Chapter 10: Three-Dimensional Perspective Diagrams

THREE-DIMENSIONAL PERSPECTIVE diagrams combine information from maps and cross-sections into a single illustration to enhance understanding of their relationship. Such diagrams are presented as various types of perspective blocks. The top of the blocks shows an oblique aerial view of the geological and topographic features of the upper surface. This upper surface is typically that of the Earth's surface but, also, may be a horizontal slice through several tilted or deformed layers in the subsurface. The sides of the blocks provide a simultaneous view of the subsurface geology. The geological structure of an area thus displayed can be understood by non-specialists, involved in mining, petroleum, and engineering operations. This chapter concentrates on the graphical variety of 3-D display methods to aid professionals, such as engineers and geologists, in deciding which type of diagram is most appropriate for each particular application.

Contents: Two types of perspective diagrams are outlined in sections 10-1 and 10-2. Isometric block diagrams with flat top surfaces are discussed in section 10-3. Isometric diagrams, including the topographic relief of the ground surface, are introduced in section 10-4. The final section, 10-5, summarizes additional display methods, including fence, cabinet, coulisse, and structure-contour diagrams.

10-1 Parallel perspective

The illusion of a 3-D view in a 2-D picture can be created by graphically distorting the

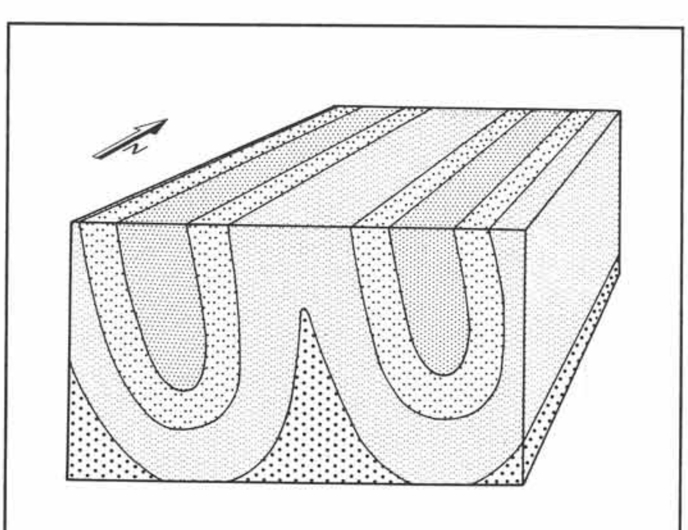

Figure 10-1: *Parallel perspective diagram of folds.*

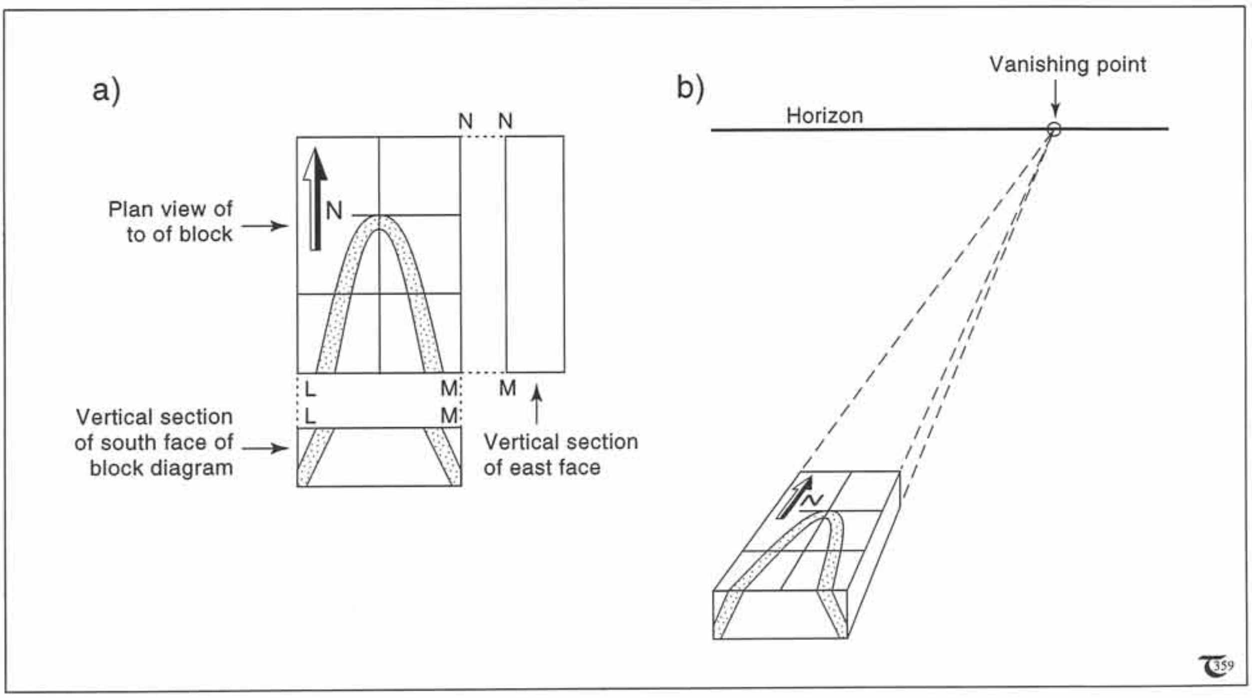

Figure 10-2: *a) & b) Construction of parallel perspective diagrams. See text.*

various parts of crustal cut-outs in a carefully controlled fashion (Fig. 1). One class of perspective diagrams show imaginary crustal blocks with the perception of depth and distance enhanced by means of one or more perspective vanishing point(s) at an imaginary horizon (Fig. 10-2b). Consequently, the front of the map appears larger than its back. Distances and angles of the structure in different parts of the diagram are distorted in a gradually shifting fashion. If only one vanishing point is used, the diagram is termed a *parallel perspective*, sometimes referred to as one-point perspective or single-vanishing point perspective. Perspective diagrams involving two vanishing points, termed *angular perspectives*, are discussed in section 10-2.

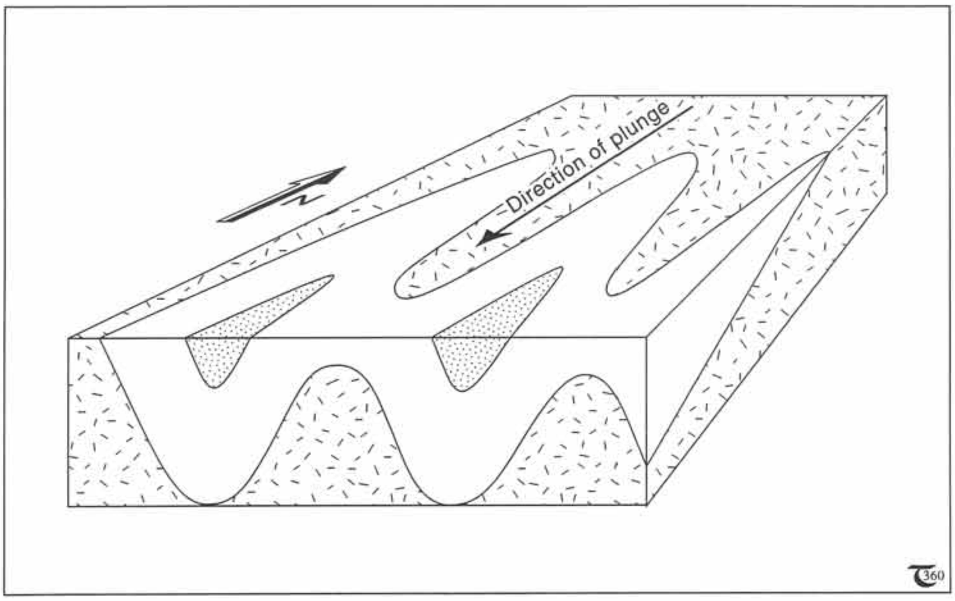

Figure 10-3: *Parallel perspective diagram of upright, south-plunging folds. See exercise 10-1.*

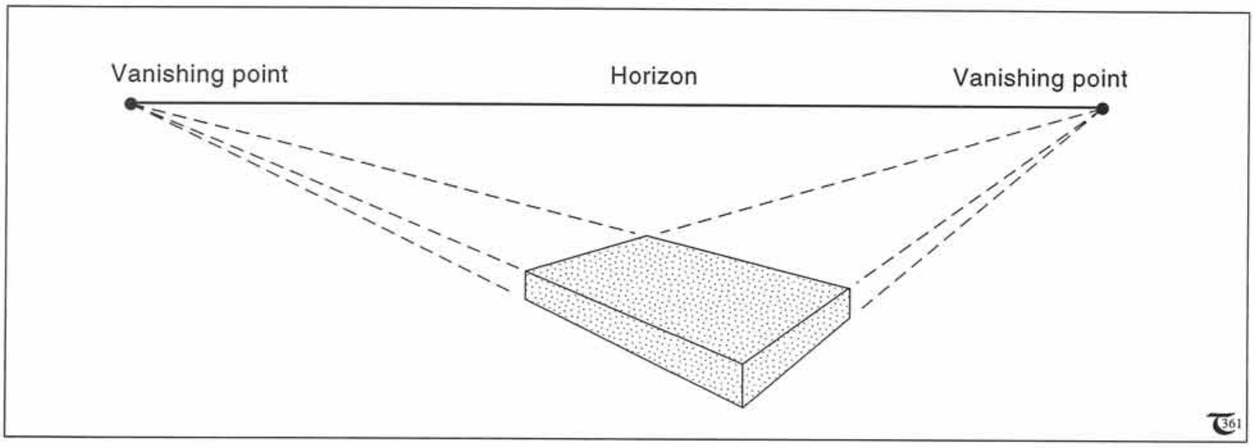

Figure 10-4: *Angular perspective diagram.*

The geology of the crustal perspective block can be completed only if the ordinary map view and two cross-sections - mutually perpendicular along the side lines of the map - are available or constructed as starting material (Fig. 10-2a). The outlines of the perspective diagram are drawn, choosing a vanishing point at an imaginary horizon. The geological information is transferred to the surfaces of the perspective diagram, visually deforming two of the panels of the perspective diagram to create the sense of depth (Fig. 10-2b). To achieve this manually, the map is subdivided into equal squares, which are then proportionally deformed, together with the geological bound-

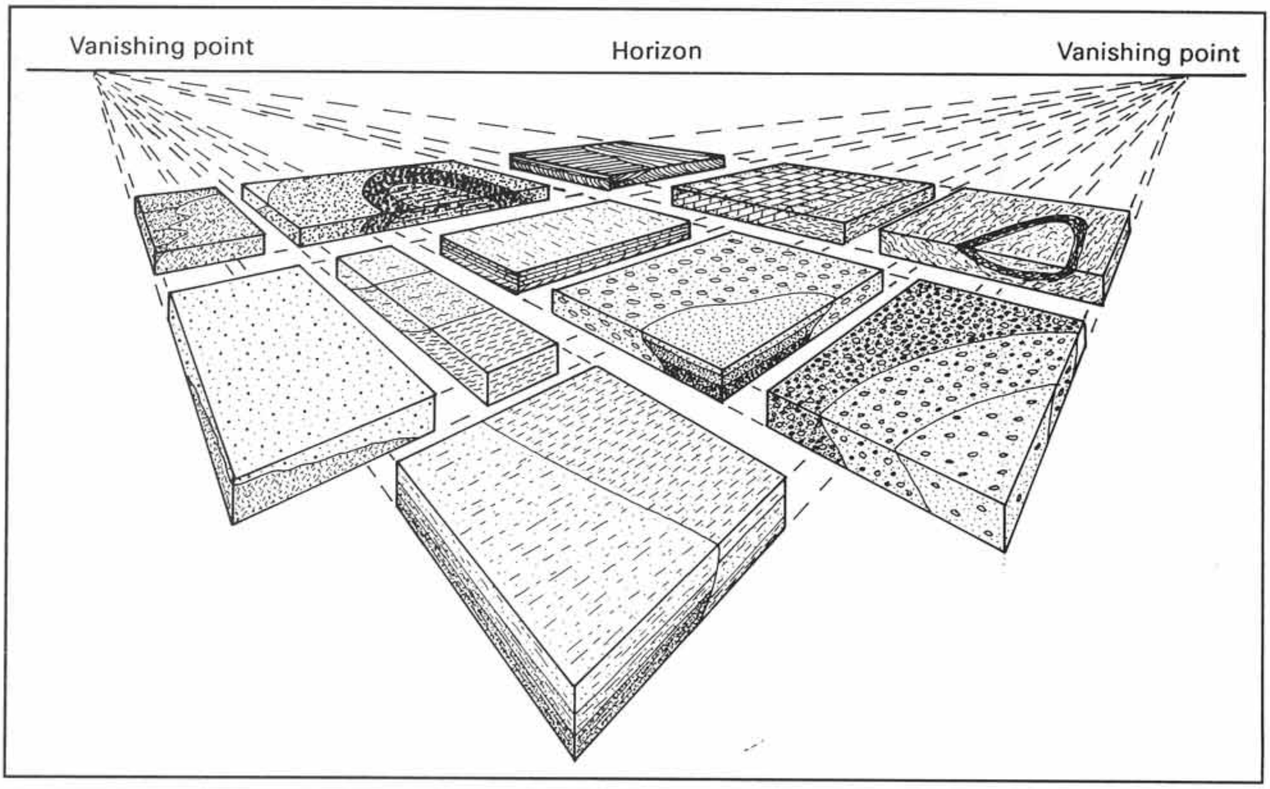

Figure 10-5: *Family of angular perspective diagrams.*

aries, into the finite units of the perspective diagram's top surface. Perspective diagrams with one vanishing point have undistorted front panels. However, the other visible side panel is deformed in a fashion controlled by the location of the perspective point, so as to create the suggestion of a 3-D view. All lines that are vertical in reality remain vertical in the perspective diagram. But much of the quantitative information on angular relationships and distances is obscured.

□Exercise 10-1: Examine the parallel perspective diagram of Figure 10-3, and construct both the vanishing point and the imaginary horizon line.

10-2 Angular perspective

Slightly more realistic is the perspective diagram with two vanishing points at the horizon (Fig. 10-4). Such *angular perspective diagrams* are, also, referred to as two-point perspectives or double-vanishing-point perspectives. Figure 10-5 illustrates an array of angular perspective diagrams, all at different rotation and distances with respect to the same horizon and vanishing points. The distance between the two vanishing points is arbitrary, as is the relative position of the block itself. The orientation of the block can be selected so that the relevant structure is displayed in the most suitable fashion. Evidently, of all 3-D display methods available, perspective diagrams have the most realistic appearance and, therefore,

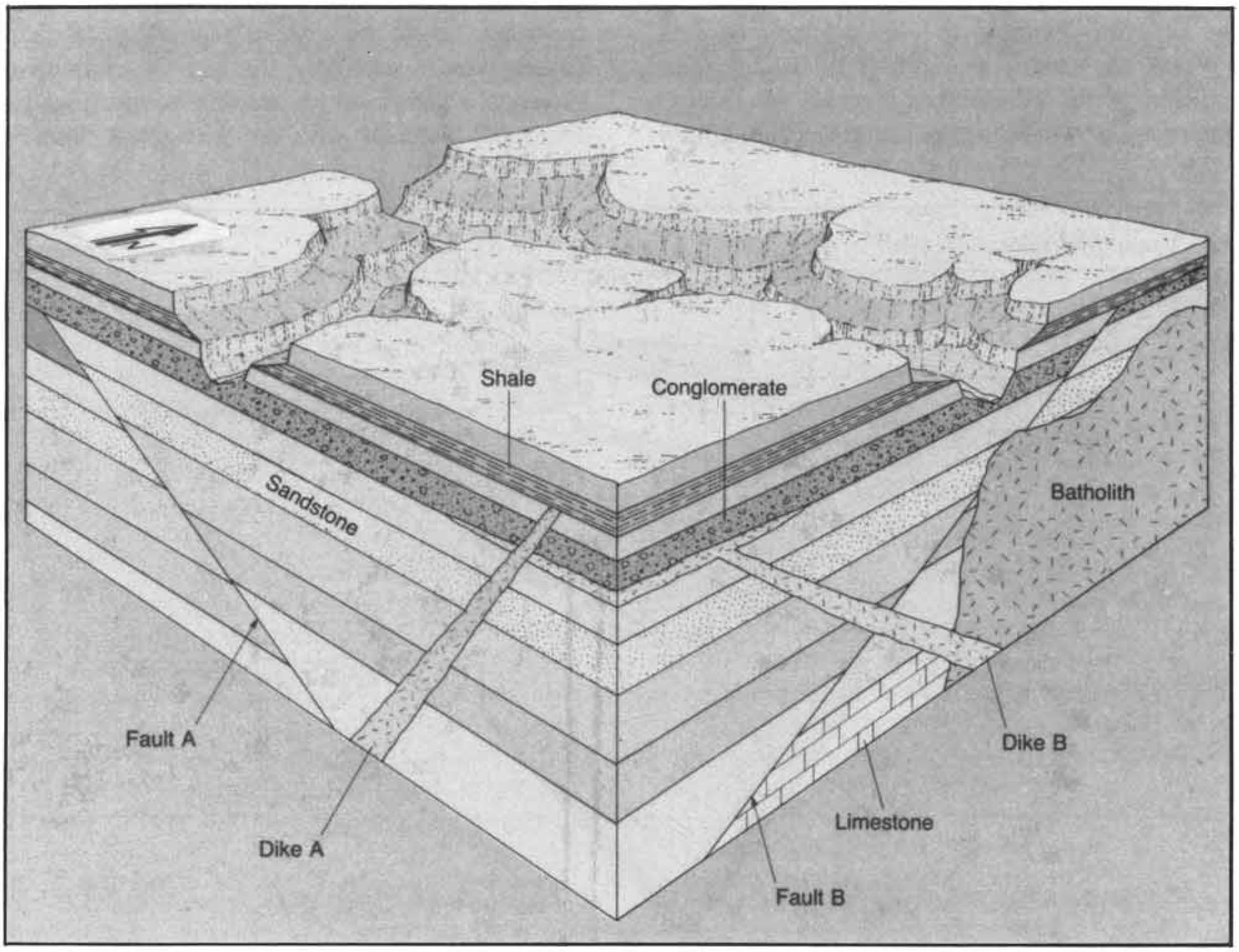

Figure 10-6: *Angular perspective diagram for exercise 10-2.*

are very suitable for rapid communication of the general three-dimensional structure of crustal blocks. Perspective diagrams are good qualitative tools, but the increasing foreshortening towards vanishing points makes them less suitable for any quantitative measurement of either distances or angles.

□Exercise 10-2: Examine the angular perspective diagram of Figure 10-6. a) Construct the vanishing points and the imaginary horizon line. b) If the canyon system at the surface were to be displayed more prominently, how would you change these perspective points? c) How could the visual prominency of the canyon system be reduced? d) Why is an angular perspective block better than a parallel perspective for displaying the faults and dikes of this region?

□Exercise 10-3: Transform the parallel perspective of Figure 10-1 into an angular perspective diagram.

10-3 Isometric perspective without topography

Isometric block diagrams differ from parallel and angular perspective diagrams in that there are no vanishing points involved with the former. The blocks are constructed by drawing three sets of lines, each set differently oriented, but all lines of the same set remaining exactly parallel (Fig. 10-7a to c). Consequently, the front- and rear-panels of an isometric block have the same area, even in the drawing plane. The dimensions of the block diagram can be defined by a Cartesian coordinate system, with the Z-axis pointing downward. The orientation of the other two axes can be fixed in an arbitrary fashion. Figures 10-7a to c illustrate three different, arbitrary orienta-

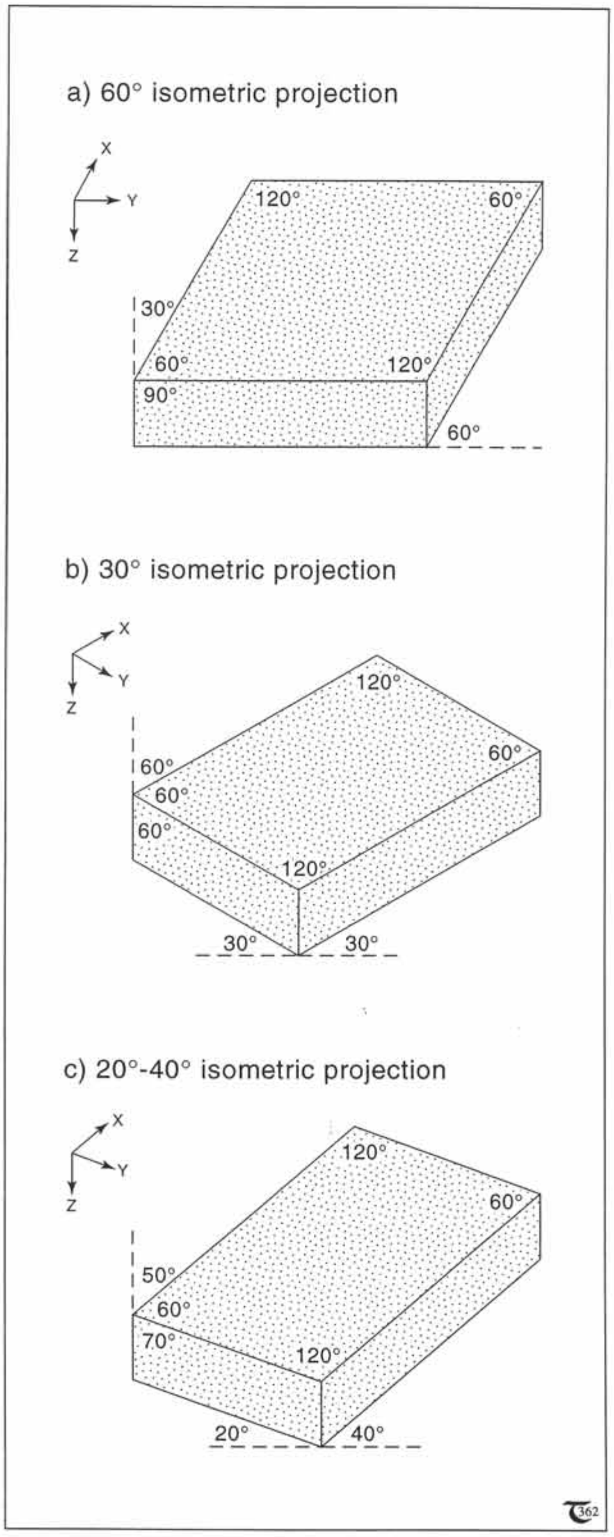

***Figure 10-7:** a) to c) Isometric block diagrams for a range of tilt angles with respect to the horizontal.*

tions for the Cartesian coordinate system, resulting in different views of the isometric block. All the distances measured along the three axes of the block are equal to the dimensions of the original map and vertical section scales used. All lines parallel in the block will be parallel in reality. All

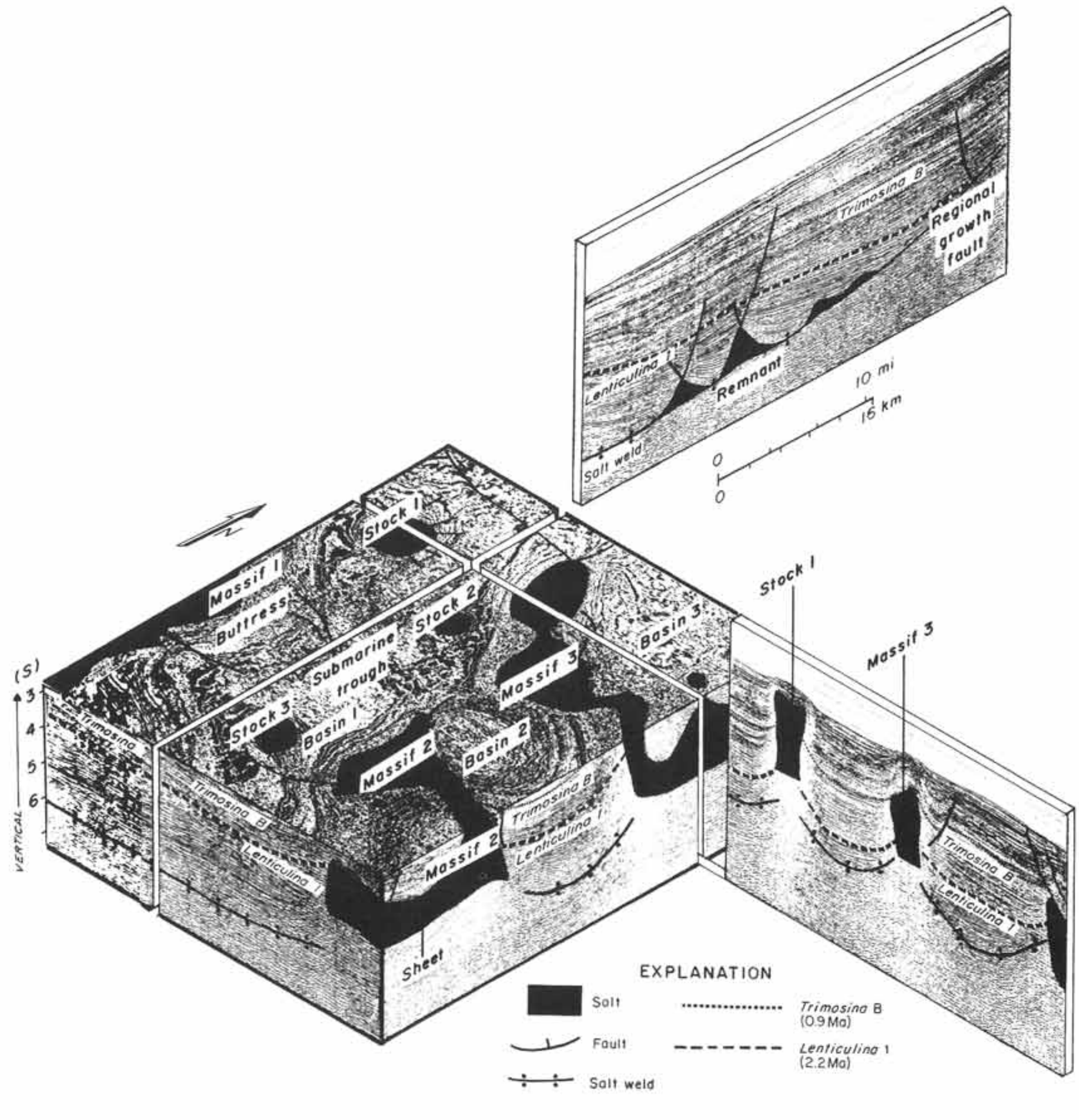

Figure 10-8: Isometric block diagram of seiscrop map and sections of salt domes in the Gulf of Mexico, off-shore Louisiana. The pull-out panels visualize the structure in the rear parts of the block.

angles in isometric blocks are distorted, except for those seen in the front-panel of the projection of Figure 10-7a.

Figure 10-8 illustrates an isometric block diagram, constructed from a horizontal seiscrop map and two sets of mutually orthogonal seismic sections. This particular diagram shows the intricate pattern of the interconnected salt masses, seen in various cuts through the subsurface of the Gulf of Mexico. The view of the subsurface structure is enhanced by two accessory panels, pulled from imaginary vertical slots in the interior, as indicated. The vertical scale (Z-direction) is exaggerated and nonlinear, as compared to the horizontal dimensions. In general, if cross-sections, used for constructing block diagrams, have vertical exaggeration, then this exaggeration will be passed on to the block diagram.

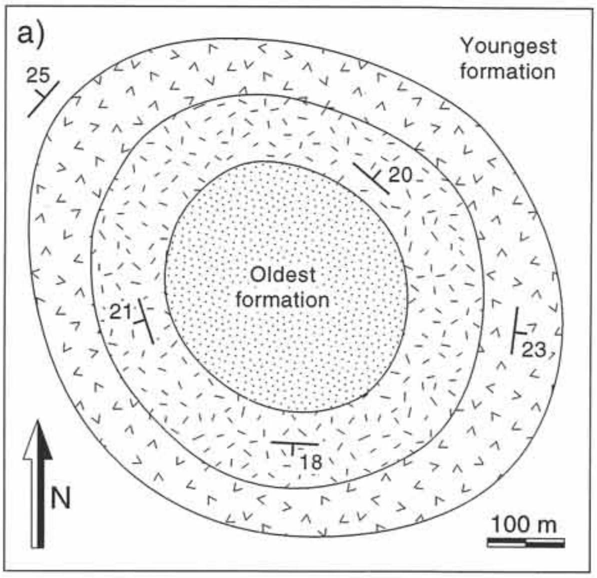

Figure 10-9a: *Map view of a dome.*

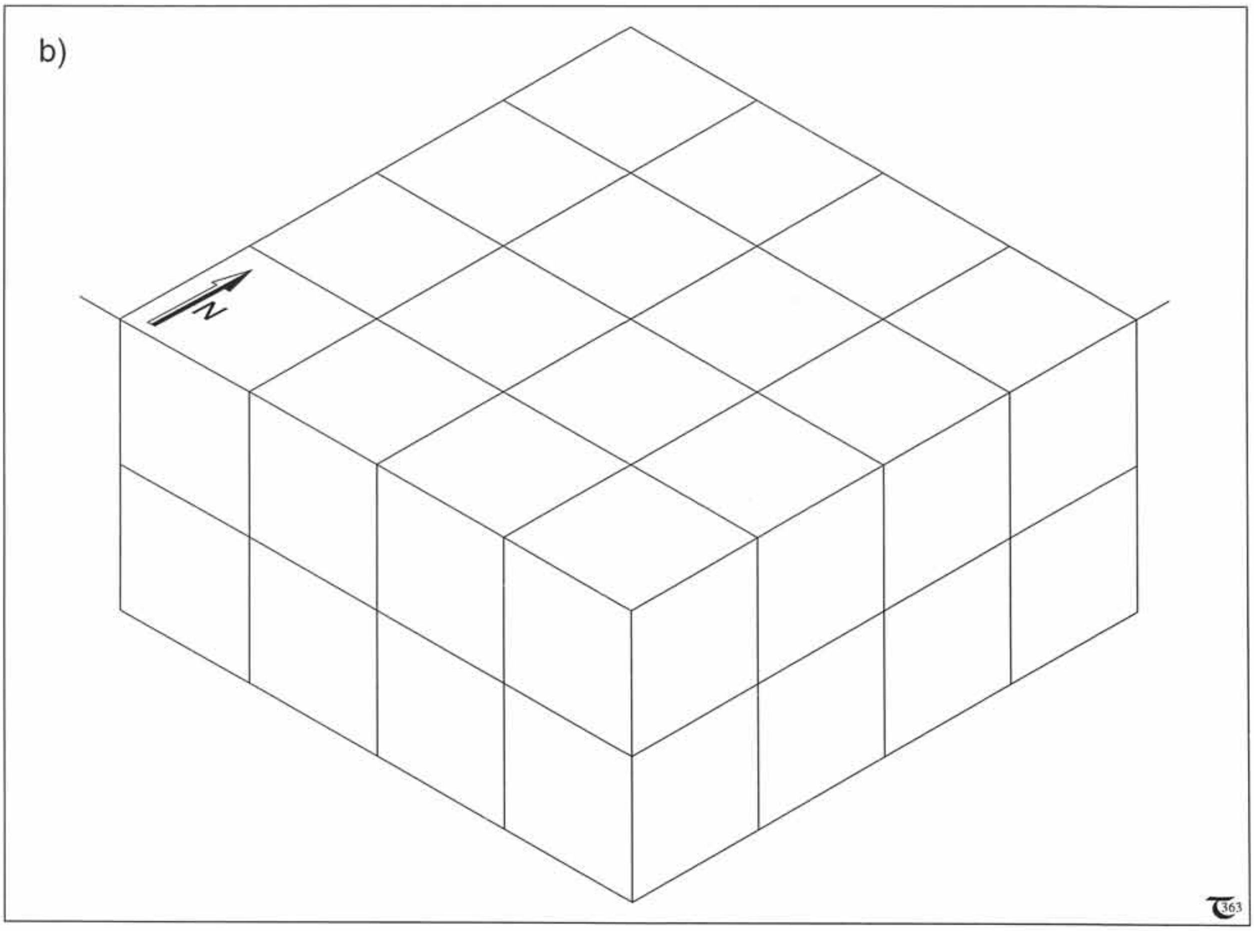

Figure 10-9b: *Isometric frame for exercise 10-4.*

The coordinate system used for any rock body in the subsurface is defined by the axes of the isometric block representation. This coordinate system may be locally defined, either in terms of distances (meters, feet) or in geographical coordinates for the horizontal dimensions (local, national, or international grid), combined with a depth scale. All geological data can then be related to the coordinate system. This allows swift manipulation of the data, particularly if computerized methods are used. Isometric block diagrams are particularly useful for detailed drilling and excavation activities of mining, petroleum, and construction companies. All isometric projections are nonperspective. This makes them less realistic to look at, but this is more than offset by their ability to yield correct lengths along the axial directions. Distances in other directions are not commensurate with the true distances. Angles in isometric projection can be read correctly with a commercially available protractor (e.g., *Linex*).

□Exercise 10-4: Complete the isometric block diagram (Fig. 10-9b) for the structure seen in the map of Figure 10-9a. Use the following steps: a) Transfer the geology from the map to the block diagram by extrapolation. b) Complete the views of the geology in the vertical walls of the block. c) Define a coordinate system for hydrocarbon exploration in the structure displayed.

10-4 Isometric perspective with topography

All the 3-D views discussed above had flat top surfaces. The topographic surface relief of the landscape will be negligible if the horizontal scale of the diagram is compressed so much that any differences in vertical elevation become invisible. Since the average elevation of continental areas is about two kilometers, vertical elevation shows up as a mere perturbation on a line of one millimeter thickness if the horizontal scale uses one millimeter for one kilometer, i.e. 1:1,000,000 or more. The effect of topography will still be minimal for diagrams in the range of 1:1,000,000 to 1:100,000 but can be enhanced by vertical exaggeration. However, sections and block diagrams of more detailed scale need to take into account the surface topography.

The topographic relief of the ground surface can be included in isometric block diagrams. But the construction of such 3-D diagrams can be

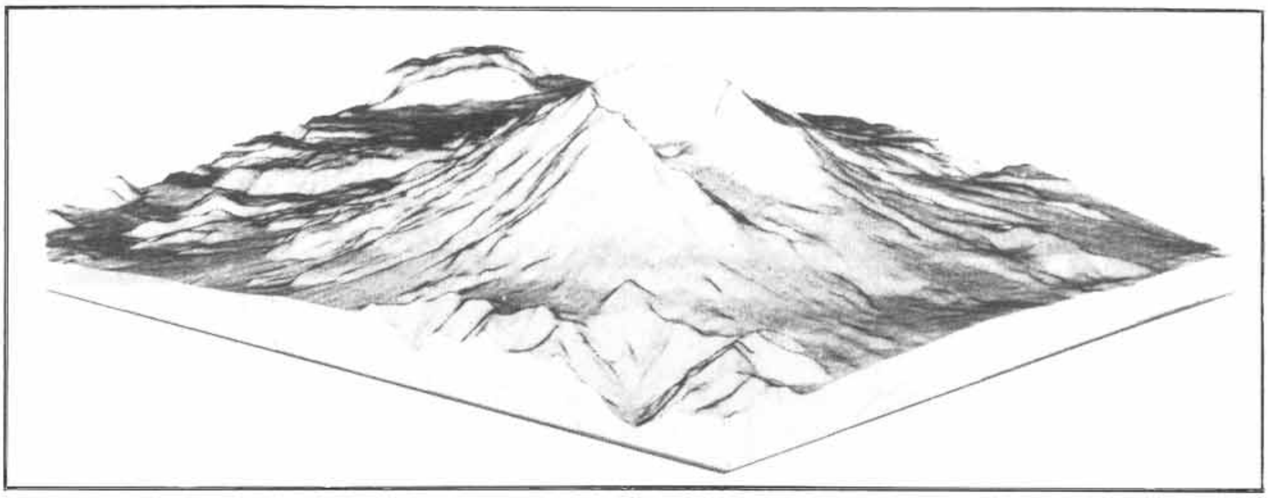

Figure 10-10: *Isometric wire-mesh diagram, showing the surface topography of Mount St. Helens with typical horseshoe opening in the summit, which collapsed in a massive landslide during the big 1980 eruption.*

elaborate and is greatly facilitated by a range of software packages, which are commercially available and continuously upgraded. If the elevation data are stored in a computer, shaded relief maps can be produced by stacking closely spaced cross-sections at right angles. Figure 10-10 illustrates an isometric block diagram - computer generated - of Mount St. Helens. Software packages for constructing such diagrams are outlined in chapter seventeen, but the basic graphical principles for creating 3-D images are discussed below. Computer methods work along the same principles but partly differ from manual methods in that they speed up the process of graphical representation.

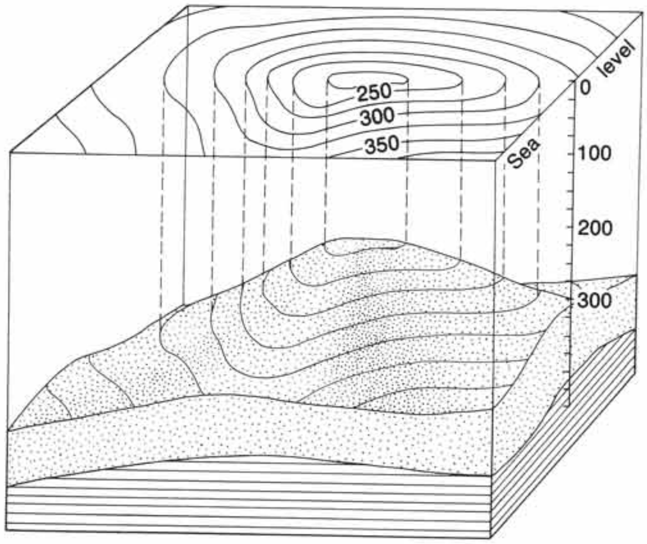

Figure 10-11: *Topographic map and the corresponding isometric block diagram with elevation contours illustrate the landscape in a 3-D perspective.*

Figure 10-11 shows a manually constructed block diagram of a gentle hillside. To show the relief, each of the topographic contours is elevated to its appropriate distance above the base level. The general construction method is illustrated in Figures 10-12a to f. The topographic contour map is the starting point. A sheet of tracing paper is laid over the topographic map, already deformed into isometric format (Fig. 10-12a). An arbitrary reference arrow is drawn on the sheet of the isometric map. This arrow is used to shift the vertical scale on the tracing paper upward, each time a contour of a particular elevation is traced (Figs. 10-12b to e). The spacing on the vertical scale determines whether or not any exaggeration of relief is included. A final shift of the tracing paper enables point zero to be traced. If all the contours are thus transferred to the tracing paper, vertical lines can be drawn from the corners of the original isometric map to border the completed block diagram (Fig. 10-12f). The endings of all contours need to be traced completely towards the edge of the isometric map. Otherwise, the surface profile between the vertical lines, forming the boundaries of the block, cannot be completed.

□Exercise 10-5: Figure 10-13a shows a merged geological and topographic map. The cross-sections PQ and QR are along the south and east boundaries of the map area (Figs. 10-13b & c). The isometric surface map is given in Figure 10-13d. a) Prepare an isometric block diagram, showing the surface topography of the area. b) Transfer the geological information to the block diagram, using the surface map and the cross-sections.

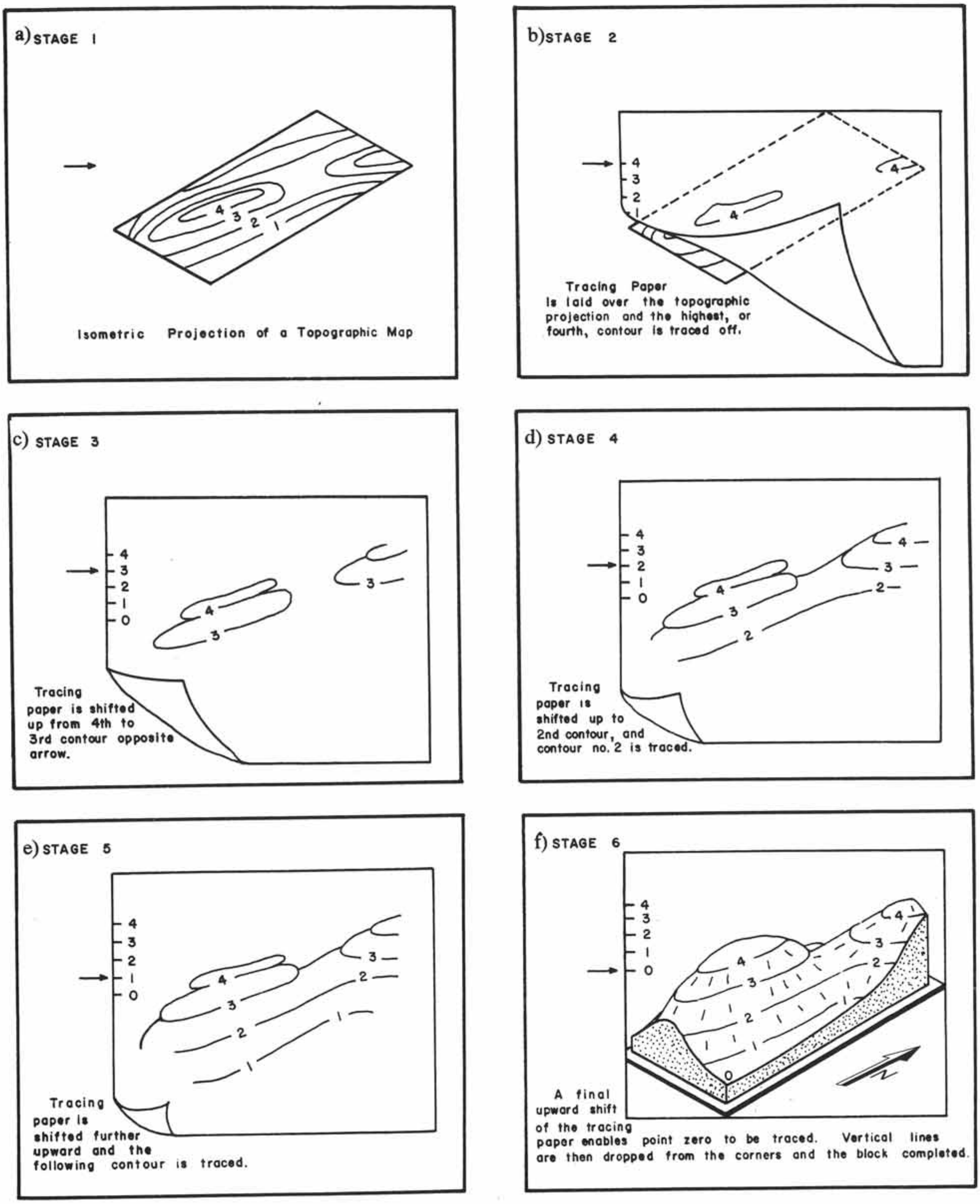

***Figure 10-12:** a) to f) Steps involved in the manual construction of an elevated-contour diagram of a landscape.*

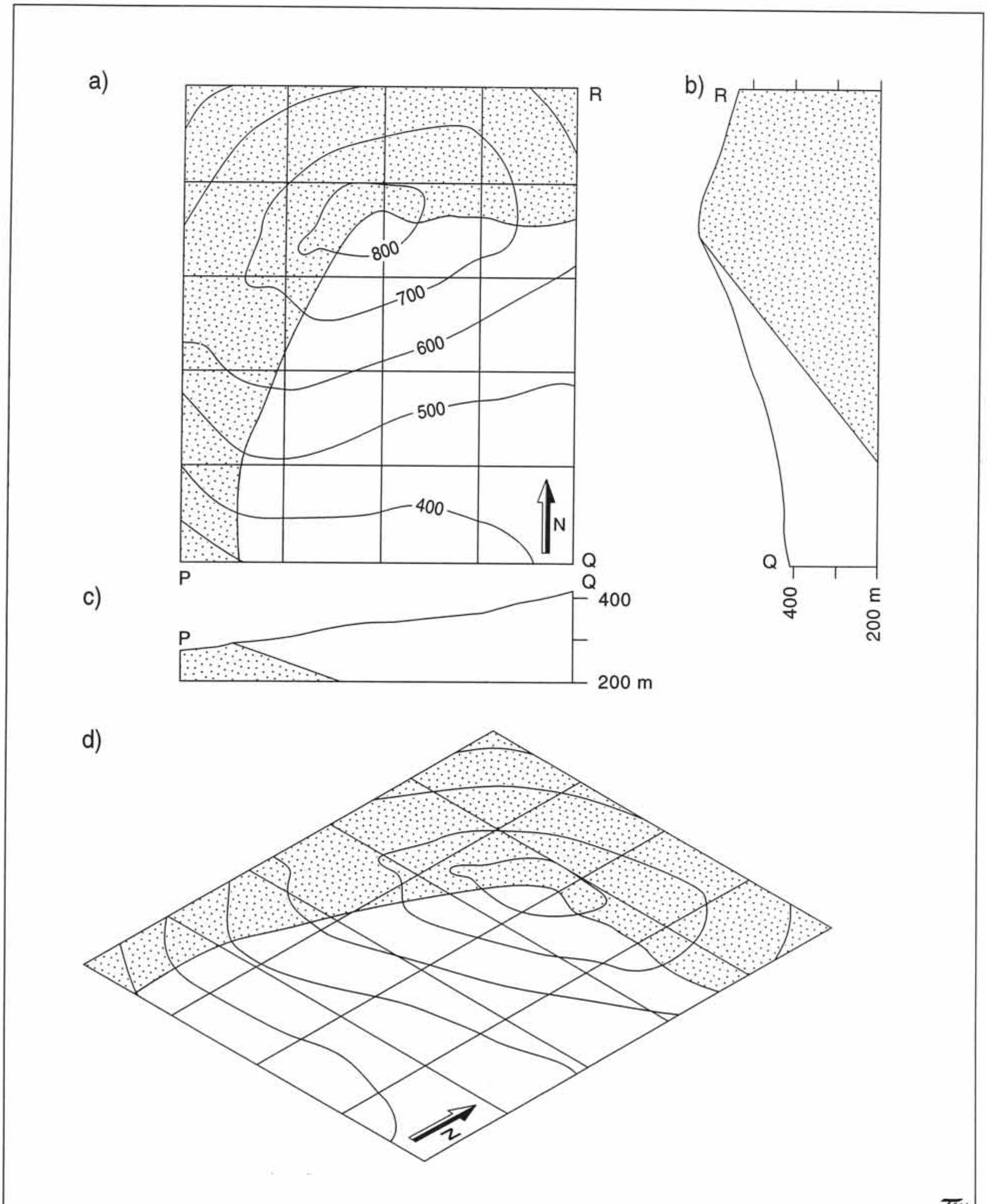

Figure 10-13: *Graphics for exercise 10-5. a) Geological map on topographic base. b) N-S section along QR. c) E-W section along PQ. d) Isometrically distorted map view.*

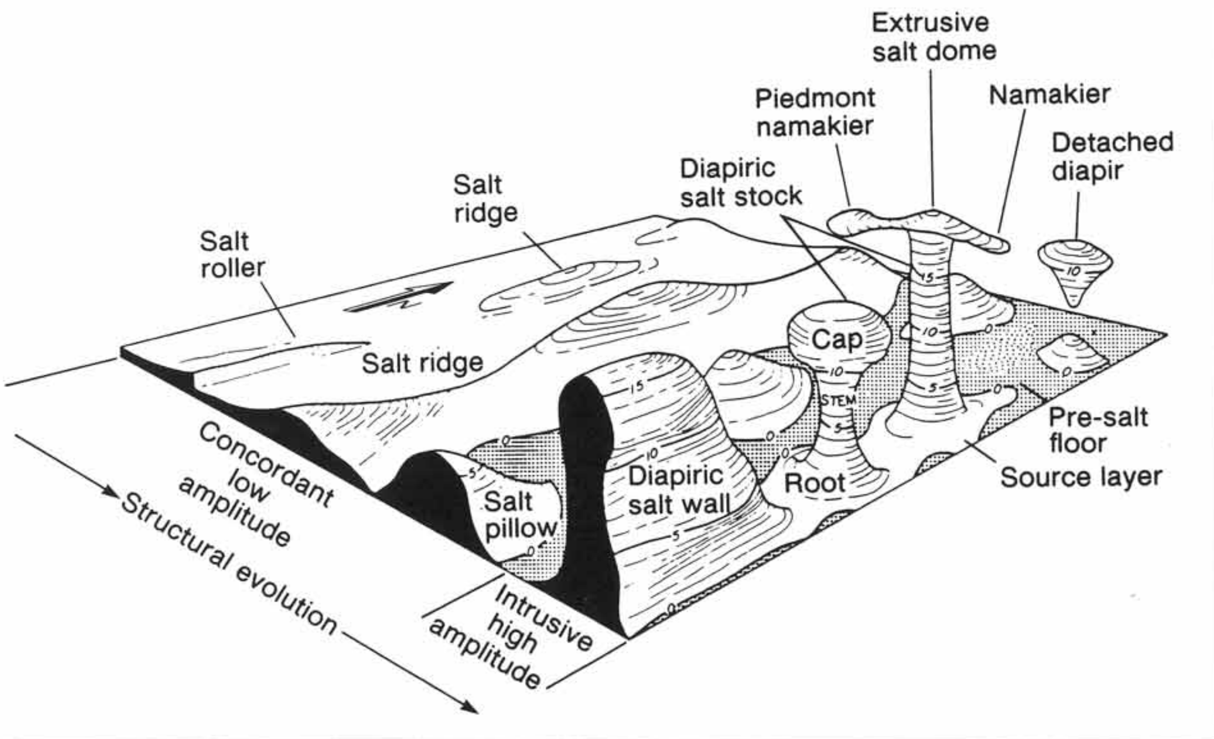

Figure 10-14: Salt structures, outlined by elevated structure-contours.

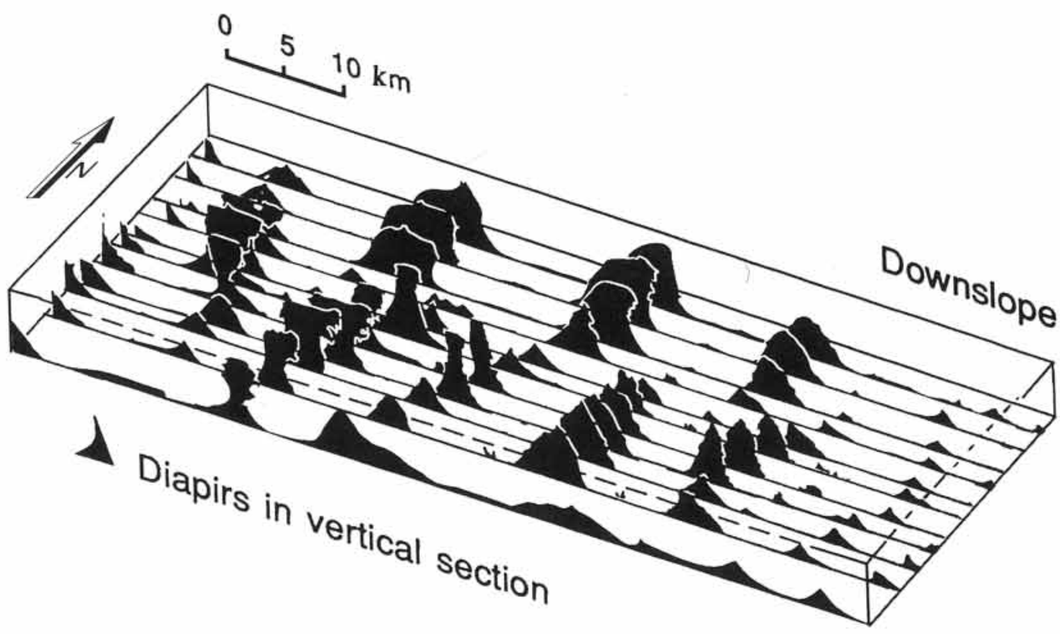

Figure 10-15: Coulisse diagram of salt ridges.

10-5 Other perspective diagrams

Additional ways to suggest 3-D views either remove or cut out portions of the isometric projection to visualize the internal structure of the subsurface. Figure 10-14 is an *elevated structure-contour diagram* of the top of large salt structures. The covering rocks have been entirely removed from the block diagram. It has been introduced to illustrate the geometric variety of subsurface salt bodies and the corresponding terms. For completeness, the namakiers or salt glaciers are subaerial and spread laterally over the ground surface. The *coulisse diagram* is an alternative method for illustrating salt domes in the subsurface, using either seismic

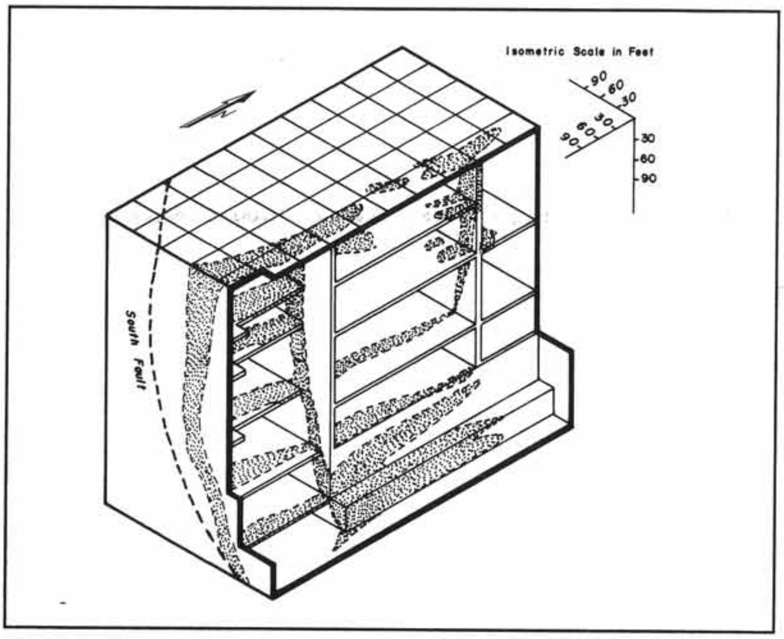

Figure 10-16: *Isometric cabinet diagram of the ore body in the Blinman Copper Mine, Australia.*

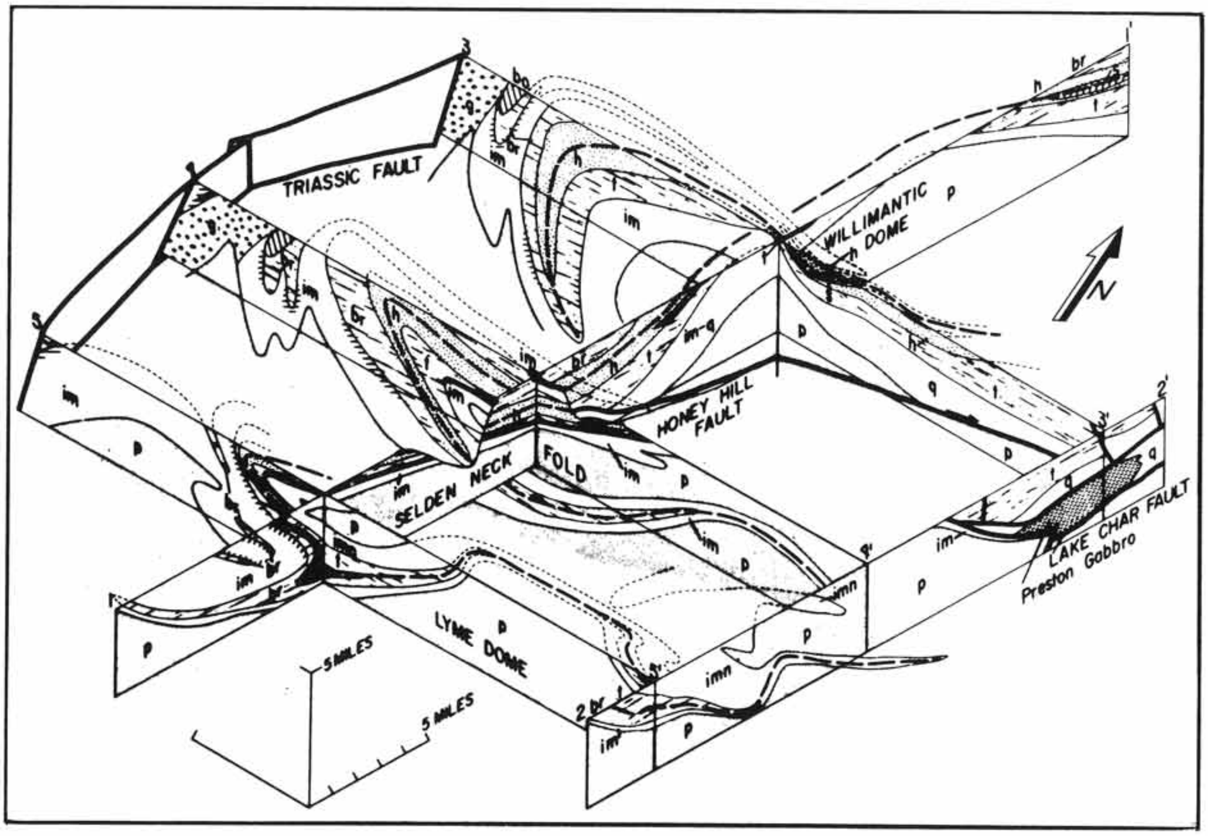

Figure 10-17: *Isometric fence diagram of complex fold structures in Connecticut, USA.*

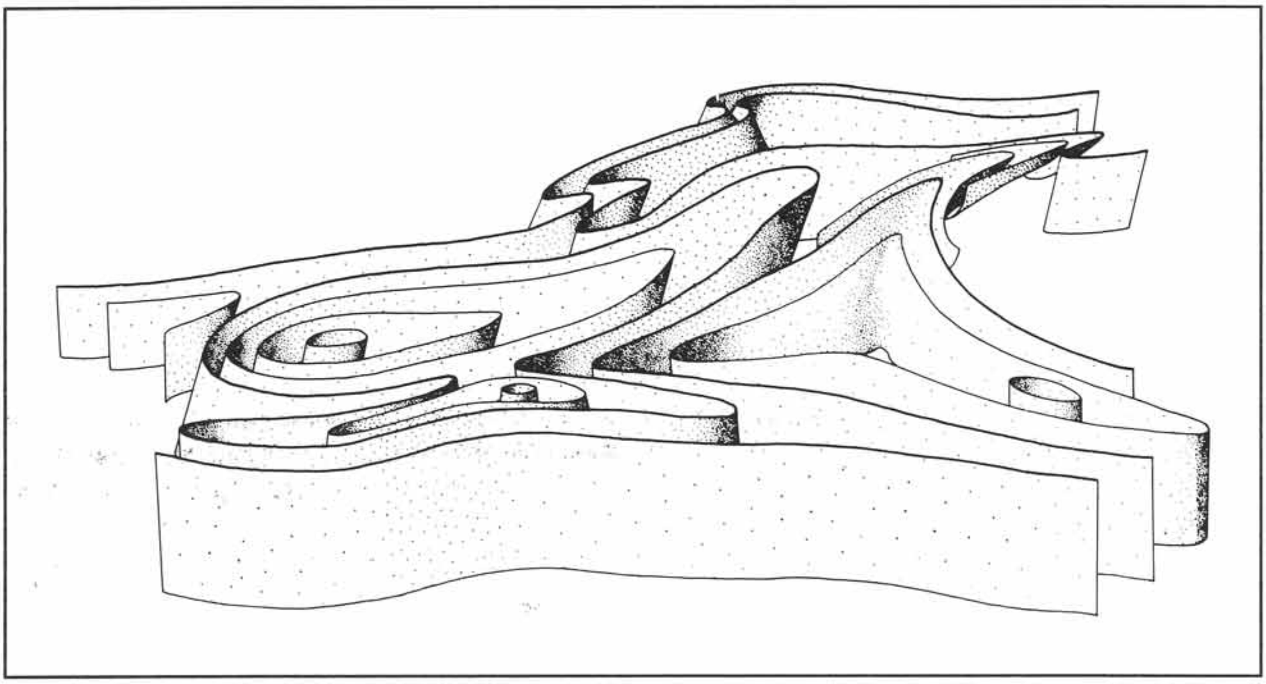

Figure 10-18a: *Perspective diagram of dome-and-basin folds of Glen Cannich, Scottish Highlands.*

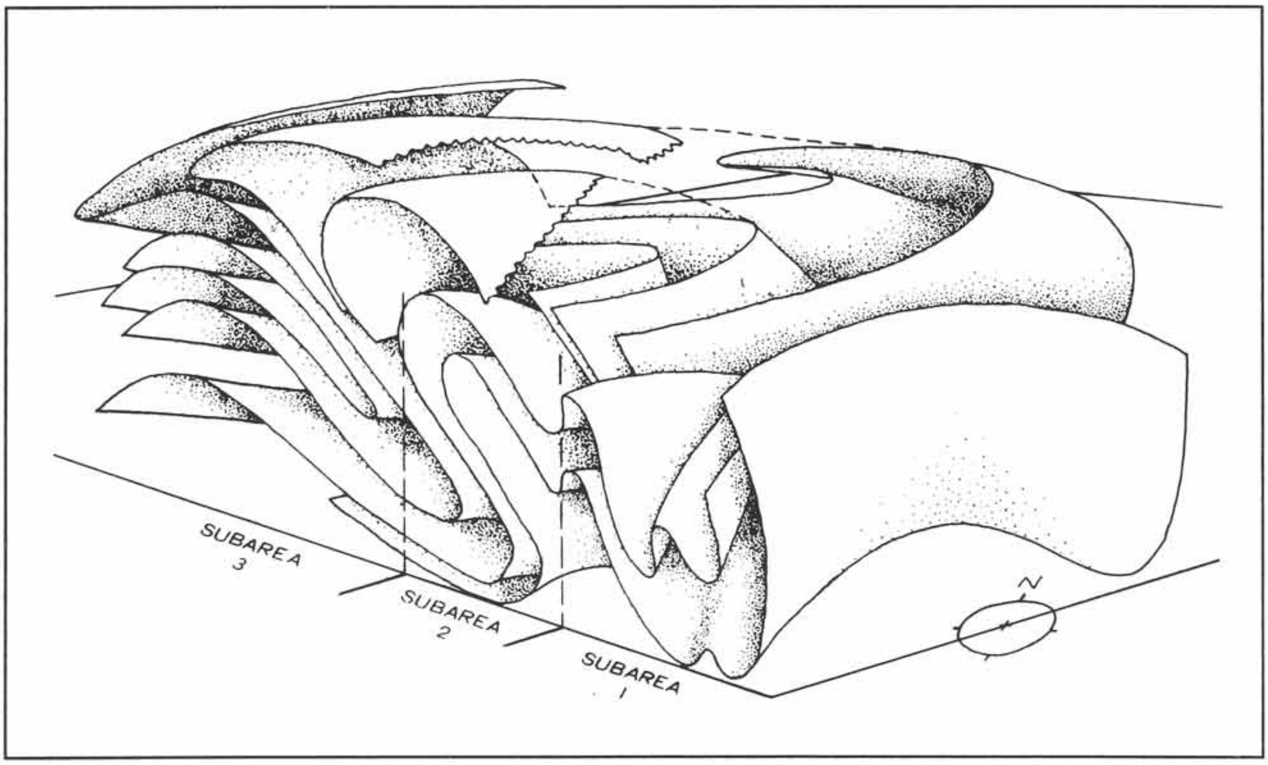

Figure 10-18b: *Perspective diagram of non-coaxially refolded folds of the Milton area, Greensboro, North Carolina.*

sections or serial cuts through small scale models. The group of narrowly spaced parallel sections is stacked to create the impression of a 3-D view (Fig. 10-15).

Figure 10-16 is an isometric *cabinet diagram*, showing the extent of the ore body of the Blinman Copper Mine, Australia. The ore body forms a vertical sheet and thus cannot be adequately represented by either a structure contour or a coulisse diagram. The isometric *fence diagram* of Figure 10-17 is used for illustrating areas of more complex internal structures. Fence diagrams are, also, widely used for undeformed rocks in sedimentary basins to show the lateral facies changes in otherwise subhorizontal strata.

Some of the most advanced diagrams, commonly used for portraying extremely complex fold structures, use multiple reference surfaces and shading to create 3-D views of the crustal interior (Figs. 10-18a & b). Such hand-drawn diagrams are largely artistic, based on a lot of practice, and no clear guidelines are available for their construction. Modern 3-D visualization software portrays similar artistic realism but is, also, quantitatively precise.