Teacher Notes

Lab 6. Plate Interactions: How Is the Nature of the Geologic Activity That Is Observed Near a Plate Boundary Related to the Type of Plate Interaction That Occurs at That Boundary?

Purpose

The purpose of this lab is to *introduce* students to the disciplinary core idea (DCI) of Plate Tectonics and Large-Scale System Interactions by having them explore plate tectonics and the geologic activity that occurs near different types of plate boundaries. In addition, students have an opportunity to learn about the crosscutting concepts (CCs) of (a) Patterns and (b) Scale, Proportion, and Quantity. During the explicit and reflective discussion, students will also learn about (a) the difference between observations and inferences in science and (b) how the culture of science, societal needs, and current events influence the work of scientists.

Important Earth and Space Science Content

The interior structure of Earth is composed of several layers (see Figure 6.1). At the center of Earth is the inner core. The inner core is a solid sphere with a radius of about 1,120 km, and it consists of mostly iron. The next layer is the outer core, which is liquid and extends beyond the inner core another 2,270 km. The next, and thickest, layer is the mantle. The mantle, which is 2,900 thick, is often divided into three sublayers: the lower mesosphere, the upper mesosphere, and the asthenosphere. The outermost layer of Earth is the lithosphere. The lithosphere includes the crust, which is relatively thin and rocky, and the uppermost mantle.

There are two types of crust found in the lithosphere: continental and oceanic. Continental crust is 35–40 km (22–25 miles) thick on average but may exceed 70 km (43 miles) in some mountainous regions such as the Himalayas and the Rockies. The continental crust is made up of many different types of rock. The average density of the rocks that make up the continental crust is about 2.7 g/cm^3, and these rocks can be as old as 4 billion years. Oceanic crust, in contrast, is only about 7 km (4 miles) thick and is composed of basalt. The rocks that make up the oceanic crust are younger and denser than the rocks that make up the continental crust. Oceanic rocks are 180 million years old and have an average density of 3.0 g/cm^3.

The theory of plate tectonics states that the lithosphere is broken into several plates that move over time (see Figure 6.2). These plates are solid and rigid relative to the asthenosphere below them and thus "float" on the asthenosphere. The plates vary in thickness. Oceanic plates are thinner than continental plates. However, oceanic plates are formed from denser rocks than continental plates. Therefore, oceanic plates are denser than continental plates.

FIGURE 6.1

The layers of Earth (illustration not drawn to scale)

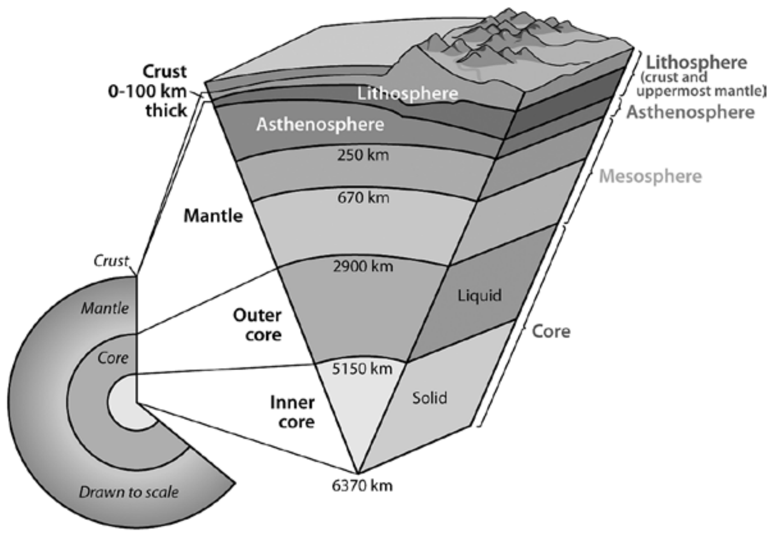
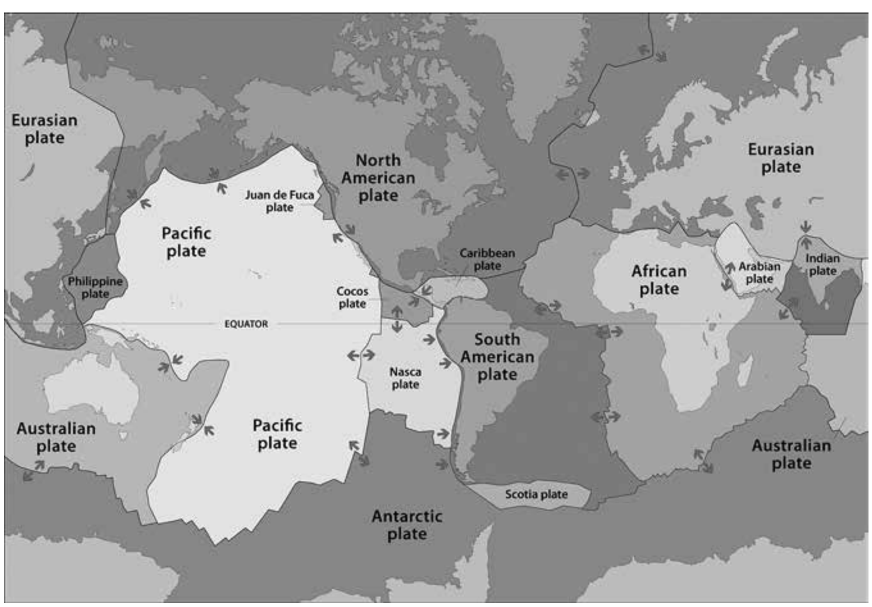


FIGURE 6.2

The major tectonic plates

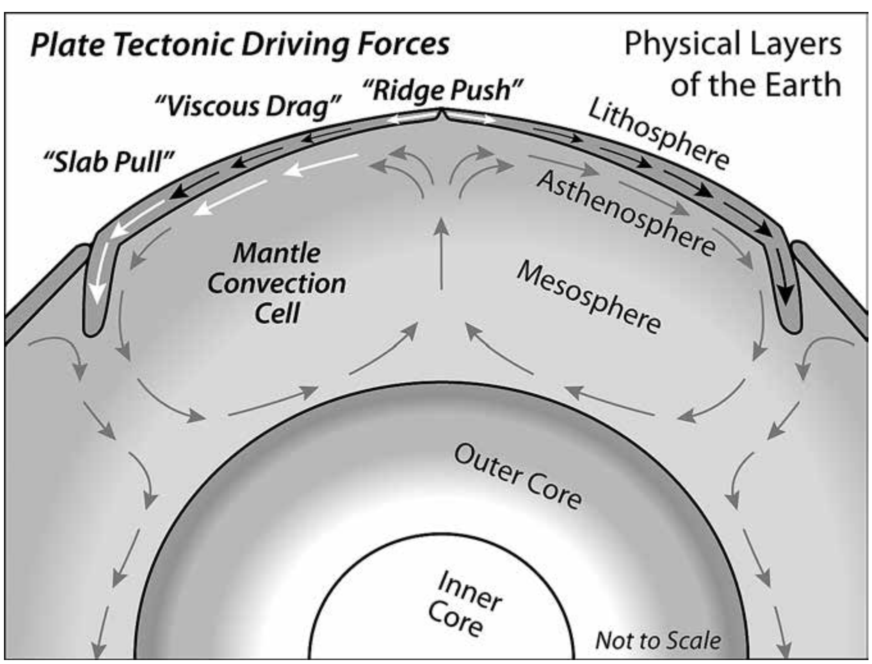


Earth scientists have identified four mechanisms that drive the movement of plates (see Figure 6.3):

- The first mechanism is *the existence of convection currents in the mantle.* These convection currents are driven by an unequal distribution of heat within Earth's interior. The mantle, as a result, is a moving fluid with a high viscosity.
- As this thick and sticky fluid moves under a plate in a given direction, it drags the plate along with it because of the force of friction. This second mechanism is often described as *viscous drag.*
- A third mechanism, called *slab pull,* occurs when one edge of a cold and dense oceanic plate sinks into the asthenosphere. As the leading edge of a plate sinks and melts over time, it "pulls" the rest of plate along. Oceanic plates sink because they are denser then the underlying asthenosphere.
- Another mechanism that contributes to movement of plates is called *ridge push.* The force of gravity drives this mechanism. Oceanic ridges are elevated. As a result, the trailing edge of a plate "slides" down the side of a ridge much like an object placed on a steep ramp slides down that ramp. As this edge of the plate slides down the ridge it pushes the rest of the plate away from the ridge. Ridge push does not contribute to plate motion as much as slab pull does, but it does plays a part.

FIGURE 6.3

Mechanisms that drive the movement of plates

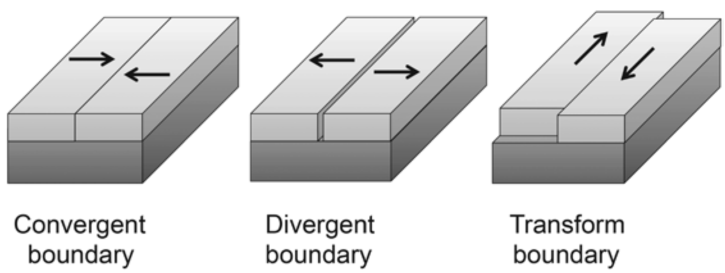


These different mechanisms help explain the why the plates move in different directions and at different rates over time.

The plates move in different directions and at different speeds in relationship to each other. Plate boundaries are found where one plate interacts with another plate. These boundaries are classified into three different categories (see Figure 6.4): a *convergent boundary* results when two plates collide with each other, a *divergent boundary* results when two plates move away from each other, and a *transform boundary* forms when two plates slide past each other.

FIGURE 6.4

Tectonic plate boundaries



Divergent boundaries are constructive boundaries because when two plates move away from each other, molten material from the mantle moves up to fill the gap that is left behind. This is called upwelling. When this rock cools, it becomes part of the existing plates. Earth scientists call this process *seafloor spreading* if it happens in the ocean or *continental rifting* if it happens on land. Divergent plate boundaries tend to be sites of volcanic fissures and shallow earthquakes.

Convergent boundaries, in contrast, are destructive boundaries. Convergent boundaries occur at locations where two plates collide with each other. When an oceanic plate and a continental plate collide, the denser oceanic plate will descend beneath the less dense continental plate, melt, and eventually be reabsorbed into the mantle. This process is called subduction. If two oceanic plates converge, the one capped with denser crust will descend beneath the other one. When two continental plates collide, the crust at the edges of the plates will be pushed up to create a mountain system. The continental crust will push upward and form a mountain system rather than subducting into the mantle, because continental crust is buoyant. A collision between continental plates like this created several mountain ranges, including the Himalayas, the Alps, the Appalachians, and the Urals. Convergent plate boundaries tend to be sites of intense volcanic activity and strong earthquakes.

At transform plate boundaries, no lithosphere is formed or destroyed. These plates slide past each other, often creating earthquakes that are relatively weak compared with those that occur at convergent boundaries.

LAB 6

Timeline

The instructional time needed to complete this lab investigation is 200-280 minutes. Appendix 3 (p. 573) provides options for implementing this lab investigation over several class periods. Option E (280 minutes) should be used if students are unfamiliar with scientific writing, because this option provides extra instructional time for scaffolding the writing process. You can scaffold the writing process by modeling, providing examples, and providing hints as students write each section of the report. Option F (200 minutes) should be used if students are familiar with scientific writing and have developed the skills needed to write an investigation report on their own. In option F, students complete stage 6 (writing the investigation report) and stage 8 (revising the investigation report) as homework.

Materials and Preparation

The materials needed to implement this investigation are listed in Table 6.1. The *Natural Hazards Viewer* interactive map, which was developed by the National Oceanic and Atmospheric Administration's National Geophysical Data Center, is available at *http://maps.ngdc.noaa.gov/viewers/hazards*. It is free to use and can be accessed online using most internet browsers. You should access the website and learn how the interactive map works before beginning the lab investigation. In addition, it is important to check if students can access and use the interactive map from a school computer or tablet, because some schools have set up firewalls and other restrictions on web browsing.

TABLE 6.1

Materials list for Lab 6

Item	Quantity
Computer or tablet with internet access	1 per group
Whiteboard, 2' × 3'*	1 per group
Lab Handout	1 per student
Peer-review guide and instructor scoring rubric	1 per student
Checkout Questions	1 per student

* As an alternative, students can use computer and presentation software such as Microsoft PowerPoint or Apple Keynote to create their arguments.

Safety Precautions

Remind students to follow all normal lab safety rules.

Topics for the Explicit and Reflective Discussion

Reflecting on the Use of Core Ideas and Crosscutting Concepts During the Investigation

Teachers should begin the explicit and reflective discussion by asking students to discuss what they know about the DCI they used during the investigation. The following are some important concepts related to the DCI of Plate Tectonics and Large-Scale System Interactions that students need to know to determine how the nature of the geologic activity that is observed near a plate boundary is related to the type of plate interaction that occurs at that boundary:

- The lithosphere is broken into several plates that are constantly moving.
- Plate boundaries are found where one plate interacts with another plate.
- Convergent boundaries result when two plates collide with each other.
- Divergent boundaries result when two plates move apart.
- Transform boundaries are formed when two plates slide past each other.

To help students reflect on what they know about these concepts, we recommend showing them two or three images using presentation software that help illustrate these important ideas. You can then ask the students the following questions to encourage students to share how they are thinking about these important concepts:

1. What do we see going on in this image?
2. Does anyone have anything else to add?
3. What might be going on that we can't see?
4. What are some things that we are not sure about here?

You can then encourage students to think about how CCs played a role in their investigation. There are at least two CCs that students need to know to determine how the nature of the geologic activity that is observed near a plate boundary is related to the type of plate interaction that occurs at that boundary: (a) Patterns and (b) Scale, Proportion, and Quantity (see Appendix 2 [p. 569] for a brief description of these CCs). To help students reflect on what they know about these CCs, we recommend asking them the following questions:

1. Why do scientists look for and attempt to explain patterns in nature?
2. What patterns did you identify and use during your investigation? Why was that useful?
3. Why is it important to consider what measurement scale or scales to use during an investigation? Why is useful to look for proportional relationships when analyzing data?

4. What measurement scale or scales did you use during your investigation? What did that allow you to do? Did you attempt to look for proportional relationships when you were analyzing your data? Why or why not?

You can then encourage students to think about how they used all these different concepts to help answer the guiding question and why it is important to use these ideas to help justify their evidence for their final arguments. Be sure to remind your students to explain why they included the evidence in their arguments and make the assumptions underlying their analysis and interpretation of the data explicit in order to provide an adequate justification of their evidence.

Reflecting on Ways to Design Better Investigations

It is important for students to reflect on the strengths and weaknesses of the investigation they designed during the explicit and reflective discussion. Students should therefore be encouraged to discuss ways to eliminate potential flaws, measurement errors, or sources of uncertainty in their investigations. To help students be more reflective about the design of their investigation and what they can do to make their investigations more rigorous in the future, you can ask the following questions:

1. What were some of the strengths of the way you planned and carried out your investigation? In other words, what made it scientific?
2. What were some of the weaknesses of the way you planned and carried out your investigation? In other words, what made it less scientific?
3. What rules can we make, as a class, to ensure that our next investigation is more scientific?

Reflecting on the Nature of Scientific Knowledge and Scientific Inquiry

This investigation can be used to illustrate two important concepts related to the nature of scientific knowledge and the nature of scientific inquiry: (a) the difference between observations and inferences in science and (b) how the culture of science, societal needs, and current events influence the work of scientists (see Appendix 2 [p. 569] for a brief description of these two concepts). Be sure to review these concepts during and at the end of the explicit and reflective discussion. To help students think about these concepts in relation to what they did during the lab, you can ask the following questions:

1. You made observations and inferences during your investigation. Can you give me some examples of these observations and inferences?

2. Can you work with your group to come up with a rule that you can use to tell the difference between an observation and inference? Be ready to share in a few minutes.
3. People view some types of research as being more important than other types of research because of cultural values and current events. Can you come up with some examples of how cultural values and current events have influenced the work of scientists?
4. Scientists share a set of values, norms, and commitments that shape what counts as knowing, how to represent or communicate information, and how to interact with other scientists. Can you work with your group to come up with a rule that you can use to decide if something is science or not science? Be ready to share in a few minutes.

You can also use presentation software or other techniques to encourage your students to think about these concepts. You can show examples of information from the investigation that are either observations or inferences and ask students to classify each example and explain their thinking. You can also show examples of research projects that were influenced by cultural values and current events and ask students to think about what was going on in society when that research was conducted and why that research was viewed as being important for the greater good.

Remind your students that, to be proficient in science, it is important that they understand what counts as scientific knowledge and how that knowledge develops over time.

Hints for Implementing the Lab

- Learn how to use the interactive map before the lab begins. It is important for you to know how to use the interactive map so you can help students when they get stuck or confused.
- A group of three students per computer or tablet tends to work well.
- Allow the students to play with the interactive map as part of the tool talk before they begin to design their investigation. This gives students a chance to see what they can and cannot do with the interactive map.
- Be sure that students record actual values (e.g., number or severity of geologic events) rather than just attempting to describe what they see on the computer screen (e.g., there are lots of volcanoes, there were more earthquakes). The interactive map contains a number of tools that will allow the students to collect quantitative data during this investigation.
- Students often make mistakes during the data collection stage, but they should quickly realize these mistakes during the argumentation session. It will only take them a short period of time to re-collect data, and they should be allowed

to do so. During the explicit and reflective discussion, students will also have the opportunity to reflect on and identify ways to improve the way they design investigations (especially how they attempt to control variables as part of an experiment). This also offers an opportunity to discuss what scientists do when they realize that a mistake is made during a study.

- This lab provides an excellent opportunity to discuss how scientists need to make choices about what data to use when there is too much data to analyze. Be sure to give students advice about how to address this issue as they are working and discuss this issue as part of the explicit and reflective discussion.
- This lab also provides an excellent opportunity to discuss how scientists identify a signal (a pattern or trend) from the noise (measurement error) in their data. Be sure to use this activity as a concrete example during the explicit and reflective discussion.

Connections to Standards

Table 6.2 highlights how the investigation can be used to address specific (a) performance expectations from the *NGSS* and (b) *Common Core State Standards* in English language arts (*CCSS ELA*).

TABLE 6.2

Lab 6 alignment with standards

***NGSS* performance expectations**	History of Earth • MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. • 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
***CCSS ELA*—Reading in Science and Technical Subjects**	Key ideas and details • CCSS.ELA-LITERACY.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts. • CCSS.ELA-LITERACY.RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. Craft and structure • 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 *grade 6–8 texts and topics*.

Continued

TABLE 6.2 (*continued*)

***CCSS ELA*—Reading in Science and Technical Subjects** (*continued*)	Craft and structure (*continued*) • CCSS.ELA-LITERACY.RST.6-8.5: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic. • CCSS.ELA-LITERACY.RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text. Integration of knowledge and ideas • 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). • CCSS.ELA-LITERACY.RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text. • CCSS.ELA-LITERACY.RST.6-8.9: Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.
***CCSS ELA*—Writing in Science and Technical Subjects**	Text types and purposes • CCSS.ELA-LITERACY.WHST.6-8.1: Write arguments focused on *discipline-specific content*. • CCSS.ELA-LITERACY.WHST.6-8.2: Write informative or explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes. Production and distribution of writing • CCSS.ELA-LITERACY.WHST.6-8.4: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. • CCSS.ELA-LITERACY.WHST.6-8.5: With some guidance and support from peers and adults, develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on how well purpose and audience have been addressed. • CCSS.ELA-LITERACY.WHST.6-8.6: Use technology, including the internet, to produce and publish writing and present the relationships between information and ideas clearly and efficiently. Range of writing • CCSS.ELA-LITERACY.WHST.6-8.10: Write routinely over extended time frames (time for reflection and revision) and shorter time frames (a single sitting or a day or two) for a range of discipline-specific tasks, purposes, and audiences.

Continued

TABLE 6.2 (*continued*)

***CCSS ELA*—Speaking and Listening**	Comprehension and collaboration • CCSS.ELA-LITERACY.SL.6-8.1: Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6–8 topics, texts, and issues, building on others' ideas and expressing their own clearly. • CCSS.ELA-LITERACY.SL.6-8.2:* Interpret information presented in diverse media and formats (e.g., visually, quantitatively, orally) and explain how it contributes to a topic, text, or issue under study. • CCSS.ELA-LITERACY.SL.6-8.3:* Delineate a speaker's argument and specific claims, distinguishing claims that are supported by reasons and evidence from claims that are not. Presentation of knowledge and ideas • CCSS.ELA-LITERACY.SL.6-8.4:* Present claims and findings, sequencing ideas logically and using pertinent descriptions, facts, and details to accentuate main ideas or themes; use appropriate eye contact, adequate volume, and clear pronunciation. • CCSS.ELA-LITERACY.SL.6-8.5:* Include multimedia components (e.g., graphics, images, music, sound) and visual displays in presentations to clarify information. • CCSS.ELA-LITERACY.SL.6-8.6: Adapt speech to a variety of contexts and tasks, demonstrating command of formal English when indicated or appropriate.

* Only the standard for grade 6 is provided because the standards for grades 7 and 8 are similar. Please see *www.corestandards.org/ELA-Literacy/SL* for the exact wording of the standards for grades 7 and 8.