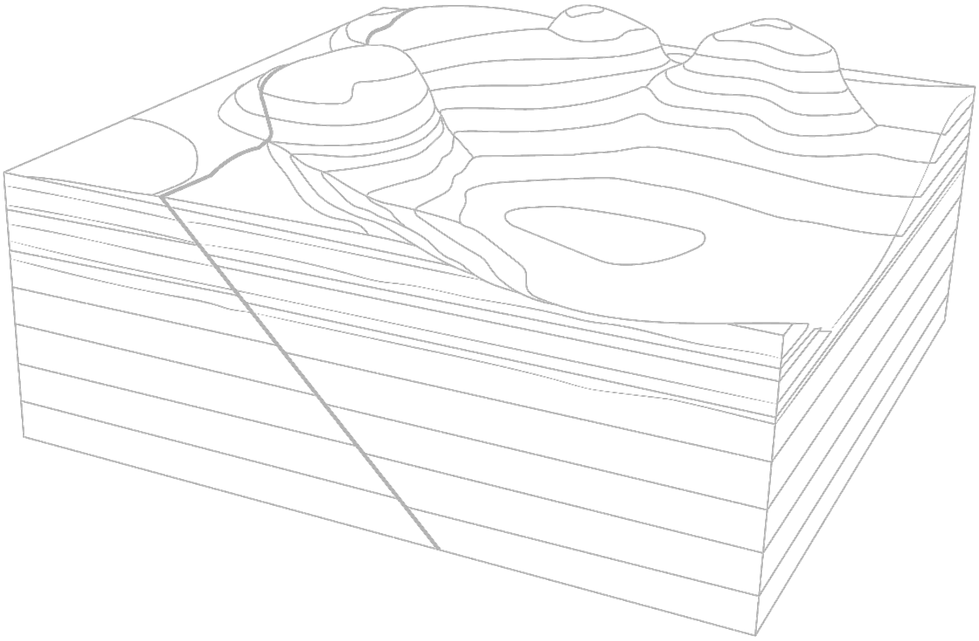
Lesson plan



Faults: normal, reverse and strike-slip

Learning objectives:

- Use the displacement of layers across a fault plane to identify the direction of motion.
- Identify different types of fault depending on the direction of motion.
- Anticipate what kind of tectonic forces were active to generate different types of fault.

Key Visible Geology skills:

- Apply faults to a block model
- Change the strike, dip, plunge and slip of a fault
- Change the strike and dip of layers

Timelines:

- Workflow 1 – 11: ~45 mins
- Questions and Exercise: ~30 mins

Glossary:

- See page 5

What are faults?

Faults are surfaces where rocks slide past each other. This can occur on both the micro (mm – cm) or macro (km) scale! We can classify different types of faults based on the relative direction of motion of the rocks on either side of the fault. Here, we'll use the Geology Explorer module to explore different types of faults. Ready? Let's get started!

Workflow

1. First, let's add some more layers until our block model is completely filled in.

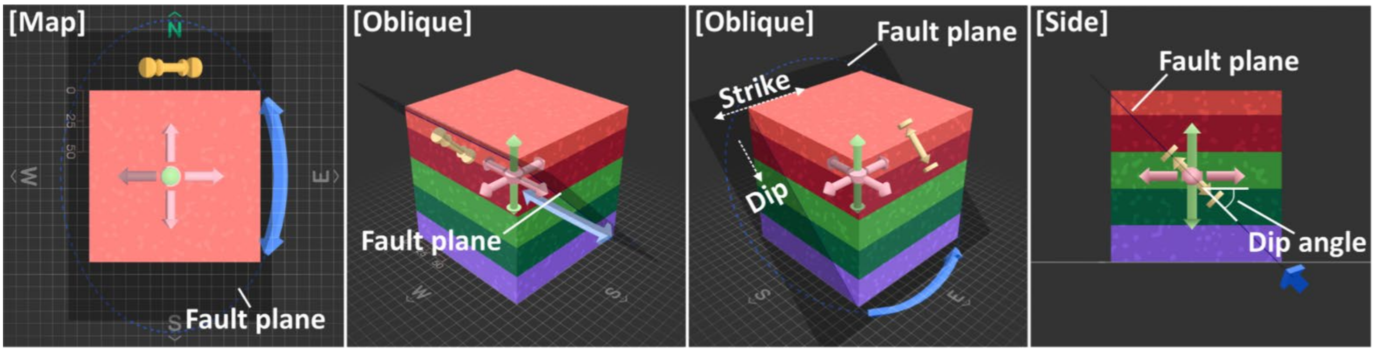
   <u>Layers</u> -> add (add at least two more layers above the top of the block – this will make sure it's always filled in later when we start manipulating the layers!)

2. Next, let's create a fault through our block.

   <u>Events</u> -> Fault -> Fault -> strike = 000, dip = 45, plunge = 90, slip = 0 (don't click apply just yet, let's keep working first!)

ⓘ Learning observation!

The surface where rocks slide past each other is called the **fault plane**. This is a planar feature, so it has a strike and dip, just like geological layers and beds (for more on strike and dip, see the *Dipping Layers* module!).



3. Change the strike and dip values several times and rotate your block to get a feel for how the orientation of the fault plane changes (keeping in mind where north is). Once you've done this, return it back to the original values.

   You can either enter new strike and dip values into the panel on the right side of your screen, or you can click and drag on the green and red arrows!

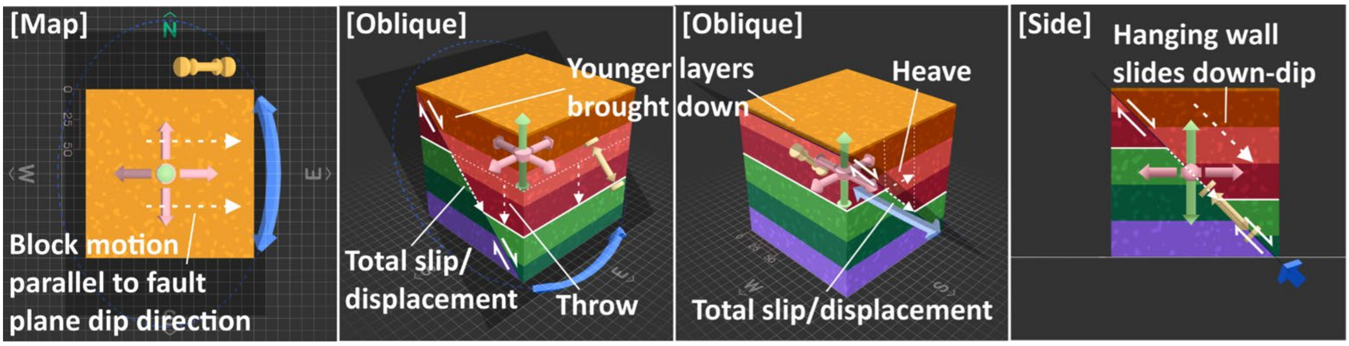
   Then return to -> strike = 000, dip = 45, plunge = 90, slip = 0 (again don't click apply!)

4. Now let's look at slip. Click and drag on the yellow arrow to move the top block downwards.

   Click and drag on the yellow arrow, or enter slip = 60

ⓘ Learning observation!

The slip of a fault in Visible Geology represents the **displacement** across that fault plane. This is the distance the rocks on each side have moved past each other. For a dipping fault plane, this can be separated into two components: the vertical **throw** and the horizontal **heave**.



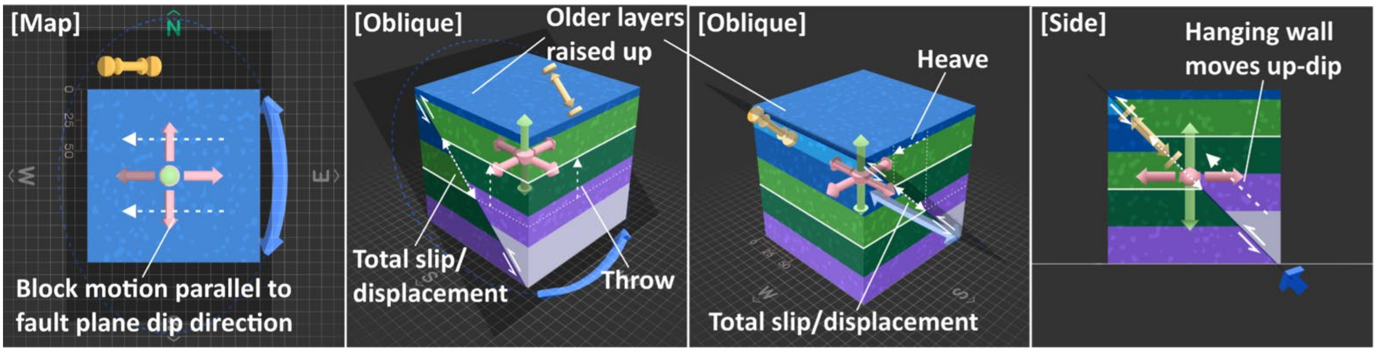
Here, the top block (a.k.a the **hanging wall**) has slipped downwards relative to the bottom block (a.k.a. the **footwall**) *in the same direction as the dip of the fault plane*. We call these **dip-slip faults** because the slip is in the same direction as the dip! When the hanging wall has moved *down*, we call this type of dip-slip faults **normal faults** and they are typically found in extentional tectonic settings where rocks are being pulled apart (e.g., a rift valley or a sedimentary basin).

5. Ok, so what happens if we move the top block the other way? Click and drag on the yellow arrow to move the top block upwards.

   Click and drag on the yellow arrow, or enter slip = -60

ⓘ Learning observation!

The top block has now moved *upwards* relative to the block below *in the same direction as the dip of the fault plane*. We call these types of dip-slip faults **reverse faults** and they are typically found in compressional tectonic settings where rocks are being pushed together (e.g., around mountain ranges). Note, you may also hear the term **thrust fault** used in a similar context: this specifically applies to reverse faults where the dip of the fault plane is shallow (<45°).



6. Ok so we've covered blocks moving up and down, but what about side-to-side? This means changing the plunge of the fault in our model. In Visible Geology, the plunge of the fault refers to the orientation of the direction of motion of one side of the fault relative to the other along the fault plane. The plunge is a compass bearing between 0° and 180°, where 0° is parallel to the fault plane (so motion is sideways across it) and 90° is perpendicular to the fault plane (so motion is up/down the fault plane like we've been exploring). So, to explore sideways motion on a fault, we need to change to the plunge to either 0 or 180.

   strike = 000, dip = 45, plunge = 0, slip = 0 (again don't click apply!)

7. Now, drag the yellow slip arrow backwards and forwards to simulate lateral motion. Is it easy to see how much displacement there is?

   Click and drag on the yellow arrow, or enter slip = 60

8. It’s hard isn’t it! That’s because the strike of our layers is also parallel to the strike of our fault plane and our fault plunge. So, let’s quickly rearrange the model to a better view.

   Click ‘X’ on the top right of the Fault panel to leave without applying your fault.

   <u>Events</u> -> Tilt -> strike = 000, dip = 90 -> apply

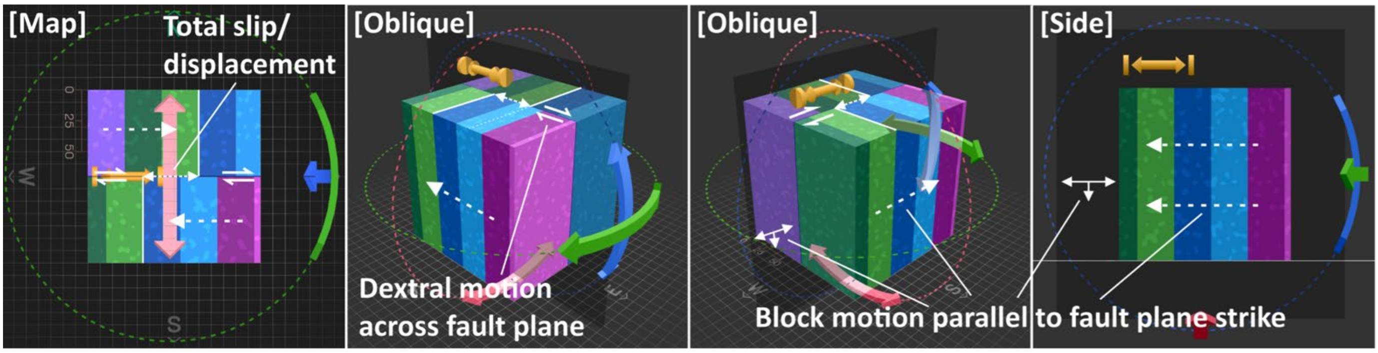
   <u>Events</u> -> Fault -> strike = 090, dip = 90, plunge = 0, slip = 0 (don’t click apply!)

9. Now our layers are tilted vertically, the strike of our fault plane (090) is orientated perpendicular (90°) to the strike of the layers in the block (000), the dip of our fault plane is 90 so it is vertical, and the plunge of the fault is 0 so all displacement is horizontal. Any sideways displacement is now easy to see! Click and drag on the yellow slip arrow to simulate lateral motion.

   Click and drag on the yellow arrow, or enter slip = 60

ⓘ Learning observation!

The motion of the fault is now sideways, parallel to the strike of the fault plane. We call these **strike-slip faults** and they are typically found at *transform* plate boundaries where two tectonic plates are sliding past each other (e.g., the San Andreas Fault in California, US, or the Alpine Fault in Aotearoa/New Zealand).



Like with dip-slip faults, we can classify the motion of the fault further depending on the direction! If the *far side* of the fault has moved to the *right* (like in the screenshots above), we call this motion **dextral**. If the *far side* has moved to the *left*, we call this **sinistral**.

10. Ok, so we’ve seen the end-member scenarios, but what happens if the fault motion is a combination of sideways AND up/down? Representing this requires us to quickly reconfigure the block again.

    Click ‘X’ on the top right of the Fault panel to leave without applying your fault.

    <u>History</u> -> Tilt -> Edit (middle logo on the right) -> strike = 000, dip = 45

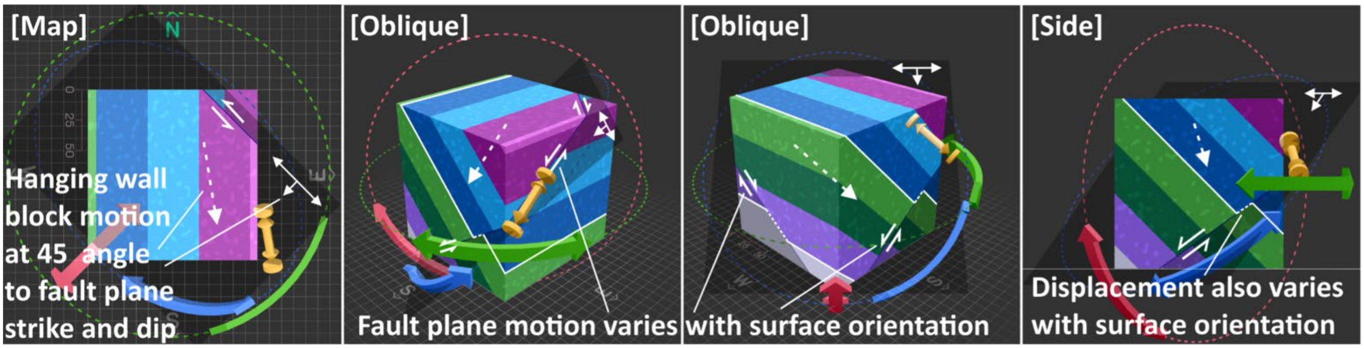
    <u>Events</u> -> Fault -> strike = 135, dip = 45, plunge = 45, slip = 0

11. We’ve now set it up so that when we move the hanging wall block up and down at an oblique angle (i.e., not just straight up or sideways but an angle in between), we can easily see the displacement on all sides of our block. Drag the yellow slip arrow backwards and forwards and see how the displacement is expressed!

    Click and drag on the yellow arrow, or enter slip = 60

ⓘ Learning observation!

Because the relative motion for normal, reverse and strike slip faults is either completely straight down, up or sideways, displacement is only expressed on one side of the block model in VG. When the relative motion is at an angle (i.e., fault plunge 0 < x < 90), the diagonal movement of the hanging wall means displacement can now be observed on all sides of the block! We call these kinds of faults **oblique faults** and they are common in all compressional and extensional tectonic settings where local stress distribution means fault motion is a combination of sideways and up/down.



We can subdivide oblique faults further depending on whether the block is sideways and up or sideways and down: sideways and up movement is called **transpressional** (forms in com**pressi**ve settings) and sideways and down is called **transtentional** (forms in ex**tensional** settings).

Questions

- When identifying sinistral vs dextral motion across a fault plane, is the motion the same on all sides of the model?
- How might you identify in map view whether a fault is a normal or reverse fault, without visible displacement markers like the coloured layers in Visible Geology?
- How might identifying fault types and motions be useful when trying to understand the geological history of an area?

12. Exercise: Below are images of real-world faults. First, identify the type of fault (normal, reverse, strike-slip). Then, recreate a simple version of it in Visible Geology! Note: as you have already seen, oblique motion is hard to identify so don't worry about that here!

Displaced layers across a fault seen from above in map view. Castle Point, Aotearoa/New Zealand. Photo: Luisa Rollwage

Displaced layers across a fault exposed on a cliff face. Castle Point, Aotearoa/New Zealand. Photo: Luisa Rollwage

Glossary:

Fault plane: the surface along which two rocks move past each other

Displacement: the distance along the fault plane one side is moved past the other

Hanging wall: the upper block above an inclined fault plane

Footwall: the lower block below an inclined fault plane

Heave: the horizontal distance travelled by the hanging wall in the direction of dip

Throw: the vertical distance travelled by the hanging wall

Dip-slip fault: a fault where the hanging wall moves up/down, i.e., parallel to the dip of the fault plane

Normal fault: a fault where the hanging wall moves downwards

Reverse fault: a fault where the hanging wall moves upwards

Thrust fault: A reverse fault where the dip of the fault plane is shallow (typically <45°)

Strike-slip: A fault where motion is sideways, i.e., parallel to the strike of the fault plane

Dextral: describes strike-slip fault motion where the far side of the fault plane moves to the right

Sinistral: describes strike-slip fault motion where the far side of the fault plane moves to the left

Oblique fault: a fault where motion across the fault plane is not purely parallel to the dip direction (normal/reverse) or the strike (strike-slip) but at an angle in between.

Transpressional: fault motion where the hanging wall moves upwards as well as sideways

Transtentional: fault motion where the hanging wall moves downwards as well as sideways