Lesson 13: How can we use our science ideas to explain what happened at the Midcontinent Rift?

Previous Lesson *We modeled forces on the plates and investigated how gravity can be represented as components when objects are on an incline. We connected this to plate motion and updated our Plate Interactions Consensus Model poster and our Progress Trackers.*

This Lesson

Putting Pieces Together

1 day

Data Source: ArcGIS

We revisit our Scale Chart poster and add processes from Lesson 12. We update connections on our Scale Chart poster and revisit our Driving Question Board. We reflect on our experiences in this unit and engage in a transfer task to explain why the Midcontinent Rift did not tear apart. We catalog our unanswered questions for future units.

Next Lesson *There is no next lesson.*

BUILDING TOWARD NGSS

HS-PS1-8, HS-ESS1-5, HS-ESS2-1, HS-ESS2-3

What students will do

13.A Revise an explanation based on valid and reliable evidence to answer Driving Question Board questions that involve explaining the change over time in stability of the interactions between motions of the mantle and the plates. (SEP: 6.2; CCC: 7.1; DCI: ESS2.A.2, ESS2.B.2, ESS2.B.3)

What students will figure out

- Many processes on the Scale Chart poster have effects on other processes at different scales.
- Processes that occurred at the Midcontinent Rift 1.1 billion years ago are similar to what is occurring at Afar today.
- Thermal convection and the interaction of forces with plates can be used to explain how the Midcontinent Rift failed.

Lesson 13 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**REVISIT THE SCALE CHART** Revisit the Scale Chart poster. Add ridge push and slab pull. Take a final pass at identifying relationships between the components and mechanisms.	A	Scale Chart poster, 3x5 sticky notes, chart paper markers
2	10 min		**REVISIT THE DRIVING QUESTION BOARD** Return to the DQB to determine which questions we have answered. Reflect on experiences during the unit.	B-D	sticky dots (red), sticky dots (yellow), sticky dots (green), Driving Question Board, Takeaways poster, Scale Chart poster, chart paper markers
3	30 min		**COMPLETE THE FINAL ASSESSMENT** Complete an assessment comparing the processes that occurred at the Midcontinent Rift and the current processes in the Afar region, and predicting the future of Afar if it follows the same processes.	E	*Midcontinent Rift Transfer Task*, Scale Chart poster

End of day 1

Lesson 13 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • sticky dots (red) • sticky dots (yellow) • sticky dots (green) • *Midcontinent Rift Transfer Task*		• Scale Chart poster • 3x5 sticky notes • chart paper markers • Driving Question Board • Takeaways poster

Materials preparation (15 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.

Prepare a piece of chart paper for a poster titled “Takeaways”.

Make sure all students will have access to sticky dots (green, yellow, and red) to revisit the Driving Question Board.

Consider gathering artifacts such as posters from previous lessons and positioning them around the DQB to help students make connections between what we have learned and the questions that we can now answer.

Make a copy of the *Midcontinent Rift Transfer Task* for each student. Review the *Failed Midcontinent Rift Key* prior to administering the assessment. Consider what modalities you want to provide for students to complete the assessment. See the *Attending to Equity* callout in the assessment section of this teacher guide for ideas of different ways to administer this assessment.

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

This lesson is designed to coherently build ideas related to the following disciplinary core ideas (DCI)s:

- **ESS2.A.2: Earth Materials and Systems:** Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical ~~and chemical~~ processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (HS-ESS2-3)
- **ESS2.B.2: 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. (ESS2.B Grade 8 GBE) (HS-ESS2-1) (secondary to HS-ESS1-5)
- **ESS2.B.3: Plate Tectonics and Large-Scale System Interactions:** Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks ~~and minerals~~ within Earth's crust. (HS-ESS2-1)

This lesson revisits the Scale Chart poster to identify that all components, mechanisms, and their interactions on the chart represent the Theory of Plate Tectonics.

This lesson also touches back on the questions posted on the Driving Question Board. Students can now answer questions based around the DCIs from prior lessons, using their understanding of Earth's internal processes and the interaction of forces, matter, and energy that cause the changes over time.

After a review of the Scale Chart poster and the Driving Question Board, students engage in a transfer task of modeling to explain why the Midcontinent Rift, which appears to have processes similar to what the Afar region is currently experiencing, did not result in a new ocean 1.1 billion years ago.

This lesson is designed to support students toward the Next Generation Science Standards (NGSS) Nature of Science Understanding titled **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** (Appendix H). The relevant understanding element reads:

- Models, mechanisms, and explanations collectively serve as tools in the development of a scientific theory.

Where We Are NOT Going

Within the assessment, students explain why the Midcontinent Rift did not create a new ocean 1.1 billion years ago. This process, however, is currently being debated by geologists. Some believe that a hotspot also existed under the rift, causing active rifting to occur as well, among other theories. This complex process is not included in this assessment, nor are theories unrelated to the outcomes of this unit. Students are to explain this rifting process and the failing of the rift based upon what they have learned in the unit. After the assessment, consider sharing the other possible reasons for this rifting process; emphasize that there is no definitive evidence for any of these, as this research is an ongoing geological endeavor.

Further, the theorized plate boundaries and other interactions that occurred around Amazonia and Laurentia are complex and uncertain. Because of this, the assessment explains the separation of Laurentia and Amazonia using a simplified model that removes other cratons believed to have been present on the same plate with Amazonia.

The assessment also does not use north, south, east, and west directions, instead using the terms “left” and “right” for the direction of movement. This is to make the assessment more accessible for students who may have trouble situating the continents with cardinal directions. In addition, Amazonia and Laurentia did not move cleanly in one direction or another. Referring to their movement as “left” and “right” can help students better explain changes in net force and how energy from the mantle is driving the tectonic processes.

Though the Midcontinent Rift is considered a fossil rift, it has many parallels to the processes occurring at Afar, and there is still uncertainty regarding its formation. Many online resources offer more information about the Midcontinent Rift. To learn more, consider visiting one of these sites:

- https://www.youtube.com/watch?v=HO1FplJGsgY
- https://eos.org/features/new-insights-into-north-americas-midcontinent-rift
- https://www.sciencedirect.com/science/article/pii/S0012825221002920

LEARNING PLAN for LESSON 13

1 · REVISIT THE SCALE CHART

5 min

MATERIALS: Scale Chart poster, 3x5 sticky notes, chart paper markers

Reflect on the phenomena identified in Lesson 12. Project **slide A**. Bring students' attention to the Scale Chart poster, and ask them to reflect on their experiences in the prior lesson. Ask, *What processes did we identify last time that we can now add to our Scale Chart?* Guide students to recall that we identified slab pull and ridge push in the prior lesson. If they have difficulty remembering the last class period, direct them to look back at any of their artifacts from Lesson 12, including the updated consensus model.

Add these phenomena to the Scale Chart poster. Ask students to identify where ridge push and slab pull should go on the poster. They should say that these happen over a large time period and over a large space. The sticky notes for these processes should be placed somewhere between the deformation of plate material and new plate creation on the temporal axis, and to the right of the earthquakes (but not as far right as the mantle convection) on the spatial axis.

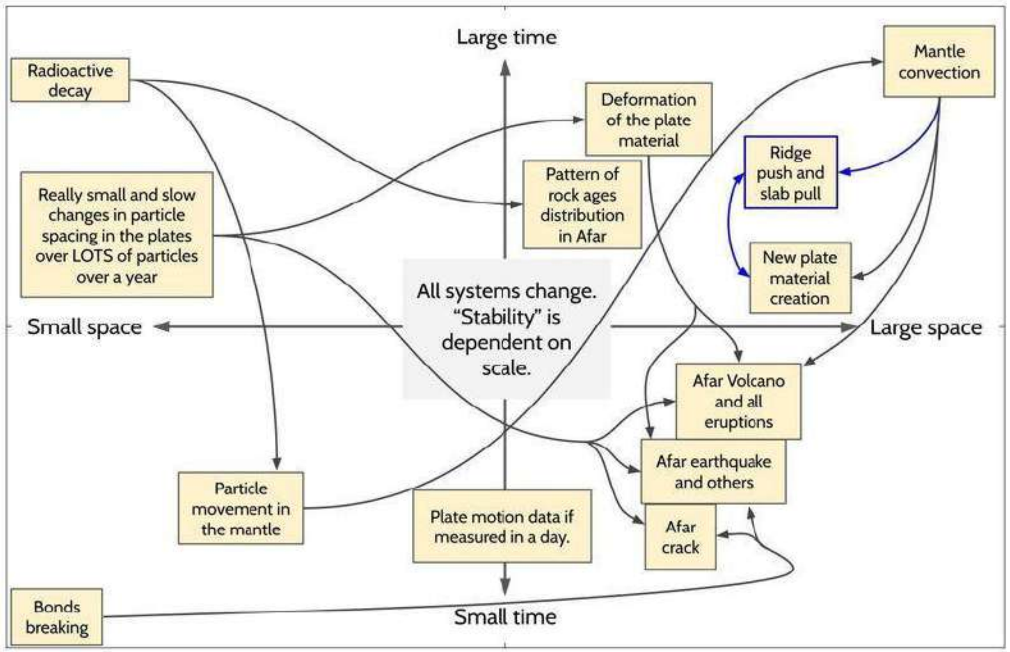
Connect these phenomena to other processes. Ask students to identify any connections between these processes and the others on the chart. They should say that mantle convection causes slab push and ridge pull, and that slab push and ridge pull (particularly ridge pull) create new plate material at the surface. This arrow should be double-headed, because this can create a feedback loop. See the image below for an example, with the new items outlined in blue.

Ridge push and slab pull were added to the chart. Depending on the class discussion, these could go anywhere by new plate material creation.

Connections were made between **mantle convection**, **new plate material creation**, and these two items.

Double arrows were added between **ridge push**, **slab pull**, and **new plate material creation**.

Additional arrows should be added at the class's discretion.



Make additional connections. Encourage students to continue looking at the chart and identify any other connections that they now see. Some may make further connections to ridge push, slab pull, earthquakes as well as cracks, and so forth. Ask students to explain the connections they are pointing out. Honor these connections, and draw arrows to show the relationships between these processes.

Ask, *What do you notice about the scales of these changes that were seemingly independent, but that we now see as connected?* Students should respond that many connections exist across the temporal and spatial scales, and changes at one scale have an effect on processes at other scales.

Consider the role of scale in processes. Point out that all of the connections on this chart really tell the story of plate tectonics on Earth. Summarize for the class that over the course of our lessons in this unit, we have explained the past and current movements of rocks at Earth's surface, and we now have a framework for understanding our geologic history by developing models and explanations and adding those mechanisms and interactions to our chart. Say that what we have explored is known as the Theory of Plate Tectonics. Use a marker to circle everything on the chart, and create a large label at the top saying "The Theory of Plate Tectonics".

2 · REVISIT THE DRIVING QUESTION BOARD

10 min

MATERIALS: science notebook, sticky dots (red), sticky dots (yellow), sticky dots (green), Driving Question Board, Takeaways poster, Scale Chart poster, chart paper markers

Frame the activity. Reorganize the class around the DQB. Present **slide B**. Say, *We've figured out so much! I bet we can answer many of our questions on the Driving Question Board.* ✱

Mark patterns in questions answered and unanswered. Facilitate identifying patterns in the DQB questions. Focus the discussion on identifying (1) questions we agree we can answer, (2) questions we have at least a partial answer to, and (3) questions we cannot answer at all. Explain that we will use a different color of sticky dots to mark each category. Distribute a set of sticky dots to each student, and have them come up to the DQB and add their dots to the posted questions.

ALTERNATE ACTIVITY	If you have time, have students choose one question from the DQB that has sticky dots for categories 1 or 2 to answer individually in their science notebook, and then share their answer during the discussion.

Discuss the DQB questions we can answer. Present **slide C**. Gather the class in a Scientists Circle for a discussion of the questions we can now answer. Display the Takeaways poster to record the answers. Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that were important to them at the onset of the unit.

As students share, put an emphasis on any questions that we have previously constructed an answer for but can now more fully explain. When this occurs, ask students to explain what evidence we collected has helped them revise the answer. Also ask them to identify the scale at which the process occurs, and whether that process has an effect on another part of the Earth system. When possible, make connections back to the sticky notes and arrows on the Scale Chart poster.

ASSESSMENT OPPORTUNITY

What to look for/listen for:

- Look/listen for students to use multiple sources of evidence to explain a surface feature, or the motion of the mantle and the plates and their stability and change over time, using matter changes and interactions, forces acting on matter, and/or energy flow. (SEP: 6.2; CCC: 7.1; DCI: ESS2.A.2, ESS2.B.3)
- Look/listen for students to use multiple sources of evidence to explain that changes that occur over a long time through the process of plate tectonics may appear stable over short time periods. (SEP: 6.2; CCC: 7.1; ESS2.B.2)

✱ ATTENDING TO EQUITY

Revisiting the Driving Question Board is important for helping students feel that their questions are valued and recognized. Though not all questions will have been addressed (it's more likely that 50–75 percent will be at least partially answered), this enables students to see the hard work they have done to answer many of their own questions.

What to do:

- If students are in disagreement about an answer, ask questions to seek clarification or more information, such as: *Can you tell me more? What investigation helped us figure out that piece of information? Can anyone point to evidence to support ___'s answer?*
- If students are uncertain as to the scale on which their answer occurs, have them map their question to the Scale Chart poster. Ask them to identify whether other connections made on the poster also apply to their answer, and whether any processes at a larger or smaller spatial or temporal scale would be affected or involved within their answer.

Building toward: 13.A Revise an explanation based on valid and reliable evidence to answer Driving Question Board questions that involve explaining the change over time in stability of the interactions between motions of the mantle and the plates. (SEP: 6.2; CCC: 7.1; DCI: ESS2.A.2, ESS2.B.2, ESS2.B.3)

Celebrate the class's accomplishments. Say, *I can't believe how far we've come since we first read about Afar in Lesson 1. We should be very proud of what we've accomplished.*

Have students reflect upon their experiences. Present **slide D**. Direct students to find a blank piece of paper in their notebook, label it "Reflection", and record their answers to the questions on the slide:

- *What was most challenging in this unit?*
- *What was most rewarding in this unit?*

Ask each student to share out part of their reflection. Taking time to reflect upon the process of this unit allows them to think metacognitively about what works well for them as learners.

3 · COMPLETE THE FINAL ASSESSMENT

30 min

MATERIALS: *Midcontinent Rift Transfer Task*, science notebook, Scale Chart poster

Administer the assessment. Present **slide E.** Say, *In this unit, we've figured out not only why the crack in Afar happened, but also why other surface features happen elsewhere around the world. Did you know we have a rift system similar to Afar's in the middle of the United States? Scientists have said that this system, the Midcontinent Rift, began creating a new ocean like we see in the Afar region, but instead of opening into a new ocean, it failed. Let's see whether we can use our knowledge of Afar, along with more information about the Midcontinent Rift, to explain what might have happened.*

✱ ATTENDING TO EQUITY

Universal Design for Learning: Consider allowing students to *express* their understandings of the Midcontinent Rift in

Distribute the *Midcontinent Rift Transfer Task* to each student. This task will take the remainder of the class period to complete. ✱ Students should turn in their completed assessments for feedback.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See the accompanying key.

What to do: Use the key to assess students, and for suggestions on how to provide productive feedback for students who are working with foundational ideas but not yet linking them, students who are linking ideas but not yet organizing them, and students who are organizing ideas and need an additional challenge.

This assessment is not building toward a lesson-level performance expectation. It is designed to assess a performance expectation (PE) from the NGSS, below.

Transfer Task 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. (SEP: 2.3; CCC: 7.2; DCI: ESS2.A.1, ESS2.B.2)

As well as the SEP, CCC, and DCIs associated with this PE, this assessment addresses one additional CCC element and one additional DCI element:

- **5.4 Energy and Matter.** Energy drives the cycling of matter within and between systems.
- **ESS2.A.2 Earth Material and Systems.** ~~Evidence from deep probes and seismic waves, reconstructions of historical changes in Earth's surface and its magnetic field, and an understanding of physical and chemical processes lead to a model of Earth with a hot but solid inner core, a liquid outer core, a solid mantle and crust.~~ Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of energy from Earth's interior and gravitational movement of denser materials toward the interior. (HS-ESS2-3)

At the end of the period, bring the class back together and point to the unanswered questions on the DQB. Tell students that, over the course of future units, we will need to keep these questions in mind to see whether we can eventually answer them.

ADDITIONAL GUIDANCE

Students may have questions, such as those focused on acceleration or gravity, that require use of different disciplinary core ideas, crosscutting concepts, or science and engineering practices than those utilized in this unit. Keep these questions to revisit in later units. For instance, in *Vehicle Collisions Unit*, students will explore the idea of Newton's second law in more depth, and in *Meteors Unit* and *Cosmology Unit*, they will learn more

various ways. Some students may benefit from orally responding to the prompts, or by using manipulatives such as the foam pieces to physically represent what they believe happened in North America 1.1 billion years ago. Online tools such as Flip can assist students in showing and explaining their ideas in more than just writing.

about the history of Earth and the universe. This will allow some resolution on these unanswered questions in the future.

Additional Lesson 13 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	This is the CCMS-related idea that is used to support sensemaking in this lesson: **Number and Quantity** ● **CCSS.MATH.CONTENT.HS.N-VM.1** Represent and Model with Vector Quantities: Recognize vector quantities as having both magnitude and direction. In the assessment, students use vectors to describe the magnitude and direction of multiple forces acting on Laurentia and Amazonia before and after their separation.