11

Geologic Structures, Maps, and Block Diagrams

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OBJECTIVES

A. Be able to identify common kinds of geologic structures in three dimensional block diagrams and know the symbols used to represent them on geologic maps.

B. Be able to construct geologic cross sections from geologic maps and interpret them.

C. Be able to read and interpret geologic maps.

MATERIALS

Pencil, eraser, laboratory notebook, ruler, set of colored pencils, scissors, Models 1–6 (located at the end of this chapter), and a geologic map (provided by your instructor, or obtained as noted by your instructor).

INTRODUCTION

Structural geology is the study of how *geologic units* (bodies of rock or sediment) are arranged when first formed and how they are deformed afterward. When a body of rock or sediment is subjected to severe *stress* (directed pressure), then it may eventually *strain* (undergo deformation, such as a change in shape). Therefore, deformed formations are geologic units that have adjusted to a severe stress. Much of the study of structural geology involves deciphering stress and strain relationships.

Generally, geologists can see how bodies of rock or sediment are positioned where they *crop out* (stick out of the ground as an outcrop) at Earth's surface (Figure 1A). Geologists record this outcrop data on flat (two-dimensional) **geologic maps** using different colors and symbols to represent the different units of rock or sediment and their positions (Figures 1B, 2, 3). They apply information from geologic maps to infer the three-dimensional arrangement of the units. The structural geology of an area can be described and interpreted from this three-dimensional arrangement, viewed as a conceptual model in your mind, or as a physical model. You will interpret as many as six different (physical) cardboard models of structural geology in this laboratory.

PART A: STRUCTURAL GEOLOGY

Three representations of Earth are commonly used by structural geologists. These are the geologic map, cross section, and block diagram:

- **Geologic map**—shows the distribution of rocks at Earth's surface. The rocks commonly are divided into mappable rock units that can be recognized and traced across the map area. This division is made on the basis of color, texture, or composition.

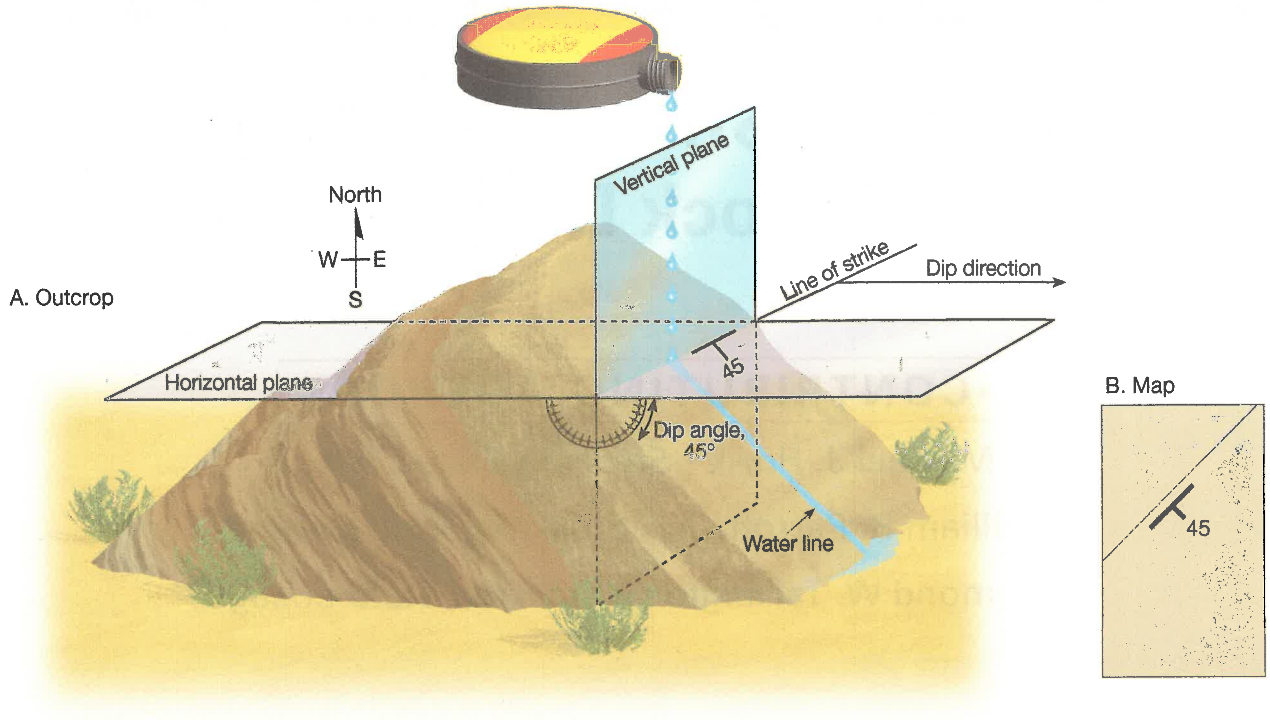
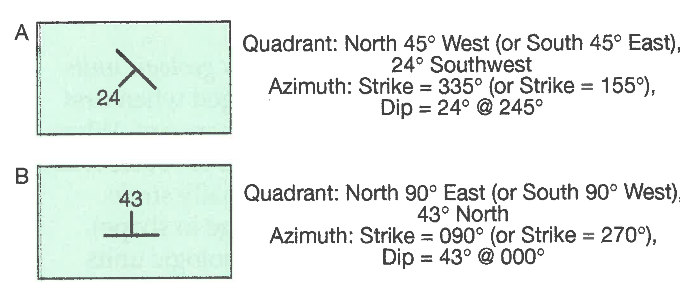


FIGURE 1 Strike and dip of a rock layer as directly observed in nature **(A)** and as represented on a geologic map **(B)**. *Strike* is the direction of a line formed by the intersection of the surface of an inclined (tilted) rock layer and a horizontal plane. *Dip* is the maximum angle of inclination (tilting) of the rock layer, always measured perpendicular to the line of strike (looking straight down on it, in map view) and in the direction that the rock layer tilts down into the ground. Water poured onto a dipping rock layer drains along the angle of dip. The **"T"** and **45** together form the standard strike-and-dip symbol. The long top of the **"T"** is the line of strike, the short upright of the **"T"** shows the dip direction, and **"45"** is the dip angle in degrees.

Such mappable rock units are called **formations.** They may be subdivided into **members** comprised of **beds** (individual layers of rock or sediment). The boundaries between geologic units are **contacts,** which form lines on geologic maps. A geologic map also shows the topography of the land surface with contour lines, so it is both a geologic *and* topographic map.

- **Geologic cross section**—a drawing of a vertical slice through Earth, with the material in front of it removed: a cutaway view. It shows the arrangement of formations and their contacts. A good cross section also shows the topography of the land surface, like a topographic profile.
- **Block diagram**—a combination of the geologic map and cross section. It looks like a solid block, with a geologic map on top and a geologic cross section on each of its visible sides (e.g., Figure 4). Each block diagram is a small three-dimensional model of a portion of Earth's crust.

FIGURE 2 Geologic maps with strike and dip symbols indicating the attitude of rock layers. Note that strike and dip can be expressed in quadrant or azimuth form. When expressing strike and dip directions as azimuth bearings, they should be expressed as three digits in order to distinguish them from two-digit dip angles. Note also that a line of strike can be expressed as a bearing in either direction. For example **(A),** a line of strike with a quadrant bearing of North 45° West also has a bearing of South 45° East. A line of strike with an azimuth bearing of 335° also has a bearing of 155° (i.e., 180° less than 335°).



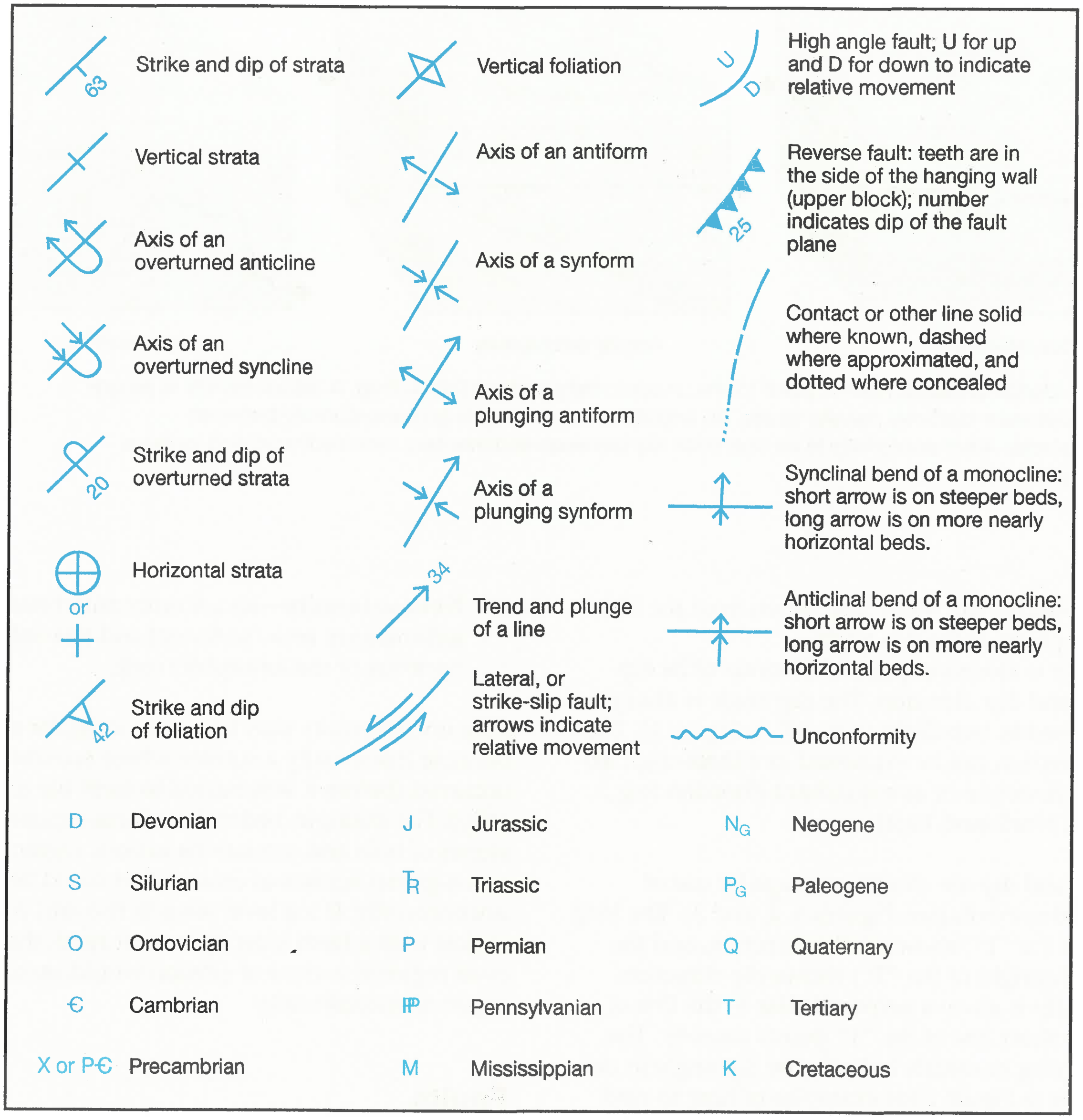


FIGURE 3 Structural symbols and abbreviations used on geologic maps.

Measuring the Attitude of Rock Units

Attitude is the orientation of a rock unit or surface. Geologists have devised a system for measuring and describing attitude to understand three-dimensional relationships of formations and geologic structures. Strike and dip serve this purpose (see Figure 1):

- **Strike**—the *compass bearing* (direction) of a line formed by the intersection of a horizontal plane (such as the surface of a lake) and an inclined layer (bed, stratum) of rock, fault, fracture, or other surface (Figure 1). If strike is expressed in degrees east or west of true north or true south, it is called a *quadrant bearing*. Strike can also be expressed as a three-digit *azimuth bearing* in degrees between 000 and 360. In azimuth form, north is 000° (or 360°), east is 090°, south is 180°, and west is 270°.
- **Dip**—the *angle* between a horizontal plane and the inclined (tilted) stratum, fault, or fracture. As you can see in Figure 1, a thin stream of water poured onto an inclined surface always runs downhill along the **dip direction,** which is always perpendicular to the line (bearing) of strike. The

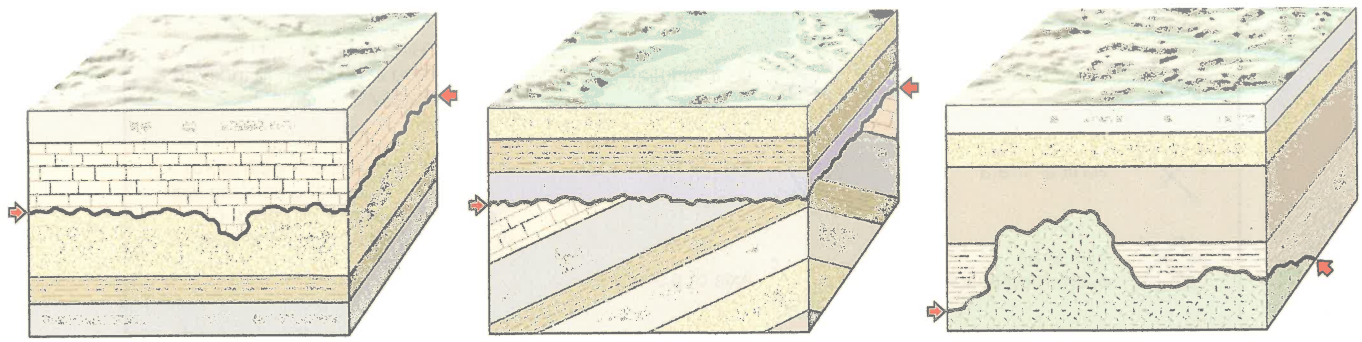


FIGURE 4 Unconformities. Arrows point to the unconformity surface (black line). A *disconformity* is an unconformity between relatively *parallel* strata. An *angular unconformity* is an unconformity between *nonparallel* strata. A *nonconformity* is an unconformity between sedimentary rock/sediment and igneous or metamorphic rock.

inclination of the water line, down from the horizontal plane, is the **dip angle.**

Dip is always expressed in terms of its dip angle and dip direction. The dip angle is always expressed in two digits (e.g., 45° in Figure 1). The dip direction can be expressed as a three-digit azimuth direction or as a quadrant direction (e.g., North, Northeast, East).

Strike and dip are shown on maps by use of "T"-shaped symbols (see Figures 1, 2, and 3). The long line (top of the "T") shows strike direction, and the short line (upright of the "T") shows dip direction. Note that dip is always perpendicular to the line of strike. The short line of the "T" points *downdip*. The accompanying numerals indicate the dip angle in degrees. Refer to Figure 2 for examples of how to read and express strike and dip in quadrant or azimuth form. Also note that special symbols are used for horizontal strata (rock layers) and vertical strata (Figure 3).

Unconformities

Structural geologists must locate, observe, and interpret many different structures. Fundamentally, these include unconformities, faults, and folds. There are three common types of *unconformities* (see Figure 4):

- **Disconformity**—an unconformity between relatively *parallel* strata.
- **Angular unconformity**—an unconformity between *nonparallel* strata.
- **Nonconformity**—an unconformity between sedimentary rock/sediment and *non-sedimentary* (igneous or metamorphic) rock.

Any unconformity may be a very irregular surface, because it is usually a surface where erosion has occurred (before it was buried to form the unconformity). For example, bedrock surfaces exposed on the slopes of hills and mountains in your region are part of a regional surface of erosion that could become an unconformity. If sea level were to rise and cover your region with a fresh layer of mud or sand, then the uneven regional surface of erosion would become a regional unconformity.

Faults

Faults in rock units are breaks along which movement has occurred. Faults form when brittle rocks experience three kinds of severe stress: *tension* (pulling apart or lengthening), *compression* (pushing together, compacting, and shortening), and *shear* (smearing or tearing). The three kinds of stress force the rocks to fault in distinctive ways (Figure 5).

Normal faults, *reverse faults*, and *thrust faults* all involve vertical motions of rocks. These faults are named by noting the *sense of motion* of the top surface of the fault (top block) relative to the bottom surface (bottom block), regardless of which one actually has moved. The top surface of the fault is called the **hanging wall** and is the base of the **hanging wall** (top) **block** of rock. The bottom surface of the fault is called the **footwall** and forms the top of the **footwall block.** The headwall block sits on top of the footwall block.

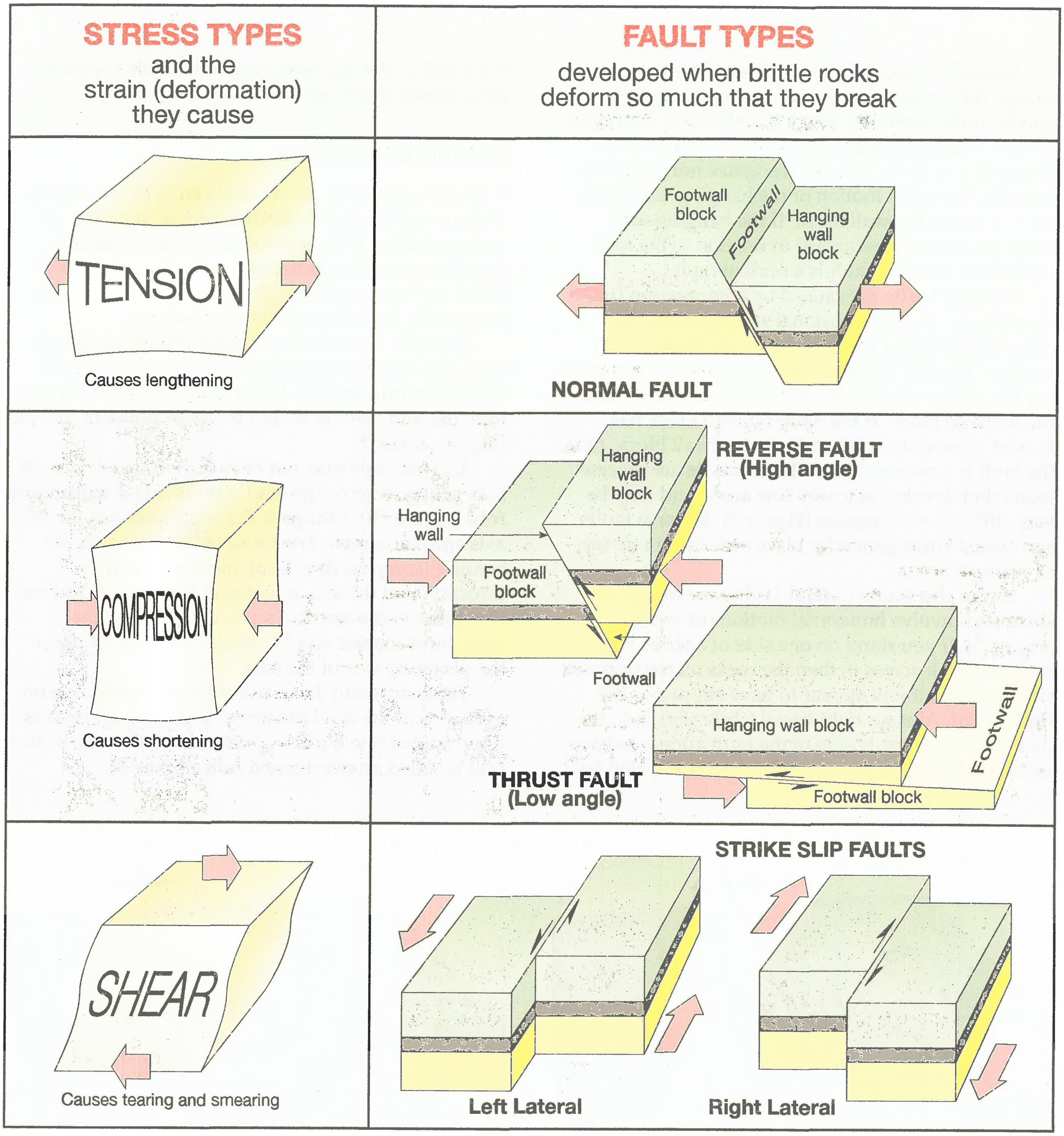


FIGURE 5 Three types of stress and strain and the fault types they produce.

Normal faults are caused by tension (rock lengthening). As tensional stress pulls the rocks apart, gravity pulls down the hanging wall block. Therefore, normal faulting gets its name because it is a normal response to gravity. You can recognize normal faults by recognizing the motion of the hanging wall block relative to the footwall block. If the hanging wall block has moved downward in relation to the footwall block, then the fault is a normal fault.

Reverse faults are caused by compression (rock shortening). As compressional stress pushes the rocks together, one block of rock gets pushed atop another. You can recognize reverse faults by recognizing the motion of the hanging wall block relative to the footwall block. If the hanging wall block has moved upward in relation to the footwall block, then the fault is a reverse fault. **Thrust faults** are reverse faults that develop at a very low angle and may be very difficult to recognize (Figure 5). Reverse faults and thrust faults generally place older strata on top of younger strata.

Strike slip faults (**lateral faults**) are caused by shear and involve horizontal motions of rocks (Figure 5). If you stand on one side of a strike slip fault and look across it, then the rocks on the opposite side of the fault will appear to have slipped to the right or left. Along a *right-lateral (strike slip) fault*, the rocks on the opposite side of the fault appear to have moved to the right. Along a *left-lateral (strike slip) fault*, the rocks on the opposite side of the fault appear to have moved to the left.

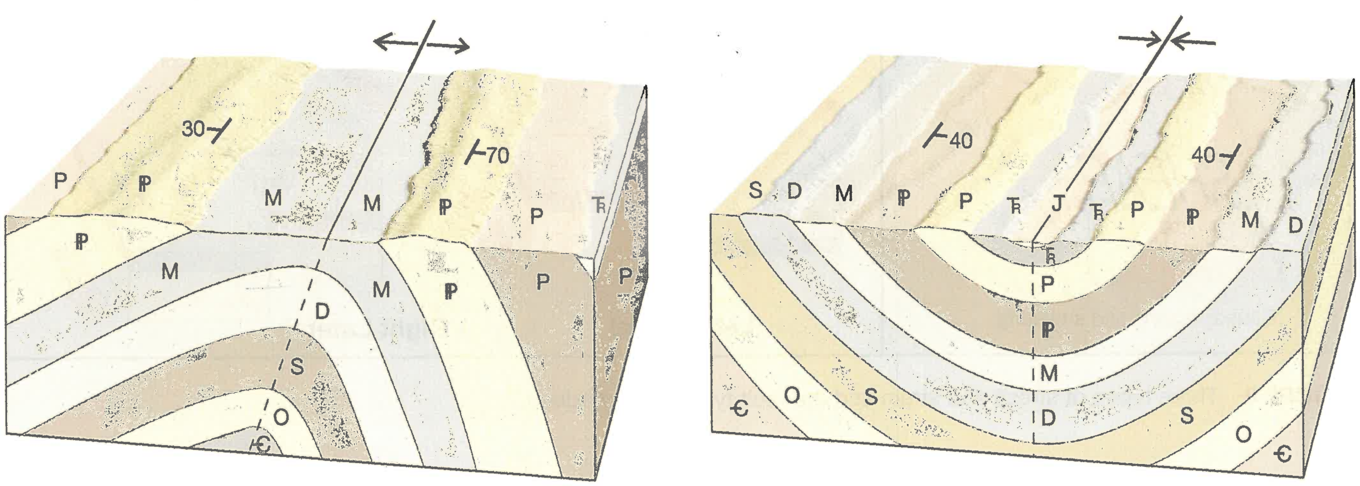
Folded Structures

Folds are upward or downward bends of rock layers (Figures 6, 7, 8, and 9). **Antiforms** are "upfolds" or "convex folds." If the *oldest* rocks are in the middle, then they are called **anticlines. Synforms** are "downfolds" or "concave folds." If the *youngest* rocks are in the middle, then they are called **synclines.**

In a fold, each stratum is bent around an imaginary axis, like the crease in a piece of folded paper. This is the **fold axis** (or **hinge line**). For all strata in a fold, the fold axes lie within the **axial plane** of the fold (Figures 6 and 7).

The fold axis may not be horizontal, but rather it may plunge into the ground. This is called a **plunging fold** (Figure 7B). **Plunge** is the angle between the fold axis and horizontal. The **trend** of the plunge is the bearing (compass direction), measured in the direction that the axis is inclined downward. You can also think of the trend of a plunging fold as the direction a marble would roll if it were rolled down the plunging axis of the fold.

Folds normally have two sides, or **limbs,** one on each side of the axial plane (see Figure 7). If a fold is tilted so that one limb is upside down, then the entire fold is called an **overturned fold** (Figure 8).



A. ANTICLINE (asymmetrical): oldest rocks (€) occur in the center of the fold

B. SYNCLINE (symmetrical): youngest rocks (J) occur in the center of the fold

FIGURE 6 Folds—the two common types. Letters on rock layers indicate their relative ages on the geologic time scale (Figure 3). Note that solid lines (dashed where underground) are used to show the position of the axial planes of the folds. Note the symbols for axis of an anticline and axis of a syncline in Figure 3. Also note the orientation of symbols for strike and dip in relation to the attitude (orientation) of rock layers (strata).

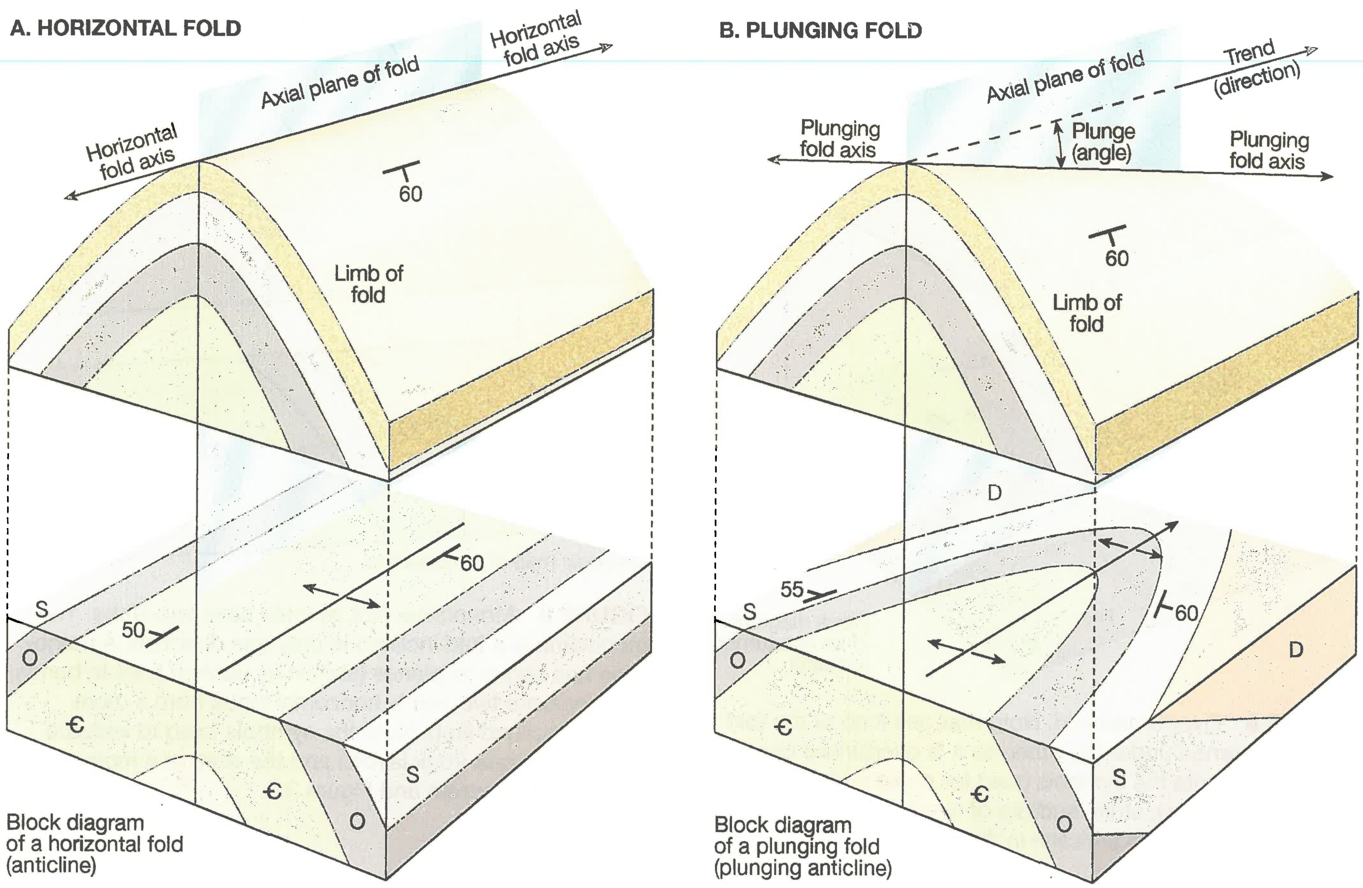


FIGURE 7 Fold terminology and block diagrams. **A.** Simple horizontal fold (anticline). **B.** More complex plunging fold (plunging anticline). Note that the fold axis plunges into Earth, but the *trend* is the compass direction (bearing) on the surface. Also note the orientation of rock layers, symbols for strike and dip, and symbols for the fold axes in the block diagrams.

Monoclines have two axial planes that separate two nearly horizontal limbs from a single, more steeply inclined limb (Figure 9).

Domes and **basins** (Figure 10) are large, somewhat circular structures formed when strata are warped upward, like an upside-down bowl (dome) or downward, like a bowl (basin). Strata are oldest at the center of a dome, and youngest at the center of a basin.

Block Diagrams

Six block diagrams (Models 1–6) are provided at the back of this chapter. Carefully remove them from the book and cut off the torn edges, so you can fold them into blocks. To fold them, follow the procedure in Figure 11. *Be sure that you have cut out and folded your cardboard models before you proceed to the items below.*

You will also need to understand and apply the symbols for geologic structures from Figure 3 and follow the set of simple rules for interpreting geologic maps on the tops of the block diagrams.

Model 1

This model shows Devonian (green), Mississippian (brown), Pennsylvanian (yellow), and Permian (salmon) formations striking due north and dipping 25° to the west. Cambrian (tan) and Ordovician (gray) formations strike due north and are vertical (dip angle = 90°). Provided are a complete geologic map (the top of the diagram) and three of the four vertical cross sections (the south, east, and west sides of the block diagram).

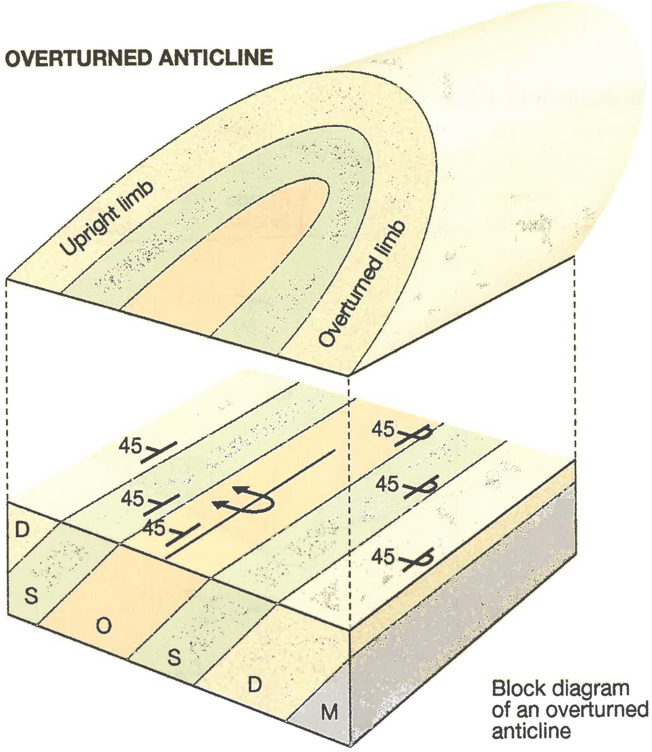


FIGURE 8 Overturned fold. Note that one limb of the fold has been turned under the other, so it is overturned (upside down). Also note the symbols used for strike and dip of strata (rock layers), strike and dip of overturned strata, and axis of an overturned anticline in the block diagram and Figure 3.

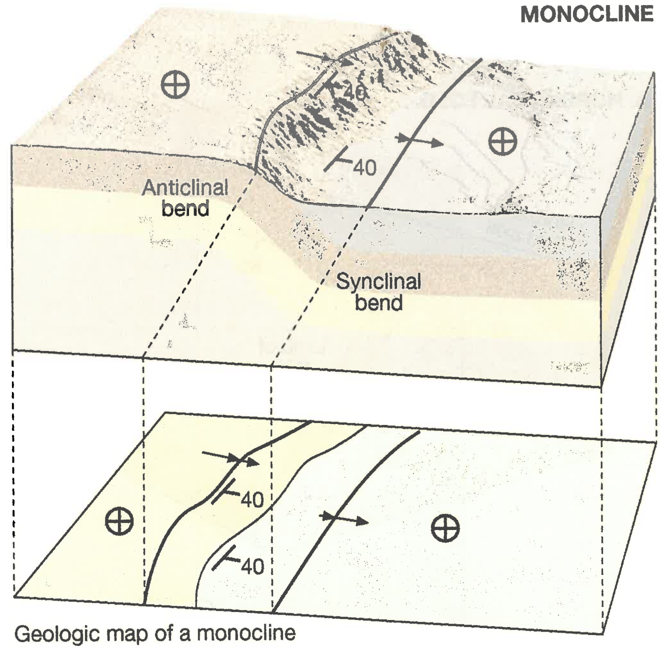


FIGURE 9 Monocline. Not all folds have two limbs. The monocline is a fold inclined in only one direction. A monocline has two axial planes (shown as dashed lines in bends) that separate two nearly horizontal limbs from a more steeply inclined limb. Note the symbols used to indicate horizontal strata (rock layers) and the axes of a monocline in the block diagram and Figure 3.

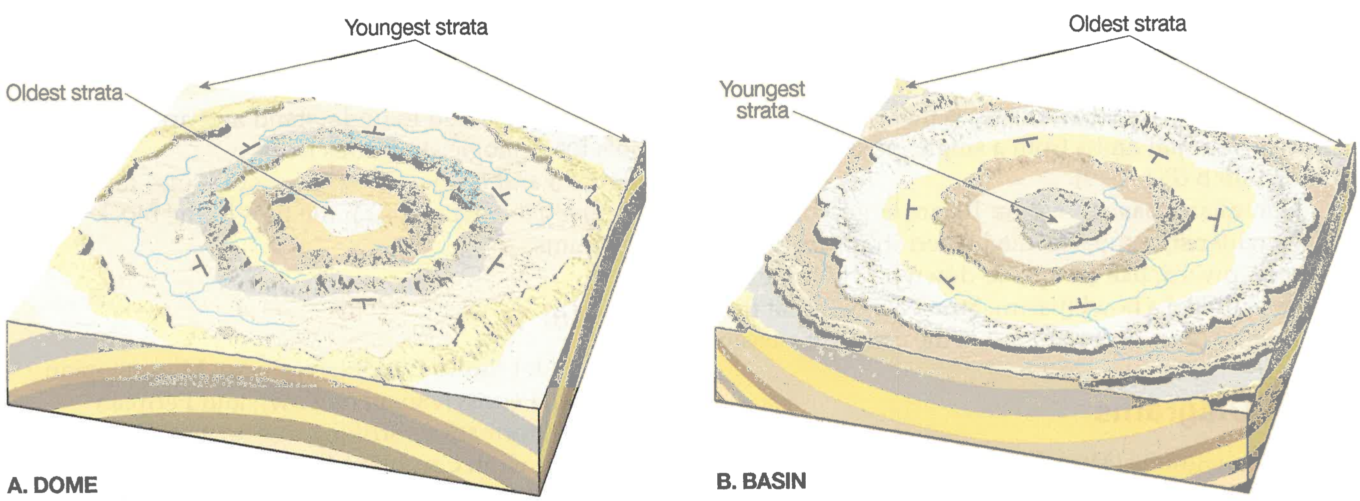


FIGURE 10 Dome and basin. Both of these structures are bowl-shaped in three dimensions and appear as relatively circular "bull's eye" patterns on maps. **A.** A *dome* is convex (bowed upward, like an upside-down bowl) and has the oldest strata in its center. Rocks dip away from the center of the dome (note strike-dip symbols). **B.** A *basin* is concave (bowed downward; bowl shaped) and has the youngest strata in its center. Rocks dip toward the center of the basin (note strike-dip symbols).

FORMING THE STRUCTURE MODELS

1. Lay the paper with the model on it face down in front of you. Orient the long dimension of the paper up and down, as if you were going to read a normal typewritten page.
2. Carefully curl back one side until you can see the solid black line that runs all the way from the top to the bottom of the page. Crease the paper exactly along that line.
3. Now repeat this process for the other side of the paper.
4. Unfold the two sides, and curl back the top until you see the solid black line that runs across the page. Crease the paper exactly along that line.
5. Now repeat this process for the bottom of the paper.
6. To make a block, you still need to do something about the extra material where the corners are. In each corner there is a dashed line. Start at one corner and push that line toward the inside of the block. Fold the sides down so that they match, and crease the flap you folded in. Your crease should be approximately along the dashed line. Do the same thing with the other three corners.
7. If the block is folded correctly, the top will be flat and the strata will match on the map (top) and on the cross sections (sides).
8. The block will not really stay together without tape, but do not tape it. You will find that it is easier to draw on the block if you can unfold it and lay it out flat.
9. Write your name on the blank inside of the block so that your instructor can identify your work when you hand it in.

FIGURE 11 Directions for forming the structure models.

Questions

1. Finalize Model 1 as follows. First construct the vertical cross section on the north side of the block so it shows the formations and their attitudes (dips). On the map, draw a strike and dip symbol on the Mississippian sandstone that dips 25° to the west and on the Ordovician gray shale that is vertical (see Figure 3 for the strike and dip symbol for a vertical bed). Also draw in the symbol for an unconformity (Figure 3) at the contact between the Ordovician gray shale and the Devonian and Mississippian formations plus everywhere else that the unconformity occurs in the north and south cross sections of the diagram.
2. Complete the following questions:

   a. Note that both the yellow Pennsylvanian sandstone and Ordovician gray shale formations have the same thickness, but the yellow sandstone makes a much wider band on the geologic map (top of block). Why?

   b. What kind of unconformity is present in this block diagram, and how can you tell?

   c. Explain the sequence of events that led to the relationships that now exist among the formations in this block diagram.

Model 2

This model is slightly more complicated than the previous one. The geologic map is complete, but only two of the cross sections are available.

Questions

3. Finalize Model 2 as follows. First, complete the north and east sides of the block. Notice that the rock units define a fold. This fold is an antiform, because the strata are convex upward. It is nonplunging, because its axis is horizontal. (Refer back to Figure 7 for the differences between plunging and nonplunging folds if you are uncertain about this.) On the geologic map, draw strike and dip symbols to indicate the attitudes of formation E (gray formation) at points **I, II, III,** and **IV.** Also draw the proper symbol on the map (top of model) along the axis of the fold (refer to Figure 3).
4. How do the strikes at all four locations compare with each other?
5. How does the dip direction at points **I** and **II** compare with the dip direction at points **III** and **IV?** *In your answer, include the dip direction at all four points.*

Model 3

This model has a complete geologic map. However, only one side and part of another are complete.

Questions

6. Finalize Model 3 as follows. Complete the remaining two-and-a-half sides of this model, using as guides the geologic map on top of the block and the one-and-a-half completed sides. On the map, draw strike and dip symbols showing the orientation of formation **C** at points **I, II, III,** and **IV.** Also draw the proper symbol along the axis of the fold (refer to Figure 3).
7. How do the strikes of all four locations compare with each other?
8. How does the dip direction (of formation **C**) at points **I** and **II** compare with the dip direction at points **III** and **IV?** *Include the dip direction at all four points in your answer.*
9. Is this fold plunging or nonplunging? Is it an antiform or a synform?
10. On the basis of this example, how much variation is there in the strike at all points in a nonplunging fold?

Model 4

This model shows a plunging antiform and an unconformity. The antiform plunges to the north, following the general rule that *anticlines plunge in the direction in which the fold closes* (refer to rules, Figure 12).

Questions

11. Finalize Model 4 as follows. Complete the north and east sides of the block. Draw strike and dip symbols on the map at points **I, II, III, IV,** and **V.** Draw the proper symbol on the map along the axis of the fold, including its direction of plunge. Also draw the proper symbol on the geologic map to indicate the orientation of beds in formation **J.**
12. How do the directions of strike and dip differ from those in Model 3?
13. What type of unconformity is at the base of formation **J?**

A SET OF SIMPLE RULES FOR INTERPRETING GEOLOGIC MAPS

1. Anticlines have their oldest beds in the center.
2. Synclines have their youngest beds in the center.
3. Anticlines plunge toward the nose (closed end) of the structure.
4. Synclines plunge toward the open end of the structure.
5. Contacts between horizontal beds "V" upstream and are parallel to topographic contour lines.
6. Contacts of horizontal beds, or of beds that have a dip lower than stream gradient, "V" upstream.
7. Contacts of beds that have a dip greater than stream gradient "V" downstream if they are dipping downstream.
8. Contacts of beds that have a dip greater than stream gradient will "V" upstream if they are dipping upstream.
9. Vertical beds do not "V" or migrate with erosion.
10. The upthrown blocks of faults tend to be eroded more than downthrown blocks.
11. Contacts migrate downdip upon erosion.
12. True dip angles can only be seen in cross section if the cross section is perpendicular to the fault or to the strike of the beds.

FIGURE 12 Simple rules used by geologists to interpret geologic maps.

Model 5

This model shows a plunging synform. Two of the sides are complete and two remain incomplete.

Questions

14. Finalize Model 5 as follows. Complete the north and east sides of the diagram. Draw strike and dip symbols on the map at points **I, II, III, IV,** and **V** to show the orientation of layer **G.** *Synforms plunge in the direction in which the fold opens* (refer to rules, Figure 11). Draw the proper symbol along the axis of the fold to indicate its location and direction of plunge.

15. In which direction does this synform plunge?

Model 6

This model shows a fault that strikes due west and dips 45° to the north. Three sides of the diagram are complete, but the east side is incomplete.

Questions

16. Finalize Model 6 as follows. At point **I,** draw a strike and dip symbol showing the *orientation of the fault.* On the west edge of the block, draw arrows parallel to the fault, indicating relative motion. Label the hanging wall and the footwall. Complete the east side of the block. Draw arrows parallel to the fault, indicating relative motion. Now look at the geologic map and at points **II** and **III.** Write **U** on the side that went up and **D** on the side that went down. At points **IV** and **V,** draw strike and dip symbols for formation **B.**

17. Is the fault in this model a normal fault or a reverse fault? Why?

18. On the geologic map, what happens to the contact between units **A** and **B** where it crosses the fault?

19. There is a general rule that, as erosion of the land proceeds, *contacts migrate downdip.* Is this true in this example? Explain.

20. Could the same offset along this fault have been produced by strike-slip motion?

PART B: BLOCK DIAGRAMS, GEOLOGIC CROSS SECTIONS, AND GEOLOGIC MAPS

Illustrated block diagrams and geologic maps are provided for you to develop your skills of identifying, describing, and interpreting geologic structures. You will need to understand and apply the symbols from Figure 3 and follow the set of simple rules for interpreting geologic maps (Figure 12). Refer back to Figures 4–10 as needed.

Questions

21. Complete each block diagram in Figure 13 as directed. On the line provided, indicate what kind of geologic structure is represented in the diagram.

22. Complete the geologic cross section in Figure 14 (you will need pencil, scratch paper, ruler, and protractor; colored pencils are optional). Place the edge of a piece of scratch paper along line X – Y and mark it to record the exact width of each colored formation. Transfer this information to the topographic surface line in the geologic cross section. Use a protractor to extend the colored formations with known dips into the subsurface of the geologic cross section (lightly in pencil). Draw in the remaining colored formations parallel to the ones with known dips, and smooth the contacts to form the geologic structure(s) beneath the surface. Finally, project the geologic structure up above the topographic surface line to show how the geologic structure(s) existed there before being eroded.

a. Label your geologic cross section to indicate the kind(s) of geologic structure(s) revealed by your work. Then add the appropriate symbols from Figure 3 to the geologic map in order to show the axes of the folds revealed in your geologic cross section.

b. Add half-arrows to the fault near the center of the geologic map to show the relative motions of its two sides. Exactly what kind of fault is it (Refer to Figure 5)?

23. Complete the geologic cross section in Figure 15 (you will need pencil, scratch paper, ruler, and protractor; colored pencils are optional). Place the edge of a piece of scratch paper along line X – Y and mark it to record the exact width of each colored formation. Transfer this information to the topographic surface line in the geologic cross section. Use a protractor to extend the colored formations with known dips into the subsurface of the geologic cross section (lightly in pencil). Draw in the remaining colored formations parallel to the ones with known dips, and smooth the contacts to form the geologic structure(s) beneath the surface. Finally, project the geologic structure up above the topographic surface line to show how the geologic structure(s) existed there before being eroded.

a. What kind of geologic structure is present, and how do you think it formed?

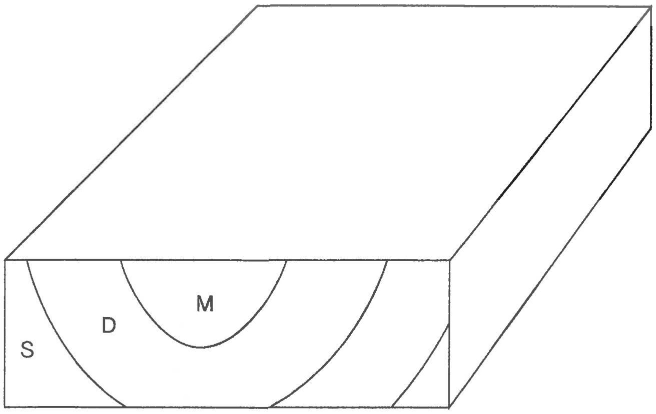
b. Modify the geologic map by adding the appropriate symbols from Figure 3 to show the - position of the structure on the map the best you can.

24. Refer to the geologic maps in Figure 16. Do the following for each of these maps.

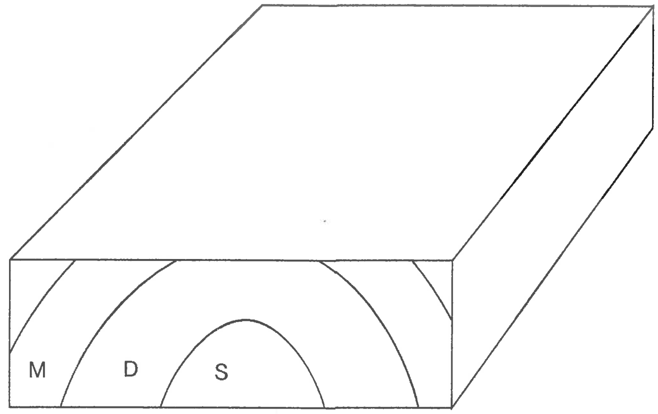
a. Make a list of the ages of rocks present in the map, from oldest at the bottom of the list to youngest at the top of the list. Indicate in your list, and on the map, where there are unconformities (gaps or missing intervals of rock in the sequence), if any.

b. Make a list of other geologic structures that you can identify on the map, then describe where each structure is located.

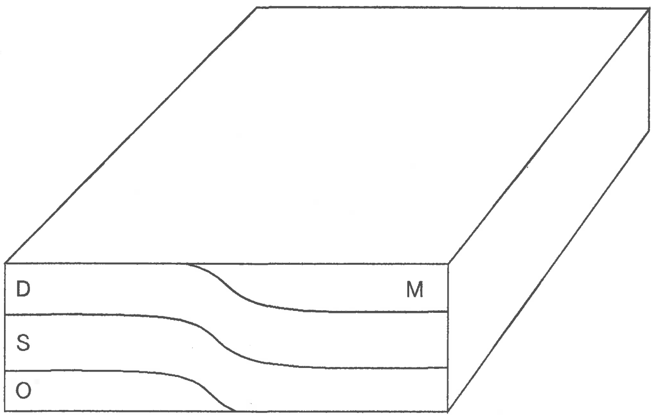
c. Write a paragraph or outline of the general geologic history of the region (i.e., describe when the rock layers formed and how they were deformed or eroded).



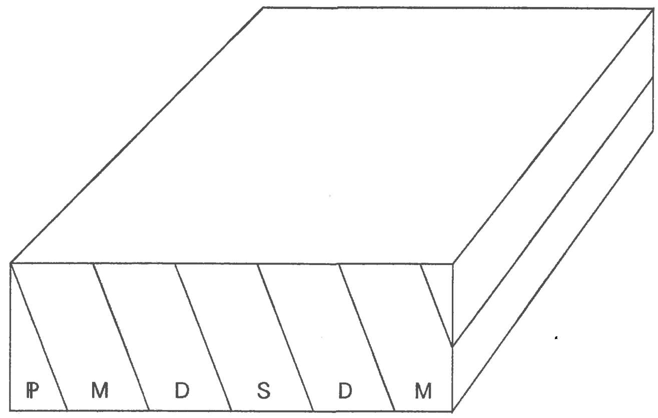
A. Complete top and side. Add appropriate symbols from Figure 3. What geologic structure is present?



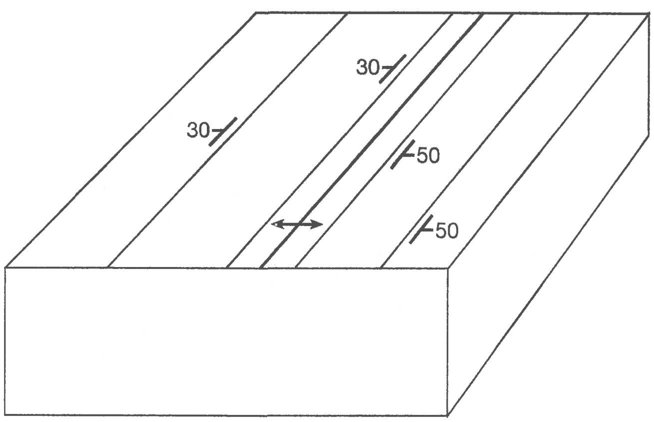
B. Complete top and side. Add appropriate symbols from Figure 3. What geologic structure is present?



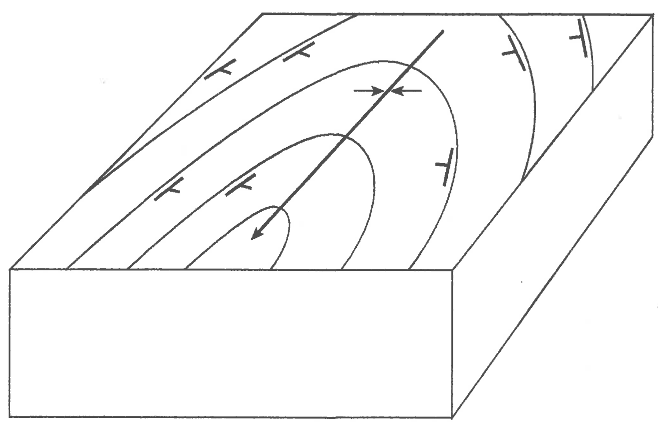
C. Complete top and side. Add appropriate symbols from Figure 3. What geologic structure is present?



D. Complete top of diagram. Add appropriate symbols from Figure 3. What geologic structure is present?

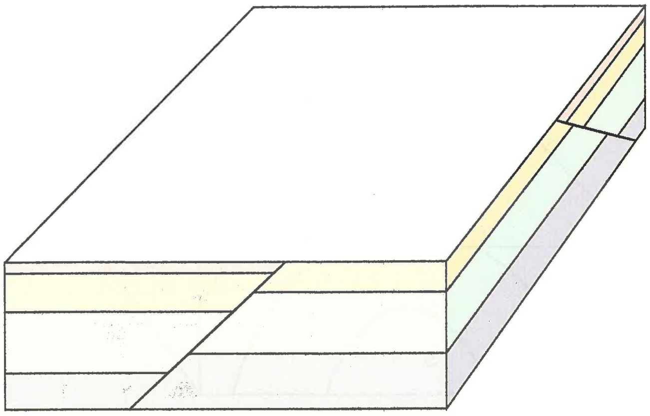


E. Complete the sides of the diagram. What geologic structure is present?

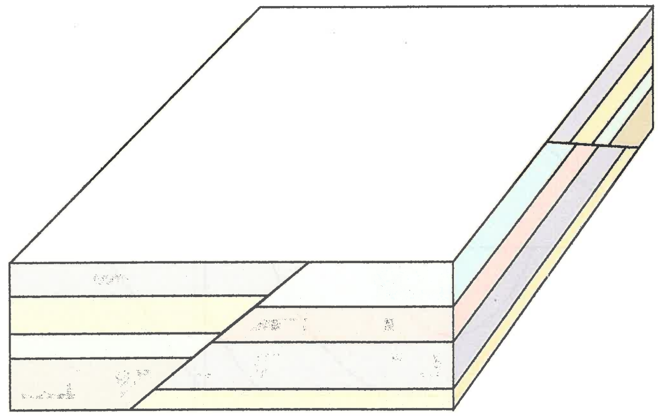


F. Complete the sides of the diagram. What geologic structure is present?

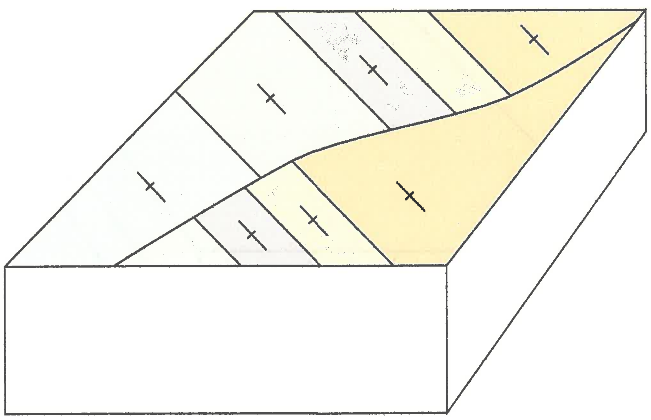
FIGURE 13 Block diagrams to complete (Question 21).



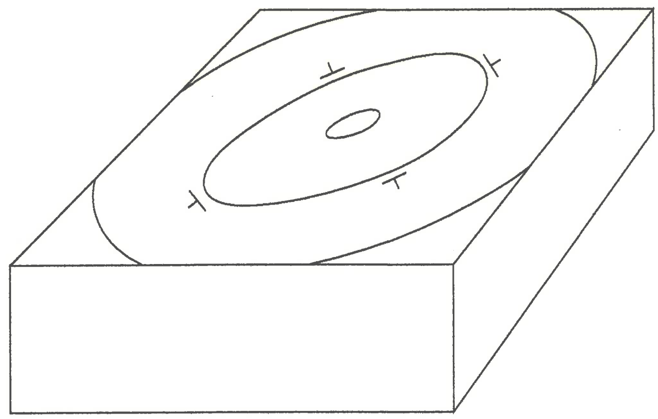
G. Complete top of diagram. Add appropriate symbols from Figure 3. What geologic structure is present?



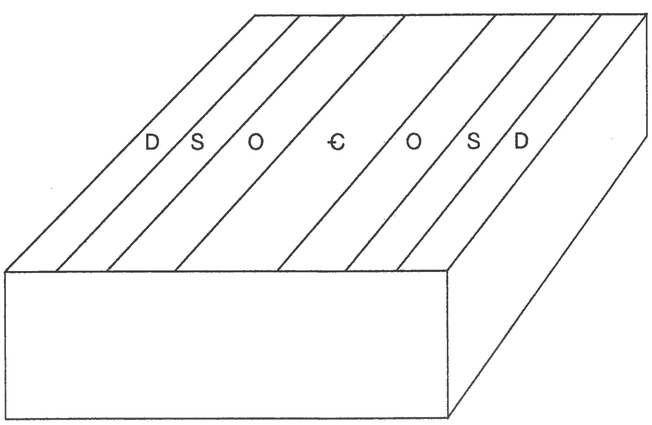
H. Complete top of the diagram. Add appropriate symbols from Figure 3. What geologic structure is present?



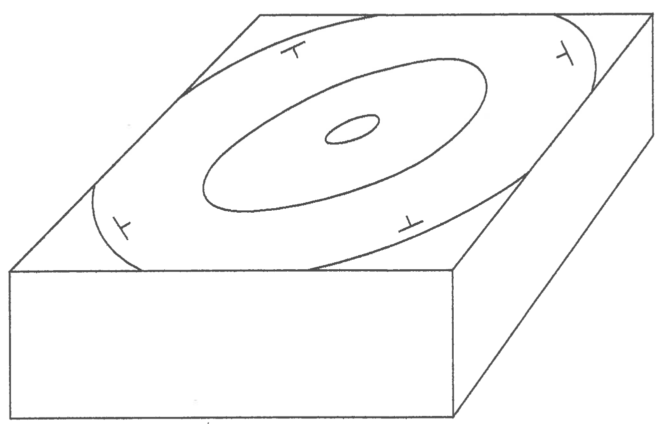
I. Complete the sides of the diagram. Add half-arrows. What geologic structure is present?



J. Complete the sides of the diagram. What geologic structure is present?



K. Complete sides of the diagram. Add appropriate symbols from Figure 3. What geologic structure is present?



L. Complete the sides of the diagram. What geologic structure is present?

FIGURE 13 (CONTINUED) Block diagrams to complete (Question 21).

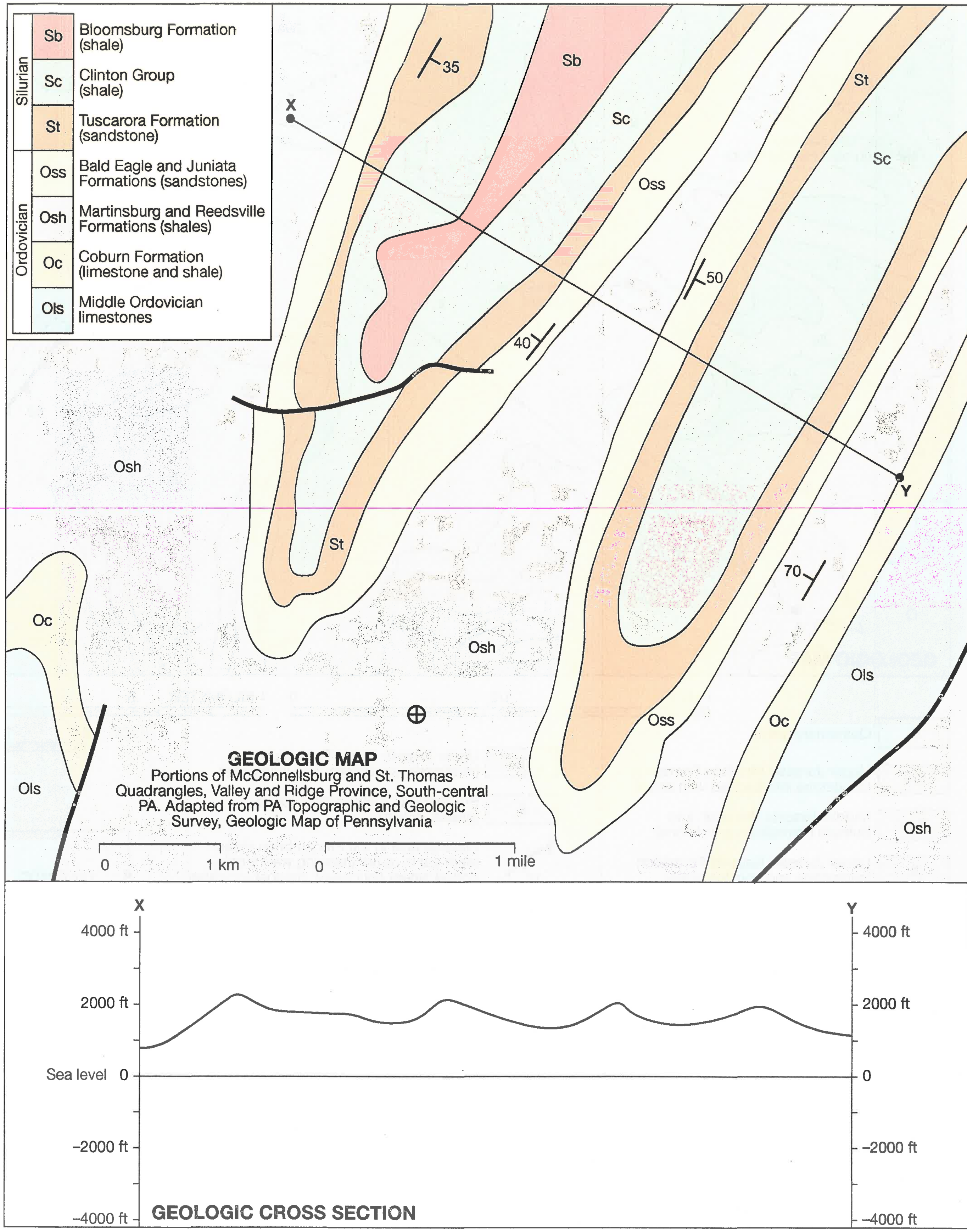


FIGURE 14 Geologic map and cross section to complete (Question 22).

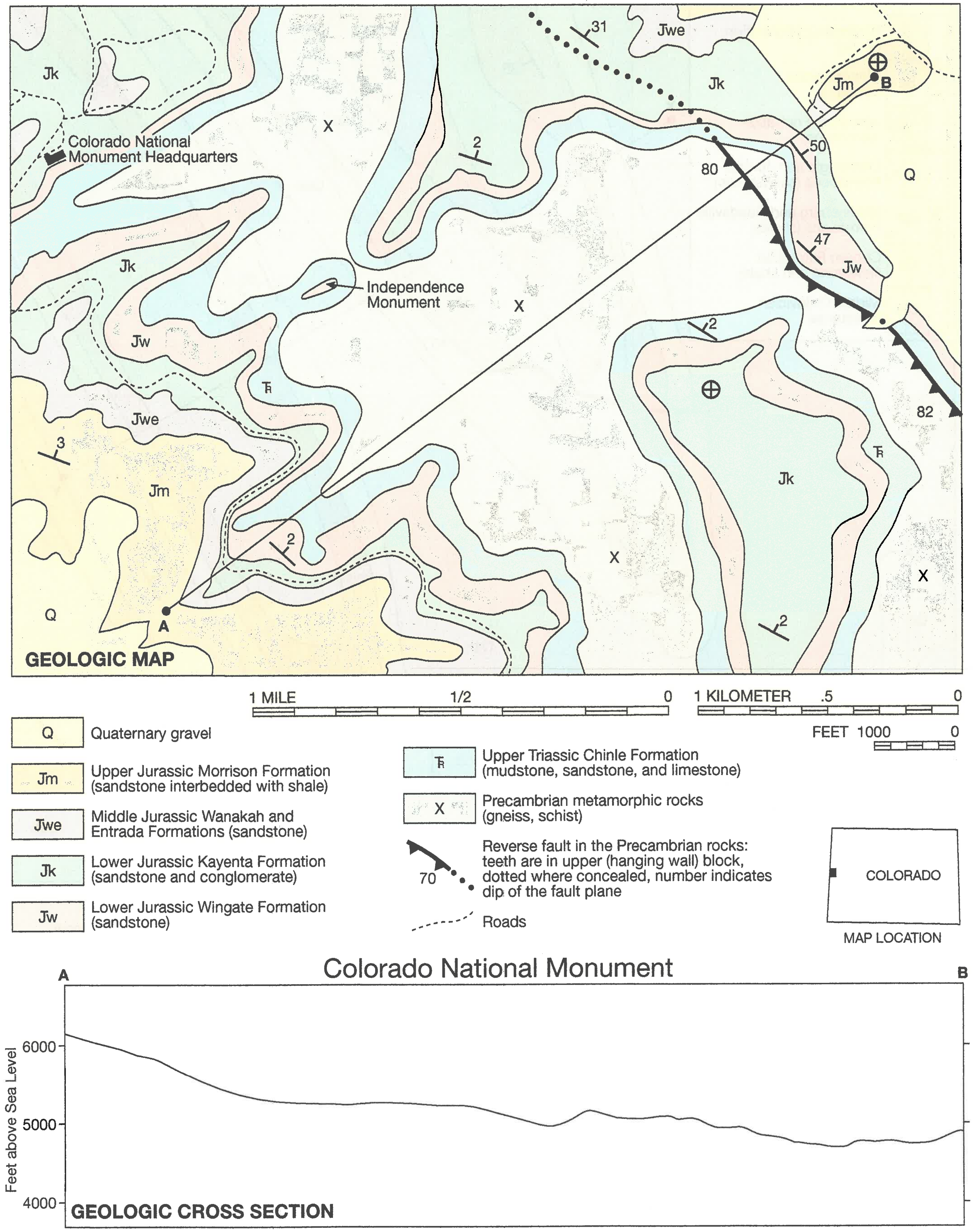


FIGURE 15 Geologic map and cross section to complete (Question 23). Map data adapted from USGS Geologic Investigations Series I-2740 by Robert B. Scott *et al.*

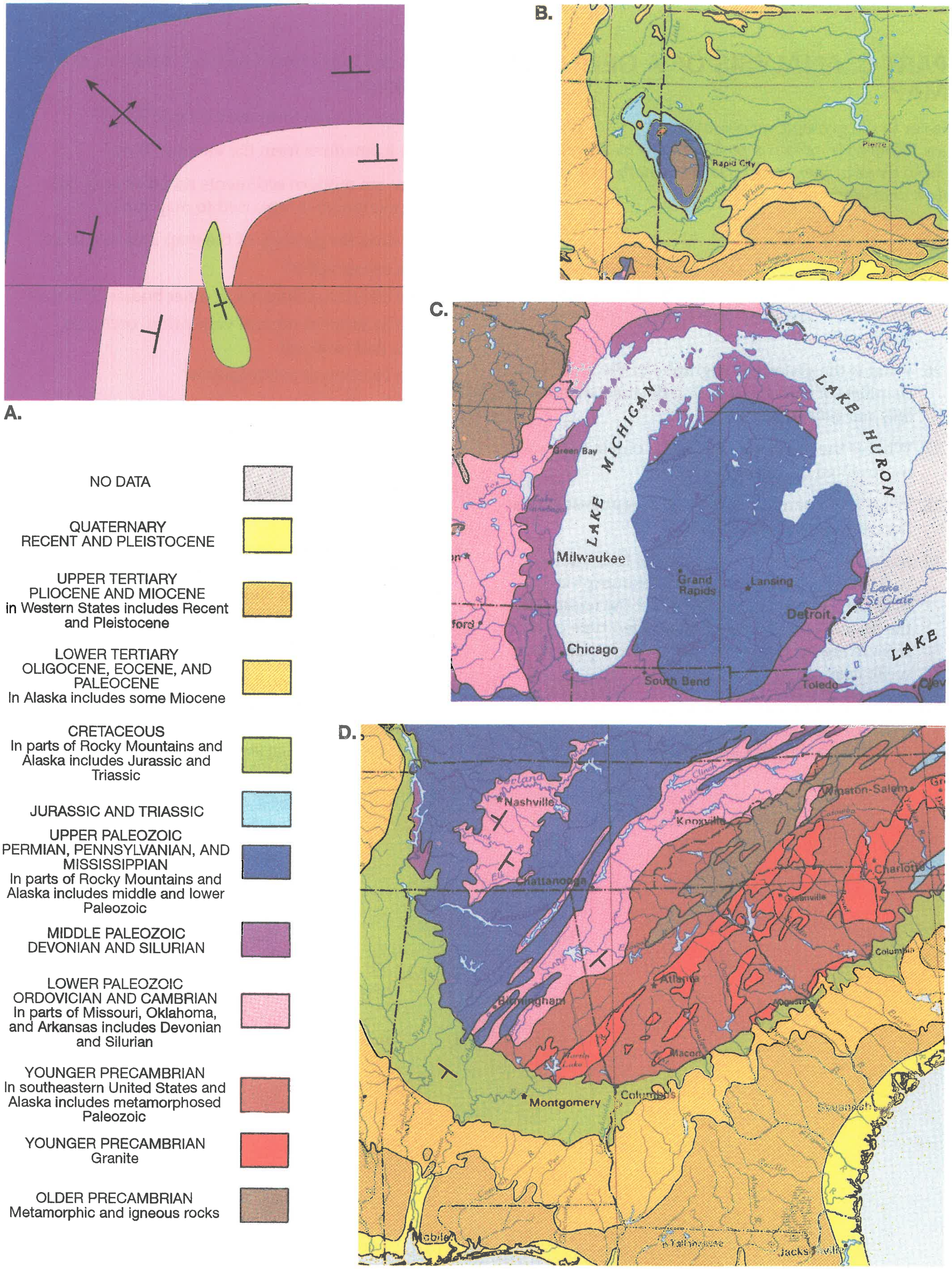


FIGURE 16 Geologic maps for analysis and interpretation (Question 24).

PART C: ANALYSIS OF A GEOLOGIC MAP

Refer to the geologic map provided by your instructor. Otherwise, obtain a geologic map as directed to do so by your instructor. (*Do not mark the map with any dark lines or pen marks!*)

Questions

25. What geographic area (quadrangle or other geographic division) does this geologic map represent?

26. What is the general topography of the area? *Use elevations, if available, and describe orientations of hills and valleys.*

27. What is the name and age of the oldest formation represented on the map?

28. What is the name and age of the youngest formation represented on the map?

29. Make three list headings: igneous formations, sedimentary formations, and metamorphic formations. Under each heading, list the names of the formations that are the indicated type of rock. If there are no formations of one rock type, then write *none* under the heading.

30. What unconformities (see Figure 4) have developed, or are currently developing, in the sequence of formations of this area? Describe where they occur and how much time/rock is missing at each unconformity.

31. What formations form the hilltops? Why?

32. What formations form the valleys? Why?

33. Where are modern sediments accumulating, and what symbol(s) is/are used to map them?

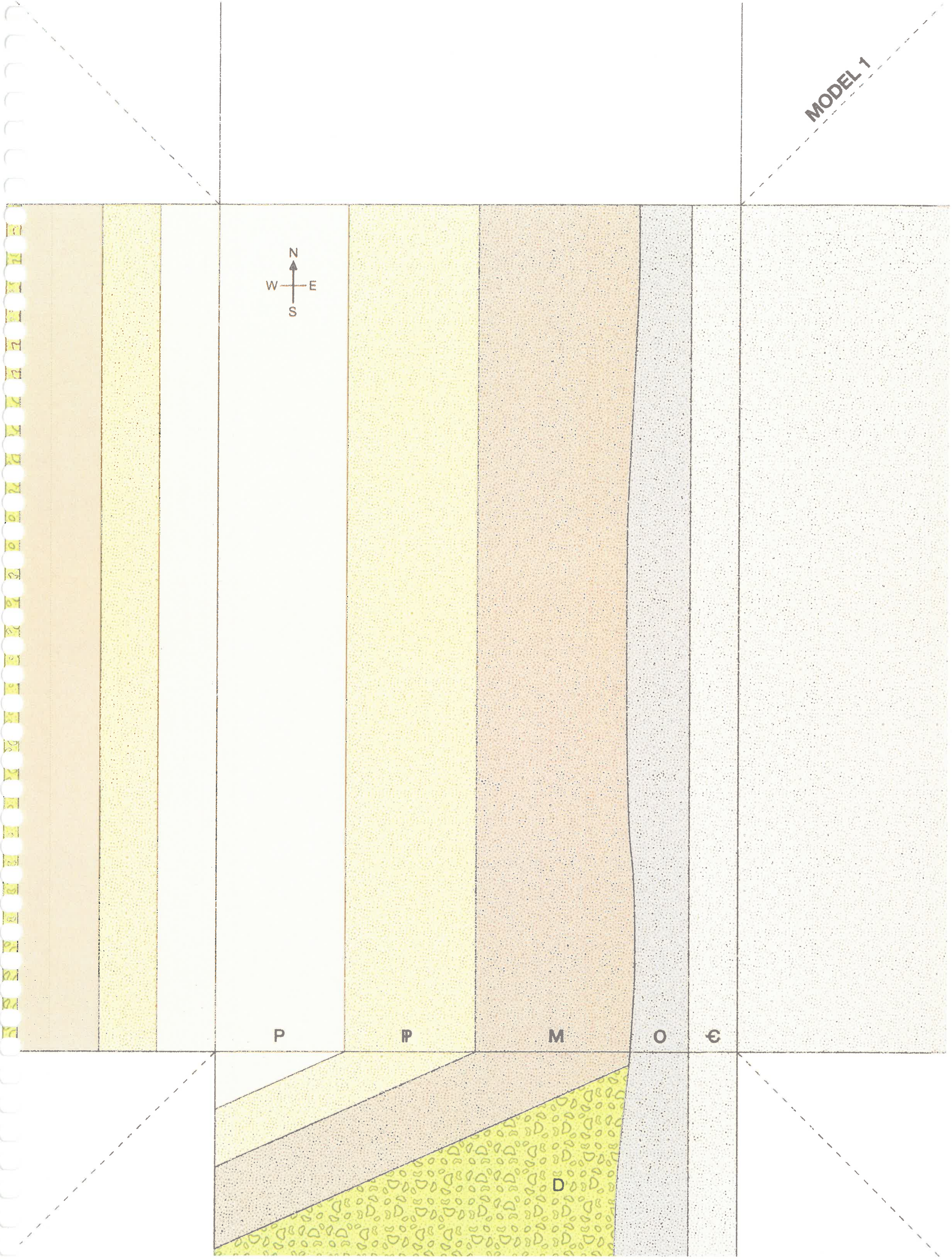
34. How does the geology of the map area influence:

- **a.** the topography?
- **b.** the location of streams or other bodies of water?
- **c.** the location of natural vegetation, orchards, farms, and ranches?
- **d.** the location of communities?
- **e.** the location of quarries or mines, if any?

35. List and describe any folds, domes, basins, or significant faults in the map area.

36. List, describe, and give the ages of any igneous intrusions in the map area.

37. Write a one- or two-page summary of the geologic history of this region. Start with the oldest formation and events and end with the present time. Mention all of the formations by name and how they developed (sedimentary, igneous, or metamorphic processes). Mention when any formations were eroded or deformed into geologic structures (unconformities, folds, domes, basins, faults). Also describe the kinds of stresses that may have caused the structures to develop.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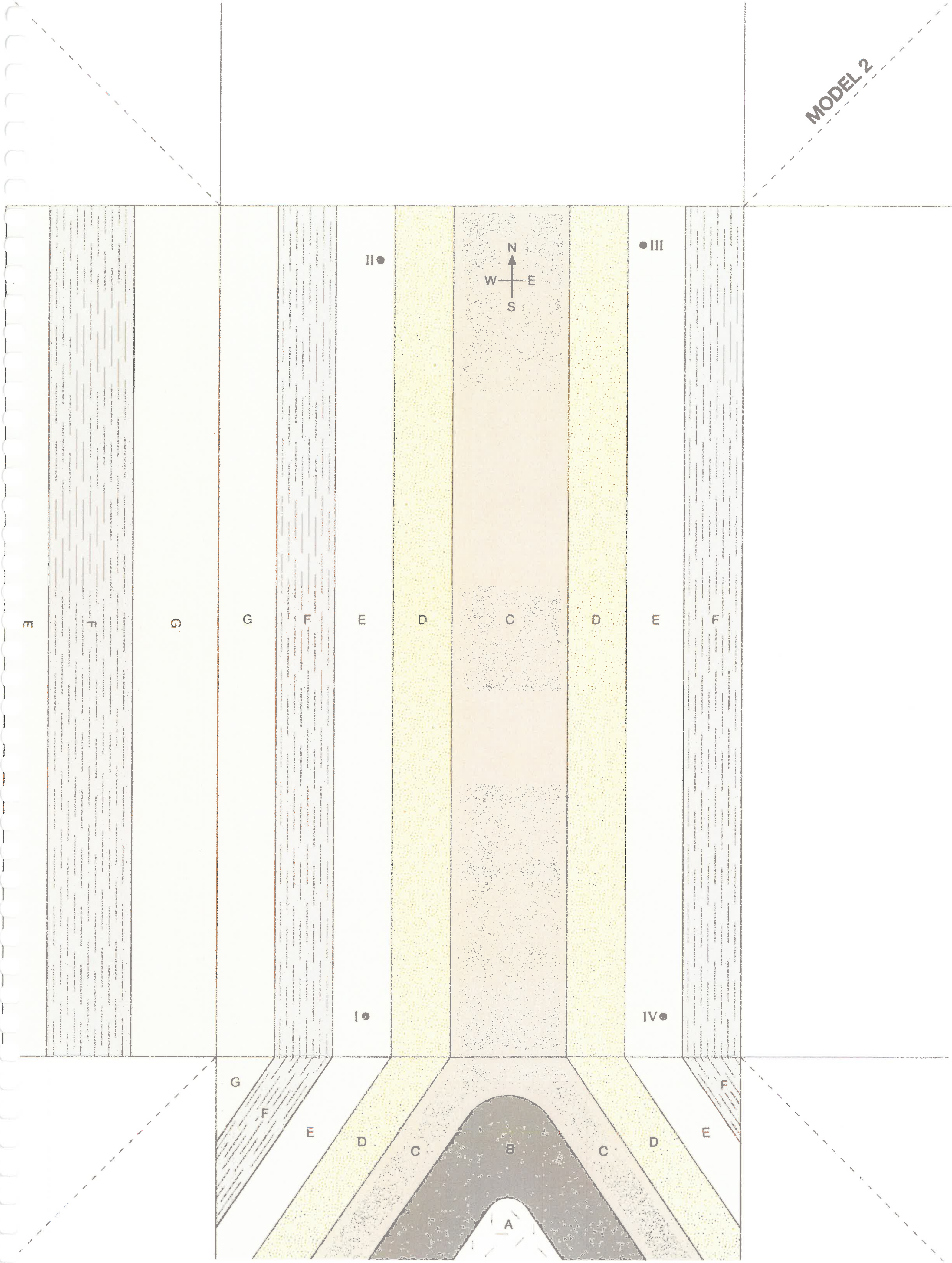
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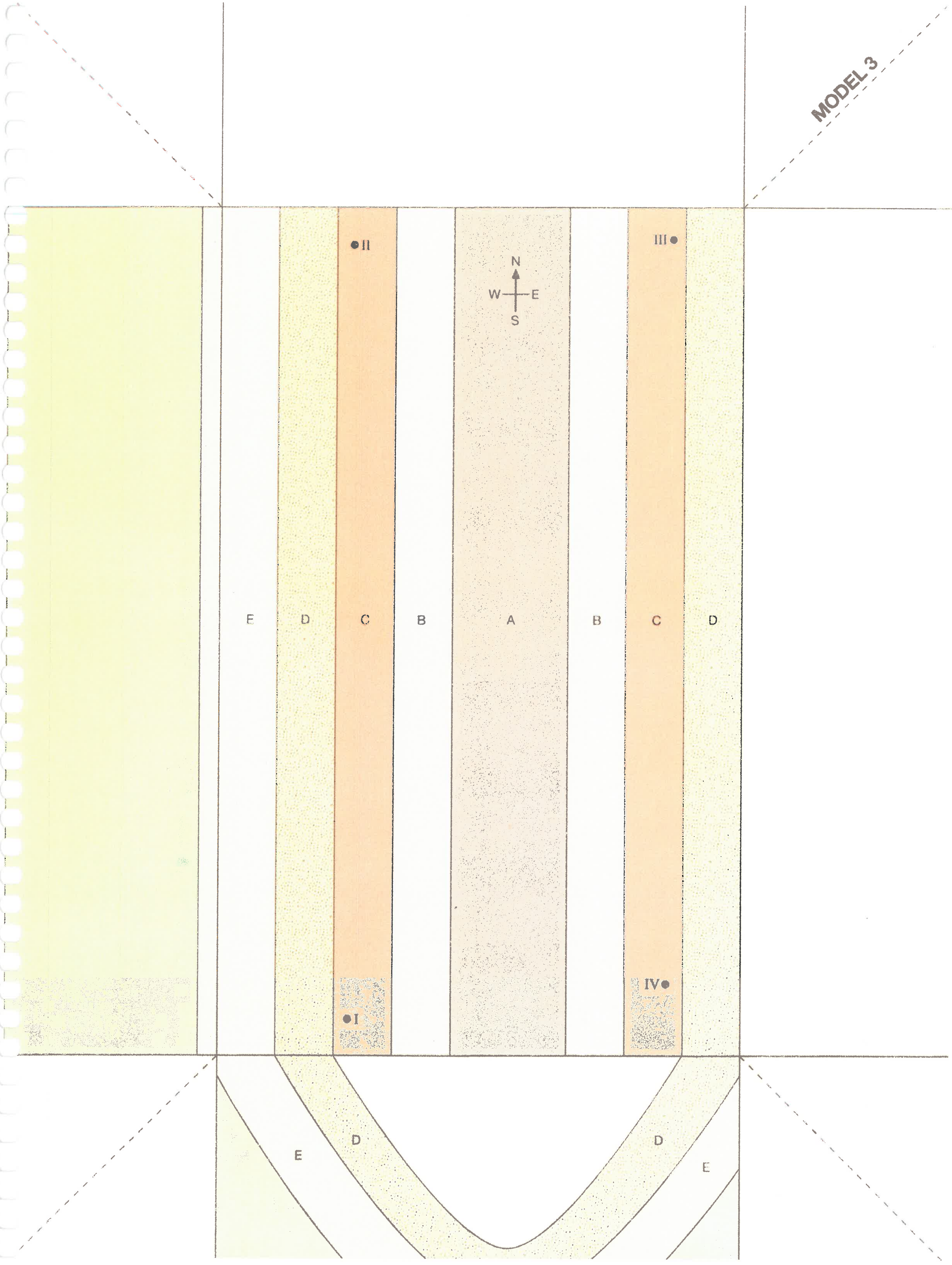
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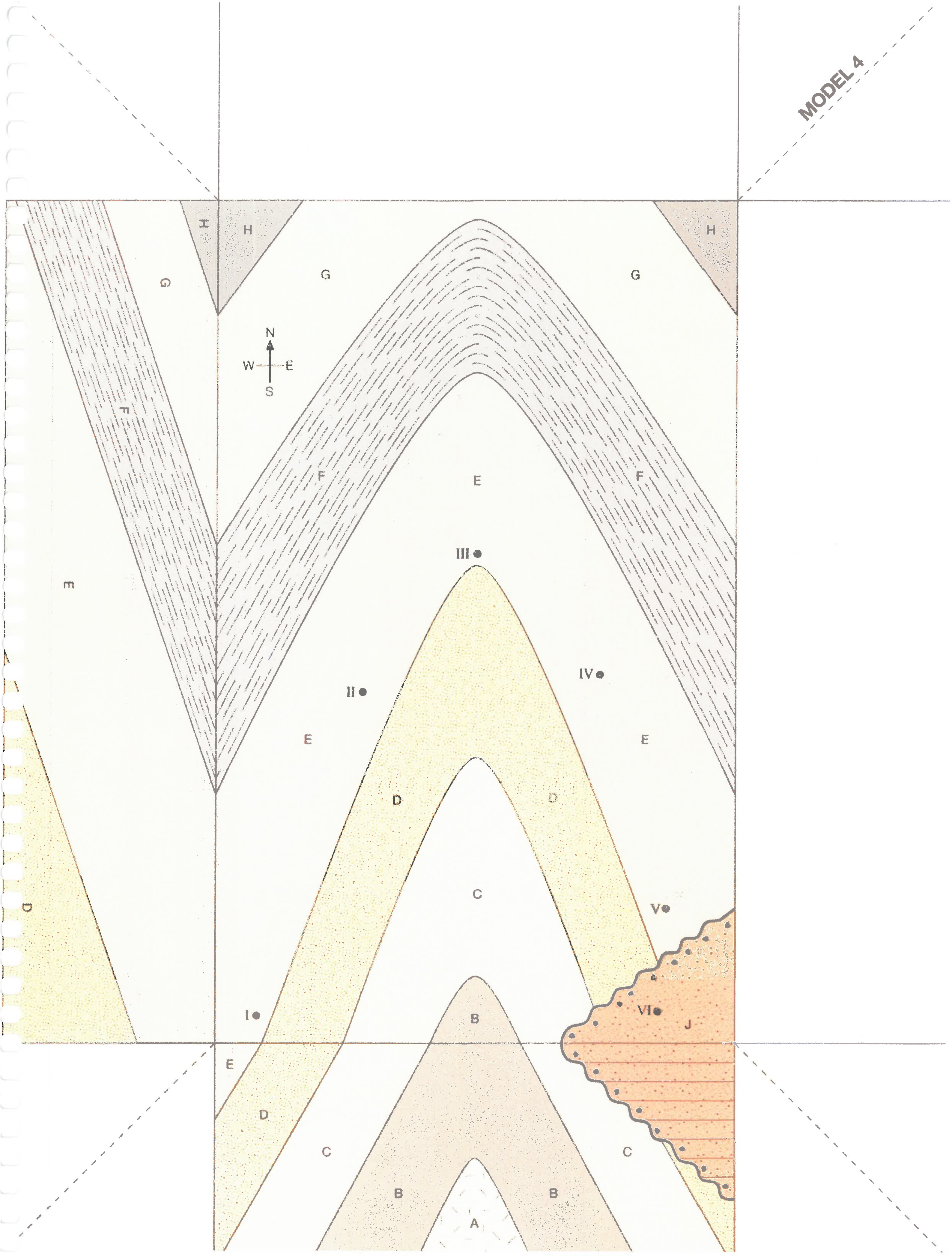
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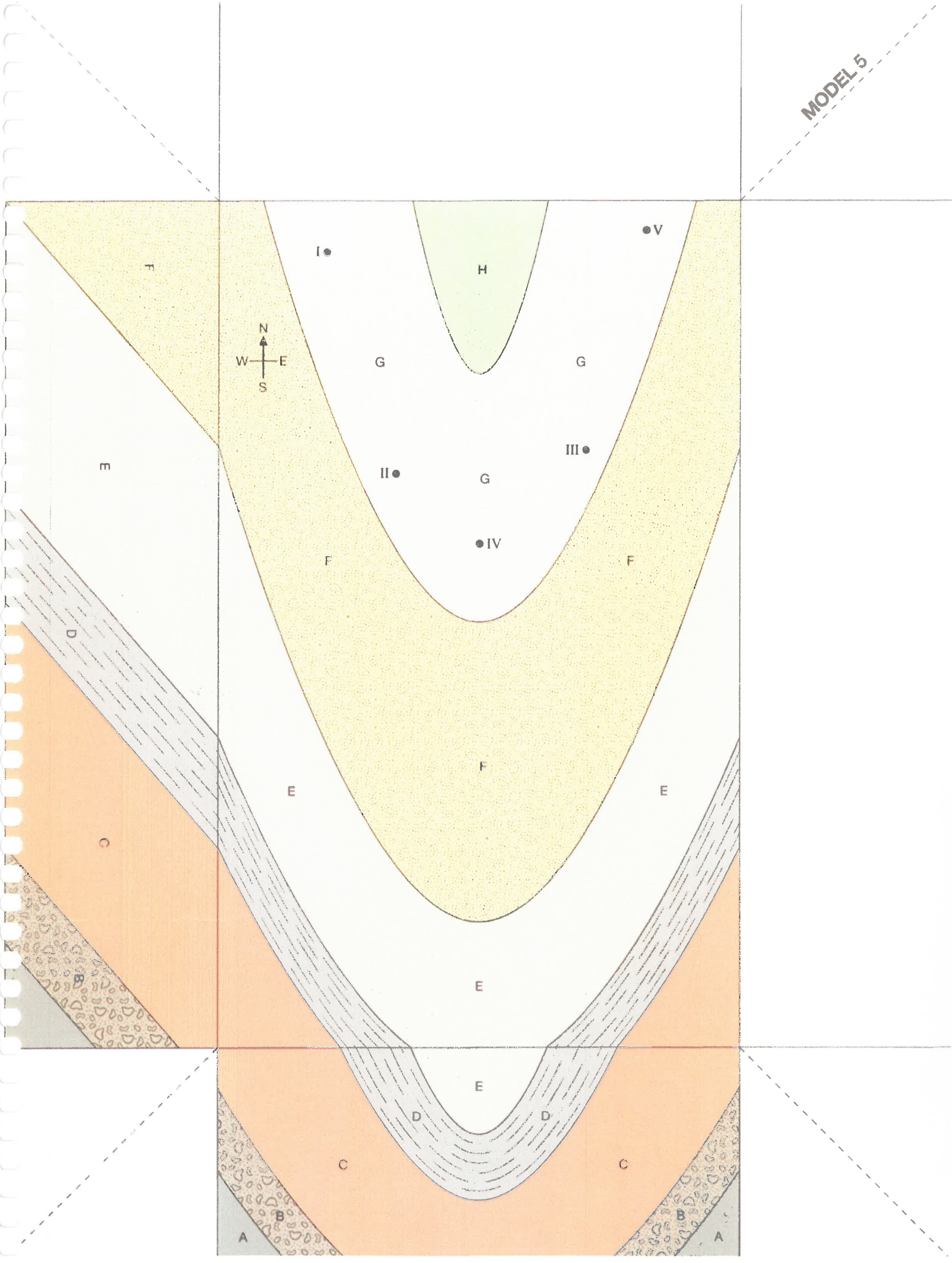

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