Exploring Patterns of Global & Regional Seismicity

Using the Interactive Earthquake Browser

www.iris.edu/hq/inclass/lesson/455

Version 5.3 (10/11/17)

IRIS
www.iris.edu/educate

Incorporated Research Institutions for Seismology
Created for IRIS by Lev Horodyskyj and Michael Hubenthal.

OVERVIEW

In this activity, students review their prior knowledge about various types of plate boundaries. Next students use the IRIS Earthquake Browser (IEB; Appendix A) to investigate well-known examples of some of these boundaries. Students are asked to pay particular attention to the spatial distribution, rate of seismicity, and depth of quakes in each area. Students then point IEB to a new region and are asked to use the "templates" of seismic evidence they have previously constructed for the primary plate boundaries to argue for what is occurring within the mystery region.

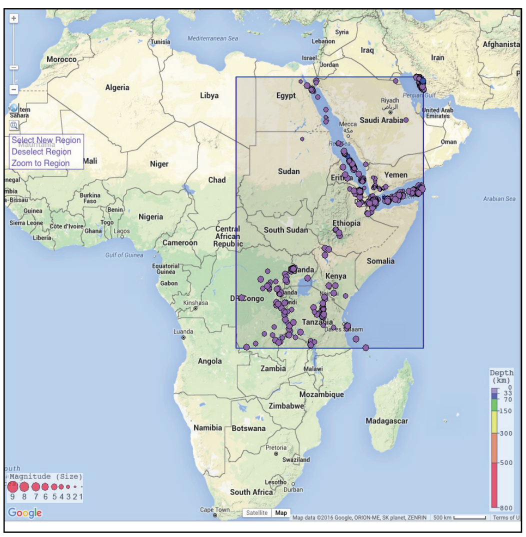


***Figure 1:** Screen grab of IEB's "mystery" location of all earthquakes since 1/1/2011.*

This activity is designed to engage students in evidence that supports plate tectonics while also raising questions about earthquakes and plate tectonics. Questions and claims developed during this lesson should be recorded and used to drive follow-up instruction during the EXPLAIN phase of the activity.

Intermediate

70–80 min

Individual or pairs

Web-Based

OBJECTIVES

Students will be able to use the IRIS Earthquake Browser to

- Explore current seismicity of our planet
- Examine earthquake patterns at tectonic plate boundaries
- Identify geomorphologic features associated with these plate boundaries
- Describe the global distribution of earthquakes
- Use seismic evidence to identify the plate boundary model that "best" supports the data for each site.

TABLE OF CONTENTS

MATERIALS

- Computers or tablets with internet access for each student or pair of students
- IRIS Earthquake Browser (IEB): www.iris.edu/ieb
- Student Worksheets Pages SW-1 – SW-6

PREREQUISITES

- Complete the short-term activity, "Where's Waldo" and/or the longer activity, "*What's Shaking*?" from the lesson, "*Plotting Earthquake Epicenters*": www.iris.edu/hq/inclass/lesson/467

TEACHER PREP

- Read "Using IRIS Earthquake Browser" in Appendix A to practice using IEB.
- For Plate Tectonics background, see Appendix B and the animations and videos in the gray box below.
- The egg analogy of Earth's layers is addressed in the Student Worksheets. See Appendix C.
- Print Student Worksheets, Pages SW-1 – SW-5.

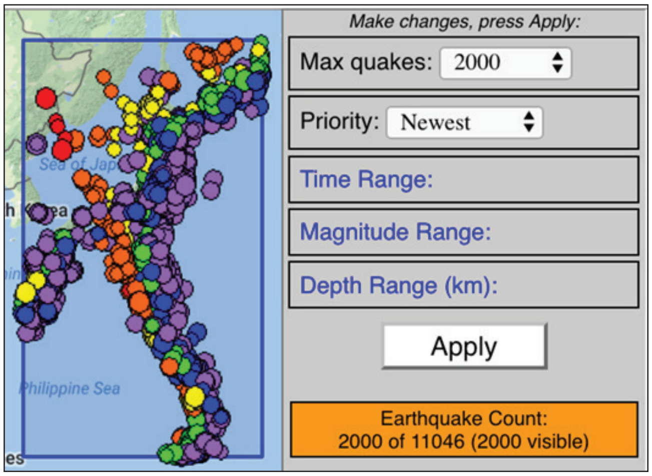


Figure 2: *Screen grab of IEB's "Site 1" that includes epicenters for all earthquakes since 1/1/2011*

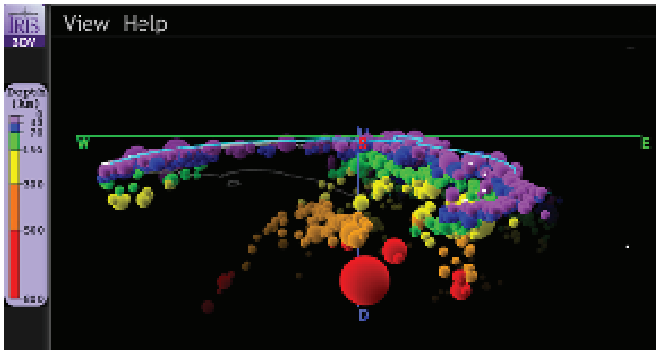


Figure 3: *Screen grab of Figure 2 map in 3-D view above, with "View" > "Look" > "North" selected.*

ANIMATIONS & VIDEOS ABOUT PLATE BOUNDARIES

3 boundary types – Animation:

- www.iris.edu/hq/inclass/animation/492

3 boundary types – Video Lecture:

- *www.iris.edu/hq/inclass/video/106*

Plate tectonics/convection—What are the forces that drive plate tectonics-

- www.iris.edu/hq/inclass/animation/557

Divergent Boundaries

- www.iris.edu/hq/inclass/animation/90
- www.iris.edu/hq/inclass/animation/132

Convergent Boundaries

- www.iris.edu/hq/inclass/animation/89
- www.iris.edu/hq/inclass/animation/468

Transform Boundaries

- www.iris.edu/hq/inclass/animation/58
- www.iris.edu/hq/inclass/animation/53

LESSON DEVELOPMENT

This activity is structured using the "OPERA" system (Appendix D) . Tasks A and B of Part 4 of the Student Workshop uses an Inquiry qpproach to help students use Evidence and Reasoning (Appendix E) to explain the phenomena they have researched using the IRIS Earthquake Browser. There are two options, A and B, depending on student level and/or time to complete the task.

Open

Open the IRIS Earthquake Browser with your students and give them a brief overview of how it works (Appendix A). They will use this web application to examine earthquake event data on a map.

Prior Knowledge – 5 Minutes

If needed, review knowledge about the tectonic plates, such as::

1. *Which crust is older, oceanic or continental?*
2. Which type of oceanic crust is more likely to be subducted, old or new? Why?
3. Predict the results of the following plate collisions and the surface morphology you would see as a result:
    - Ocean–Ocean
    - Ocean–Continent
    - Continent–Continent

After you have briefly reviewed knowledge about plate boundaries, ask the students to consider:

?? *"How often do earthquakes occur?"*

?? *"Where do earthquakes occur?"*

In both cases accept all answers and make a list to be revisited during the "Reflect" phase of this lesson. The goal is to uncover any alternative thoughts that the students may have.

We will return to these two questions in the Reflect phase.

Explore/Explain – 40 Minutes

To get the students used to the controls of IEB, have them set the "Max quakes" to 10,000 to think about:

Where are the greatest concentrations of earthquakes?

Where do the deepest earthquakes (≥300 km) occur?

Click "Show plates" on.

Now set "Magnitude Range" by clicking off "All Values" and typing in "8 ≤ mag ≤ 10"

Where do the big (≥8.0 magnitude) earthquakes occur?

Switch to a satellite view of the world. Do earthquake patterns correlate with any visible features? If so, describe the correlations.

Now assign students to work either independently or in small groups to complete Parts 1 through 4 oaf the Student Worksheets. Here they have an extended opportunity to explore and organize earthquake event data. The Tasks in Part 4 are optional, but offer an opportunity to use Evidence & Reasoning.

Discovery questions for each site are on the next page in gray box..

Table 1*: Lesson flow and timing*

OPERA	Time (min)
Open	10
Prior knowledge	5
Explore/Explain	40
Reflect	20
Apply	Homework or 15
	70 - 85

TIMING TIP

If needed, the activity can be shortened by omitting any of the following:

- One or more questions from **Part 2** of the Student Worksheet
- **Site 4** from the data table.
- **Task A** and **B** from Part 4

DISCOVERY QUESTIONS FOR THE 4 SITES IN THE STUDENT WORKSHEET

Site 1: CONVERGENT BOUNDARY (Ocean-continent collision; Japan)

How frequent are earthquakes in this region?

What is the depth distribution of the earthquakes? Is there a pattern in the earthquake depths? If so, how do you explain it?

Do the earthquakes correspond to any visible features in satellite view? If so, what are these features?

Find another region of the world that has similar features to the ones you noted near Japan. What is the region and are the earthquake patterns there similar?

Site 2: DIVERGENT BOUNDARIES (Mid-ocean ridge; Mid-Atlantic Ridge)

How frequent are earthquakes in this region? How does this compare to the seismicity near Japan?

What is the typical depth of earthquakes in this region? How does this compare to earthquakes near Japan?

How do you explain the differences in depth and frequency of earthquakes between the mid-ocean ridge and Japan?

Do the earthquakes correspond to any visible features in satellite view? If so, what are these features?

Find another region of the world that has similar features to the ones you noted in the central Atlantic. What is the region and are the earthquake patterns there similar?

Site 3: CONVERGENT BOUNDARY (Continent-continent collision; Himalayas)

Do the earthquakes correspond to any visible features in satellite view? If so, what are these features?

How does this region compare to Japan?

Why do you think that the earthquake belt is so broad across the highlands?

Site 4: DIVERGENT BOUNDARY (Continental rift zone; East African Rift)

Which countries are the most seismically active?

Do earthquakes in East Africa tend to be deep or shallow?

Of the types of boundaries investigated earlier, which one best explains the pattern you see in East Africa?

In satellite view, do you see any features consistent with the type of boundary you proposed in the previous question? If so, identify them. If not, why do you think that is?

Based on the type of plate boundary you have discovered in this region, what do you think will happen in this region of the world over time? What large-scale features do you expect to see developing in the future?

Reflect – 15 Minutes

As a whole class, reflect again on the students' responses to the two questions raised in the "Prior Knowledge" section above.

?? *How often?* [Answered in Appendix F]

?? *Where?*

ANSWER: Earthquakes occur on or near plate boundaries principally in 3 large zones of the Earth: the Pacific Ring of Fire, The Alpide Belt (from Sumatra and Himalayas, to the Atlantic), and the Mid-Atlantic Ridge.

?? *How are the various sites similar and different from one another?*

ANSWERS:

Similar: Earthquakes cluster near plate boundaries. Similar physical features are associated with the different models. The 2 convergent sites show deepening earthquakes beneath the overlying slab (subduction = Japan; continental collision = Himalayas). The Mid-Atlantic Ridge, and the East African triple junction at the Red Sea (Figure 4) both have active spreading ridges that separate two plates thus have shallow earthquakes.

Different: Depth, size, and distrubution of the earthquakes. Topography.

?? *Which of the tectonic models (Page SW-4) was best supported by the evidence from Site 4*?

ANSWER: Site 4 is a tricky region with a triple junction that connects two spreading regions: the Red Sea is a spreading center between two plates. The E. African Rift Zone is a diffuse area of incipient rifting that may become a spreading ridge in millions of years. Thus, the best model is Model 3—Divergent boundary.

?? *How about the other Sites?* **Note**: Plate boundary models can further support the discussion.

Apply – Homework (or 15 minutes in class): Part 5 of the Student Worksheet.

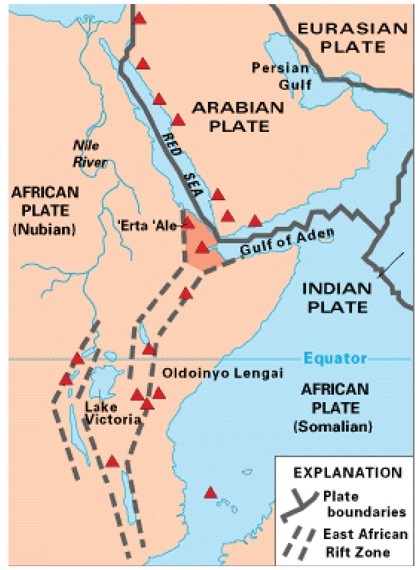


Figure 4*: Site 4 from Table 1 of student worksheets. This complicated zone can be considered optional for shorter class time.*

APPENDIX A

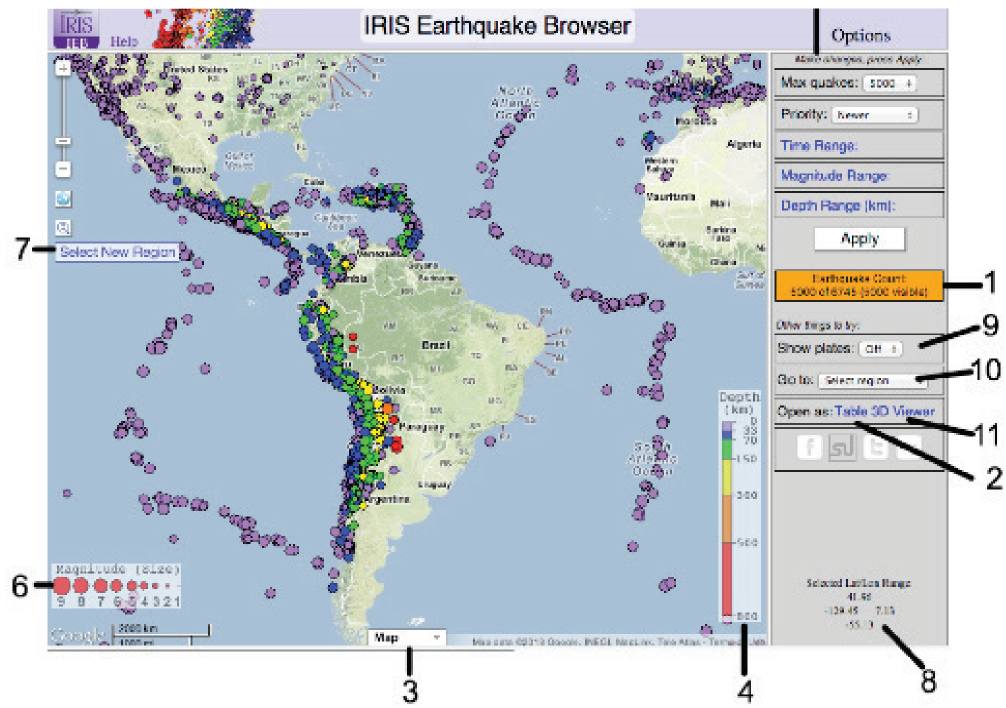
Using the IRIS Earthquake Browser (IEB)

The IRIS Earthquake Browser (IEB; http://www.iris.edu/ieb/) is an interactive map service for viewing Earthquake Epicenters superimposed on a map of the world. This web-service accesses several earthquake catalogs stored in the IRIS database. In total, the database contains around 2 million unique events dating from the early 1960s until present. By filtering the data, the user can interrogate the catalogues by controlling a number of different parameters (magnitude, depth, timeframe etc), and determining how many matching events are shown. Because of practical limitations, only a small subset of all earthquakes may be shown in any given map view. However, by zooming and panning, the user can quickly discover all of the earthquakes held in the IRIS database for any region of the globe.

Map Overview

This diagram describes some of the features available in the IEB, with numbered descriptions below :

For a full overview of this site and all its many features, please visit: www.iris.edu/ieb/help/



1. **Earthquake Count** - Displays how may earthquakes are displayed, how many could have been displayed (and how many are visible on the map at this time).
2. **Open as Table** - Use to links to export data from the map, currently to a table, where you can copy and paste into other programs like Excel.
3. **Map Views** - Select from various Google map view modes such as satellite or terrain.
4. **Depth Scale** - Circle colors indicate the depths of earthquakes (kilometers)
5. **Earthquake Filter** - A set of options that allow one to determine which subset of available earthquakes are displayed.
6. **Magnitude Scale** - Circle sizes indicate earthquake magnitudes
7. **Region Selection** - Use this to select a map region and zoom down to it. Only events in the selected region will be displayed.
8. **Navigation Information** - Displays the lat/lon bounds of the current selection and the lat-lon coordinates of the cursor.
9. **Show Plates** - Shows or hides the display of (clickable) tectonic plate boundaries.
10 **Go To Region** - Takes map to one of several predefined regions of interest.
11. **NEW! 3D Viewer** - Opens a new window with a rotatable, zoomable 3D view of the data. See next page for tip.

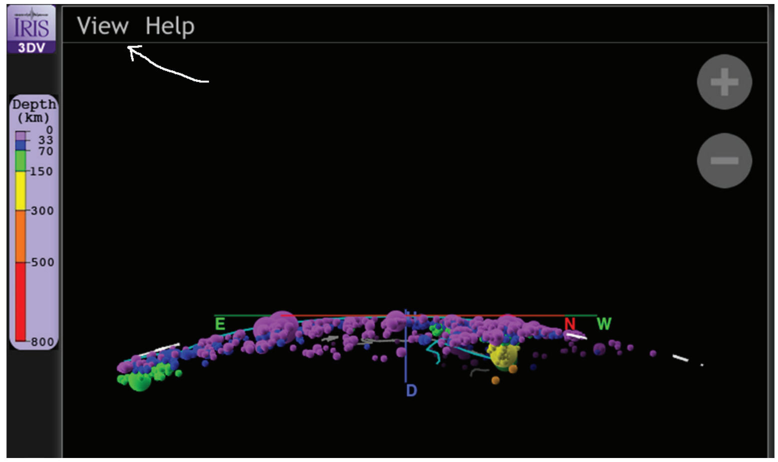
TIP FOR USING THE 3-D VIEWER

Because it is difficult to control the motion of the 3-D view, have students practice selecting just two options shown at images B and C:

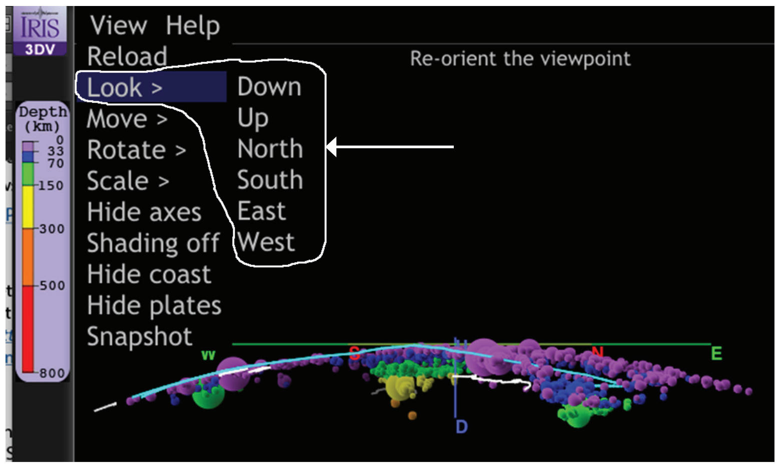
- ***A.** Click "**3D View**" to find "View" pull-down menu*
- ***B.** "**View**" > "**Look**" > "**North**" and*
- ***C.** "**View**" > "**Rotate**" > "**Side to Side**".*

Students can compare the 3D views more easily by controlling the motion.

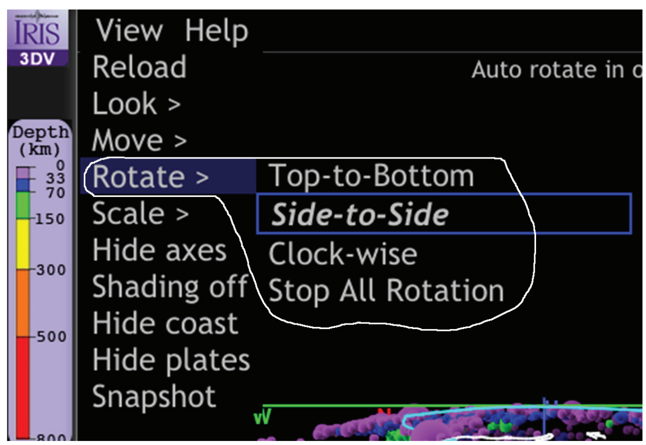
A



B



C



APPENDIX B

Teacher Background

Plate Tectonics

Plate tectonics theory describes how Earth's rigid lithosphere, composed of Earth's crust plus the uppermost mantle, is broken into many large pieces called lithospheric, or tectonic plates. The lithospheric plate "floats" on the more-dense, flowing asthenosphere. These plates move so slowly that the motion can only be detected by sensitive GPS (Global Positioning Systems). Plate motion is driven by density differences in the asthenosphere. As the plates move about they are constantly interacting with one another in a variety of ways. Depending on the type of interaction and the density of the crust, these interactions can result in the formation of large-scale features, such as mountains and deep ocean trenches. They also cause more abrupt and catastrophic effects, such as earthquakes, tsunamis, and volcanism.

CRUSTAL COMPOSITION

The density of the crust determines its behavior. There are 2 types of crust:

Oceanic crust is chiefly basalt, which is relatively dense (~2.9 g/cm^3).

Continental crust is primarily granite, which is less dense than basalt (~2.7 g/cm^3).

Both types are less dense than the highly viscous asthenosphere (3.1 to 3.3 g/cm3) below them. During convergence, however, the denser rock (like oceanic basalt) sinks lower into the asthenosphere than less-dense rock (like continental granites).

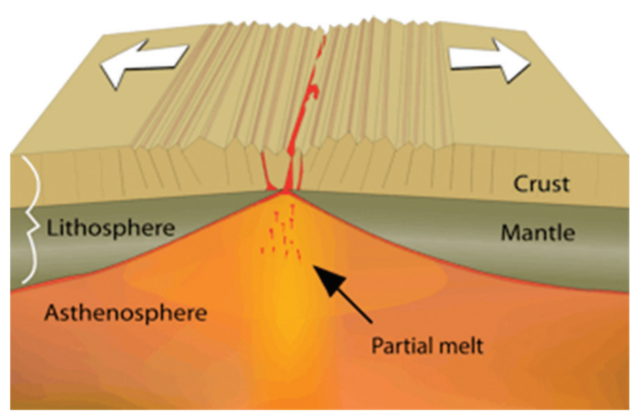
Plate Boundaries

There are three general types of plate boundaries: ***divergent*** (constructive; crust is created), ***convergent*** (destructive; crust is destroyed), and ***transform*** (crust is neither created nor destroyed). Each general type has multiple 'species': Divergent boundaries can be spreading ocean ridges or continental rift zones. Convergent boundaries can occur between two oceanic plates, an oceanic and continental plate, or between two continental plates. Transform boundaries are found on the sea floor, where they connect segments of diverging mid-ocean ridges. California's San Andreas fault is also a transform boundary.

It is important to note that the static size of the Earth implies that crust must be destroyed (at convergent boundaries) at about the same rate it is being created (at divergent boundaries).

Divergent Boundaries - New ocean crust is created at divergent boundaries, where plates are moving apart. In these regions, mantle material (magma) penetrates the thinning crust and solidifies. As the oceanic plates pull apart, dense oceanic crust is formed creating a mid-ocean ridge. Divergent boundaries can form either in oceanic or continental lithosphere. If a divergent boundary develops within continental crust, the region breaks into a system of mountains and valleys, known as basins and ranges. The low-lying area may eventually fill with water and form a new ocean basin. Newer, hotter oceanic crust is more buoyant (less dense) than older, colder oceanic crust, thus the ocean floor adjacent to spreading ridges is bathymetrically higher than away from the ridge (watch the following animation to learn more about basins and ranges: www.iris.edu/hq/inclass/animation/132.)

Divergent boundary



Earthquakes occur only in brittle rock, thus there are no earthquakes in the asthenosphere.

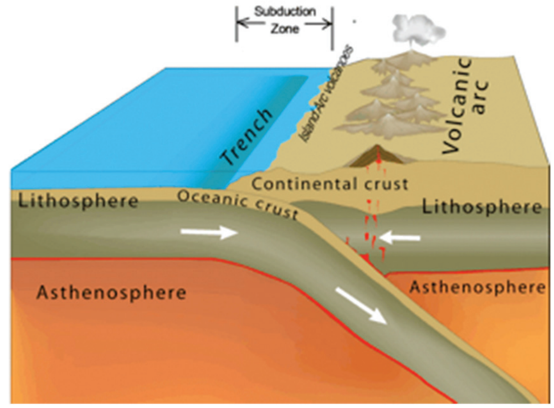
Convergent Boundaries - As plates move, some collide with one another at convergent boundaries. At an ocean-ocean, or ocean-continent convergent boundary, denser crust will be subducted beneath less-dense crust. At a continent-continent boundary, neither will subduct and crust is thrust upward.

Ocean-ocean plate boundaries can form very deep ocean trenches Ex. Marianas Trench).

At ocean-continent boundaries, subducting crust plunges into the mantle, the sinking plate releases water as it warms up in the mantle (think of the plate as sweating). The water triggers small amounts of melting in the hotter rocks of the overlying mantle rock. This results in rising magma that slowly penetrates the crust above the zone of melting, resulting in volcanoes. Over time, oceanic crust is destroyed in subduction zones. (Ex. Cascadia, Andes, Aleutian Islands, Indonesia.)

When continent-continent boundaries collide, neither can be subducted since the density of continental crust is too low to allow subduction into the denser mantle. As a result, the collision will result in mountain formation (Ex. Himalayas, Alps).

Convergent boundary

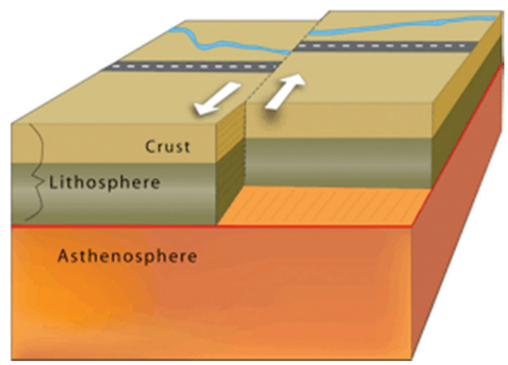


The deepest earthquakes occur in subduction zones where the diving plate is still cold and brittle as it reaches over 500 km deep.

Transform Boundaries - Plates do not always collide or pull apart. Sometimes they grind horizontally against each other with strike-slip motion, resulting in the formation of a transform fault. Although the main motion is horizontal, transform boundaries may have slight convergent or divergent motion adding a slight vertical component. Transform boundaries are not a single strike-slip fault, but consist of a zone of parallel and subparallel strike-slip faults.

While this activity doesn't specifically include Transform boundaries, students could examine the seismicity of the San Andreas, CA region and compare it to what they have learned about the other types of plate boundaries.

Transform boundary



Earthquakes in strike-slip zones tend to be shallow.

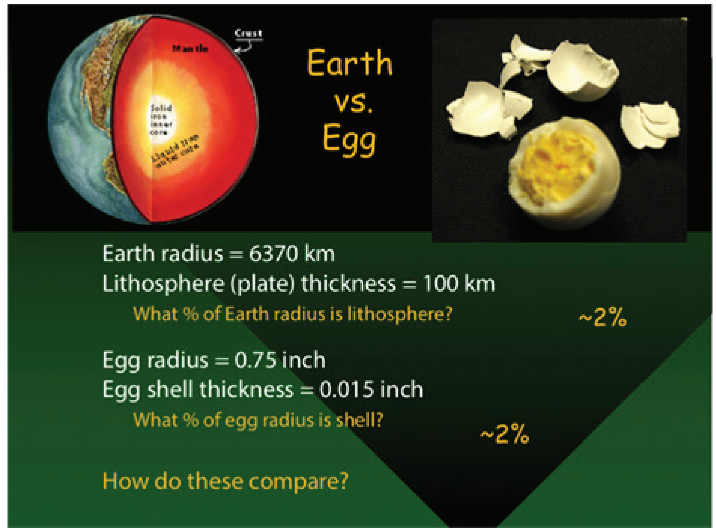
APPENDIX C

Earth vs. Egg—Comparing layer thickness

Video demonstration of the simple math:
www.iris.edu/hq/inclass/video/101

The exercise of comparing the Earth to an egg is a useful visualization that helps students understand the thickness of plates on a global scale. We live on the surface of a really big sphere, thus it is difficult to grasp the sense of scale.

This classroom lecture presents a simple conceptual model of the relative thicknesses of the Lithosphere by measuring a simple hard-boiled egg. The hard-boiled egg is used as a scale model for the zones of the Earth. The shell is to the egg as the lithosphere is to the Earth; the yolk is to the egg as the core is to the Earth. This demonstration highlights the idea that the lithosphere is a thin shell.



Key Comparisons from Video Demo (screen grab**)**

- Measure the diameter of the egg, then measure the thickness of the egg shell
- Ratio of egg shell to egg radius is about 2%
- Ration of lithosphere to Earth's radius is about 2%

Initial questions and analagous scale

?? *What is the outer layer of the earth and egg each called?*

Earth's lithosphere (tectonic plate) solid outer layer, and the egg's shell.

?? *What is the middle layer of the earth and egg each called?*

Earth's mantle and the egg white

?? *What is the center layer of the earth and egg each called?*

Earth's core and the egg yolk

Thickness & Composition of Earth's Layers

Lithosphere

- Thickness - 50–100 km thick (The crust is about 6 km or 4mi thick)
- Composition - Rock - Includes the continents and the ocean floor

Mantle

- Thickness: 2,900 km or1,802 mi thick
- Composition - silicon, oxygen, aluminum, iron, and magnesium - solid rock

Core

- Thickness ~ 3477 km (Inner core = 1192 km or 745 mi. Outer core = 2285 km or 1,428 mi
- Composition: Nickle and iron

APPENDIX D

OPERA Learning Cycle

A learning cycle is a model of instruction based on scientific inquiry or learning from experience. Learning cycles have been shown to be effective at enhancing learning because by providing students with opportunities to develop their own understanding of a scientific concept, explore and deepen that understanding, and then apply the concept to new situations. A number of different learning cycles have been developed. However, all are closely related to one another conceptually, and differ primarily in how many steps the cycle is broken into. The “flavor” of learning cycle that you choose is primarily up to what works best for you, just pick one or two and use it as the basic formula for all your instruction.

This lesson is designed around a learning cycle that can be remembered as O-P-E-R-A. OPERA is convenient when designing lesson-level instruction because one can generally incorporate all the major components into the single experience. Each phase of the OPERA cycle is briefly outlined below.

	Instructional Stage
Open	**Open** the lesson with something that captures students’ attention. This is an invitation for learning and leaves students wanting to know more.
Prior knowledge	Assess students’ **Prior Knowledge** and employ strategies that make this prior knowledge explicit to both the instructor and the learner
Explore	Plan and implement a minds-on experience for students to **Explor**e the content
Reflect	**Reflect** on the concepts the students have been exploring. Students verbalize their conceptual understanding or demonstrate new skills and behaviors. Teachers introduce formal terms, definitions, and explanations for concepts, processes, skills, or behaviors.
Apply	Practice concepts, skills and behaviors by **Applying** the knowledge gained in a novel situation to extend students’ conceptual understanding.

APPENDIX E

Inquiry and Scientific Explanations: Helping Students Use Evidence and Reasoning

(download full article from:
www.katherinelmcneill.com/uploads/1/6/8/7/1687518/mcneillkrajcik_nsta_inquiry_2008.pdf

"Science is fundamentally about explaining phenomena by determining how or why they occur and the conditions and consequences of the observed phenomena. For example, ecologists may try to explain why species diversity is decreasing in an ecosystem, or astronomers may try to explain the phases of the Moon based on the relative positions of the Sun, Earth, and Moon. When scientists explain phenomena and construct new claims, they provide evidence and reasons to justify them or to convince other scientists of the validity of the claims.

"To be scientifically literate citizens, students need to engage in similar inquiry. They need to understand and evaluate explanations that appear in newspapers, in magazines, and on the news to determine their credibility and validity. For example, a newspaper article may claim that stem cell research is important for human health and for treating diseases. Students need to be able to critically read that article by evaluating the evidence and reasoning presented in it. That capability allows students to make informed decisions. 122 Science as Inquiry in the Secondary Setting Students should also support their own written claims with appropriate justification. Science education should help prepare students for this complex inquiry practice where students seek and provide evidence and reasons for ideas or claims"

TABLE: Base Explanation Rubric is Appendix B from the above article

Component	**Level**		
	0	**1**	**2**
Claim—A conclusion that answers the original question.	Does not make a claim, or makes an inaccurate claim.	Makes an accurate but incomplete claim.	Makes an accurate and complete claim.
Evidence—Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.	Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim).	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support claim.
Reasoning—A justification that links the claim and evidence. It shows why the data count as evidence by using appropriate and sufficient scientific principles.	Does not provide reasoning, or only provides reasoning that does not link evidence to claim.	Provides reasoning that links the claim and evidence. Repeats the evidence and/or includes some—but not sufficient—scientific principles.	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.

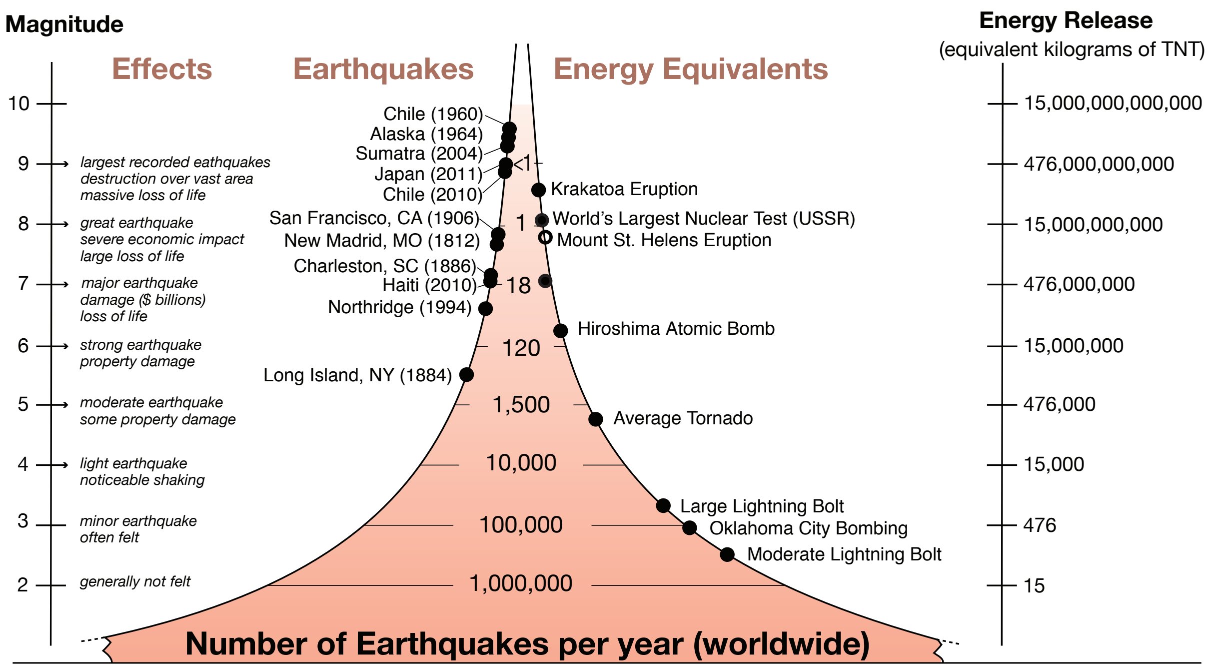
APPENDIX F—HOW OFTEN DO EARTHQUAKES OCCUR?

[The complete fact sheet below is available from: **www.iris.edu/hq/inclass/fact-sheet/153]**

Earthquakes are always happening somewhere

Earth is an active place and earthquakes are always happening somewhere. In fact, the National Earthquake Information Center locates about *12,000-14,000 earthquakes each year!*

This fact sheet illustrates information on the frequency of earthquakes of various magnitudes, along with details on the effects of earthquakes and the equivalent energy release. On average, Magnitude 2 and smaller earthquakes occur several hundred times a day world wide. Major earthquakes, greater than magnitude 7, happen more than once per month. "Great earthquakes", magnitude 8 and higher, occur about once a year.



The left side of the figure above describes the effects of an earthquake by magnitude. The larger the number, the bigger the earthquake. Significant earthquakes are noted on the left side of the shaded tower. The shaded area indicates how many earthquakes of each magnitude occur every year. The events on the right side of the tower show equivalent energy release.

The 2004 earthquake in Haiti, for example, was magnitude 7.0. Earthquakes this size occur about 20 times each year worldwide. Although the Haiti earthquake is considered moderate in size, it caused unprecedented devastation due to poor building material and construction techniques resulting in estimates of $11 billion to reconstruct. The earthquake released the energy equivalent to 476 million kilograms of explosive, about 100 times the amount of energy that was released by the atomic bomb that destroyed the city of Hiroshima during World War II.

The largest recorded earthquake was the Great Chilean Earthquake of May 22, 1960 which had a magnitude of 9.5. The great earthquake in 2004 in Sumatra, Indonesia measuring magnitude 9.1 produced tsunamis that caused widespread disaster in 14 countries. A magnitude 9.0 earthquake in Japan in 2011 also caused large tsunamis. All three were mega-thrust earthquakes on subduction-zone boundaries that, in a period of minutes, released centuries of accumulated strain and caused rebound in the overlying plates. Because great earthquakes release so much energy, the five largest earthquakes are responsible for half of the total energy released by all earthquakes in the last century.

Earth's Systems

MS-ESS2-3 Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.
http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=225

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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.	**ESS1.C: The History of Planet Earth** Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.	**Patterns** Patterns in rates of change and other numerical relationships can provide information about natural systems.

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	Disciplinary Core Ideas	Crosscutting Concepts
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)	**ESS2.A: Earth Materials and Systems** Earth's systems, being dynamic and interacting, cause feedback effects that can increase or decrease the original changes. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geologic history. Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust.	**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.

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

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Using Mathematics and Computational Thinking Mathematical and computational thinking at the 6–8 level builds on K–5 experiences and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.	**PS4.A: Wave Properties** A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude.	**Patterns** Graphs and charts can be used to identify patterns in data..

HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy. http://ngss.nsta.org/DisplayStandard.aspx?view=pe&id=122

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 9–12 builds on K–8 experiences and progresses to evaluating the validity and reliability of the claims, methods, and designs.	**PS4.C: Information Technologies and Instrumentation** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.	**Cause and Effect** Systems can be designed to cause a desired effect.

Name ______________________________

Date ______________

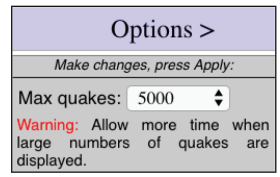
www.iris.edu/earthquake

EXPLORING PATTERNS IN GLOBAL & REGIONAL SEISMICITY

Part 1: Global Seismicity

Step 1: Visit the IRIS Earthquake Browser (http://www.iris.edu/ieb). You will be using this web application to plot earthquake event data on a map. Upon opening the site, you will be presented with a map of the world with the 1000 most recent earthquakes plotted.

Step 2: Use the drop down menu to change the number of quakes displayed to 5000. Then click "Apply" and note the distribution of earthquakes.



Question(s)

1. In what ways do you think a cracked hard-boiled egg might serve as a model for the spatial distribution of earthquake data?

2. In what ways do you think the comparison to the c acked hard-boiled egg fails as a model?

3. Describe any other models you might think of besides this one to describe the seismic data.

Part 2: Global Seismicity

Step 1: Explore! You can zoom in on the map, move it around, select a specific region of interest, and click on individual events to get more details about that particular earthquake. On the right-hand side of the window, you will be able to change the number of events displayed as well as the time, magnitude, and depth ranges of events that are displayed on the map. You can also change the view from geopolitical boundaries to a satellite or terrain view.

Step 2: Use the IRIS Earthquake Browser to answer the following qustions.

1. How many events happened globally on your birthday? How large was the largest event on that day and where was it? How deep was the deepest event, and where was that event located?

2. Describe how a global map looks different if you only display 5000 events that are all Magnitude 7.5 or larger?

3. How many events occurred in our state in the past year? How does your findings compare to an analysis of the same region during the 12 months from April 1 2005 to April 1 2006)?

4. After exploring the map and data:

   a) Describe at least three observations you made about earthquakes.

   b) Write at least two questions you now have about earthquakes as a result of exploring this data.

Part 3: Exploring Specific Regions…

Use the URLs in Table 1 to visit **Sites 1- 4**. Respond to the following prompts for each site in the table.

Fill in Table 1

- Name the location
- Describe the *frequency* and *magnitude* range of earthquakes for each site.
- Describe the *depth distribution* of the earthquakes for each site.
  You should view both the map colors as well as clicking on "3D VIEWER" in the right menu.
- Describe the *spatial distribution* of the earthquakes for each site.
- Turn on satellite view for each region. Describe *physical features* that appear to correspond to earthquakes.
- Identify other region(s) of the world that have *similar features* to those you noted for each site.

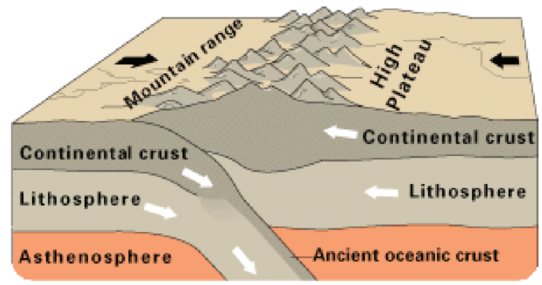
TABLE 1	**Site 1** http://goo.gl/8dRNBo	**Site 2** http://goo.gl/Cbh3UV	**Site 3** http://goo.gl/TD0u2A	**Site 4** http://goo.gl/rqElGb
Location				
Frequency/ Magnitude				
Depth distribution (sketch?)				
Spatial distribution				
Physical features				
Similar region(s)				

Part 4: Comparing researched region sites to accepted models

Earth's outer surface is broken into many large rigid pieces called tectonic plates. Over long periods of time, these plates move very small amounts annually. As the plates move about they are constantly interacting with one another in a variety of ways. Depending on the type of interaction and the density of the plate material, these interactions can result in the formation of large-scale features, such as mountains and deep ocean trenches. They can cause more abrupt and catastrophic effects, such as earthquakes, tsunamis and volcanism. Below are three models for the ways in which scientists believe these plates interact with one another.

Model 1: As plates move sometimes they are squeezed into one another. As a result, high mountains are formed. This model is called a convergent boundary and generally is known for a high rate of seismicity, and can generate in large quakes.

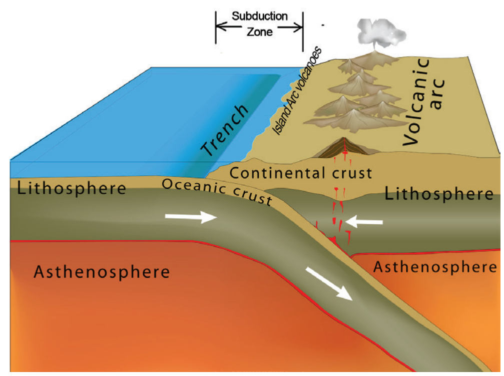
Name a Site location from Table 1: ______________________



Continental-continental convergence

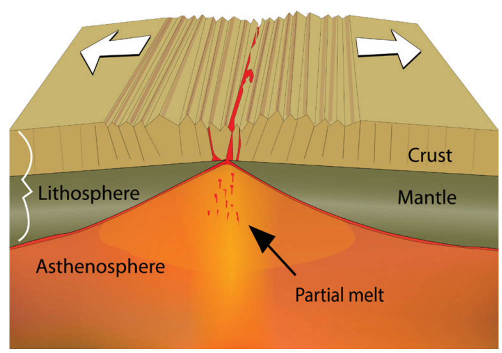
Model 2: Sometimes the two plates that are squeezed together are made of different material. When this occurs the denser plate is forced below the less dense plate in a process known as subduction. This is generally known for a high rate of seismicity, can generate very large quakes, and can result in the formation of very deep ocean trenches.

Name a Site location from Table 1: ______________________



Model 3: In some places plates are push/pulled apart to allow new material to come to the surface and form new plate material. These regions, known as divergent boundaries have relatively low rates of seismicity that occur in relatively narrow bands, and are generally shallow and small events.

Name a Site location from Table 1: ______________________



Task A: Now that you have reviewed the models and given Site examples for each, let's go back to **Site 1**.

You are going to develop an argument for the model that best describes the data from Site 1.

First let's develop a what, where, why, or how question about what you learned in Part 3. As an example we will look at **Site 2**. Sample questions that we could ask (because we have evidence for them) include:

- How are the earthquakes different from those in a subduction zone? They are all shallow and rarely very big. Look at the 3-D view by selecting "**View**" > "**Look North**" and "**View**" > "**Rotate Side to Side.**" When you compared the 3-D views of Site 1 and Site 2 you could see how different they were.
- Where do the earthquakes occur in Site 2? Close to the spreading ridge itself where the rock is brittle.

Now think of a question about Site 1 that you can write a claim about:

Question

Claim A statement that answers the original question or problem.
What conclusion can you make about your original question or problem?

Evidence (List scientific data that are relevant to the problem and sufficient to support the claim.)
What data or observations do you have to support your claim?

Task B: Review each model and compare each to the data you collected in **Table 1**.

Now, develop an argument for the model that best describes the data from **Site 4,** plus one other site of your choosing.

As you compare and contrast, include the following elements in your argument:

Question Develop a question about what you learned in Part 3 that can be answered by the elements below.

Claim Write a conclusion that answers the original question about a phenomenon.

Evidence (List scientific data that are relevant to the problem and help determine and support the claim. The data needs to be appropriate and sufficient to support the claim.)

Reasoning (A justification that links the claim and evidence. It shows why the data count as evidence by using appropriate and sufficient scientific principles.)

Part 5: Revisiting the Egg Model

Revisit your responses to questions 1 and 2 in Part 1. Now that you have explored the earthquake event data and accepted models of plate tectonics more deeply, you may wish to revise your responses.

1. In what ways do you think a cracked hard-boiled egg might serve as a model for the spatial distribution of earthquake data and the three models of plate interactions?

2. In what ways do you think the comparison to the cracked hard-boiled egg fails as a model?

INSTRUCTOR ANSWER KEY

www.iris.edu/earthquake

Name ______________________________

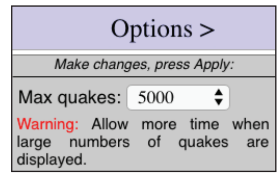
Date ____________________

EXPLORING PATTERNS IN GLOBAL & REGIONAL SEISMICITY

Part 1: Global Seismicity

Step 1: Visit the IRIS Earthquake Browser (http://www.iris.edu/ieb). You will be using this web application to plot earthquake event data on a map. Upon opening the site, you will be presented with a map of the world with the 1000 most recent earthquakes plotted.

Step 2: Use the drop down menu to change the number of quakes displayed to 5000. Then click "Apply" and note the distribution of earthquakes.



Question(s)

1. In what ways do you think a cracked hard-boiled egg might serve as a model for the spatial distribution of earthquake data?

Like the rocky outer layer of Earth (the lithosphere) the egg shell is the thinnest layer Consider the scale of shell relative to the whole egg.

The cracks (representing earthquake locales) are places where the pieces of the egg shell are able to move slightly and interact with one another.

The brittle texture of the egg shell is relative to the brittle rocky outer layer of Earth (lithosphere). The semi solid egg white is relative to Earth's solid but not brittle mantle layer below.

2. In what ways do you think the comparison to the cracked hard-boiled egg fails as a model?

Scale, composition, ; lack of heat source to generate convection and plate motion.

3. Describe any other models you might think of besides this one to describe the seismic data.

Answers will vary

INSTRUCTOR ANSWER KEY

Part 2: Global Seismicity

Step 1: Explore! You can zoom in on the map, move it around, select a specific region of interest, and click on individual events to get more details about that particular earthquake. On the right-hand side of the window, you will be able to change the number of events displayed as well as the time, magnitude, and depth ranges of events that are displayed on the map. You can also change the view from geopolitical boundaries to a satellite or terrain view.

Step 2: Use the IRIS Earthquake Browser to answer the following qustions.

1. How many events happened globally on your birthday? How large was the largest event on that day and where was it? How deep was the deepest event, and where was that event located?

   Answers will vary

2. Describe how a global map looks different if you only display 5000 events that are all Magnitude 7.5 or larger?

   They cluster near the edges of continents where subduction occurs convergent margins, vs. spreading across continents

3. How many events occurred in our state in the past year? How does your findings compare to an analysis of the same region during the 12 months from April 1 2005 to April 1 2006)?

   Answers will vary

4. After exploring the map and data:

   a) Describe at least three observations you made about earthquakes.

   Answers will vary

   b) Write at least two questions you now have about earthquakes as a result of exploring this data.

   Answers will vary

Part 3: Exploring Seismicity in Specific Regions

Use the URLs in Table 1 to visit **Sites 1- 4**. Respond to the following prompts for each site in the table.

Fill in Table 1 below

- Name the location
- Describe the *frequency* and *magnitude* range of earthquakes for each site.
- Describe the *depth distribution* of the earthquakes for each site. You should view both the map colors as well as clicking on "3D VIEWER" in the right menu.
- Describe the *spatial distribution* of the earthquakes for each site.
- Turn on satellite view for each region. Describe *physical features* that appear to correspond to earthquakes.
- Identify other region(s) of the world that have *similar features* to those you noted for each site.

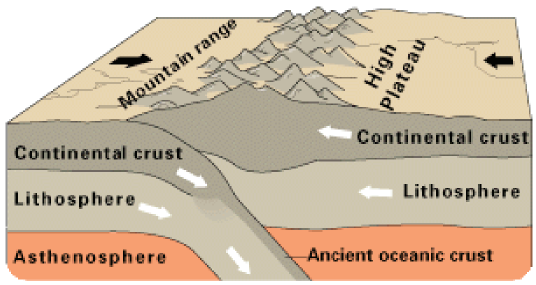
TABLE 1 Location	**Site 1** http://goo.gl/8dRNBo	**Site 2** http://goo.gl/Cbh3UV	**Site 3** http://goo.gl/TD0u2A	**Site 4** http://goo.gl/rqElGb
	Japan	**Mid Atlantic Ridge**	**Himalayas**	**East African Rift**
Frequency/ Magnitude	Lots! >11,000 of all magnitudes, but only 13 > M 7	Few! 500 since 2011 But only 1 > M 7	Medium Almost 3,000 since 2011, but only 7 > M 7	Only 365 since 2011 none >M 5
Depth distribution (sketch?)	Varies but many deep From shallow to over 500 km deep	most are shallow	Varies but many deep Very few deeper than150 Km	All < 33 km
Spatial distribution	Broad smear concentrated along subductio n-zone boundaries	Narrow and linear Concentrated along the mid- ocean ridge	Sharp line along the plate boundary But broadly distributed in the compressed region	Concentration along the plate boundariy, but scattered in the south.
Physical features	Mountains and the trench are defined by earthquakes	Zooming in shows the structure of the mountain range & faults	Most earthquakes occur in the mountainous region	

Part 4: Comparing to accepted models

Earth's outer surface is broken into many large rigid pieces called tectonic plates. Over long periods of time, these plates move very small amounts annually. As the plates move about they are constantly interacting with one another in a variety of ways. Depending on the type of interaction and the density of the plate material, these interactions can result in the formation of large-scale features, such as mountains and deep ocean trenches. They can cause more abrupt and catastrophic effects, such as earthquakes, tsunamis and volcanism. Below are three models for the ways in which scientists believe these plates interact with one another.

Model 1: As plates move sometimes they are squeezed into one another. As a result, high mountains are formed. This model is called a convergent boundary and generally is known for a high rate of seismicity, and can generate in large quakes.

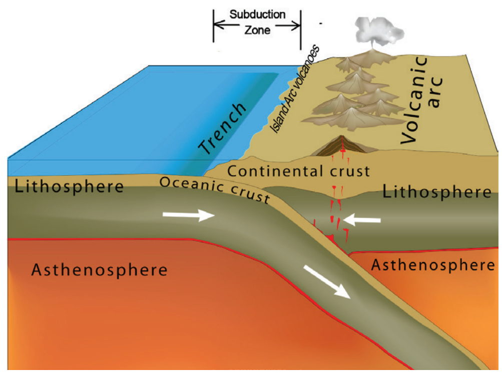
Name a Site location from Table 1: Site 3, Himalayas



Continental-continental convergence

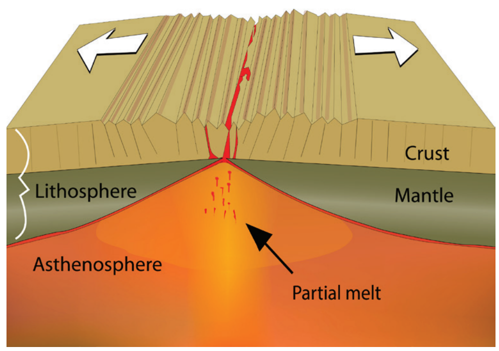
Model 2: Sometimes the two plates that are squeezed together are made of different material. When this occurs the denser plate is forced below the less dense plate in a process known as subduction. This is generally known for a high rate of seismicity, can generate very large quakes, and can result in the formation of very deep ocean trenches.

Name a Site location from Table 1: Site 1, Japan



Model 3: In some places plates are push/pulled apart to allow new material to come to the surface and form new plate material. These regions, known as divergent boundaries have relatively low rates of seismicity that occur in relatively narrow bands, and are generally shallow and small events.

Name a Site location from Table 1: Site 2, Mid-Atlantic Ridge



INSTRUCTOR ANSWER KEY

Task A: Now that you have reviewed the models and given Site examples for each, let's go back to **Site 1**.

You are going to develop an argument for the model that best describes the data from Site 1

First let's develop a what, where, why, or how question about what you learned in Part 3. As an example we will look at **Site 2**. Sample questions that we could ask, because we have evidence for them, include:

- How are the earthquake different from those in a subduction zone? They are all shallow and rarely very big
  Look at the 3-D view by selecting "**View**" > "**Look North**" and "**View**" > "**Rotate Side to Side.**"
  When you compared the 3-D views of Site 1 and Site 2 you could different they are.
- Where do the earthquakes occur in Site 2? Close to the spreading ridge itself where the rock is brittle.

Now develop a question about Site 1 that you can write a claim about

Question

Answers will vary

Claim A statement that answers the original focus question or problem.
What conclusion can you make about your original question or problem?

Answers will vary

Evidence (List scientific data that are relevant to the problem and sufficient to support the claim.)
What data or observations do you have to support your claim?

Answers will vary

INSTRUCTOR ANSWER KEY

Task B: Review each model and compare each to the data you collected in Table 1.

Now, develop an argument for the model that best describes the data from **Site 4,** plus one other site of your choosing.

As you compare and contrast, include the following elements in your argument:

Question Develop a question about what you learned in Part 3 that can be answered by the elements below.

Answers will vary but site 4 is most similar to model 3

Claim Write a conclusion that answers the original question about a phenomenon**.**

Answers will vary

Evidence (List scientific data that are relevant to the problem and help determine and support the claim. The data needs to be appropriate and sufficient to support the claim.)

Answers will vary

Reasoning (A justification that links the claim and evidence. It shows why the data count as evidence by using appropriate and sufficient scientific principles.

Answers will vary

Part 5: Revisiting the Egg Model

Revisit your responses to questions 1 and 2 in Part 1. Now that you have explored the earthquake event data and accepted models of plate tectonics more deeply, you may wish to revise your responses.

1. In what ways do you think a cracked hard-boiled egg might serve as a model for the spatial distribution of earthquake data and the three models of plate interactions?

   - Both have a thin, brittle shell.
   - cracked shell of a hardboiled egg is broken into pieces that can be analogous to plates.
   - The plates move relative to each other.
   - The plates have edges, where the earthquakes could occur

2. In what ways do you think the comparison to the cracked hard-boiled egg fails as a model?

   - Eggshell pieces, for the most part, have the same density whereas the plates on Earth vary in density.
   - The eggshells do not move while the plates do.
   - There is no internal heat to drive the convection, thus plate motion.
   - Plate motion makes earthquakes
   - The egg has one inner section (yolk) whereas the Earth's core comprises a solid inner core and a liquid outer core.
   - Motion is continuous, not a static earth.