ShakeAlert® activities for formal and informal learning settings

Introduction to Faults and Plate Tectonics

An Activity about Forces, Faults, and Friction

Version 6/29/20

Activity modified from L.W. Braile, Purdue University

This interactive activity provides three options to demonstrate the geometry of faults (normal, reverse, and strike-slip) and fault displacements with 3-D models. A 5-minute option provides several interactive demonstrations that introduce the concepts of forces, stress and strain. Building on this introduction, a 15-minute option allows learners to manipulate fault models (Figure 1) to explore different types of faults that result from the forces presented. In the 30-minute version, the learners apply previous learning experiences to solve geologic puzzles presented in images of faults at local and regional scales.

Fault models aid in the visualization and understanding of how faults are created and move because the instructor and their learners can manipulate a 3-D model for a hands-on experience. These models represent Earth's faults and tectonic structures, and their relative motions. However, it should be appreciated that the spherical shape of the Earth, different rock types and properties, plus geological development over millions of years has resulted in the complexity of actual fault systems and plate tectonic boundaries we see today.

Why is it important to learn about forces, faults and plate tectonics? More than 143 million people are exposed to potential earthquake hazards in the U.S. that could cost thousands of lives and billions of dollars in damage. An understanding of these concepts is fundamental to mitigating earthquake hazards. An important tool for mitigation is the ShakeAlert® Earthquake Early Warning System for the West Coast of the U. S. which detects significant earthquakes quickly so that alerts can be delivered to people and automated systems.

Beginner

5 min 15 min 30 min

Large Group

Demo Materials

Time: 5-, 15- and 30-minute guided activities, which can be adapted for your audience.

Audience: Can be done with novice geoscience learning groups. It can also work for informal education or public outreach venues as a demo or interactive activity.

Subject: Natural Hazards: Earthquakes, Geoscience, Tectonics.

OBJECTIVES

Learners will be able to:

- Demonstrate the forces, stress and strain that result in particular fault motions
- Explain the geometry of faults (normal, reverse, and strike-slip) and fault displacements with 3-D fault models
- Describe how the three types of faults are related to the different types of plate motions (divergent, convergent, and transform)

TABLE OF CONTENTS

MATERIALS

Fault models can be made from a variety of materials such as foam, sponges, or wood.

- For example, a 2" x 4" foam or wood board can be cut into 12" lengths. Two angled cuts are made to represent faults (Figure 2). Draw or color at least three horizontal layers on the model to represent rock layers to aid in the visualization of fault movement.
- Models can also be made with the supplemental "Paper Fault Models" downloaded with this activity.
- Learner worksheets for the fault-block models (Appendix C)
- Optional reading (Appendix D)

RELEVANT MEDIA RESOURCES

Videos

- Demonstration of the fault model (Figure 1)
- Class presentation on plate boundaries

Animations

- Three basic fault types and stress direction
- How *stress* affects faults and plate boundaries
- Plate boundaries and how they work

Figure 1: Dr. Robert Butler demonstrates the fault model using large foam blocks. (See video above.)

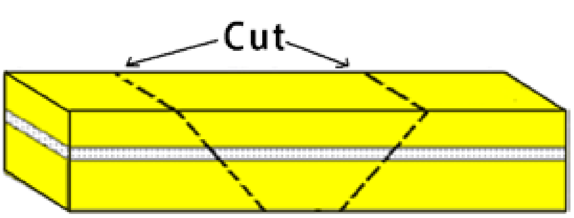


Figure 2: Prepare fault models as shown in this drawing.

INSTRUCTOR PREPARATION

Faults are fractures in Earth's crust where movement has occurred (Appendix A; Vocabulary). Sometimes faults are small and barely noticeable between the rock layers. But they can also be hundreds of miles long, such as the San Andreas Fault in California, which is visible from space.

Faults provide evidence that the rocks that make up Earth's outer shell are continually subjected to stress. The forces that drive Earth's crustal plate motions build stress along and between faults. When the accumulated stress overcomes the force of friction that holds the two adjacent blocks of rock or the boundary between tectonic plates together, the sudden slip or rupture along the fault releases the accumulated stress in an earthquake.

Familiarize yourself with the concepts by watching the videos and animations (left). Terms such as force, stress, and elastic deformation are defined in the Appendix A.

Appendix B introduces the user to the types of stress that lead to faulting and/or deformation. The concept of stress is relevant to the 5-minute demonstrations.

The three-section, fault-block model (Page 4) permits the center section to move independently in response to the push of compression or pull of extension. The two-section paper model (Page 6) requires sliding one section in a deliberate upward motion, and extension in a downward sliding motion. The two section model can also be made using other materials.

Faults, plate boundaries, and the effects of stress are described in Appendix D as well as in the animations. For place-based learning, refer to the interactive maps linked in Appendix E.

NGSS standards are found in Appendix F.

DEMONSTRATIONS AND ACTIVITIES

The three short demonstrations on the next page help learners understand that the force, stress and strain they observe are analogous to ongoing Earth processes (Appendix B). What we observe is the result of these forces on faults. For instance, when the force imposed on the fault is greater than the force of friction, we observe the sudden slip or rupture along a fault as it releases the accumulated stress as an earthquake.

IF YOU HAVE 5 MINUTES

Did You Know?

- Did you know that stress can make rocks bend?
- Did you know that elasticity in rocks can be compared to an uncooked pasta noodle?

Yes, rocks can bend! This is because rocks are elastic. Just as a rubber band can be stretched, or a piece of spaghetti can be bent and then return to its original shape, so too, rock can be bent and return to its normal shape! (See Appendix B for more information regarding the science of the model.)

Three quick demonstrations:

1. Stretch a rubber band and release it. (Figure 3)

The rubber band stretches when your fingers apply force. The force that your fingers exert on the rubber band is stored in the material as elastic potential energy. When you relax your fingers and remove the imposed force the stored energy in the rubber band quickly returns the elastic material to its normal shape.

2. Bend a piece of spaghetti. (Figure 4)

Another example of elastic deformation and response can be seen when you slightly bend a single piece of uncooked spaghetti. The pasta will bend as force is applied to the pasta. The force imposed from your fingers to the pasta is now stored in the pasta as elastic potential energy. When you remove the imposed force from your fingers, the pasta strand converts its stored elastic potential energy to kinetic energy returning the strand to its original shape.

3. Bend actual rock! (Figure 5)

This same principle can now be demonstrated with actual rock!

You can use an actual prepared stone threshold! Watch "*Seeing IS Believing, Rocks are Elastic*", or show an enlarged copy of Figure 5. This version is cut from a marble threshold, which are available from home improvement stores or online ($23 and up). The marble thresholds are 24" long and can be cut into several 'tongs'; three 8" lengths should work. A professional at a local home improvement store should cut the marble threshold up the middle with a rock saw. The marble 'tongs' are fragile, so make a backup and do not let students play with them.

In this example, the force from your fingers can compress and squeeze the rock together! The force from your fingers is transferred to the rock and stored as elastic potential energy. When your fingers release the imposed force, the stored potential energy in the rock rebounds elastically, releasing its stored energy in the form of motion, heat and seismic waves.

Figure 3: Rubber band demonstration of elastic strain.

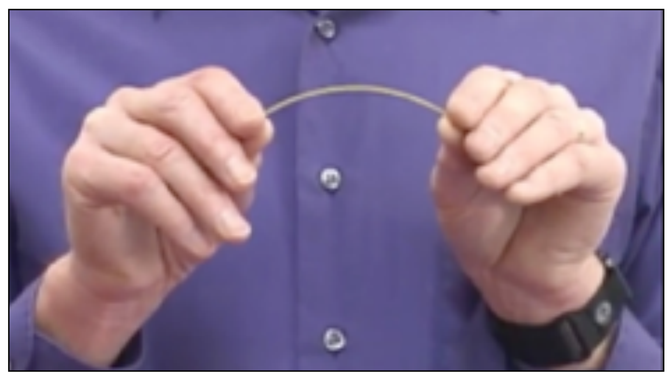


Figure 4: Spaghetti demonstration of elastic strain.

Figure 5: Rock demonstration of elastic strain. Here we used a piece of marble threshhold slit with a rock saw.

IF YOU HAVE 15 MINUTES

Did You Know?

- Did you know that earthquakes occur on faults, like the San Andreas Fault in California?

With enough force, rock will reach a critical point where it will overcome the force of friction along the fault, and allow the fault to move. The drop in stress (force/area) releases stored energy along the fault and an earthquake occurs. When we feel shaking, what we experience is the seismic waves (kinetic energy) from the earthquake!

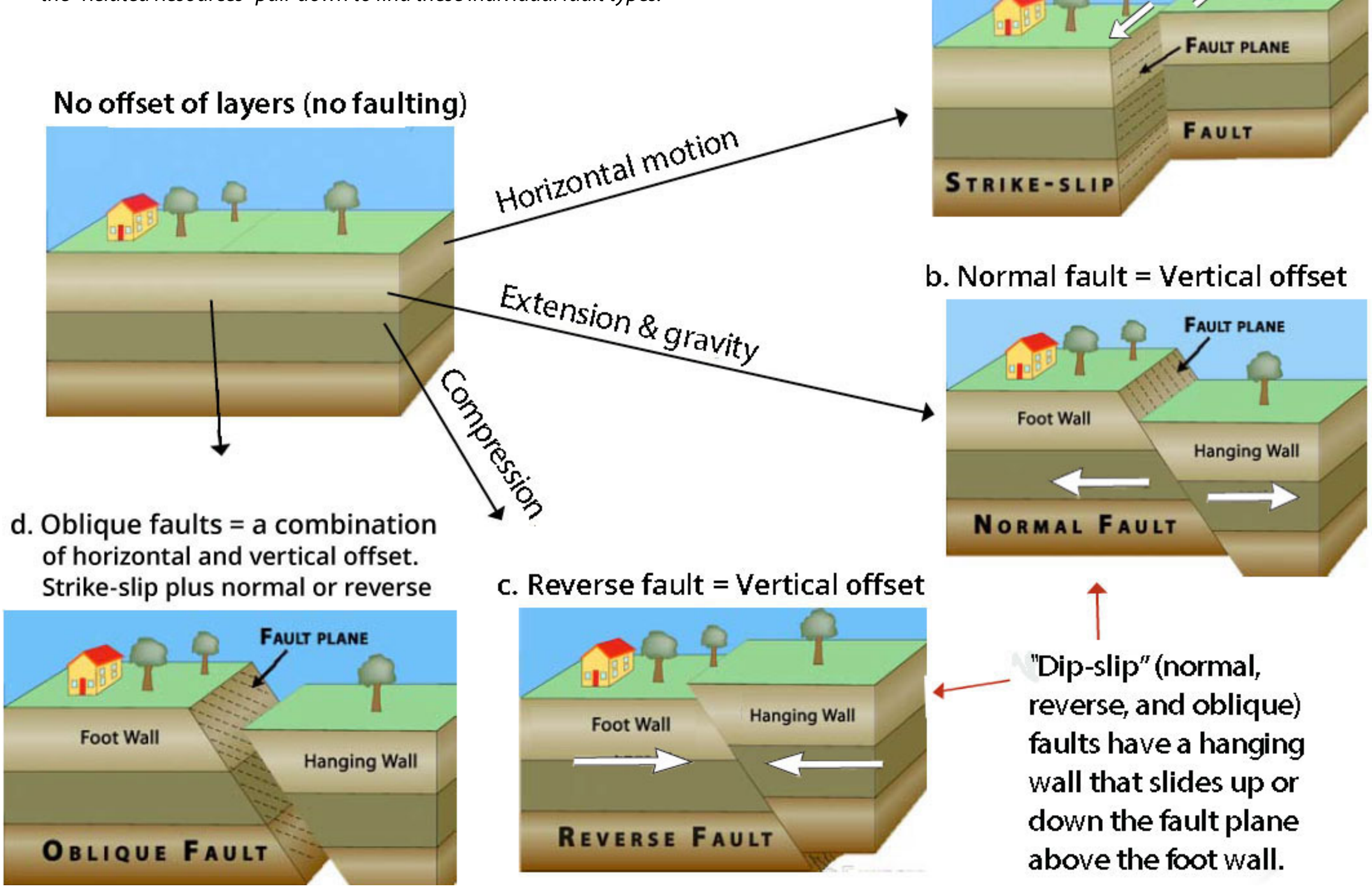
This short demonstration shows the three basic types of forces that stretch (pull), squeeze (push), and shear (slide) rock, creating different types of faults (Figure 6).

The instructor can incorporate one or more short demonstrations from the 5-minute option to engage the critical concept of stress and force on rock and faults before introducing this activity.

We will use fault models for the activity. See directions for making class sets of fault models made from a 2″x4″ wood block (Model A), or paper models (Model B). The three section fault block model (Model A) permits the center section to move independently in response to the push of compression or pull of extension. The two section paper model (Model B) requires sliding one section in a deliberate upward motion, and extension, a downward sliding motion.

If you have more time: Take a dishwashing cloth and place over the fault models. After watching the dishcloth deform due to fault movement, ask your audience whether they think it's smart to build across the fault. Why or why not?

Figure 6 (below): Types of faults and direction of offset. Links to animations in "Relevant Media Resources" on Page 2. You can download animations and GIFs of these faults from [Fault Types: 3 Basic responses to stress.] On that page, click the "Related Resources" pull-down to find these individual fault types.



MODEL A—Using the 3- Block Fault Model

When using fault models made with 2"x4" blocks of wood, you will have three (3) pieces that create two (2) faults as seen in Figure 7A. Follow the instructions for Normal, Reverse, and Strike-slip faults.

Normal Faulting—Extension (pulling) stretches the earth's crust.

- Hold the fault model in the air. (Figure 7A)
- Slowly pull your hands apart. (Figure 7B)
- Note that, as the two outer blocks are moved apart, the inner block drops down or "subsides."
- Forces cause outer blocks to move away from the fault.

Normal faulting is common in areas affected by extensional forces like mid-ocean ridges, basin and range topography, and divergent plate boundaries.

If making a PowerPoint presentation, use animated GIFs found as optional downloads on these pages:

- Fault Normal
- Plate Boundary—Divergent (fast-spreading ridge)

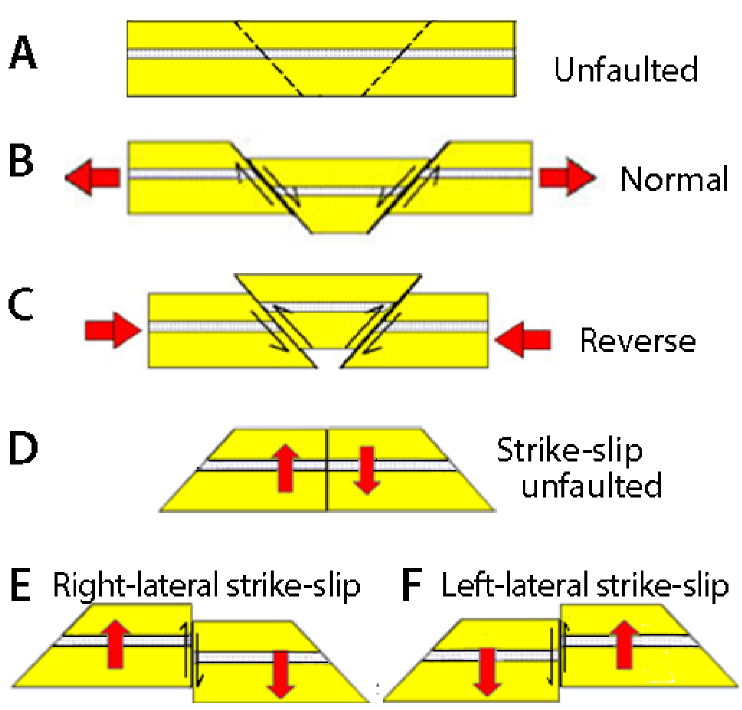


Figure 7: How to use the fault blocks to demonstrate different types of faults. Letters A-F refer to notes in the text.

Reverse Faulting—Compression (pushing) squeezes the earth's crust.

- Hold the fault model in the air. (Figure 7A)
- Slowly push your hands together. (Figure 7C)
- Note that the inner block will be pushed (thrust) upwards over the two outer blocks.
- Forces cause the inner block to move up and over adjacent blocks..

Reverse faulting is found at convergent plate margins, either associated with continent to continent collision that forms mountains like the Himalayas or where an oceanic plate subducts beneath a continental one like at the Cascadia Subduction Zone, where the Juan de Fuca oceanic plate subducts beneath the continental North American Plate.

If making a PowerPoint presentation, use animated GIFs found as optional downloads on these pages:

- Fault—Reverse
- Plate Boundary—Convergent margin

Strike-slip Faulting—Horizontal-slip (shearing or sliding) moves the earth's crust laterally

- Blocks can be placed on a table.
- Hold the outer two blocks of the fault model with the blunt end edges facing each other. (Figure 7D).
- Slide the blocks horizontally. In real life, how could you determine how far the blocks moved?
- Forces cause blocks to move horizontally.

Strike-slip faults are typically vertical fractures where the blocks have mostly moved horizontally. If the block opposite an observer looking across the fault moves to the right, the slip style is termed right-lateral (Figure 7E). If the block moves to the left, the motion is termed left-lateral (Figure 7F). Examples of strike-slip faulting occur on the earth's surface on the San Andreas Fault Zone, and in offset segments of oceanic spreading ridges, which create a stair-stepped appearance on the ocean-floor.

For PowerPoint presentations, use animated GIFs found as optional downloads on this page:

- Fault—Strike slip

MODEL B—Paper Fault Model

The paper fault models have just two sections of the model and one fault where the sections touch (Figure 8). Models are included as a separate file with the activity download.

Normal Faulting

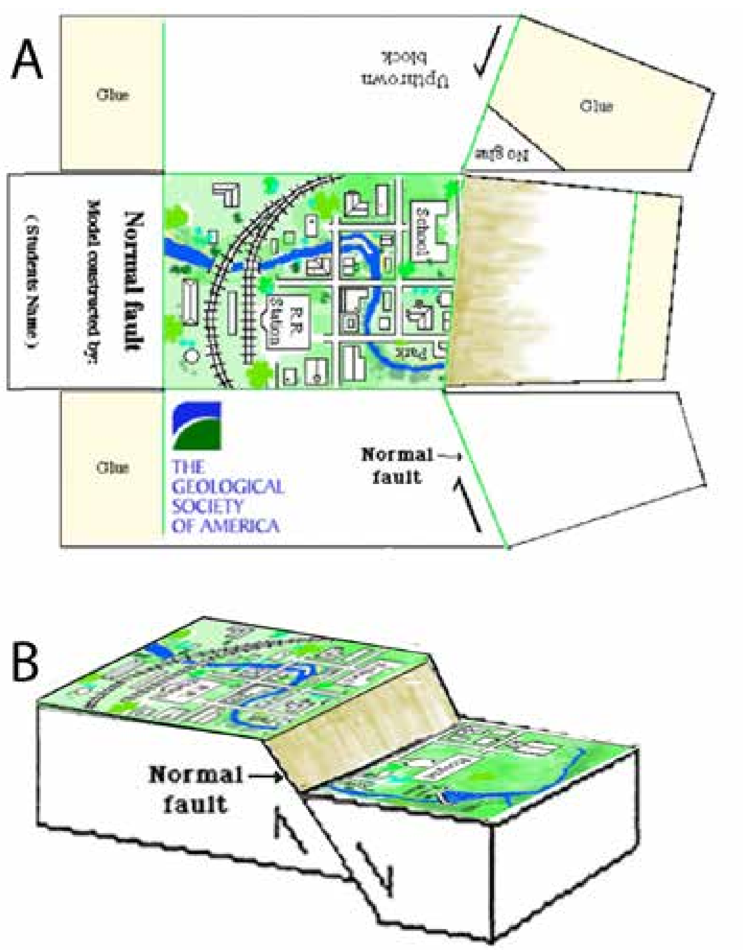
- Make sure that the fault planes remain in contact. One hand remains steady holding one side of the model. Extension allows the hand holding the other half of the model to slide in a downward motion following the plane of the fault.

Reverse Faulting

- Make sure that the fault planes remain in contact. One hand remains steady holding one half of the model. Compression causes the hand holding the other half of the model to slide in an upward motion. This is also known as a thrust fault.

Strike-slip Faulting

- Follow the directions provided for the 2″x4″ wood block models.



IF YOU HAVE 30 MINUTES

This activity is best suited for a classroom or laboratory setting. The instructor should open this activity with the "Did You Know?" questions and short activities featured in both the 5-minute and 15-minute options, as an introduction. With the remaining time, the learners can challenge themselves to identify different types of faults seen in photos from road cuts and outcrops as well as diagrams of large-scale faults comprising plate boundaries. Using the learner worksheet found in Appendix C, learners synthesize their experience by taking their earlier explorations and new knowledge and applying it to real world examples. Learners may use their notes and the models to help them complete the worksheet activity (Figure 8). Appendix D includes optional background information, which could be used in a flipped classroom design.

Figure 8 (left): How to use the paper fault models to demonstrate different types of faults. In this case, the demonstration is of a normal fault. Full-size model for printing was included with the activity download.

APPENDIX A — VOCABULARY LISTS

VOCABULARY I—Basic Physics

Deformation—process where rocks are folded, faulted, sheared or compressed by Earth stresses.

Brittle Deformation—irreversible strain where the material (rock) fractures/ breaks response to stress.

Ductile Deformation— When rocks deform in a ductile manner they bend, instead of fracturing to form faults. The resulting structures are called folds. At high temperature and confining pressures, brittle rock can become ductile. Folds result from compressional or shear stresses acting over considerable time.

Elastic Deformation—reversible strain that, when the deforming force is removed, the distorted body returns to its original shape and size. Earthquakes are caused by the sudden release of energy as strain is overcome and the sides of the fault move past each other. This form of energy release is the only kind that can be stored in sufficient quantity to be regionally damaging.

Elastic Properties—the measure of an objects ability to change shape when a force is applied to it, and return to its original shape when the force on it is released.

Elastic Rebound—an object's ability to return to its original shape after strain is overcome, and the sides move apart.

Force—the push, pull, or shear on an object that causes it to change velocity (to accelerate)

Stress—the amount of force applied across the area of an object.

Strain— changes in size, shape, or volume of an object due to stress.

VOCABULARY II—Geologic Features

Fault—A fracture or zone of fractures in rock along which the two sides have been displaced relative to each other.

Fault plane—The planar (flat) surface along which there is slip during an earthquake.

Footwall—The underlying side of a fault.

Hanging Wall—The top side of a fault.

Normal Fault—A fault, formed by extension, where the main sense of movement on the hanging wall is down.

Reverse Fault—A fault, formed by compression, where the main sense of movement on the hanging wall is up.

Strike-slip Fault—A fault, formed by shearing, where the main sense of movement on the hanging wall is horizontal. These can be classified as left lateral (where the block opposite to the one you are standing on is moving left, relative to where you are), or right lateral (the block opposite to the one you are standing on is moving right, relative to where you are.)

APPENDIX B —THE SCIENCE OF THE MODEL

The faults that we observe provide evidence that the rocks that make up Earth's outer shell are continually subjected to stresses. (Animation: "*Earthquake Faults, Plate Boundaries, & Stress—How are they related?*")

Stress is the amount of force applied across the area of an object. There are three types of stress affecting rocks. Rocks can be squeezed (compressional stress), stretched (tensional stress) or sheared (shear stress). In response to the ongoing stress, rocks are said to strain or change in their size, shape or volume. As the stress increases, rocks respond by passing through three successive stages of deformation.

Rocks respond (strain) to stress in three ways. Initially rocks respond elastically. Elastic deformation is reversible. This means that when the stress is removed the material will return to its original position. A common example of elastic deformation is the change in shape a rubber band undergoes when you pull on it. Once this stress is removed, the rubber band returns to its original shape.

As rocks pass their elastic limit, they undergo ductile deformation. Ductile deformation is irreversible or permanent. This means that, when the stress is removed, the deformation remains.

If the stress becomes too great, the rock may fracture or undergo irreversible strain. Here, the material is separated into two or more pieces. A common example is a piece of uncooked spaghetti. When enough stress is applied, the strain becomes so great that the spaghetti bends and then breaks. If the two sides of the fracture have been displaced relative to each other we call this a fault and the planar (flat) surface along which there is slip, the fault plane.

Different types of stress cause different types of faults to form. For example, tensional stress applies to rocks results in a normal fault (Figure A). Here the crust extends and the rock layers above the fault plane ("hanging wall") drop down relative to the rock layers on the other side of the fault plane ("foot wall"). A reverse fault is formed by compressional stress (Figure B). Strike-Slip faults (Figure C) are vertical or nearly vertical fractures where the blocks have mostly moved horizontally. The fault motion of a strike-slip fault is caused by shearing forces.

Figure A: Outcrop of a normal fault. Offset of the rock layers indicates that hanging wall moved down relative to the footwall. Lancashire, U.K. (University College Dublin).

Figure B: Outcrop of a small reverse fault. The hanging wall has moved up relative to the footwall, as seen in the offset of the rock layers. Teran Wash, Cochise Co. | (photo by Esty Pape)

Figure C: A strike-slip fault observed along farmland. When you look from the part of the fault nearest to you in the picture, the opposite side has moved left. This fault is therefore a left-lateral strike-slip fault. (Photo by D. Cavit, USGS)

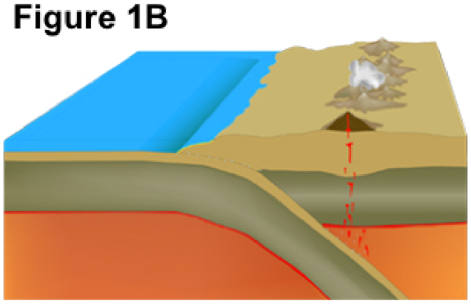
NAME: ____

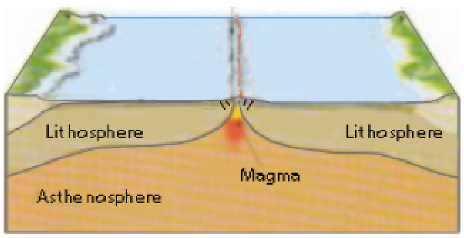
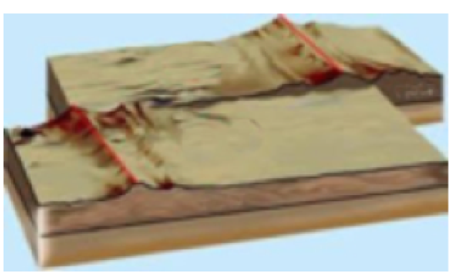
PERIOD: ________ DATE:______________________________

Fault Models

1. Briefly describe in your own words how earthquakes occur along faults and plate boundaries

2. Study the images below.
   - The figure pairs relate to the same tectonic force creating faults.
   - In the pair, Figure A shows a picture of a fault that can be seen at an outcrop or road cut. Figure B shows a diagram of a much larger plate boundary created by the same force.
   - Use the Fault Models and what you have learned from this activity to complete the table below.

Examples of the local fault and related Plate Boundary Draw arrows indicating the stress direction	Name the force involved (extension, compression, or shearing)	Name the type of Fault and related Plate boundary	Name and provide specific examples of the geologic and tectonic features created in each figure.
Figure 1A  **Figure 1B** 			

Examples of the local fault and related Plate Boundary Draw arrows indicating the stress direction	Name the force involved (extension, compression, or shearing)	Name the type of Fault and related Plate boundary	Name and provide specific examples of the geologic and tectonic features created in each figure.
Figure 2A  **Figure 2B** 			
Figure 3A  **Figure 3B** 			

APPENDIX D — BACKGROUND: FAULTING AND PLATE BOUNDARIES

Why is it important to learn about forces, faults and plate tectonics? Because they can cause earthquakes! More than 143 million people in the U.S are exposed to potential earthquake hazards that could cost thousands of lives and billions of dollars in damage. We can better understand why a ShakeAlert® Earthquake Early Warning System alert can help create more resilient communities.

There are three main types of faults that we can find on the west coast of the United States.

1) Normal faults (extension)

Normal faulting is common in areas affected by pulling or extensional forces, as observed at divergent plate boundaries (Table 1; Figure 9A). Examples of divergent plate boundaries include:

- Mid-ocean ridges (like the Mid-Atlantic Ridge and the East Pacific Rise) where seafloor spreading occurs. These comprise the longest (submarine) mountain range in the world. (Figure 9B)
- The Basin and Range Province in the Western U.S. displays signature normal faulting with many down-dropped fault blocks (grabens) that form topographic basins and adjacent high areas (horsts) that form topographic ranges. (Figure 9C)
- 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.

2) Reverse faults (compression)

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; Figure 10A). 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 oceanic Juan de Fuca Plate subducts beneath the continental North American Plate. (Figure 10B; Peru-Chile subduction zone is similar.)
- The Himalayas, where two continental plates have been colliding for about 50 million years. It is the highest mountain range on Earth and is also one of the youngest. See Figure 10C.

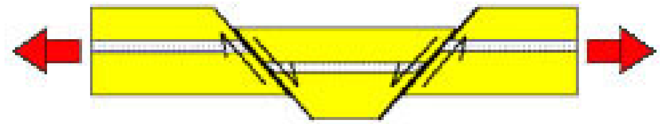


Figure 9A. Normal faulting using the fault model. Red arrows represent extension.

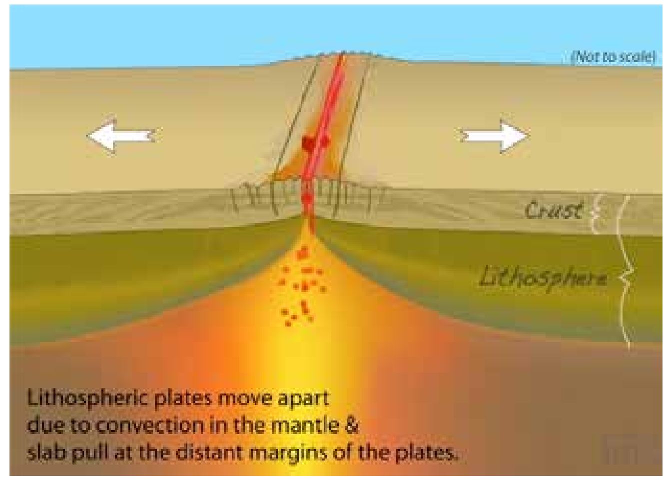


Figure 9B: Fast spreading, mid-ocean ridge.

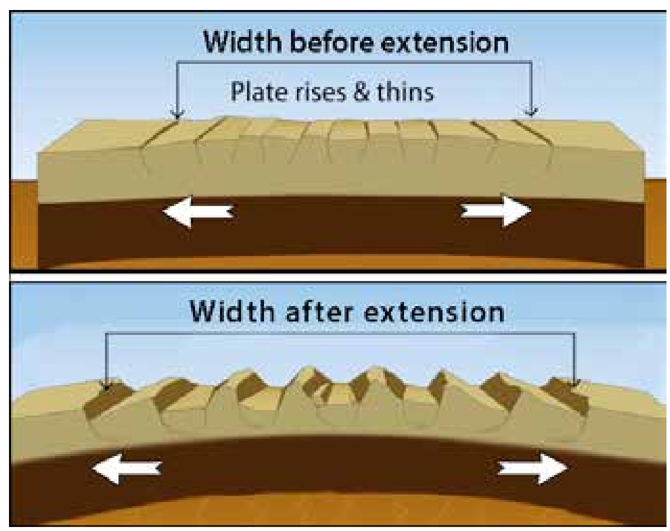


Figure 9C: Mid-continent extension creates basin and range topography. Also called horst and graben topography.

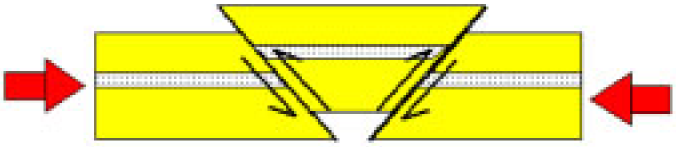


Figure 10A. Reverse faulting using the fault model. Red arrows represent compression.

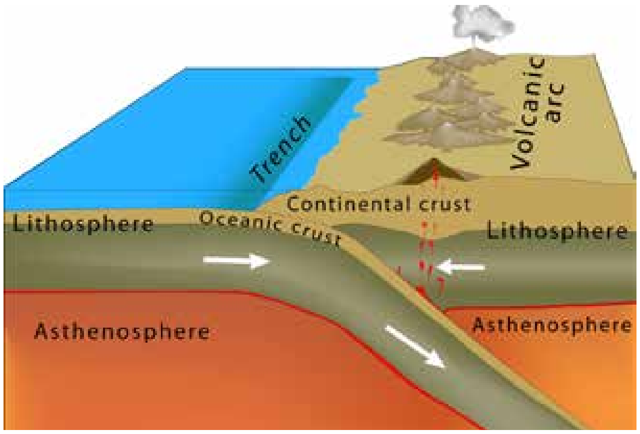


Figure 10B. Subduction zone: megathrust earthquakes and volcanoes. Ex. Cascades in Pacific NW; Andes in So. America.

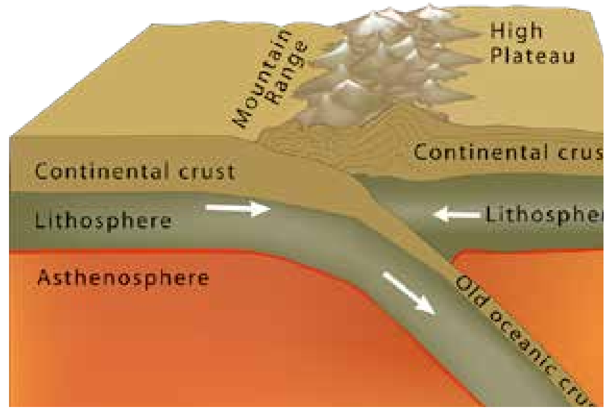


Figure 10C: Collision zone: high mountains and plateaus. Ex. Himalayas, Alps.

Table 1: Definitions of features and forces described in the learner worksheet (Appendix C)

Fault Names	**Tectonic Forces**	**Plate Boundary Descriptions**	**Related Tectonic and Geologic Features**
Normal	Extension	Divergent (extensional, moving apart, spreading, construction—because new lithosphere is generated in the extended zone).	Rifts, grabens, sometimes volcanism, regional uplift but local down dropped fault blocks, shallow earthquakes.
Reverse or Thrust	Compression	Convergent (compressional, collision, subduction, moving together, constructive [two continents collide], destructive [where one plate dives, or “subducts” into the mantle beneath the other less-dense plate].	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.
Strike-slip	Shearing	Transform (horizontal slip). On the ocean floors, these connect segments of spreading ridges to each other.	Linear topographic features, offset stream channels, sometimes lakes or depressions in pull-apart basins or local uplifts along constraining bends. Shallow earthquakes.

3) Strike-slip or horizontal-slip faults (shear)

Strike-slip faults are typically vertical fractures where the blocks have mostly moved horizontally. Strike-slip faults that form the boundary between two tectonic plates are called transform faults (Table 1; Figures 11A-B). This type of strike-slip fault accommodates the relative horizontal slip between other tectonic elements.

Examples of strike-slip faults include:

- Oceanic transform faults that offset segments of oceanic spreading ridges to produce a stair-stepped appearance (Figure 11C).
- The San Andreas Fault Zone in Southern California, is a system of strike-slip faults that forms a zone of mostly NW-trending faults that stretch from Baja California to Mendocino, in Northern California.
- Transform plate boundary between the N. American Plate and the Pacific Plate (Figure 11D). It connects the East Pacific Rise and the Juan de Fuca Plate (see map in Appendix E).

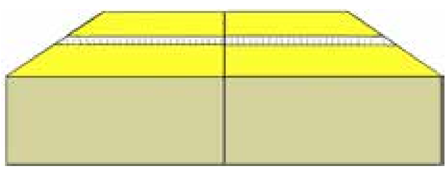


Figure 11A: View of a strike-slip fault made by butting together the two outer blocks from the three-piece model.

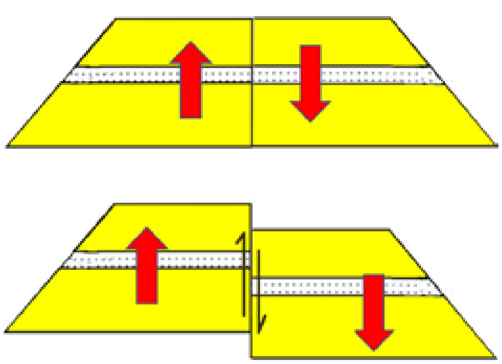


Figure 11B: Block models viewed from above with red arrows showing the direction of shearing. After fault displacement, the half-arrows show the direction of relative motion across the fault.

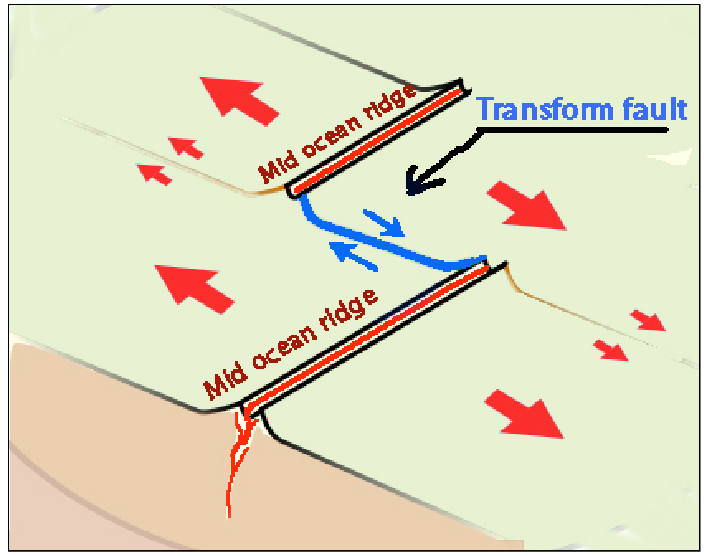


Figure 11C: Mid-ocean ridges have moved away from each other along a transform fault (blue line).

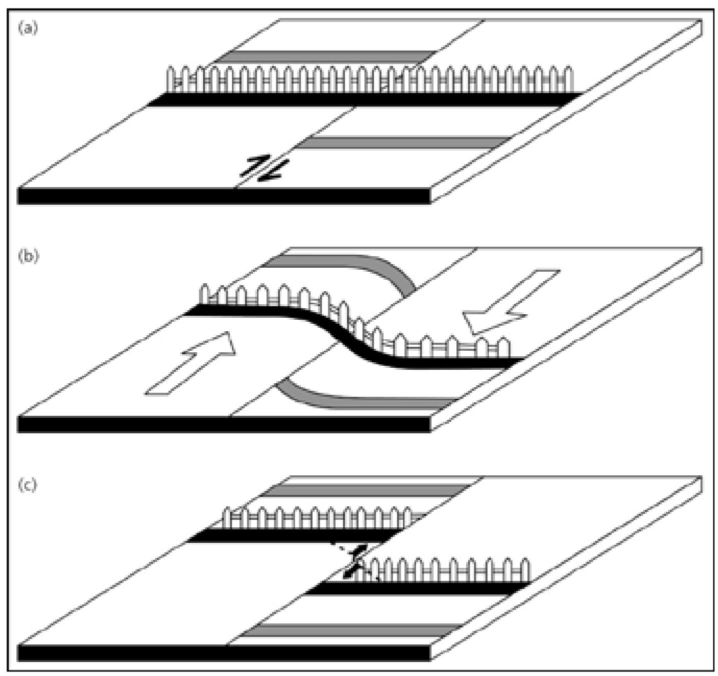


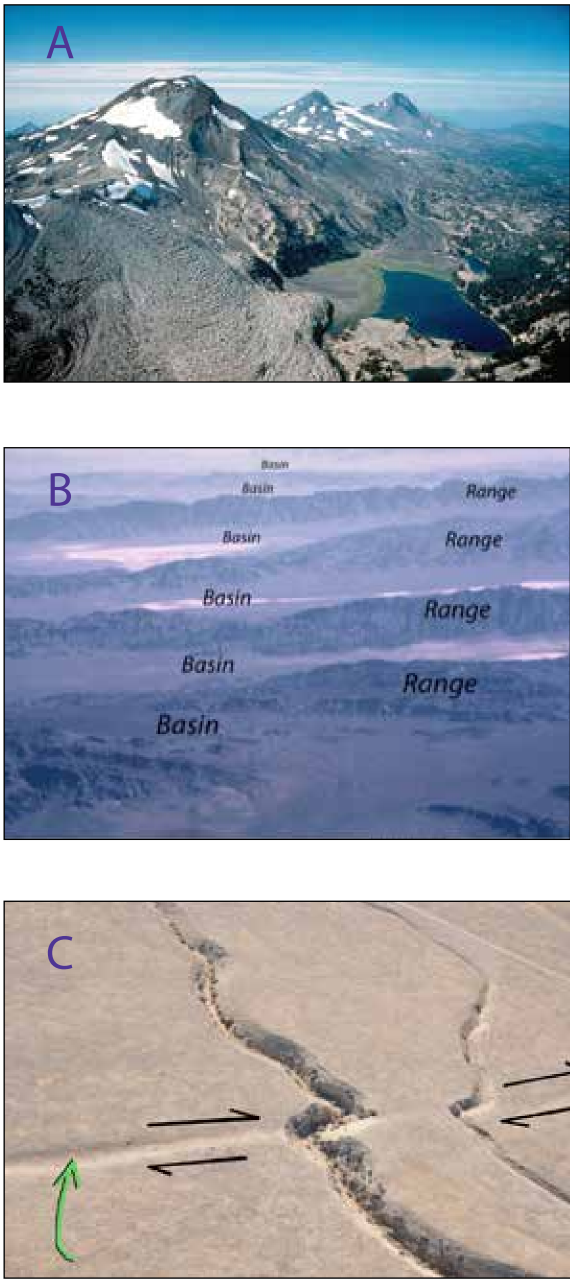
Figure 11D: Stress buildup and release along a strike-slip fault. Stress deforms the ground until friction is overcome and an earthquake causes the land to slip in a process called "elastic rebound."

APPENDIX E — FAULT MAPS OF THE WESTERN UNITED STATES

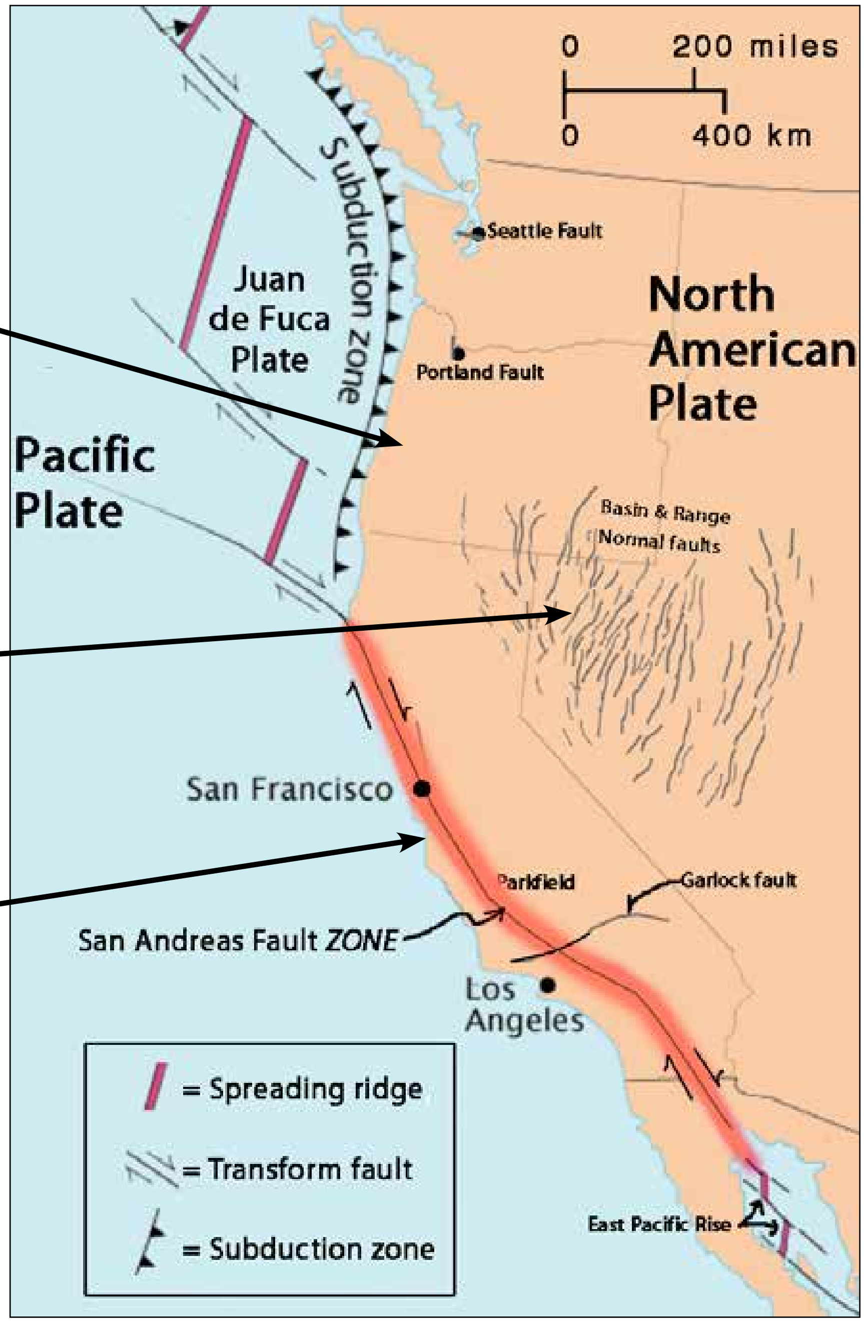
Generalized map and images of tectonic setting

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



Photographs of features associated with (A) convergent (Three Sisters, OR. USGS photo), (B) divergent (Basin & Range; Marlee Miller photo), and (C) transform margins (Carrizo Plain, CA. USGS photo).



Generalized tectonic map of the Western United States. Image modified from original U.S. Geological Survey tectonic map.

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.

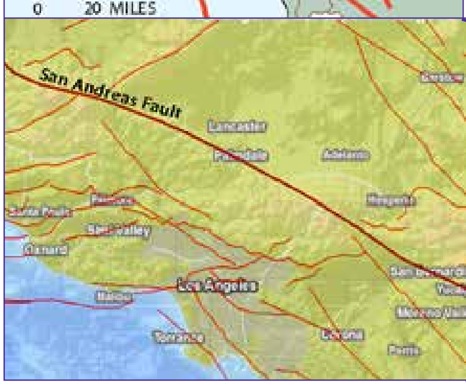
Mapping faults is difficult, and scientists interpret where faults are based on field work, map interpretation, or more recently, on lidar images that can "see" through the forests. Therefore, don't be surprised if fault maps look somewhat different.

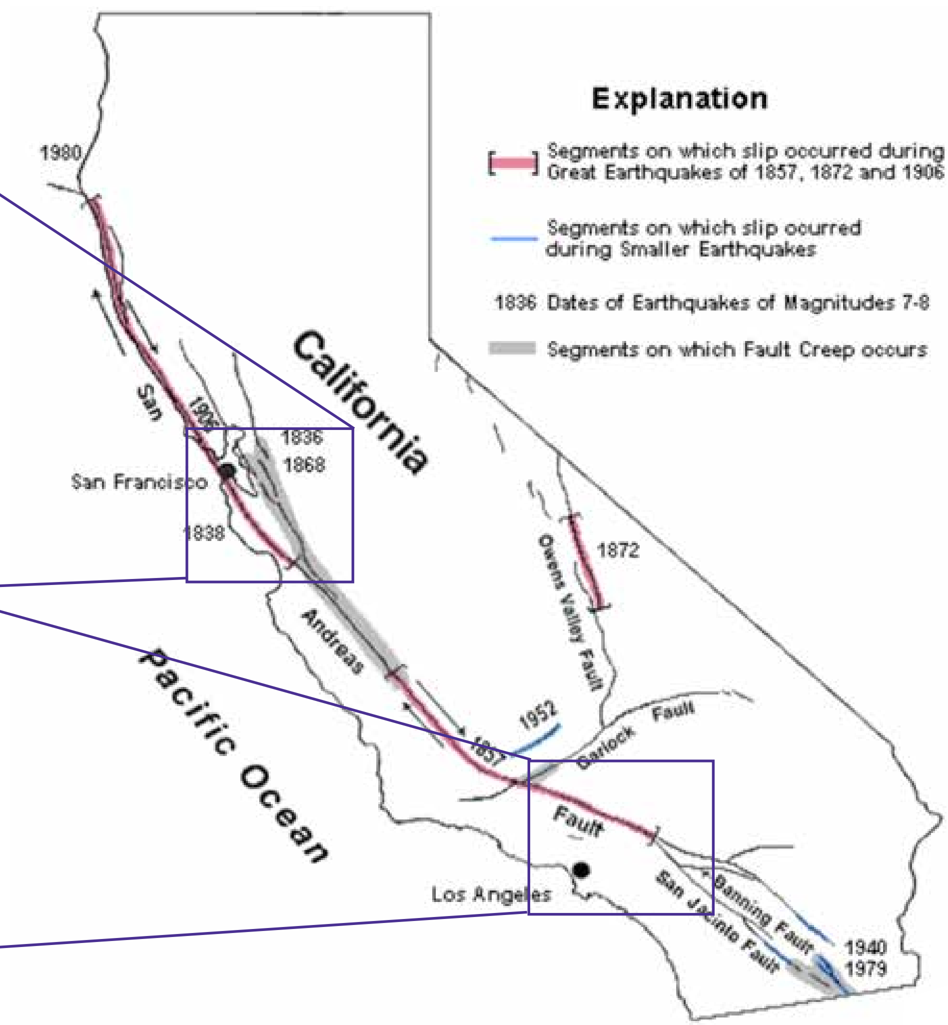
Fault map of Washington and Oregon from the [Pacific Northwest Seismic Network "Recent Events"](#) map. To see faults on the PNSN map, go to "Control Panel" and check the faults box.

Below right: *Fault map of California. See "Explanation". Zoom in on this link to see an [Interactive map of California's faults.](#)*

Below left: *Parallel faults indicate the width of the San Andreas Fault ZONE in the Bay Area. Only major faults are shown.*

Bottom: *Significant faults of the Los Angeles area.*





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. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=149

Science and Engineering Practices

Planning and Carrying Out Investigations
Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Stability and Change
Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

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. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=224

Science and Engineering Practices

Constructing Explanations and Designing Solutions
Constructing explanations and designing solutions in 6–8 builds on K–5 experiences and progresses to include constructing explanations and designing solutions supported by multiple sources of evidence consistent with scientific ideas, principles, and theories.

Disciplinary Core Ideas

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.

Crosscutting Concepts

Scale, Proportion, and Quantity
Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

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. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=183

Science and Engineering Practices

Developing and Using Models
Modeling in 9–12 builds on K–8 experiences and progresses to using, synthesizing, and developing models to predict and show relationships among variables between systems and their components in the natural and designed world(s)

Disciplinary Core Ideas

ESS2.A: Earth Materials and Systems
Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes.

Crosscutting Concepts

Stability and Change
Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible.

Incorporated Research Institutions for Seismology

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