LAB 10: STRUCTURAL GEOLOGY PART II

Lab Structure

Recommended additional work	Yes – review for final lab project
Required materials	Printed block models 1 to 6, pencil, pencil crayons, ruler, protractor

Learning Objectives

After carefully reading this chapter, completing the exercises within it, and answering the questions at the end, you should be able to:

- Describe the types of stresses that exist within the Earth's crust.
- Explain how rocks respond to those stresses by brittle, elastic, or plastic deformation, or by fracturing.
- Summarize how rocks become folded and know the terms used to describe the features of folds.
- Summarize the different types of faults, including normal, reverse, thrust, and strike-slip.
- Visualize layers of rocks that form complex geologic structures in three-dimensional space.
- Recognize and describe geologic structures in block models and on geological maps.
- Describe the geologic history of a structurally complex area.

Key Terms

- Stress
- Strain
- Compression
- Tension
- Shear
- Ductile
- Brittle
- Deformation
- Anticline
- Syncline
- Limbs
- Axial plane
- Hinge zone
- Fracture
- Hanging wall
- Footwall
- Normal fault
- Reverse fault
- Strike-slip fault
- Left-lateral
- Right-lateral

Observing and understanding geological structures helps us to determine the kinds of stresses that have existed within Earth's crust in the past. This type of information is critical to our understanding of plate tectonics, earthquakes, the formation of mountains, metamorphism, and Earth resources. Some of the types of geological structures that are important to study include bedding planes, planes of foliation, dykes and sills, fractures, faults, and folds. Structural geologists make careful observations of the orientations of these structures and the amount and direction of offset along faults. Locating and mapping these structural features is important for safe engineering of infrastructure such as roads and housing. A good understanding of geological structures in the subsurface is also critical for mineral and petroleum exploration.

10.1 Stress and Strain

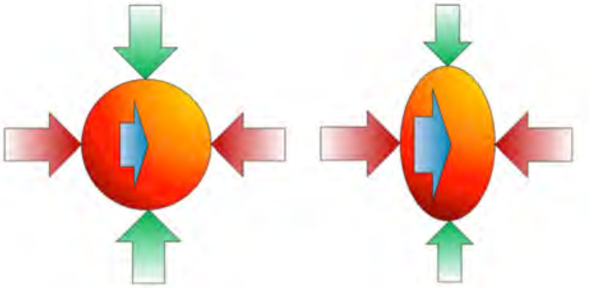

Figure 10.1.1: Depiction of the stress applied to rocks within the crust. The stress can be broken down into three components. Assuming that we're looking down in this case, the green arrows represent north-south stress, the red arrows represent east-west stress, and the blue arrows (the one underneath is not visible) represent up-down stress. On the left, all of the stress components are the same. On the right, the north-south stress is least and the up-down stress is greatest.

Rocks are subject to **stress**—mostly related to plate tectonics but also to the weight of overlying rocks—and their response to that stress is **strain** (**deformation**). In regions close to where plates are converging stress is typically **compressional**—the rocks are being squeezed. Where plates are diverging the stress is **tensional**—rocks are being pulled apart. At transform plate boundaries, where plates are moving side by side there is sideways or **shear stress**—meaning that there are forces in opposite directions parallel to a plane. Rocks have highly varying strain responses to stress because of their different compositions and physical properties, and because temperature is a big factor and rock temperatures within the crust can vary greatly.

We can describe the stress applied to a rock by breaking it down into three dimensions—all at right angles to one-another (Figure 10.1.1). If the rock is subject only to the pressure of burial, the stresses in all three directions will likely be the same. If it is subject to both burial and tectonic forces, the pressures will be different in different directions.

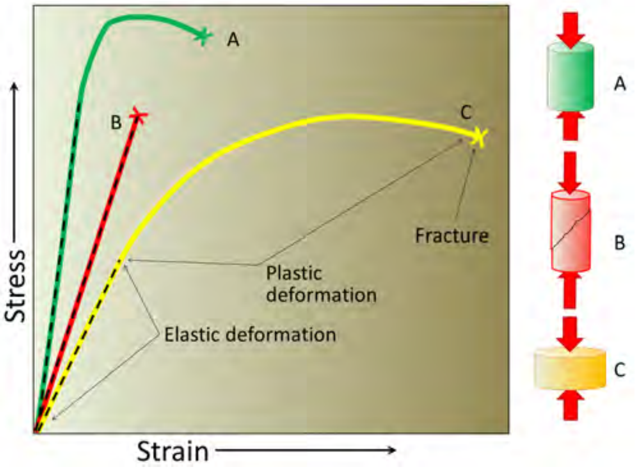

Figure 10.1.2: The varying types of response of geological materials to stress. The straight dashed parts are elastic strain and the curved parts are plastic strain. In each case the X marks where the material fractures. A, the strongest material, deforms relatively little and breaks at a high stress level. B, strong but brittle, shows no plastic deformation and breaks after relatively little elastic deformation. C, the most deformable, breaks only after significant elastic and plastic strain. The three deformation diagrams on the right show A and C before breaking and B after breaking.

Rock can respond to stress in three ways: it can deform elastically, it can deform plastically, and it can break or fracture. **Elastic strain** is reversible; if the stress is removed, the rock will return to its original shape just like a rubber band that is stretched and released. **Plastic strain** is not reversible. As already noted, different rocks at different temperatures will behave in different ways to stress. Higher temperatures lead to more plastic behaviour. Some rocks or sediments are also more plastic when they are wet. Another factor is the rate at which the stress is applied. If the stress is applied quickly (for example, because of an extraterrestrial impact or an earthquake), there will be an increased tendency for the rock to fracture. Some different types of strain response are illustrated in Figure 10.1.2.

The outcomes of placing rock under stress are highly variable, but they include fracturing, tilting and folding, stretching and squeezing, and faulting. A **fracture** is a simple break that does not involve significant movement of the rock on either side. Fracturing is particularly common in volcanic rock, which shrinks as it cools. The basalt columns in Figure 10.1.3a are a good example of fracture. Beds are sometimes tilted by tectonic forces, as shown in Figure 10.1.3b, or folded.

a) Fracturing in basalt near to Whistler BC

b) Tilting of sedimentary rock near to Exshaw, AB

a) Stretching of limestone at Quadra Island, BC. The light grey rock is limestone and the dark rock is chert. The body of rock has been stretched parallel to bedding. The chert, which is not elastic, has broken into fragments which are called **boudins**.

d) Faulting within shale beds at McAbee, near to Cache Creek, BC. The fault runs from the lower right to the upper left, and the upper rock body has been pushed up and to the left.

Figure 10.1.3: Rock structures caused by various types of strain within rocks that have been stressed.

When a body of rock is compressed in one direction it is typically extended (or stretched) in another. This is an important concept because some geological structures only form under compressional stress, while others only form under tensional stress. Most of the rock in Figure 10.1.3c is limestone, which is relatively weak and easily deformed when heated. The dark rock is chert, which is relatively stronger and remains brittle. As the limestone stretched (parallel to the hammer handle) the brittle chert was forced to break into fragments to accommodate the change in shape of the body of rock. Figure 10.1.3d shows another type of brittle structure called a **fault.** Like fractures, faults result from brittle breaking of a rock unit. The key difference is that the bodies of rock on either side of the fault have been displaced relative to each other by the faulting.

Media Attributions

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10.2 Folding

When a body of rock, especially sedimentary rock, is squeezed from the sides by tectonic forces, it is likely to fracture and/or become faulted if it is cold and brittle, or become folded if it is warm enough to behave in a ductile manner.

The nomenclature and geometry of folds are summarized in Figure 10.2.1. An upward fold is called an **anticline** (or, more accurately, an antiform if we don't know if the beds have been overturned or not), while a downward fold is called a **syncline**, (or a synform if we don't if the beds have been overturned). In many areas it's common to find a series of antiforms and synforms (as in Figure 10.2.1), although some sequences of rocks are folded into a single antiform or synform. A plane drawn through the crest of a fold in a series of beds is called the **axial plane** of the fold. The sloping beds on either side of an axial plane are called the **limbs** of the fold. An antiform or synform is described as **symmetrical** if the angles between each of limb and the axial plane are generally similar, and **asymmetrical** if they are not. If the axial plane is sufficiently tilted that the beds on one side have been tilted past vertical, the fold is known as an **overturned** antiform or synform.

If the limbs dip away from one another, they form an antiform. If the limbs dip toward one another, they form a synform.

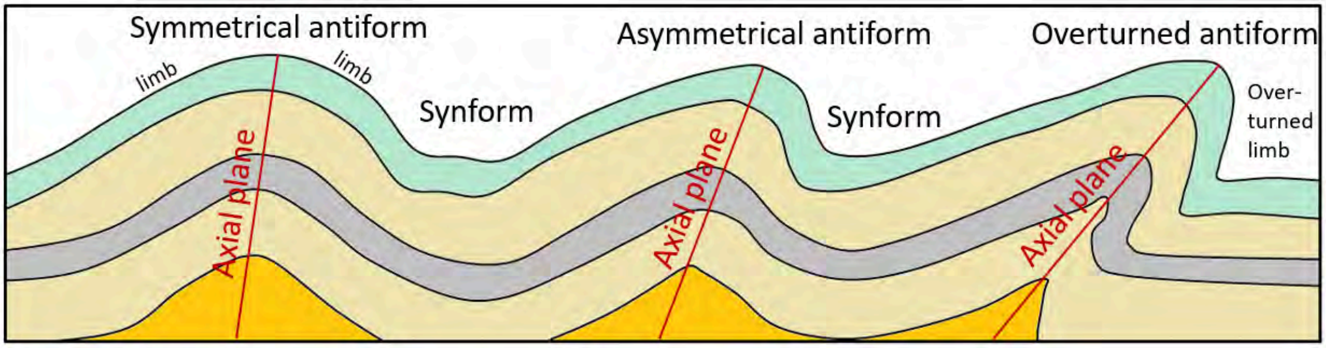

Figure 10.2.1: Examples of different types of folds and fold nomenclature. Axial planes are only shown for the anticlines, but synclines also have axial planes.

A very tight fold, in which the limbs are parallel or nearly parallel to one another is called an **isoclinal fold** (Figure 10.2.2). Isoclinal folds that have been overturned to the extent that their limbs are nearly horizontal are called **recumbent folds**.

Folds can be of any size, and it's very common to have smaller folds within larger folds (Figure 10.2.3). Large folds can have wavelengths of tens of kilometres, and very small ones might be visible only under a microscope.

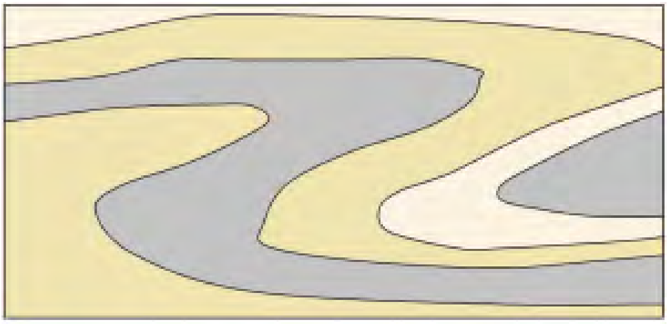

Figure 10.2.2: An isoclinal recumbent fold.

Figure 10.2.3: Folded limestone (grey) and chert (rust-coloured) in Triassic Quatsino Formation rocks on Quadra Island, B.C. The image is about 1 metre across.

Antiforms are not necessarily, or even typically, expressed as ridges in the terrain, nor synforms as valleys. Folded rocks get eroded just like all other rocks and the topography that results is typically controlled mostly by the resistance of different layers to erosion (Figure 10.2.4).

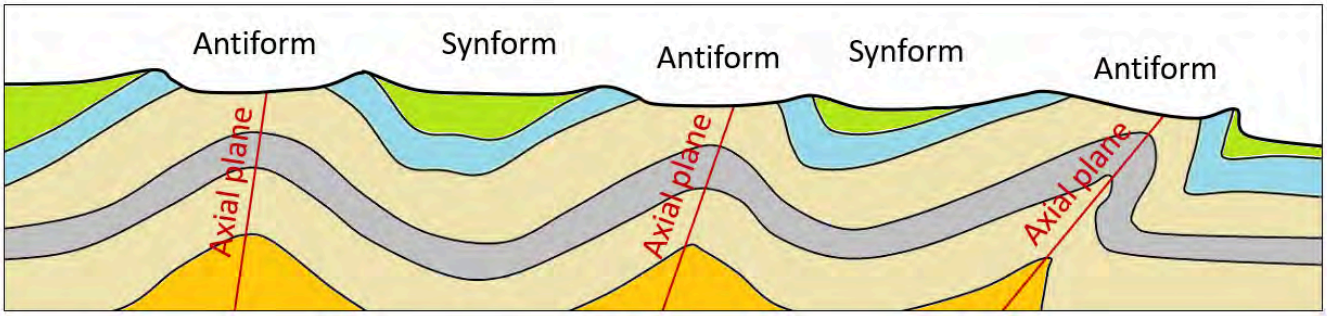

Figure 10.2.4: Example of the topography in an area of folded rocks that has been eroded. In this case the blue and green rocks are most resistant to erosion, and are represented by hills. The pale cream-coloured rocks are the least resistant to erosion, and are represented by valleys.

As folded rocks are eroded away, anticlines and synclines can be recognized not only by the dip directions of their limbs, but also by examining their map patterns in plan view (Figure 10.2.5). Eroded anticlines expose older rocks near the surface trace of the axial plane, and the rocks get progressively younger as you move away from the axial plane in either direction. Eroded synclines have the youngest rocks exposed near the surface trace of the axial plane, and the rocks get progressively older as you move away from the axial plane in either direction. Examine Figure 10.2.5 to confirm this: the youngest rock in the diagram (labeled '6') is exposed in the centre of the syncline, whereas the oldest rock visible in plan view is exposed in the centre of the anticline (labeled as '4').

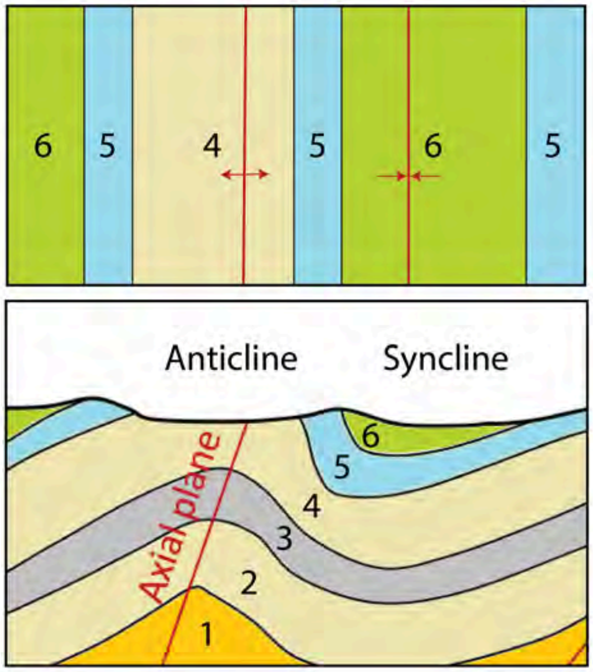

Figure 10.2.5: Plan view (top) and cross-section (bottom) of a portion of Figure 10.2.4. Numbers 1 to 6 refer to the relative ages of the layers, where 1 is the oldest and 6 is the youngest. The surface traces of the axial planes are shown for both the anticline and the syncline (red lines with arrows).

Practice Exercise 10.1 Folding style

Figure 10.2.6 shows folding near near Golden, B.C. in the Rocky Mountains. Describe the types of folds using the appropriate terms from above (symmetrical, asymmetrical, isoclinal, overturned, recumbent etc.). You might find it useful to first sketch the outcrop by tracing one or two beds to get a better idea of the shapes of the folds, then sketch in the axial planes.

Figure 10.2.6

See Appendix 2 for Practice Exercise 10.1 answers.

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10.3 Faulting

A body of rock that is brittle—either because it is cold or because of its composition, or both— is likely to break rather than fold when subjected to stress, and the result is fracturing or faulting.

Fracturing

Fracturing is common in rocks near the surface, either in volcanic rocks that have shrunk on cooling (Figure 10.1.3a), or in other rocks that have been exposed by erosion and have expanded (Figure 10.3.1). Fractures, by definition, do not displace rock. There is no movement on a fracture plane.

Figure 10.3.1: Granite in the Coquihalla Creek area, B.C. (left) and sandstone at Nanoose, B.C. (right), both showing fracturing that has resulted from expansion due to removal of overlying rock.

Faulting

A fault is a boundary between two bodies of rock along which there has been relative motion (Figure 10.1.3d). You may recall from lecture that an earthquake involves the sliding of one body of rock past another. Earthquakes don't necessarily happen on existing faults, but once an earthquake takes place a fault will exist in the rock at that location. Some large faults, like the San Andreas Fault in California or the Tintina Fault, which extends from northern B.C. through central Yukon and into Alaska, show evidence of hundreds of kilometres of motion, while others show less than a millimetre. In order to estimate the amount of motion on a fault, we need to find some geological feature that shows up on both sides and has been offset (Figure 10.3.2).

Figure 10.3.2: A fault (white dashed line) in intrusive rocks on Quadra Island, B.C. The pink dyke has been offset by the fault and the extent of the offset is shown by the white arrow (approximately 10 centimetres). Because the far side of the fault has moved to the right, this is a right-lateral fault. If the photo were taken from the other side, the fault would still appear to have a right-lateral offset.

There are several kinds of faults, as illustrated on Figure 10.3.3, and they develop under different stress conditions. The terms **hanging wall** and **footwall** in the diagrams apply to situations where the fault is not vertical. The body of rock above the fault is called the hanging wall, and the body of rock below it is called the footwall. If the fault develops in a situation of compression, then it will be a **reverse fault** because the compression causes the hanging wall to be pushed up relative to the footwall. If the fault develops in a situation of extension, then it will be a **normal fault**, because the extension allows the hanging wall to slide down relative to the footwall in response to gravity. The map symbols for these types of faults are illustrated in Figure 10.3.4.

The third situation is where the bodies of rock are sliding sideways with respect to each other, as is the case along a transform fault (see Lab 1). This is known as a **strike-slip fault** because the displacement is along the "strike" or the length of the fault. On strike-slip faults the motion is typically only horizontal, or with a very small vertical component, and as discussed above the sense of motion can be right lateral (the far side moves to the right), as in Figure 10.3.2, or it can be left lateral (the far side moves to the left). Map symbols for these strike-slip faults are illustrated in Figure 10.3.5. Transform faults are strike-slip faults.

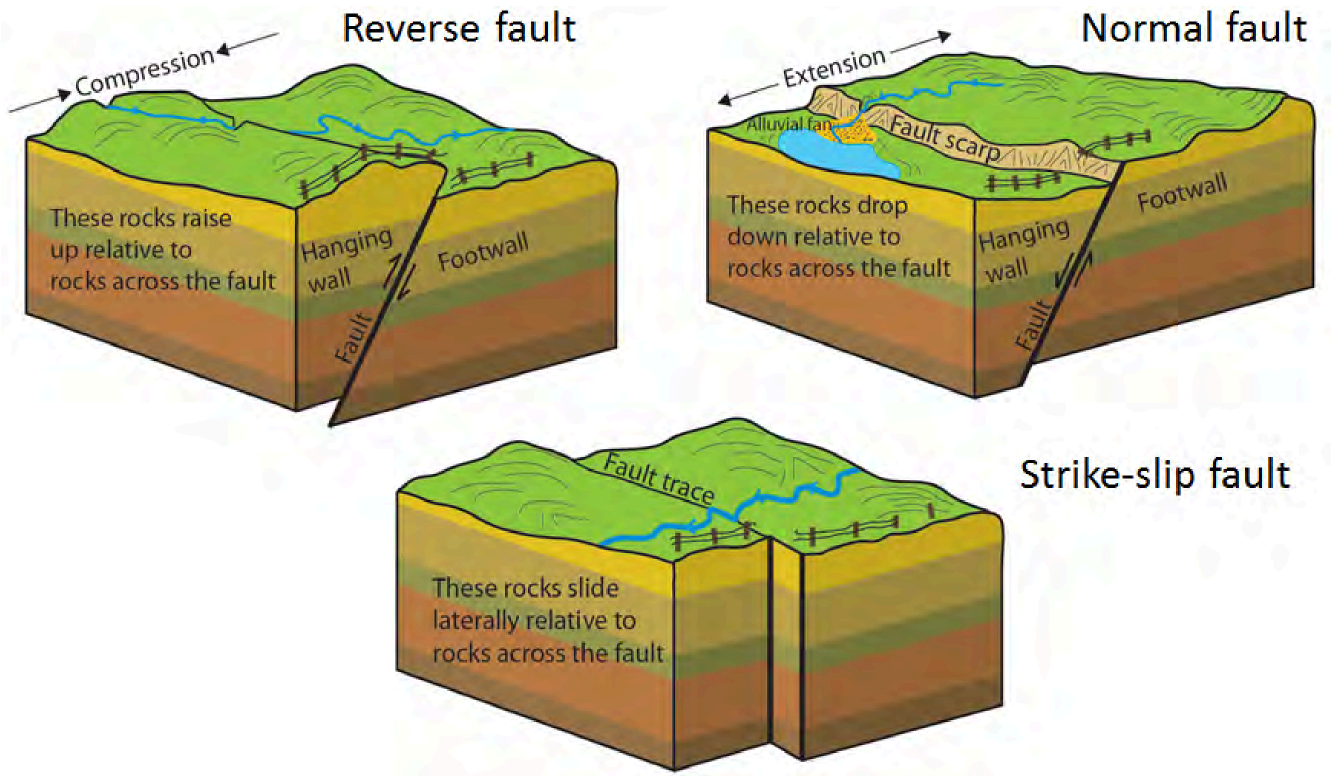

Figure 10.3.3: Depiction of reverse, normal, and strike-slip faults. Reverse faults happen during compression while normal faults happen during extension. Most strike-slip faults are related to transform boundaries.

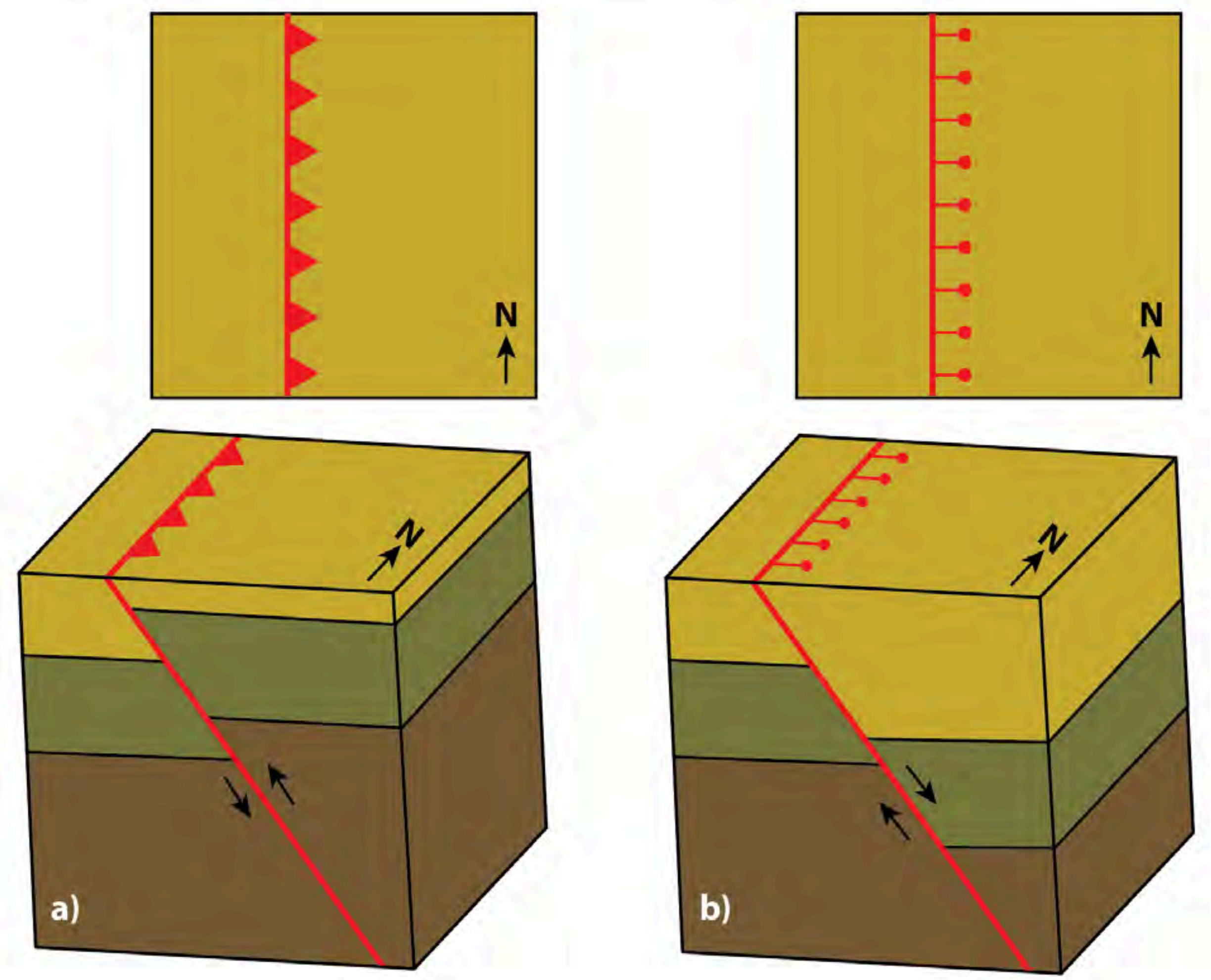

Figure 10.3.4: Block model and corresponding plan view depictions of reverse (a) and normal (b) faulting. Black arrows on the south-facing side of each block indicate the sense of displacement along the fault. Symbols in plan view indicate the type of fault and are always drawn on the hanging wall side.

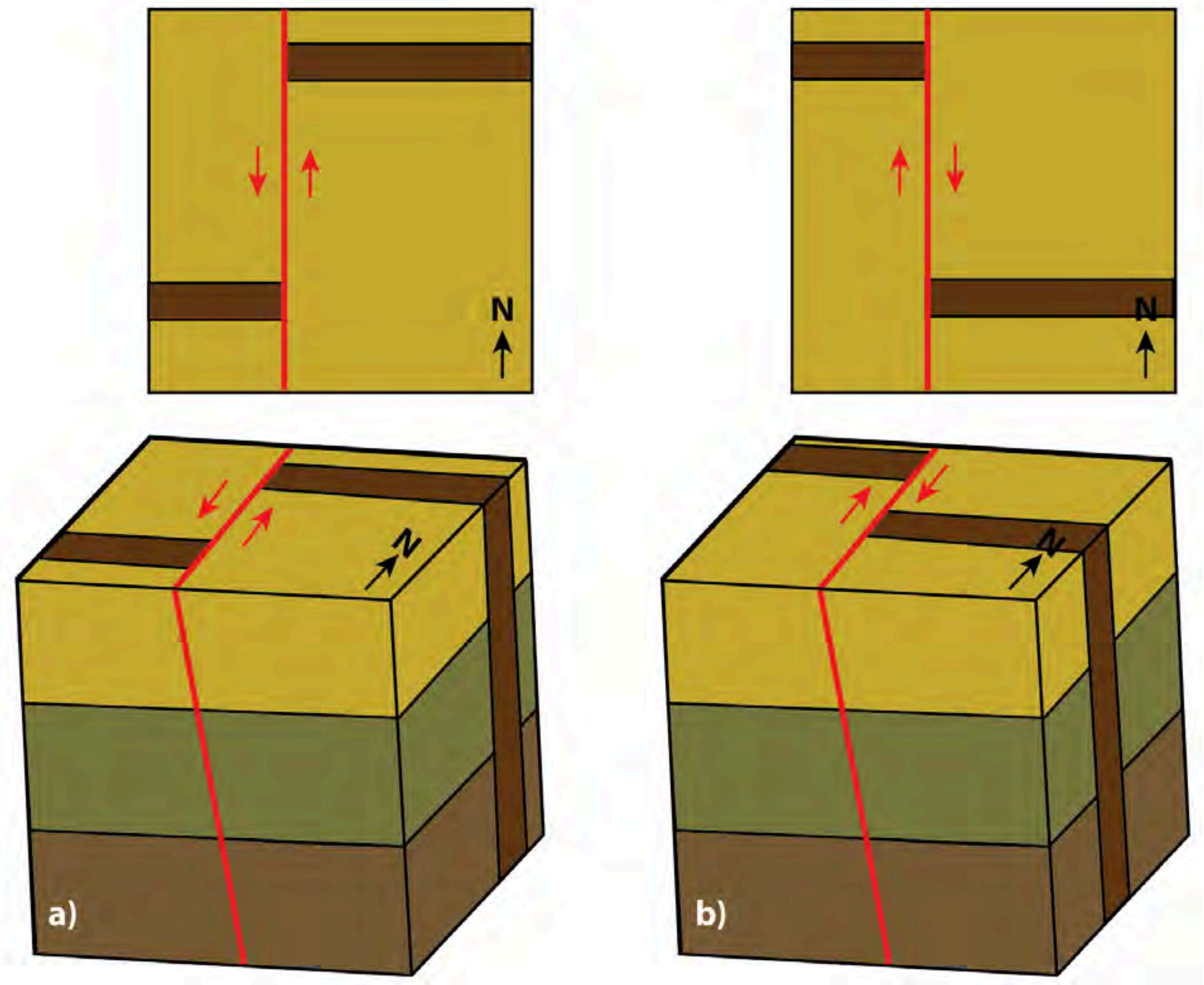

Figure 10.3.5: Block model and plan view depictions of left-lateral (a) and right-lateral (b) strike-slip faulting resulting in the offset of a dyke in plan view. Symbols in plan view indicate the sense of displacement along the fault.

In areas that are characterized by extensional tectonics, it is not uncommon for a part of the upper crust to subside with respect to neighbouring parts. This is typical along areas of continental rifting, such as the Great Rift Valley of East Africa or in parts of Iceland, but it is also seen elsewhere. In such situations a down-dropped block is known as a **graben**(German for ditch), while an adjacent block that doesn't subside is called a **horst** (German for heap) (Figure 10.3.6). There are many horsts and grabens in the Basin and Range area of the western United States, especially in Nevada.

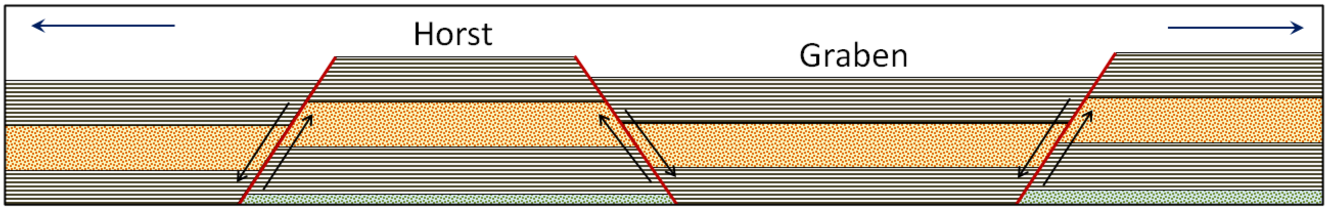

Figure 10.3.6: Depiction of graben and horst structures that form in extensional situations. All of the faults are normal faults.

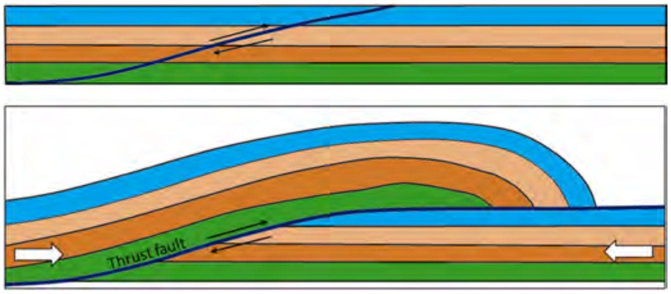

Figure 10.3.7: Depiction a thrust fault. Top: prior to faulting. Bottom: after significant fault offset.

A special type of reverse fault, with a very low-angle fault plane, is known as a **thrust fault**. Thrust faults are relatively common in areas where fold-belt mountains have been created during continent-continent collision. Some represent tens of kilometres of thrusting, where thick sheets of sedimentary rock have been pushed up and over top of other rock (Figure 10.3.7).

There are numerous thrust faults in the Rocky Mountains, and a well-known example is the McConnell Thrust, along which a sequence of sedimentary rocks about 800 metres thick has been pushed for about 40 kilometres from west to east (Figure 10.3.8). The thrusted rocks range in age from Cambrian to Cretaceous, so in the area around Mt. Yamnuska Cambrian-aged rock (around 500 Ma) has been thrust over, and now lies on top of Cretaceous-aged rock (around 75 Ma) (Figure 10.3.9).

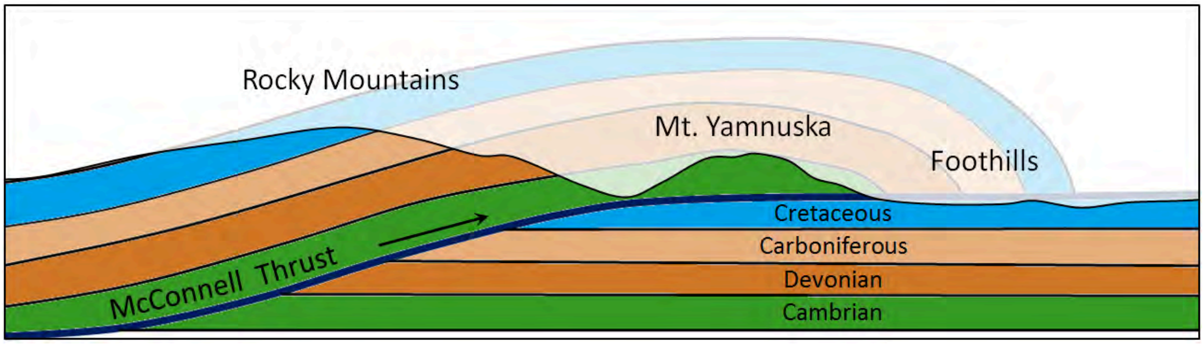

Figure 10.3.8: Depiction of the McConnell Thrust in the eastern part of the Rockies. The rock within the faded area has been eroded

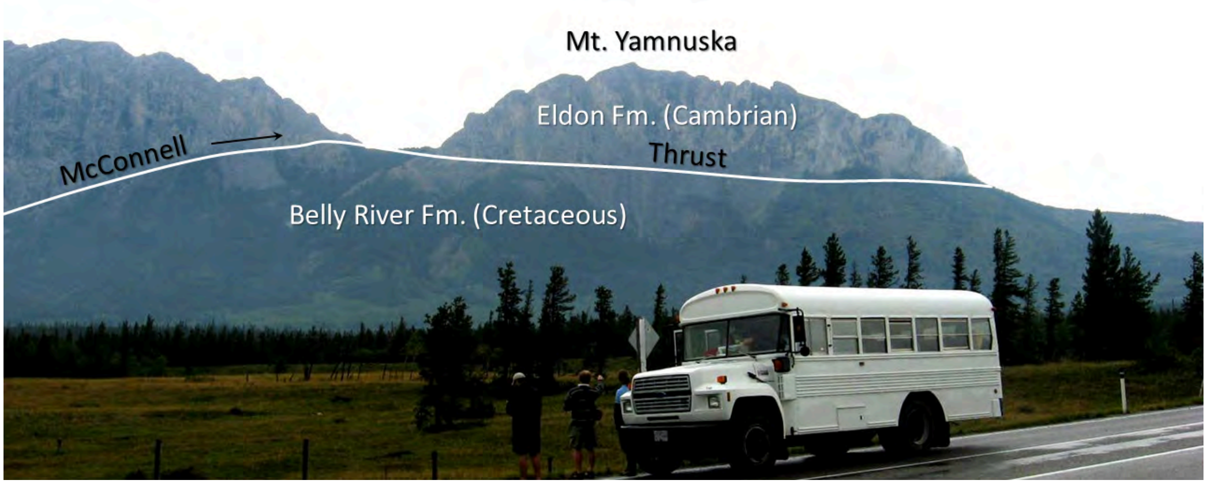

Figure 10.3.9: The McConnell Thrust at Mt. Yamnuska near Exshaw, Alberta. Carbonate rocks (limestone) of Cambrian age have been thrust over top of Cretaceous mudstone.

Practice Exercise 10.2 Types of faults

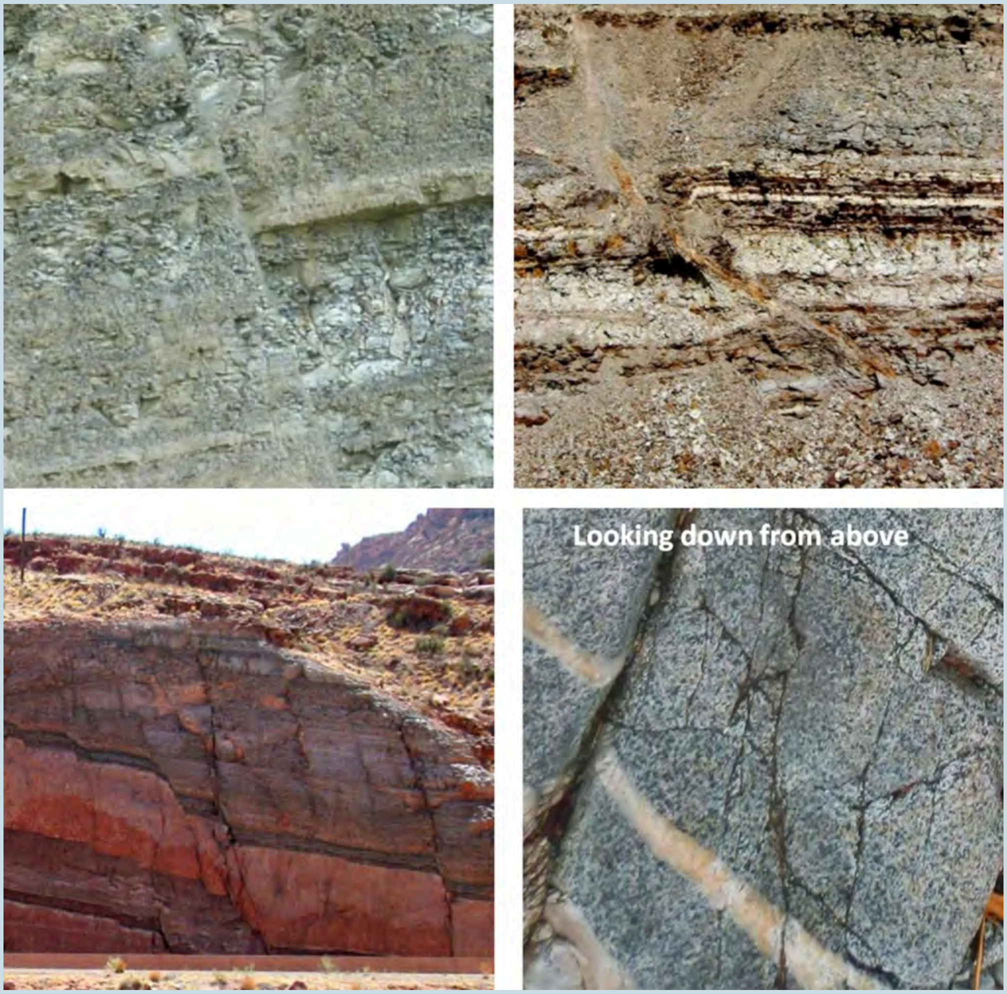

Figure 10.3.10

The four images are faults that formed in different tectonic settings. Identifying the type of fault allows us to determine if the body of rock was under compression or extension at the time of faulting. Complete the table below the images, identifying the types of faults (normal or reversed) and whether each one formed under compressional or tensional stress.

Type of Fault and Type of Stress
Top left (looking at a cliff face):
Bottom left (looking at a cliff face):
Top right (looking at a cliff face):
Bottom right (looking down onto the ground):

See Appendix 2 for Practice Exercise 10.2 answers.

Media Attributions

- Figure 10.3.1, 10.3.2, 10.3.6, 10.3.7, 10.3.8, 10.3.9: © Steven Earle. CC BY.
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- Figure 10.3.10 (all except bottom left): © Steven Earle. CC BY.
- Figure 10.3.10 (Bottom left): “Moab fault with vehicles for scale” © Andrew Wilson. CC BY-SA.

Lab 10 Exercises

The ability to visualize strata in three-dimensions is a spatial skill that is fundamental to understanding geology in the real world. For some, this skill comes easily. Bur for others, spatial thinking and visualization can be difficult concepts, especially at first. Regardless of which category of student you fall into, while these skills may come more naturally to some, they can be taught and will improve with practice! To practice visualizing in three-dimensions, think about the difference between how an object looks from above (in plan view), and how a slice through that object would look (in cross-section).

Spatial thinking and cross-sections

Imagine an apple. How would the apple look in plan view?

Now imagine slicing the apple in half, along a straight line. If you pull the two halves apart to examine the internal structure of the apple, you are looking at a cross-section. The photographs below show how the apple looks in plan view (left), and in cross-section (right). The dashed white line is the line of cross-section, from X to Y.

For more practice, imagine and sketch what the cross-section of the following objects would be:

- an orange
- a lemon cut in half from end to end
- a round loaf of sourdough bread, cut into slices
- a pyramid with a square base, cut along a diagonal line from corner to corner

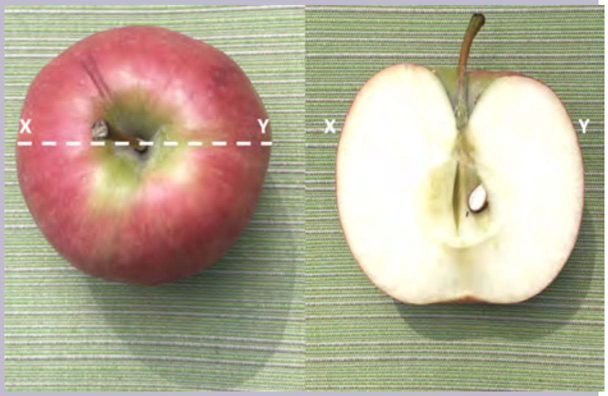

Figure A

Today you will use printed copies of the block models in Appendix 5 to explore geologic structures. Recall that the top surface of a block model represents the plan view of the Earth's surface, and the four sides represent four cross-sectional views down into the subsurface. On each of the six block models below, the geology drawn on the south- and west-facing sides shows the geology of the subsurface. This will give you some clues about the attitude (dip and dip direction) of the formations, as well as any structures present. Examine each of the block models, complete the missing sides, and use your completed model to answer the questions below. Unless otherwise stated, assume all the formations below represent sedimentary rocks.

For some of the models you will be asked to write a point-form geologic history based on what you observe in the model. This is an excellent way to review the relative dating and geologic time concepts from Lab 7. For example, try writing a point-form geologic history for Block Model 1 that shows a sequence of Cambrian (brown), Ordovician (light grey), Silurian (cream), Devonian (blue grey), and Mississippian (orange) formations that are dipping to the east, as well as a Cretaceous gabbro dyke (dark brown).

A point-form geologic history for Block Model 1 would look something like this:

Youngest (most recent)

- Erosion +/- uplift to present
- Intrusion of Cretaceous gabbro dyke (*cross-cutting relationships*)
- Tilting of the Cambrian to Mississippian formations toward the east (*original horizontality*)
- Deposition and lithification of the Mississippian formation (*superposition*)
- Deposition and lithification of the Devonian formation (*superposition*)
- Deposition and lithification of the Silurian formation (*superposition*)
- Deposition and lithification of the Ordovician formation (*superposition*)
- Deposition and lithification of the Cambrian formation (*superposition*)

Oldest

Notice how the history is formatted such that the oldest event is at the bottom, and the youngest or most recent event is listed at the top. The italic font in parentheses indicates the principle of stratigraphy used to justify the position of each event in the timeline. Also note that the terms used to describe the different geologic events match the type of rocks: **deposition** for sedimentary rocks, **intrusion** for the igneous dyke. Recall from Lab 3, that gabbro is a mafic intrusive igneous rock, that cooled beneath the Earth's surface. Since the gabbro dyke is now exposed at the surface of the Earth, the most recent event must be that the area has been uplifted and any overlying rocks or sediment have been eroded away.

Block model 1

Cut out block model 1, then construct the model by folding along the red lines. Fold in the corners of the model to create a 3D rectangular shape. Do not staple or tape the corners yet, as the model is easier to complete when laid flat on a hard surface. Later, you may want to staple or tape these corners so that your model maintains its shape.

This model shows a sequence of Cambrian (brown), Ordovician (light grey), Silurian (cream), Devonian (blue grey), and Mississippian (orange) formations that are dipping to the east. A Cretaceous (dark brown) dyke is also shown.

1. Complete the north- and east-facing sides of the block by drawing in the geology. You do not need to colour in the block model, but your formations must be labeled.
2. Draw a black arrow in plan view to indicate the dip direction of the Ordovician formation (O) at point i.
3. Using your protractor, measure the dip of the Ordovician formation on the south-facing side of the block. Remember, dip is measured in degrees from horizontal (0°) down to the inclined plane. Review Figures 9.1.2 and 9.1.3 if you are unsure where the angle of dip should be measured on your block model. Dip:
4. Draw a black arrow in plan view to indicate the dip direction of the Cretaceous dyke (K) at point ii.
5. Using your protractor, measure the dip of the Cretaceous dyke on the south-facing side of the block. Dip:

Block model 2

This model shows a sequence of Cambrian (brown), Ordovician (cream), Silurian (light grey), and Devonian (blue grey) formations. This model is a little more complex than Model 1, as the strata here have been folded.

1. Complete the north- and east-facing sides of the block by drawing in the geology. You do not need to colour in the block model, but your formations must be labeled.
2. Draw a black arrow in plan view to indicate the dip direction(s) of the Silurian formation (S) at points i, ii, and iii.
3. Draw on the axial plane for each fold in red pen on the south- and north-facing sides of the model.
4. In plan view and using a ruler, draw the surface traces of the axial planes for the folds in red pen. Add the appropriate symbols to indicate the type of fold (see Figure 10.2.5).
5. What type of stress is required to produce the geologic structures observed in this block model?

Block model 3

This model shows a faulted sequence of Cambrian (green), Ordovician (blue), Silurian (grey), and Devonian (cream), and Mississippian (brown) formations. Examine the offset of the formations shown in the south-facing side of the block.

1. Complete the north- and east-facing sides of the block by drawing in the geology. You do not need to colour in the block model, but your formations must be labeled.
2. Draw a black arrow in plan view to indicate the dip direction of the Mississippian formation (M) at point i.
3. Draw a black arrow in plan view to indicate the dip direction of the fault at point ii.
4. Draw a black arrow in plan view to indicate the dip direction of the Silurian formation (S) at point iii.
5. Label the hanging wall and footwall on the south- and north-facing sides of the model (the blocks above and below the fault).
6. Draw red arrows on either side of the fault to indicate the sense of displacement along the fault.
7. Is the fault in this model a normal or reverse fault? Why?

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8. Draw the appropriate map symbol for the fault in plan view. Consult Figure 10.3.4 for more information on map symbols for faults.
9. What type of stress is required to produce the fault observed in this block model?

Block model 4

This model shows a faulted sequence of Cambrian (green), Ordovician (blue), Silurian (grey), and Devonian (cream), and Mississippian (brown) formations. Examine the offset of the formations shown in the south-facing side of the block.

1. Complete the north- and east-facing sides of the block by drawing in the geology. You do not need to colour in the block model, but your formations must be labeled.
2. Draw a black arrow in plan view to indicate the dip direction of the Mississippian formation (M) at point i.
3. Draw a black arrow in plan view to indicate the dip direction of the fault at point ii.
4. Draw a black arrow in plan view to indicate the dip direction of the Ordovician formation (O) at point iii.
5. Label the hanging wall and footwall on the south- and north-facing sides of the model (the blocks above and below the fault).
6. Draw red arrows on either side of the fault to indicate the sense of displacement along the fault.
7. Is the fault in this model a normal or reverse fault? Why?

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8. Draw the appropriate map symbol for the fault in plan view. Consult Figure 10.3.4 for more information on map symbols for faults.
9. What type of stress is required to produce the fault observed in this block model?

Block model 5

This model shows a faulted sequence of Cambrian (orange), Devonian (grey), and Mississippian (cream) formations, as well as a younger Cretaceous dyke (dark brown). Examine the offset of the dyke shown in the south-facing side of the block.

1. Complete the north- and east-facing sides of the block by drawing in the geology. You do not need to colour in the block model, but your formations must be labeled.
2. What is the dip of the Mississippian formation (M) at point i? Dip:
3. What is the dip and dip direction of the Cretaceous dyke (K) at point ii?

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4. Draw red arrows on either side of the fault at point iii to indicate the sense of displacement along the fault.
5. What type of strike-slip fault is this? Why?

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6. Write a point-form geologic history for this block model. Be sure to specify any unconformities (if present), and which principles of stratigraphy you use as evidence for your timeline.
7. What type of stress is required to produce the fault observed in this block model?

Block model 6

This is a structurally-complex block model. This model shows a deformed sequence of Cambrian (brown), Ordovician (cream), Silurian (pale grey), and Devonian (blue grey) formations, as well as a Jurassic dyke (dark brown). The black unit on the south-facing side labeled 'M' is a Mississippian sill, a type of igneous intrusion.

1. Complete the north- and east-facing sides of the block by drawing in the geology. You do not need to colour in the block model, but your formations must be labeled.
2. What is the dip of the Silurian formation (S) at points i and ii? Indicate the dip direction in plan view at points i and ii by drawing black arrows.
3. Draw on the axial plane for the fold in red pen on the south- and north-facing sides of the model.
4. In plan view and using a ruler, draw the surface trace of the axial plane for the fold in red pen. Add the appropriate symbol to indicate the type of fold.
5. What is the dip and dip direction of the Jurassic dyke (J) at point iii?

6. What is the dip and dip direction of the fault at point iv?

7. Label the hanging wall and footwall on the east- and west-facing sides of the model.
8. Draw red arrows on either side of the fault to indicate the sense of displacement along the fault.
9. Is the fault in this model a normal or reverse fault? Why?

10. Write a point-form geologic history for this block model. Be sure to specify any unconformities (if present), and which principles of stratigraphy you use as evidence for your timeline.

Media Attributions

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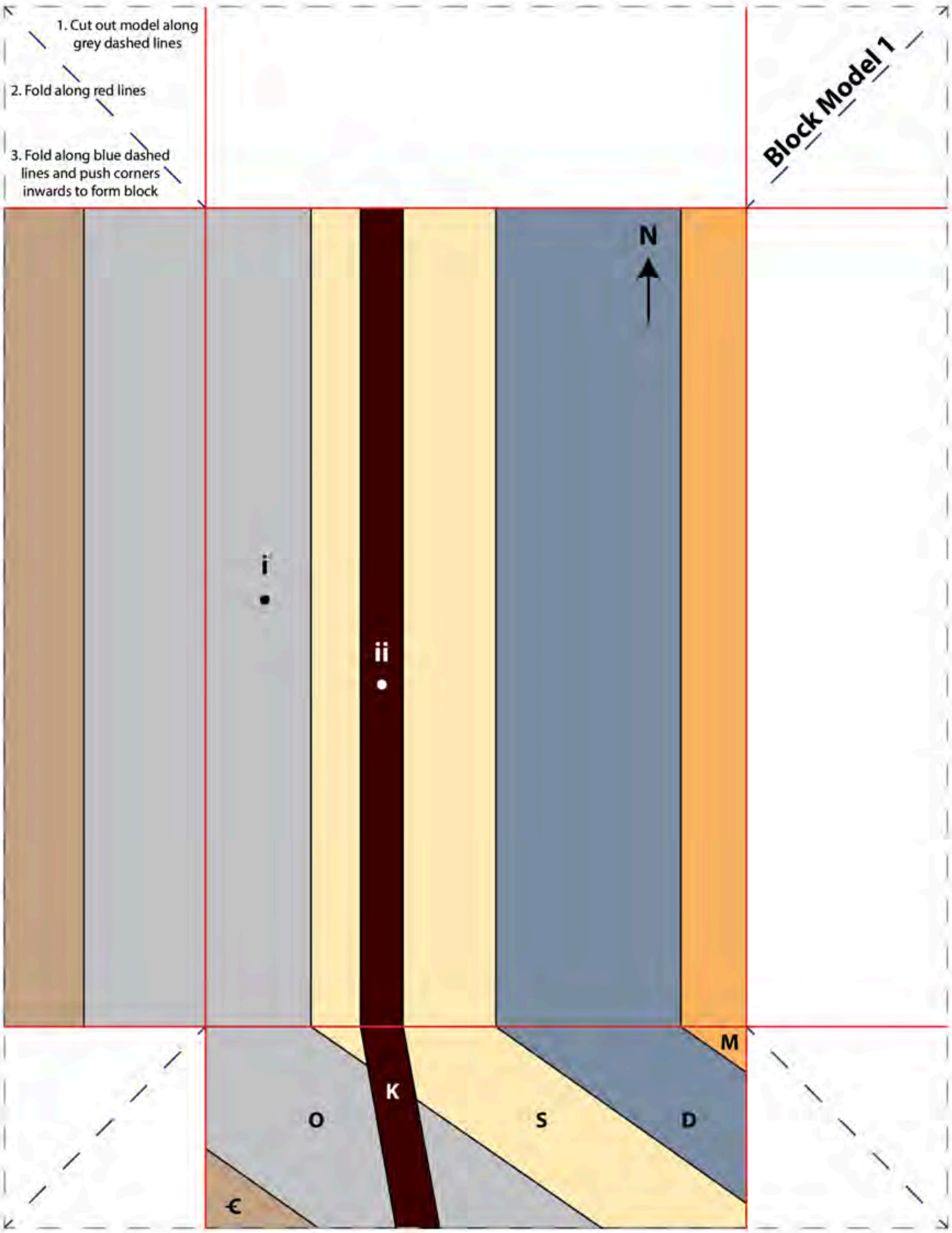
- Block Models 1, 2, 3, 4, 5, 6: © Siobhan McGoldrick. CC BY.

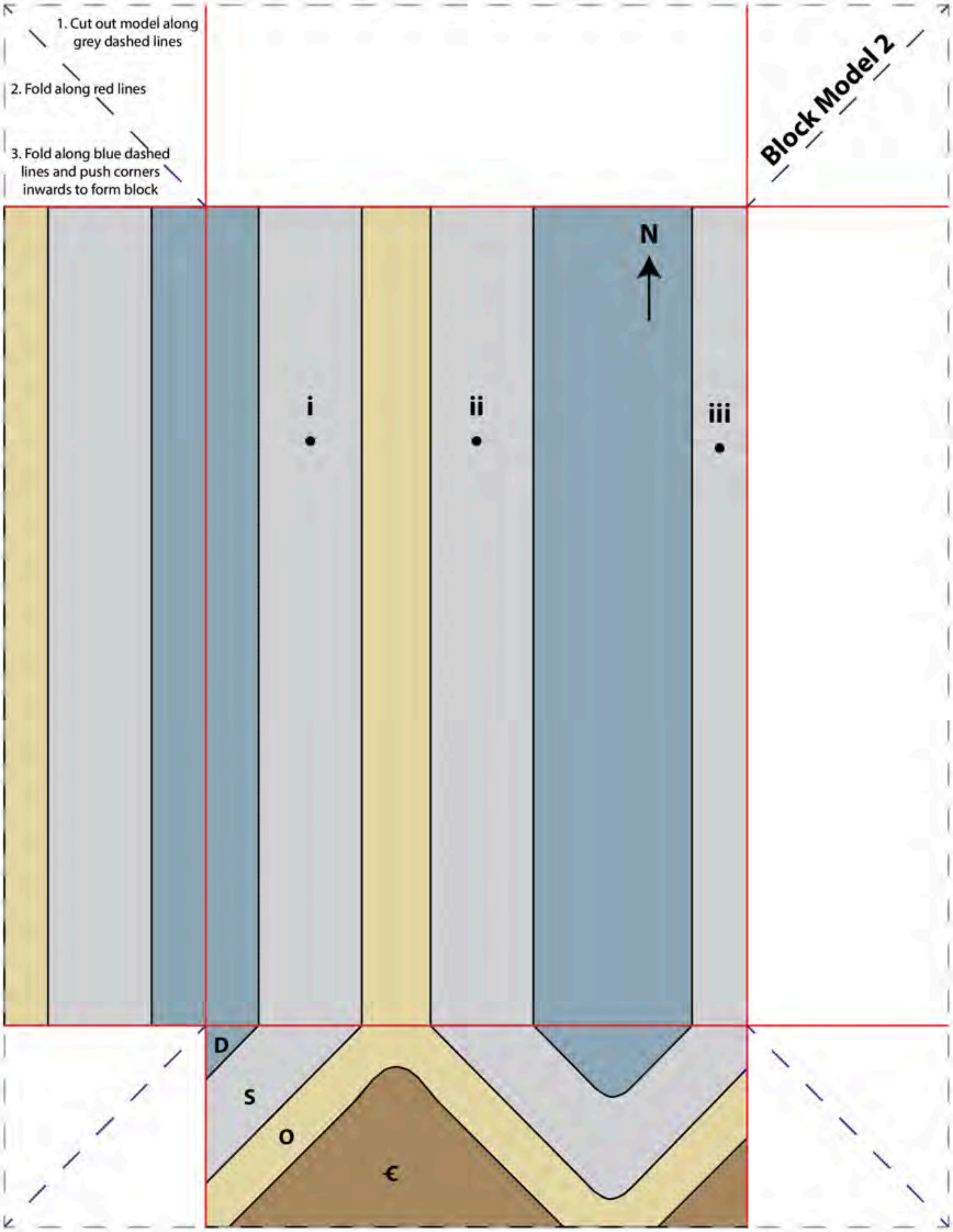
Summary

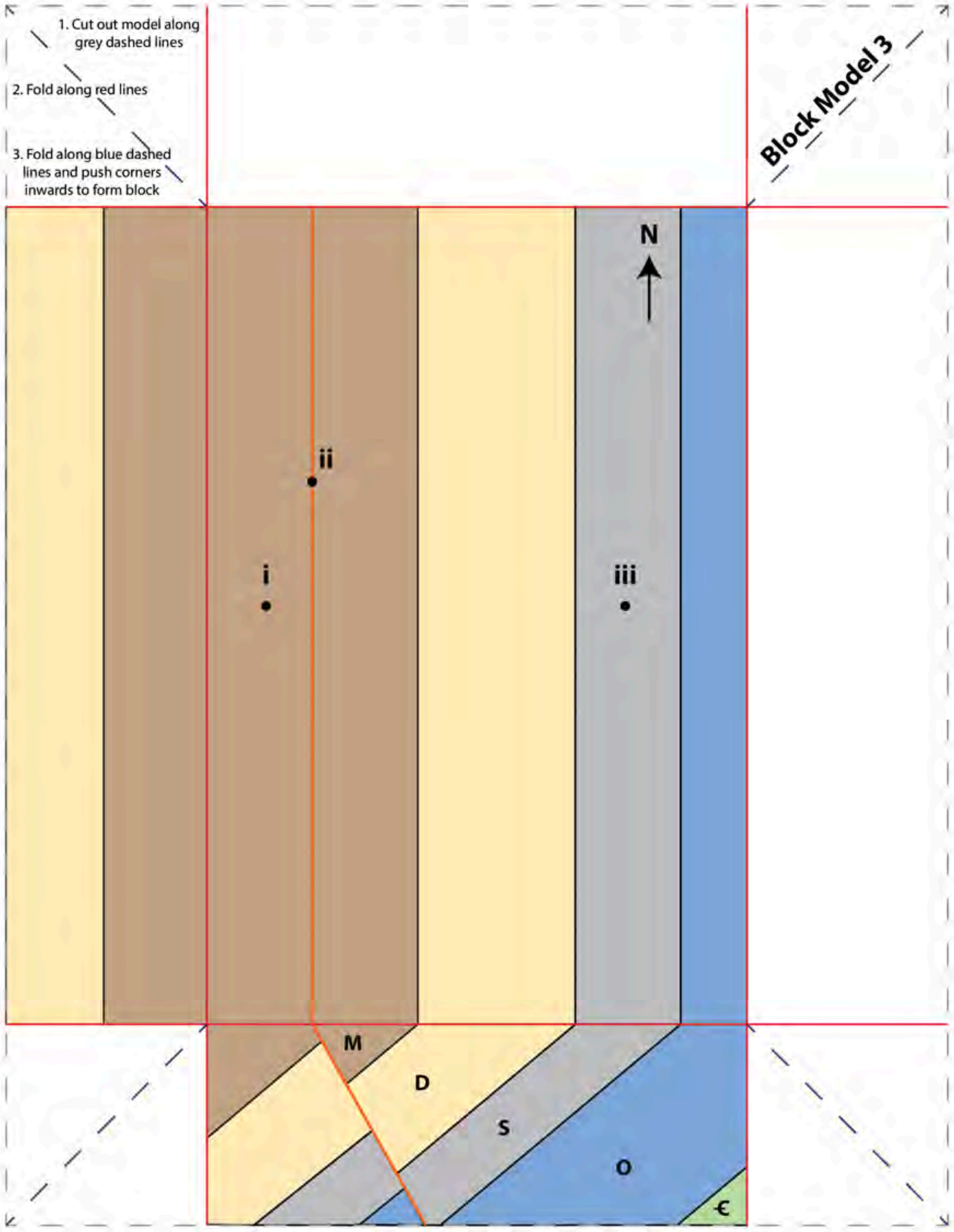
The topics covered in this chapter can be summarized as follows:

Section	Summary
10.1 Stress and Strain	Stress within rocks—which includes compression, extension and shearing—typically originates from plate-boundary processes. Rock that is stressed responds with either elastic or plastic strain, and may eventually break. The way a rock responds to stress depends on its composition and structure, the rate at which strain is applied, and also to the temperature of the rock body and the presence of water.
10.2 Folding	Folding is generally a plastic response to compressive stress, although some brittle behaviour can happen during folding. An upward fold is an antiform. A downward fold is a synform. The axis of a fold can be vertical, inclined, or even horizontal. If we know that the folded beds have not been overturned, then we can use the more specific terms: anticline and syncline.
10.3 Faulting	Fractures (joints) typically form during extension, but can also form during compression. Faulting, which involves the displacement of rock, can take place during compression or extension, as well as during shearing at transform boundaries. Thrust faulting is a special form of reverse faulting.
Lab 10 Exercises	Block models are useful tools for examining and recognizing geologic structures in 3D. Writing a geologic history for the units shown on a block model is an excellent way to practice using the principles of stratigraphy to determine relative ages.

Appendix 5: Block Models



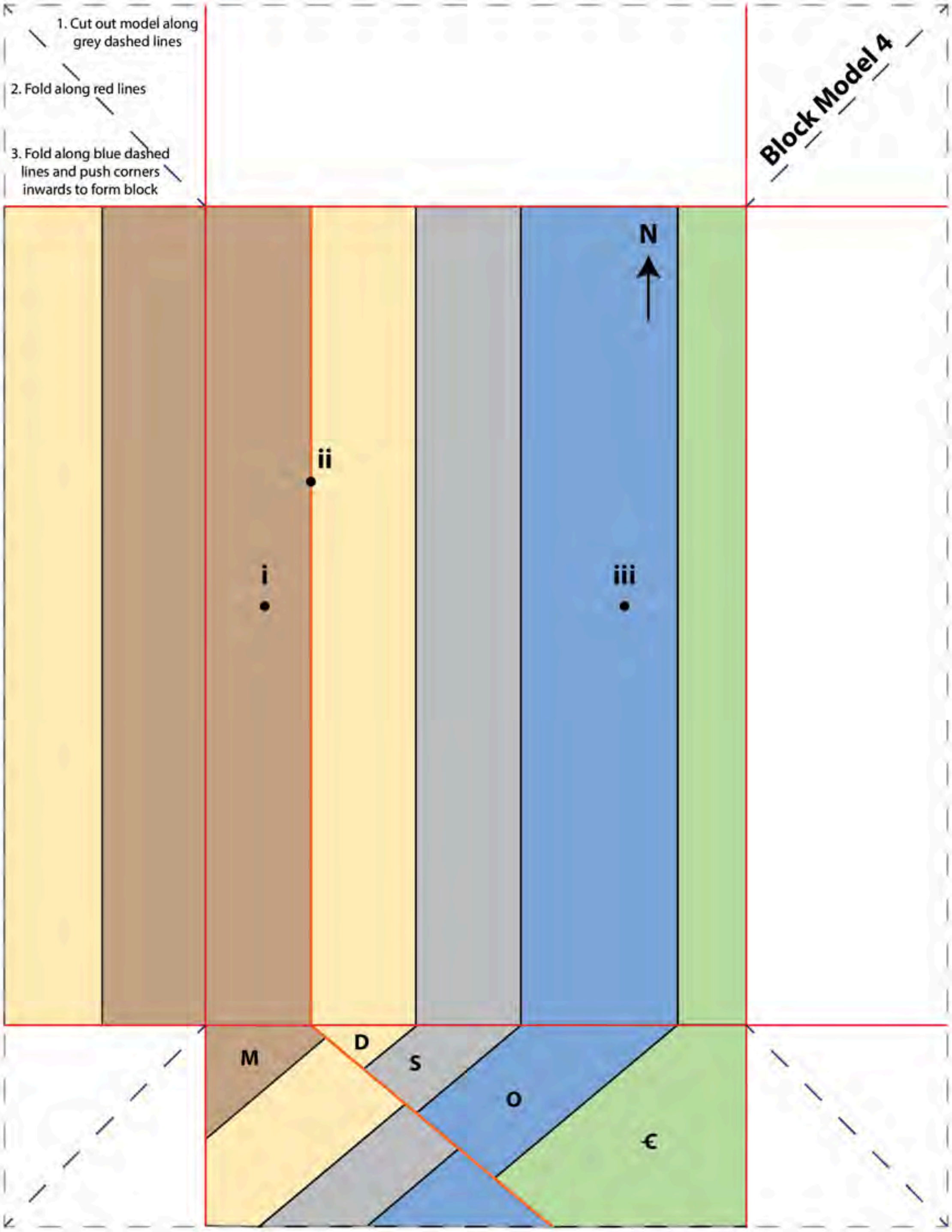

1. Cut out model along grey dashed lines
2. Fold along red lines
3. Fold along blue dashed lines and push corners inwards to form block
Block Model 2
N
i
ii
iii
D
S
O
€

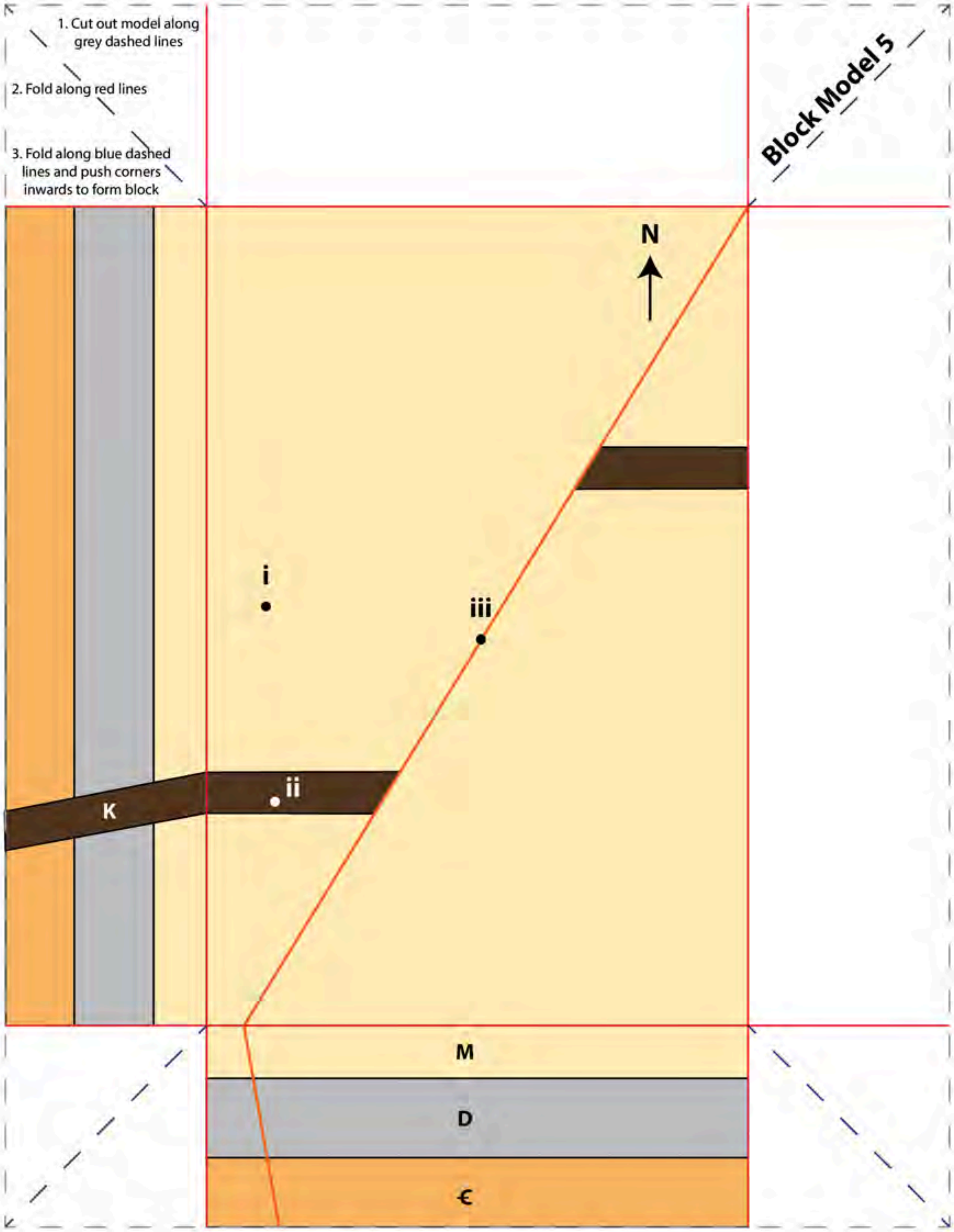


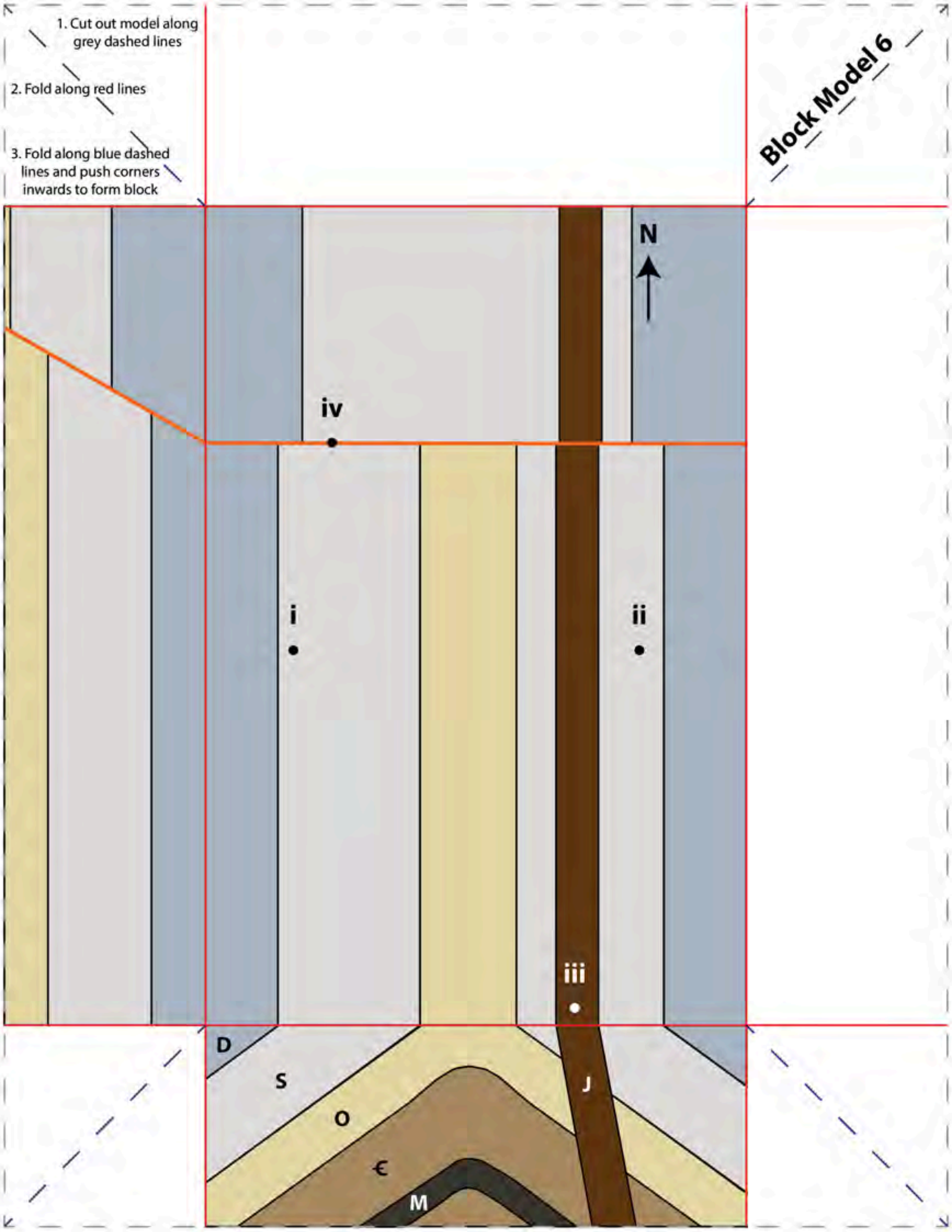
1. Cut out model along grey dashed lines

2. Fold along red lines

3. Fold along blue dashed lines and push corners inwards to form block


1. Cut out model along grey dashed lines
2. Fold along red lines
3. Fold along blue dashed lines and push corners inwards to form block
Block Model 4
N
ii
i
iii
M
D
S
O
Є


1. Cut out model along grey dashed lines
2. Fold along red lines
3. Fold along blue dashed lines and push corners inwards to form block
Block Model 5
N
i
ii
iii
K
M
D
€



Block Model 6

1. Cut out model along grey dashed lines
2. Fold along red lines
3. Fold along blue dashed lines and push corners inwards to form block