Exploring Patterns in Regional Seismicity: An East African Mystery

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Time – 70 - 80 Minutes

Suggested Level - 9th Grade Earth Science

5E Phase - Extension. Students should have previously learned about Earth structure and the various layers of the Earth.

Materials List -

- Computer Lab (pair of students or individually)
- IRIS Earthquake Browser (IEB) <u>www.iris.edu/ieb</u>
- Class set of activity
- Foam models of plate boundaries http://web.ics.purdue.edu/~braile/edumod/foammod/foammod.htm
- Optional: Narrated animations of plate boundaries http://www.iris.edu/hq/programs/education and outreach/aotm/11

Content Objectives - By the end of the exercise, students should be able to:

- Describe the basic properties of crustal rocks
 - Predict how these properties affect interactions at plate boundaries and the land features they generate
 - Predict relative ages of crust based on rock properties and boundary interactions
- Use the IRIS Earthquake Browser to
 - Explore current seismicity of the planet
 - Explore the earthquake patterns at convergent and divergent plate boundaries
 - Identify geomorphological features associated with plate boundaries
- Apply knowledge to identify a developing plate boundary
 - Identify and describe earthquake pattern in East Africa
 - Use evidence (seismicity and geomorphology) to determine the type of boundary in East Africa
 - Make predictions about future geomorphology in the region

Lesson Description -

This lesson is designed as an Extension phase of a 5E Model. Thus, prior to this lesson students should have already *Explored* the evidence for Plate tectonics and been introduced to the basic concepts in the *Explain* phase.

This extension phase activity begins by reviewing basic plate tectonic concepts through the use of an

OPERA	Time (min)
O pen	5
Prior knowledge	20 - 30
Explore/Explain	30
R eflect	5
A pply	10
	70 - 80

egg analogy. Next, students use the IRIS Earthquake Browser to extend their understanding by investigate well-known examples of some of these boundaries, and then apply their learning to a "mystery boundary" in East Africa to determine the most likely cause of seismicity in this area of the world.

Open – 5 Minutes

Show bathymetric view of Earth (Google Earth flight?) See what I can find... perhaps this dynamic planet map?

Prior Knowledge – 20 Minutes

Ask how this complex surface was generated. Following discussion lead students through the following ideas...

- Earth's rigid lithosphere, composed of Earth's crust and the upper most mantle, is broken into many large pieces called tectonic plates.
- Over long periods of time, these plates are moved (only very small amounts annually) around the surface of the planet.
- This motion is driven by density differences in Earth's less rigid mantle. 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 or they can cause more abrupt and catastrophic effects, such as earthquakes and volcanism.

Have students complete questions 1-3 on handout and review answers. If necessary (re)explain content described in the Teacher Background.

Explore/Explain – 30 Minutes

Intro to IRIS Earthquake Browser (Global Seismicity): ~ 10 Minutes

- Point students to http://www.iris.edu/ieb to introduce them to the IRIS Earthquake Browser (IEB)
- Allow a period of free exploration of program, followed by a discussion of the following key functions
- Have students use IEB to answer questions in their handout about global seismicity

Convergent Boundaries: ~ 10 Minutes

- Instruct students to visit <u>http://goo.gl/8dRNBo</u>
- Students should use IEB to answer the questions in their handout about convergent boundaries

Divergent Boundaries: ~ 10 Minutes

- Instruct students to visit <u>http://goo.gl/Cbh3UV</u>
- Students should use IEB to answer the questions in their handout about divergent boundaries

Reflect – 5 Minutes

As a class, review students' answers to their lab (Student Worksheet). The use of Foam Fault models (see Materials List above) during this discussion is particularly helpful to allow students to visually make connections between the patterns in the seismicity they see on the IEB and the interactions of the plates.

Apply – 10 Minutes

African Mystery:

- Instruct students to visit <u>http://goo.gl/rqElGb</u>
- Students should use IEB to answer the questions in their handout about divergent boundaries

Teacher Background

Using the IRIS Earthquake Browser (IEB)

The IRIS Earthquake Browser (IEB - <u>http://www.iris.edu/ieb/</u>) 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

The following diagram describes some of the features available in the IEB :



- 1. **Earthquake Count** <u>Displays</u> 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 <u>links</u> 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 <u>options</u> 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 <u>select a map region</u> 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.

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

Plate Tectonics

Earth's rigid lithosphere, composed of Earth's crust and the upper most mantle, is broken into many large pieces called tectonic plates. Over long periods of time, these plates are moved (only very small amounts annually) around the surface of the planet. This motion is driven by density differences in Earth's less ridgid mantle. 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 or they can cause more abrupt and catastrophic effects, such as earthquakes and volcanism.

Crustal Composition

On Earth, there are two types of crust: oceanic and continental. Oceanic crust is composed of basalt, which is relatively dense (~2.9 g/cm³). Continental crust is composed primarily of granite, which is less dense than basalt (~2.7 g/cm³). Since both are less dense than the asthenosphere (3.1 to 3.3 g/cm³), part of the mantle just below the lithosphere, the crust floats in the asthenosphere like an iceberg floats in water. Denser rocks (like oceanic basalts) sink lower into the asthenosphere than less dense rocks (like continental granites).

Convergent Boundaries

As plates move some collide with one another at boundaries called convergent boundaries (Figure 1). At a convergent boundary, denser crust will be subducted beneath less dense crust. This can result in the formation of very deep ocean trenches. As the subducted crust plunges into the mantle, it heats up and more volatile parts of it melt. This results in rising magma that can penetrate through the crust above the zone of melting, resulting in volcanoes. Over time, oceanic crust is destroyed in subduction zones.

If continental crust collides, 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.

Divergent Boundaries

New ocean crust is created at divergent boundaries, where plates are pulling apart. In these regions, mantle material penetrates through the thinning crust and solidifies. Divergent boundaries can form either in oceanic or continental crust. As



Figure 1: A highly simplified and stylized sketch of the Plate Tectonics system is useful for illustrating key components.

the plates pull apart, dense oceanic crust is formed. If a divergent boundary develops within continental crust, 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.

Transform Faults

Plates do not always collide or pull apart. Sometimes they can slide past each other, resulting in the formation of a transform fault. While this activity doesn't specifically include Transform boundaries, students could examine the seismicity San Andreas, CA region and compare it to what they have learned about the other types of plate boundaries.



Figure 2: Narrated animations of a convergent and divergent boundaries at: http://www.iris.edu/hq/programs/education and outreach/aotm/11

Student Worksheet

Name:

Date:

Review Questions

1. Which crust is older, oceanic or continental? Why?

- 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

Global Seismicity

Go to the following website (<u>http://www.iris.edu/ieb</u>). You will be utilizing this web application to plot earthquake data. When you open the website, you will be presented with a map of the world and the 200 most recent earthquake events.

You can zoom in on the map, move it around, and click on events to get more details about particular earthquakes. 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. In the upper right-hand corner, you can change the view from geopolitical boundaries to satellite or terrain. Modify these settings to explore global seismicity, then answer the following questions.

Note: Displaying a large number events may cause browsers on slower machines to stall or *freeze up. Keep this in mind when plotting data.*

Questions

- 4. Do you have a good sense of where plate boundaries are? If not, how can you change the settings to give you a better idea of where plate boundaries may be?
- 5. How many large earthquakes (\geq 7.0 magnitude) have occurred so far this year?
- 6. Where do the deepest earthquakes (\geq 300 km) tend to occur?
- 7. Switch to a satellite view of the world. Do earthquake patterns correlate with any visible features? If so, describe the correlations.
- 8. How common are earthquakes in Africa compared to elsewhere in the world?

9. Zoom in on Africa. Where do African earthquakes tend to occur?

Convergent Boundaries (Continent – Ocean Collision)

We will now explore the seismicity of a plate boundary between ocean and continental crust. In the lower left-hand corner, click "Select a region", then draw a box over Japan, including some of the nearby ocean. Navigate to the following URL (<u>http://goo.gl/8dRNBo</u>) for a view with the following settings:

Location: An area containing North Korea, South Korea, Japan, into Pacific OceanView: Satellite (you will need to adjust this)Display: 2000 eventsTime Range: From 2011-01-01 to latest availableDepth Range (km): All Values

Questions

- 10. How frequent are earthquakes in this region?
- 11. What is the depth distribution of the earthquakes? Is there a pattern in the earthquake depths? If so, how do you explain it?
- 12. Do the earthquakes correspond to any visible features in satellite view? If so, what are these features?
- 13. 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?

Divergent Boundaries (Mid-Ocean Ridge)

We will now explore the seismicity of a divergent boundary in the central Atlantic, the midocean ridge. Navigate to the following URL (<u>http://goo.gl/Cbh3UV</u>) for a view with the following settings:

Location: Middle of Atlantic Ocean (e.g. from eastern edge of Brazil to western edge of Guinea)View: Satellite (you will need to adjust this)Display: 2000 eventsTime Range: From 2011-01-01 to latest availableDepth Range (km): All Values

Questions

- 14. How frequent are earthquakes in this region? How does this compare to the seismicity near Japan?
- 15. What is the typical depth of earthquakes in this region? How does this compare to earthquakes near Japan?
- 16. How do you explain the differences in depth and frequency of earthquakes between the mid-ocean ridge and Japan?

- 17. Do the earthquakes correspond to any visible features in satellite view? If so, what are these features?
- 18. 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?

African Mystery

Now that we have explored global seismicity as well as two types of plate boundaries, we will explore a Mysterious the pattern of earthquakes in Eastern Africa. Navigate to the following URL (http://goo.gl/rqElGb) for a view with the following settings:

Location: An area from Sudan down through the northern tip of Madagascar	
View: Satellite (you will need to adjust this)	Display: 2000 events
<i>Time Range:</i> From 2011-01-01 to latest available	
Magnitude Range: All Values	Depth Range (km): All Values

Questions

- 19. Which countries are the most seismically active?
- 20. Do earthquakes in East Africa tend to be deep or shallow?
- 21. Of the types of boundaries investigated earlier, which one best explains the pattern you see in East Africa?
- 22. 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?
- 23. 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?

Want to explore one more place? Check out this mystery site! What does the seismicity tell you is occurring here?? http://goo.gl/TD0u2A