Introduction
This short interactive activity has learners manipulate fault blocks to better understand different types of earthquake-generating faults in different tectonic regimes: extensional (divergent margins result in normal faults), compressional (convergent margins form reverse faults), and horizontal shearing (strike-slip, or transform faults). See Table 1. Fault models aid in visualizing and understanding faulting and plate motions because the educator and their learners can manipulate a 3-D model for a true hands-on experience.

These models represent Earth faulting and plate tectonic structures and motions. However, it should be appreciated that the spherical shape of the Earth, the complexity of different rock types and rock properties, and geological development over millions of years result in complexity of actual fault systems and plate tectonic boundaries.

Objectives
Learners will be able to
• Understand the geometry of faults (normal, reverse, and strike-slip) and fault displacements using 3-D fault models
• Relate these geologic structures to different types of plate motions (divergent, convergent, and transform)

Time: 5-30 Minutes

Audience: This can be done with most any novice geoscience learning group. It can also work for informal education or public outreach venues as a demonstration or interactive.

Subject: Natural Hazards: Earthquakes, Geoscience, Tectonics

Materials: Fault models can be made from a variety of materials such as foam, sponges, or wood. For example, a 2” X 4” board can be cut into 12” lengths. Two angled cuts are made to represent faults. Draw or color at least three horizontal layers on the model representing rock layers will aid visualizing fault movement.

Figure 2: Prepare fault models as shown in this drawing.

Relevant Media Resources

Fault Types
Video
• Demo (Fig.1) www.iris.edu/hq/inclass/video/54

Animations of fault types (see Figure 3)
• Strike-slip www.iris.edu/hq/inclass/animation/53
• Normal www.iris.edu/hq/inclass/animation/51
• Reverse www.iris.edu/hq/inclass/animation/52
• Oblique www.iris.edu/hq/inclass/animation/57

Plate Boundaries (see Appendix A)
• Animation www.iris.edu/hq/inclass/animation/492
• Video www.iris.edu/hq/inclass/video/106

NOTE: This activity has been modified to include descriptions used with permission from various sources for the ShakeAlert education program.
Table 1: Faults, Plate Boundaries and Relative Motions. Table used for Activity.

<table>
<thead>
<tr>
<th>Fault Names</th>
<th>Tectonic Forces</th>
<th>Plate Boundary Descriptions</th>
<th>Related Tectonic and Geologic Features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Extension</td>
<td>Divergent (extensional, moving apart, spreading, construction—because new lithosphere is generated in the extended zone).</td>
<td>Rifts, grabens, sometimes volcanism, regional uplift but local downdropped fault blocks, shallow earthquakes.</td>
</tr>
<tr>
<td>Reverse or Thrust</td>
<td>Compression</td>
<td>Convergent (compressional, collision, subduction, moving together, constructive [two continents collide], destructive [where one plate dives, or &quot;subducts&quot; into the mantle beneath the other plate], less-dense plate).</td>
<td>Subduction zones typically has an ocean trench, volcanoes on over-riding plate, shallow and deep earthquakes in subducting plate; and megathrust earthquakes between the plates. Continental collision zones have reverse faults with folded and uplifted mountain ranges.</td>
</tr>
<tr>
<td>Strike-slip</td>
<td>Shearing</td>
<td>Transform (horizontal slip). On the ocean floors, these connect segments of spreading ridges to each other.</td>
<td>Linear topographic features, offset stream channels, sometimes lakes or depressions in pull-apart basins or local uplifts along constraining bends. Shallow earthquakes.</td>
</tr>
</tbody>
</table>

Figure 3. Types of faults and direction of offset. Links to animations on the previous page.
Demonstrating Faulting and Plate Boundaries

1) Normal Faulting (Extension)

To demonstrate normal faulting, move the two outer blocks apart as shown in Figure 4A. This procedure is best performed by holding the blocks “in the air” in front of you and supporting center block by the two outer blocks. Note that, as the two outer blocks are moved apart, the inner block drops down or “subsides.” This is called “normal faulting”. The down-dropped valley is called a “graben”. Normal faulting is common in areas affected by extensional forces, like divergent plate boundaries (Table 1). Examples of divergent plate boundaries include:

- Mid-ocean ridges (the Mid-Atlantic Ridge and the East-Pacific Rise) where seafloor spreading is occurring. These comprise the longest mountain range in the world.
- The Basin and Range Province in the Western U.S. displays the signature of normal faulting with many down-dropped fault blocks (grabens) forming topographic basins and adjacent high areas (horsts) forming topographic ranges.
- The East African Rift where extension over the past 30 million years has produced a concentration of normal faults that are beginning to break apart the African continent.

![Figure 4A. Normal faulting using the fault model. Red arrows represent extension.](image)

2) Reverse Faulting (Compression)

To demonstrate reverse (also called thrust) faulting, move the two outer blocks together as shown in Figure 5. The inner block will be pushed (thrust) upwards over the two outer blocks. It is called “reverse faulting” because the block above a fault moves up with respect to the block below the fault. Reverse faulting is common in areas affected by compressional forces, like convergent plate boundaries where two lithospheric plates are moving together or colliding (Table 1). Convergent zones are associated with mountain ranges from collision and compression, but also from volcanoes that form where one plate dives beneath another. Examples of convergent plate margins include:

- Cascadia, where the Juan de Fuca oceanic plate is subducting beneath the continental North American Plate. (The Andes is similar.)
- The Himalayas where two continental plates have been colliding for about 50 million years. Although it is the highest mountain range on Earth, it is also one of the youngest.

![Figure 5A. Reverse faulting using the fault model. Red arrows represent compression.](image)

![4B: Fast spreading, mid-ocean ridge.](image)

![4C: Mid-continent extension creates basin and range topography. Also called horst and graben topography.](image)

![5B. Subduction zone: megathrust earthquakes and volcanoes. Ex. Cascadia in Pacific NW; Andes in So. America.](image)

![Collision zone: high mountains and plateaus. Ex. Himalayas, Alps.](image)
3) Strike-slip or Horizontal-slip fault motion (shear)

Note: This does not require building another fault model. You can demonstrate strike-slip faulting by butting together the ends of the two outer blocks from the 3-piece model as shown in Figure 6A. Strike-slip faults are generally vertical faults.

To demonstrate horizontal-slip or strike-slip fault motion, prepare fault blocks as shown in Figure 6A. Explain to learners that the line crossing the fault could represent a fence or road built across the fault. Move the blocks horizontally on a tabletop, to demonstrate strike-slip fault motion (6B). Gigantic strike-slip faults at the boundary between two tectonic plates are called transform faults (Table 1). This type of strike-slip fault accommodates the relative horizontal slip between other tectonic elements.

Examples of strike-slip faults include:

- Ocean-floor transform faults that offset segments of oceanic spreading ridges to produce a stair-stepped appearance (Figure 6C).
- The San Andreas Fault Zone in Southern California, is a system of strike-slip faults that forms a transform plate boundary between the N. American Plate and the Pacific Plate. It connects the East Pacific Rise and the Juan de Fuca Plate (see map in Appendix A).

6C: Mid ocean ridges have moved away from each other along a transform fault (blue line)

6B: Block model viewed from above with red arrows showing the direction of shearing. After fault displacement, the half-arrows show the direction of relative motion across the fault.

6D Stress buildup and release along a strike-slip fault. Stress deforms the ground until friction is overcome and an earthquake causes the land to jump in a process called “elastic rebound.”
Fault Models—Learner Worksheet

How Do Earthquakes Happen Along Plate Boundaries and Faults?

Using what you have discovered from the Fault Model activity, complete Table 1 below.

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Generalized map and images of tectonic setting
The west coast of the U.S. is seismically active! Scientists study identified faults, as well as searching and identifying new faults as part of on-going research, for potential seismic activity. The map on this page shows the generalized tectonic regime. For more detail of the faults, see the next page.

**ANIMATION:** 3 fault types of the Pacific Northwest:
https://www.iris.edu/hq/inclass(animation/376)

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**APPENDIX A—TECTONIC MAPS**

**Left:** Photograph of features associated with convergent (Three Sisters, OR. USGS photo), divergent (Basin & Range; Marlee Miller photo), and transform margins (Carrizo Plain, CA. USGS photo).  **Right:** Generalized tectonic map of the Western United States. (Image modified from: https://geomaps.wr.usgs.gov/archive/socal/geology/geologic_history/san_andreas_history.html)
State fault maps
The faults on these maps of Washington, Oregon and California include three different locations within or between the tectonic plates, including:

- Shallow crustal
- Deep (aka, intraplate or intraslab)
- Megathrust (aka, subduction zone.)

Whereas particular faults are not all identified by type (normal, reverse, strike-slip) or location, the prevalence of faults across the region shows the dynamic potential for earthquakes and the critical need for earthquake awareness and preparedness.

Mapping faults is difficult, and scientists interpret where faults are based on field work, map interpretation, or more recently, on lidar images that can “see” through the forests. Therefore, don’t be surprised if fault maps look somewhat different.

Right below: Fault map of California (from USGS publication: https://pubs.usgs.gov/gip/earthq3/)
For an interactive map of California’s faults go here & zoom in: https://earthquake.usgs.gov/hazards/qfaults/map/#qfaults

Below: San Francisco Bay Area Faults show the width of the San Andreas Fault ZONE

Bottom: Los Angeles area faults.
# APPENDIX B—NGSS SCIENCE STANDARDS & 3 DIMENSIONAL LEARNING

## Motion and Stability: Forces and Interactions

### MS-PS2-2
Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object. [Link](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=149)

### PS2.A: Forces and Motion

**The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The greater the mass of the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion.**

All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.

## Earth’s Systems

### MS-ESS2-2
Construct an explanation based on evidence for how geoscience processes have changed Earth’s surface at varying time and spatial scales. [Link](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=224)

### ESS2.A: Earth Materials and Systems

**The planet’s systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth’s history and will determine its future.**

## HS-ESS2-1
Develop a model to illustrate how Earth’s internal and surface processes operate at different spatial and temporal scales to form continental and ocean-floor features. [Link](http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=183)

### ESS2.A: Earth Materials and Systems

**Earth’s systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.**