Earthquakes, Tsunamis, and Volcanoes: Who's at Risk? - Teacher Materials

Unit 3	Earth and Space Science

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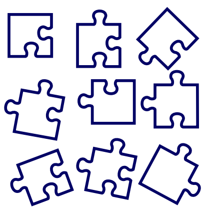
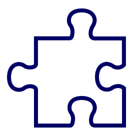
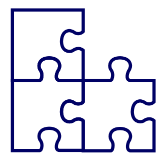
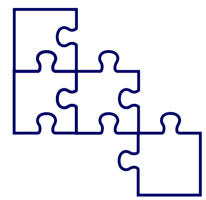
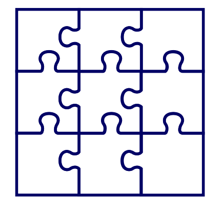
Unit 3 Earthquakes, Tsunamis, and Volcanoes: Who's at Risk?
Earth's Interior

Performance Expectations
HS-ESS3-1, HS-ESS2-3, HS-ESS1-5, HS-ESS2-1

Time
24-31 days

What locations on Earth are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future? Why do populations live in these risky areas?

In 2011, an earthquake and tsunami in Japan caused a nuclear disaster that we are still recovering from. In 2022 a volcanic eruption occurred at Tonga that was heard thousands of miles away and produced a massive tsunami. Natural disasters caused by tectonic plate movement, like these, are not new to Earth's history, and have long played a part in human societies. After learning about these events and others, how they occur, and the vulnerability of different populations, students explain how these events have impacted humans in both positive and negative ways.

Unit Opening	Earth's Interior	Surface Features & Plate Boundaries 5E	Energy and Matter 5E	Unit Closing
Anchor Phenomenon →		**5E Lessons connect learning to the performance task** →		**Performance Task**
				
What locations on Earth are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future? Why do populations live in these risky areas?	*Where did the material for new islands come from after Krakatoa erupted?*	*Why does seismic activity happen in some areas more than others?*	*Where is all the energy coming from to move plates apart from each other? What processes are occurring inside Earth that can cause it to reach Earth's surface? And why do people continue to live in these hazardous areas?*	*What locations on Earth are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future?*

Unit Introduction

How do we make science education meaningful and relevant to our students? High school earth and space science courses are traditionally filled with lectures and cookbook labs, memorizing vocabulary, and an occasional research report. New science education standards (NGSS/NYSSLS) require a more engaging, accessible vision of science teaching and learning to help *all* students learn about the natural world and become scientifically literate citizens.

The three-dimensional, phenomenon-driven materials in this unit support students in engaging in the authentic practices of science. Students construct meaning about the natural world through modeling, investigations, labs and experiments. As students have opportunities to manipulate the physical tools of science, they also engage in productive struggle that can be resolved through creating models from evidence and engaging in consensus building discussions. The materials support teachers in becoming skillful facilitators of student sense-making and deepen teachers' understanding of how to teach science in an interactive way that is driven by students' questions and ideas.

This unit was intentionally designed to build on the second unit of this course, Probability of Life Elsewhere, in which students construct explanations based on multiple lines of evidence. In Earthquakes, Volcanoes, and Tsunamis: Who's at Risk?, students continue to engage with multiple types of evidence, including models, to construct scientific explanations. The common embedded group learning routines and curriculum structures introduced in the first unit are revisited, providing students and teachers multiple opportunities to engage in a culture of collaborative sensemaking around a phenomenon. In this unit, students are encouraged to explain how international organizations can use the scientific understanding of the causes of tectonic hazards combined with the realities of differing vulnerability and population needs of different tectonically active regions.

The embedded group learning routines and formative assessments found in each of the Earth and Space Science units support teachers in learning about their students, both academically and personally. Whether students had strong science programs prior in prior courses, of if three-dimensional teaching and learning is brand new to them (or the teacher!), this unit is designed to reinforce and further build on students' earlier experiences with three-dimensional learning.

Unit Coherence

In Unit 3, the overall question about which regions are most at risk of tectonic hazards and why people even live in those areas is intended to motivate student engagement across the unit. From the students' perspective, there should be a clear and explicit unit storyline that guides the sequence of activities. Rather than one long continuous unit, we have chosen to use an instructional model to develop three coherent sequences of lessons within Unit 3. Each sequence is based on students' questions and builds towards figuring out something that contributes to the overall unit-level question about what conditions combine to increase the risk from tectonic activity and why people live in those areas. This in turn allows students to explain how international organizations can prioritize disaster preparedness funds. The phenomena, the instructional model, and the routines embedded throughout the sequences of lessons are all used in service of coherence across Unit 3.

Phenomenon-Driven Instruction

Phenomena are a key part of instruction in A Framework for K-12 Science Education and the NGSS. As in the work of scientists, students should be encouraged to move from observable phenomena to generalizable explanations of the natural world. Too often, traditional science instruction has started with generalizable principles, sidelining the lived experience and intuitions that all young people bring to school. In this unit (and all New Visions units) there are two kinds of phenomena: anchor phenomena and investigative phenomena.

Anchor Phenomenon	Investigative Phenomena
• One per unit; drives the learning of the unit • Attention-grabbing and relevant • Does not have to be phenomenal	• One per 5E sequence (three in this unit) • Presented in the Engage phase of each 5E

Anchor Phenomenon

To support coherence, students are prompted to figure out one overarching, real-world question over the course of the unit. The anchor phenomenon question is revisited across the unit, and this question motivates the investigations conducted in each of the 5E instructional sequences. A good anchor phenomenon should be attention-grabbing and relevant to students but also thought-provoking, comprehensible, and connected to the science learning goals. It needs to be observable to students through firsthand experiences or through someone else's experiences, such as through a video or secondary data. If a teacher feels the anchor phenomenon will not be familiar or accessible to all students, we suggest relating it to similar, more familiar phenomena. It is important to notice that the phenomenon question anchoring the unit is different from the more generalized and abstracted science question for the unit. This difference is part of what helps make the unit more student-centered, rather than teacher-centered.

Investigative Phenomena

Based on the Anchor Phenomenon and three-dimensional learning goals for students for the unit, each 5E instructional sequence has a related investigative phenomenon, typically presented in the Engage phase. This phenomenon brings students together around a shared puzzle or experience that frames the learning for that 5E sequence. Similar to the anchor phenomenon question, the questions about the investigative phenomena are intended to be specific and contextualized, rather than the traditional content questions teachers use as their lesson aims. They present what is being figured out; therefore, the scientific concepts that are in the learning goal cannot be part of the wording of the question!

Storyline and Pacing Guide

Unit Opening

What locations on Earth are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future? Why do populations live in these risky areas?	**Performance Expectations**	**Anchor Phenomenon**	**Time**
	HS-ESS3-1	Major earthquakes, volcanic eruptions, and tsunamis happen all over the world, causing loss of life and property, yet humans have been living continuously in these hazardous areas for thousands of years.	3 days

Student Questions	What Students Do	Student Ideas
These questions motivate the unit storyline. • What caused the events in Japan and Krakatoa? • Where do earthquakes, volcanoes, and tsunamis occur? • What causes earthquakes, volcanoes, and tsunamis? • How do tectonic plates move? • How do tectonic plates cause earthquakes, volcanoes, and tsunamis? • Do earthquakes, volcanic eruptions, and tsunamis happen often? • Can earthquakes, volcanic eruptions, or tsunamis happen where we live? • Where do the biggest earthquakes occur? Why? • Is there a relationship between volcanoes, earthquakes, and tsunamis? • Why have people been living in places where these hazards occur for thousands of years? • How are human populations of the past and present impacted by hazards? • How big are human populations in places where these hazards occur? • What technology and resources do populations that live where these hazards occur have access to? • Are the populations that live where these hazards can occur rich or poor?	Students recall big earthquakes that happened during their lifetimes, then reflect on the biggest earthquakes. They are asked - what is the risk where you live of a big earthquake? To better understand earthquakes and other tectonic hazards, students are introduced to two events through video, then analyze maps that represent many other deadly tectonic hazards in recent history. Students refer to texts regarding tectonic disasters in order to tell the story of the phenomenon. Students are then introduced to the unit performance task, develop initial models that illustrate their ideas about how earthquakes, volcanic eruptions, and tsunamis occur and generate questions for a Driving Question Board that will drive instruction throughout the unit.	*These ideas are revisited throughout the unit storyline.* • In the 2011 Japan earthquake, people felt the earthquake right away and then the tsunami occurred, also in Japan. The tsunami caused a lot of damage. • In Tonga, a volcanic eruption caused chaos in nearby villages and a tsunami that followed destroyed what was left of those villages and even caused havoc in villages across the sea. • We can create models to represent what may have happened inside Earth to lead to these events.

One of the categories will be about what causes earthquakes, volcanoes, and tsunamis to occur. Set students up to investigate these questions first.

Earth's Interior	Where did the material for new islands come from after Krakatoa erupted?	**Performance Expectations** HS-ESS2-3, HS-ESS3-1	**Investigative Phenomenon** When Krakatoa erupted in 1883, the major island disappeared, and temporary islands appeared. In the time since then, new islands have been growing.	**Time** 8-10 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • What causes earthquakes, volcanoes, and tsunamis? • What is underneath these hazards? • What is the Earth made of?	Students examine a volcanic eruption that resulted in new islands forming. Students ask questions about what is going on underneath the surface at the locations where this eruption occurred and are introduced to the concept of using seismic station data. They see an anomaly occur in the seismogram data for major earthquake events. When investigating waves further through an online simulation, they observe that some of the waves don't travel through the middle of the Earth. They examine how layers form using the concept of density to figure out how layers of Earth may be different. Using these observations and concepts of structure and function of different types of materials in Earth's interior, students are able to conclude that the Earth's interior structure is divided into layers and make claims about their composition. Students then examine sampling and magnetic data to draw conclusions about the composition of the Earth. Finally, students apply their understanding of Earth's layers to the rock cycle to determine how new islands are formed, and use that knowledge to model and explain how the structure of Earth creates volcanic hazards.	*Students figure out these ideas in this 5E sequence.* • Seismic waves are not consistent in each area of the Earth • Some waves arrive later than others after an event. • P waves are distorted and slowed in the middle of Earth's interior, S waves do not pass through the middle of Earth's interior. • Seismic waves can tell us the structure of the Earth, determined based on the density of the layers). • Waves' velocity and intensity relate to the density of the medium through which they are traveling. • S waves can only move through solids • Earth's interior is composed of a solid inner core, a liquid outer core, a semi-solid mantle, and a solid crust, which is broken into plates. Data from seismic waves helped scientists develop this model. • Although the system cannot be studied directly (we can't actually go into the Earth to see the layers), effects from various earthquakes supports scientists' understanding of the system. We are only able to make these inferences when we look at data over a large spatial scale. • The layers of the earth are made of different rocks, minerals, and solid and liquid forms of iron and nickel • The Earth has a magnetic field, which tells us that one layer of Earth is liquid metal • The rock cycle explains how volcanic eruptions bring material from lower in Earth's layers to the surface

Students revisit the anchor phenomenon and driving question board, and they are able to use what they have figured out about Earth's interior structure and composition to consider how the structure of Earth creates tectonic hazards. Students still have questions about where these hazards are more common, why people live in those regions, and how risk is determined.

Surface Features & Plate Boundaries 5E

Why does seismic activity happen in some areas more than others?

Performance Expectations
HS-ESS1-5, HS-ESS2-1, HS-ESS3-1

Investigative Phenomenon
Seismic activity occurs in a pattern at the surface of the Earth. Why does that pattern exist?

Time
7-9 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. • What causes earthquakes, volcanoes, and tsunamis? • How do tectonic plates cause earthquakes, volcanoes, and tsunamis? • Is there a relationship between volcanoes and earthquakes, and tsunamis? • Why are volcanoes near earthquakes? • What created the tsunamis? Questions generated from the Earth's Interior 5E: • What causes tectonic hazards to happen? • How does their interaction cause what we observe and experience on Earth's surface?	Students observe patterns of seismic activity around the world. Then students analyze the age of the ocean floor and models of magma rising at ocean ridges to make claims about the direction of plate motion. After coming to conclusions about the direction of some plates based on ocean floor data, students are introduced to the theory of plate tectonics and determine the merits of plate tectonics theory by evaluating evidence they have seen so far and identifying further evidence needed. They also wonder if plate tectonics can explain the pattern in earthquake, volcanic eruption, and tsunami occurrence and model to figure out whether energy and matter flow associated with plate motion can cause these tectonic hazards. Finally, students use what they have learned about plate tectonics to revise their models of risk and determine which regions may be more at risk than others.	*Students figure out these ideas in this 5E sequence.* • Patterns in the age of crust at different locations all around Earth provide multiple pieces of evidence that support the theory of plate tectonics. • New crust formed by magma pushes the existing crust away, so that explains why crust gets older as you move away from divergent boundaries. • At convergent boundaries where one plate submerges under the other, the submerging plate is more dense - we know that more dense stuff sinks under less dense stuff due to gravity. • The strongest earthquakes, volcanic eruptions, and tsunamis occur at convergent plate boundaries. Mountain building also occurs at convergent plate boundaries. • This makes sense because a lot of energy would build up there as the plates push together. • Volcanoes form and erupt when the energy due to friction heats magma, causing it to become less dense and therefore rise toward the surface.

Students revisit the anchor phenomenon and driving question board, and use ideas related to the cause of earthquakes, volcanoes / eruptions, and tsunamis at the different types of plate boundaries and historical earthquake data to revise their models for how earthquakes, volcanic eruptions, and tsunamis occur and which location is most at risk of loss of human life and property. The scale of energy associated with tectonic plate movement and hazards, causes students to ask questions related to what's occurring inside Earth that produces so much energy and how it reaches the surface.

Energy and Matter 5E	Where is all the energy coming from to move plates apart from each other? What processes are occurring inside Earth that can cause it to reach Earth's surface? And why do people continue to live in these hazardous areas?	**Performance Expectations** HS-ESS2-3, HS-ESS2-1	**Investigative Phenomenon** The Great Rift Valley is the cradle of humanity, but also experiences significant amounts of seismic activity from plates moving apart from each other.	**Time** 5-6 days

Student Questions	What Students Do	Student Ideas
These questions motivate this 5E sequence and the unit storyline. From Unit Launch: • What causes earthquakes, volcanic eruptions and tsunamis to occur? • Why do people live in these hazardous areas? Questions generated from Waves Inside the Earth 5E: • Where does all the energy required to move plates come from? • Will the energy released ever run out? • How would the heat get from the core to the surface?	Students look at various evidence for the energy release from Earth in the form of heat: volcanoes and geysers. They Investigate the sources of this heat and the amount of energy involved in these different phenomena. Students then compare different ways heat is transferred, learning more about radioactive decay, convection, and conduction. They construct an explanation (using a C-E-R scaffold) about heat inside the Earth and revise their models both at the particle level and at the macro level to show risk where they live.	*Students figure out these ideas in this 5E sequence.* • Early Earth was super hot! As the Earth began to cool, denser materials sank to the core, forcing less dense materials closer to Earth's surface. Some of these materials are radioactive. • Along with residual heat from primordial Earth, radioactive decay in the mantle is generating most of the heat that moves the plates, causing all of the lithospheric phenomena we observe that release energy. • Radioactive materials decay at a constant rate, producing heat. This heat is transferred towards the surface by conduction and convection currents in the outer core and mantle, causing plate movement. • Energy gets out of the core by conduction. • The effects of the different types of plate movement on the surface are due to energy transfer from the core and mantle, initially by conduction, and then by convection/gravity. • The lower melting point of water relates to changes in density that contribute to the mechanism of plate motion. • Tectonically active places tend to have high concentrations of minerals and other ecosystem resources

Students revisit the anchor phenomenon and driving question board, and they are able to make connections to what they figured out about where energy inside Earth is coming from and how that energy and matter inside the Earth are cycled to Earth's surface. Students use what they have learned so far to revise their risk models and explanations for why large populations live near some areas that are highly susceptible to natural hazards caused by plate boundaries.

Unit Closing

What locations on Earth are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future?

Performance Expectations
HS-ESS3-1

Anchor Phenomenon
Major earthquakes, volcanic eruptions, and tsunamis happen all over the world, causing loss of life and property, yet humans have been living continuously in these hazardous areas for thousands of years.

Time
1-3 days

Student Questions	What Students Do	Student Ideas
These questions are addressed in the performance task. • Which region is most at risk from tectonic activity?	Students generate more ideas about how to determine the risk of an earthquake or tsunami by reading the vulnerability profiles of each region and comparing how earthquake deaths have changed over time. Students then further investigate unanswered questions from their Driving Question Board. Finally, students develop a final explanation about how technology, as seen in the vulnerability profiles, contributes to the reduced risk from seismic hazards and changes their impact on human populations.	*These ideas were developed throughout the unit storyline.* • Risk varies depending on where a person lives. • Proximity to different types of boundaries, age of rocks, rate of plate movement, population density, seismicity, proximity to water, and technology like building codes and warning systems are all factors into determining risk.

Unit Standards

This unit is designed to meet Next Generation Science Standards Performance Expectations. Since this unit is part of a full-year Biology course, the design includes intentional foregrounding of a limited number of Crosscutting Concepts (CCCs) and Science and Engineering Practices (SEPs). Further, since an aspect of NGSS design is connections to Common Core Math and ELA standards, these connections are highlighted in this section.

Performance Expectations

HS-ESS3-1 **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.**
Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.
Assessment Boundary: None

In NYS, the clarification statement has been edited as follows: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards could include those from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as blizzards, hurricanes, tornados, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations could include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

HS-ESS2-3 **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.**
Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Rocks and minerals can be identified and classified using various tests and protocols that determine their physical and chemical properties. Examples of evidence could include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.

HS-ESS1-5 **Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.**
Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).
Assessment Boundary: None

In NYS, the clarification statement has been edited as follows: Examples of evidence could include that the age of oceanic crust increases with distance from mid-ocean ridges as a result of plate spreading and that the North American continental crust contains a much older central ancient core compared to the surrounding continental crust as a result of complex and numerous plate interactions.

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.** Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion). Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

In NYS the clarification statement and assessment boundary have been edited as follows: Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and deposition) and destructive processes (such as weathering, subduction, and coastal erosion). Assessment Boundary: Assessment does not include recalling the details of the formation of specific geographic features of Earth's surface.

Three-Dimensional Learning Goals in This Unit

Given the breadth of three-dimensional standards for high school Earth and Space Science, Unit 3 focuses primarily on ideas related to Earth's interior, including the structure of Earth and plate tectonic theory. These ideas fall within Core Ideas ESS2 of the NGSS/NYSSLS, *Earth's Systems*. This unit also continues strengthening students' use of the SEP of Constructing Explanations and Designing Solutions and has a secondary focus on the SEP of Modeling. That is not to say that students will not engage in other SEPs throughout the lessons; however, it is important to foreground and be explicit about a limited number of practices with enough duration to see how students develop their understanding and ability to use this practice. This is important for both student and teacher learning! Similarly, the foregrounded CCC for this unit is *Patterns*, which fits well with our selected SEP and the understanding that patterns in Earth's processes and systems allows scientists to determine the structure and composition of Earth. Two secondary CCCs for the unit, Energy and Matter and Stability and Change are also useful to students as they use these ideas in two ways: (1) examining the changes to Earth's surface as a result of tectonic activity and; (2) developing explanations for how energy and matter move together during tectonic activity. The design of instruction across the unit supports students' three-dimensional learning and shifts classrooms to become more NGSS-aligned spaces.

Three Dimensions Foregrounded in Unit 3

This chart is a high-level summary of the foregrounded standards. For more detail about specific elements, see the section on Assessment later in this document.

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models	ESS1.C The History of Planet Earth	Patterns
Constructing Explanations and Designing Solutions	ESS2.A Earth Materials and Systems	Cause and Effect
Engaging in Argument from Evidence	ESS2.B Plate Tectonics and Large-Scale System Interactions	Energy and Matter
	ESS3.A Natural Resources	Stability and Change
	ESS3.B Natural Hazards	
	PS1.C Nuclear Processes	

Building on Middle School

High school science teaching necessarily builds on student learning from middle school. It is helpful to consider the middle school standards in order to enact a unit that builds on students' prior experiences. As we are in the middle of a multi-year transition, however, it is also critical to keep in mind that not all students will have experienced an NGSS-designed unit when they come to high school, so the process of building on middle school learning may be particularly complex for years to come. The following sections detail the ways in which this unit builds on middle school standards across the three dimensions.

Disciplinary Core Ideas from Middle School

ESS2.A Earth Materials and Systems

- In middle school, students learn that all Earth's processes are a result of energy flowing and matter cycling within and between Earth's systems over different scales. In this unit, students build upon that understanding by considering how energy drives the motion of matter during tectonic activity.

ESS2.B Plate Tectonics and Large-Scale System Interactions

- Students in middle school learn that Earth's plates have moved. This unit builds on that basic idea by adding complexity to the mechanisms of that motion, including how Earth's structure contributes to that motion and how energy from radioactive decay in Earth's mantle drives the movement.

ESS1.C The History of Planet Earth

- In middle school, students learn foundational concepts about tectonic activity slowly generating the seafloor and ocean ridges. In this unit, students expand upon that understanding by relating it to the rates of change that construct Earth's surface features and connect it to plate tectonic theory.

Crosscutting Concepts from Middle School

Stability and Change

This unit builds on the following aspects of Stability and Change in middle school:

- Middle school students learn that changes in one part of a system can impact other parts, and that change can happen quickly or over a long period of time. This unit builds on that background as students examine changes that happened gradually over Earth's history and disruptions that caused more rapid changes over shorter scales.

Patterns

This unit builds on the following aspects of Patterns in middle school:

- Middle school students learn that patterns in rates of change can provide information about natural systems. This unit builds on that background by using patterns at different scales to gain information about Earth's structure and plate tectonic theory.

Energy and Matter

This unit builds on the following aspects of Energy and Matter in middle school:

- Middle school students learn that matter is conserved and that the transfer of energy drives the movement of matter. This unit builds on that background as students examine the sources and movement of energy driving the movement of matter during tectonic activity.

Science and Engineering Practices from Middle School

Constructing Explanations and Designing Solutions

- Students in middle school have experience constructing explanations using multiple lines of evidence. In this unit, students build upon that practice by adding student-generated sources of evidence from investigations in order to make a claim about the relationship between different variables.

Assessment

Performance expectations (PEs) in the NGSS describe what students should know and be able to do. Unit 3 targets a bundle of four PEs taken from the first and second core ideas in high school Earth and Space Science (ESS1, ESS2); those standards are HS-ESS1-5, HS-ESS2-1, HS-ESS2-3, and HS-ESS3-1. This PE bundle informs the types of three-dimensional tasks in which students engage across the unit. Each sequence of lessons within the unit targets elements from one or more of the performance expectations for the unit, and the teacher has opportunities to collect evidence of student learning around these elements within that learning sequence. The unit-level Performance Task only targets a subset of three-dimensional learning goals informed by the bundled PEs for the unit. All other evidence of learning related to the other dimensions/elements in the PEs can be found within the instructional sequences. The **Teacher Materials** for each sequence of lessons includes a matrix that lists which student artifacts can provide evidence of student learning for each of three-dimensional learning goals from that sequence.

This unit was designed to support teachers in tracking student progress across the three dimensions, not for mastery within individual lessons. The targeted disciplinary core ideas (DCIs) listed below will be developed throughout the unit. While all of the science and engineering practices (SEPs) may be utilized across the unit, the three target SEPs for the unit are listed below. Similarly, many crosscutting concepts (CCCs) may be useful in making sense of the phenomena in this unit, however the foregrounded, targeted CCCs are listed below.

The following Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts are assessed throughout the unit:

	Earth's Interior	Surface Features & Plate Boundaries 5E	Energy and Matter 5E
Developing and Using Models	✔	✔	✔
Constructing Explanations and Designing Solutions	✔	✔	✔
Engaging in Argument from Evidence		✔	
ESS1.C The History of Planet Earth		✔	
ESS2.A Earth Materials and Systems	✔		✔
ESS2.B Plate Tectonics and Large-Scale System Interactions	✔	✔	✔
ESS3.A Natural Resources			✔
ESS3.B Natural Hazards	✔	✔	✔
PS1.C Nuclear Processes		✔	
Patterns	✔	✔	
Cause and Effect			✔
Energy and Matter	✔		✔
Stability and Change	✔	✔	✔

At the end of Unit 3, teachers will have evidence in student work (tasks) related to the elements listed in this table and can therefore make claims at the end of this unit related to student proficiency for all three performance expectations.

To support assessment throughout the unit, rubrics have been included in the **Student Materials** to support the Evaluate phase in every 5E instructional sequence. Teachers should customize these rubrics to support their schools' grading systems. Rubrics address both individual reflection, peer review, and the teacher's feedback. The Unit 3 Performance Task also includes a rubric, and the task can be considered a final summative assessment for the unit - we have not included a traditional "unit test" in our materials. Teachers may opt to create their final exam using their states' previous exam questions, however we believe that the formative assessment tasks embedded in the materials (such as the Looks and Listen For notes, the Explore phase summaries, and the modeling done in the Evaluate phases), along with the Performance Task can serve as sufficient evidence of what students know and can do.

Common Core State Standards (Mathematics)

Standards for Mathematical Practice

MP2 Reason abstractly and quantitatively.	Mathematically proficient students make sense of the quantities and their relationships in problem situations. Students bring two complementary abilities to bear on problems involving quantitative relationships: the ability to decontextualize—to abstract a given situation and represent it symbolically and manipulate the representing symbols as if they have a life of their own, without necessarily attending to their referents—and the ability to contextualize, to pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Quantitative reasoning entails habits of creating a coherent representation of the problem at hand; considering the units involved; attending to the meaning of quantities, not just how to compute them; and knowing and flexibly using different properties of operations and objects.
MP3 Construct viable arguments and critique the reasoning of others.	Mathematically proficient students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. Mathematically proficient students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. Elementary students can construct arguments using concrete referents such as objects, drawings, diagrams, and actions. Such arguments can make sense and be correct, even though they are not generalized or made formal until later grades. Later, students learn to determine domains to which an argument applies. Students at all grades can listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.
MP4 Model with mathematics.	Mathematically proficient students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. In early grades, this might be as simple as writing an addition equation to describe a situation. In middle grades, a student might apply proportional reasoning to plan a school event or analyze a problem in the community. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. Mathematically proficient students who can apply what they know are comfortable making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.
MP6 Attend to precision.	Mathematically proficient students try to communicate precisely to others. They try to use clear definitions in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, including using the equal sign consistently and appropriately. They are careful about specifying units of measure, and labeling axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the problem context. In the elementary grades, students give carefully formulated explanations to each other. By the time they reach high school they have learned to examine claims and make explicit use of definitions.

Common Core State Standards (ELA/Literacy)

Speaking and Listening Standards

SL.9-10.4	Present information, findings, and supporting evidence clearly, concisely, and logically such that listeners can follow the line of reasoning and the organization, development, substance, and style are appropriate to purpose, audience, and task.

Reading Standards for Literacy in Science and Technical Subjects

RST.9-10.1	Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
RST.9-10.7	Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

Writing Standards for Literacy in History/Social Studies, Science, and Technical Subjects

WHST.9-10.1	Write arguments focused on discipline-specific content.
WHST.9-10.2	Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.
WHST.9-10.5	Develop and strengthen writing as needed by planning, revising, editing, rewriting, or trying a new approach, focusing on addressing what is most significant for a specific purpose and audience.
WHST.9-10.9	Draw evidence from informational texts to support analysis, reflection, and research.

Implementing Unit 3

This unit is designed to be the third unit of the Earth and Space Science course. We do not recommend spending more than two months on this unit, as our field testing showed that six to eight weeks is the maximum amount of time students can stay engaged with the unit-level anchor phenomenon.

Within the unit, we also suggest spending no more than two weeks on each 5E instructional sequence. It is important to trust that ideas will build over time. Part of learning to teach NGSS-designed curriculum is getting comfortable with moving on, even if not every student "gets it," with the knowledge that there are additional opportunities to revisit particular standards. See the Assessment section below for guidance on providing multiple opportunities for assessment throughout the unit.

The first time enacting any unit with students may take longer than anticipated, particularly if the pedagogical approach is significantly different from what a teacher is used to. A teacher may want to skip entire lessons or activities, or revert to more traditional approaches when it seems like time is running out. We often ask teachers to think about the best way to modify recipes. Just like when using a recipe for the first time, it's a good idea to stay as true to the materials as possible before making modifications or substitutions! As teachers become more familiar and comfortable with the instructional model, the embedded routines, and three-dimensional teaching overall, the desire to skip things will dissipate. Teachers using our curriculum over time have noticed that they are able to move a bit quicker through this and other NGSS-designed units each year.

Routines

The table below summarizes the routines embedded in this unit. The number indicates the number of times a given routine appears in a lesson.

	Unit Opening	Earth's Interior	Surface Features & Plate Boundaries 5E	Energy and Matter 5E	Unit Closing
Class Consensus Discussion		2	2	1	
Consensus Building Share			1		
Consensus-Building Share		1			
Domino Discover		3	5	1	
Driving Question Board	1				
None	2				
Read-Generate-Sort-Solve				1	
Rumors				1	

Literacy Strategies

The table below summarizes the literacy strategies embedded in this unit. The number indicates the number of times a given strategy appears in a lesson.

	Unit Opening	Earth's Interior	Surface Features & Plate Boundaries 5E	Energy and Matter 5E	Unit Closing
None	1				
Sequence Cards			1		
Text Annotation	1				

Simulations in this Unit

Lesson	Simulation Title	Source	Technical Notes	Permissions Notes
Surface Features & Plate Boundaries 5E	Iris Interactive Earthquake Viewer	https://ds.iris.edu/ieb/index.html?format=text&nodata=404&starttime=1970-01-01&endtime=2025-01-01&minmag=0&maxmag=10&mindepth=0&maxdepth=900&orderby=time-desc&src=&limit=200&maxlat=73.30&minlat=-73.30&maxlon=180.00&minlon=-180.00&zm=3&mt=ter	NA	NA
Surface Features & Plate Boundaries 5E	Plate Motion Simulation	https://sepup.lawrencehallofscience.org/geology-unit-plate-boundaries/	NA	NA

Videos in this Unit

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Unit Opening	How the Tonga volcanic eruption rippled through the earth, ocean and atmosphere	https://www.youtube.com/watch?v=tNoA1n-rLhA	NA	NA
Unit Opening	Japan Tsunami (first 1:24 only)	https://www.youtube.com/watch?v=oWzdgBNfhQU	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Earth's Interior	Krakatoa - the Great Volcanic Eruption	https://www.youtube.com/watch?v=MrEIT66oPqU&t=3778s	NA	NA
Earth's Interior	Earthquake Monitoring	https://www.youtube.com/watch?v=GcNVpMZlIDo	NA	NA
Earth's Interior	Demonstrating P and S waves	https://www.youtube.com/watch?v=gjRGIpP-Qfw&feature=emb_logo	NA	NA
Surface Features & Plate Boundaries 5E	120 Years of Earthquakes and Their Tsunamis: 1901-2020	https://www.youtube.com/watch?v=ilFEKSZQv5o&t=11s	NA	NA
Surface Features & Plate Boundaries 5E	Significant Volcanic Eruptions	https://www.ngdc.noaa.gov/hazard/data/publications/significant-volcanic-eruptions.pdf	NA	NA
Surface Features & Plate Boundaries 5E	Aerial Footage Captures Volcano Spewing Lava in Iceland	https://www.youtube.com/watch?v=0B3LNztgh9M	NA	NA
Surface Features & Plate Boundaries 5E	How mountain ranges are formed at convergent plate boundaries	https://www.youtube.com/watch?v=r9Uu-Gp2ztg	NA	NA
Surface Features & Plate Boundaries 5E	Birth of a Tsunami | PBS LearningMedia	https://ny.pbslearningmedia.org/resource/nvkq.vid.earth.tsunami/birth-of-a-tsunami/	NA	NA
Surface Features & Plate Boundaries 5E	Plate Tectonics and Volcanoes | The Next Pompeii | PBS LearningMedia	https://ny.pbslearningmedia.org/resource/nvtnp-sci-volcanotectonics/plate-tectonics-and-volcanoes-the-next-pompeii/	NA	NA

Lesson	Video Title	Source	Technical Notes	Permissions Notes
Surface Features & Plate Boundaries 5E	How Earth Recycled a Mountain Range	https://www.youtube.com/watch?v=3qBFwPT6Jww	NA	NA
Energy and Matter 5E	The Great Rift Valley, Africa	https://www.youtube.com/watch?v=arQoxEl8w-s	NA	NA
Energy and Matter 5E	Model 1	https://drive.google.com/file/d/19lcS8yo3B7TlV06MBiuiRE4_qYR7UUIj/view?resourcekey	NA	NA
Energy and Matter 5E	Model 2	https://drive.google.com/file/d/1e4seWwphfJhYznw6kdjBYF0S4YMndxeW/view?resourcekey	NA	NA
Energy and Matter 5E	Model 3 - Top View	https://drive.google.com/file/d/14JpOlUMXSgVfZV9TJ9RJyacbQm8YnrBK/view?resourcekey	NA	NA
Energy and Matter 5E	Model 3 - Side View	https://drive.google.com/file/d/1OarMjjPuT86BGJRvTS0pYjPgUaRBT-EF/view?resourcekey	NA	NA
Energy and Matter 5E	World Population History	https://worldpopulationhistory.org/map/1/mercator/1/0/25/#	NA	NA
Unit Closing	Stop natural hazards from becoming disasters	https://www.youtube.com/watch?v=6go1Gi8mP0g	NA	NA

Lab Materials in this Unit

Lesson	Lab	Materials needed (per group)
Earth's Interior	Layering of Materials and Composition of the Earth's Core Lab minutes: 45-60 minutes	❑ Assorted rock samples - preferably matching the rock information cards ❑ Magnetite or lodestone ❑ compass ❑ magnetic and nonmagnetic items ❑ bar magnet ❑ iron filings and a clear piece of glass or plastic (or a magnetic field visualizer)

Other Materials in this Unit

Lesson	Materials needed
Unit Opening	❑ Poster paper ❑ markers ❑ Post-it notes Chart paper
Earth's Interior	❑ Data Visualization: Global Seismogram Viewer ❑ Simulation: Seismic Waves ❑ *Rock and Mineral Information Cards*
Surface Features & Plate Boundaries 5E	❑ Option 1: Text books-Copy paper-Markers ❑ Option 2: Plate Motion Simulation ❑ Option 3: Clay in Multiple Colors ❑ Chart paper ❑ Markers ❑ *Adirondack Mountain Cards* ❑ *Adirondack Mountain Timeline*
Unit Closing	❑ Driving Question Board

Teacher Materials for Unit 3

# Unit Opening	What locations on Earth are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future? Why do populations live in these risky areas?	**Performance Expectations** HS-ESS3-1	**Anchor Phenomenon** Major earthquakes, volcanic eruptions, and tsunamis happen all over the world, causing loss of life and property, yet humans have been living continuously in these hazardous areas for thousands of years.	**Time** 3 days

In 2011, an earthquake and tsunami in Japan caused a nuclear disaster that we are still recovering from. In 2022 a volcanic eruption occurred at Tonga that was heard thousands of miles away and produced a massive tsunami. Natural disasters caused by tectonic plate movement, like these, are not new to Earth's history, and have long played a part in human societies. After learning about these events and others, how they occur, and the vulnerability of different populations, students develop and revise models related to the interior of the Earth, how energy travels in the Earth, and how different plate boundaries cause different patterns of tectonic events, and explain how these events have impacted humans in both positive and negative ways. These models support students in explaining how risk has changed as technological advances have been made.

ANCHOR PHENOMENON	How have earthquakes, tsunamis, and volcanoes impacted people in the past, and why do humans still live in those areas? Who is currently most at risk from these types of hazards?	This is a topic that should incite student curiosity and wonder! By working with students to surface students will express both their prior knowledge and their curiosity, allowing them to engage with the unit and increasing student buy-in.
PERFORMANCE TASK	Students review the performance task.	Review the Performance Task with students.
DRIVING QUESTION BOARD	Students develop their own questions to investigate throughout the unit.	Based on ideas that have surfaced through student discussion, students create an initial model and driving question board.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

How have earthquakes, tsunamis, and volcanoes impacted people in the past, and why do humans still live in those areas? Who is currently most at risk from these types of hazards?

This is a topic that should incite student curiosity and wonder! By working with students to surface students will express both their prior knowledge and their curiosity, allowing them to engage with the unit and increasing student buy-in.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table groups	❏ None	❏ Text Annotation

Materials

Handouts	Lab Supplies	Other Resources
❏ Tell the Story	None	❏ How the Tonga volcanic eruption rippled through the earth, ocean and atmosphere ❏ Japan Tsunami (first 1:24 only)

Surfacing Student Ideas

1. Ask students if they have ever felt an Earthquake, or heard about an earthquake, tsunami, or volcano impacting people.
2. Ask students to list events that they've heard of, and what they think happened to people or other organisms after those events.
3. Tell students that we will be looking at these types of natural disasters, and share that there have been a few big events in the recent past. Show students the two videos How the Tonga volcanic eruption rippled through the earth, ocean and atmosphere and Japan Tsunami (first 1:24 only).
4. Ask students if they think these types of events could impact them where they live. Regardless of this answer, ask them why they believe that. Probe for ideas about historical incidences of tectonic activity or the idea that some areas are more prone to these natural disasters than others.
5. Tell students that they will now investigate a bit about the history of these natural disasters and how they have impacted different populations.

Access for All Learners

The questions of whether people live near where big earthquakes occur and whether they can occur where students live should spark curiosity in all students. Show the videos, Japan Tsunami and Building Swaying 9.1 Earthquake to provide important context and set the stage for this fascinating investigation.

Telling the Story

1. Provide students with the *Tell the Story* texts.
2. Students independently read and use **text annotation** for the three texts, circling three details from each text that are the most important to the phenomenon being described.
3. Students share their ideas in their group, with every individual identifying the details that they thought were important.

Conferring Prompts

Confer with students as they work in groups to tell the story.

- Why do you think this detail is important?
- Did your group members and you circle the same details?
- How did you agree, as a group, to the overall story?

4. Use the **Domino Discover** group learning routine, to surface student ideas. Document these ideas for the class.
5. As a group, students decide which ideas they think are important, and use those ideas to write out what has occurred, or the story of the phenomenon.

Access for All Learners

This is the first time students are using the strategy **text annotation**. Be sure to look at the Earth & Space Science Course Guide for the action pattern for this routine.

Routine

This is the first time **Domino Discover** is being used in this unit. This routine is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Performance Task

Students review the performance task.

Review the Performance Task with students.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table groups	❑ None	❑ None

Materials

Handouts	Lab Supplies	Other Resources
❑ Performance Task Introduction ❑ Initial Model	None	❑ Poster paper ❑ markers

Launching the Performance Task

1. Remind students of all the loss of life and human property they noted when telling the story of the unit phenomenon. Explain that because of the huge human and economic costs caused by these types of natural hazards, organizations like the United Nations, nonprofit organizations, and governments are doing their best to determine risk around the world and how to minimize loss of life and property.
2. Distribute the *Performance Task Introduction* handout to the class. Allow students time to read the task and ask a few clarifying questions. Respond to student clarification questions.

Develop Initial Models

1. Provide students with the handout *Initial Model*. Ask students to consider the class's ideas so far, as well as their own prior knowledge, to independently develop an initial model in response to the following prompt: *How and why do the natural hazards observed in tell the story texts (earthquake, volcanic eruption, and tsunamis) occur?*
2. Have students take turns sharing their ideas in their table groups, then work together to develop an initial model that brings the range of their ideas together.
3. Confer with students as they collaboratively develop their initial models.

Conferring Prompts

Confer with students as they work in groups to develop their initial models.

- What details from the Tell the Story resources do you think are most relevant to answering the question about how these natural hazards occur? Why?
- How can you represent your ideas clearly?
- How can you use labels, arrows, and other types of annotations to represent your ideas?

4. Tell students to take a few minutes to observe other groups' initial models, looking for similarities and differences. Ask a few students to share what they have noticed with the rest of the class.

5. Let students know that they will now have an opportunity to reflect on what they know in relation to the performance task and generate questions they would like to investigate further in order to determine which locations on Earth are most in need of support in reducing risk of these natural disasters.

Driving Question Board

Students develop their own questions to investigate throughout the unit.

Based on ideas that have surfaced through student discussion, students create an initial model and driving question board.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table groups	❏ Driving Question Board	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❏ Post-it notes Chart paper

Developing Questions

1. At this point, students should have a lot of questions! Let them know that they will continue to investigate what parts of the world are most at risk from earthquakes, volcanic eruptions, and tsunamis.
2. Individually, students come up with questions they would need to answer in order to figure out what parts of the world are most at risk from earthquakes, volcanic eruptions, and tsunamis. Each question goes on a separate sticky note.
3. As a whole class or in small groups, students share and categorize their questions, as they organize the questions on chart paper.

Conferring Prompts

Confer with students as they create and categorize questions.

- Why do these questions belong together?
- What is the category that connects these?
- Are there other questions within this category?
- Now that you see all of your questions grouped together, do other questions come up?
- For each category, is it possible to develop an umbrella question that encompasses all of the other sub-questions in that category?

4. Let students know that they will be investigating their questions throughout the unit.

Standards in Unit Opening

Performance Expectations

HS-ESS3-1 **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.**

Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Assessment Boundary: None

In NYS, the clarification statement has been edited as follows: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards could include those from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as blizzards, hurricanes, tornados, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations could include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
	ESS3.A Natural Resources • Resource availability has guided the development of human society. ESS3.A(1) ESS3.B Natural Hazards • Natural hazards and other geologic events have shaped the course of human history; they have significantly altered the sizes of human populations and have driven human migrations. ESS3.B(1)	

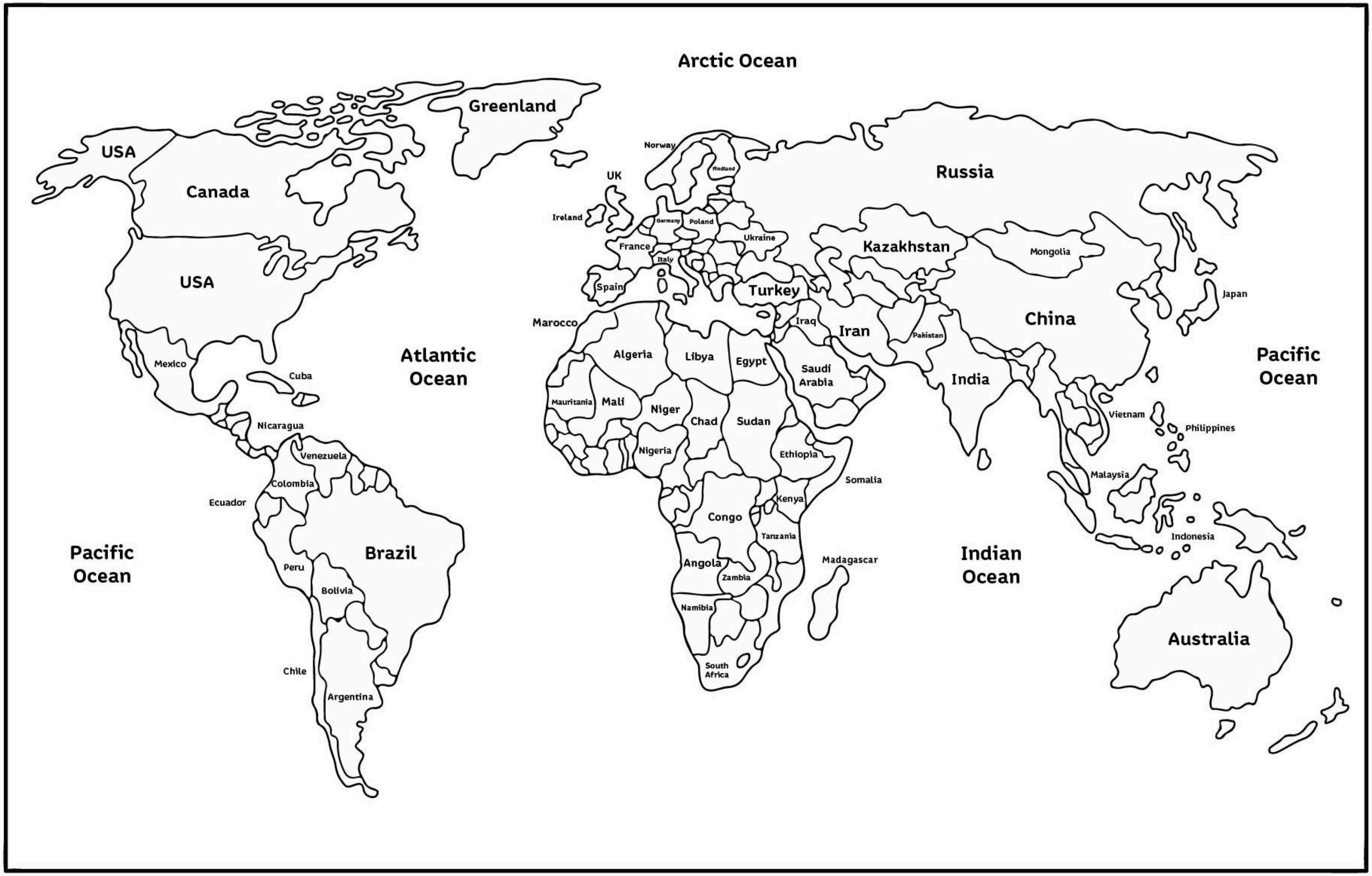
Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task
ESS3.A Natural Resources	*Tell the Story*		
ESS3.B Natural Hazards	*Tell the Story*		

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task
Mathematics			
ELA/Literacy	RST.9-10.1 RST.9-10.7 WHST.9-10.2 SL.9-10.1 SL 9-10.4		

Classroom Resources for Unit Opening
Black and White World Map



Arctic Ocean
Greenland
USA
Canada
USA
Mexico
Cuba
Nicaragua
Venezuela
Colombia
Ecuador
Peru
Brazil
Bolivia
Chile
Argentina
Pacific Ocean
Atlantic Ocean
Norway
Findland
UK
Ireland
Germany
Poland
Ukraine
France
Italy
Spain
Marocco
Russia
Kazakhstan
Mongolia
Turkey
Iraq
Iran
China
Japan
Algeria
Libya
Egypt
Saudi Arabia
Pakistan
India
Mauritania
Mali
Niger
Chad
Sudan
Nigeria
Ethiopia
Somalia
Kenya
Congo
Tanzania
Angola
Zambia
Namibia
South Africa
Madagascar
Indian Ocean
Vietnam
Philippines
Malaysia
Indonesia
Pacific Ocean
Australia

Earth's Interior

Where did the material for new islands come from after Krakatoa erupted?

Performance Expectations
HS-ESS2-3, HS-ESS3-1

Investigative Phenomenon
When Krakatoa erupted in 1883, the major island disappeared, and temporary islands appeared. In the time since then, new islands have been growing.

Time
8-10 days

In order to figure out how earthquakes and volcanic eruptions occur and who is at risk, during this 5E instructional sequence, students are investigating their questions about where these hazards occur and what is occurring underneath the Earth's surface at these locations.

ENGAGE	What happened to Krakatoa?	Students observe evidence of **changing land forms after the volcanic eruption of Krakatoa** in order to **begin considering the components of Earth's Systems.**
EXPLORE 1	How do we figure out what's underneath the Earth's surface?	Students **use computer and physical models** to collect **empirical evidence of patterns** associated with the movement of energy from earthquakes in the form of **seismic waves**, and begin to make inferences about **Earth's interior structure using density**.
EXPLAIN 1	What do differences in seismic waves detected around the world tell us about Earth's interior?	Students use differences in the way that **energy** from **earthquakes drive the movement of matter** in the form of **p and s-waves** and information about **density** to **develop a model** of **Earth's interior structure that explains** patterns of **wave arrival at Earth' surface**.
EXPLORE 2	What is the composition of Earth's interior layers? What is the earth made of near the surface where these hazards occur?	Students calculate the **density** of three liquids and make observations from a **model** in order to **identify empirical evidence of patterns** regarding **relative density and sinking/rising**.
EXPLAIN 2	How can information about what Earth is made of help us figure out where the new islands came from?	Students **evaluate additional evidence** about the **density of Earth's materials and its magnetism** to revise their **models of Earth's interior and determine** where volcanic magma comes from.
ELABORATE	How do materials move to form new islands?	Students use **various models** of the Rock Cycle and Earth's interior to analyze how **various rock types show evidence** of the **cycling of matter through Earth's layers.**
EVALUATE	How have people been impacted?	Students use their learning to **model Earth's interior** and **analyze empirical evidence** of volcanic eruptions to **explain** which regions are most at risk for **human impact from natural disasters**.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

What happened to Krakatoa?

Students observe evidence of **changing land forms after the volcanic eruption of Krakatoa** in order to **begin considering the components of Earth's Systems.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Changing Islands	❑ Laptops	❑ Krakatoa - the Great Volcanic Eruption

Launch

1. Remind students that, during the Driving Question Board launch, one category of questions that emerged was related to how volcanic eruptions occur.
2. Tell students that there have been some huge volcanic eruptions that have destroyed islands, including one, in 1883, called Krakatoa. Show students the video Krakatoa - the Great Volcanic Eruption (0-3:32). Tell them that these eruptions have disrupted human populations, resulting in destroyed towns and villages, some areas of which have never been reinhabited.
3. Tell students that they will now have an opportunity to look at a set of images that will allow them to start to answer some of their questions.
4. Provide students with the handout, *Changing Islands*, and ask students to work independently to complete the See-Think-Wonder based on their observations, then use their See-Think-Wonders to discuss the findings from the investigation.
5. Ask groups to come up with one important idea and / or question to share with the whole class, from their See-Think-Wonder.
6. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from the three texts.

Integrating Three Dimensions

In this unit students will continue to develop proficiency related to **CCC#7 Stability and Change: change and rates of change can be quantified and modeled over very short or very long periods of time.** Students interacted with this element in Unit 2, so use this Engage phase to reinforce that concept as it relates to Earth's surface.

Look & Listen For

Possible student ideas and questions:

- I noticed that first the big island disappeared, and then temporary islands appeared. Over time, new islands appeared, and Anak Krakatau seems to be growing
- I think the missing islands went into the ocean; I think the new islands came up out of the ground
- I think the new islands are built out of lava
- I wonder where the new islands came from/I wonder where the lava came from

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

7. Let students know that they will now have an opportunity to investigate what is inside the Earth that could have caused those changes.

Explore 1

How do we figure out what's underneath the Earth's surface?

Students **use computer and physical models** to collect **empirical evidence of patterns** associated with the movement of energy from earthquakes in the form of **seismic waves**, and begin to make inferences about **Earth's interior structure using density**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs ❏ Table groups	❏ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ What's Inside the Earth? ❏ Making Sense of the What's Inside the Earth Investigation	❏ Laptops ❏ Water (20mL) ❏ Vegetable Oil (20mL) ❏ Isopropyl Alcohol (20mL) ❏ Graduated Cylinder (2) ❏ Balance that Measures in Grams ❏ 3 colors of food coloring	❏ Data Visualization: Global Seismogram Viewer ❏ Simulation: Seismic Waves ❏ Earthquake Monitoring

Launch

1. Remind students that, during the unit launch and / or the Engage phase, they had questions about what is inside the Earth and what is going on at and underneath volcanic eruptions.
2. Ask if students noticed, in the Video Krakatoa - the Great Volcanic Eruption , that the scientists say "these vibrations are airborne, they're not coming through the ground. It is not an Earthquake." Explain to students that earthquakes cause shaking that can be felt through the Earth. Share with students that scientists study Earthquakes by measuring the movement of the Earth associated with the energy they generate.
3. Show the video, Earthquake Monitoring .
4. Help students understand that seismic waves are the movement of matter that is caused by energy generated from an earthquake, by demonstrating or allowing students to try a seismic activity recorder on a smartphone and provide an opportunity to ask clarifying questions about seismometers.
5. Tell students that, as scientists studied Earthquakes using seismic wave data, they also discovered some interesting information about the interior of the Earth. Tell students that they will now have the opportunity to view that same type of data in order to understand what clues it holds about what is underneath Earth's surface on a global scale.
6. Provide students with a laptop and the handout *What's Inside the Earth?*. Demonstrate how to use the interactive Global Seismogram Viewer and support students in understanding the parameters. Point out to students that they can look at seismic data from the specific Earthquakes they observed during the unit launch (e.g Japan, 2011).
7. Have students run the model and complete the See-Think-Wonder organizer based on the seismic data observations from earthquakes in the regions they viewed during the Unit Launch. They should see the same patterns regardless of which earthquakes they choose to observe.
8. Once students have recorded their observations, thoughts and wonderings, have them discuss in groups and decide on one observation, thought, or wondering to share with the class.
9. Use the group learning routine **Domino Discover** for groups to share their: observations, thoughts and wonderings.

Integrating Three Dimensions

While **CCC#5 Energy and Matter** is not foregrounded until the next phase of this investigation, it's important that the teacher leverages the video Earthquake Monitoring and a seismic activity recorder on a smartphone to support students in understanding that seismic waves are the movement of matter that is caused by energy generated from an earthquake, in order to build on this during the Explain 1 phase.

Integrating Three Dimensions

During this Explore phase, there are many opportunities to assess student proficiency with **CCC#1 Patterns**: **Empirical evidence is needed to identify patterns**, as students identify patterns in service of analyzing data. Do not prompt them to do so prior to the analysis of the data, as it is important to assess whether students are citing empirical evidence of patterns they identify on their own at this point. If students do not cite empirical evidence that is needed to identify patterns they name, use probing questions to nudge them to cite empirical evidence for patterns and prompt them to think about the importance of doing so.

Look & Listen For

Possible student ideas and questions:

- I notice that the earthquake is not felt at the same time everywhere. The time when the waves appear at different locations is at different points of the y axis.
- As you move further from the earthquake location, the time it takes waves to arrive increases steadily, but then it suddenly doesn't. There is an almost straight trend line of time as you move further from the location of the earthquake, then the trend line moves up abruptly.
- I think the pattern of time when the Earthquake is felt increases steadily as the distance between location of the seismogram and the earthquake epicenter increases makes sense because if the location is further from the epicenter, so it should take longer to get there.
- I think something inside the Earth is slowing the earthquake down where the sudden jump is.
- Why is there an abrupt change in the pattern of arrival time?
- What's inside the earth that can be causing this?

1. Tell students that they will now have a chance to work with and observe a computational model that depicts what may be occurring with earthquake waves that can explain the abrupt change in the arrival time pattern that was observed
2. Have students break into pairs for the investigation.

Investigation: Part 1. Seismic Waves

1. Remind students that they had ideas in questions about what is inside the Earth that can cause the abrupt change in the pattern of seismic wave arrival time at different locations.
2. Prompt students to open their *Seismic Waves Inside the Earth* handout and have students go to simulation Seismic Waves . Point out that the data comes specifically from the Japan earthquake in 2011 that they observed during the unit launch.
3. Have students follow the handout to set the simulator and run it a few times, responding to the prompts in Part 1 of their handout.

Implementation Tip

When students first use the viewer, they turn off the interior layer labels and only view the shadow zone waves, which are the waves in their simplest form. Using this view, they should be able to see that there is a difference in how p and s waves travel through the center of Earth. However, this simplified view could give the impression that there are only two layers to Earth, and that the core is uniform. In step 3, students are prompted to change the "shadow zone" view to "standard waves," which will also show how the P waves change as they encounter different layers of the Earth. Students should not get distracted by the reflecting parts of the waves; the goal here is for students to observe that P waves appear to hit two different layers in the middle, helping them identify two layers in Earth's core.

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- What do you observe about p wave movement?
- What do you observe about s waves?
- What do you observe about surface waves?
- What do you think might explain the distortion of waves while they travel through the Earth?
- What do you think might explain why s-waves don't move through the core of the Earth?

Investigation: Part 2. Forming Layers

1. Ask students to share the general patterns they noticed in Part 1. Listen for students to say that there appear to be different parts of the Earth, arranged in layers.

2. Ask students what they know about layers and how they form. Ask students if they have ever seen liquids layer or separate, like oil and water in salad dressing or foam on top of a latte drink. Ask them if they know what causes these layers to form.

3. Have students turn to Part 2 of their investigation, How do different materials form layers? Arrange students into table groups and provide them with their lab materials.

4. Assist students as they conduct the investigation and gather data. Confer with students as they work in groups

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- How do you calculate the mass of the liquids alone, when they are measured in graduated cylinders?
- What patterns do you notice?
- Why do you think they are layering this way?

Whole-Class Investigation Summary

1. Provide students with the *Making Sense of the What's Inside the Earth Investigation* handout and have them note their observations, thoughts and questions in the see-think-wonder table on the handout.

2. Ask groups to discuss their See-Think-Wonder and come up with one important idea or question to share with the whole class.

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' discussions.

Look & Listen For

Possible student ideas and questions:

- A pattern I notice is P waves are faster than s waves. The distance between the red and blue lines keeps increasing. This happened during all earthquakes I observed.
- Another pattern I notice is that P waves travel all the way through the Earth, but are distorted and slowed when they pass through the middle of Earth's interior. The red lines slowed down and broke apart when they reached the middle of the Earth. This happened during all earthquakes.
- S waves don't move through the middle of Earth's interior. The blue lines disappeared once they reached near the center of the Earth. This happened during all earthquakes I observed.
- P waves appear to rebound or reflect twice as they pass through the Earth.
- I think the Earth has different layers.
- I think the layers might be caused by density
- I think there is something blocking the earthquake waves, or reflecting the p waves.
- I think the different layers may be made of different types of rocks that might affect the way the earthquake waves travel.
- Why would waves travel differently through different rocks / materials?

4. If students don't surface any of the important observations or questions named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations and raising those questions before moving on, as they will be key to success in the Explain phase that follows.

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Access for Multilingual Learners

Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Earth & Space Science Course Guide for more information on this routine.

Explain 1

What do differences in seismic waves detected around the world tell us about Earth's interior?

Students use differences in the way that **energy** from **earthquakes** **drive the movement of matter** in the form of **p and s-waves** and information about **density** to **develop a model** of **Earth's interior structure** **that explains** patterns of **wave arrival at Earth' surface**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table Groups	❏ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Modeling the Structure of Earth's Interior ❏ Summary Task	None	❏ Demonstrating P and S waves

S & P Wave Properties

1. In the Explore phase, students discovered that the arrival of earthquake waves not being constant at different locations is due to something inside of the Earth. Remind students that they used the data from earthquakes to determine that there are differences in the Earth's interior structure. In this activity they are going to start to determine what those differences are.

2. Let students know that they are now going to model the way that energy from an earthquake moves matter through Earth's interior in the form of the p and s-waves they observed during the Explore phase. Have several students volunteer to take part in creating the model as classmates note observations, thoughts and questions. Provide students with the*Modeling the Structure of Earth's Interior* handout and have them complete Part 1 of the handout, the See-Think-Wonder table, while their classmates model earthquake waves, and answer the question that follows.

3. After completing the See-Think-Wonder Table have students think about how this model helps explain what they saw in the explore phase.

Look & Listen For

Possible student ideas and questions:

- P-waves are when energy from an earthquake moves through molecules within the earth straight ahead.
- The molecules moved by energy in the form of p-waves can be bonded like in a solid or not bonded like in the liquid because they still push each other.
- This is why p-waves can move through both solids and liquids.
- S-waves are when energy from an earthquake moves through molecules within the earth side-to-side.
- The molecules moved by energy in the form of s-waves have to be bonded like in a solid because as they move side to side and if they are not bonded they will not move each other.
- This is why s-waves can only travel through solids.
- I think the outer-core of the Earth is made of liquid and the mantle is made of solid.

Integrating Three Dimensions

In this unit students are developing proficiency with the **CCC#5 Energy and Matter**, specifically the idea that energy drives the motion and/or cycling of matter within and between systems. Be sure to elevate student ideas in order to support their understanding that earthquake waves are the movement of matter driven by energy generated by an earthquake. Students will continue to develop proficiency of this element of **CCC#5 Energy and Matter** within this investigation and the Energy transfer investigation that follows.

Access for All Learners

Students may struggle to connect to this content, for students who do better with kinesthetic learning it might be more effective to do the demonstration with the students instead of showing the video.

Density Properties

1. In the Explore phase, students discovered that materials layer based on density.

2. Let students know that they are now going to connect what they saw in their density columns to the layers of Earth. Have students turn to the Density and Gravity section of their handouts. Help them connect the density column to gravity in the spherical Earth by viewing the image of gravity columns all around Earth. Allow students time to grasp the concept that gravity is not pulling things "down," but towards the center of the Earth.

3. Have students work in their table groups to answer work through the Gravity and Density section of the handout.

Constructing a Scientific Model

1. Remind students why we use scientific models and that models can change as we learn new information.

2. Have students use their observations and notes from discussion in the explore and explain phase to create their model in part 2 of the *Modeling the Structure of Earth's Interior* handout. Students should be able to make a 3 layer model of the Earth based on what they have seen in the explore and explain phases so far, including that the outer core layer is liquid, and that the layers are stacked based on density. Use the questions below to assist students who are struggling at seeing the connections in the data.

Differentiation Point

If students are struggling with starting their models use these guiding questions:

- What did we see in the simulations during the explore phase?
- What do our observations from the explore phase tell us about earthquake waves?
- How did the video from the explain phase expand our understanding of what we know from the explore phase?
- Why might certain earthquake waves pass through the Earth and others do not?

Integrating Three Dimensions

In this unit students are developing models that show the relationships between parts of a system, a key part of **SEP#2 - Developing and Using Models** at the high school level. Students should be able to construct a model of the Earth showing the physical relationships between different layers of the Earth using evidence from their prior investigations.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
    - "We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about why earthquake waves travel at different speeds inside of the Earth."

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student models to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of the interior structure of the Earth. The decision about which models to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.

3. Ask the first student or group to share their model. You can do this by:
    - Projecting using a document camera; OR
    - Copying the written explanation to be shared and passing them out to the class; OR
    - Taking a picture of each explanation and projecting them as slides.

4. Proceed through the steps in the Consensus Discussion Steps.

5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Earth & Space Science Course Guide for detailed steps of this routine.

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #5 - Energy and Matter** explicit for students by elevating and probing for ideas related to the concept that energy drives the motion of matter within and between systems (Earth's interior to Earth's surface).

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- There are different parts to the interior of the Earth
- Not all earthquake waves can travel through the different parts of the Earth
- Based on our observations we know that P-waves and S-waves can only travel through certain materials
- Knowing this allows us to determine the state of matter of each of the sections of Earth's interior (solid outside layers and a liquid core)
- There are at least 3 layers in Earth
- The outer layer is solid, and the middle layer is liquid. We don't know the phase of the innermost layer.
- These layers stack based on density.
- We don't know what the layers are actually made of

6. Let students know they will be able to investigate their questions about the Earth's interior layers.

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about what's inside the Earth.

Implementation Tip

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions to make sense of a phenomenon** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Explore 2

What is the composition of Earth's interior layers? What is the earth made of near the surface where these hazards occur?

Students calculate the **density** of three liquids and make observations from a **model** in order to **identify empirical evidence of patterns** regarding **relative density and sinking/rising**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ What are the Layers Made of? ❑ Making Sense of the What are the Layers Made of? Investigation	❑ Assorted rock samples - preferably matching the rock information cards ❑ Magnetite or lodestone ❑ compass ❑ magnetic and nonmagnetic items ❑ bar magnet ❑ iron filings and a clear piece of glass or plastic (or a magnetic field visualizer)	❑ *Rock and Mineral Information Cards*

Launch

1. Remind students of questions they still had about Earth's interior like: *What is the composition of Earth's interior layers? What is the earth made of near the surface where these hazards occur? Is it the same everywhere?* And questions about why Earth would have a layered interior structure *and whether that makes sense.*

2. Share with students that scientists have been able to develop theories of what Earth's interior layers are composed of by analyzing the composition of meteorites since they were formed at the same time as Earth with the same ingredients through a similar process, analyzing rock samples from the surface of the Earth and boreholes deep within rocks and under the ocean floor, and observing how magnetism works at the surface of Earth.

3. Let them know that they will examine samples and magnetism in order to determine what the layers of Earth may be made of.

Investigation: What are the Layers Made of?

1. Provide students with the *What are the Layers Made of?* handout, rock samples, and *Rock and Mineral Information Cards*

2. Have students make observations in their handouts about the types of rocks and their common materials, as well as where those samples were found.

Implementation Tip

Explicit rock identification is not part of the NGSS. For New York State teachers, a line has been added that "Rocks and minerals can be identified and classified using various tests and protocols that determine their physical and chemical properties." Students do not need to perform rock analysis to categorize them, but they do need to understand that there are different types of rocks, which are related to the rock cycle. Students will have additional practice with the rock cycle in the Elaborate phase of this 5E and in the Surface Features and Plate Boundaries 5E.

3. Confer with students while they work in groups

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- What materials seem to be most common across the different rock types?
- How do the rocks vary in where they are found?
- What do you think this can tell us about the layers of Earth?

4. Tell students that sampling can tell us information about materials that make it to the surface of Earth, but that we cannot get samples from deep within Earth's interior. Tell students that scientists have used other properties of Earth in order to gain information about the deeper layers.

5. Provide students with the materials for the Magnetic Earth part of the investigation.

6. Help students as they work through the handout to complete this investigation. Confer with students as they work in groups.

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- What does the magnetic activity of Earth tell us about its interior?
- What similarities do you see between Earth and the bar magnet?

Investigation: Whole-Class Investigation Summary

1. Provide students with the *Making Sense of the What are the Layers Made of? Investigation* handout, and have them complete the See-Think-Wonder and the analysis questions.
2. Ask groups to discuss their See-Think-Wonder and analysis questions, and come up with one important idea or question to share with the whole class from any part of the handout.
3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' discussions.

Look & Listen For

Possible student ideas and questions:

- The samples show that the upper layers of Earth are made of rocks like granite and basalt, which have silicon.
- The samples show that rocks have different amounts of magnesium, oxygen, silicon, and other materials
- The magnetism of Earth suggests that Earth is functioning as a bar magnet, and likely has metal inside
- The fact that the magnetic pole is moving makes me think that it is related to the liquid layer of Earth

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Access for Multilingual Learners

Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Earth & Space Science Course Guide for more information on this routine.

Integrating Three Dimensions

This is another opportunity to assess **CCC#1 Patterns**: **Empirical evidence is needed to identify patterns**. Students should be citing empirical evidence from their investigation as they model what each layer is made of.

Explain 2

How can information about what Earth is made of help us figure out where the new islands came from?

Students **evaluate additional evidence** about the **density of Earth's materials and its magnetism** to revise their **models of Earth's interior and determine** where volcanic magma comes from.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Table Groups	❏ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Explaining Krakatoa's New Islands ❏ Summary Task	None	

Revising our Models of Earth's Interior Structure

1. Remind students that we are still trying to get a complete picture of what Earth's interior is made of, including the structure and composition of its layers.
2. Tell students that they will have an opportunity to put together all of the lines of evidence they have explored so far in order to revise their models of Earth's interior and understand where the new islands came from after the eruption of Krakatoa.
3. Provide students with the *Explaining Krakatoa's New Island* handout and have students work in table groups to complete the Magnetism and Earth section of the handout.
4. Once students have read the text and responded to the questions that follow, have students share their responses so the class can come to a consensus about the underlying science ideas that explain Earth's magnetism

Integrating Three Dimensions

In this unit students are developing proficiency with the **SEP#6 Constructing Explanations based on evidence from a variety of sources**. Students have engaged with this element before. In this Explain phase, help students combine evidence from multiple lines of evidence to explain where Krakatoa's new islands came from.

Look & Listen For

Possible student ideas:

- The fact that Earth has polarity and magnetism tells us that it operates as a bar magnet
- We know that magnets are made of magnetized metal
- Earth must have a big chunk of metal on the inside
- Earth's poles are not constant; the North pole has wobbled and sometimes the polarity flips altogether
- The metal that makes up the magnetism of Earth must be in motion. It is probably a liquid layer.
- We don't yet know how the metal inside became magnetized.

5. Once students are clear on the liquid metal part of Earth, have groups move on to Part 2: how does this apply to Earth's interior? In this section, students will combine ideas about Earth's layers, density, sampling data, and magnetism to revise their models.

6. Finally, students will explain where the new islands in Krakatoa came from by comparing the composition of the islands to the layers of the Earth.

Differentiation Point

It is key that students do not leave with the misconception that liquid lava comes from the liquid core of the Earth. The magma is from the upper layers of Earth, and is made from melted rocks. In the Elaborate phase and in later 5Es, students will learn how those rocks ended up melted.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
    - “We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how and why Earth’s common materials are layered inside the Earth.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student models to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of the interior structure of the Earth and evidence and science ideas to support their claims. The decision about which models to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.

3. Ask the first student or group to share their model. You can do this by:
    - Projecting using a document camera; OR
    - Copying the written explanation to be shared and passing them out to the class; OR
    - Taking a picture of each explanation and projecting them as slides.

4. Proceed through the steps in the Consensus Discussion Steps.

5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Earth & Space Science Course Guide for detailed steps of this routine.

Integrating Three Dimensions

The depth of this discussion will really depend on what you’ve observed in the room and how you respond. Be sure to make **SEP#6 Constructing Explanations and Designing Solutions** explicit for students by elevating and probing for ideas related to valid and reliable evidence for their claims about Earth’s interior in order to determine the merits of their claims.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- Materials that come from the interior of the Earth have different densities
- Just like the common household substances, they must have separated into layers when Earth formed.
- The most dense materials have more mass in the same space so gravity has a greater effect on them and they must have sunk to the core of Earth, forcing the less dense materials close to the surface just like we saw in the layering of materials investigation.
- This also supports what we figured out by analyzing the way different seismic waves travel through Earth. The outer layer or crust of the earth seems to be a combination of various materials with relatively low density.
- These outer materials are rocks
- The outer core is made of molten iron and nickel, and creates the magnetism of Earth
- The inner core is solid iron and nickel
- New islands form from materials that are near the top of the Earth, in what we call the "mantle" layer

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about what's inside the Earth.

Implementation Tip

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions to make sense of a phenomenon** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

How do materials move to form new islands?

Students use **various models** of the Rock Cycle and Earth's interior to analyze how **various rock types show evidence** of the **cycling of matter through Earth's layers.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Consensus-Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
❑ How do materials move to create new islands?	None	

Investigation

1. Remind students that the new islands that emerged after the eruption of Krakatoa came from the upper layers of the Earth, which are called the crust and the mantle. Remind students that these layers are rock, and usually rock is solid. Somehow the rocks had to rearrange themselves.

2. Provide students with the handout: *How do materials move to create new islands?*

Note: for New York State Teachers, this phase uses images from pages 11, 13, and 14 of the New York State Earth and Space Science Reference Tables

3. Have students work in table groups to analyze how the temperatures of Earth's layers, the melting of rock, and the motion of magma create the motion of matter seen in volcanic eruptions.

4. When students are done, use the group learning routine Consensus Building Share to help the class reach an agreement on how materials are moving

Look & Listen For

Possible student ideas and questions:

- Heat from Earth's interior melts solid mantle and crust rock into magma
- Hot magma is less dense and rises up, pushing on the crust
- As it travels up, it cools, and rocks solidify at different temperatures
- This differential solidification creates different rock types at different levels of Earth's crust

Routine

This is the first time the routine **Consensus-Building Share** appears in this unit. This routine is a way to make sensemaking visible and move towards a class-wide consensus around a new idea. As a checkpoint before moving the class to the next part of the activity, it is important to use this routine to ensure that all students understand why they believe the sea floor to be spreading in this location.

For the first time using this routine, it is appropriate to prompt students with questions such as "Did any group find something similar?" or "Can anyone add to that?"

Evaluate

How have people been impacted?

Students use their learning to **model Earth's interior** and **analyze empirical evidence** of volcanic eruptions to **explain** which regions are most at risk for **human impact from natural disasters**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Revisit the Performance Task: Earth's Interior 5E ❑ Who is most at risk? ❑ Earth's Interior Model Rubric ❑ Earth's Interior Explanation Rubric	❑ Laptops	

Revisit the Performance Task

1. Provide students with the handout *Who is most at risk?* Give students time to work in groups to review the magnitude and frequency data for historical volcanic eruptions
2. Confer with students while they are working.
3. When students are ready, have them turn to the *Revisit the Performance Task: Earth's Interior 5E* and work individually to create their model and explanation in the PTO.

Revisit the Driving Question Board

1. Use the **Driving Question Board Routine** to discuss which of the class's questions have been answered.
2. Have students identify which categories or questions they have not figured out yet. Prompt students to share these questions, and document new questions that arise based on what they have been learning.
3. Add new questions to the Driving Question Board.

4. One question category still unanswered relates to questions about what is occurring along plate boundaries where earthquakes, volcanic eruptions, and tsunamis occur? How do these plate boundaries cause these natural hazards

Standards in Earth’s Interior

Performance Expectations

HS-ESS2-3 **Develop a model based on evidence of Earth’s interior to describe the cycling of matter by thermal convection.**
Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth’s three-dimensional structure obtained from seismic waves, records of the rate of change of Earth’s magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth’s layers from high-pressure laboratory experiments.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Rocks and minerals can be identified and classified using various tests and protocols that determine their physical and chemical properties. Examples of evidence could include maps of Earth’s three-dimensional structure obtained from seismic waves, records of the rate of change of Earth’s magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth’s layers from high-pressure laboratory experiments.

HS-ESS3-1 **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.**
Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.
Assessment Boundary: None

In NYS, the clarification statement has been edited as follows: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards could include those from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as blizzards, hurricanes, tornados, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations could include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3) • Develop a complex model that allows for manipulation and testing of a proposed process or system. SEP2(6) Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2)	ESS2.A 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, and 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. ESS2.A(2) ESS2.B Plate Tectonics and Large-Scale System Interactions • The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. ESS2.B(1) • Minerals are the building blocks of igneous, metamorphic, and sedimentary rocks and can be identified using physical and chemical characteristics. These rock types are evidence of stages of constant recycling of Earth material by surface processes and convection currents in the mantle. ESS2.B(4)NYS ESS3.B Natural Hazards • Natural hazards and other geologic events have shaped the course of human history; they have significantly altered the sizes of human populations and have driven human migrations. ESS3.B(1)	Patterns • Empirical evidence is needed to identify patterns. CCC1(5) Energy and Matter • Energy drives the cycling of matter within and between systems. CCC5(4) Stability and Change • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. CCC7(2)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Developing and Using Models		*Modeling the Structure of Earth's Interior*	*Making Sense of the What are the Layers Made of? Investigation* *Explaining Krakatoa's New Islands*		*Revisit the Performance Task: Earth's Interior 5E*
Constructing Explanations and Designing Solutions		*What's Inside the Earth?* *Making Sense of the What's Inside the Earth Investigation*	*Explaining Krakatoa's New Islands* *Summary Task*	*How do materials move to create new islands?*	*Revisit the Performance Task: Earth's Interior 5E*
ESS2.A Earth Materials and Systems		*Modeling the Structure of Earth's Interior* [material: ESS.U3.L1.Explain1.H2]	*What are the Layers Made of?* *Making Sense of the What are the Layers Made of? Investigation* *Explaining Krakatoa's New Islands*		*Revisit the Performance Task: Earth's Interior 5E*
ESS2.B Plate Tectonics and Large-Scale System Interactions		*What's Inside the Earth?* *Making Sense of the What's Inside the Earth Investigation* *Modeling the Structure of Earth's Interior* *Summary Task*	*What are the Layers Made of?* *Making Sense of the What are the Layers Made of? Investigation*	*How do materials move to create new islands?*	*Revisit the Performance Task: Earth's Interior 5E*
ESS3.B Natural Hazards					*Revisit the Performance Task: Earth's Interior 5E*
Patterns		*What's Inside the Earth?* *Making Sense of the What's Inside the Earth Investigation* *Modeling the Structure of Earth's Interior* *Summary Task*	*What are the Layers Made of?* *Making Sense of the What are the Layers Made of? Investigation* *Explaining Krakatoa's New Islands* *Summary Task*		*Revisit the Performance Task: Earth's Interior 5E*

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Energy and Matter		*What's Inside the Earth?* *Making Sense of the What's Inside the Earth Investigation* *Modeling the Structure of Earth's Interior* *Summary Task*		*How do materials move to create new islands?*	
Stability and Change	*Changing Islands*				

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP2 MP3 MP4 MP6	MP2 MP3 MP4 MP6		
ELA/Literacy		WHST.9-10.9	WHST.9-10.9	WHST.9-10.1 WHST.9-10.5 SL.9-10.4	WHST.9-10.1 WHST.9-10.9

Classroom Resources for Earth's Interior

Rock and Mineral Information Cards

Rock and Mineral Information Cards

Gabbro
Igneous Rock

Composition:
Elements: high in iron, magnesium, and calcium; low in silica
Minerals: pyroxene, plagioclase, and low amounts of hornblende and olivine

Location:
Found within the top layer of Earth, usually beneath other materials

Somewhat rare at Earth's surface

Basalt
Igneous Rock

Composition:
Elements: high in iron, magnesium, and calcium; low in silica
Minerals: pyroxene, plagioclase, and low amounts of hornblende and olivine

Location:
Found mostly on the ocean floor

Very common on the ocean floor

Peridotite
Igneous Rock

Composition:
Elements: high in magnesium, lower in iron and calcium; low in silica
Minerals: high amounts of olivine and pyroxene, lower amounts of hornblende

Location:
Found below the highest layer of the Earth, in deep boreholes, and where the layers are mixing is breaking through the crust

Not common at Earth's surface

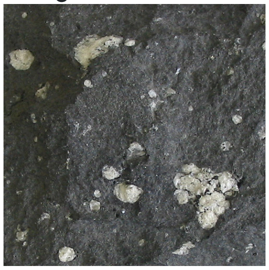
Rhyolite
Igneous Rock

Composition:
Elements: very high in silica, lower in other elements
Minerals: high amounts of quartz and alkali feldspar

Location:
Usually found within mountainous continental areas

Common at Earth's surface

Andesite
Igneous Rock



Composition:
Elements: more than half silica, low in metals
Minerals: plagioclase and pyroxene or hornblende

Location: found in Earth's top layer, often at ocean-adjacent mountain ridges

Relatively common at Earth's Surface

Olivine
Mineral

Composition:
Elements: Magnesium, iron, and silica
Minerals: Olivine is a mineral

Location: found below Earth's top layer, or in areas where the layers mixed

Not common at Earth's surface

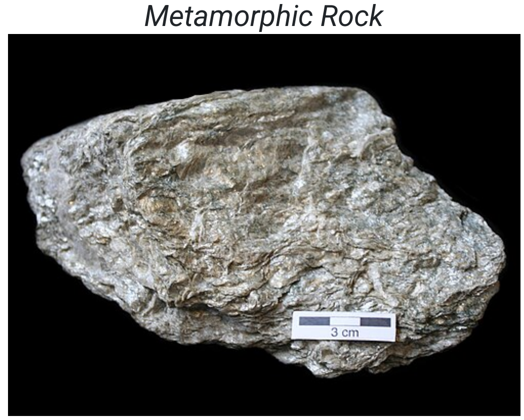
Garnet
Mineral

Composition:
Elements: Always includes silica, can also contain other elements like magnesium, iron, and calcium
Minerals: Garnet is a mineral

Location: found below Earth's top layer, or in areas where the layers mixed

Not common at Earth's surface

Schist
Metamorphic Rock



Composition:
Elements: silica, aluminum, some magnesium
Minerals: Mica, talc, often quartz, feldspar, and granite

Location: Areas that have experienced high temperatures and compression, often in mountains

Commonly found in mountains

Gneiss
Metamorphic Rock

Composition:
Elements: Varies, but always has silica and may have magnesium, iron, and aluminum
Minerals: can have many different mixes, but low in mica. May have garnet, biotite, feldspar, or quartz

Location: Found in mountain ranges on Earth's surface

Commonly found on Earth's surface in the oldest mountains

Limestone
Sedimentary Rock

Composition:
Elements: calcium and sometimes magnesium
Minerals: calcite and aragonite

Location: Found at Earth's surface in lakes, caves, and shallow ocean waters

Common at Earth's surface

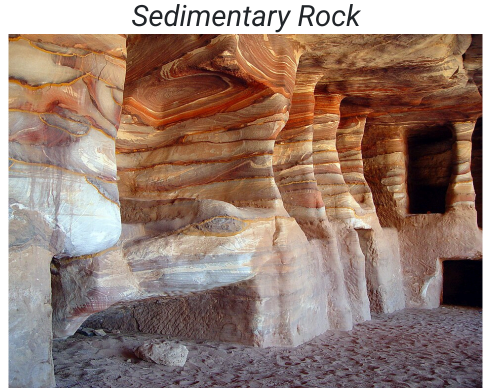
Phyllite
Metamorphic Rock

Composition:
Elements: silica and lower amounts of magnesium, iron, or aluminum
Minerals: mica, quartz, and chlorite

Location: found in a variety of settings on Earth's surface

Relatively common at Earth's surface within mountains and other surface features

Sandstone
Sedimentary Rock



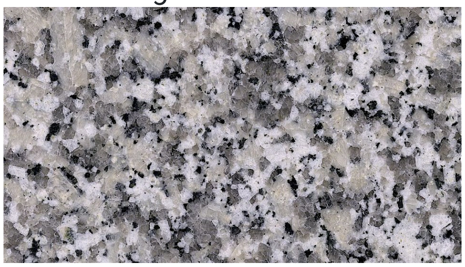
Composition:
Elements: silica, sodium, calcium
Minerals: quartz and feldspar

Location: Found in basins where erosional deposits collect, like in ocean trenches, riverbeds, dunes, beaches, lake beds, and some deserts

Commonly found at Earth's surface

Granite

Igneous Rock



Composition:
Elements: silica and different mixes of aluminum, sodium, and calcium, among others
Minerals: quartz, feldspar, and plagioclase

Location: Found within the top layer of Earth, often buried beneath other rock types

Commonly found at Earth's surface

Dacite

Igneous Rock

Composition:
Elements: high in silica, low amounts of potassium and sodium
Minerals: plagioclase feldspar and quartz

Location: Found in Earth's top layer, often near volcanoes

Relatively common at Earth's surface

# Surface Features & Plate Boundaries 5E	Why does seismic activity happen in some areas more than others?	**Performance Expectations** HS-ESS1-5, HS-ESS2-1, HS-ESS3-1	**Investigative Phenomenon** Seismic activity occurs in a pattern at the surface of the Earth. Why does that pattern exist?	**Time** 7-9 days

In this 5E instructional sequence, students are investigating the questions about earthquakes, tsunamis, and volcanic eruption occurrence during the Driving Question Board launch, such as "Where do earthquakes, tsunamis, and volcanic eruptions occur? "How do earthquakes, tsunamis, and volcanic eruptions occur?" and "Is every place equally at risk of seismic hazards?". Students use different kinds of evidence to arrive at conclusions about how plate movements cause the patterns at plate boundaries, focusing on the occurrence of earthquakes. Students extend their thinking of surface features to examine the history of New York State. Students then apply what they learn as they develop models and explanations about who is at risk from seismic hazards.

ENGAGE	Where is seismic activity happening most?	Students use **evidence from maps and interactives** to form initial ideas and questions about the **patterns of earthquakes, tsunamis, and volcanic eruptions** across the Earth.
EXPLORE 1	Why did earthquakes and volcanic eruptions occur in Iceland?	Students analyze **multiple pieces of evidence** about **change and the rates of change of seafloor rock and seismic activity** to construct an initial model showing the **relationships between plate boundaries, seismic activity, and the layers of the Earth**.
EXPLAIN 1	How does the evidence support our explanation of why Earth's crust is youngest in at ocean ridges?	Students evaluate evidence for the claim that new crust is produced at Earth's divergent plate boundaries on the ocean floor by reviewing empirical evidence of patterns and considering whether there are processes supported by science ideas that can connect the evidence to the claim.
EXPLORE 2	Why does seismic activity happen in areas far from mid ocean ridges?	Students analyze **multiple pieces of evidence** about **surface features and seismic activity** to **construct a model** showing the **relationships between plate boundaries, seismic activity, and the layers of the Earth**.
EXPLAIN 2	How do plate movements cause natural hazards and surface features?	Students **develop an explanation based on evidence** of why **earthquakes, volcanoes, and tsunamis** occur in **patterns** and how they form the **surface features found on Earth.**
ELABORATE	How did the Adirondack Mountains Form?	Students **construct an explanation** of how the **rock cycle and tectonic plate theory** can account for the formation of **surface features** over **different periods of time**, like the Adirondack mountain in New York State, far from plate boundaries.
EVALUATE	Who's at risk?	Students use what they have learned about the **patterns of how earthquakes, volcanic eruptions, and tsunamis occur at plate boundaries** to **model** how the structure of Earth and tectonic plate motion creates surface features and **explain** how it puts different regions at risk.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

Where is seismic activity happening most?

Students use **evidence from maps and interactives** to form initial ideas and questions about the **patterns of earthquakes, tsunamis, and volcanic eruptions** across the Earth.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Global Patterns of Seismic Activity	None	❑ 120 Years of Earthquakes and Their Tsunamis: 1901-2020 ❑ Significant Volcanic Eruptions

Launch and Surfacing Student Ideas

1. Remind students that, during the Driving Question Board launch, one category of questions that emerged was related to where earthquakes, volcanic eruptions, and tsunamis occur. Remind them also that at the end of the last investigation, they understood how the structure of the Earth creates seismic hazards, but not who is particularly at risk from them. Students had questions about how these hazards happen, where they happen, and why.

2. Tell students that we will begin to investigate where seismic hazards like earthquakes, tsunamis, and volcanoes tend to occur. Provide students with the handout *Global Patterns of Seismic Activity*

3. Ask students to complete the See-Think-Wonder based on their observations from the texts.

4. Ask groups to come up with one important idea and question to share with the whole class, from their See-Think-Wonder.

5. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections.

Integrating Three Dimensions

In this 5E investigation students are developing proficiency with **CCC#1 Patterns**, specifically the idea that empirical evidence is needed to identify patterns.The prompts in the student handout are meant to focus student observations on aspects of the video that highlight the consistency in the evidence showing patterns of where seismic events take place.

Look & Listen For

Possible student ideas and questions:

- Tsunamis, earthquakes, and volcanoes have very overlapping patterns of activity
- Tsunamis appear to happen when earthquakes occur at coastal regions
- I think plate tectonics is related to why and where seismic hazards occur
- I think seismic activity is happening near plate boundaries
- I wonder why volcanoes are less frequent than earthquakes
- I wonder why seismic activity happens in these areas but not others

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. In the Engage phase, it is often used to surface student ideas that can be used to transition the class to the investigation.

Explore 1

Why did earthquakes and volcanic eruptions occur in Iceland?

Students analyze **multiple pieces of evidence** about **change and the rates of change of** **seafloor rock and seismic activity** to construct an initial model showing the **relationships between plate boundaries, seismic activity, and the layers of the Earth**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs ❏ Table Groups	❏ Domino Discover ❏ Consensus Building Share	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Seismic Activity in the Ocean ❏ Making Sense of the Seismic Activity in the Ocean Investigation	❏ Map of Sea Floor Spread ❏ Rulers ❏ Calculators	❏ Aerial Footage Captures Volcano Spewing Lava in Iceland ❏ Iris Interactive Earthquake Viewer

Launch

1. Remind students that at the end of the end of the Engage phase, they had questions related to why seismic activity is happening in these locations.

2. Tell students that one area with a lot of earthquakes and volcanic activity is Iceland. Show them where Iceland is located on the maps. Build interest in this area by showing students the video Aerial Footage Captures Volcano Spewing Lava in Iceland .

3. Let them know that they are going to have the opportunity to look at several pieces of evidence to help them understand what is happening above and below some of the areas where seismic activity is taking place, including Iceland.

Investigation: Seismic Activity in the Ocean

1. Provide the handout, *Seismic Activity in the Ocean.* Have students work in pairs to complete parts 1 and 2 of the investigation.
2. When students are done, have the pairs join into table groups to discuss the prompt: what do you think is causing the pattern you observe?
3. Use the routine **Consensus Building Share** to ensure that the class is aligned in their predictions about what is causing the pattern of new crust and mid-ocean ridges before moving on to part 3.

Look & Listen For

Possible student ideas and questions:

- The sea floor is moving apart in the red regions, which is creating ocean ridges and new crust

4. Tell students that they will now have an opportunity to observe further evidence to help them understand what is happening in these locations.
5. Provide students with the full size, color print of Map of Sea Floor Spread , calculators and rulers. Have students work in their pairs to complete Part 3 of the investigation.
6. Support students in completing their calculations. After students have completed part 1, ask a few students to share out about their findings and whether they support their initial claims about the amount of time it takes for the formation of mid-ocean ridges and volcanoes like the ones that erupted in Iceland. All students should have calculated roughly the same number on the scale of 10s of millions of years and that it is because the plates move apart at a rate of about 1.8 cm/yr.

Note: this depends a bit on how and where students measure the plates. They may get a range of 1.5-2 cm/year

7. Circulate to support students with the calculations and use conferring prompts to push their thinking

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- Where are you going to take your measurements?
- How will you set up your calculations to determine how far the plates have moved?
- What does the metric conversion factor chart tell you?
- How will you use the equation to calculate the spreading rate?
- How does the scale help you?

8. Tell students that they will look at one last piece of evidence to help them determine what is happening in these locations.

Routine

This is the first time the routine **Consensus-Building Share** appears in this 5E. This routine is a way to make sensemaking visible and move towards a class-wide consensus around a new idea. As a checkpoint before moving the class to the next part of the activity, it is important to use this routine to ensure that all students understand why they believe the sea floor to be spreading in this location.

It is appropriate to prompt students with questions such as "Did any group find something similar?" or "Can anyone add to that?"

Integrating Three Dimensions

This Explore phase is another opportunity for students to develop proficiency with and be assessed on use of **CCC#1 Patterns** - specifically the idea that empirical evidence is needed to identify patterns. As you circulate using the conferring questions, pay attention to whether students cite evidence for the patterns they identify without prompting. If they don't, be sure to prompt them to do so.

9. Have students open the Iris Interactive Earthquake Viewer and turn to Part 4 of the investigation. Help students as they learn to navigate the earthquake viewer, and then have them work in their pairs to complete this section of the investigation.

10. Use conferring prompts to support students during the investigation

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- What shape do the Earthquakes make in the 3D view under Iceland?
- How deep are the Earthquakes under Iceland?
- What does this tell you about the structure of the plates under Iceland?
- Do you see any relationship between the distribution and depth of the earthquakes in Iceland and what you saw happening with crustal boundaries?

Investigation: Whole-Class Investigation Summary

1. Provide students with the handout *Making Sense of the Seismic Activity in the Ocean Investigation and* ask students to work independently to complete the See-Think-Wonder section of the investigation.

2. Have groups discuss the prompt: what do you think is happening in these areas that is creating the patterns you observed?

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence.

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Look & Listen For

Possible student ideas and questions:

- The age of oceanic crust is youngest near the mid-ocean ridges where magma comes out and increases in age with proximity to the continents.
- Magma rises to form new crust at ocean ridges.
- The shape of earthquakes under Iceland supports this model because it looks like a shallow trough of seismic activity, as if there is a shallow space between two plates as they spread apart
- I think the new magma might push the older rock away from the plate boundary.
- Why is the oldest ocean rock near continents?
- What is the age of the rock on continents?
- Do they fit the same pattern as we see in the ocean rocks?

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in

making those observations before moving on, as they will be key to success in the Explain phase that follows.

5. After groups have discussed the prompt, have students individually construct an initial model in the analysis question.

Access for Multilingual Learners

Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Earth & Space Science Course Guide for more information on this routine.

Explain 1

How does the evidence support our explanation of why Earth's crust is youngest in at ocean ridges?

Students evaluate evidence for the claim that new crust is produced at Earth's divergent plate boundaries on the ocean floor by reviewing empirical evidence of patterns and considering whether there are processes supported by science ideas that can connect the evidence to the claim.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ What explains the patterns in the age of the ocean floor? ❑ Summary Task	None	❑ Option 1: Text books-Copy paper-Markers ❑ Option 2: Plate Motion Simulation ❑ Option 3: Clay in Multiple Colors ❑ Chart paper ❑ Markers

Launch

1. Remind students that during the Explore phase, they surfaced a relationship between the age of ocean rock and its proximity to different plate boundaries, predicting that new crust is formed when magma rises between spreading tectonic plates.

2. Tell students that many scientists have conducted a great deal of research to make sense of the patterns related to plate boundaries, and in fact, used the same evidence the class has collected to develop explanations that explain these patterns.

3. Let students know that their task is to compare their ideas so far with a theory called plate tectonics, and construct a model demonstrating the connection between the evidence they observed in the investigation and this theory.

4. Provide students with the handout, *What explains the patterns in the age of the ocean floor?*, and have them read the first paragraph.

5. Help students visualize what is happening according to plate tectonic theory using one or more of three demonstrations.
   - Option 1: Use a textbook, copy paper, and markers to physically demonstrate plate spreading, using the instructions below
     1. Start by selecting a sizable textbook and positioning it so the spine faces downward, forming a wedge-like shape resembling cross-sections of Earth's interior. This textbook will serve as a representation of a slice of Earth's mantle beneath its surface. Mark it as the "mantle" using a sticky note or a piece of scrap paper attached to the book.
     2. Next, fold a piece of copy paper in half and insert it into the book, ensuring it's sandwiched between pages in the middle, with a portion protruding beyond the book's pages by 2-3 cm. This folded paper will symbolize the upward flow of matter, akin to magma emerging through fractures in the plates to form new rock. Tell students you will use a marker to color the paper where it emerges, signifying the crystallization into new rock. Any color will do, but let's decide based on the majority's preference, which may be red, for instance.
     3. Invite a student to add color to the folded copy paper where it emerges from the book. For optimal results, ensure the marker is inserted vertically into the fold, touching both sides of the paper simultaneously. As the student colors, gently pull the copy paper out of the book to simulate the upward movement.
     4. Pause to examine the resulting pattern on the paper, emphasizing its symmetrical nature and discussing why the marker ink appears on both sides.
     5. Referencing an image depicting the age pattern of ocean crust, identify the colors representing various age ranges. Assign different students to handle each marker color, and reset the model with a fresh piece of copy paper.
     6. Confer with students to ensure the final representation mirrors the map section, featuring a red line at the center and a rainbow gradient extending outward.
   - Option 2: Show students the Plate Motion Simulation for Divergent Plate Boundaries over 20 million years
   - Option 3: Use modeling clay to form layers and demonstrate separating the top layers and pushing the lower layer up between the separated top pieces.

6. Have students work in their table groups to discuss how the evidence they observed fits plate tectonic theory. Students should individually construct their models based on those conversations, including

Integrating Three Dimensions

This Explain phase uses **SEP #2, Developing and Using Models**, as a support for **SEP #7 - Engaging in an Argument from Evidence**. In this learning sequence, students are focusing on evaluating the strength of evidence used in an argument, and in order to support that analysis, they are relating the evidence to the argument using a model. Help students understand that this model is not complete if it does not contain annotations explaining the evidence they used to support plate tectonics theory annotations, and talk in pairs or table groups to answer the questions that follow.

6. Once students have completed their observations and responded to the prompt, have each pair share observations and responses with another pair and decide on a response they would like to share with the class. Ask several groups to share their responses to the prompt.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
   - "We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how well the evidence we have supports the theory of plate tectonics.

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student explanations to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how well the evidence we have supports the theory of plate tectonics.The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.

3. Ask the first student or group to share their explanation. You can do this by:
   - Projecting using a document camera; OR
   - Copying the written explanation to be shared and passing them out to the class; OR
   - Taking a picture of each explanation and projecting them as slides.

4. Proceed through the steps in the Consensus Discussion Steps.

5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Earth & Space Science Course Guide for detailed steps of this routine.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- Empirical evidence from radiometric dating tells us that ocean crust is youngest along mid-ocean ridges and gets older as you look further away from those ridges
- Measuring the rate of change of the sea floor gives us evidence that new crust is being formed very slowly
- That evidence supports the idea that plates are moving away from each other at these areas, and that new crust is being formed in between, very slowly
- Empirical evidence shows that earthquakes happen along mid-ocean ridges
- The earthquakes that happen under Iceland, which is on the Atlantic mid-ocean ridge, are shallow and distributed evenly across the ridge.
- That evidence supports the idea that there is a shallow space between the two sides of the mid-ocean ridge
- The evidence shows that there is a lot of volcanic activity in Iceland
- That evidence supports the idea that magma can rise in the space between the two sides of the mid-ocean ridge, which could form the new crust in that area

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **SEP #7 - Engaging in Argument from Evidence** explicit for students by elevating and probing for ideas related to evaluating how well evidence supports the currently accepted explanation, an important element of SEP #7 at the high school level. The Conferring Prompts about the amount of evidence that support the claim and science mechanisms can be useful here.

6. Let students know that they will be able to investigate further to figure out what else happens as a result of plate tectonics, and to try to figure out what causes seismic activity taking place away from mid-ocean ridges. They will also try to figure out what areas and people are most at risk of the types of hazards they observed in the unit launch.

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework. Consider starting the next class period with a brief discussion about prompt 4-6 which relate to the foreground three dimensions.

2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about plate tectonic theory.

Implementation Tip

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions to make sense of a phenomenon** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Explore 2

Why does seismic activity happen in areas far from mid ocean ridges?

Students analyze **multiple pieces of evidence** about **surface features and seismic activity** to **construct a model** showing the **relationships between plate boundaries, seismic activity, and the layers of the Earth**.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ Pairs	❏ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Coastal and Continental Seismic Activity ❏ Making Sense of the Coastal and Continental Seismic Activity Investigation	None	❏ Iris Interactive Earthquake Viewer

Launch

1. Remind students that at the end of the Explain 1 phase, they evaluated the evidence about divergent plate boundaries to support plate tectonic theory, but that they only explained some of the seismic activity on earth. Tell them that they will now try to explain the rest of the patterns of seismic activity in areas other than ocean ridges.

2. Provide each student with the *Coastal and Continental Seismic Activity* handout. Give students a few minutes to obscure the first map and answer two questions in Part 1. Then ask students to share the locations they've identified. Ask students if they have any predictions, based on the previous investigation, about what is causing high levels of seismic activity in areas far from the midocean ridges.

Look & Listen For

Possible student ideas and questions:
- Maybe these areas are where plates are colliding

Integrating Three Dimensions

In this phase, students will continue to develop proficiency of **CCC#1 - Patterns**, specifically the idea that empirical evidence is needed to identify patterns. As you circulate using the conferring questions, pay attention to whether students cite evidence for the patterns they identify without prompting. If they don't, be sure to prompt them to do so.

3. Tell students that they will now have the opportunity to take a closer look at the surface and underneath these areas to better understand what is taking place.

Investigation: Coastal and Continental Seismic Activity

1. Have students work in pairs to complete Part 2 of the activity, circulating and listening for groups identifying that these regions tend to be mountainous and have volcanoes on the surface.

2. When students are done, have them turn to Part 3 and open the Iris Interactive Earthquake Viewer . Students already used this browser to observe Iceland in the Explore 1 phase, and now they will be using it to observe coastal and continental earthquake zones.

Differentiation Point

It can be hard to determine the shapes of the plates underneath some of these zones. If students are struggling, provide them with the following assistance:

- When students are looking at coastal and island earthquake-heavy areas, suggest that they view Japan or Indonesia. These areas show clear wedges of subduction zones
- When students are looking at continental areas, both Myanmar and the Great Rift Valley are good choices. Students will see a wedge pattern when they observe Myanmar, which shows a convergent plate boundary, and a diffuse, shallow pattern when looking at the Great Rift Valley, which is a divergent plate boundary. Students do not need to memorize the terms convergent and divergent, but they should know that some plates are moving apart from each other and others are colliding, and that these areas have different substructures.

3. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- What shapes are you seeing in the earthquakes under these regions?
- How are those shapes similar to or different from the one you saw underneath Iceland?
- What do you think is happening in these regions?

4. Have students turn to Part 4 of the handout and observe the patterns in the ages of continental crust. Support them in making connections between the patterns in ocean crust they observed before, their predicted motions of the plates, and the types of boundaries they observed in the simulation.

Integrating Three Dimensions

Keep in mind, the third Conferring Prompt is meant to support students in developing the idea that **change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible**, an important element of **CCC #7 Stability and Change** at the high school level.

Investigation: Whole-Class Investigation Summary

1. Provide students with the *Making Sense of the Coastal and Continental Seismic Activity Investigation* handout. Ask students to work independently to complete the See-Think-Wonder section and the analysis questions, then use these completed pages to discuss the findings from the investigation.

2. Ask groups to come up with one important idea to share with the whole class, from their Summary notes.

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' Summary sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence.

Look & Listen For

Possible student ideas and questions:

- Earthquakes and volcanic activity happen when plates collide
- In these areas, it appears that one plate goes underneath another one, and earthquakes form there
- On the surface, there are mountains and volcanoes
- Continental crust is the oldest, probably because it is furthest from the midocean ridges but hasn't collided yet

4. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Access for Multilingual Learners

Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Earth & Space Science Course Guide for more information on this routine.

Explain 2

How do plate movements cause natural hazards and surface features?

Students **develop an explanation based on evidence** of why **earthquakes, volcanoes, and tsunamis** occur in **patterns** and how they form the **surface features found on Earth.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Modeling Natural Hazards and Surface Features ❑ Summary Task	None	❑ How mountain ranges are formed at convergent plate boundaries ❑ Birth of a Tsunami | PBS LearningMedia ❑ Plate Tectonics and Volcanoes | The Next Pompeii | PBS LearningMedia ❑ Plate Motion Simulation

Launch

1. Remind students that they are trying to figure out which of the key 5 regions are most at risk for tectonic activity and its associated natural disasters. To do that, they need to understand what causes earthquakes, volcanoes, and tsunamis to happen in certain areas and not others, and why they tend to be worse in some areas and not others.

2. Tell students that scientists have explained some of these patterns using Plate Tectonic Activity.

3. Provide students with the handout Modeling Plate Tectonics and have them turn to Part 1. Evaluating Evidence for Plate Tectonic Theory. Give students a few minutes to read the text individually.

Note: for New York State teachers, the Cross Section Model of Earth's Surface and Interior comes from page 11 of the New York State Earth and Space Science Reference Tables

4. Open a discussion about Plate Tectonic Theory and ask students how it helps explain the patterns they have observed. Help students gain a deeper understanding of the surface features caused by tectonic motion by showing them the three videos: How mountain ranges are formed at convergent plate boundaries , Birth of a Tsunami | PBS LearningMedia , Plate Tectonics and Volcanoes | The Next Pompeii | PBS LearningMedia .

5. Tell students that their job will be to connect the evidence they have seen to this theory.

Differentiation Point

For students who are having trouble visualizing the motion of tectonic plates shown in the Cross Section Model of Earth's Surface and Interior, use the Plate Motion Simulation to demonstrate the plate activity demonstrated by the model.

Evaluating Evidence for a Claim

1. Tell students that many scientists have conducted a great deal of research to make sense of the patterns related to plate boundaries, and in fact, used the same evidence the class has collected to develop explanations that explain these patterns.
2. Let students know that their task is to compare their ideas so far with a model that represents the ideas proposed by a theory called plate tectonics, and evaluate the evidence they have collected to determine if it supports the theory of plate tectonics. Ask students what they want to consider as they evaluate the evidence for the model. Document student ideas as you have several students share out.

Look & Listen For

Possible student ideas and questions:

- Is there evidence for the theory?
- Are there multiple pieces of evidence supporting the theory?
- Does what the theory claims make sense?
- Is there a mechanism or process that can connect the evidence to the theory?

3. Encourage students to keep these ideas in mind as they evaluate how strongly the evidence supports the theory of plate tectonics. Ask students to work in pairs or small table groups to describe the ideas represented in a model of plate tectonics and evaluate the evidence for these ideas.
4. Confer with students as they describe work on evaluating the evidence and develop a mechanistic model to see if the evidence supports the claim.

Conferring Prompts

- What are all the ideas represented in the model?
- Have we come across any evidence that supports that idea? What is the evidence?
- Does more than one piece of evidence support the model?
- What might provide the evidence needed?
- Does the model include a mechanism that makes sense? Are there science concepts that make this mechanism reasonable?

Integrating Three Dimensions

Keep in mind, the Conferring Prompts are meant to support students in working toward proficiency with **developing models based on evidence to illustrate the relationships between systems or between components of a system**, an important high school element of **SEP#2 Developing & Using Models**.

5. Once students have completed part 1, surface student ideas with the group learning routine, **Domino Discover.**

Look & Listen For

Explaining the Pattern of Seismic Activity

1. Have students turn to Part 2 of the handout.

2. Have students work individually to construct their explanations of the pattern of seismic activity using the evidence from this learning sequence

Note: for New York State Teachers, the Global Tectonic Activity of the Last One Million Years Diagram comes from page 12 of the New York State Earth and Space Science Reference Tables.

3. When they are done, have students discuss their explanations in groups and write a combined group response on another sheet of paper.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
    - "We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some decisions about how plate interactions cause natural hazards and the formation of surface features.

> **Class Consensus Discussion Steps**
>
> 1. We select a few different groups' ideas.
> 2. The first group shares out their work.
> 3. One person repeats or reiterates what the first group shared.
> 4. Class members ask clarifying questions about the work.
>
> Repeat steps 2-4 for each group that is sharing work.
>
> 5. Everyone confers in table groups.
> 6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

2. Select two or three student models to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of how plate boundaries cause natural hazards and the formation of surface features. The decision about which explanations to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.

3. Ask the first student or group to share their explanation. You can do this by:
    - Projecting using a document camera; OR
    - Copying the written explanation to be shared and passing them out to the class; OR
    - Taking a picture of each explanation and projecting them as slides.

4. Proceed through the steps in the Consensus Discussion Steps.

5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Earth & Space Science Course Guide for detailed steps of this routine.

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC#5 - Energy & Matter** and **SEP#2 - Developing & Using Models** explicit for students by elevating and probing for ideas related to the the concept that **change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible**. And that the amount of time it takes for surface features to form and hazards to occur is directly associated with the time scale of the process that cause them.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- Earthquakes occur at all types of plate boundaries.
- Volcanoes form and erupt at oceanic-continental convergent plate boundaries.
- This further confirms ideas about the earthquake-volcanic eruption phenomenon in Iceland we observed during the Engage phase and volcanic eruptions we have observed during the unit launch, like Krakatoa.
- Mountains form at convergent plate boundaries.
- Mid-ocean ridges, like the Mid-Atlantic Ridge where Iceland is located, form at divergent oceanic-oceanic plate boundaries.
- Tsunamis are caused by volcano collapses, underwater volcanic eruption, or plates slipping. This helps us explain the occurrence of tsunamis in the unit launch, like the Japan and Krakatoa tsunamis.
- Mountains form at convergent plate boundaries
- The amount of time it takes for surface features to form and hazards to occur is directly associated with the time scale of the process that causes them.
- Some of these phenomena happen very slowly and some happen very suddenly.
- Surface features can disappear or change form, but natural hazards are not reversible.
- When an oceanic plate converges with a continental plate the oceanic plate goes underneath because it is more dense.
- Volcanoes form at divergent plate boundaries because when the plates move apart, the heat from Earth (magma) which has a lot of pressure built up is like a pressure cooker and is able to come up to the surface.
- At convergent plate boundaries where plates have different density, like ocean plates and continental plates, the more dense oceanic plate goes under the less dense continental plate because it is more affected by gravity.
- Volcanoes form and erupt at convergent oceanic-continental plate boundaries when the energy due to friction heats magma, causing it to become less dense and therefore rise toward the surface.
- Including a source of energy that drives movement strengthens our models because it shows the science that supports our mechanism.
- We still don't know where the heat that causes pressure and the eruption of volcanic eruptions comes from.
- We still don't know how the heat energy inside the Earth moves to the surface to move these massive plates.

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework. Consider starting the next class period with a brief discussion about prompt 4-6 which relate to the foreground three dimensions.
2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about plate tectonic theory.

Implementation Tip

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions to make sense of a phenomenon** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

How did the Adirondack Mountains Form?

Students **construct an explanation** of how the **rock cycle and tectonic plate theory** can account for the formation of **surface features** over **different periods of time**, like the Adirondack mountain in New York State, far from plate boundaries.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Domino Discover	❑ Sequence Cards

Materials

Handouts	Lab Supplies	Other Resources
❑ Constructing New York State	None	❑ *Adirondack Mountain Cards* ❑ *Adirondack Mountain Timeline* ❑ How Earth Recycled a Mountain Range

Evidence Analysis Based Task

1. Ask students if they think that all of the surface features of Earth have been formed at tectonic plate boundaries, and if not, what other processes do they think might contribute to different landforms? Also, ask students how they think mountains form in areas far from plate boundaries, like the Adirondack Mountains in New York State?

2. Tell students that they will now have the opportunity to analyze how the combination of processes happening at different time scales have created the wide variety of surface features on Earth, including on continents.

3. Provide students with the handout: *Constructing New York State*, and have students work in table groups to complete the first page of the handout

4. When students are done, use the group learning routine Domino Discover to surface the different mechanisms of change and the timescales on which they operate

Look & Listen For

Possible student ideas and questions:

- Volcanic Eruptions cause change by erupting and bringing magma up to the surface of the Earth. It can destroy and create land masses. It happens very quickly, on the timescale of 1-10 years (short time scale)
- Tectonic plate motion causes change by the movement of the plates, creating continents, oceans, ridges, mountains, and volcanoes. It happens very slowly, over tens of thousands of years. (long time scale)
- Erosion causes change by wearing away at rocks. It causes things like mountains and craters to wear away, and happens over hundreds to thousands of years. (long time scale)

5. Have students work in groups to complete the rest of the investigation, including watching the video and sorting the *Adirondack Mountain Cards* onto the *Adirondack Mountain Timeline*.

Note: For New York State Teachers, the maps and diagrams in this section come from pages 8, 10, and 14 of the New York State Earth and Space Science Reference Tables.

Evaluate

Who's at risk?

Students use what they have learned about the **patterns of how** **earthquakes, volcanic eruptions, and tsunamis occur at plate boundaries** to **model** how the structure of Earth and tectonic plate motion creates surface features and **explain** how it puts different regions at risk.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Pairs	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Who is Most at Risk? ❑ Plate Boundaries & Surface Features Model Rubric ❑ Plate Boundaries & Surface Features Argument Rubric ❑ Revisit the Performance Task: Surface Features and Plate Boundaries 5E	None	

Revisit the Performance Task

2. Provide students with the handout *Who is Most at Risk?*. Give students time to confer in groups about the data

2. Confer with students while they are working.

Conferring Prompts

Confer with students as they work to develop their arguments. Prompt students to return to the class wide scientific argument characteristics, posted in the room.
Suggested conferring questions:

- What do the different substructures under these regions tell you about the plates they are on top?
- What do those plate types tell you about the risk of those areas?
- How does the historical data contribute to your understanding of Risk?

3. Have students turn to the *Revisit the Performance Task: Surface Features and Plate Boundaries 5E* and work independently to construct their models and explanations.

Integrating Three Dimensions

Use the Conferring Prompts to support students' use of evidence in their explanations in support of **SEP #6 - Constructing an Explanation from Reliable Evidence**. Students will then base their explanations about which performance task location is most at risk on what they have about how Plate Tectonics theory explains the occurrence of natural hazards and how it relates to performance task locations.

Document Class Thinking

1. Prompt students to discuss with their groups their ideas about which places on Earth are most at risk from earthquakes, volcanos, and tsunamis. Students can use the notes in their performance task organizers in these discussions.

2. Conduct a **Domino Discover** to hear from each group, and tally the responses on chart paper. It is not necessary to discuss all the positions or get to class consensus at this point.

Revisit the Driving Question Board

1. Use the **Driving Question Board Routine** to discuss which of the class's questions have been answered.

2. Have students identify which categories or questions they have not figured out yet. Prompt students to share these questions, and document new questions that arise based on what they have been learning.

3. Add new questions to the Driving Question Board.

4. One question category still unanswered relates to questions about what is inside Earth and what is occurring inside Earth that produces enough energy to cause the plates to move.

Performance Expectations

HS-ESS1-5 **Evaluate evidence of the past and current movements of continental and oceanic crust and the theory of plate tectonics to explain the ages of crustal rocks.**
Clarification Statement: Emphasis is on the ability of plate tectonics to explain the ages of crustal rocks. Examples include evidence of the ages oceanic crust increasing with distance from mid-ocean ridges (a result of plate spreading) and the ages of North American continental crust increasing with distance away from a central ancient core (a result of past plate interactions).
Assessment Boundary: None

In NYS, the clarification statement has been edited as follows: Examples of evidence could include that the age of oceanic crust increases with distance from mid-ocean ridges as a result of plate spreading and that the North American continental crust contains a much older central ancient core compared to the surrounding continental crust as a result of complex and numerous plate interactions.

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.**
Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).
Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

In NYS the clarification statement and assessment boundary have been edited as follows: Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and deposition) and destructive processes (such as weathering, subduction, and coastal erosion). Assessment Boundary: Assessment does not include recalling the details of the formation of specific geographic features of Earth's surface.

HS-ESS3-1 **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.**
Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.
Assessment Boundary: None

In NYS, the clarification statement has been edited as follows: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards could include those from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as blizzards, hurricanes, tornados, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations could include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3) Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2) Engaging in Argument from Evidence • Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. SEP7(2)	ESS1.C The History of Planet Earth • Continental rocks, which can be older than 4 billion years, are generally much older than the rocks of the ocean floor, which are less than 200 million years old. ESS1.C(1) ESS2.B 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(2) • Plate movements are responsible for most continental and ocean-floor features and for the distribution of most rocks and minerals within Earth's crust. ESS2.B(3) • Minerals are the building blocks of igneous, metamorphic, and sedimentary rocks and can be identified using physical and chemical characteristics. These rock types are evidence of stages of constant recycling of Earth material by surface processes and convection currents in the mantle. ESS2.B(4)NYS ESS3.B Natural Hazards • Natural hazards and other geologic events have shaped the course of human history; they have significantly altered the sizes of human populations and have driven human migrations. ESS3.B(1) PS1.C Nuclear Processes • Spontaneous radioactive decays follow a characteristic exponential decay law. Nuclear lifetimes allow radiometric dating to be used to determine the ages of rocks and other materials. PS1.C(2)	Patterns • Empirical evidence is needed to identify patterns. CCC1(5) Stability and Change • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. CCC7(2)

Assessment Matrix

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Developing and Using Models		*Seismic Activity in the Ocean* *What explains the patterns in the age of the ocean floor?*	*Coastal and Continental Seismic Activity* *Making Sense of the Coastal and Continental Seismic Activity Investigation*	*Constructing New York State*	*Revisit the Performance Task: Surface Features and Plate Boundaries 5E*
Constructing Explanations and Designing Solutions			*Modeling Natural Hazards and Surface Features* *Summary Task*	*Constructing New York State*	*Revisit the Performance Task: Surface Features and Plate Boundaries 5E*
Engaging in Argument from Evidence		*What explains the patterns in the age of the ocean floor?* *Summary Task*	*Modeling Natural Hazards and Surface Features* *Summary Task*		
ESS1.C The History of Planet Earth			*Coastal and Continental Seismic Activity* *Making Sense of the Coastal and Continental Seismic Activity Investigation*	*Constructing New York State*	
ESS2.B Plate Tectonics and Large-Scale System Interactions	*Global Patterns of Seismic Activity*	*Seismic Activity in the Ocean* *Making Sense of the Seismic Activity in the Ocean Investigation* *What explains the patterns in the age of the ocean floor?* *Summary Task*	*Coastal and Continental Seismic Activity* *Making Sense of the Coastal and Continental Seismic Activity Investigation* *Modeling Natural Hazards and Surface Features* *Summary Task*	*Constructing New York State*	*Revisit the Performance Task: Surface Features and Plate Boundaries 5E*
ESS3.B Natural Hazards					*Revisit the Performance Task: Surface Features and Plate Boundaries 5E*
PS1.C Nuclear Processes		*Seismic Activity in the Ocean*			

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Patterns	*Global Patterns of Seismic Activity*	*Seismic Activity in the Ocean* *Making Sense of the Seismic Activity in the Ocean Investigation* *What explains the patterns in the age of the ocean floor?* *Summary Task*	*Coastal and Continental Seismic Activity* *Making Sense of the Coastal and Continental Seismic Activity Investigation* *Modeling Natural Hazards and Surface Features* *Summary Task*		*Revisit the Performance Task: Surface Features and Plate Boundaries 5E*
Stability and Change		*Seismic Activity in the Ocean* *Making Sense of the Seismic Activity in the Ocean Investigation* *What explains the patterns in the age of the ocean floor?* *Summary Task*	*Coastal and Continental Seismic Activity* *Making Sense of the Coastal and Continental Seismic Activity Investigation* *Modeling Natural Hazards and Surface Features* *Summary Task*	*Constructing New York State*	*Revisit the Performance Task: Surface Features and Plate Boundaries 5E*

Common Core State Standards Connections

	Engage	Explore/Explain 1	Explore/Explain 2	Elaborate	Evaluate
Mathematics		MP2 MP3 MP4 MP6	MP2 MP3 MP4 MP6		
ELA/Literacy		WHST.9-10.9	WHST.9-10.9	WHST.9-10.1 WHST.9-10.5 SL.9-10.4	

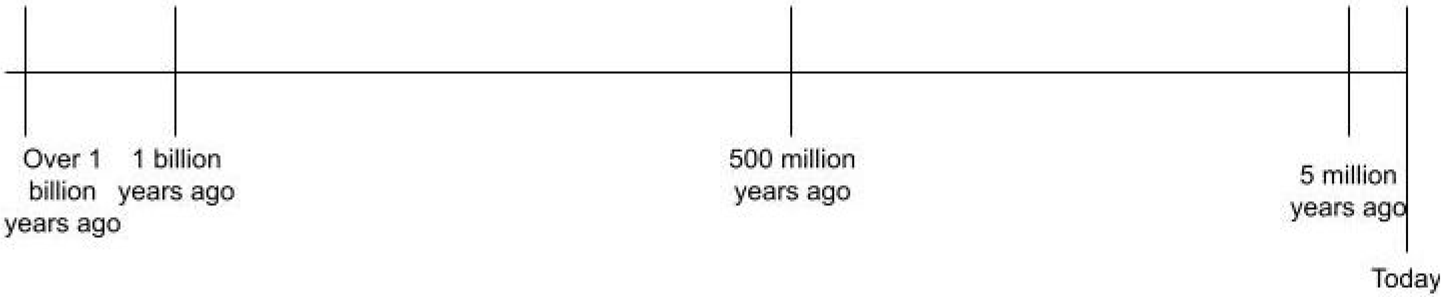
Classroom Resources for Surface Features & Plate Boundaries 5E

Adirondack Mountain Cards
Adirondack Mountain Timeline

Adirondack Mountain Cards

Magma deep underground formed anorthositic rocks	Tectonic activity lifted anorthositic rock up into a massive mountain range	Erosion acted on the Grenville mountains and they decreased in size
A shallow ocean formed on top	Sedimentary rock formed in the ocean above the mountain	Uplift forced the mountains, covered in sedimentary rock, back up
Erosion wore away the sedimentary rocks covering the anorthositic rocks	Now we have ancient rocks at the top of the adirondack mountains, surrounded by younger rocks	

Adirondack Mountain Timeline



Energy and Matter 5E

	Where is all the energy coming from to move plates apart from each other? What processes are occurring inside Earth that can cause it to reach Earth's surface? And why do people continue to live in these hazardous areas?	**Performance Expectations** HS-ESS2-3, HS-ESS2-1	**Investigative Phenomenon** The Great Rift Valley is the cradle of humanity, but also experiences significant amounts of seismic activity from plates moving apart from each other.	**Time** 5-6 days

In this 5E instructional sequence, students are investigating the questions about the reasons for the movement of plates, such as *How does the Earth's interior move plates?* Students are also returning to the question *Why do people continue to live in hazardous areas?* This leads to questions about ways in which the heat energy powers plate tectonics and where heat energy comes from. Students use different kinds of evidence to arrive at conclusions about the processes that move plates and the way heat is generated inside the Earth, concluding that energy is being generated all over Earth's mantle and that models of convection further supports their understanding of how different areas of the Earth are at varying risk of earthquakes. This idea leads them to consider the types of matter that are moved by this energy, and determine that there are resource benefits to living at plate boundaries.

ENGAGE	What is happening inside Earth that drives plate motion?	Students use what they know about **Earth's interior** to **make initial claims about** the **source of energy** that **moves plates** associated with the **movement of matter** observed in the Great Rift Valley.
EXPLORE	How do differences in temperature affect matter inside the Earth lead to the movement of matter caused by the Tonga volcanic eruption?	Students **develop and use a physical model** that presents analog behavior for **processes within Earth's interior** in order to collect **empirical evidence of patterns** in **movement of matter and energy**.
EXPLAIN	How does plate motion occur?	Students **develop an explanatory model** for how **energy inside the Earth drives the motion** of **tectonic plates on Earth's surface**.
ELABORATE	Why do people live in these hazardous areas?	Students **evaluate evidence** about the **cycling of matter driven by the movement of energy** in order to **explain how resource availability has guided the development of human populations**.
EVALUATE	How does tectonic plate motion impact humans positively and negatively?	Students use what they learn about **energy and matter flow in Earth's interior** to **model** the **energy and matter resources** of tectonic plate boundaries and **explain** how tectonic activity **impacts populations in both positive and negative ways.**

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Engage

What is happening inside Earth that drives plate motion?

Students use what they know about **Earth's interior** to **make initial claims about** the **source of energy** that **moves plates** associated with the **movement of matter** observed in the Great Rift Valley.

Preparation

Student Grouping	Routines	Literacy Strategies
None	❑ Rumors	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Energy Inside the Earth	None	❑ The Great Rift Valley, Africa

Launch and Surfacing Student Ideas

1. Remind students that one category of their questions that remains from the DQB is related to what is going on inside Earth that causes plate motion and in turn natural hazards and surface features. And that when they evaluated the theory of plate tectonics, they pointed out that the evidence that was presented was not yet supported by a mechanism for plate motion or for the production of energy that drives plate motion.
2. Reestablish that while they were able to use evidence from seismic waves, analysis of meteorites and volcanic eruptions to model Earth's interior structure and properties, they still do not know what process or mechanism is occurring inside Earth that drives plate motion and why the inside of Earth is so hot (contains so much energy).
3. Remind students also that we haven't figured out yet why people continue to live in these dangerous areas.
4. Tell students that they will now have the opportunity to observe an area on Earth where humans have been living for 100,000 years, which happens to also be in a place where tectonic plates are moving away from each other. By zooming in on this area, we will be able to get a better look at where energy is coming from to move these plates, and also take a look at some of the materials that are getting moved along with them in order to better understand why people live in these areas.
5. Provide students with the handout The Great Rift Valley and show them the video The Great Rift Valley, Africa

Routine

The goal of the **Rumors** routine is to have students exchange ideas while listening for similarities and differences in thinking. It's meant to be low stakes, so it is frequently used to surface initial student ideas about phenomena during the Engage phases. Please read the Earth & Space Science Course Guide for detailed steps about this routine.

6. Have students consider the prompt: where do you think the energy to split this continent apart is coming from?

7. Use the group learning routine, **Rumors**, to support students in sharing their ideas about the energy source

Look & Listen For

- The heat from the Earth's interior boils over.
- Hot stuff rises because there's so much pressure and it bursts out at the surface
- The eruptions happen inside the Earth and make it all the way to the surface.
- Is the heat energy coming from the really hot part of the interior like the core or mantle?
- How does the heat from layers inside rise up so far to the Earth's surface?

8. Let students know that they will have the opportunity to explore these questions through this investigation.

Explore

How do differences in temperature affect matter inside the Earth lead to the movement of matter caused by the Tonga volcanic eruption?

Students **develop and use a physical model** that presents analog behavior for **processes within Earth's interior** in order to collect **empirical evidence of patterns** in **movement of matter and energy**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Domino Discover	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Modeling Earth's Interior Processes ❑ Modeling Earth's Interior Processes	❑ Model 1: vegetable oil; beaker; hot plate; oregano ❑ Model 2: plastic tub; red and blue food coloring; water/ice ❑ Model 3: vegetable oil; casserole dish; tea candles; oregano; 4 plastic pieces (tectonic plates)	❑ Model 1 ❑ Model 2 ❑ Model 3 - Top View ❑ Model 3 - Side View

Launch

1. Remind students about their questions regarding whether the movement of matter observed in the Great Rift Valley was caused by the heat from the core or mantle and how it rises so far to reach the Earth's surface, and that during the last investigation they figured out that Earth's interior is divided into layers composed of different substances and that as you go deeper into the Earth, the temperature.

2. Tell students that they will be building on these ideas by modeling conditions with layers of different materials and increasing heat.

Investigation: Modeling Earth's Interior Processes

1. Provide each student with the *Modeling Earth's Interior Processes Investigation* handout.
2. Use conferring questions to push students' thinking about the investigation while they are collecting data.

Conferring Prompts

Confer with students during the investigation. Suggested during-lab conferring questions:

- When you initiated each model, where was the greatest amount of energy located?
- What did you notice about the movement of matter?
- What patterns did you observe related to matter (stuff) rising?
- What patterns did you observe related to matter (stuff) sinking?
- What effect do you think the heating and cooling has on the colored water and oil? Why does this affect its movement?
- What is happening to the plastic plates at the surface? What is causing that?
- How is the energy affecting the motion of matter?
- How might what you're observing explain the movement of matter observed in the Great Rift Valley.

Integrating Three Dimensions

Keep in mind, the Conferring Prompts are meant to support students in developing the idea that **energy drives the motion and/or cycling of matter within and between systems**, an important element of **CCC #5 Energy and Matter** at the high school level.

Investigation: Whole-Class Investigation Summary

1. Provide students with the *Modeling Earth's Interior Processes* Handout. Direct students to work independently to complete the See-Think-Wonder section, then use this completed table to discuss the findings from the investigation.

2. Ask groups to come up with one important idea to share with the whole class, from their See-Think-Wonder tables.

3. Use the group learning routine **Domino Discover** to surface important trends, inferences, and questions from groups' See-Think-Wonder sections. Plan forward based on the various understandings that students or student groups have articulated. It is appropriate to go onto the next phase once students have had a chance to make sense of the data, and have had the opportunity to clarify what they have figured out about the investigative phenomenon under study in this learning sequence..

Routine

The **Domino Discover** is an opportunity to surface students' thinking to the whole class and the teacher. It allows students to learn from each other and for the teacher to assess whether the class is ready to move to the next phase of instruction. Refer to the Earth & Space Science Course Guide for support with this routine.

Look & Listen For

Possible student ideas and questions:

- When we initiated model 1, the greatest amount of energy was at the bottom of the beaker (hot plate).
- When we initiated model 2, the greatest amount of energy was in the red colored hot water in the bottle at the top.
- When we initiated model 3, the greatest amount of energy was at the middle of the bottom of the dish (candles).
- Stuff or matter was rising then sinking. I also saw the plastic plates in the middle move apart and crash into other plastic plates on the outside.
- Matter that was rising was initially hot or next to something hot (a high energy source).
- Matter that started sinking was not initially next to something hot or it was cool like the blue colored ice.
- I think that when the matter was next to an energy source and heated or was hot to begin with, it became or was less dense.
- I think that when the matter was not next to an energy source and cooled or cool to begin with, it became or was more dense.
- I know that more dense stuff sinks and displaces less dense stuff that is forced to rise. That might explain the rising and sinking we observed in all models.
- Heat from the models 1 and 3 moved from the bottom to the top - this might explain the eruption and the movement of matter caused by the Tonga volcanic eruption.
- The plates at the top of model 3 seemed to be moved apart by the oil that was rising in the middle and then crashed into the plates on the outside. This must be what is happening at divergent and convergent plate boundaries.
- Those plates moved toward other plates on the outside - this is like convergent plate boundaries where volcanoes form and erupt.

Access for Multilingual Learners

Using **Domino Discover** at this stage provides support for multilingual learners who are **emerging** and **transitioning**. Providing different types of unique comprehensible input, all from peers in the classroom, supports students' language development. Refer to the Earth & Space Course Guide for more information on this routine.

5. If students don't surface any of the important observations named in the Look and Listen For, direct students back to appropriate investigation resources and use conferring questions to support them in making those observations before moving on, as they will be key to success in the Explain phase that follows.

Explain

How does plate motion occur?

Students **develop an explanatory model** for how **energy inside the Earth drives the motion** of **tectonic plates on Earth's surface**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Class Consensus Discussion	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Explaining the Great Rift Valley ❑ Summary Task	None	

Launch

1. Review all the student ideas that surfaced from the Explore phase and tell students that they are now going to bring all those ideas together to develop an explanatory model for what inside the Earth is causing plate motion associated with the movement of matter seen at plate boundaries.

2. Provide students with the handout, *Explaining the Great Rift Valley*. Tell students that they will first have an opportunity to make connections between the models they observed in the Explore and Earth's interior. Have students begin work in table groups on part 1 of the handout, pausing after they have made connections between the two models.

3. Review what parts of model 3 connect to the Earth's interior and how density is affected by temperature with the class. Students combine these two ideas to draw preliminary convection currents combining their information about density and heat.

4. Prompt students to consider where the heat comes from. Ask students why they think the center of the Earth is so hot.

5. Regardless of their answers, leverage their prior knowledge to turn to the next part of the handout, *Where does the heat come from?* Support students as they read the text and diagram. Confer with students as they discuss in their table groups where the heat comes from.

Integrating Three Dimensions

In this unit students are developing proficiency with the **CCC#5 Energy and Matter**. This is an opportunity for students to build on their ideas that surfaced about energy and matter during the two previous investigations.

Conferring Prompts

- Did we see any evidence of oxygen gas inside the Earth?
- Do we have evidence that the planet is hot enough to cause nuclear fusion?
- Which type of reaction could be creating heat in Earth's interior?

6. Take a moment to review with the class the key information they gained from the text.

Conferring Prompts

- Some of the heat in the mantle comes from residual heat from the creation of Earth, radiating out of the crust
- The rest of the energy comes from radioactive decay

7. Tell students that they will now combine all of that information into a complete explanatory model of energy inside Earth.

Developing and Explanatory Model

1. Remind students that they already created a simple model of convection in Earth's interior, but that they didn't include some of the components that we knew it should have had. The simple model showed Earth's core as one layer, but students know that it has two layers. That model also didn't include the new information they learned about energy being generated from radioactive decay in the mantle.

2. Remind students that we also never addressed where the energy came from to create Earth's magnetic field. Tell students that metal becomes magnetized when it is in motion. Remind them that we know that the outer core is liquid metal, and that we already knew there was some motion in it because we knew that magnetic north moves. Ask them if, based on what they just learned, they can explain why the liquid metal in the outer core is moving.

Look & Listen For

- Convection currents in the outer core from residual heat radiating outwards are causing the movement of matter in the outer core

3. Remind students also that they have seen evidence that rocks are not evenly distributed throughout the crust and mantle. Ask them if they think radioactive decay is happening uniformly.

Look & Listen For

- Radioactive decay is likely not uniform throughout Earth's interior

4. Have students turn to part 2 of the handout, *Modeling the Movement of Energy and the Motion of the Great Rift Valley* and work in table groups to complete the model of the movement of Energy and the motion of the Great Rift Valley.

5. Confer with students as they develop their explanatory models.

Conferring Prompts

- What are the different parts of your model? Why did you include them?
- How do these parts of the system affect each other? How are you showing this?
- Where is energy driving the motion of matter? Where is the energy coming from?
- How is the energy causing matter to move?
- What is your evidence for what you included in the model?
- What science ideas support what you included in your model?

Integrating Three Dimensions

Keep in mind, the third Conferring Prompt is meant to support students in developing the idea that **energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems** and **energy drives the motion and/or cycling of matter within and between systems**, two important element of **CCC#5 Energy and Matter** at the high school level. The other Conferring Prompts are meant to support students in working toward proficiency with **developing models based on evidence to illustrate the relationships between systems or between components of a system**, an important high school element of **SEP#2 Developing & Using Models**.

Differentiation Point

Have students that have struggled with connecting multiple concepts to explain a phenomenon sit in one to two small groups. Sit with these groups and prompt them to draw arrows that show the motion of the olive oil in model 3 and how it leads to the plastic pieces moving apart. Then use probing questions to support students in applying relevant concepts to explain convection in model 3. Prompts may include:

- Where was the oil heated?
- What happens to the density of matter when it is heated?
- Does less dense matter rise or sink?
- What happens to matter as it moves further away from a heat source?
- How does the cooling of matter affect its density?
- Does more dense matter rise or sink?

As students respond to probing questions, have them annotate the diagram of model 3 to apply these concepts. After students have completed their annotations of model 3, have them individually transfer what they learned to the diagram of Earth's interior.

After they have modeled how convection happens in Earth's interior, have them refer to their models of how plate motion cause volcanic eruptions from the previous investigation, so they can incorporate those ideas and explain the movement of the Great Rift Valley.

Class Consensus Discussion

1. Orient the class to the purpose and the format of a class consensus discussion. You may say something like this:
   - "We are going to use a **class consensus discussion**, just like we did in the last 5E, to learn about all the thinking in the room and come to some conclusions about what processes inside Earth might be causing plate motion associated with the movement of matter seen in the Great Rift Valley."

Class Consensus Discussion Steps

1. We select a few different groups' ideas.
2. The first group shares out their work.
3. One person repeats or reiterates what the first group shared.
4. Class members ask clarifying questions about the work.

Repeat steps 2-4 for each group that is sharing work.

5. Everyone confers in table groups.
6. Engage in whole-class discussion about the ideas that were shared, in order to come to agreement.

Routine

Class Consensus Discussions are so important for the Explain phase across this unit. This routine is a way to ensure that the accurate scientific ideas students are figuring out are made public and visible for all students to access. It requires skillful teacher facilitation, as it is important to not tell students what they need to know, instead supporting students as a class in using the information they have from investigations, their models and texts in order to figure out and state those important ideas. Please read the Earth & Space Science Course Guide for detailed steps of this routine.

2. Select two or three student explanatory models to share with the class. At this point, do not select them randomly. The point of this discussion is to elevate ideas that move the class towards greater understanding of what processes inside Earth are causing Earth's plates to move. The decision about which models to share with the class should be based on both the ideas circulating in the classroom and the goals of this part of the 5E sequence.

3. Ask the first student or group to share their explanation. You can do this by:
    - Projecting using a document camera; OR
    - Copying the written explanation to be shared and passing them out to the class; OR
    - Taking a picture of each explanation and projecting them as slides.

4. Proceed through the steps in the Consensus Discussion Steps.

5. During the whole-class discussion, there will be opportunities to identify important terms and concepts that emerge in the discussion. Sometimes, important points get buried in student talk.

Take Time for These Key Points

Pause the discussion and ask for clarification, particularly of the following key points:

- There are differences in temperature in Earth's interior which cause differences in density of the matter inside Earth.
- The temperature is highest in the core, so it transfers heat to the mantle which is lower in temperature.
- When mantle rock is heated by the core, it expands and becomes less dense.
- Lower temperature rock that is more dense is pulled down by gravity and forces the hotter less dense rock up.
- When the hotter less dense rock is forced up close to Earth' surface it can come out as new crust at divergent plate boundaries, which drives those plates toward convergent plate boundaries with another plate.
- As rock rises and gets closer to earth's surface it cools because it transfers heat to the cooler surroundings and becomes more dense. Gravity then causes it to start sinking and be part of the cycle of sinking and rising rock in Earth's mantle that forces Earth's massive plates to move and cause natural hazards and surface features.

6. Return to student questions that bring up lingering issues not yet resolved, such as:
    - Why is Earth's interior so hot? Why is there so much energy inside Earth? Where is the energy coming from?

Integrating Three Dimensions

The depth of this discussion will really depend on what you've observed in the room and how you respond. Be sure to make **CCC #2 - Energy and Matter** explicit for students by elevating and probing for ideas related to the concept that **energy cannot be created or destroyed—it only moves between one place and another place, between objects and/or fields, or between systems** and **energy drives the motion and/or cycling of matter within and between systems.**

Summary

1. Students individually complete the *Summary Task*. This can be completed as an exit ticket or for homework.

2. The results of this task can be used to make determinations about which students need more time to engage in sense-making about what processes inside Earth are causing Earth's plates to move.

Implementation Tip

This summary is really important! It's an opportunity to check in on each student's thinking at this point in the unit, in a few different areas: 1) **understanding how they are using the three dimensions, including the concept of energy and how it drives the cycling of matter, to make sense of a phenomenon** 2) ideas about how they and their peers are building knowledge together; 3) how they think the class consensus discussion went. It's important to get all of this from individual students, so you know these things on a student-by-student basis.

Elaborate

Why do people live in these hazardous areas?

Students **evaluate evidence** about the **cycling of matter driven by the movement of energy** in order to **explain** **how resource availability has guided the development of human populations**.

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Table Groups	❑ Read-Generate-Sort-Solve	None

Materials

Handouts	Lab Supplies	Other Resources
❑ How do energy and minerals impact human populations? ❑ Minerals, Energy, and Human Populations	None	❑ World Population History

Evaluating Evidence

1. Remind students about their questions about why populations have been living in hazardous areas for thousands of years.

2. Tell students that this pattern goes back long in history. Show students the interactive World Population History (it will play as a video if you press the play icon on the bottom left where it says Animate Map and Timeline). Point out to students that, up until about 1500, when colonialism increased, most societies were living along areas that we know now to be tectonically active.

3. Provide each student with the handout, *How do energy and minerals impact human populations?* and the *Minerals, Energy, and Human Populations*.

4. Ask students to independently complete the Generate section based on the data tables and science ideas found on their handout.
5. After students have had the opportunity to view the data and generate ideas, use the Group Learning Routine, **Read-Generate-Sort-Solve** to facilitate student collaboration as they develop responses to the guiding prompts.
   - How has resource availability guided the development of human populations and societies?
   - Why do people live in these areas?
6. Have various groups share their responses to the two guiding prompts.

Routine

The **Read-Generate-Sort-Solve** routine promotes collaborative engagement in problem-solving and supports students in articulating their thinking and making it transparent, before considering solutions. Please read the Earth & Space Science Course Guide for detailed steps of this routine.

Look & Listen For

Possible student ideas and questions:

- Tectonic plate boundaries have resources that are beneficial to human populations
- The circulation of hot fluids concentrates trace elements, so these areas have precious metals and gems
- Tectonically active areas have diverse landscapes
- Volcanic areas have fertile soil
- Tectonically active areas are often near coasts or other bodies of water

Access for All Learners

Read-Generate-Sort-Solve is an important routine because it builds in individual think time and opportunities for all students to contribute to the group answer. Students who need additional processing time, or a chance to adjust their thinking after hearing from peers, get that opportunity. This additional time for language input is especially helpful for **emerging language learners**.

Evaluate

How does tectonic plate motion impact humans positively and negatively?

Students use what they learn about **energy and matter flow in Earth's interior** to **model** the **energy and matter resources** of tectonic plate boundaries and **explain** how tectonic activity **impacts populations in both positive and negative ways.**

Preparation

Student Grouping	Routines	Literacy Strategies
❑ Independent ❑ Table Groups	None	None

Materials

Handouts	Lab Supplies	Other Resources
❑ Tectonically Active Region Resources ❑ Energy Transfer Model Rubric ❑ Energy and Matter Explanation Rubric ❑ Revisit the Performance Task: Energy and Matter	None	

Revisit the Performance Task

1. Provide students with *Tectonically Active Region Resources*
2. Have students talk in groups about the resources found in each region of focus
3. When students are ready, have them turn to the performance task organizer and independently construct their models and explanations.
4. Confer with students while they are working.

Conferring Prompts

Confer with students as they work to develop their arguments. Prompt students to return to the class wide scientific argument characteristics, posted in the room.

Suggested conferring questions:

- What evidence did you generate in this 5E sequence?
- Where did the evidence come from?
- How well does that evidence support the claim?
- What ideas or contradictory evidence weaken the claim?

Performance Expectations

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.**
Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and orogeny) and destructive mechanisms (such as weathering, mass wasting, and coastal erosion).
Assessment Boundary: Assessment does not include memorization of the details of the formation of specific geographic features of Earth's surface.

In NYS the clarification statement and assessment boundary have been edited as follows: Clarification Statement: Emphasis is on how the appearance of land features (such as mountains, valleys, and plateaus) and sea-floor features (such as trenches, ridges, and seamounts) are a result of both constructive forces (such as volcanism, tectonic uplift, and deposition) and destructive processes (such as weathering, subduction, and coastal erosion). Assessment Boundary: Assessment does not include recalling the details of the formation of specific geographic features of Earth's surface.

HS-ESS2-3 **Develop a model based on evidence of Earth's interior to describe the cycling of matter by thermal convection.**
Clarification Statement: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Examples of evidence include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.
Assessment Boundary: None

In NYS the clarification statement has been edited as follows: Emphasis is on both a one-dimensional model of Earth, with radial layers determined by density, and a three-dimensional model, which is controlled by mantle convection and the resulting plate tectonics. Rocks and minerals can be identified and classified using various tests and protocols that determine their physical and chemical properties. Examples of evidence could include maps of Earth's three-dimensional structure obtained from seismic waves, records of the rate of change of Earth's magnetic field (as constraints on convection in the outer core), and identification of the composition of Earth's layers from high-pressure laboratory experiments.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Developing and Using Models • Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. SEP2(3) Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2)	ESS2.A 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, and 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. ESS2.A(2) ESS2.B Plate Tectonics and Large-Scale System Interactions • The radioactive decay of unstable isotopes continually generates new energy within Earth's crust and mantle, providing the primary source of the heat that drives mantle convection. Plate tectonics can be viewed as the surface expression of mantle convection. ESS2.B(1) ESS3.A Natural Resources • Resource availability has guided the development of human society. ESS3.A(1) ESS3.B Natural Hazards • Natural hazards and other geologic events have shaped the course of human history; they have significantly altered the sizes of human populations and have driven human migrations. ESS3.B(1)	Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1) Energy and Matter • Energy drives the cycling of matter within and between systems. CCC5(4) Stability and Change • Change and rates of change can be quantified and modeled over very short or very long periods of time. Some system changes are irreversible. CCC7(2)

Assessment Matrix

	Engage	Explore	Explain	Elaborate	Evaluate
Developing and Using Models		*Modeling Earth's Interior Processes*			*Revisit the Performance Task: Energy and Matter*
Constructing Explanations and Designing Solutions			*Explaining the Great Rift Valley* *Summary Task*	*How do energy and minerals impact human populations?*	*Revisit the Performance Task: Energy and Matter*
ESS2.A Earth Materials and Systems	*Energy Inside the Earth*	*Modeling Earth's Interior Processes*	*Explaining the Great Rift Valley* *Summary Task*		*Revisit the Performance Task: Energy and Matter*
ESS2.B Plate Tectonics and Large-Scale System Interactions			*Explaining the Great Rift Valley*		*Revisit the Performance Task: Energy and Matter*
ESS3.A Natural Resources				*How do energy and minerals impact human populations?*	*Revisit the Performance Task: Energy and Matter*
ESS3.B Natural Hazards				*How do energy and minerals impact human populations?*	*Revisit the Performance Task: Energy and Matter*
Cause and Effect				*How do energy and minerals impact human populations?*	
Energy and Matter	*Energy Inside the Earth*	*Modeling Earth's Interior Processes*	*Explaining the Great Rift Valley* *Summary Task*		*Revisit the Performance Task: Energy and Matter*
Stability and Change					*Revisit the Performance Task: Energy and Matter*

Common Core State Standards Connections

	Engage	Explore	Explain	Elaborate	Evaluate
Mathematics		MP2 MP3 MP4 MP6		MP2 MP3 MP4 MP6	
ELA/Literacy		WHST.9-10.9	WHST.9-10.1 WHST.9-10.5 SL.9-10.4	WHST.9-10.9	WHST.9-10.1 WHST.9-10.9

Unit Closing

What locations on Earth are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future?	**Performance Expectations** HS-ESS3-1	**Anchor Phenomenon** Major earthquakes, volcanic eruptions, and tsunamis happen all over the world, causing loss of life and property, yet humans have been living continuously in these hazardous areas for thousands of years.	**Time** 1-3 days

Based on the investigations and learning throughout the unit, students generate a final explanation detailing how technology and resources shape the vulnerability of populations at risk of natural disasters from seismic hazards.

ANCHOR PHENOMENON	What regions are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future?	Based on the investigations and learning throughout the unit, students review their ideas about which regions are most at risk from natural disasters caused by tectonic activity.
DRIVING QUESTION BOARD	What questions about who's at risk have we not answered yet?	Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.
PERFORMANCE TASK	What regions are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future?	Based on the investigations and learning throughout the unit, students generate a final explanation of which regions are most at risk from natural disasters caused by tectonic activity.

Science & Engineering Practices | Disciplinary Core Ideas | Crosscutting Concepts

Anchor Phenomenon

What regions are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future?

Based on the investigations and learning throughout the unit, students review their ideas about which regions are most at risk from natural disasters caused by tectonic activity.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Earthquake Deaths Over Time	None	❏ Stop natural hazards from becoming disasters

Generating Ideas about Anchor Phenomenon

1. Students return to the anchor phenomenon and review their ideas about which regions are most at risk of natural hazards caused by tectonic activity.
2. Ask students to consider what, besides physical risk of an earthquake, volcano, or tsunami, could impact how many people are killed by a natural disaster. Have students consider factors like population density, resources, and ability to prepare for disasters.
3. Show students the video Stop natural hazards from becoming disasters
4. Provide students with the handout *Earthquake Deaths Over Time*. Ask students to notice patterns and trends in which regions are demonstrating decreases in deaths from disasters even as population levels rise.

Driving Question Board

What questions about who's at risk have we not answered yet?

Based on the investigations and learning throughout the unit, students return to the Driving Question Board to reflect on questions generated throughout the unit.

Preparation

Student Grouping	Routines	Literacy Strategies
None	None	None

Materials

Handouts	Lab Supplies	Other Resources
None	None	❑ Driving Question Board

Revisit the Driving Question Board

1. Students return to the questions generated throughout the unit and reflect. What questions have been answered? Are there questions that we still need to investigate?

2. Note that not all of the students' questions will be answered at the end of the unit, and students may have generated entirely new questions. Depending on student interest and instructional time, prompt students to explore some of the unanswered questions independently.

Performance Task

What regions are most at risk of loss of life and property caused by an earthquake, volcanic eruption, or tsunami in the near future?

Based on the investigations and learning throughout the unit, students generate a final explanation of which regions are most at risk from natural disasters caused by tectonic activity.

Preparation

Student Grouping	Routines	Literacy Strategies
❏ None	None	None

Materials

Handouts	Lab Supplies	Other Resources
❏ Vulnerability Profiles ❏ Earthquake Deaths Over Time ❏ Final Performance Task	None	

Develop an Explanatory Model

1. Remind students of our overarching goal to explain how the UN can allocate money to reduce the risk to populations from tectonic activity.

2. Provide students with the Vulnerability Profiles. Have students read the vulnerability profiles and discuss the technologies that seem to protect populations from disasters when natural hazards occur.

3. Provide students with the Unit Closing Task and have students work independently to explain how technological advances and preparedness have decreased the impact on human populations from natural hazards, and how that could influence UN decisions around resource allocation.

Standards in Unit Closing

Performance Expectations

HS-ESS3-1 **Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.**
Clarification Statement: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards can be from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as hurricanes, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.
Assessment Boundary: None

In NYS, the clarification statement has been edited as follows: Examples of key natural resources include access to fresh water (such as rivers, lakes, and groundwater), regions of fertile soils such as river deltas, and high concentrations of minerals and fossil fuels. Examples of natural hazards could include those from interior processes (such as volcanic eruptions and earthquakes), surface processes (such as tsunamis, mass wasting and soil erosion), and severe weather (such as blizzards, hurricanes, tornados, floods, and droughts). Examples of the results of changes in climate that can affect populations or drive mass migrations could include changes to sea level, regional patterns of temperature and precipitation, and the types of crops and livestock that can be raised.

Aspects of Three-Dimensional Learning

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
Constructing Explanations and Designing Solutions • Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. SEP6(2)	ESS3.A Natural Resources • Resource availability has guided the development of human society. ESS3.A(1) ESS3.B Natural Hazards • Natural hazards and other geologic events have shaped the course of human history; they have significantly altered the sizes of human populations and have driven human migrations. ESS3.B(1)	Patterns • Empirical evidence is needed to identify patterns. CCC1(5) Cause and Effect • Empirical evidence is required to differentiate between cause and correlation and make claims about specific causes and effects. CCC2(1)

Assessment Matrix

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Constructing Explanations and Designing Solutions			*Final Performance Task*	
ESS3.A Natural Resources			*Final Performance Task*	
ESS3.B Natural Hazards	Generating Ideas			
Patterns			*Final Performance Task*	
Cause and Effect	Generating Ideas		*Final Performance Task*	

Common Core State Standards Connections

	Anchor Phenomenon	Driving Question Board	Performance Task	Unit Reflection
Mathematics	MP.2 MP.4			
ELA/Literacy	RST.9-10.1 RST.9-10.7 WHST.9-10.2 WHST.9-10.1 WHST.9-10.9 SL.9-10.4			