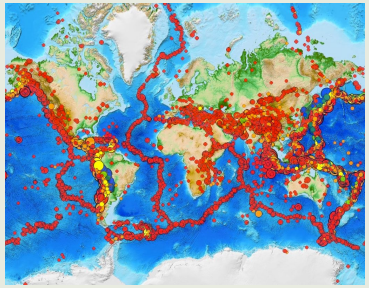
LESSON 3: Why do earthquakes happen in specific patterns around the world?

PREVIOUS LESSON *We investigated patterns in earthquake activity in different regions. We figured out that earthquakes happen in cluster and line patterns, which vary when we change spatial and time scales. We also investigated other locations known for earthquake activity and noted differences in how the earthquakes related to local landforms and wondered why earthquakes happen in areas with mountains, volcanoes, and other landforms.*

THIS LESSON

INVESTIGATION

2 days



In this lesson, we read an article about how scientists have historically collected data about earthquakes. As scientists collect data about earthquakes and plot where they occur, they notice patterns of lines located across the globe near mountain ranges and in the middle of the ocean. We read that scientists mostly agree that there are 9 large plates on earth and multiple little plates, and we use Seismic Explorer to map out where we think these plates are located. We revisit Mt. Everest and read about how data is collected today to monitor movement. We analyze GPS data for Mt. Everest and revisit our site locations to analyze GPS data for each location to determine if the Earth is moving there as well.

NEXT LESSON *We will use information from photographs, texts, and rock samples to develop representations of plates and answer questions about what plates are made of and how deep they go. We will also explore ultra-deep mines and the depth at which earthquakes occur.*

BUILDING TOWARD NGSS

MS-ESS1-4, MS-ESS2-1, MS-ESS2-2, MS-ESS2-3

WHAT STUDENTS WILL DO

Integrate quantitative scientific information in written text with data in an earthquake visualization to clarify patterns in earthquake data in order to locate plates and the direction of their movement.

Analyze and interpret GPS data to provide evidence for the patterns in speed and direction of different plate movements, showing that all plates are moving at different rates and directions, and this movement happens very slowly over millions of years.

WHAT STUDENTS WILL FIGURE OUT

- Earth's surface is not a solid continuous piece of crust; rather, there are at least 9 large pieces of Earth called plates and the edges can be observed using earthquake data.
- A network of GPS sensors provide data on the speed and direction of plate movement.
- On one side of Mt. Everest, one plate is moving at a speed of 6 cm/yr in a northern direction, while on the other side, a plate is moving at a speed of 2 cm/yr in a southwest direction. The plates are moving toward each other.
- In other locations, the plates are either moving toward each other or away from each other, and at different speeds too.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Recall patterns where earthquakes occur.	A	
2	15 min	**CLOSE READING ON WHERE EARTHQUAKES OCCUR** Read about how earthquakes have been measured over time.	B-C	*Reading: Why do earthquakes happen in specific patterns around the world?*
3	20 min	**REVISIT CLASS MAP** Revisit World Relief Map and argue from evidence where the 9 major plates are located.	D	*Reading: Why do earthquakes happen in specific patterns around the world?*, World Relief Map, extra sticky notes, markers, 9 sticky notes numbered 1-9, clear plastic shower curtain, red dry erase marker
4	5 min	**EXIT TICKET** Reflect on what we have figured out and how this helps us explain why earthquakes occur where they do.	E	notecards
				End of day 1
5	3 min	**NAVIGATION** Brainstorm how plate movement might be affecting changes at Mt. Everest.	F	
6	15 min	**WHAT IS HAPPENING AT MT. EVEREST?** Read about how scientists today use GPS data to measure what is happening to the Earth's surface over time.	G	*Reading: How is movement measured at Mount Everest?*, *Direction and Speed*, sticky notes
7	10 min	**REVISIT WORLD RELIEF MAP** Revisit map and add in GPS data and movement of the land under the site locations.	H	*Reading: Why do earthquakes happen in specific patterns around the world?*, *Reading: How is movement measured at Mount Everest?*, extra sticky notes, markers, World Relief Map
8	10 min	**UPDATE OUR PROGRESS TRACKER** Update our Progress Tracker with what we have figured out about why there are patterns to the earthquake data.	I	
9	5 min	**NAVIGATION** Wonder about what the plates are made of and how they are moving.	J	
				End of day 2

Lesson 3 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *Reading: Why do earthquakes happen in specific patterns around the world?* • notecards • *Reading: How is movement measured at Mount Everest?* • *Direction and Speed* • sticky notes		• World Relief Map • extra sticky notes • markers • 9 sticky notes numbered 1-9 • clear plastic shower curtain • red dry erase marker

Materials preparation (5 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Between Day 1 and Day 2, draw the earthquake data pattern on a clear plastic shower curtain using a red dry erase marker. This will be overlayed onto the World Relief Map. To draw the pattern, cover the World Relief Map with a clear plastic shower curtain. Trim the curtain to fit the map. Then, use the earthquake data pattern from Seismic Explorer to sketch the approximate pattern of earthquake activity onto the shower curtain. A pattern for this has been provided in *Template for Map Overlay*.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

The purpose of this lesson is to provide students with GPS data that serves as evidence for plate movement. There is a network of GPS sensors distributed around the world that monitor plate motion. Within certain regions, countries have additional monitoring networks to study plate motion associated with earthquakes, a serious hazard for people. Students will use this data to argue that plates collide (convergent boundaries) and spread apart (divergent boundaries).

Where We Are NOT Going

This lesson is not trying to build a “theory” of plate tectonics, which is a high school DCI and requires additional sources of data and scientific principles that are beyond the scope of middle school, rather, it uses plate motion to help students understand that (1) plates can be indirectly observed using data, and that (2) plates move in different directions and speeds.

Also, while the network of GPS sensors exist to help monitor the potential for earthquakes and other seismic hazards, it is not the goal of this lesson or unit to discuss natural hazards. This topic will be addressed in future OpenSciEd unit.

LEARNING PLAN for LESSON 3

1 · NAVIGATION

5 min

MATERIALS: science notebook

Recall patterns in earthquake activity. Ask students to open their notebooks to the page from Lesson 2 where they recorded patterns they noticed in the earthquake data. Review with students some of the patterns they noticed when they explored the different locations in Seismic Explorer.

Project **slide A**. Say, *What are some of the patterns we noticed about where earthquakes occur? What are some of your initial ideas for why earthquakes happen in these patterns?* Allow a few moments for some students to share the patterns they noticed.

Ask students to consider what evidence we could collect that could explain these patterns about where earthquakes occur. Say, *I have an article that might provide us with some information to help us figure out why earthquakes happen in patterns.*

2 · CLOSE READING ON WHERE EARTHQUAKES OCCUR

15 min

MATERIALS: *Reading: Why do earthquakes happen in specific patterns around the world?*

Introduce the reading. Pass out *Reading: Why do earthquakes happen in specific patterns around the world?* to each student. A full-color version of the reading and a close-up of the map are also included in the student edition. Project **slide B**. As a class, set the purpose for doing the reading. Say, *Let's make sure we know what our purpose is for reading the article. What do we want to know more about?*

Suggested prompt	Sample student response
Why are we reading this article? What do we want to know more about?	*We are wondering about why earthquakes occur where they do.* *We are wondering why earthquakes happen in patterns near mountains and think that if we can learn more about how earthquakes are measured, it might help us figure out why earthquakes happen in patterns.*

Have students write the purpose for the article at the top: *Why do earthquakes happen in patterns?*

Remind students of the close reading strategies they use in the Storms Unit. If necessary, remind students that close reading requires reading more than once with different purposes and using strategies to interact with the text. Review the steps with the students which are listed on **slide C**. Then give them time to read the article with their small group.

Once students finish reading the article, they should work together ***with their small group*** to annotate the map at the end, showing where they think the 9 major plates are found on Earth. If this map is printed in black and white for students to use, they may need a color version to refer to so they can more confidently label where they think the 9 major plates are located. A larger, full-color version of the map is available in the student edition.

3 · REVISIT CLASS MAP

20 min

MATERIALS: science notebook, *Reading: Why do earthquakes happen in specific patterns around the world?*, World Relief Map, extra sticky notes, markers, 9 sticky notes numbered 1-9, clear plastic shower curtain, red dry erase marker

Argue from evidence for the location of the 9 major plates. Project **slide D**. Facilitate an Initial Ideas Discussion to share ideas from the reading that could help explain the patterns for where earthquakes occur. As students share where their group labeled the 9 major plates in the reading, have different students use the sticky notes that are numbered 1 -9, and the projected slide that has the map with earthquake patterns to identify where they think these plates are located. As they share, encourage them to explain why they are placing the sticky note in the spot they choose. As this discussion unfolds, if the idea of "plates" comes up, ask them what they think a plate is and where these plates are located. The focus of the discussion is to have students begin to see a connection between where earthquakes happen and where these plates interact. There will be new questions that will naturally be shared as different volunteers come up and place the sticky notes up on the map. Encourage students to record these questions.

ADDITIONAL GUIDANCE

In between the two days of this lesson, you will add a clear overlay to the World Relief Map that contains red lines drawn with draw erase to represent the earthquake data from Lesson 2. For this discussion, students will need these lines (or earthquake pattern data) on the world map to be able to know where to place the 9 sticky notes but adding this to the DQB map doesn't make sense until this point in the lesson. Therefore there is a slide with an enlarged map of the earthquake data that can be projected for students to use as they argue where these 9 major plates could be on Earth. If you have a document camera, this could be printed out in color and placed under the camera, projected and used. Or if you have a Smartboard, the students could draw the arrows right on the image using the Smart board utensils. If you choose to have the clear overlay ready to put up and prefer to use this during the discussion, you will need to remove it in between classes if you teach more than one section of science.

Suggested prompt	Sample student response
Let's remind ourselves, what was our purpose for reading the article?	*We want to know more about why earthquakes happen in the types of patterns they do.*
Okay, so what did you figure out from the reading to explain the patterns in the earthquake data?	*In the reading, we read that as scientists collected data about where earthquakes were happening, they also noticed changes to the land.*
What kind of changes? That is so crazy! To think a large piece of earth can break... and move! What else did you figure out from the article about this movement of the surface?	*Land breaking apart* *Land shaking or moving* *Land raising up or sinking down* *As scientists mapped these movements of the surface, they noticed they happened mostly near mountains and in the middle of the ocean. This is like the data we looked at!* *Because scientists saw that the surface of Earth sometimes breaks apart, they used the edges of where these breaks happen to identify different large sections of earth and called them plates.*

Suggested prompt	Sample student response
Were you able to identify different sections on your map that could be the different plates mentioned in the article?	*Yes!*

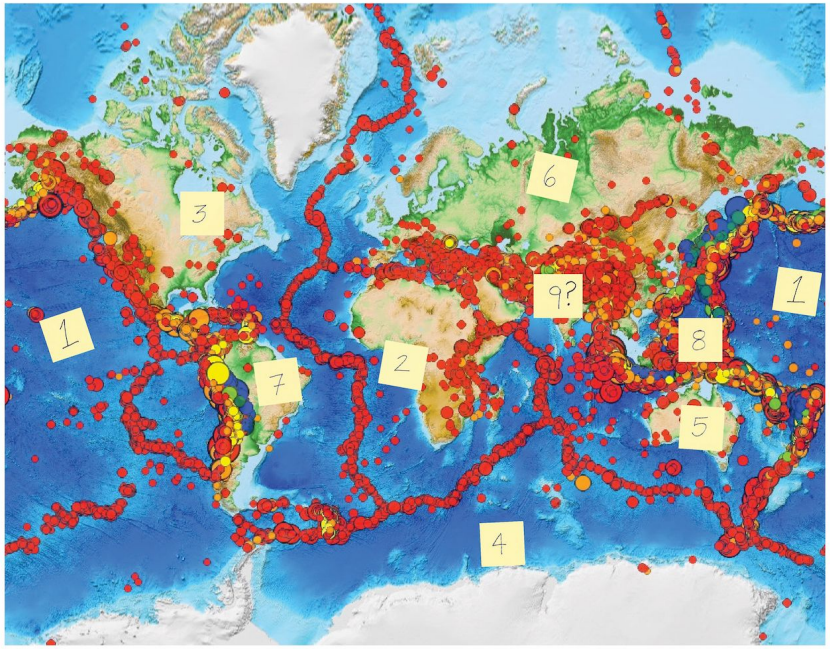
KEY IDEAS

Purpose: The focus of this discussion is to help students use the reading to share their ideas about plates and their location. This is the first time that some students would have heard about plates. In addition, you will want to press students to connect the earthquake data they examined during the last lesson and the location of plates

Listen/look for:

- There are 9 major pieces of Earth that are moving, called plates.
- Earthquakes happen where these plates touch or collide.

Place sticky notes where students identify plate locations. Ask a volunteer to come to the map and place the the nine, numbered sticky notes on the map where the 9 different major plates from the reading are located. Once this student has placed them, ask whether others agree or disagree. If there is some disagreement, ask a volunteer to move the sticky notes to represent their thinking. It is possible your class will agree on all 9, or only agree on some of the 9. If there is some disagreement, place sticky notes with question marks on them on the areas of disagreement. A sample is included below:



4 · EXIT TICKET

5 min

MATERIALS: notecards

Have students complete an Exit Ticket. Project **slide E**. Pass out a notecard to each student. They should read the question on the slide and answer it on their notecard. Students should turn in the notecard before they leave class.

ASSESSMENT OPPORTUNITY	This exit ticket can be used as a **formative assessment** to help you understand what students are thinking at this point and how they could apply what they learned to explain what happened at Mt. Everest. On Day 2, students will read about how GPS data is currently used to track plate movements.

Before the next day, use the large clear overlay to draw the earthquake pattern data onto so it can be taped up over the DQB map. This will be used on the next day of this lesson. Use *Template for Map Overlay* as a reference when creating the overlay with these patterns.

End of day 1

5 · NAVIGATION

3 min

MATERIALS: None

Connect to the previous day. Display **slide F**. Say, *Looking at our map and our ideas about where we think the different plates might be, let's zoom back into Mt Everest and see if we can figure out how the land is moving there. How might what we recently discovered help us explain what happened at Mt. Everest? What data would you want to help you explain Mt. Everest?*

Tell students, *I have another article for us to analyze. This article includes both text and data to analyze for patterns of how the land near Mt. Everest is moving.*

6 · WHAT IS HAPPENING AT MT. EVEREST?

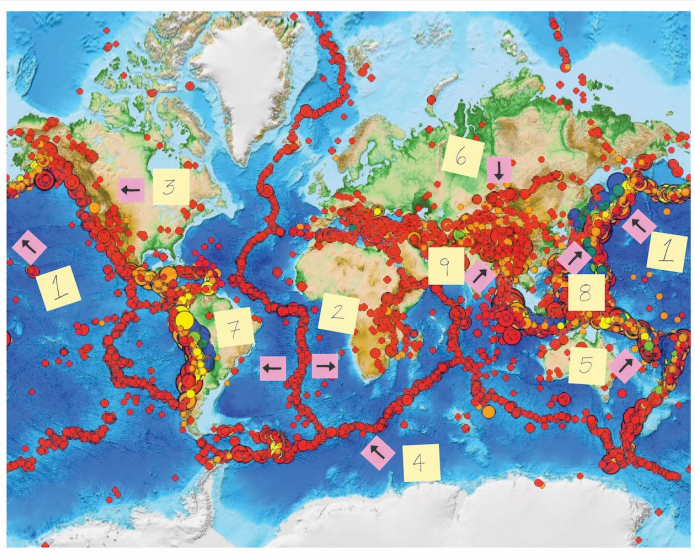
15 min

MATERIALS: *Reading: How is movement measured at Mount Everest?*, *Direction and Speed*, science notebook, sticky notes

Read about Mt. Everest and the global GPS network used to track movement. Hand out *Reading: How is movement measured at Mount Everest?* to each student and also have student edition available to look at *Direction and Speed* for reference. There is also a full-color version of the reading in the student edition as well.

Project **slide G**. Set a purpose for the reading to find out how earthquakes are measured today. Then, ask students to read through the article with a partner.

Analyze data of different plate motions and apply to each case study site. From the reading, students should figure out that different places on Earth are moving in different directions. As they finish the reading, ask students to analyze the data on *Direction and Speed* for their site location. They should follow the directions on the handout to add data to the class map near the DQB using different sized arrows to represent how fast or slow the plates are moving near their site locations.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7 · REVISIT WORLD RELIEF MAP

10 min

MATERIALS: science notebook, *Reading: Why do earthquakes happen in specific patterns around the world?*, *Reading: How is movement measured at Mount Everest?*, extra sticky notes, markers, World Relief Map

Summarize ideas from the reading. Form a Scientists Circle around the World Relief Map and ask students to share some of the ideas they gleaned from the reading about GPS monitoring and movement at different plate boundaries.

Suggested prompt	Sample student response
What did you read about how earthquakes are measured today?	*Scientists use GPS data to keep track of how different places on Earth are moving.*
What is GPS data and how did the reading explain how it is recorded?	*There are satellites above the Earth that send constant signals to Earth. Then on Earth there are multiple receivers that are used to pinpoint the movement.*
So if these signals are constantly being sent and received, why do you think the data about how much each plate is moving isn't one number?	*Maybe because there are so many different receivers on Earth?* *Maybe if signals are being sent all the time and the land is always moving (is it always moving?), then the numbers change constantly.... Like the light meters in the Storms Unit when we were trying to figure out how much light reaches the Earth??*
Oh... so are you all thinking that the data is reported as a range of data because the receivers and satellites and land are always moving?	*Yeah...*

Record ideas of what students figured out from the reading, such as:

- What GPS data is and what it measures
    - Triangulation between satellites
    - Multiple pieces of data compiled together
    - This gives us a range to use when comparing movement of plates
- How the different pieces of Earth are moving near Mt. Everest
    - One moving about 6 cm NE
    - One moving about 2 cm S
- How to calculate overall movement
    - Because there is so much movement and so many data points, scientists can only get a range of movement in cm

Share data gathered from the reading to see global patterns of movement. Display **slide H**. This portion of the Scientists Circle is intended to display data across sites that can support the consensus discussion. Each group should first share the speed and direction of the movement of plates of their site location by posting their sticky notes at their site, placing the sticky note on either site to represent the two plates that interact at the site.

Once all sites have been recorded onto the map, ask students what they notice about the different movements worldwide.✱ Listen for ideas about:

- The plates are moving in all different directions.
- The plates are moving at different speeds.

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICAL AND COMPUTATIONAL THINKING

During this discussion around the map, it is important for students to understand why the average speed of plate movement is reported as a range of speeds taken at different specific points on the plates. When scientists record plate movement on Earth, the mathematics behind this data is very complicated and beyond grade band. Due to the make-up of the plates, different rates of heating from the mantle, and collision between edges, it is very difficult to report "one single number" to capture plate movement. In this lesson, students work with ranges of data to report movement to account for the complexity of the data.

8 · UPDATE OUR PROGRESS TRACKER

10 min

MATERIALS: science notebook

Update Progress Trackers in science notebooks. Project **Slide I.** Tell students to turn to their Progress Tracker section in their science notebooks, make another row in the two-column table, and record the question, *Why do earthquakes happen in patterns on Earth?* Individually they should record what they have figured out about this so far. Below are some sample ideas:

Question	What I figured out in words/pictures
Why do earthquakes happen in patterns on Earth?	*Large sections of Earth's surface are moving in different directions and when they bump into each other, we think that is why there are earthquakes.* *The crust is made of a bunch of moving pieces called plates that are moving in all different directions and at different speeds. But they are moving really, really slow.*

ADDITIONAL GUIDANCE

The purpose of the Progress Tracker is for students to have a space to consolidate what they have figured out about how the Earth's surface is moving. It will be helpful for them to take stock of what they have read and analyzed about as to what is happening with plates on the surface, before they investigate what plates are made of and begin looking below the surface. This Progress Tracker should not be formally assessed, as it is a space for students to keep track of their thinking.

9 · NAVIGATION

5 min

MATERIALS: None

Wonder about the plates. Display **slide J.** Take a moment to summarize where the class is currently in what they have figured out and where they will go next. Say, *We have figured out that the Earth is covered with large, solid pieces of crust called plates. But what are the plates made of and how they can move? We haven't figured that out yet.* Give students a moment to think about and share their ideas. Problematize this for students by asking how the big, heavy pieces of rock can move.

Additional Lesson 3 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	This lesson has an explicit focus on developing standards from Common Core ELA, including: • CCSS.ELA-LITERACY.RST.6-8.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 6-8 texts and topics*. • CCSS.ELA-LITERACY.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). Each reading is provided as a handout for students to mark-up, calling out key words and ideas; questions they have; and data from tables and images.