4

Geologic Structure Sections

Objective

- **Learn to draw geologic structure sections through folded and faulted terrain.**

A geologic map is a two-dimensional representation of geologic features 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. Structure sections are widely used as the basis for geologic interpretations in petroleum and mineral exploration, hydrological studies, assessment of geologic hazards, and in basic research. 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.

Under the best of circumstances, drill core and geophysical data are available to help the geologist "see" into the earth, but many structure sections are based solely on a geologic map. Geologists use their understanding of the geometry and kinematics of structures to project the mapped geology into the subsurface, but this is still inferential. 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. 4.1a and the two structure sections based on it. The map shows three groups of rocks: Mesozoic metabasalt, serpentinite, and Tertiary sandstone. The serpentinite 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 serpentinite as occurring in the core of a partially eroded anticline. However, additional fieldwork revealed that the northern patch of serpentinite is more likely a large landslide block that long ago slid off the southern serpentinite mass (Fig. 4.lc). 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 a structure section, remember that, in general, 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

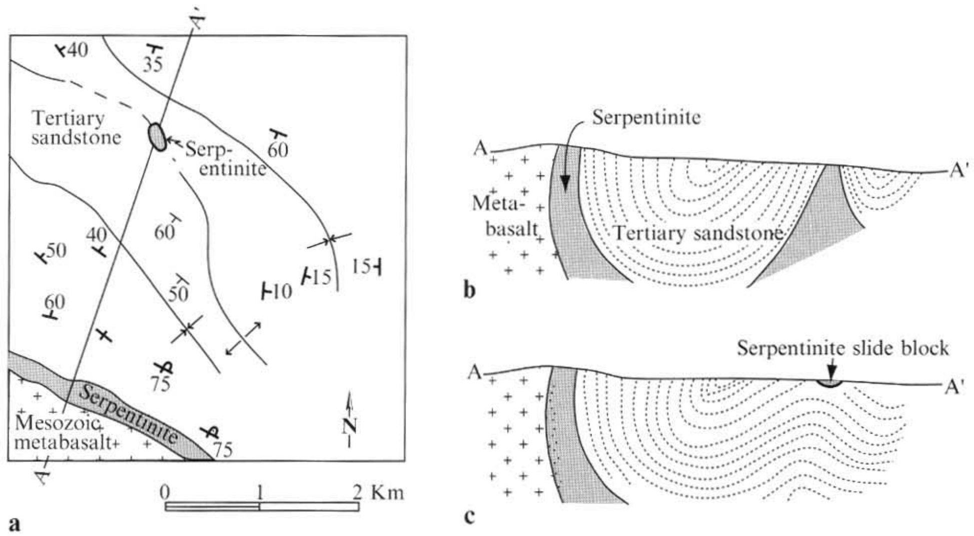

Fig. 4.1 Geologic map with two contrasting interpretations of structure section A–A′. Generalized from Dibblee (1966). (a) Geologic map. (b) Original structure section in which the northern serpentinite block is interpreted as the exposed core of an anticline. (c) Revised structure section in which the northern exposure of serpentinite is interpreted as a landslide block.

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. In some structurally complex regions, particularly where faulting has moved rocks into or out of the plane of the structure section, it may not be possible to draw a strictly balanced structure section.

Structure sections of folded layers

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

The simplest structure sections to draw are those that are perpendicular to the strike of the bedding. Figure 4.2 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. Show as much depth below the earth's surface as the data permit.

In very few cases are the strikes of the beds all parallel, as they are in Fig. 4.2. 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 4.3 shows a geologic map in which the strike of Formation B has been projected along the 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

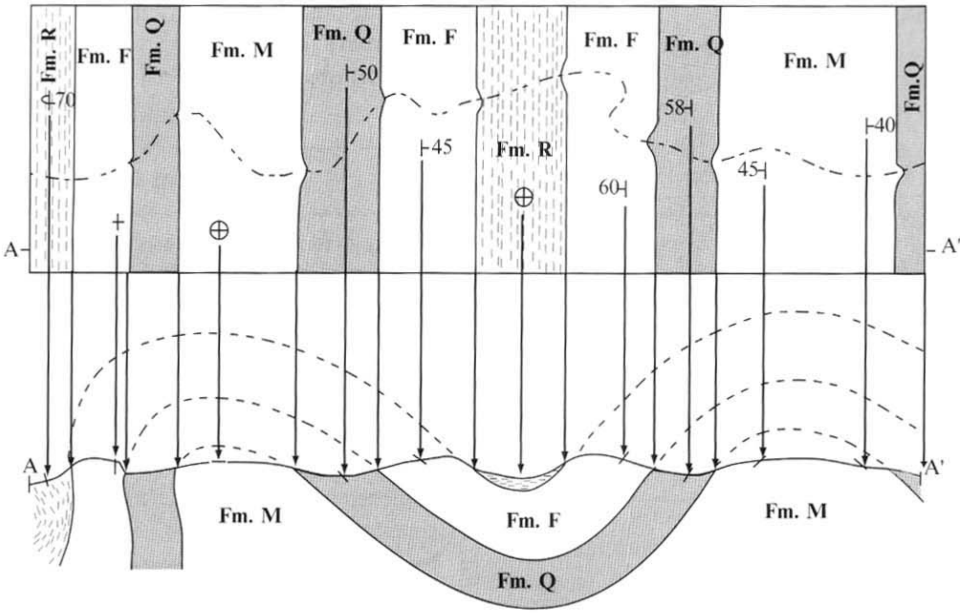

Fig. 4.2 Basic technique for drawing a geologic structure section perpendicular to the strike of the bedding. Arrows show transfer of attitudes from map to section. Dashed lines represent beds that have been eroded away.

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.

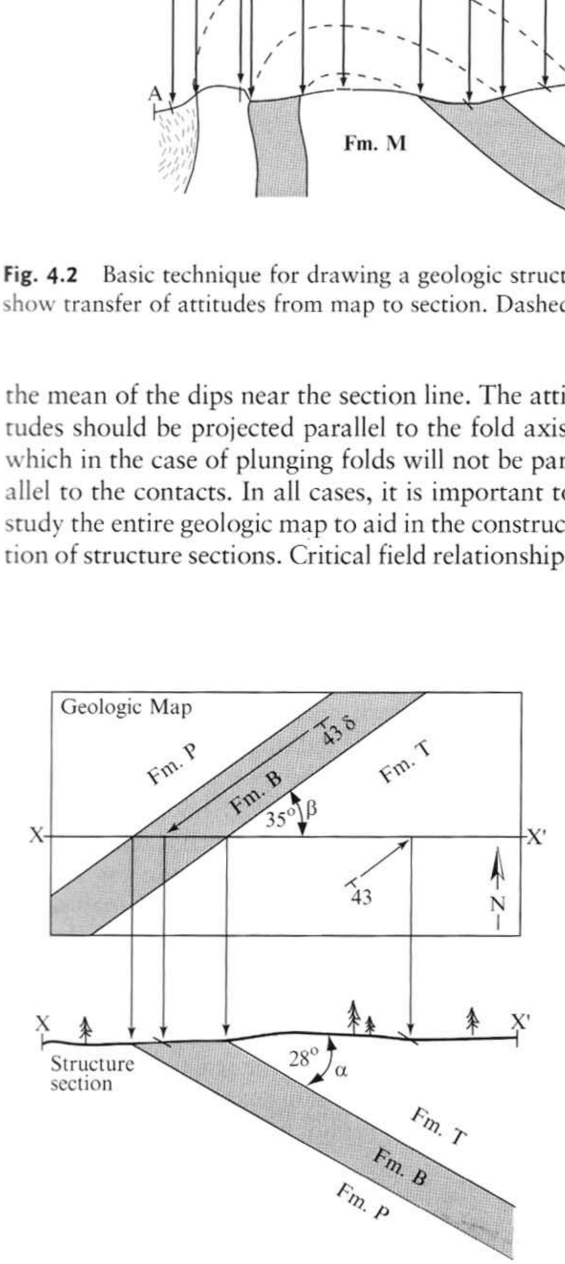

Fig. 4.3 Geologic map and corresponding structure section drawn at an angle to strike. Dip on map becomes an apparent dip on the structure section.

Structure sections of intrusive bodies

Tabular intrusive bodies, such as dikes and sills, present no special problem. Irregular plutons, however, are problematic 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. 4.4.

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 regions of

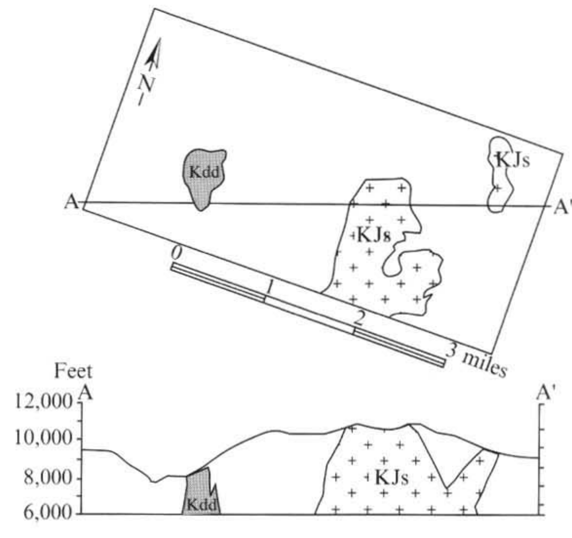

Fig. 4.4 Example of a structure section with intrusive bodies. After Huber and Rinehart (1965).

basins and domes or gently folded areas 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. "Volume 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. 4.5. 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 the 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. 4.5b 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 drawing compass. Point 1 on Fig. 4.5c 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 4.5d shows the completed structure section. Notice that some arcs were drawn with unlikely sharp corners in order for thicknesses to remain constant.

Drawing a topographic profile

Up to this point in this chapter, in all of the examples and problems, a topographic profile has been provided. Topographic profiles show the relief at the earth's surface along the top of the structure section. Usually you will have to construct your own topograhic profile. The technique for drawing a topographic profile one is as follows:

1 Draw the section line on the map (Fig. 4.6a).
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. 4.6b).
3 Scale off and label the appropriate elevations on a piece of graph paper (Fig. 4.6c). Graph paper with 10 or 20 squares per inch is ideal for 7.5-minute quadrangle maps because the scale is 1 inch = 2000 ft. Notice that the map scales on Fig. 4.6a and 4.6b are the same as the vertical scale on Fig. 4.6c and 4.6d. It is very important that the vertical and horizontal scales are the same on 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.
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. 4.6c).
5 Connect the points (Fig. 4.6d).

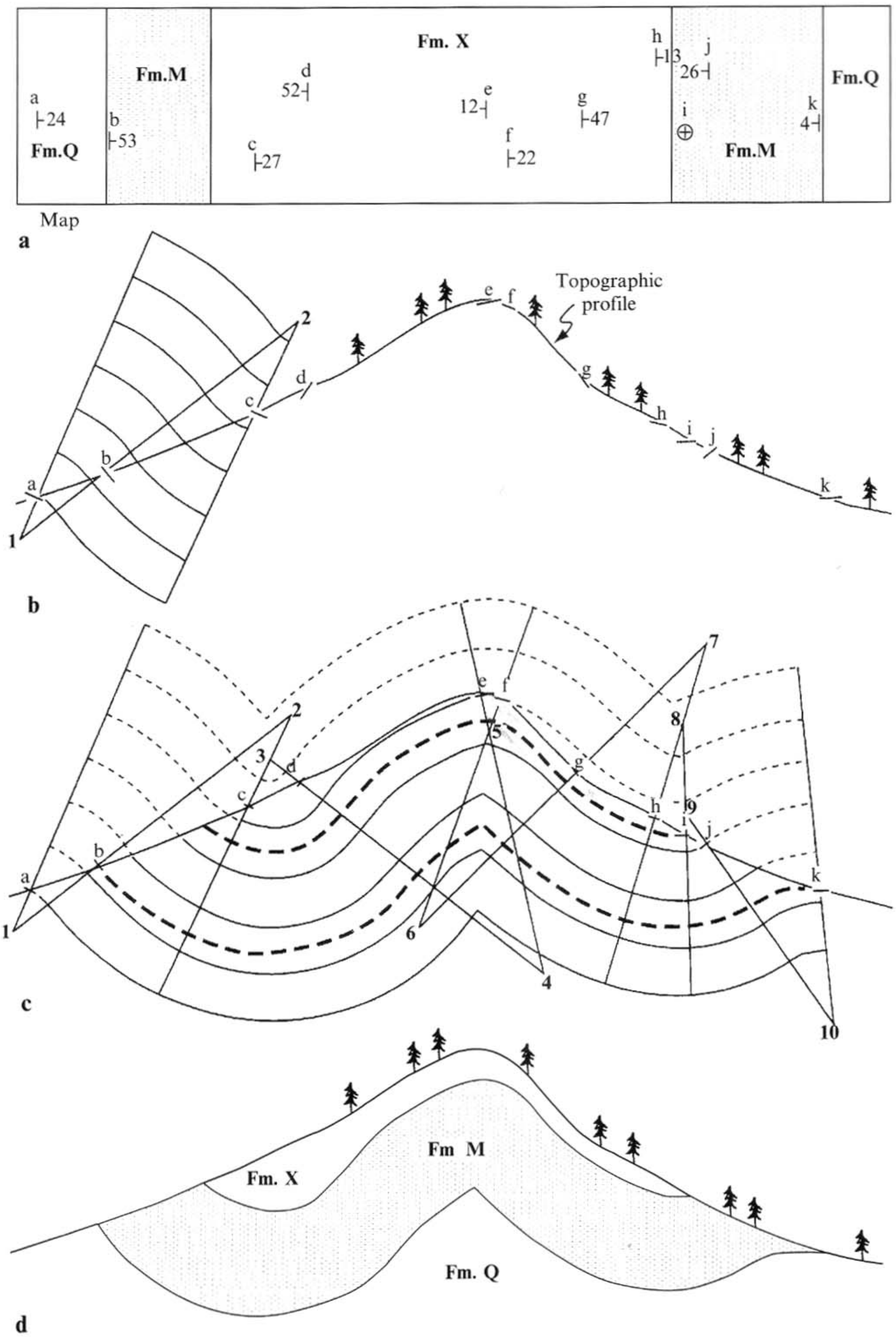

Fig. 4.5 Arc method for drawing structure sections of folded beds. (a) Geologic map. (b) Topographic profile with beginning arcs. (c) Completion of arcs. (d) Completed structure section.

> **Box 4.1** A note about vertical exaggeration
>
> For routine structure sections, including all that you draw for exercises in this book, be sure that the vertical and horizontal scales are exactly the same. This means that there is **no vertical exaggeration**. However, there are circumstances under which vertical exaggeration is desired. For example, suppose you are preparing a structure section for an interpretive display at a state park; you might want to exaggerate the vertical scale to emphasize topographic features in the park. In such cases, use Appendix D to determine the adjusted dip of beds in the structure section, and be sure to indicate the amount of vertical exaggeration on the drawing (e.g., "4 × vertical exaggeration"). If there is no vertical exaggeration on a structure section, write "No vertical exaggeration" or "V : H = 1 : 1" beneath the section.

Structure-section format

Formal structure sections should include the following characteristics:

1 A descriptive title.
2 Named geographical all 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.
6 A legend should be included that identifies symbols and scale.
7 Vertical exaggeration, if any, should be indicated; if none, indicate "no vertical exaggeration".

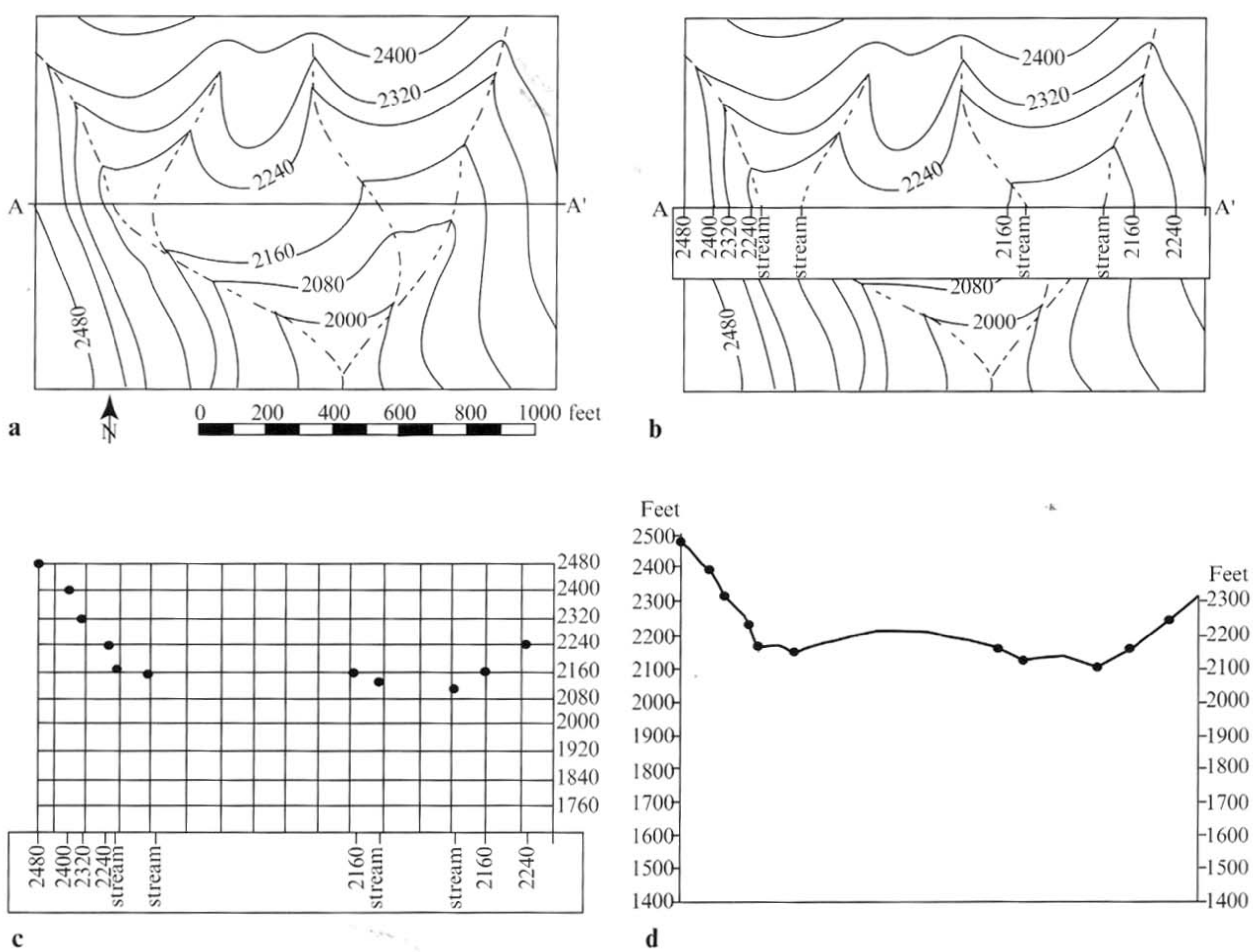

Fig. 4.6 Technique for drawing a topographic profile. (a) Draw section line on map. (b) Transfer contour crossings, streams, and other features to another sheet of paper. (c) Transfer points to proper elevation on cross-section sheet. (d) Connect points in a way that reflects the topographic subtleties recorded on the map.

8 Depositional and intrusive contacts should be thin dark lines; faults should be thicker dark lines.
9 Construction lines should be erased.
10 Rock units should be colored as they are on the map.