ShakeAlert® activities for formal and informal learning settings

Mapping Worldwide Earthquake Epicenters

An Activity for Seismic Discovery

Version 7/1/20

Modified from an activity by Incorporated Research Institutions for Seismology (www.iris.edu/hq/inclass/lesson/467) by ShakeAlert®

This activity is intended to have an instructor guide learners through the materials. Computer-based visualizations and/or current earthquake reports are used to determine worldwide patterns of earthquake magnitude, depth, and location. The short 5- and 15-minute web-based visualizations are best suited for informal learning settings. The longer activities include: a 30-45 minute exercise, and a semester-long (or longer) exercise best suited for a formal classroom setting. These activities use the IRIS Earthquake Browser (**IEB; Figure 1**) and are designed to stimulate interest in global earthquake patterns and their causes. This activity provides a natural transition to teaching plate tectonics. The inquiry-based nature of the activities promotes critical thinking and questioning.

IRIS's Recent Earthquake Teachable Moment are designed specifically for the classroom and can be used in tandem with the longer activities, to allow learners to better understand the context of recent significant earthquakes.

Why is it important to learn about where earthquakes occur? 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. Understanding where earthquakes occur, both locally and globally, is fundamental to earthquake hazard mitigation. 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.

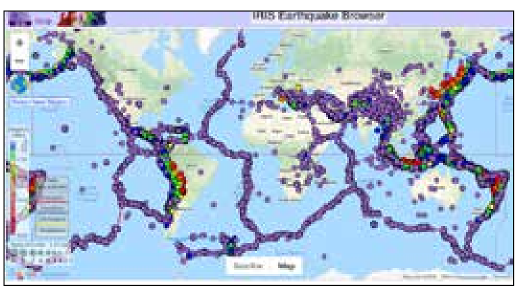


*Figure 1: **IEB** showing 20,000 of the most recent earthquakes and plate boundaries (mostly obscured by earthquakes.)*

Beginner

5 min | 15 min | 45 min

Large Group | Small Group

Student Investigation | Web-Based

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

Audience: This can be done with novice and experienced geoscience learning groups.

Subject: Natural Hazards: Earthquakes, Geoscience.

OBJECTIVES

These lessons are designed to provide learners the skills to:

- Discover unique patterns of earthquakes
- Identify locations of plate boundaries
- Identify types of plate boundaries
- Identify locations of large earthquakes
- Develop skills in plotting latitude and longitude
- Develop skills in navigating the IRIS Earthquake Browser

TABLE OF CONTENTS

MATERIALS

For the 5- and 15-minute activities:

- Instructor computer with IRIS Earthquake Browser
- Computer projection system

For the 30–45 minute activity and semester or longer activity:

- Computer projection system
- Overhead projector
- Class set of world map learner activity sheets in grayscale, photocopied (Appendix D)
- One reference world map in color per table group
- Colored pencils
- Pencil with eraser
- Rulers

Optional: computers for learners to research on-line data

RELEVANT MEDIA RESOURCES

- VIDEO: *IRIS Earthquake Browser tutorial*
- "Fault Types: 3 Basic responses to stress" Short excerpt from animation below.
- ANIMATION: "Earthquake Faults, Plate Boundaries, & Stress – How are they related?"
- Introduction to Faults and Plate Tectonics Activity
- ANIMATION: "Magnitude Explained: Moment Magnitude vs. Richter Scale"

RESOURCES FOR EARTHQUAKE DATA

- IRIS Earthquake Browser (IEB)
- USGS Earthquake Catalog
- Recent Earthquake Teachable Moments Archive

INSTRUCTOR PREPARATION

Familiarize yourself with the Vocabulary (Appendix A), background material on triangulation, latitude, and longitude (Appendices B and C) and the "Relevant Media Resources" on faults, plates, and magnitude before beginning the activity.

For all lengths of activity, review the types of earthquake faults: convergent, divergent, and transform.

For the 5- and 15-minute activities (pages 4–5)

a. Become familiar with navigating the IRIS Earthquake Browser and save the link for use in the web-based activities.

b. Review vocabulary terms: seismic moment and plate boundaries (Appendix A)

For the 30–45 minute activity (page 6)

a. Review Vocabulary terms (Appendix A).

b. Review background material on triangulation found in Appendix B.

c. Print in grayscale class set(s) of the World Map activity sheets in as large a printer format paper available. Preferably 11"X17". (Appendix D page 13)

d. Print a color version of the World Map sheet (Appendix D) for each table group. (Could be hand colored and laminated for repeated use.)

e. Prepare a list of recent earthquakes, their magnitude, depth, latitude, and longitude. (Choose the number of earthquake data that works for your class time.)

   Optional: If learners have access to computers, they could be assigned finding data for a region and a specific number of earthquakes in a given year to include: magnitude, depth, latitude, and longitude. For additional data sources, see "Resources for Earthquake Data" at left.

For the semester or longer activity (page 6)

a. Become familiar with the IRIS Teachable Moments website and save the link for use in the activity.

b. Continue to use the world maps the learners used in the 30-45 minute activity or print new class set(s) of the World Map activity sheets in as large a printer format paper available. Preferably 11"x17". (Appendix D)

ACTIVITIES AND DEMONSTRATIONS

The IRIS Earthquake Browser (IEB) allows users to create short computer-based visuals that allow learners to observe the types of plate boundaries and where major and great earthquakes occur on plate boundaries, then 'Play' the earthquakes to watch as they occur over time.

Software Overview

For these activities, we will use two of the '*Options*' functions found on the IRIS Earthquake Browser (Figure 2) including 'Show plate boundaries' and the location of all major and great earthquakes since 1970 using 'Magnitude Range'. This visualization could be used to complement a PowerPoint or stand-alone tabletop presentation that would apply to plate tectonics, plate boundaries, faults, and location of earthquakes by magnitude.

The instructor can switch between two modes (earthquakes/no earthquakes) by tapping the '*Animate the earthquakes*' text to review the types of plate boundaries and discuss the location of large earthquakes. (Click the blue text, '*Animate the earthquakes*' again and the earthquakes will reappear. The 'play' button will reveal earthquakes sequentially.

For a spreadsheat that has details on the visible earthquakes, choose '*View earthquakes as: Table*'

The default screen has the 'Options' task bar open. To hide it, click the 'Options' button (Figure 2-a).

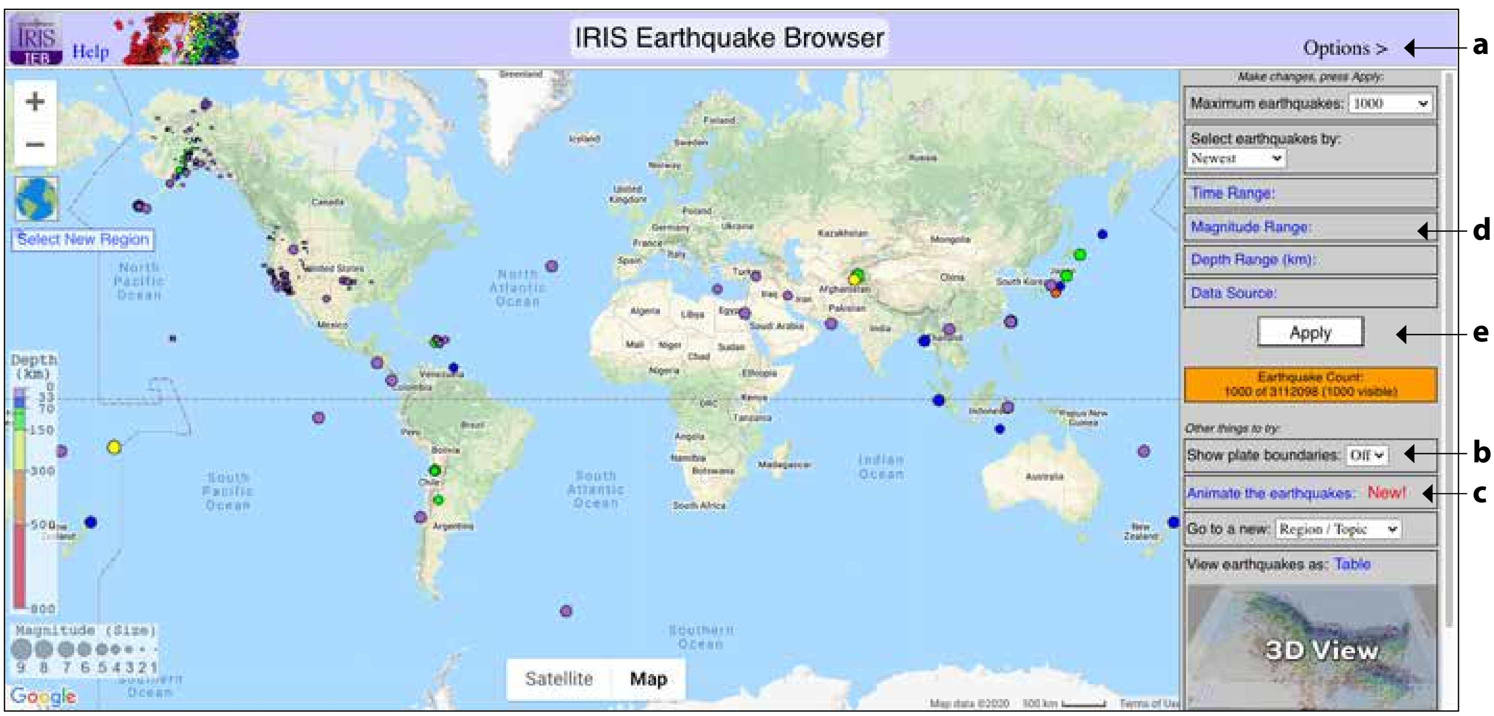


Figure 2: IRIS Earthquake Browser opening window with the default setting that shows only:

- *Maximum earthquakes: the most-recent 1,000 earthquakes*
- *Time and Magnitude Range: since 1970. NOTE: This default window includes all magnitudes. However, because it only shows 1,000 newest earthquakes, it includes only those happened in just the past month or less, even though the* Time Range *goes back to 1970!*
- *"Show Plate Boundaries" is turned "OFF"*

*Letters "**a**" through "**e**" to the right of the* **Options** *panel refer to* **Directions** *on page 4.*

IF YOU HAVE 5 MINUTES

Did You Know?

- Did you know that earthquakes cluster on or near plate boundaries?
- Did you know that large earthquake (M7 or greater) primarily occur on plate boundaries?

Directions:

1. Open the Earthquake Browser.
2. To see the plate boundaries, set the '*Show plate boundaries*:' option in the grey 'Options' task bar from 'Off' to 'On' (Figure 2-b).
3. Immediately below, click the '*Animate the earthquakes*' button and the default earthquake dots will disappear. At this point in the exercise, you only want to see the plate boundaries. Don't click the 'play' button (Figure 2-c).
4. Review with learners the three basic types of plate boundaries. Point out the legend on the lower left showing that divergent boundaries (red lines) move apart, transform (strike-slip) boundaries (blue lines) move past each other, and convergent boundaries (yellow lines) move toward each other.
5. Ask learners to notice where plate boundaries are located relative to continents and countries. For example, ask if plate boundaries are near New Zealand or Australia? Iceland or Scandinavia and the British Isles? The west coast of the Americas or the east coast? Ask learners to identify other examples.
6. To show where large earthquakes occur in relation to the plate boundaries, make the following changes in the Options:
   a. Set Magnitude Range: Remove (unclick) the 'All Values' box and enter **7 <=** and (keep the default) **<=10** (Figure 2d), then click the '*Apply*' button (Figure 2e).
   b. Toggle the earthquakes on and off by clicking on the Animate the earthquakes button. You will want to turn the earthquakes on and off several times so that learners can clearly see the plate boundaries. (Don't 'Play' the animation at this time.)

Questions for Discussion:

- What earthquake patterns do you notice?
  (*The main clusters of earthquakes are near or on plate boundaries; although a few clusters are far from plate boundaries. Point out dots indicating locations on the IEB map*.)
- Why do you think that large earthquakes occur primarily on plate boundaries?
  (*Only plate boundaries have a fault area large enough to potentially rupture in a single, large event. The seismic moment, which determines the moment magnitude (M_w), takes this area into consideration. Refer to Vocabulary for more information.)*

IF YOU HAVE 15 MINUTES

This activity builds on the previous 5-minute activity and continues the exploration and focus on why large earthquakes occur on convergent plate boundaries (Figure 3). This is particularly useful for understanding Pacific Rim seismic history and hazards, and the risk for the next great earthquake on the Cascadia Subduction Zone.

Did You Know?

- Did you know the largest earthquakes occur at convergent boundaries? (Figure 3).

Directions:

1. With the IEB, begin with "Show plate boundaries" toggled "On" to observe where the convergent plate boundaries (yellow) are located:
   a. Open the Magnitude Range setting and unclick the 'All Values' button, then select magnitudes from
   7<= magnitude <=10 and click Apply.
   Note for instructor: Under the Apply button, notice the text inside the orange box displays the number of earthquakes shown on the map out of the total number of earthquakes in the archive meeting the criteria (M>7).
   b. Point the learner's attention to notice where the earthquakes (illustrated by color-coded and sized dots) are located on the convergent plate boundaries (yellow). Select "Animate the earthquakes" to see the earthquakes and click again to remove them. You will need to do this several times so that learners can clearly see the color of the plate boundaries that the earthquakes cover. (Don't "Play" the animation at this time.)
   c. Point the learner's attention to notice the colors of the dots, which indicate earthquake depth. Refer to the legend on the far lower left of the screen for explanation.
2. Compare major (M>7) with minor (M<4) magnitude earthquakes and their locations.
   In Options: (For instructors: open another copy of the IEB in a browser and set up a follows.)
   a. Set "Maximum earthquakes" to 1000 or 1500.
   b. Set "Magnitude Range" to 2.5 <= Magnitude <= 4, then tap Apply.
   Experiment with zooming in and out of the display by clicking control + scroll. Or use the + and – located at the top left of the screen.
3. As an extension:
   a. Experiment with different magnitudes and what depths they occur.
   b. Select a region and zoom in to investigate patterns.

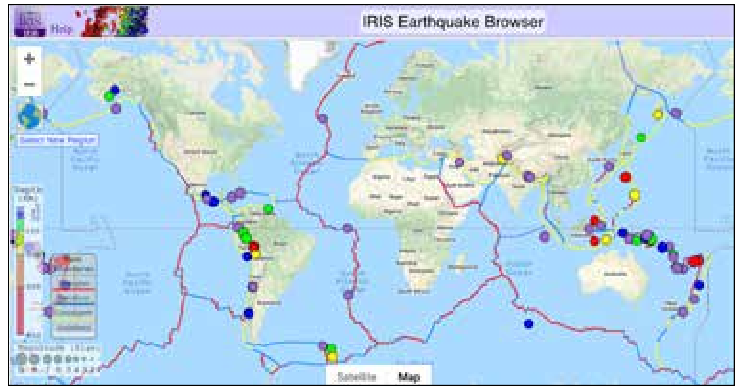


Figure 3: IRIS Earthquake Browser showing major earthquakes >M7 (for the past five years only) and plate boundaries.

Questions for Discussion:

- What patterns do you notice with the large (M>7) earthquakes?
  (*These earthquakes tend to occur on plate boundaries*)
- On what type of plate boundary do large earthquakes (M>7) primarily occur?
  (*These earthquakes tend to occur on convergent plate boundaries. Some of the very shallow earthquakes occur on any type of boundary*)
- Why do you think large earthquakes (M>7) primarily occur there?
  (*Convergent plate boundaries have large areas that can rupture in an earthquake. See the moment magnitude formula (Figure 8) which takes the area of the fault rupture into consideration.)*
- What is happening on a convergent plate boundary?
  (*Two plates are coming together and pressing against one another*)
- Where are minor earthquakes (M< 4) found?
  (*Minor earthquakes occur all over the globe, on major plate boundaries and on crustal faults*)
- Where do we see minor (M<4) earthquakes where bigger earthquakes (M>7) do not occur?
  (*Minor earthquakes occur on crustal faults. Larger earthquakes don't typically occur on crustal faults because the faults are not long enough and deep enough to produce large earthquakes.)*

IF YOU HAVE 30–45 MINUTES

In this longer activity, learners investigate individual earthquakes in greater detail by their geographical coordinates in latitude and longitude, and depth. Learners discover how to plot epicenter coordinates in guided instruction, then begin plotting additional epicenters with data that either the instructor provides, or with data they research on their own. The goal is to show how patterns of earthquake activity emerge over time, and that earthquakes mainly occur on faults and plate tectonic boundaries.

Did You Know?

- Did you know that earthquakes can occur anywhere from just below the surface down to 800 km (500 mi) deep?

Important Note: Photocopies of the world map that learners receive will be in grayscale. Therefore, they need to be instructed to color the plate boundary where the epicenters they plot have occurred (color is defined in the legend). Learners should refer to the colored reference map in Appendix D for their table group.

Activity Sequence

1. Plotting earthquake epicenters (Figure 4) requires that learners understand a few key concepts about where earthquakes occur. Depending on time and content depth you would like to present, review with learners the following:
   a. An earthquake epicenter is a point on the earth's surface directly above the location where an earthquake originated, called the hypocenter (Figure 5).
   b. Most earthquakes occur near the surface from 0 – 70 km (43.5 miles). However, earthquakes can occur at much greater depths. Scientists have observed earthquakes up to 800 km (500 mi) depth (Figure 6).
   c. All earthquakes occur on faults, and the largest earthquakes occur on plate boundaries, which are long, continuous faults (Figure 7).
   d. Though earthquakes occur on faults anywhere in the world, it may surprise learners to find that the majority of large and great earthquakes occur on plate boundaries. Only plate boundaries have an area large enough to potentially rupture in a single,

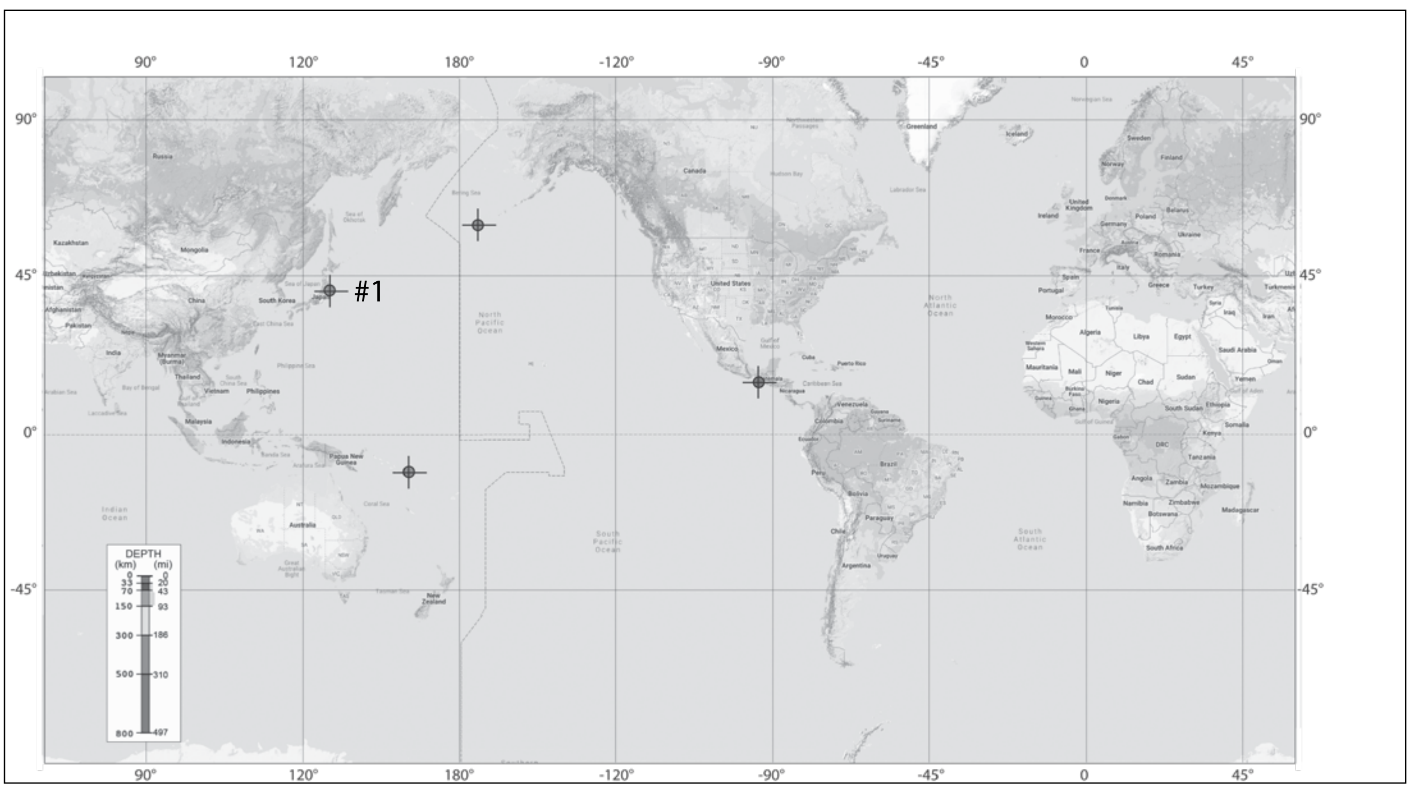


Figure 4: Black & White version of the world map from Appendix D. Earthquake coordinate lines and epicenters as they would appear in the activity. NOTE: The Appendix D map can be printed in grayscale and have students color the plate boundaries.

large event. The seismic moment, which determines the moment magnitude (M_w), takes the area into consideration. (Refer to the vocabulary and watch the animation on Magnitude for more information.)

e. The importance of the area is represented in the formulas defining the seismic moment and determining the moment magnitude of large and great earthquakes (Figure 8). See Appendix A, Vocabulary for definitions.

f. The difference between *P* and *S* seismic wave arrival times provides the distance to the epicenter at each seismometer (Figure 9). Using triangulation, the distances from three seismographs are used to locate the latitude and longitude of an earthquake. If you draw a circle on a map around three different seismographs where the radius of each circle is the distance from that station to the earthquake, the intersection of those three circles is the epicenter. See Appendix B for additional information.

2. Work through an example of plotting an earthquake with students. We can plot earthquake epicenters on a map with latitude and longitude coordinates, which reveal important information and patterns about plate tectonic processes and earthquakes. (A review of latitude and longitude spherical coordinates can be found in Appendix C.)

   a. Project the world map that learners will use, which can be found in Appendix D.

   b. Point out degrees latitude on the sides of the map and degrees longitude top and bottom of the map.

      I. The lines of latitude, such as the equator, go around the globe. The lines of longitude go through the North and South poles.

      II. Point out that a negative number in degrees latitude refers to the southern hemisphere. Negative degrees longitude refers to the 180° west of the Prime Meridian (Greenwich).

      III. Demonstrate how to plot the geographic coordinates of an actual earthquake.

   c. On July 14, 2019 a M7.3 earthquake occurred in Indonesia. The coordinates are Latitude: -0.529° | Longitude: 128.0931°. Given the small scale of the world map, round the coordinates to one decimal place. The new coordinates are:

      Latitude: -0.5° | Longitude: 128.1°

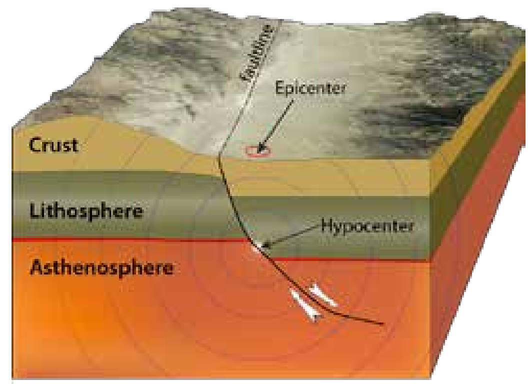


Figure 5: The relationship between the earthquake hypocenter (focus) and epicenter.

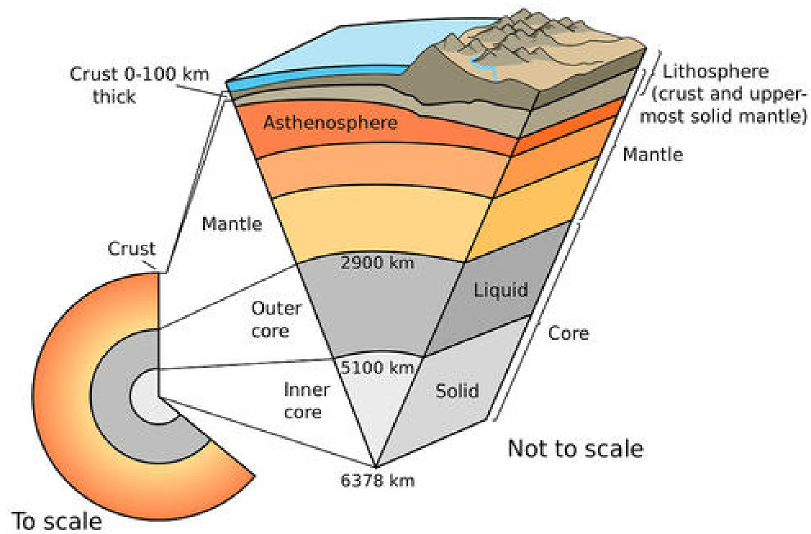


Figure 6: Layers of the earth, in both chemical/compositional terms (crust, mantle, outer core, inner core) and mechanical terms (lithosphere, asthenosphere, mantle, core).

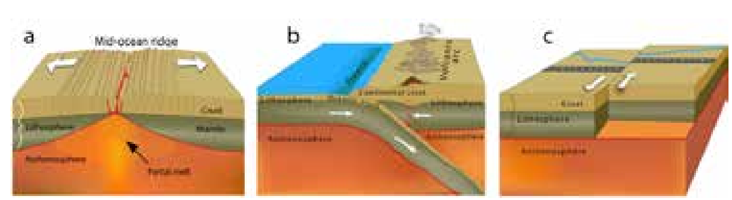


Figure 7: Types of tectonic plate boundaries, (a) divergent, (b) convergent, and (c) transform.

d. First, locate the approximate location where the latitude and longitude intersect on the world map. Next, in pencil, lightly draw short ½ inch lines representing the latitude and then the longitude coordinates (+). Refer to sample locations in Figure 4.

e. At the point of intersection where the lines cross, make a solid dot. Place a small number (+ 1) next to the dot, which will correspond to a list of earthquake coordinate data.

d. On the back of the map (or on a separate piece of paper which is attached to the map) record the number you used for the earthquake plotted, its magnitude, date, depth, region and geographic coordinates. See Appendix E for a sample data table.

3. The plotting of earthquake epicenters can be done as a whole group with the same data, or as pairs or table groups using additional data depending on how many epicenters you want to see plotted.
   a. Distribute: individual world maps you have enlarged and printed, the colored world map reference sheet (one per table group), earthquake data sheets, colored pencils and rulers. See the Instructor Preparation section on page 2 for more information if needed.
   b. Optional: Learners could use computers to research data. Refer to Instructor Preparation on page 2.

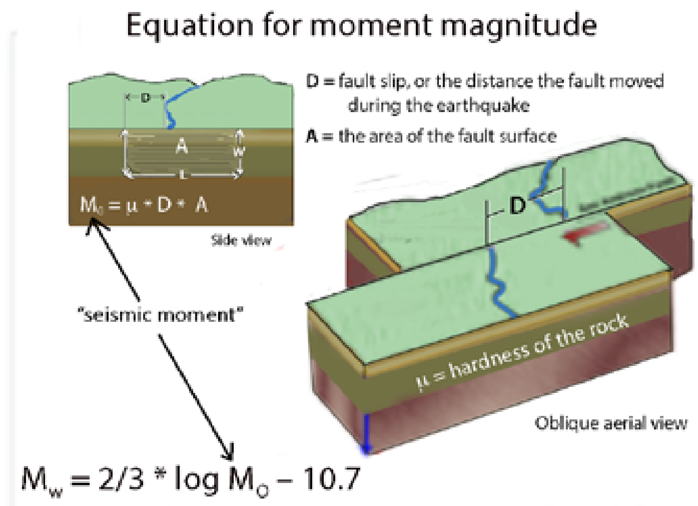


Figure 8: The relationship of slip on the fault to magnitude for seismic moment and moment magnitude. Animation about the equation linked here: [Moment magnitude.]

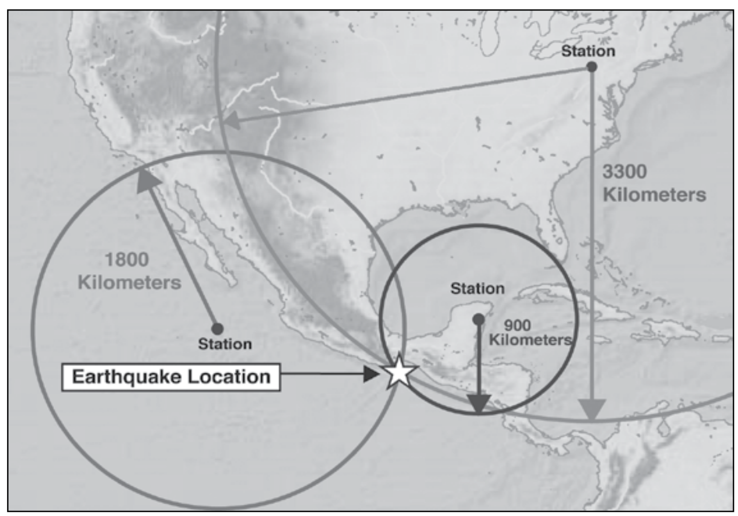


Figure 9: Triangulation showing the point of intersection identifying the location of the earthquake epicenter

Questions for Discussion

Answers will vary for the following three questions:

- What patterns do you notice for the locations of the earthquake epicenters?
- Do the epicenters occur on plate boundaries? If so, what types of plate boundaries?
- What patterns do you notice for the depth of the earthquakes?

NGSS Standards for this activity can be found in Appendix F.

IF YOU HAVE A SEMESTER OR LONGER

This activity should follow the 30-45 minute activity as an ongoing investigation. NGSS Standards for this activity can be found in Appendix F.

Using the same world-map activity sheet, new earthquake epicenters are added over the course of a semester or longer. Instructors may also sign up for IRIS Recent Earthquake Teachable Moments to automatically receive new earthquake notifications (Figure 10) and a 5-15 slide PowerPoint presentations that describe the geologic context for recent earthquakes greater than M7, which can be used in the classroom. Instructors may take time the same day or whenever available to help students understand earthquakes that appear in the news. (Sign up: eno_quakes@lists.ds.iris.edu)

As data is presented, learners will record basic information including the earthquake's date, magnitude, depth, and general location on a separate piece of paper and attach it to the map. They will also plot the epicenter on their individual World Map.

The on-going longer duration activity allows learners to see that earthquakes are not just data, but rather real events that often have serious consequences that impact people and property. Additionally, earthquakes on subduction zones often create tsunami hazards, which leads to interesting discussions about why some large earthquakes have tsunamis and some do not. A short animation on how Megathrust Earthquakes generate tsunamis explains why this occurs.

At the end of the recording period, discuss the maps the learners have created.

Questions for Discussion: (*Answers will vary for the following three questions*.)

- What did you learn from doing this project over a long period of time?
- What kind of patterns do you see in the epicenters you plotted?
- What can we learn from these earthquakes that will help us better understand and prepare for future earthquakes?

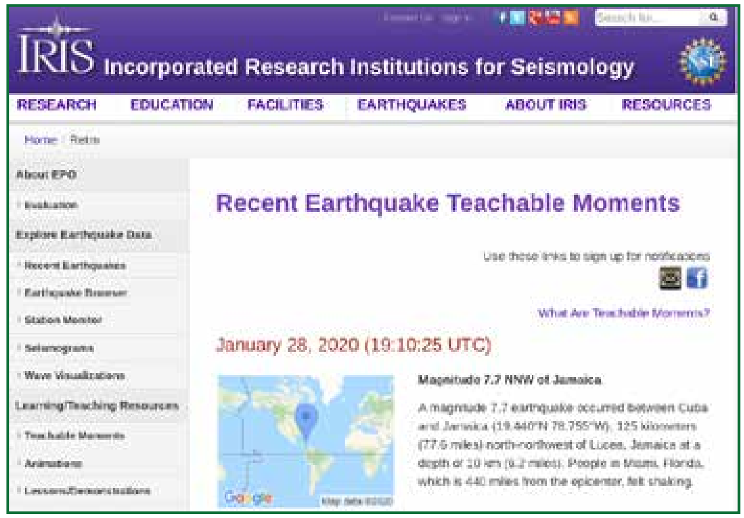


Figure 10: Screen grab of IRIS's Recent Earthquake Teachable Moments homepage.

About Recent Earthquake Teachable Moments

Each IRIS Teachable Moment:

- Provides a 5-15 slide PowerPoint presentation that contains interpreted USGS regional tectonic maps and summaries, computer animations, seismograms, AP photos, and other event-specific information.
- Generated within hours of the event!
- Prepared by seismologists and educators!
- A classroom-ready product that can be customized!
- Available to subscribers free of charge through internet notifications when new products are ready!

Use the link here to view Teachable Moments SUBSCRIBE: then click on the envelope icon to subscribe.

VOCABULARY

Crust: The Earth's crust is a thin shell on the outside of the Earth, accounting for less than 1% of Earth's volume. It is the top component of lithosphere, a division of Earth's layers that includes the crust and the upper part of the mantle. Watch animation of plate vs crust.

Epicenter: The point on Earth's surface directly above the hypocenter of an earthquake.

Hypocenter: The point within Earth that is the origin of an earthquake, where stored energy is first released as seismic waves. Refer to Figure 5.

Lithosphere: solid, rocky, outer part of the Earth, ~100 km thick (50 miles) comprised of the crust and the solid portion of the mantle. The thickness is age dependent; older continental lithosphere is thicker than younger oceanic lithosphere. The lithosphere below the crust is brittle enough at some locations to produce earthquakes by faulting, such as within a subducted oceanic plate. Refer to Figure 6.

Magnitude: A number that characterizes the size of an earthquake. The current measurement of earthquake magnitude uses the Seismic Moment (the average distance of slip (displacement), the area of fault rupture (length and width) and the resistance of the rock to bending (and shaking) when a force is applied) to calculate the size. Magnitude is calculated using the height or amplitude of seismic waves recorded on a seismograph and correcting for the distance to the epicenter of the earthquake. Watch animation that explains magnitude.

Plate Boundary: The tectonically active contact between tectonic plates can be convergent, divergent, and transform. Refer to Figure 7.

VOCABULARY (cont)

Seismic Moment: The force required to overcome the friction sticking the rocks together to generate the recorded waves on a seismometer. The seismic moment is based on the area of fault rupture, the average amount of slip (displacement), and the rock rigidity which provides the frictional resistance to slipping). For the same displacement and area of slip, high rigidity rocks yield a stronger earthquake while softer rocks shear more easily and result in weaker earthquakes. Rock rigidity increases as depth in the lithosphere as the pressure on rocks increase with depth. Refer to Figure 8. (Watch animation to learn what seismic moment is.)

Tectonic Plates: The large, thin, relatively rigid plates that move relative to one another on the outer surface of the Earth. Comprised of the solid section of the Earth's crust and outermost mantle that moves over the deeper mantle. Also known as a Lithospheric Plate. Scientists have observed earthquakes as deep as 800 km or 500 miles deep in the upper mantle. Refer to Figure 6. Watch animation of plate vs crust.

Triangulation: Uses distances from three seismographs to locate an earthquake. If you draw a circle on a map around three different seismographs where the radius of each circle is the distance from that station to the earthquake, the intersection of those three circles is the epicenter. Refer to Appendix B.

APPENDIX B — HOW EARTHQUAKE EPICENTERS ARE DETERMINED (NOVICE)

Adapted from the USGS's "The Science of Earthquakes"

Scientists use seismograms to locate earthquakes. The accurate determination of the arrival time between the P- and S-waves are important. P and S waves each shake the ground in different ways as they travel through it. P waves are faster (move through the ground more quickly) than S waves, which allows us to determine where an earthquake happened.

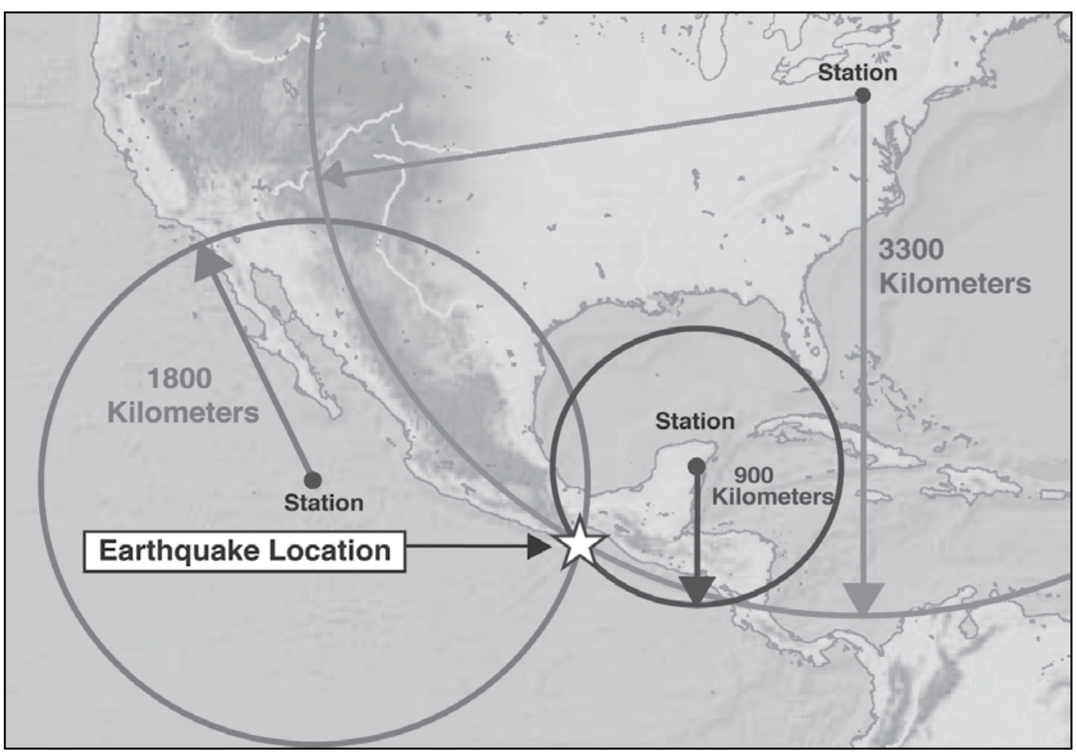
To understand how this works, let's compare P and S waves to lightning and thunder. Light travels faster than sound, so during a thunderstorm you will first see the lightning and then you will hear the thunder. If you are close to the lightning, the thunder will boom right after the lightning, but if you are far away from the lightning, you can count several seconds before you hear the thunder. The further you are from the storm, the longer it will take between the lightning and the thunder.

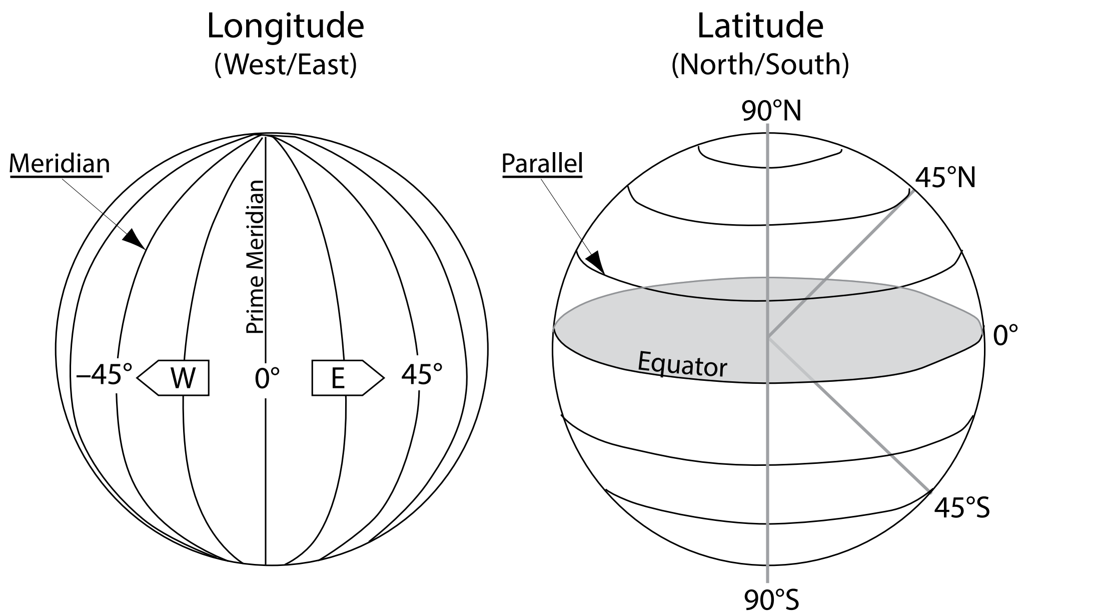
P waves are like the lightning, and S waves are like the thunder. The P waves travel faster and shake the ground where you are first. The S waves follow and also shake the ground. If you are close to the earthquake, the P and S waves will come in rapid succession; in fact, if you are above an earthquake you won't be able to distinguish the two. If you are far away, there will be more time between the two. By measuring the time between the P and S wave on a seismogram recorded on a seismograph, scientists can tell how far away the earthquake was from that location. However, they can't tell in what direction from the seismograph the earthquake occurred, only how far away it was. If they draw a circle on a map around the station where the radius of the circle is the determined distance to the earthquake, they know the earthquake lies somewhere on the circle. But where?

Scientists then use a method called triangulation to determine where the earthquake is located (figure below). It is called triangulation because a triangle has three sides, and it takes three seismographs to locate an earthquake. If you draw a circle on a map around three different seismographs where the radius of each circle is the distance from that station to the earthquake, the intersection of those three circles is the epicenter!

The aim of the ShakeAlert® Earthquake Early Warning System is to quickly detect the P-waves, and determine the earthquake's location and magnitude. If the earthquake is above a certain magnitude threshold, an alert is sent out, hopefully with enough time to take a protective action, such as Drop, Cover, and Hold On.

Note: In reality, finding an earthquake's epicenter is much more complex due to the depth of the hypocenter and composition of the crust the seismic waves are traveling through. But triangulation is good for approximation.

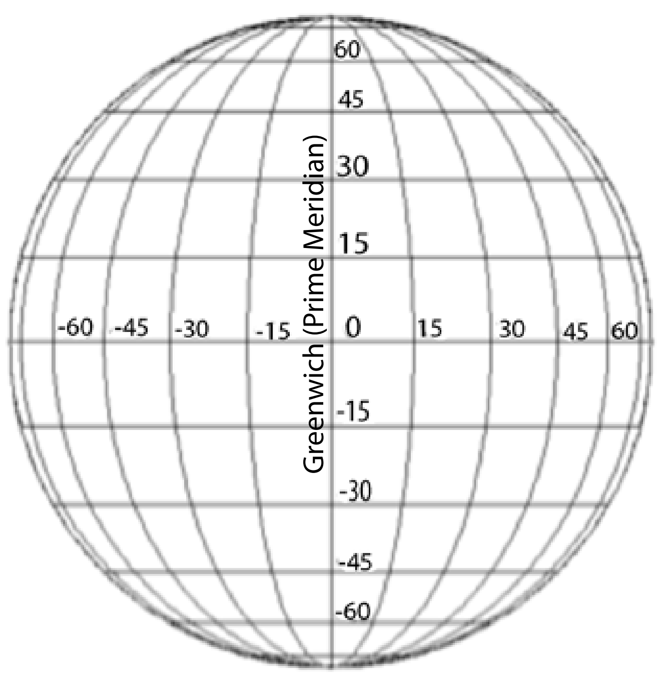




From 0° at Greenwich to
180 E and W to other side of globe

From 0° at the Equator
to 90· at the N and S Poles

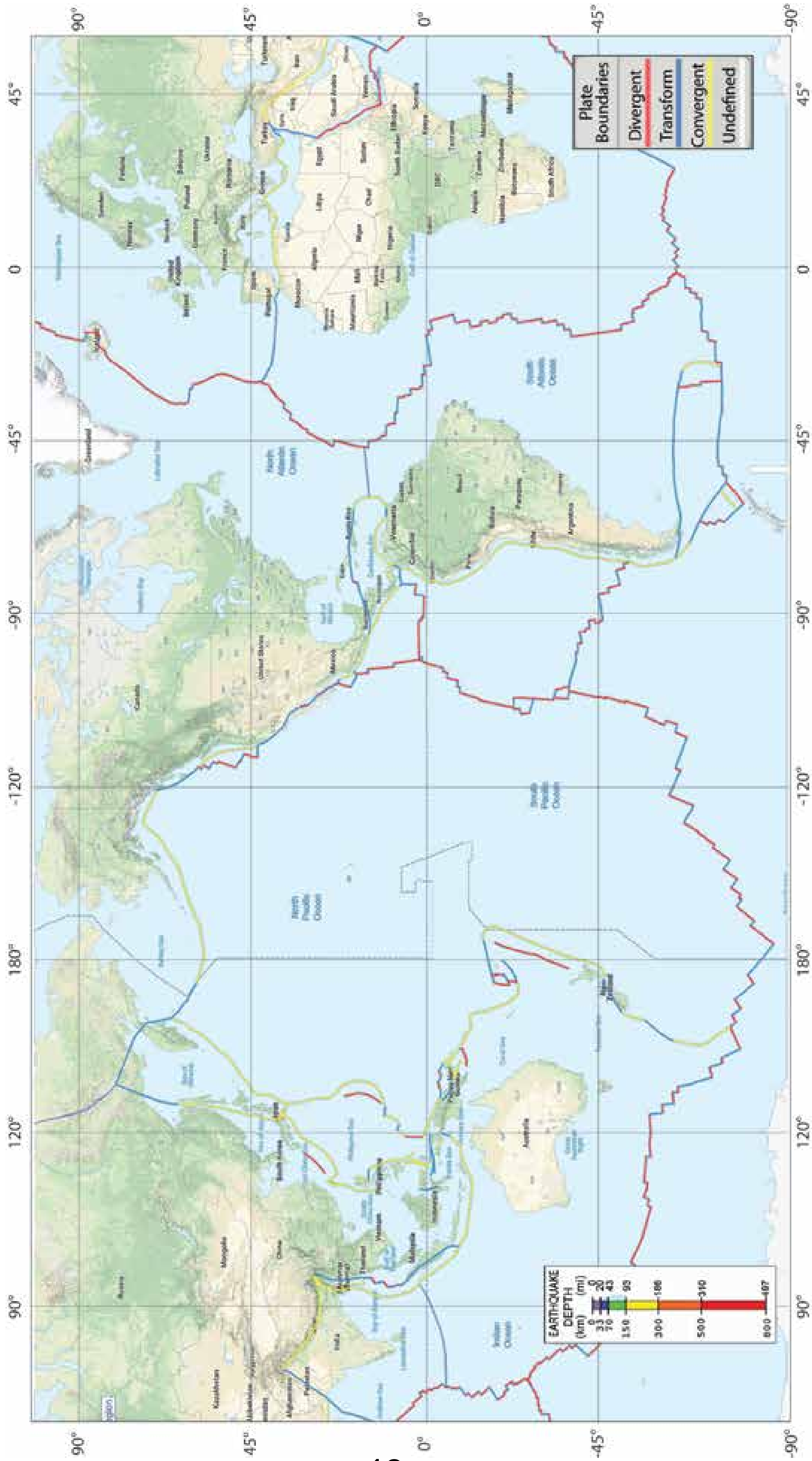
The lines of latitude, such as the equator (0 degrees latitude), go around the globe. The lines of longitude go through the North and South poles.



Spherical Coordinates showing degrees latitude and longitude

APPENDIX D — WORLD MAP LEARNER ACTIVITY SHEET

Print in Black and White and have students color the plate boundaries, legend, and earthquake depths.



APPENDIX E — SAMPLE LEARNER DATA SHEET FOR PLOTTING EARTHQUAKE EPICENTERS

EQ number Plotted on map	**Magnitude**	**Date**	**Depth** km	**Region**	**Geographic coordinates Latitude**	**Geographic coordinates Longitude**
1	7.3	2019	19	Indonesia	-0.529°	128.0931°

Touch the url links to get more information

Earth's Systems

- **MS-ESS3-2** Analyze and interpret data on natural hazards to forecast future catastrophic events and inform the development of technologies to mitigate their effects.
  http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=213
- **ESS3.B**: Natural Hazards for 3-D Disciplinary Core Ideas
  Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)

Science and Engineering Practices

Analyzing and Interpreting Data
Analyzing data in 6–8 builds on K–5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis

Disciplinary Core Ideas

ESS3.B: Natural Hazardss
Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events. (MS-ESS3-2)

Crosscutting Concepts

Patterns
Graphs, charts, and images can be used to identify patterns in data.(MS-ESS3-2)

Waves and Their Applications in Technologies for Information Transfer

- **HS-PS4-1** Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. [Clarification Statement: Examples of data could include electromagnetic radiation traveling in a vacuum and glass, sound waves traveling through air and water, and seismic waves traveling through the Earth.] http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=116
- **Use PS4.A:** Wave Properties for 3-D Disciplinary Core Ideas
  The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=191

Science and Engineering Practices

Developing and Using Models
Modeling in 6–8 builds on K–5 experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems.

Disciplinary Core Ideas

PS4.A: Wave Properties
The wavelength and frequency of a wave are related to one another by the speed of travel of the wave, which depends on the type of wave and the medium through which it is passing.

Crosscutting Concepts

Cause and Effect
Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects.