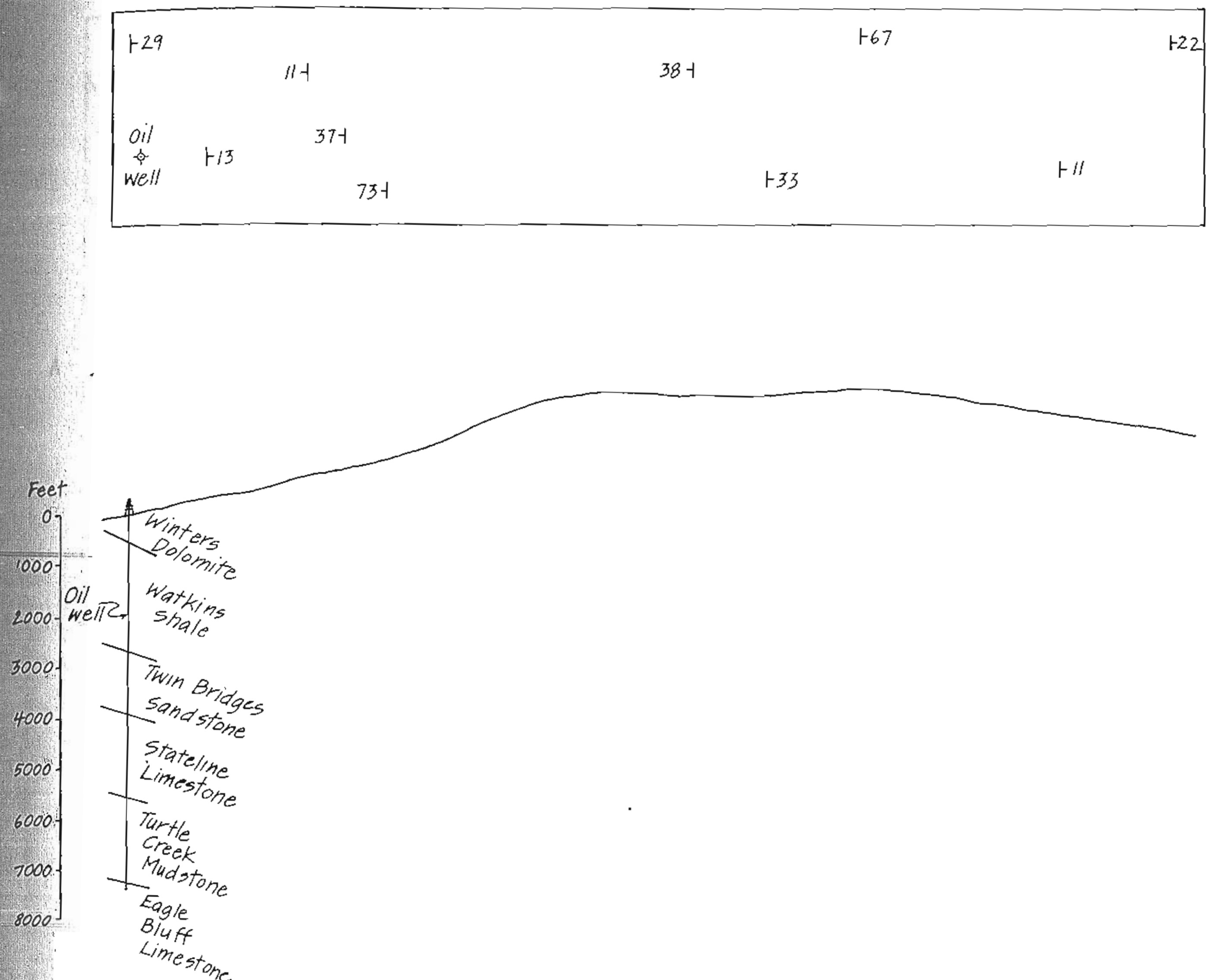


Fig. 4.8 Map, topographic profile, and well log for Problem 4.2.

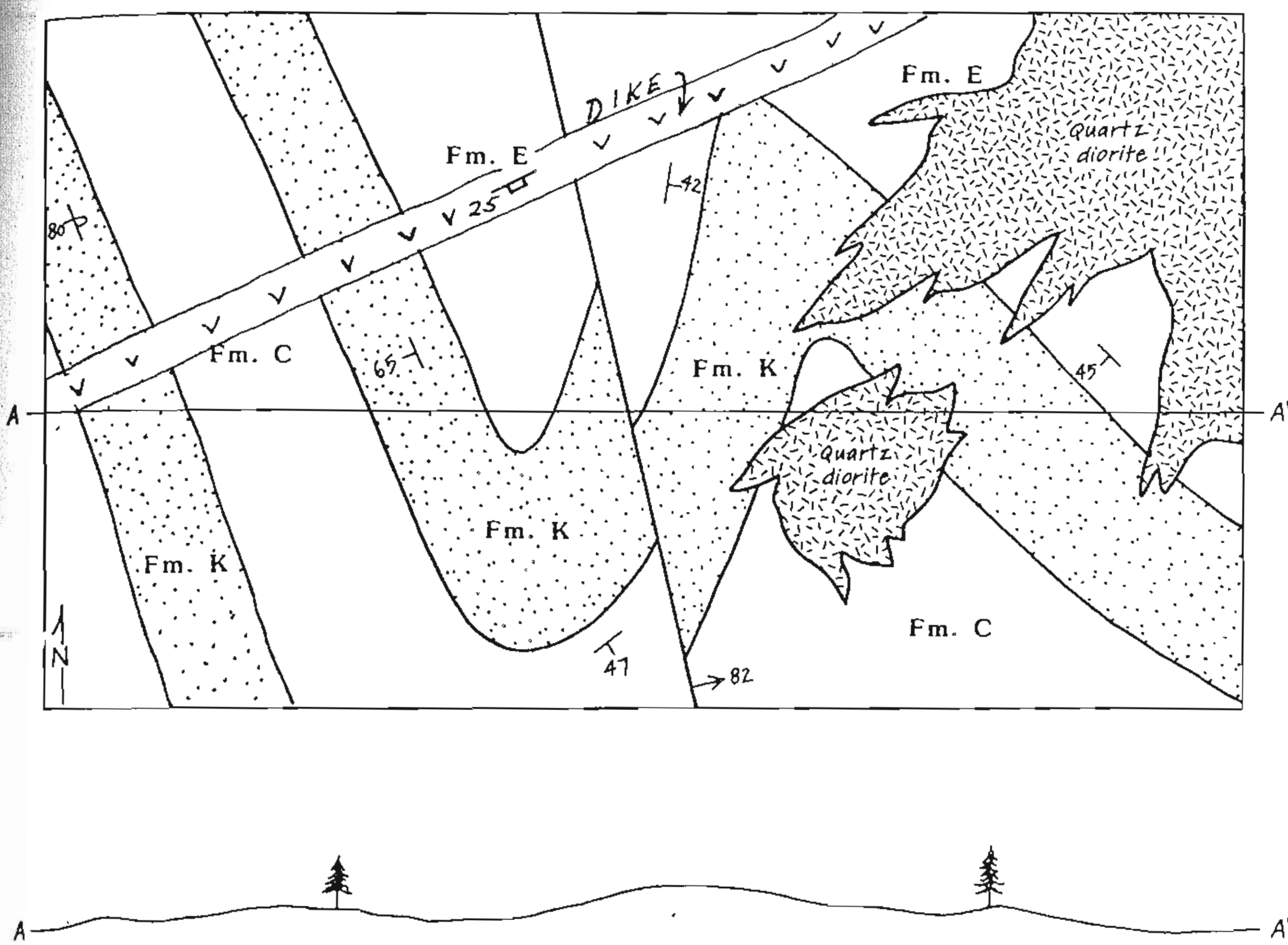


Fig. 4.9 Map and topographic profile for Problem 4.3.