VISUALIZATION 2: EARTHQUAKES AT CONVERGENT PLATE BOUNDARIES

as part of the series:

'Global Earthquakes: Teaching about Earthquakes with Data and 3D Visualizations'

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Activity Description

Summary of the activity:

The purpose of this activity is to introduce students to the distribution and characteristics of earthquakes associated with convergent plate boundaries. Students will learn about how the magnitude and distribution of earthquakes at convergent boundaries are related to processes that occur at these boundaries, and to the geometry and position of the two converging plates. Because the depth of earthquakes can be difficult for students to visualize in 2D representations, this activity allows students to visualize the 3D distribution of earthquakes within and below Earth's surface, which is essential for understanding how different types of earthquakes occur in different tectonic settings. Locations featured in the visualization include the Chile-Peru Subduction Zone, the Aleutian Islands, the Fiji Subduction Zone, and the Himalayas. Talking points and questions are included to use this visualization as part of an interactive lecture. In addition to playing back the visualization, instructors can also download the visualization software and data set and explore it themselves.

Intended audience:

Introductory level undergraduate students, although this visualization could be adapted for younger students with more background given.

Teaching materials:

Computer and projector to run and project visualization movie.

Conceptual Learning Goals:

- Deep, large magnitude earthquakes commonly occur at convergent plate boundaries.
- Earthquakes at convergent plate boundaries are distributed with predictable locations and depths.
- There are two different types of convergent margins that have different types of earthquakes associated with them.
- Earthquakes at subduction zones occur as one tectonic plate slides under another; the downgoing plate bends and shears along the base of the overriding plate. The downgoing plate grinds along the overriding plate, which generates large earthquakes.

- The position and depth of earthquakes at subduction zones is determined by the angle of the downgoing plate. Therefore, the position and angle of the downgoing plate can be determined by the position of earthquakes.
- Earthquakes occur down to a maximum depth of about 600 km; below this depth the crust is hot enough that it no longer behaves in a brittle way.

Higher Order Thinking Skills Goals:

- Synthesize large data sets to recognize naturally occurring patterns
- Use patterns in data sets to make and test predictions about the distribution and characteristics of earthquakes
- Visualize data in 3D that is traditionally represented in 2D

Instructor's Notes

How to run the activity:

This visualization is designed to follow the first visualization in this series (Visualization 1: Visualizing Global Earthquakes - Where and Why do Earthquakes Occur?). However, if this visualization is used in isolation, refer to the instructor's notes accompanying the first visualization in the series for information about introducing the visualization and how the data set was compiled.

This visualization can be used in any class format, and is presented here in a way that is especially conducive for use in a lecture-based course, including very large lecture courses.

Begin the movie and use the 'talking points' given below to highlight key aspects of the visualization to your students. When you reach a *"Quakes Question",* pause the visualization and ask your students the question. Instruct them to write down their ideas as you begin playing the visualization again. Once they have written down some ideas, pause the movie again, and either have them discuss their observations with a partner, or choose a few students to share with the entire class. Continue playing the visualization and pausing for questions and discussion.

Background for students:

Introduce these concepts prior to showing the visualization. Key terms are in **bold**.

- **Convergent boundaries** are where plates are moving toward each other. Sometimes one plate sinks, or is subducted, under another. This location where sinking of one plate occurs is called a **subduction zone**.
- [Background concepts associated with Visualization 1: Where and Why do Earthquakes Occur?]

Talking points:

- [0:00] This visualization focuses on convergent plate boundaries. We will look at how convergent plate boundaries are expressed in the topography and from the distribution of earthquakes.
    - These white lines are outlining **plate boundary zones**. As you remember from Visualization 1, they are not one plane, but rather a broad zone. Notice that where earthquakes are clustered corresponds to these plate boundary zones.

    - If we zoom in on the Aleutian Islands of Alaska we can see that a long line of earthquakes corresponds with the island chain.
- [0:25] If we turn off the earthquakes, we can recognize convergent plate boundaries in the topography.
    - At **subduction zones**, a **trench** forms where one plate plunges under another one and bends down into the athenosphere.
    - The Marianas trench is the deepest part of the world's oceans – it is where an oceanic plate is dipping under another plate. This trench continues along the whole boundary between these two plates. As in the Aleutian Islands, there are also many earthquakes at this plate boundary near the trench.
- [1:00] At plate margins where continental crust moves towards continental crust, neither plate subducts, but instead they ram into each other, causing large mountain belts, like the Himalayas, to form. Many earthquakes occur here as the crust is deforming.
- Now we'll look at a few specific examples of convergent plate boundaries.

PERU-CHILE SUBDUCTION ZONE [1:27]

- Let's go to the western margin of Chile where the Nazca Plate is subducting under the South American Plate.
- The heavier oceanic Nazca plate is dipping under the lighter continental South American Plate. A deep ocean trench is here. This is an example of **ocean-continent** convergent margin, where ocean crust subducts under continental crust.
- Notice how the location of earthquakes corresponds with this plate boundary.
- [1:46] Zoom in – let's take a closer look at these earthquakes. *The earth spins around to view earthquakes from multiple angles.*

'Quakes Question #1: Make some observations about the earthquakes at the Peru-Chile Subduction Zone. What do you notice about how the earthquakes are distributed? How big are they? Where do they occur? *Students make a list of observations and then talk about what is happening.*

Observations:

- Many earthquakes occur at depth; not all occur only at the surface.
- Earthquakes range in magnitude with some very large ones and many smaller ones.
- The earthquakes are distributed in a plane that dips in one direction down from the surface.

Follow-up Discussion:

- Earthquakes at subduction zones happen as the downgoing plate grinds along the base of the overriding plate. This generates large earthquakes. Some of these earthquakes occur close to the earth's surface, but some also occur in the downgoing plate at greater depths.
- The position of the earthquakes is determined by the position of the subducting plate. These earthquakes define the position of the plate. At some depth (around 600 km), earthquakes no longer occur because it is too hot for the crust to behave in a brittle way.

- Some very large earthquakes happen at subduction zones like this because there is a lot of motion and grinding on thick crust. The largest earthquake on record struck the coast of Chile at this boundary.
- This chain of earthquakes under the west coast of Chile continues to the north and south for a long way – for the entire length of this plate boundary.

ALEUTIAN SUBDUCTION ZONE [3:06]

- There are also convergent margins where ocean crust subducts under ocean crust, such as in the **Aleutian Islands**. The Aleutian Islands are where the Pacific Plate and the North American Plate are moving toward each other. Again, there is a trench where the downgoing plate bends down below the overriding plate.
- [1:46] Zoom in – let's take a closer look at these earthquakes. *The earth spins around to view earthquakes from multiple angles.*

> **'Quakes Question #2:** Make some observations about the earthquakes at the Aleutian Subduction Zone. What do you notice about how the earthquakes are distributed? What is the variability in earthquake magnitude? How does the dip of the subducting plate compare with the dip of the subducting plate under Chile?

- The western margin of Chile and the Aleutian Islands are part of the Pacific Ring of Fire, where about 90% of the world's earthquakes occur. The ring of fire is made up of many adjacent areas where oceanic plates are subducting under continental plates, creating many earthquakes.

FIJI-TONGA SUBDUCTION ZONE [4:15]

- The **Fiji-Tonga Subduction Zone** is north of New Zealand, and occurs where the Pacific Plate and the Australian Plate are converging. This is also part of the Pacific Ring of Fire.
- [4:25] Zoom in – let's take a closer look at these earthquakes. *The earth spins to view earthquakes from multiple angles, including from underneath.*

> **'Quakes Question #3:** Which direction is the subducting plate moving? Use the distribution of earthquakes to determine which side of the plate boundary is the overriding plate and which is the subducting plate.
>
> - The earthquakes are defining a plane that is dipping to the west – northwest. Therefore, the Pacific Plate is subducting underneath the overriding Australian plate.

'Quakes Question #4: Are there any earthquakes in this region that have characteristics not consistent with being part of a convergent plate boundary? How are they different than earthquakes associated with convergent plate boundaries?

- Northwest of the subduction zone a line of earthquakes is trending east-west. These earthquakes are all located near Earth's surface, and do not extend to depth like those found in subduction zones.
- In this region the two plates are sliding past each other, rather than converging, so earthquakes are localized near the surface.

HIMALAYAS [5:13]

- So far we have looked at regions where oceanic crust subducts underneath oceanic or continental crust. What happens when continental crust moves towards continental crust?
- Both pieces of crust are not dense and are cool. Therefore they are buoyant, so neither one dips into the mantle. Instead they converge, and the crust buckles and is pushed upwards or sideways.
- The **Himalayan Mountains** are an example of this type of convergent plate boundary, and they occur where the European and Indian plates meet. The two plates converging with each other caused the crust to buckle, wrinkle, and uplift into a high mountain range.
- Earthquakes are distributed over a wide area and do not define a very distinct belt. Many of these earthquakes are very big because the crust is so thick here.
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'Quakes Question #5: What are the characteristics of earthquakes at convergent plate boundaries? What are the characteristics that are unique to earthquakes that occur in subduction zones? Generate a summary list.

- Earthquakes occur at depth and on the surface, earthquakes are variable in magnitude with many large earthquakes occurring, and in subduction zones earthquakes define the direction and of subduction.

(NOTE: The talking points and 'Quakes Questions' could easily be adapted to an inquiry activity that students complete on their own as they watch the video.)

Evaluation:

'Quakes Questions' throughout the activity are short-answer questions that students answer while the visualization is playing to ensure that they are taking away key concepts. The final two 'Quakes Questions' requires them to apply their understanding of how earthquakes are distributed in subduction zones to a new example, and to synthesize ideas from this visualization to generate a summary list of convergent boundary earthquake characteristics.

In addition, 'ConcepTest' questions can also be used to assess whether students have met the goals of the activity. Because this activity provides a highly visual/spatial way of learning about

earthquakes and plate boundaries the assessments should also be visual/spatial. ConcepTests are questions that focus on key concepts. Poll your students in class with these questions to ensure understanding before moving on.

ConcepTest questions can be found at http://serc.carleton.edu/introgeo/conceptests/index.html.

Suggested questions:
http://serc.carleton.edu/introgeo/conceptests/examples/deepquake.html
http://serc.carleton.edu/introgeo/conceptests/examples/eqconvergentbound.html
http://serc.carleton.edu/introgeo/conceptests/examples/convergentbound.html

**Note that some of these questions require students to interpret 2D representations of earthquake distribution, and some students may have difficulty mentally translating from the 3D visualization to the 2D questions causing them to answer incorrectly even if they conceptually understand.

Software download:

The visualization software used to create this visualization is freely available and can be downloaded from http://keckcaves.org/education/. In addition to playing back the visualizations available here, instructors can also download the visualization software and data sets and explore it themselves. Download the software and quick-start guide to begin exploring your own data sets in your classroom.