Crustal Deformation

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12.1 INTRODUCTION

The Earth is an active planet shaped by dynamic forces. Such forces can build mountains and crumple and fold rocks. As rocks respond to these forces, they undergo deformation, which results in changes in shape and/or volume of the rocks. The resulting features are termed geologic structures. This deformation can produce dramatic and beautiful scenery, as evidenced in Figure 12.1, which shows the deformation of originally flat (horizontal) rock layers.

Why is it important to study deformation within the crust? Such studies can provide us with a record of the past and the forces that operated then. The correct interpretation of features created during deformation is critical in the petroleum and mining industry. It is also essential for engineering. Understanding the behavior of deformed rocks is necessary to create and maintain safe engineering struc-

Figure 12.1 | Rocks that have been deformed along the coast of Italy
Author: Randa Harris
Source: Original Work

tures. When proper geological planning is not considered in engineering, disasters can strike. For example, the Vajont Dam was constructed at Monte Toc, Italy in the early 1960's. The place was a poor choice for a dam, as the valley was narrow, thorough geological tests were not performed, and the area surrounding the dam was prone to large landslides. The steep canyon walls were composed of limestone with solution cavities, not known for its stability, and shifting and fracturing of rock that occurred during the filling of the reservoir went unheeded. In 1963, a massive landslide in the area displaced much of the water in the dam, causing it to override the top of the dam and flood the many villages downstream, resulting in the deaths of almost 2,000 people (Figure 12.2).

Figure 12.2 | An image of the Vajont reservoir shortly after the massive landslide (you can see the scar from the landslide on the right, and the dam is located in the foreground on the left).
Author: Unknown
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12.1.1 Learning Outcomes

After completing this chapter, you should be able to:
- Understand the different types of stress that rocks undergo, and their responses to stress
- Demonstrate an understanding of the concepts of strike and dip
- Recognize the different types of folds and faults, and the forces that create them
- Use block diagrams to display geologic features
- Create a geologic cross-section

12.1.2 Key Terms

Anticline	Normal fault
Basin	Reverse fault
Compressional forces	Shear forces
Contact	Strain
Dip	Stress
Dip-slip fault	Strike
Dome	Str ike-slip fault
Geologic cross-section	Syncline
Geologic map	Tensional forces
Horst & graben	Thrust fault
Monocline	

12.2 STRESS AND STRAIN

Rocks change as they undergo **stress** which is just a force applied to a given area. Since stress is a function of area, changing the area to which stress is applied makes a difference. For example, imagine the stress that is created both at the tip of high heeled shoes and the bottom of athletic shoes. In the high heeled shoe, the area is very small, so that stress is concentrated at that point, while the stress is more spread out in an athletic shoe. Rocks are better able to handle stress that is not concentrated in one point. There are three main types of stress: compression, tension, and shear. When **compressional forces** are at work, rocks are pushed together. **Tensional forces** operate when rocks pull away from each other. **Shear forces** are created when rocks move horizontally past each other in opposite directions. Rocks can withstand compressional stress more than tensional stress (see Figure 12.3).

Applying stress creates a deformation of the rock, also known as strain. As rocks are subjected to increased stress and strain, they at first behave in an elastic manner, which means they return to their original shape after deformation (Figure 12.4). This elastic behavior continues until rocks reach their elastic limit (point X on Figure 12.4), at which point plastic deformation commences. The rocks may bend into folds, or behave in a brittle manner by fracturing (brittle behavior can be easily envisioned if you think of a hammer hitting glass), but regardless they do not return to their original shape when the stress is removed in plastic deformation. The resulting deformation from applied stress

Figure 12.3 | This is a picture of the Roman Forum. Why did the Romans use so many vertical columns to hold up the one horizontal beam? If the horizontal beam spanned a long distance without support, it would buckle under its own weight. This beam is under tensional stress, so it is not as strong.
Author: Randa Harris
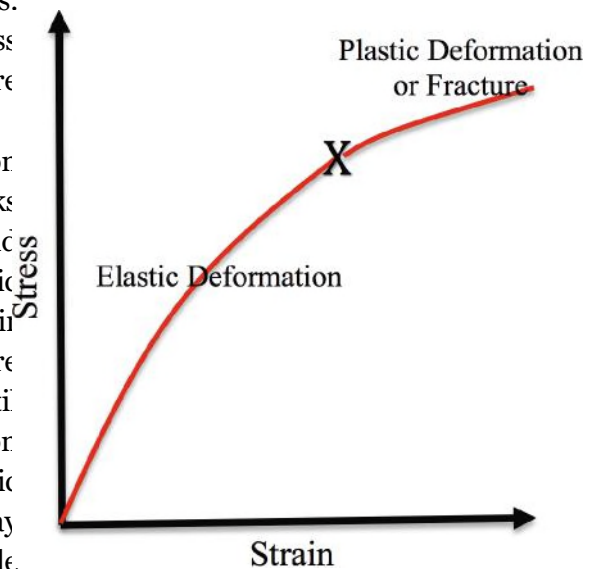**Source:** Original Work
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Figure 12.4 | A stress and strain diagram. As stress and strain increase, rocks first experience elastic deformation (and can return to their original shape) until the elastic limit is reached, depicted at point X. After this point, rocks will fracture or experience plastic deformation, so that their original shape is destroyed
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depends on many factors, including the type of stress, the type of rock, the depth of the rock and pressure and temperature conditions, and the length of time the rock endures the stress. Rocks behave very differently at depth than at the surface. Rocks tend to deform in a more plastic manner at depth, and in a more brittle manner near the Earth's surface.

12.3 STRIKE AND DIP

To learn many of the concepts associated with structural geology, it is useful to use block diagrams. As you examine these blocks, note the different ways that you can view them. If you look at a block from along the side, you are seeing the cross-section view (like what you see along roads that have been cut through the mountains). If you look at the block from directly above it, you are looking at map view (Figure 12.5).

As you think about how rocks have changed through the process of deformation, it is useful to remember how they deposited in the first place. We will briefly review some of the geologic laws that you learned in the Introduction Lab. Sedimentary rocks, under the influence of gravity, will deposit in horizontal layers (Law of Original Horizontality). The oldest rocks will be on the bottom (because they had to be there first for the others to deposit on top of them), and are

Figure 12.5 | You are viewing the top block in this image in map view, viewed from directly above the block. The lower block is from the same rock layers, and you are viewing it in cross-section (or from the side). Note that in cross-section, you can see how the rock layers are tilted.
Author: Randa Harris
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numbered with the oldest being #1 (Law of Superposition). The wooden block in Figure 12.6 displays how

Figure 12.7 | In this image, beds have been tilted. Which color bed is the oldest? To determine this, it is useful to apply Occam's Razor, which states that the simplest explanation is most likely the best. It is more likely that the gray bed on the left was the bottom bed during deposition, and therefore the oldest.
Author: Randa Harris
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Figure 12.6 | In this image, different rock types are given different colors. The oldest rock, on the bottom, is

given a #1. The youngest rock in this image is #4.
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sedimentary rocks originally deposit.Each of the boundaries between the colored rock units represents a geologic **contact**, which is simply the surface between two different rock units. Earth's rock layers are usually not this uncomplicated. Rock layers are often at an angle, not horizontal, indicating that changes have occurred since deposition. Examine Figure 12.7 to see tilted rocks.

In order to measure and describe layers like this, geologists apply the concepts of strike and dip. **Strike** refers to the line formed by the intersection of a horizontal plane and an inclined surface. **Dip** is the angle between that horizontal plane (such as the top of this block) and the tilted surface (the geologic contact between the tilted layers). In Figure 12.8, look at the tilted sedimentary layers. Strike is a line on the horizontal plane created when the dipping green layer intersects the Earth's surface. To better display the horizontal surface, it has been represented by water. The dip angle is measured from the horizontal surface to the dipping bed (outlined in orange on this image).
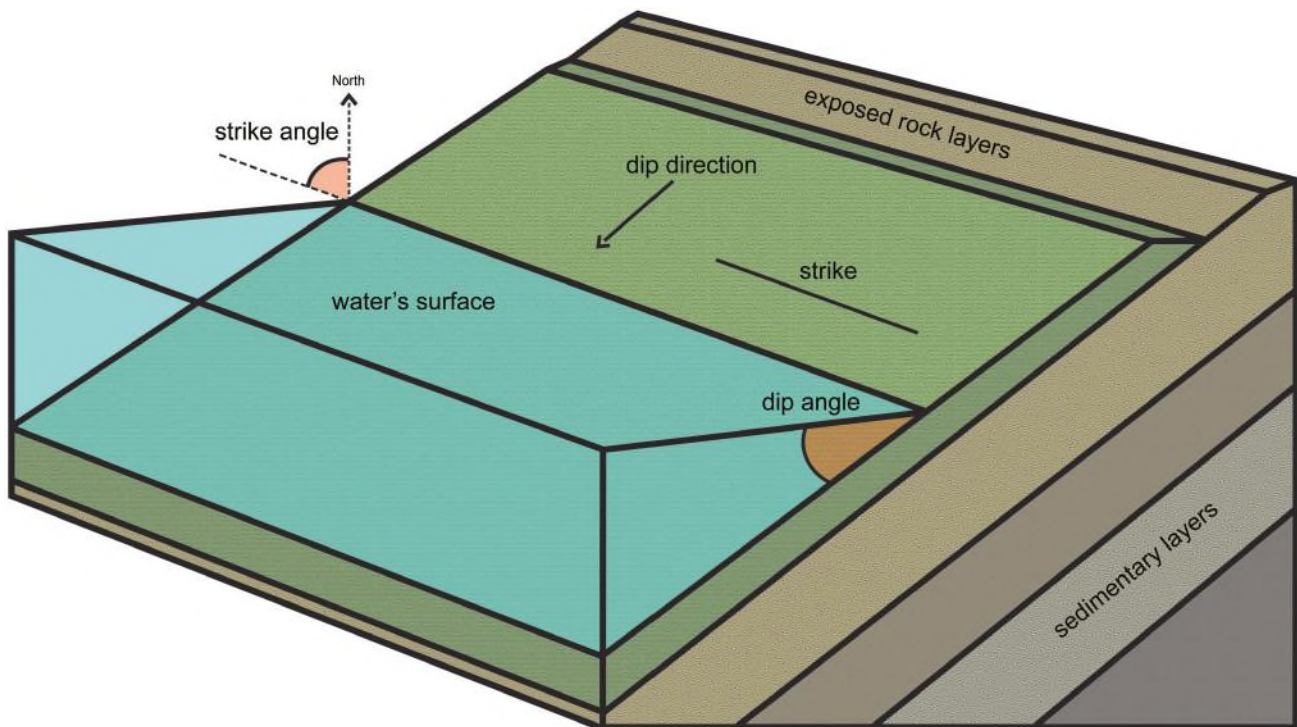
Figure 12.8 | A demonstration of strike and dip. In this example, the beds are dipping to the southwest.
Author: Corey Parson
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Now, let's apply this concept to the block of dipping beds that you just looked at (Figure 12.7). To determine strike, find where the dipping layer intersects the horizontal surface and draw a line parallel to this line of intersection on the top of the block (i.e. our horizontal surface). To determine dip, pretend that there is a drop of water between one bed and the next, for example, along the intersection of the pale blue bed and the red bed. In which direction would the water roll if it followed that contact? That is the direction of dip—towards the right in this case. The symbol for

strike and dip is given along the top of the block. Note that the dip symbol (shorter line) is perpendicular to the strike symbol (Figure 12.9).

Useful in map interpretation is the application of the Rule of V's to determine dip direction. As a stream crosses tilted strata, it will cut a V shape into the rock layers. The point of the V is in the direction of dip. In vertical strata, no V shapes are created (Figure 12.10).

Figure 12.9 | This image depicts the strike and dip for the pale blue bed. As all the beds are oriented in the same direction, they would all have the same strike and dip.
Author: Randa Harris **Source:** Original Work
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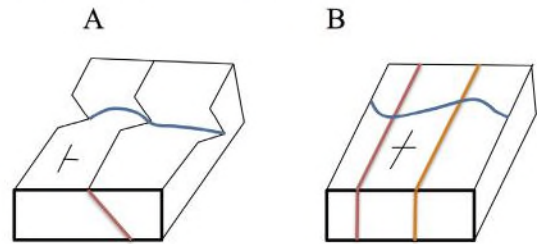
Figure 12.10 | In image A, the stream is encountering tilted strata, which results in a V shape that points towards the dip direction (in this case, to the right). In image B, the strata are vertical, so the stream cannot create a V shape. For reference on common geologic map symbols, refer to Figure 12.31 at the end of this lesson. **Author:** Randa Harris
Source: Original Work
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12.4 LAB EXERCISE

Part A (6 points)

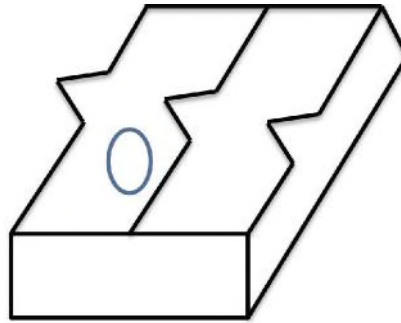1. For the following diagram, determine the correct map symbol that would go in the oval box.

a. ⊦ b. ⊣   + d. ⊕

2. For the following diagram, determine the correct map symbol that would go in the oval box.

a.   b.   c.   d

3. Using Google Earth, search for the following area in Pakistan: **27 50 35.00N 67 10 03.70E**. Zoom out to an eye altitude of approximately 25,000 feet. The inclined layers in these folded rocks can be easily seen. As you view them, in which compass direction are the beds dipping?

a. Northeast (NE) b. Southeast (SE) c. Northwest (NW) d. Southwest (SW)

12.5 GEOLOGIC STRUCTURES CREATED BY PLASTIC AND BRITTLE DEFORMATION

12.5.1 Folds

Folds are geologic structures created by plastic deformation of the Earth's crust. To understand how folds are generated, take a piece of paper and hold it up with a hand on each end. Apply compressional forces (push the ends towards each other). You have just created a fold (bent rock layers). Depending on how your paper moved, you created one of the three main fold types (Figure 12.11).
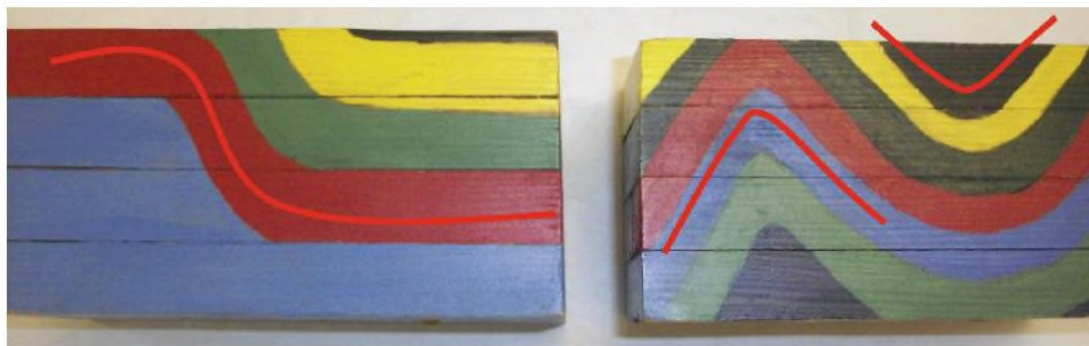
Figure 12.11 | The three main fold types, from left to right, are monocline, anticline, and syncline (the anticline and syncline are both displayed in one block).
Author: Randa Harris
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A **monocline** is a simple fold structure that consists of a [b]end in otherwise horizontal rock layers. More commonly [fo]und are anticlines and synclines. An **anticline** fold is [co]nvex up and one in which the layered strata are inclined [do]wn and away from the center of the fold (if you drew a [li]ne across it, the anticline would resemble a capital letter [A]). A **syncline** is a concave upward fold in which the [la]yered strata are inclined up (it resembles a smile). Parts [of] a fold include the axis (the hinge line), the axial plane, [an]d limbs on either side of the axis (Figure 12.12). It is [im]portant to note that anticlines do not always represent [m]ountains or high areas and synclines do not always [re]present basins or low areas. They are simply folded rock [la]yers, and do not necessarily indicate topographic high [an]d low points (see Figure 12.13).
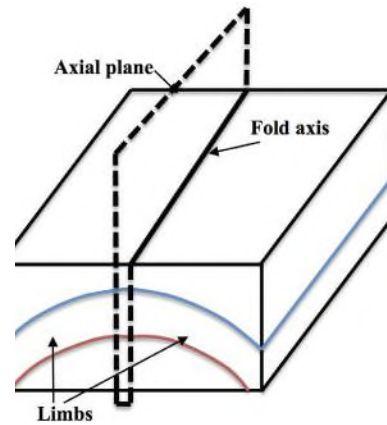
Figure 12.12 | The axial plane and [fo]ld axis, along the center of the fold, [an]d corresponding limbs on either [si]de.
Author: Randa Harris
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Figure 12.13 | This topographic high, along Interstate 68 and US 40 in Maryland, is a syncline.
Author: User "Acroterion"
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   Folds observed in cross-section look much different from map view. In map view, rather than seeing folds, you will only encounter beds that look like Figure 12.14. To help determine what type of fold you have, it is useful to determine the strike and dip of the beds you encounter. On Figure 12.14, determine the strike and dip for each location marked by an oval. Check yourself against Figure 12.15.

   Once rocks are folded and exposed at the Earth's surface, they are subjected to erosion, creating regular patterns. The erosion exposes the interiors of the folds, such that parallel bands of dipping strata can be observed along the fold axis. In an anticline, the oldest rocks are exposed along the fold axis, while it is the youngest rocks exposed at
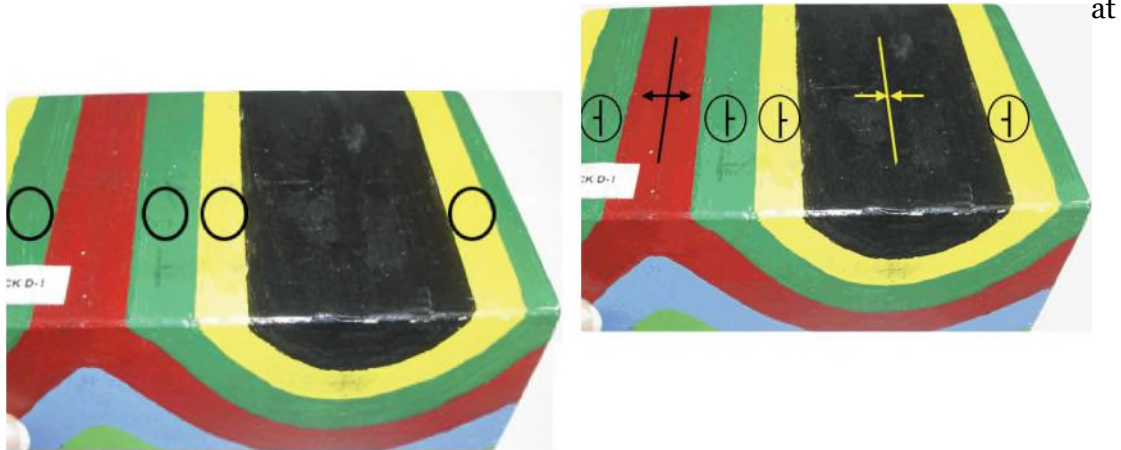
the fold axis in a syncline (Figure 12.16).

Figure 12.14 | A block diagram of an anticline and syncline. Looking from above you see map view, and from the side you observe cross-section view. Determine the strike and dip symbols that should go in the ovals.

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Figure 12.15 | In this block, the strike and dip symbols, along with the symbols for anticline and syncline, have been drawn in for you. Note that on the anticline, the beds dip AWAY from the axis, and the anticline symbol is drawn along the axis, with arrows pointing away from each other. In the syncline, the beds dip TOWARDS each other, with the syncline symbol having arrows that point inwards.

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Figure 12.16 | In the top block (A), you view a typical anticline and syncline. Look at the center of the folds. Are the beds that you see in the center of the anticline older or younger than the beds on either side of it? What about for the syncline? In the lower block (B), you see the top portion of the block removed, done so to simulate erosion of rock layers. Note the pale blue bed in the center of the anticline. It is older than the red bed on either side of it (since it is lower in side view—remember older beds are at the bottom). In the syncline, the black bed in the middle is younger than the yellow beds on either side of it.
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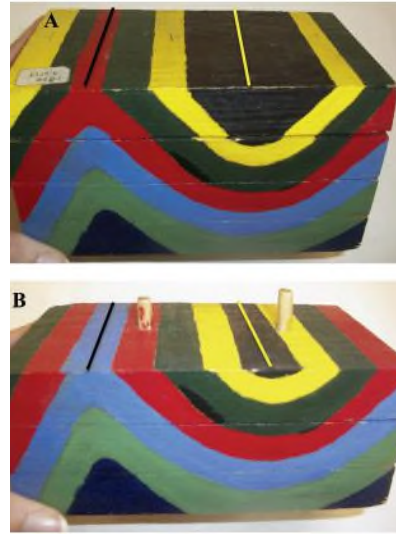
Table 12.1

Fold Type	Direction of dip of layers	Age of beds at axis
Anticline	way from axis	ldest
Syncline	owards the axis	oungest

Imagine you take that same sheet of paper that you originally created a fold with. Create a fold again, but rather than holding it horizontally, plunge one end of your paper down into your desk surface. You have now created a plunging fold, which is essentially a tilted fold that creates a V shaped pattern on the surface (Figures 12.17, 12.18, and 12.19). In an anticline, the oldest strata can be found at the center of the V, and the V points in the direction of the plunge of the fold axis. In a syncline, the youngest strata are found at the center of the V, and the V points in the opposite direction of the plunge of the fold axis.

Similar to anticlines and synclines are domes and basins, which are basically the circular (or elliptical) equivalent of those folds. A **dome** is an upfold similar to an
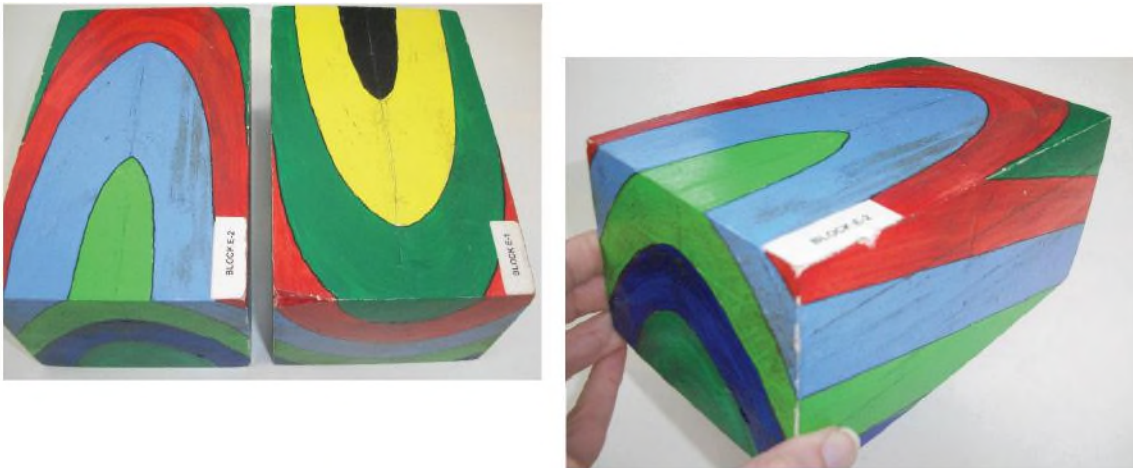
anticline, and a **basin** is an area where

Figure 12.17 | Both blocks are plunging folds. Note the V shape created in map view in a plunging fold. The fold on the left block is a plunging anticline (observe the end of the block to determine this) and the fold on the right block is a plunging syncline.
Author: Randa Harris
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Figure 12.18 | Note this side view of a plunging anticline, to better see how the rock layers plunge into the Earth.
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Figure 12.19 | These blocks depict map view for both plunging and non-plunging folds. The top block is plunging fold, with the characteristic V-shape. The lower block shows map view of non-plunging folds.
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the rocks are inclined downward towards the center, similar to a syncline (Figure 12.20). The key to identifying these structures is similar to identifying the folds. In a dome, the oldest rocks are exposed at the center, and rocks dip away from this central point. In a basin, the youngest rocks are in the center, and the rocks dip inward towards the center.
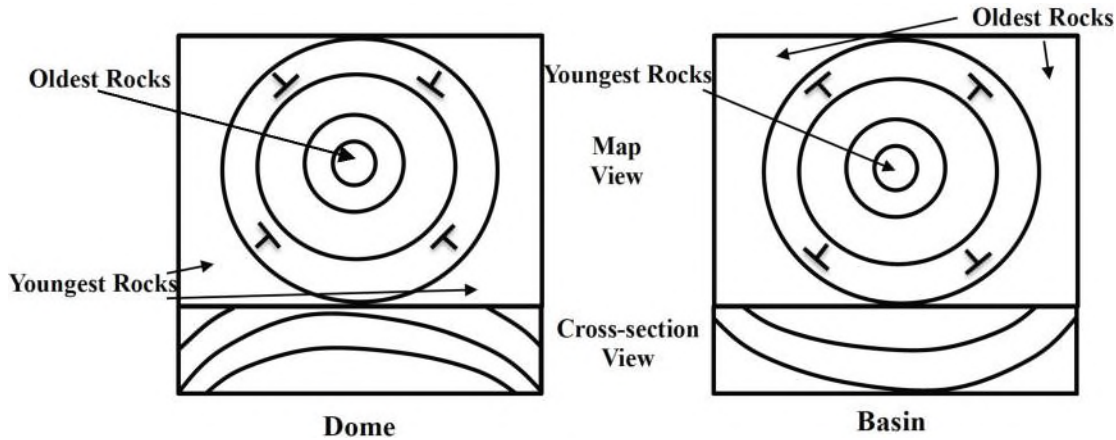
Figure 12.20 | The dome has older rocks in the center, with rocks dipping away from this point, while the basin has rocks dipping inwards and the youngest rocks in the center.
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12.5.2 Faults

As rocks undergo brittle deformation, they may produce cracks in the rocks. If no appreciable displacement has occurred along these cracks, they are called joints.
If appreciable displacement does occur, they are referred to as faults. We will first examine **dip-slip faults**, in which movement along the fault is either up or down.
The two masses of rock that are cut by a fault are termed the fault blocks (Figure 12.21). The type of fault is determined by the direction that the fault blocks have moved.

Fault block movement is described based on the movement of the hanging wall, the fault block located above the fault plane. The other fault block, located beneath the fault plane, is called the foot wall. The term hanging wall comes from the idea that if a miner was climbing along the fault plane, she would hang her lantern above her head, along the hanging wall. Alternately, you can draw a stick figure straight up and down across the fault plane. Its head will be on the hanging wall and its feet will be on the foot wall (Figure 12.22).

Figure 12.21 | Two fault blocks. The fault is the break in the block that separates the two fault blocks. **Author:** Randa Harris **Source:** Original Work **License:** CC BY-SA 3.0

When extensional forces are applied to the fault blocks, the hanging wall will move down, creating what is called a **normal fault** (an easy way to remember this is the phrase "It's normal to fall down"). As this happens, crust is stretched out and lengthened (Figure 12.23).

When compressional forces are applied to the fault blocks, the hanging wall will move up, creating a **reverse fault**. This causes the crust to shorten in the area (Figure 12.24). A special type of reverse fault is a **thrust fault**. It is a low angle reverse fault (with a dip angle of less than 450), and has a much thinner hanging wall.
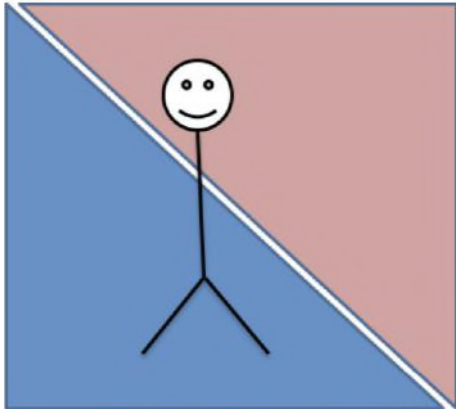
Figure 12.22 | In this image, the head of the stick figure is on the hanging wall (in mauve) and the feet of the stick figure are on the foot wall (in blue).
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Figure 12.23 | The hanging wall, on the right, has moved down relative to the footwall, resulting in a normal fault. Notice how close together the cross symbols were in Figure 12.21, compared to this figure, evidence for the lengthening of the block (along red line).
Author: Randa Harris
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Figure 12.24 | The hanging wall, on the right, has moved up relative to the footwall, resulting in a reverse fault. Note how much closer the cross symbols have become when compared to figure 21, evidence for the shortening of the block.
Author: Randa Harris
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Figure 12.25 | An example of a normal fault near Somerset, UK. Note the fault line in red, and the hanging wall sediments (on the left side) that have moved downward.
Author: Ashley Dace
Source: Wkimedia Commons
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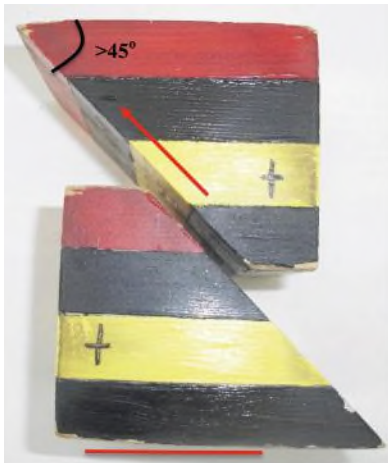
Table 12.2

ault Type	Type of Force	Direction HW moved	Length of Block
ormal	xtensional	own	engthened
everse	ompressional	p	hortened

Tensional forces acting over a region can produce normal faults that result in landforms known as horst and grabens. In **horst and grabens**, the graben is the crustal block that downdrops, and is surrounded by two horsts, the relatively uplifted crustal blocks (Figure 12.26). This terrain is typical of the Basin and Range of the western United States.
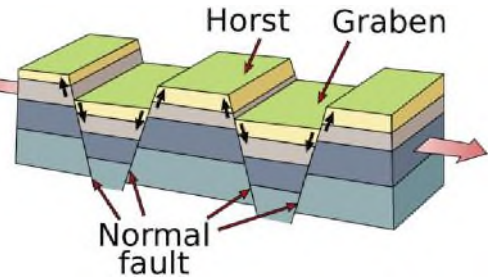
Figure 12.26 | This figure depicts an area that has been stretched by tensional forces, resulting in numerous normal faults and horst and graben landforms.
Author: User "Gregors
Source: Wikimedia Commons
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The previous faults we observed were dip-slip faults, where movement occurred parallel with the fault's dip. In a **strike-slip fault**, horizontal motion occurs (in the direction of strike, hence the name), with blocks on opposite sides of a fault slid-ing past each other due to shear forces. The classic example of a strike-slip fault is the San Andreas Fault in California (Figure 12.27). These faults can be furthered classi-fied as right-lateral or left-lateral. To determine this, an observer would stand along one side of the fault, looking across at the opposite fault block. If that fault block appears to have moved right, it is right-lateral; if it has moved left, it is left-lateral. Figure 12.28 provides all three fault types for your review.
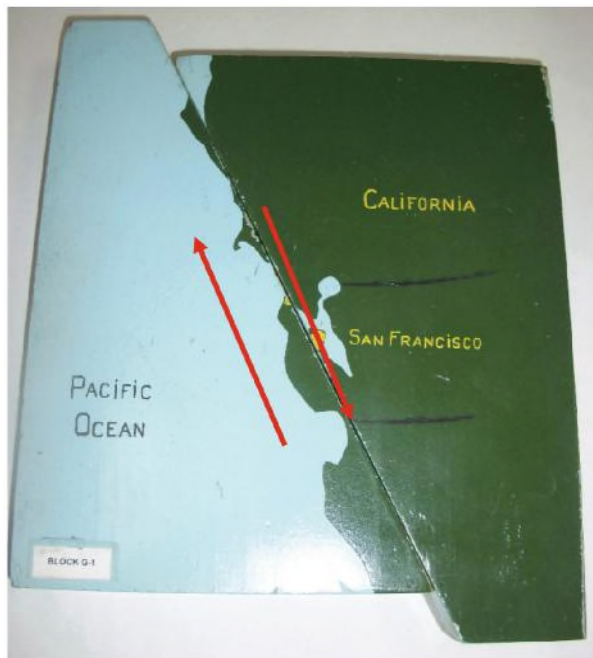

Figure 12.27 | A block diagram of the San Andreas Fault, a right-lateral strike-slip fault.
Author: Randa Harris
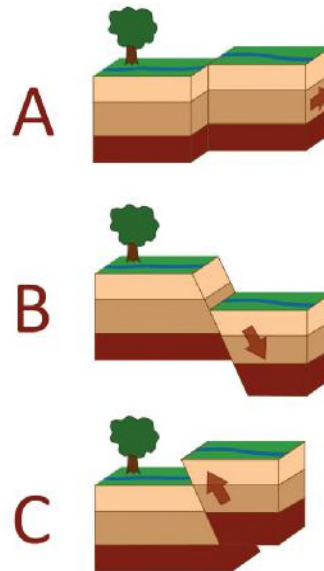**Source:** Original Work
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Figure 12.28 | The three types of faults discussed in this lab. **A** is a strike-slip fault, **B** is a normal fault, and **C** is a reverse fault.
Author: User "Karta24"
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12.6 GEOLOGIC MAPS AND CROSS-SECTIONS

A **geologic map** uses lines, symbols, and colors, to include information about the nature and distribution of rock units within an area. It includes a base map, over which information about geologic contacts and strikes and dips are included. Geologists make these maps by careful field observations at numerous outcrops (exposed rocks at the Earth's surface) throughout the mapping area. At each outcrop, geologists record information such as rock type, strike and dip of the rock layers, and relative age data. Geologic maps take practice to understand, as three-dimensional features (such as folds) are displayed on a two-dimensional surface. Remember that a geologic map will be seen in map view, as we learned about earlier with the block diagrams. Geologists use information about rocks that are exposed to visualize the unseen rocks beneath the surface, enabling them to complete the cross-sectional views we observed in the blocks. You will examine a geologic map for an area in Georgia and construct a **geologic cross-section**. A geologic cross-section shows geologic features from the side view. They are similar to the topographic profiles that you have already created, but include additional information about the rocks present. In order to construct a geologic cross-section, obey the following steps:

1.   Observe the geologic map given. Pay close attention to any strike and dip symbols, geologic contacts, and ages of the rock types.

2.   Take a scratch sheet of paper. Line it up along the line provided across the cross-section.

3.   At each geologic contact, make a mark on the scratch paper. Position the marks in the direction you believe the rocks are dipping (To determine this, use strike and dip symbols. If they are not provided, use the Rule of V's or the ages given to help determine the geologic structure).

4.   Transfer the marks from your paper to a provided diagram.

5.   Sketch in the structure, paying careful attention to dip angles (if provided). Structures may be drawn in with a dotted line above the Earth's surface to indicate rocks that were formerly present but that have since been eroded.

There are some helpful hints to remember when constructing a cross-section:

1.   Anticlines – these folds have the oldest beds in the middle, with beds dipping away from the axis. Plunging anticlines plunge towards the closed end of the V.

2.   Synclines – these folds have the youngest beds in the middle, with beds dipping towards the axis. Plunging synclines plunge towards the open end of the V.

3.   As streams intersect dipping beds of rock, they will cut V shapes in the direction of dip.

Figure 12.29 provides an example of a simple geologic cross-section, based off ages of the rock units.
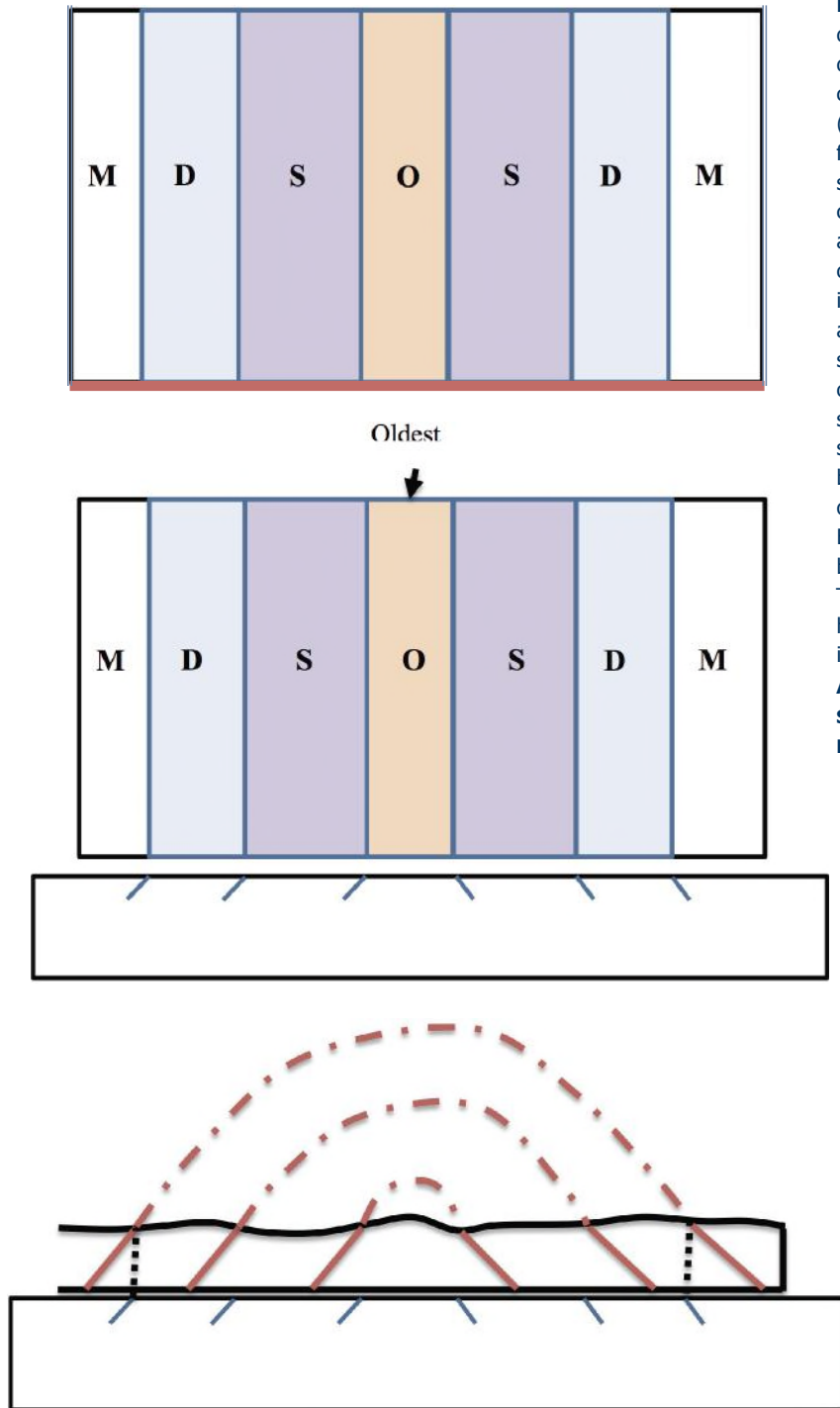

Figure 12.29 | The top figure displays the geologic map, with different rock units of different colors, and age information given (see Figure 12.30). In the second figure, the scratch sheet of paper is stretched along the bottom of the cross-section, and a mark is made at each geologic contact. Since the oldest bed is in the middle, this indicates that this structure is an anticline, so beds have been drawn so that they dip away from each other. In the bottom image, the scratch paper has been superimposed and contacts have been drawn in (as indicated by the dashed lines on each end mark). Beneath the surface, contacts have been drawn in using a solid line. The beds above the surface that have since eroded have been drawn in with a dashed line.

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Age of Rocks		Geologic Age Symbol	Geologic Time Period
Youngest		Q	Quaternary
		T	Tertiary
		K	Cretaceous
		J	Jurassic
		Tr	Triassic
		P	Permian
		lP	Pennsylvanian
		M	Mississippian
		D	Devonian
		S	Silurian
		O	Ordovician
		-C	Cambrian
Oldest		p-C	PreCambrian

Figure 12.30 | Guide to rock ages.
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Map Symbol	Explanation
⊢	Strike & Dip
✝	Vertical strata

⊣⊢	Syncline axis
↗✗	Plunging anticline axis
✗↗	Plunging syncline axis
⌇⌇	Strike-slip fault

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⊕	Horizontal strata
┼	Anticline axis

12.7 PRACTICE WITH BLOCK DIAGRAMS

For practice, complete the questions below about block diagrams. A key is provided after this section to check your work.

For each diagram, draw in the geological contacts on each side of the block. Add strike and dip symbols, and other symbols to document geologic features (like direction of movement on faults). Also state the name of the geology feature in the diagram.

1
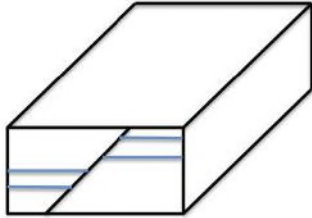
3
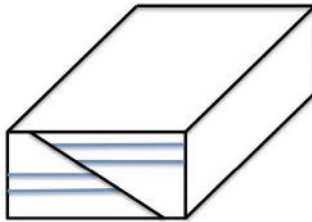
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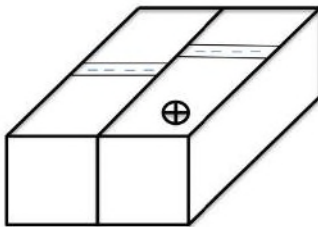
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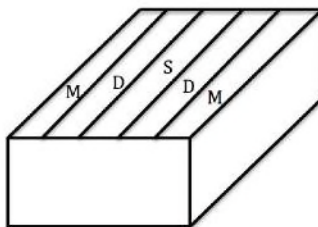
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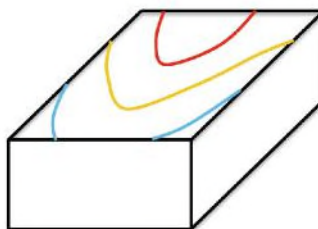
12.8 ANSWERS TO PRACTICE WITH BLOCK DIAGRAMS

1.   NORMAL FAULT
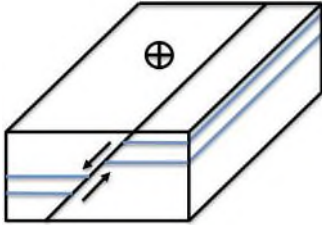
2.   REVERSE FAULT
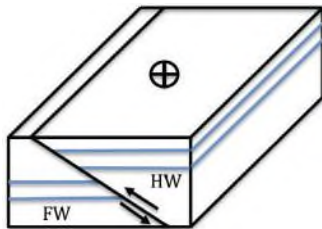
3.   STRIKE-SLIP FAULT
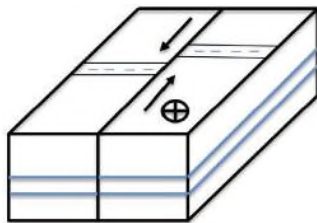
4.   ANTICLINE
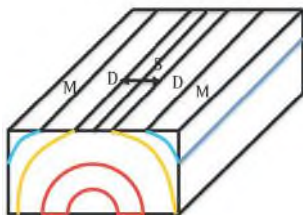
5.   PLUNGING SYNCLINE
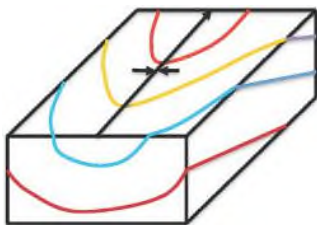
12.8 LAB EXERCISE

Student Responses   Name _____

This Lab Assignment must be mailed to your Instructor. There is no online assessment for the Crustal Deformation Lab.

Complete the entire assignment and mail to your instructor postmarked by the assessment deadline. You should make an extra copy to practice on and mail in a clean and neat version for grading. Make sure to include your name and staple all of the pages together. It is a good idea to make a copy of what you mail in, just in case it gets lost in the mail. **For several parts of this lab there are multiple interpretations! Ask if you have questions.**

Part A (6 pts) Circle the correct answer to the following questions.

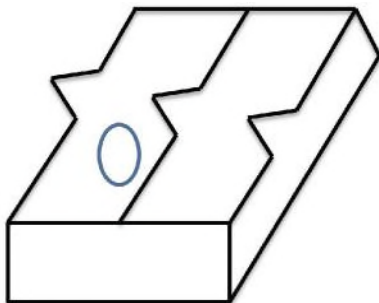1. For the following diagram, determine the correct map symbol that would go in the oval box.

   a.   b.   c.   d

2. For the following diagram, determine the correct map symbol that would go in the oval box.


   a.   b.   c.   d

3. Using Google Earth, search for the following area in Pakistan: **27 50 35.00N 67 10 03.70E**. Zoom out to an eye altitude of approximately 25,000 feet. The inclined layers in these folded rocks can be easily seen. As you view them, in which compass direction are the beds dipping?

a. Northeast (NE) b. Southeast (SE) c. Northwest (NW) d. Southwest (SW)

Part B (24 pts)

For each of the following block diagrams complete the following: 1- Complete the diagram drawing in geological contacts on each side of the block; 2- Add symbols indicating the strike and dip of each geological layer as well as symbols documenting any other geological features (include the direction of movement for any faults); 3- In the space provided under the block diagram write the specific name of the geology feature in the block diagram. Please note that in several of the blocks the ages of the layers are provided.
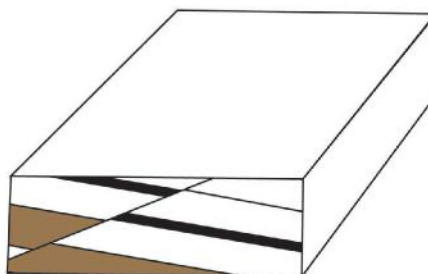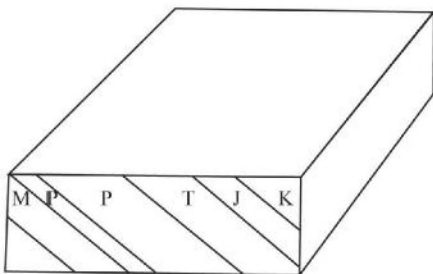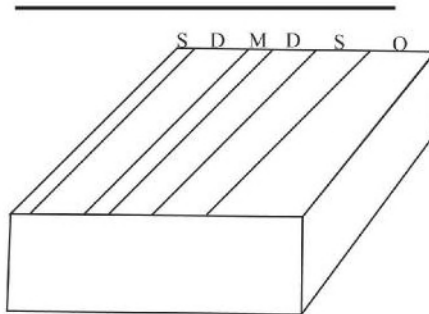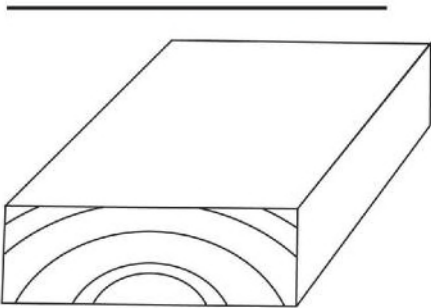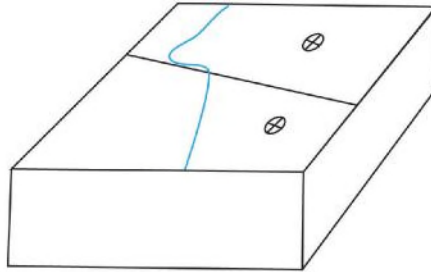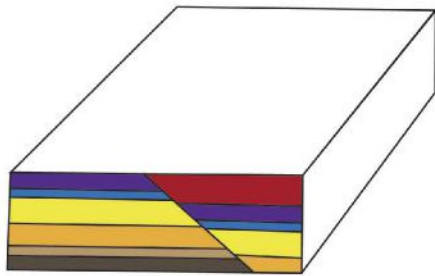
Part C (20 pts)

At the end of the lab there are two full-page block diagrams. Cut along the dashed lines and fold along the solid lines to examine the block in three dimensions. For each of the block diagrams complete the following: 1- Complete the diagram drawing in geological contacts on each side of the block; 2- Add symbols indicating the strike and dip of each geological layer as well as symbols documenting any other geological features; 3- Identify the geologic structure presented on the block and write the name of the structure on the top surface of the block. Please unfold the blocks flat to mail in to your instructor.

Part D (24 pts)

The geological map on the following page is from the Paleozoic rocks in the Northwest Georgia Mountains. Please refer to the key to rocks and their ages present on the map in order to answer the questions. Note that the rock key is in chronological order with the oldest rocks on the bottom (Conasauga shale) and the youngest rocks on top (Pennsylvanian Fm).

Cpv	Pennsylvanian Fm
Cbp	Mississippian Fm
Dc	Chattanooga shale
Srm	Red Mountain Fm
Om	Upper Chickamauga Ls
Osr	Lower Chickamauga (Stones River)
On	Newala limestone (Upper Knox)
Oϵk	Knox dolomite
ϵc	Conasauga shale
ϵr	Rome Fm
ϵs	Shady dolomite
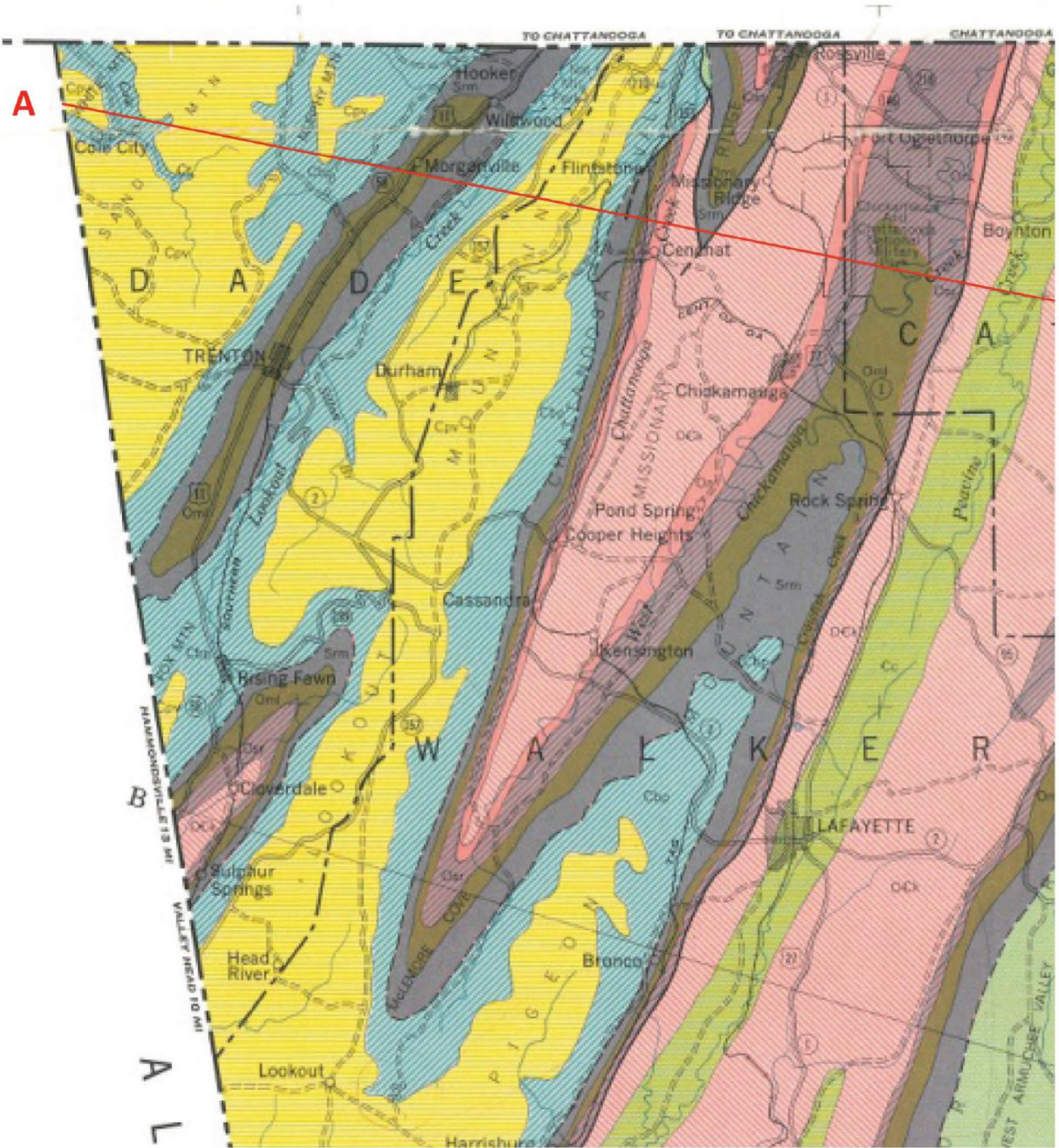
(6 pts) Examine the map and the ages of the rock layers. Based on your interpretation, label the structures and add appropriate symbols to the map to show the axis of the folds. What kind of folds are present in this area? Explain how you came to this conclusion.

(6 pts) Along the red line starting at point 'A' there are four faults indicated by bold black lines (they are also marked on the cross section in Part C). Examine the age of the rocks and the faults themselves. What type of faults are these? Explain how you came to this conclusion.

(12 pts) Complete the following geological cross section based on your understanding of the geological structures present in the area.
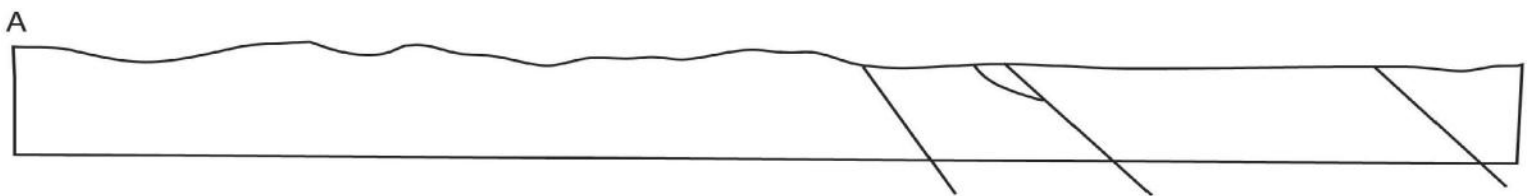
Part E - Google Earth. (26 pts)

Search for **38 04 36.00N 109 55 26.61 W** and zoom to an eye altitude of 20,000 ft, make sure to note your geographic location. (hint: re-read the section in the course content unit on Faults and in this lab manual)

You are looking at the surface expression of many fault lines (fault scarp) with the hanging wall occupying the valleys and the foot wall

representing the plateaus, what kind of faults are they?

b.   What would we call these paired features?

c.What type of stress created these features?

d.   The amount of displacement (extension or shortening) in the area can be calculated by the following equation based on the angle of the fault surface:
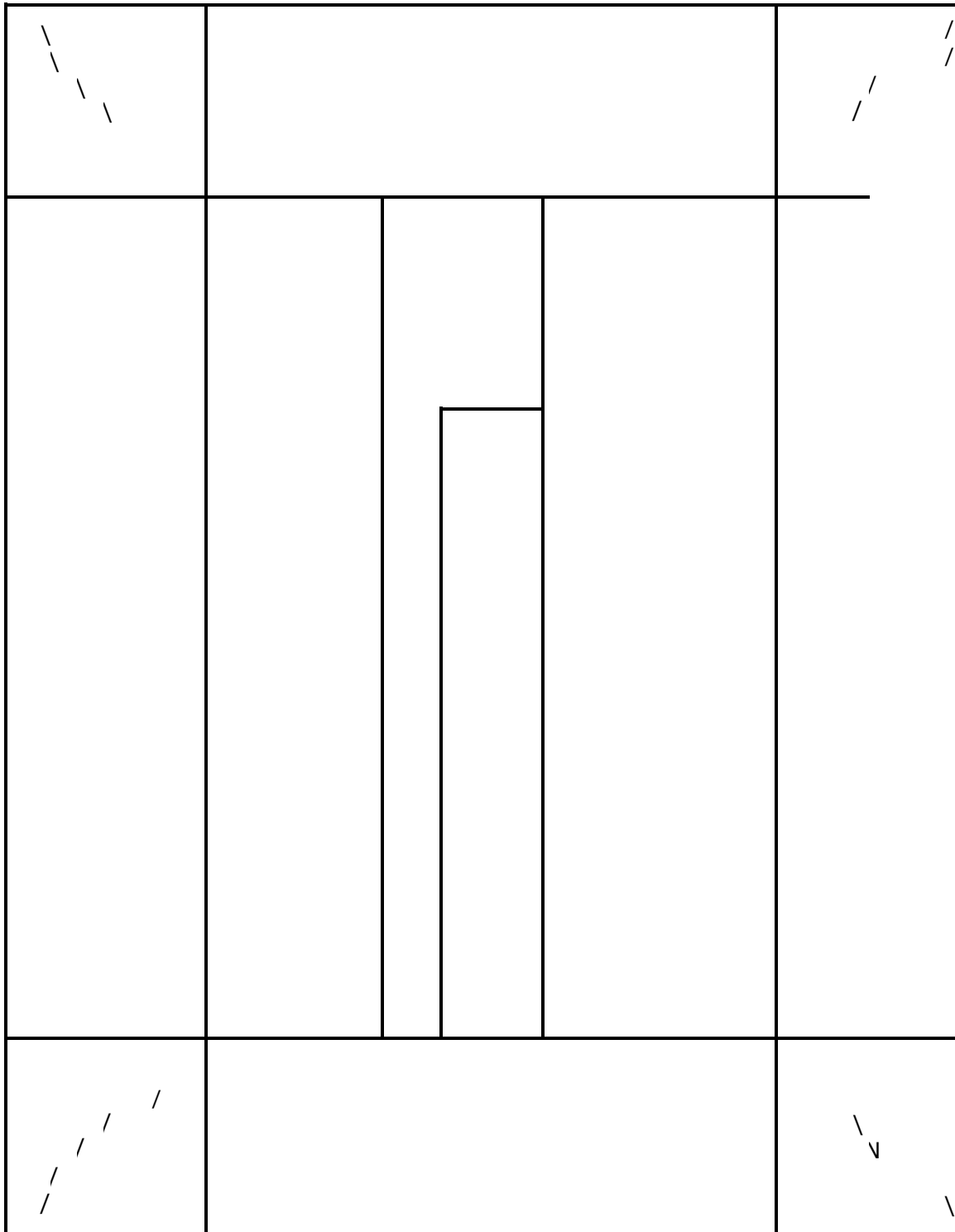
Amount of horizontal displacement = Vertical displacement along the fault surface (ft)/5.67

Measure the change in elevation of one of these features to determine the amount of extension in the area (Show your work, but feel free to use a calculator).

e.   How many of these faults would you need to make this area (Utah) a mile longer? Remember there are 5,280 feet in a mile.

8.   Search for **22 48 45.63S 117 20 12.85E** and zoom to an eye altitude of 25 miles. This feature is caused by the folding of rocks.

a.   Imagine you are a geologist trying to determine what is going on in the area. How could you tell if this large bullseye structure is a dome or a basin (State whether this is a dome or basin, and give two different ways to tell them apart)?

b.   Examine the feature ~10 miles southwest of the previous feature. Is this fold horizontal or plunging, how can you tell?

(Part ('-I)

(Part C-2)