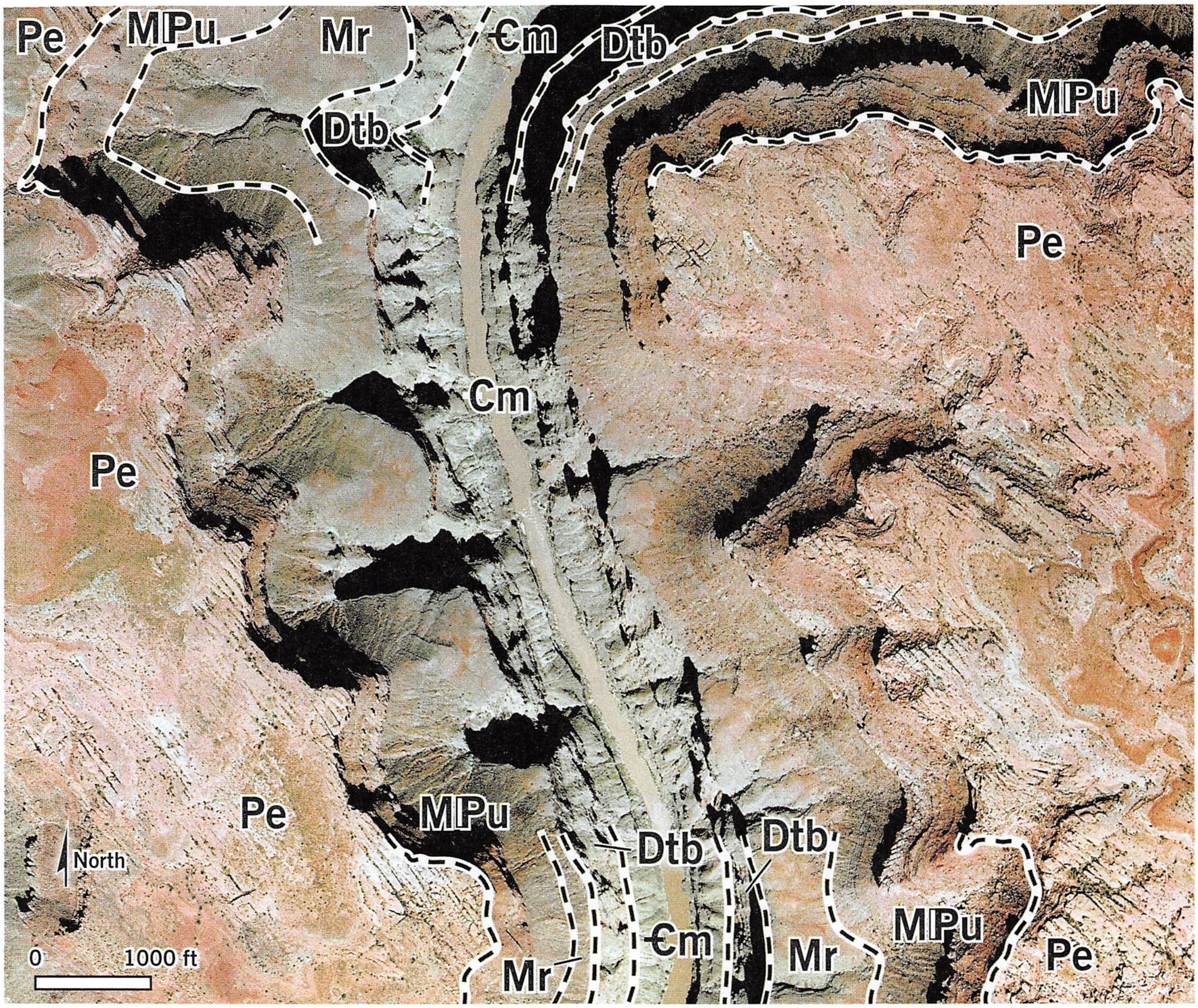
Map Contacts and Formations

Activity 10.1

Name: ______________________ **Course/Section:** ______________________ **Date:** ______________

A Fig. A10.1.1 is an aerial photograph of part of the Grand Canyon centered on latitude 36.334°N, longitude 112.725°W. The geology of this area is presented on a map by George Billingsley published in 2000 by the USGS (**http://pubs.usgs.gov/imap/i-2688/i-2688.pdf** and **http://pubs.usgs.gov/imap/i-2688/i-2688_pamphlet.pdf**). Part of several contacts are shown as dashed lines at the bottom and top of the photograph. The mapped rock units are explained in the table below the photograph.



EXPLANATION

Pe	Esplanade Sandstone (Lower Permian)
MIPu	Watahomigi Formations (L Pennsylvanian and U Mississippian)
Mr	Redwall Limestone (Upper and Lower Mississippian)
Dtb	Temple Butte Formation (Upper and Lower Devonian)
€m	Muav Limestone (Middle Cambrian)

Figure A10.1.1

1. Examine the photograph carefully. In a few words, describe what features on the slopes or visible in the rocks seem to define the place where Billingsley put each of the contacts.
   (a) Between the Esplanade Sandstone and the Watahomigi Formation

   (b) Between the Watahomigi Formation and the Redwall Limestone

   (c) Between the Redwall Limestone and the Temple Butte Formation

   (d) Between the Temple Butte Formation and the Muav Limestone

2. Complete the geologic map by tracing each of the contacts from the bottom of the map to join with the same contact at the top of the map. Make sure your teacher can see where the contacts are.

B Figure A10.1.2 is part of the USGS 7.5-minute topographic map of Havasu Falls Quadrangle, Arizona (2014). As with the aerial photograph in **Fig. A10.1.1**, George Billingsley's contacts are partially mapped.

1. Complete the geologic map in **Fig. A10.1.2** by carefully drawing the contacts while carefully noting how they might relate to the topographic contours.
2. Draw the profile along the line between X and X′ in the profile box at the bottom of **Fig. A10.1.2** using just the index contours. Four points are already plotted in the profile box for you.
3. Use the contacts that you have drawn to create a geological cross-section in the profile box. Use a pencil to work on the cross-section, and don't be shy about erasing. Refer to **Figs. 10.1B** and **10.5** for help making a cross-section.

C **REFLECT & DISCUSS** Examine your geologic map, and imagine how the Watahomigi Formation once extended across the canyon before the river eroded it. Do you think the Watahomigi Formation is deformed, or is it relatively undeformed? Why?

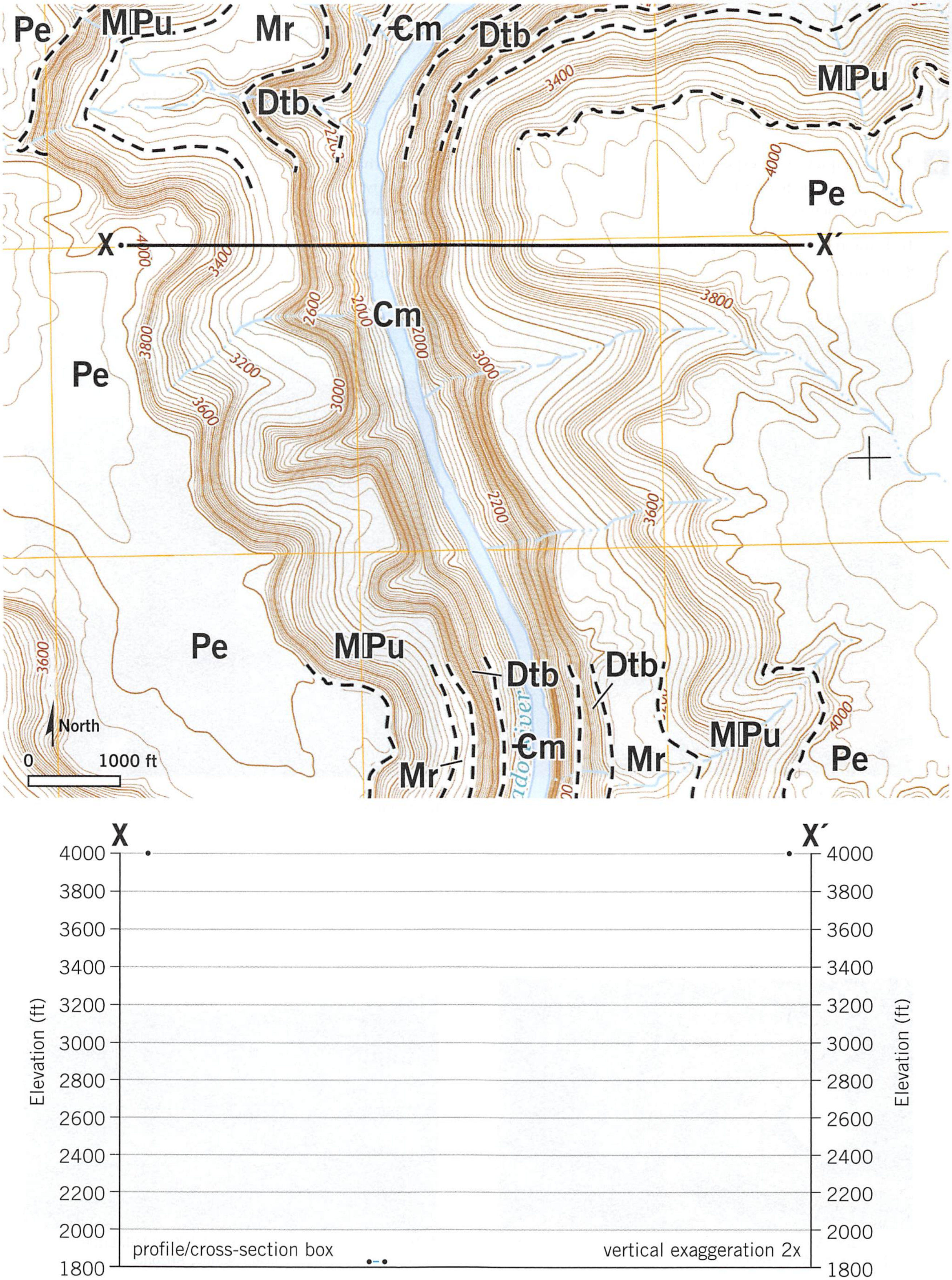


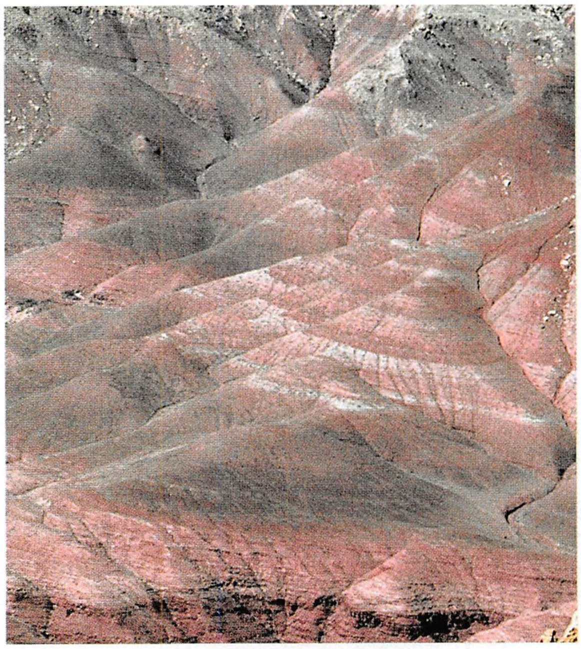
Figure A10.1.2

Activity 10.2 Geologic Structures Inquiry

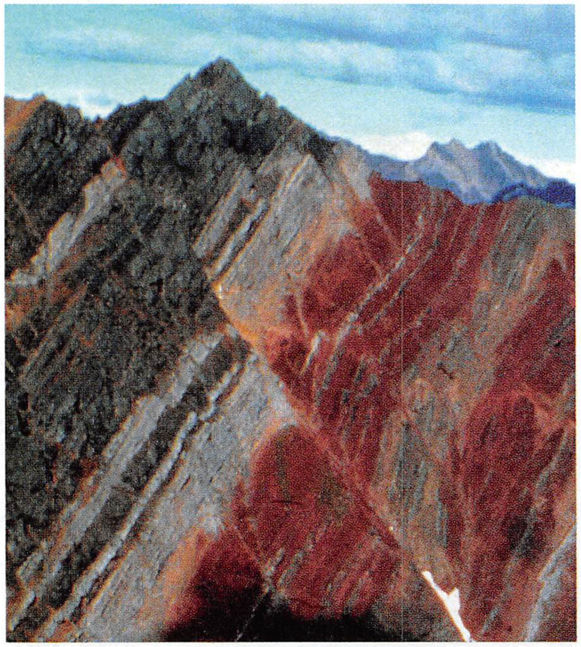
Name: ______________________ **Course/Section:** ______________ **Date:** __________

A The principles of superposition and original horizontality remind us of what an undeformed sequence of sedimentary rock layers should be like. Information presented in this lab describes several types of deformation that can be seen in rock. Examine each image in **Fig. A10.2.1**. Beneath each image, answer these two questions:

1. Is the rock in the photograph deformed or not deformed?
2. If you interpret that the rock is deformed, describe the specific features of the rock that led you to that interpretation.



1. Grand Canyon, Arizona rock layers.



2. Cliff face about 400 m tall, south-central Alaska (USGS photograph by N.J. Silberling).

3. Quartzite, Maria Mts, Riverside County, California (USGS photograph by W.B. Hamilton).

4. Sandstone on a steep wall about 100 m tall, Little Colorado River Gorge, Navajo Nation, Arizona

Figure A10.2.1

B **REFLECT & DISCUSS** Based on your analysis of deformed rocks in part **A**, classify rock deformation into two categories, and note what images in **Fig. A10.2.1** would be in each category. Be prepared to explain your classification to your classmates and teacher.

C **Figure A10.2.2** is an oblique view of a small outcrop of fine-grained layered rock that contains fossils. The layers probably represent bedding planes. The layers are inclined, and the sense of inclination can be determined by noticing the water in the lower-left corner of the photograph.

1. Using the water line as a guide, carefully draw a strike line near the top of one of the flat layers using the black-and-white image for your drawing. (Make sure your teacher can see the strike line you draw.) Remember that a strike line is a horizontal line on the inclined surface and that the waterline is also a horizontal line on that surface.
2. Examine the photograph carefully, and imagine a ball rolling down the inclined surface. Now draw what you infer to be a dip vector extending from the strike line using the black-and-white image for your drawing.
3. Identify which end of the strike line points toward the Right-Hand-Rule reference strike. Label that end of the strike line with "RHR." Refer to **Fig. 10.2** for help visualizing the RHR reference strike.
4. Let's assume that the geoscientist was pointing the camera due north when this photograph was taken. In what general direction do these beds dip? ____________
5. You cannot directly measure the dip angle in this view, but you can estimate the dip angle within perhaps 10° or so. About what is the dip angle of these beds? ____________°

D **REFLECT & DISCUSS** We have been looking at a small outcrop with inclined beds in **Fig. A10.2.2**.

1. What is the strike of a horizontal surface?
2. What is the dip angle of a vertical surface?
3. The dip direction is a general compass direction like north or southwest. What is the dip direction of a vertical surface, or does it even have a dip direction?

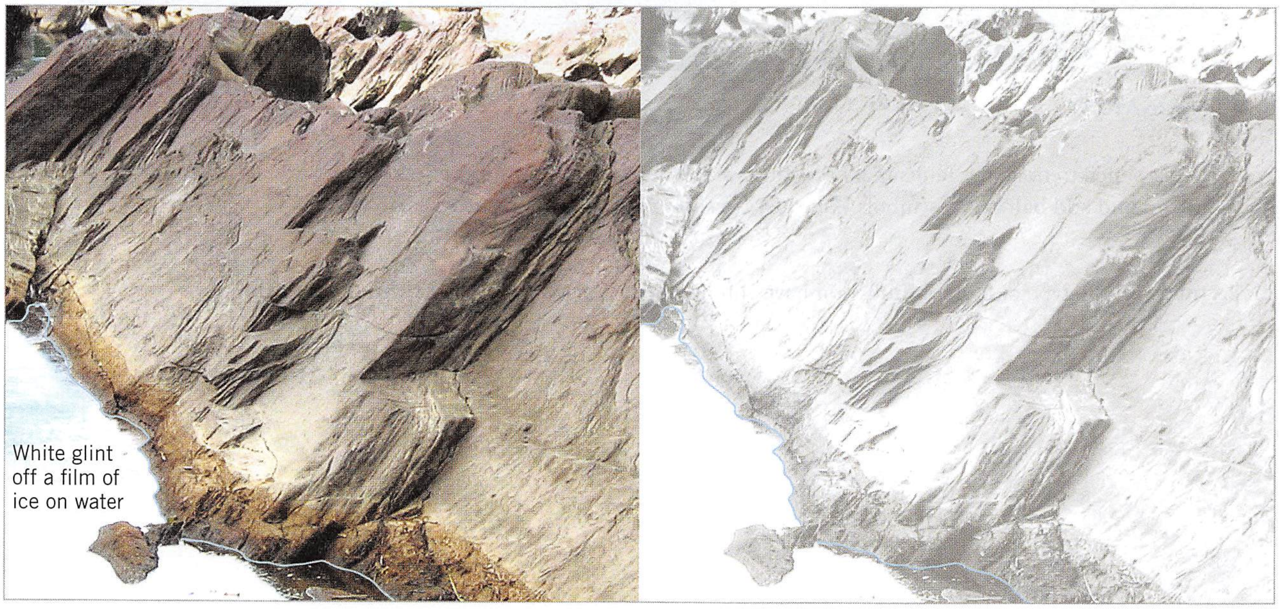


Figure A10.2.2

Activity 10.3 Fault Analysis Using Orthoimages

Name: ______________________ Course/Section: ______________ Date: __________

A Figure A10.3.1 is part of a USGS orthophotomap of the Frenchman Mountain Quadrangle, near Las Vegas, Nevada. The center of this map area is 36.1596°N, 114.9477°W. The Nevada Geological Survey has determined that faulting occurred here between 11 and 6 Myr ago.

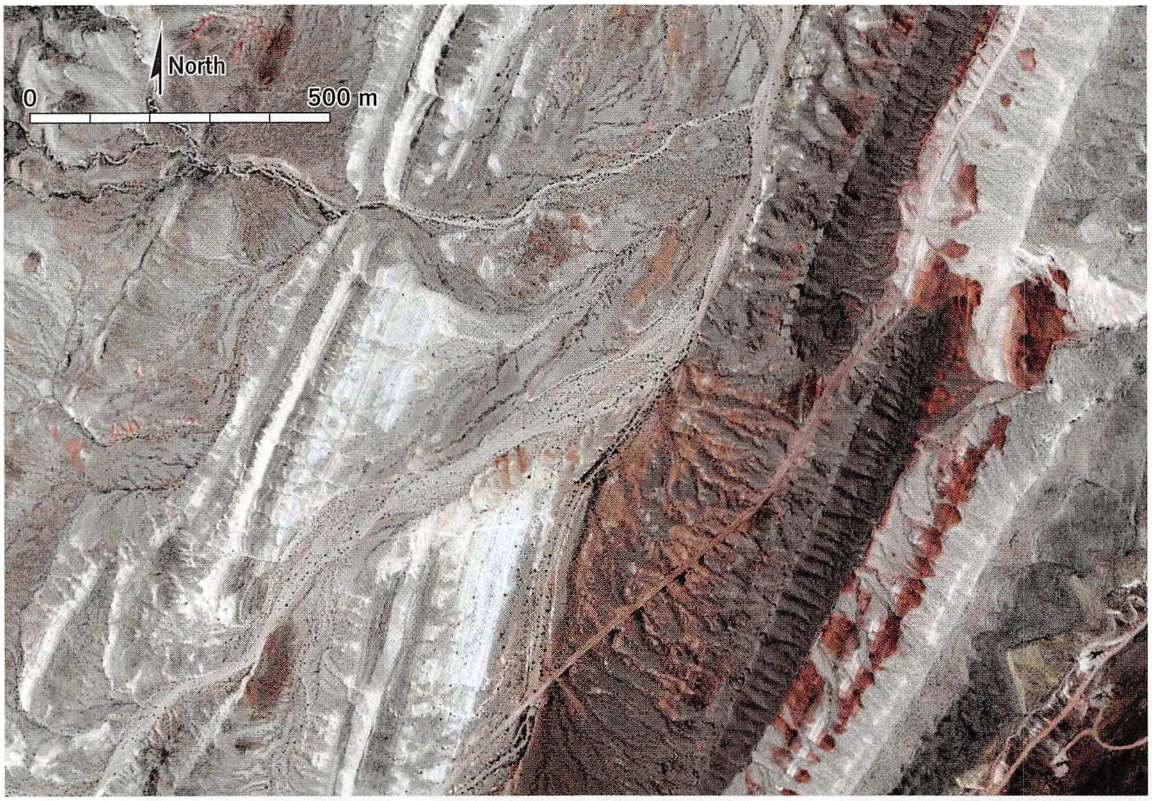


Figure A10.3.1

1. Use a pencil to trace the faults that cross this area. When you are content with your interpretation in pencil, trace over it in pen and add half-arrow symbols (**Fig. 10.4**) to show relative motion across each fault.

2. Interpret the type of fault or faults you have you mapped. What is your interpretation based on?

B Figure A10.3.2 shows an area just west of **Fig. A10.3.1** centered on 36.1387°N, 114.9783°W.

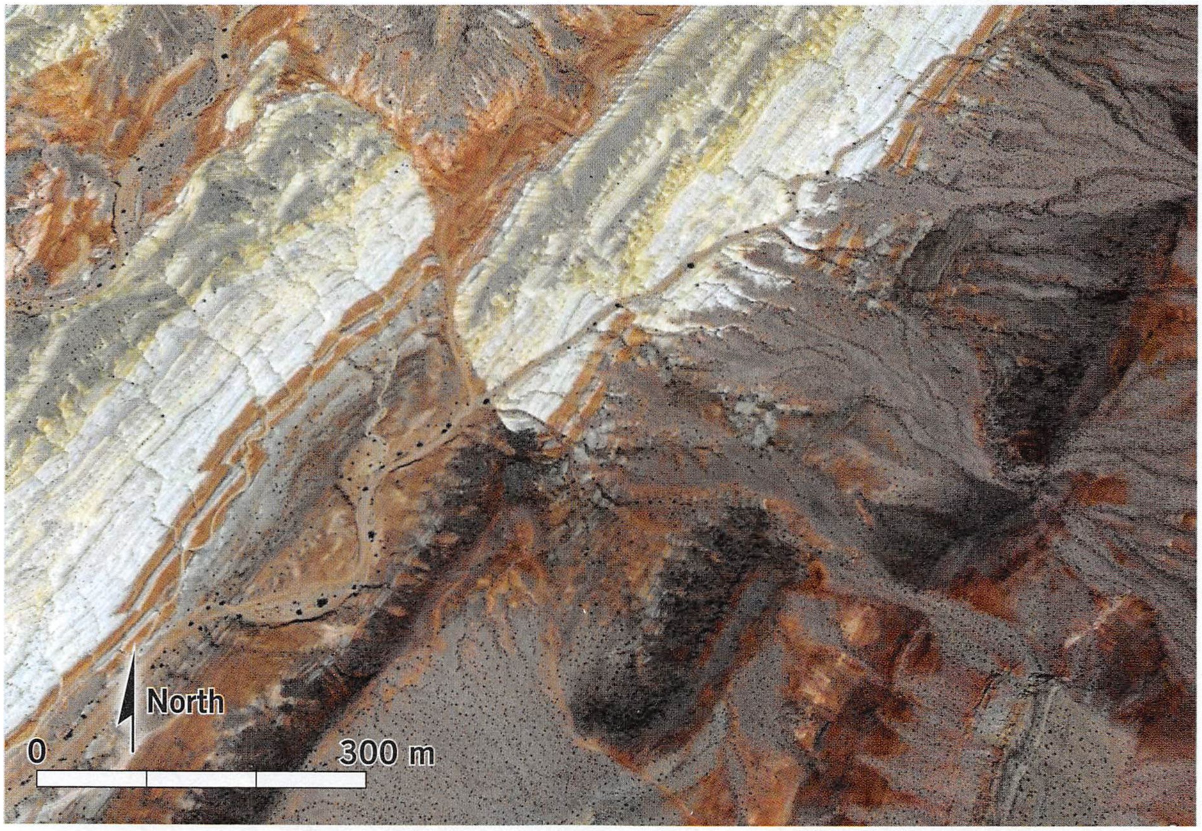


Figure A10.3.2

1. Use a pencil to trace all of the faults that you can detect in the image. When you are content with your interpretation in pencil, trace over it in pen and add half-arrow symbols to show the relative motion along the faults.
2. Interpret the type(s) of fault(s) you have mapped.

C **REFLECT & DISCUSS** Aerial photographs like these primarily give us information about possible horizontal separation of formations along faults. Make a case for the hypothesis that these inclined beds might have been separated by a vertical component of slip along a fault in addition to or instead of horizontal slip along the fault. (*Hint*: Use your hands to represent tilted beds on opposite sides of the fault to help you visualize the situation.)

Activity 10.4 Appalachian Mountains Geologic Map

Name: ____________________ Course/Section: ____________________ Date: ____________

A Complete the geologic cross-section in **Fig. A10.4.1** using the steps described in **Fig. 10.5**.

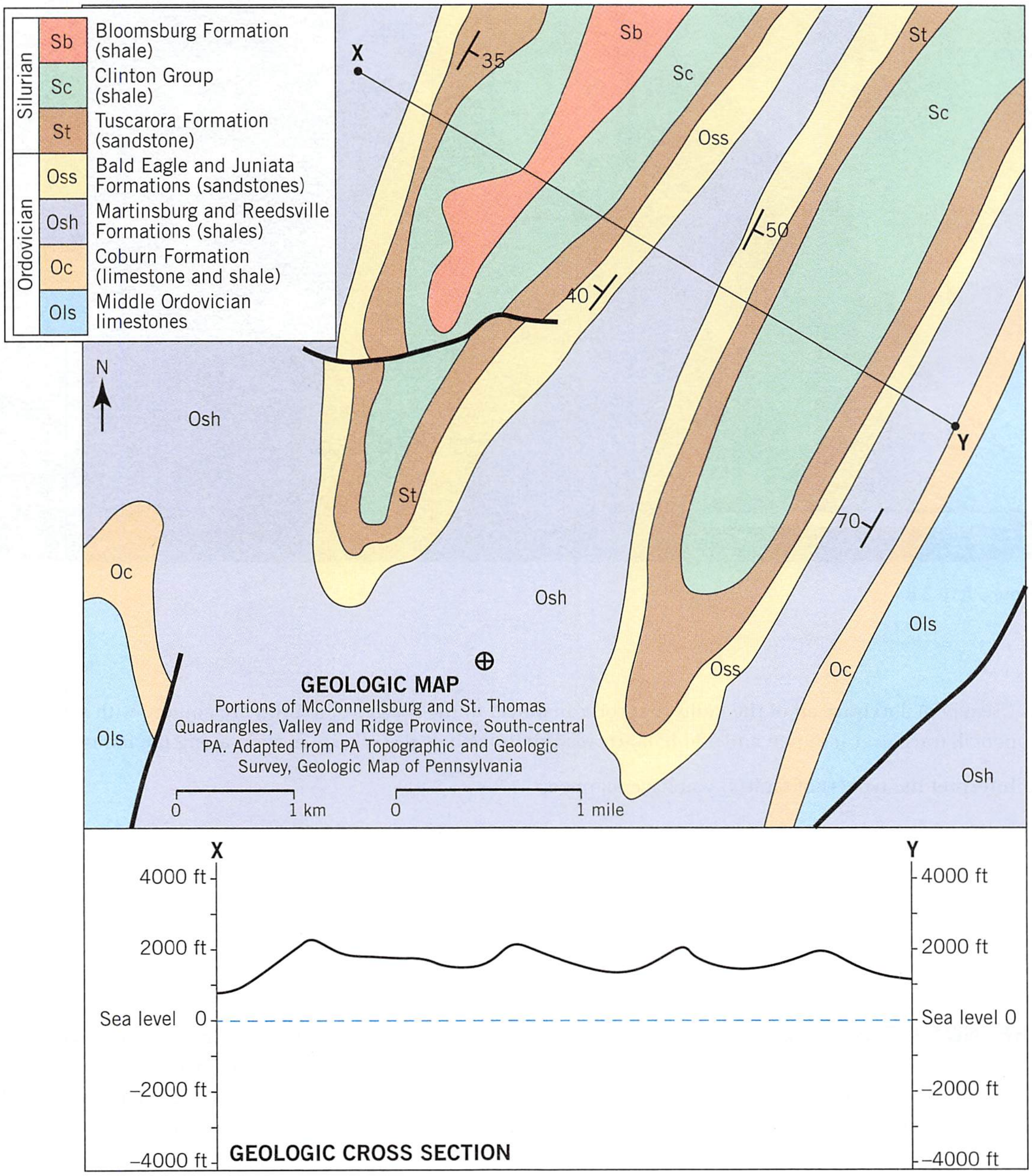


Figure A10.4.1

B Label the kind(s) of geologic structure(s) revealed by your work. Then add the appropriate symbols from **Fig. 10.4** to the geologic map to show the approximate traces of the axial surfaces for the most prominent folds on the map. Refer to **Figs. 10.14** and **10.15** for help.

C Add half-arrows to the fault near the center of the geologic map to show the relative motions of its two sides. What kind of fault do you interpret this to be?

Cardboard Model Analysis and Interpretation

Activity 10.5

Name: ______________________ **Course/Section:** ______________________ **Date:** ______________

Tear Cardboard Models 1–6 from the back of your lab manual. Cut and fold them as noted in red on each model.

A **Cardboard Model 1** This model shows Ordovician (O, green), Silurian (S, tan), Devonian (D, gray), Mississippian (M, light brown), Pennsylvanian (yellow), and Permian (P, peach) formations striking due north and dipping 24° to the west. Provided are a complete geologic map on the top of the diagram and three of the four vertical cross-sections (south, east, and west sides of the block diagram).

1. Finalize Cardboard Model 1 as follows. First construct the vertical cross-section on the north side of the block so it shows the formations and their orientations (strike and dip). On the map, draw a strike and dip symbol on the Mississippian sandstone that dips 24° to the west (see **Figs. 10.2** and **10.4** for the strike-and-dip symbol).

2. Explain the sequence of events that led to the existence of the formations and the relationships that now exist among them in this block diagram.

B **Cardboard 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. Letters **A–G** indicate ages from oldest (**A**) to youngest (**G**).

1. Finalize Cardboard 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 anticline because the fold closes upward and the oldest formation (**A**) is toward the axial surface of the fold (**Figs. 10.14** and **10.15**). It is an upright horizontal fold because its axial surface is vertical and its axis is horizontal. On the geologic map, draw strike-and-dip symbols to indicate the orientations of formation **E** (gray formation) at points **I**, **II**, **III**, and **IV**. On the map at the top of the model, draw the proper symbol along the axis of the fold (**Fig. 10.4**).

2. How do the strikes at all four locations compare with each other?

3. 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.*

C **Cardboard Model 3** This cardboard model has a complete geologic map. However, only one side and part of another are complete. Letters **A–E** are ages from oldest (**A**) to youngest (**E**).

1. Finalize Cardboard Model 3 as follows. Complete the remaining two-and-one-half sides of this model using as guides the geologic map on top of the block and the one-and-one-half completed sides. On the map, draw strike-and-dip symbols showing the orientation of formation **C** at points **I**, **II**, **III**, and **IV**. On the map at the top of model, draw the proper symbol along the axis of the fold (**Fig. 10.4**).

2. How do the strikes of all four locations compare with each other?

3. 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.*

4. Is this fold plunging or horizontal? ______________________

5. Is it an anticline or a syncline? ______________________

6. On the basis of this example, how much variation is there in the strike at all points in a horizontal fold?

D **Cardboard Model 4** Letters **A–H** indicate rock ages from oldest (**A**) to youngest (**H**). This model shows an anticline that plunges to the north.

1. Finalize Cardboard 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**. On the map at the top of model, draw the proper symbol along the axis of the fold including its direction of plunge (**Fig. 10.4**). Also draw the proper symbol on the geologic map to indicate the orientation of beds in formation **E**.

2. How do the directions of strike and dip differ from those in Cardboard Model 3?

E **Cardboard Model 5** Letters **A–H** indicate rock ages from oldest (**A**) to youngest (**H**). This model shows a plunging syncline. Two of the sides are complete and two remain incomplete.

1. Finalize Cardboard 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**. On the map at the top of model, draw the proper symbol along the axis of the fold including its direction of plunge (**Fig. 10.4**).

2. In which direction does this syncline plunge, and what is the plunge angle (the angle from horizontal to the fold axis, measured in a vertical plane)? (*Hint:* Use the cross-sections on the sides of the model to measure the plunge angle.)

F **Cardboard 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.

1. Finalize Cardboard Model 6 as follows. At point **I**, draw a symbol from **Fig. 10.4** to show the strike and dip of the fault. On the cross-section along the west edge of the block, draw arrows parallel to the fault, indicating relative motion across the fault. Label the hanging wall and the footwall. Complete the east side of the block. Draw half-arrows parallel to the fault to indicate relative motion across the fault. 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**.

2. Is the fault in this model a normal fault or a reverse fault (**Fig. 10.11**)? On what evidence do you base your interpretation?

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

4. Could the same offset of dipping contacts along this fault have been produced by strike-slip motion?

G **REFLECT & DISCUSS** There is a general principle that, as erosion of the land proceeds, *contacts migrate in the down-dip direction.* Is this true in this example? Explain.

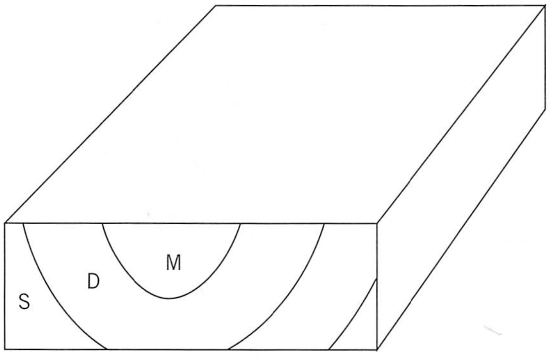
Block Diagram Analysis and Interpretation

Activity 10.6

Name: ______________________ **Course/Section:** ______________ **Date:** __________

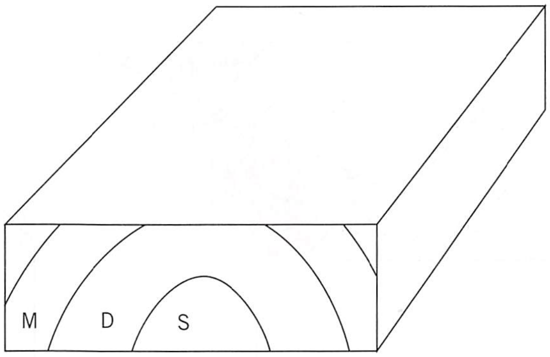
For each block diagram in **Fig. A10.6.1**:

1. Complete the diagram so that contact lines between rock formations are drawn on all sides.
2. Add symbols (**Fig. 10.4**) to indicate the orientations of all structures.
3. On the lines provided below each of the block diagrams, write the name of the geologic structure represented in the diagram.



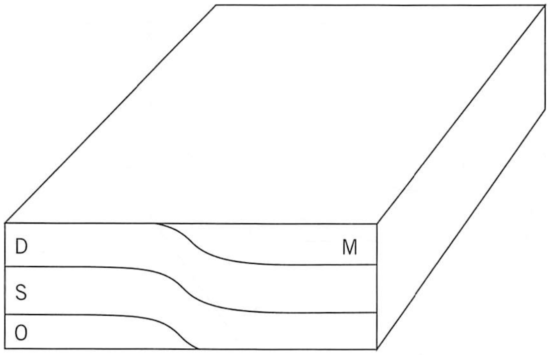
A. Complete top and side. Add appropriate symbols from Fig. 10.4. What type of fold is this?

____



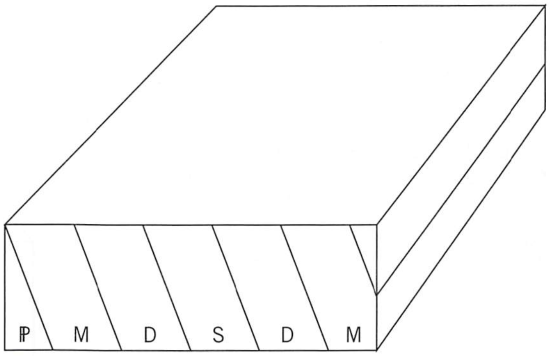
B. Complete top and side. Add appropriate symbols from Fig. 10.4. What type of fold is this?

____



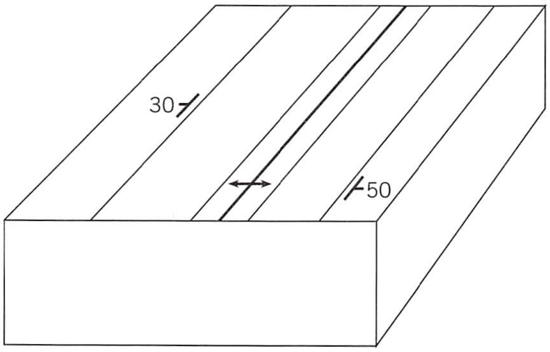
C. Complete top and side. Add appropriate symbols from Fig. 10.4. What type of fold is this?

____



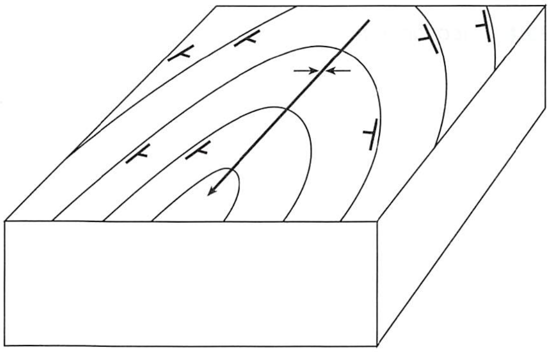
D. Complete top of diagram. Add appropriate symbols from Fig. 10.4. What geologic structure is this?

____



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

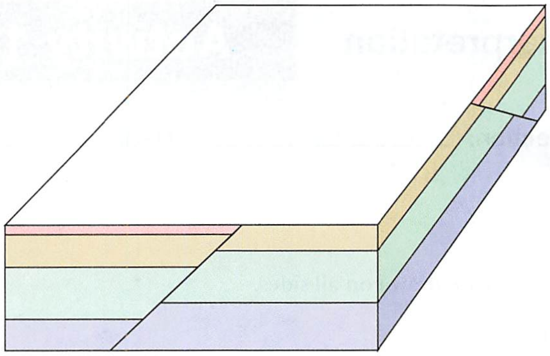
____



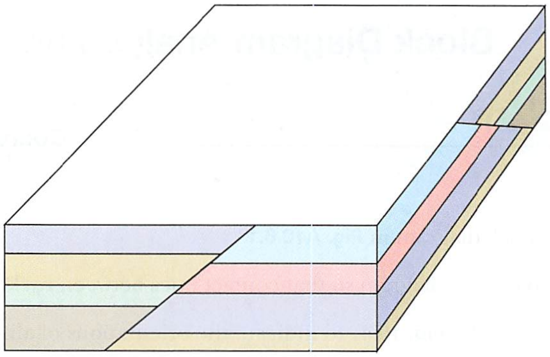
F. Complete the sides of the diagram. What geologic structure is this?

____

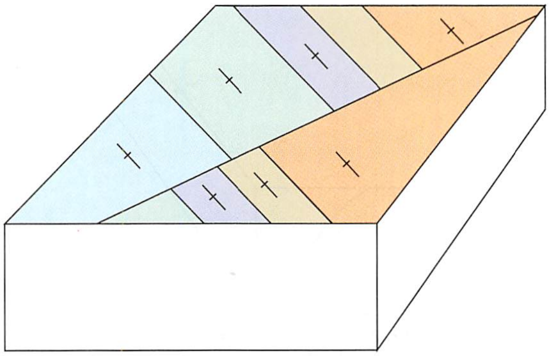
Figure A10.6.1



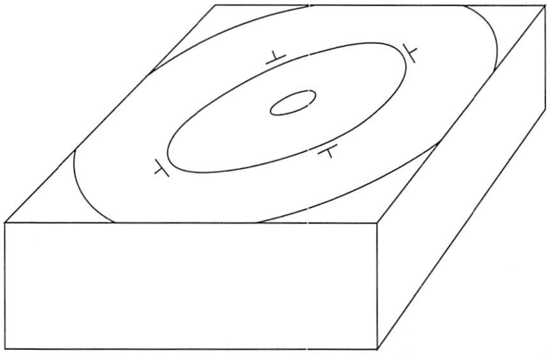
G. Complete top of diagram. Add appropriate symbols from Fig. 10.4. What geologic structure is this?



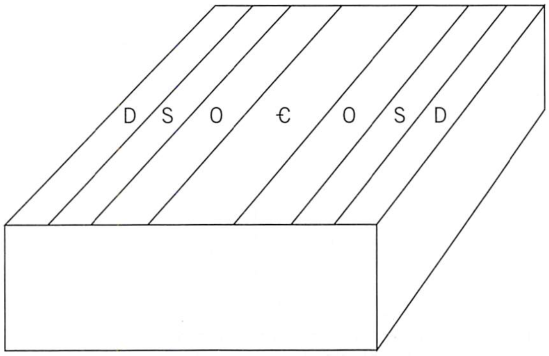
H. Complete top of the diagram. Add appropriate symbols from Fig. 10.4. What geologic structure is this?



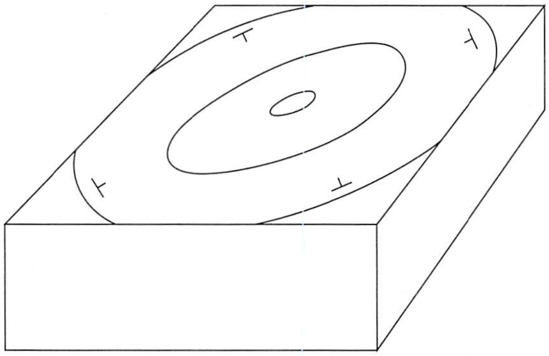
I. Complete the sides of the diagram. Add half-arrows. What geologic structure is this?



J. Complete the sides of the diagram. Put an "O" everywhere the oldest bed can be found on the ground surface. What geologic structure is this?



K. Complete sides of the diagram. Add appropriate symbols from Fig. 10.4. What geologic structure is this?



L. Complete the sides of the diagram. Put an "O" everywhere the oldest bed can be found on the ground surface. What geologic structure is this?

Figure A10.4.1 *(continued)*