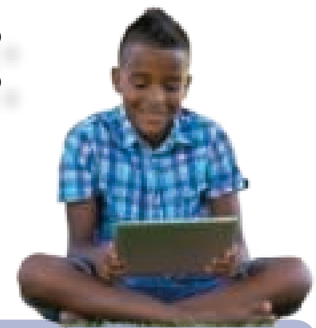
Plate Tectonics and Rock Cycling:

What causes Earth's surface to change?

Science Literacy



Teacher Guide

Core Knowledge Science®
GRADE 6
Core Knowledge®

This unit is a modified version of a unit that has earned the NGSS Design Badge. The sole instructional modification is the addition of Core Knowledge Science Literacy content. The modification has not been reviewed.

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Teacher Guide

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ISBN: 978-1-68380-789-6

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BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources

Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to:

- the unit's comprehensive materials list
- a full unit pacing snapshot
- lesson guidance slides
- all other recommended resources.

www.coreknowledge.org/cksci-online-resources

Student Work Pages

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.

Student Books

All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

What causes Earth's surface to change?

Building Toward NGSS Performance Expectations

MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history.

MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.

MS-ESS2-3: Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.

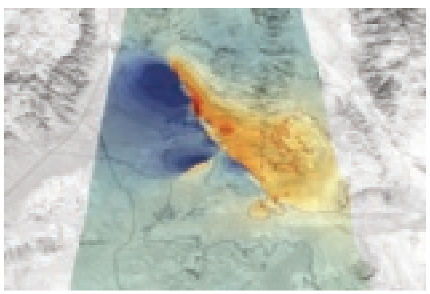
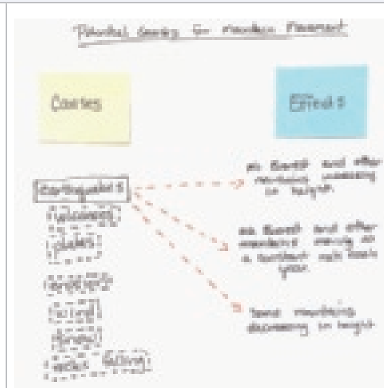
MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process.

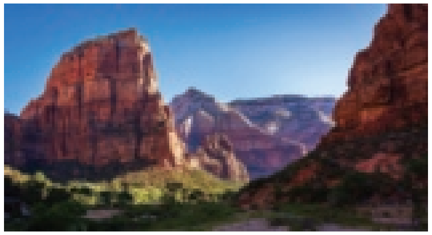
UNIT STORYLINE

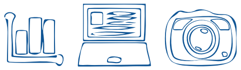
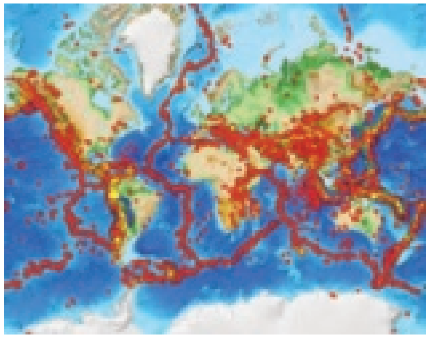
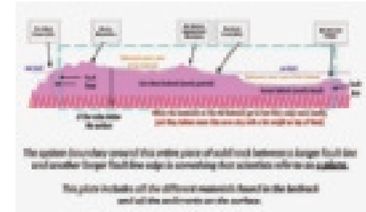
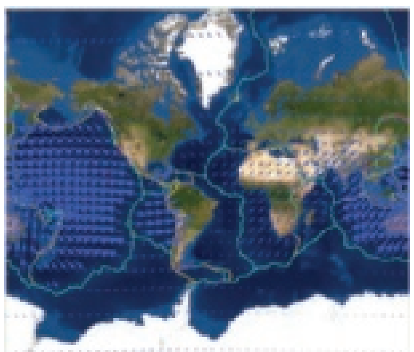
How students will engage with each of the phenomena

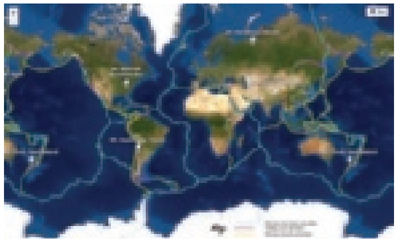
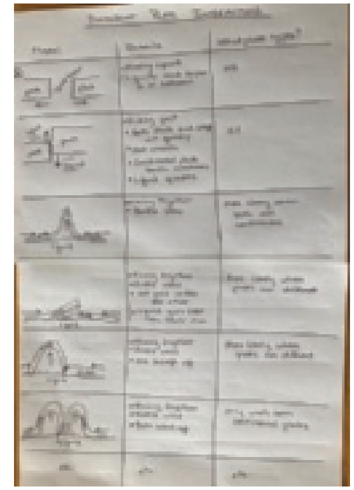
HANDS-ON/ LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

What causes Earth's surface to change?

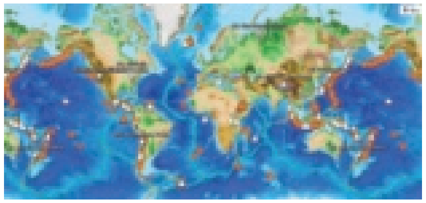
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **4 days** **What is causing Mt. Everest and other mountains to move, grow, or shrink?** Anchoring Phenomenon	 *Mount Everest and other mountains change in height and location.*	We read about how Mt. Everest is getting taller and moving yearly to the northeast. We analyze other mountain peaks around the world and find that other mountains are also getting taller, but others are shrinking. We develop an initial model explaining how mountains grow, move, and shrink. We brainstorm related phenomena, ask questions, and generate a list of data and information we need to better understand how mountain peaks can grow, shrink, and move. We figure out: • Some mountains move. • Mountains can get taller. • Mt. Everest is growing over time—new data shows. • Mountains can also shrink.	
Navigation to Next Lesson: We identified a variety of possible causes for growth and movement of mountains; one of the main ones were earthquakes. . . . So are there patterns between where earthquakes are found and where mountains are located?			
LESSON 2 **2 days** **How are earthquakes related to where mountains are located?** Investigation	 *After an earthquake occurred in Ridgecrest, California, a shift in the location and the elevation of the surface was observed.*	We look at data sources from Ridgecrest, CA before and after an earthquake. We use Seismic Explorer to determine that there seems to be a pattern with greater earthquake activity at mountains that are increasing in elevation. We figure out: • The ground moves back and forth in an earthquake. • Some parts of the surface crack open with a noticeable difference in between the ground on either side of the crack after an earthquake. • Earthquakes exist on or near almost all mountain ranges. • There seems to be a correlation between when mountains were highest or growing and where the earthquakes are the largest or most frequent. • While earthquakes seem to be correlated to changes in elevation, we are uncertain what is occurring under the surface, and what the land is like under the surface.	

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
⇩ **Navigation to Next Lesson:** We think that earthquakes are correlated to mountain changes in location and elevation, but want to know what is underground where earthquakes occur.			
LESSON 3 **2 days** **How does what we find on and below Earth's surface compare in different places?** Investigation	 *The properties of solid rock, bedrock, change as we move deeper underground due to increasing pressure and heat.*	After we figure out that earthquakes are correlated to mountain changes, we wonder what is happening underground where earthquakes occur and what we will find at and below the surface in different places around Earth. We develop models and gather data from various media and investigations about the structure and composition of materials at and below the surface. We share observations and data and update our Progress Trackers. We figure out: • Sediment and solid rock make up Earth's surface. • Solid rock, known as bedrock, is found on, near, or below the surface of Earth. • As we move deeper underground, rocks become increasingly hotter and compressed. • This can cause rocks to change state, and tend to more readily move and shift. • The rock deep below the ocean bottom is denser than the rock deep below the continents.	
⇩ **Navigation to Next Lesson:** We have considered how bedrock compares at different places on Earth, and now we are wondering what happens to that bedrock when an earthquake occurs.			

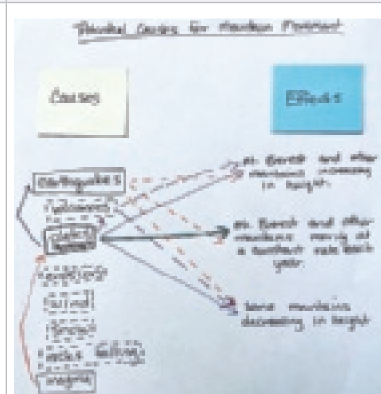
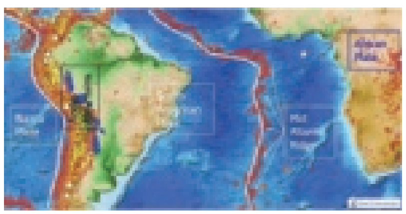
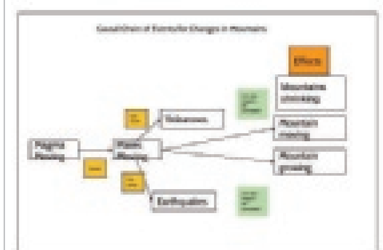
<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr><td>LESSON 4
2 days
What is happening to Earth's surface and the material below it during an earthquake?
Investigation
</td><td>
Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.
Plates on Earth's surface are surrounded by long lines of fault lines. There are many plates that make up the surface of Earth.</td><td>We develop a profile view model of Ridgecrest. We use a foam board to model the bedrock and determine the break in the land must go all the way through the bedrock. We analyze the area of the earthquake by making a cross section in Seismic Explorer. We develop a profile model of North America. We determine that the big sections of Earth between long fault lines are plates. We look at a world map for where there could be other plates on the map. We figure out:
• Sections of bedrock in between the fault lines of cracks from earthquakes are called plates.
• These cracks go down through the bedrock to where the rock begins to creep and move.
• There are other plates in the world that can be found in between the lines of other long sections of fault lines.
• Models of the crust and mantle have scale limitations due to the size of the Earth and its layers.</td><td></td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: If the North American plate is one solid plate and Mt. Mitchell is moving to the west 2 cm per year, then what is causing the mountains to move? If when a plate moves and everything above it moves too, then can plates move a whole mountain?</td></tr>
<tr><td>LESSON 5
1 day
How does plate movement affect the land around mountains such as Mt. Everest?
Investigation, Putting Pieces Together
</td><td>
Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.
Plates on Earth move at constant speeds and in specific directions.</td><td>We look for patterns in GPS data to examine land movement around Mt. Mitchell, and use a physical model to demonstrate that the entire North American plate moves at a constant speed and in a specific direction. We further revise a cross section model of the North American plate from the previous lesson to connect its movement to the behavior of the deeper, hotter bedrock. We use Seismic Explorer to investigate the movement of all plates on Earth's surface. We figure out:
• All plates are constantly moving in different directions and at different speeds.
• Plates move because they sit on top of deeper, warmer rock layers which move, or creep.
• When creep occurs, mountains and all other features on the plate above also move.</td><td></td></tr>
<tr><td colspan="4">⇩ Navigation to Next Lesson: All these plates are moving which helps us explain how mountains move, so how does this help us explain what happened at Mt. Everest and other mountains that are seeming to grow? Or about mountains that are shrinking?</td></tr>
</table>

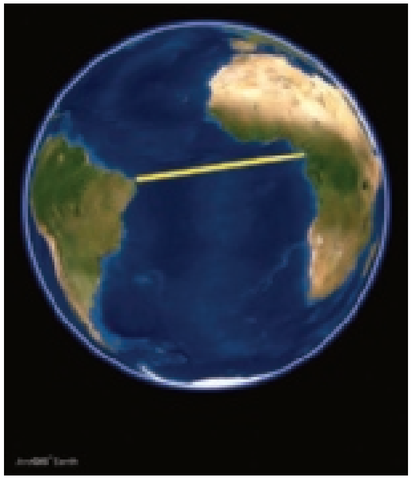
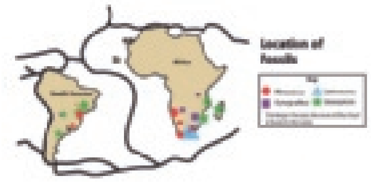
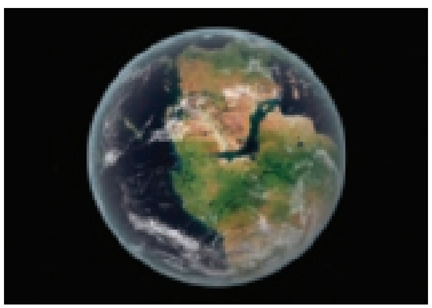
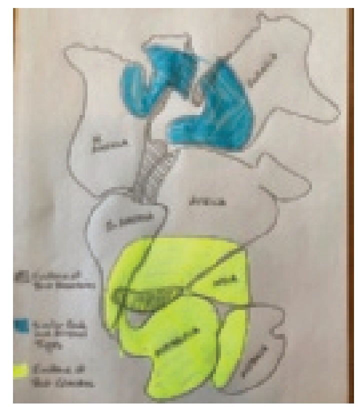
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 6 **3 days** **How could plate movement help us explain how Mt. Everest and other locations are changing in elevation?** Investigation, Putting Pieces Together	 *Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.* *When plates on Earth move, they can move together, move apart, or slide past each other. Sometimes one plate goes under another and/or pushes another plate up.*	We use models of plates and plate movement to identify and describe in detail the results of plate interactions between plates of similar or differing densities, and develop drawn models to communicate our findings. We use the models we develop to help explain what might cause the elevation changes and other changes we know about at Mt. Everest. We consider how earthquakes could be a result of uneven plate movement. We celebrate how many questions we can now answer from the DQB. We figure out: • When plates move towards each other, they collide and mountains can get taller. • Plates can move next to each other in opposite directions. • Plate boundaries or edges are rough, and so when they interact they can get stuck against each other or slip against each other, which we can feel as earthquakes. • Plate movements cause earthquakes. • Plate movements can cause mountains to get taller.	

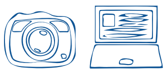
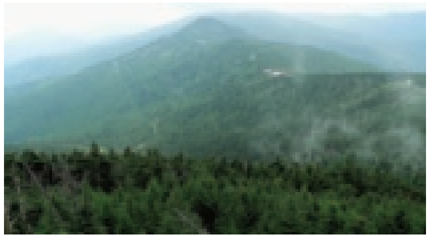
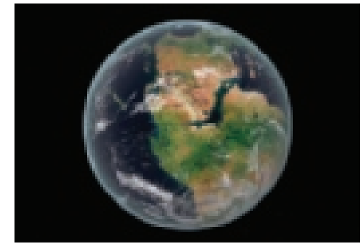
Navigation to Next Lesson: We see that earthquakes and plates have an impact on mountain size and movement, but we also saw evidence of some other potential causes that seemed to be occurring at places where these mountains were forming. We decide to revisit the cause board and see what other potential causes might be impacting mountains related to plate movement.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 **1 day** **What happens at mountains where we see volcanic activity?** Investigation	 *Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.* *Volcanoes occur where oceanic plates collide with continental plates. Volcanoes can either build up or destroy landforms when they erupt.*	In this lesson, we use map images to determine that most volcanoes occur along the boundary between oceanic and continental plates. We observe and describe what happens when a denser oceanic plate collides with a less dense continental plate. We revisit our mountain cards from Lesson 1, and read to figure out that volcanic eruptions can either add new earth material to existing landforms or destroy them. We update our Potential Causes for Mountain Movement Chart. We figure out: • Volcanoes occur in lines where an oceanic plate collides with a continental plate. • When an oceanic plate collides with a continental plate, the oceanic plate moves under the continental plate. • The oceanic plate heats up, causing the bedrock and sediments to melt and the water in the sediments to boil. • The melted earth materials and steam move upward through openings called volcanoes in the continental plate. • Volcanic eruptions can cause mountains to grow or shrink in height.	

⇩ **Navigation to Next Lesson:** We now know that volcanoes can occur where plates are colliding and as one goes under the other some of the magma comes to the surface. What is happening where plates are moving apart?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 8 **2 days** **What is occurring at locations where two plates are moving away from each other?** Investigation	 *Steaming cracks in the ground can be found along the Mid-Atlantic Ridge in Iceland.*	We make claims about what could be occurring at the Mid-Atlantic Ridge. We collect evidence to determine if the claims are supported or refuted by evidence. We use our knowledge of the ridge, volcanoes, and the presence of magma to update our Potential Causes for Mountain Movement chart. We figure out: • Plates are moving apart along the Mid-Atlantic Ridge. • Scientists call the place where two plates are moving apart a ridge. • Magma from the mantle is pushing up from under the plate, which can be seen in places like volcanoes and fissures in Iceland and along ridges. • New oceanic plate material is being formed at ridges. • The pushing of magma on the plates causes the plates to move, which causes changes to mountain elevation and location over time.	
⇩ **Navigation to Next Lesson:** We have updated our Potential Causes for Mountain Movement chart to reflect magma from the mantle as a mechanism for plate movement, and think we can now explain the causal chain of events that can lead to a change to mountain elevation and a change in location over time.			
LESSON 9 **1 day** **What causes mountains to change?** Putting Pieces Together	 *Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.* *Mountains change due to plates moving caused by magma moving.*	We revisit our Potential Causes for Mountain Movement chart to take stock of what we have figured out. We revise this chart to capture the causal chain of events that need to occur for a mountain to move or grow. We revisit the DQB to see what questions we can answer and we make predictions about what we think the Andes Mountains and the Mid-Atlantic Ridge will look like in the future and what it looked like in the past. We figure out: • Plates move because the magma underneath them is moving. • Plate movement causes changes to mountains.	
⇩ **Navigation to Next Lesson:** Now that we know what causes mountains to grow and form, we wonder if the mountains we have been investigating (and the plates they are connected to) have always been where they are today, or were they in very different places and at very different heights in the very distant past.			

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 **1 day** **Where were Africa and South America in the past?** Investigation	 *The distance between continents has been increasing over time.*	We use math to determine that Africa and South America could have been together 146 million years ago and reason out data from this time period will be found underground. We look for patterns in mapped data across the continents from this period. We then complete an exit ticket to make a claim about the two plates touching. We figure out: • Oceanic plates that were created over time were not always in existence. • Average rates of plate movement and plate direction can be used to determine where plates were once located. • Small changes to the distance between continents can add up to larger visible changes seen from a larger scale. • Older rock and associated fossils can be found under younger rock and fossils. • To support that two land masses were once together, patterns in data across the two land masses need to be similar or the same. • Data from rock strata, fossils, and other changes in land supports that the African and South American continents were once together at the Mid-Atlantic Ridge.	
⇩ **Navigation to Next Lesson:** Though we determined that Africa and South America were once together in the distant past (millions of years ago), we are now wondering if other continents (and the plates they are connected to) used to be located in different places on Earth as well in the distant past.			
LESSON 11 **2 days** **Where were the other plates located in the distant past?** Investigation, Putting Pieces Together	 *Continental plates have moved over the surface of the spherical Earth over many millions of years, resulting in their current locations on the globe.*	We use multiple types of data from models of all the land masses as evidence to develop a flat map model that predicts where the land masses used to be located relative to each other millions of years ago. We identify and discuss the strengths and weaknesses of the evidence supporting our model. We diagram our model and the data that supports it, and articulate our reasoning to explain the positions of the land masses millions of years ago that are predicted by the model. We figure out: • All major land masses were once touching, forming a part of a large single landmass that existed hundreds of millions of years ago. • Multiple sources of data are necessary to determine where plates were located in the past.	

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
⇩ **Navigation to Next Lesson:** We are wondering where mountains that aren't at plate boundaries today, like the Applachians and Urals, come from?			
LESSON 12 **1 day** **Where did mountains that aren't at plate boundaries today, like the Appalachians and Urals, come from?** Putting Pieces Together, Problematizing 	 *The Appalachian Mountains are decreasing in elevation, and the Ural Mountains are neither increasing nor decreasing in elevation.*	We use map images and data to compare the mountain sites we are studying. We remember that the Appalachians are decreasing in elevation, while the Urals are neither increasing nor decreasing. We know that colliding plates cause mountains to form and increase in elevation, but the Appalachians and the Urals are not located near plate boundaries. We use evidence from an online simulation to construct an explanation for how and when the Applachians and the Urals were formed. We figure out: • The Appalachian Mountains, first formed 470 million years ago, and the Ural Mountains, formed more than 300 million years ago, were both created in the same way that other mountains were formed—through plate collisions. • Plate interactions cannot explain why the Appalachians are decreasing in elevation or why the Ural Mountains are neither increasing or decreasing in elevation.	
⇩ **Navigation to Next Lesson:** Though we figure out when the Applachians and the Urals were formed, this still doesn't explain why there would be decreases in height occurring at Mr. Mitchell (in the Appalachians) if there is no plate boundary there now, and why we don't see similar decreases in height in a different mountain range where there is no current plate boundary now (the Urals).			
LESSON 13 **1 day** **What causes mountains to shrink in elevation?** Problematizing 	 *Scientists can measure both the rate of uplift and the rate of erosion at different mountain sites.*	After recalling what we already know about erosion and weathering, we read about erosion rates and how scientists use these rates to determine how erosion is changing the surface. Then, using both the erosion rates and uplift rates for Mt. Everest and Mt. Mitchell, we develop a representation of each model and how these two processes are affecting them. We determine that when erosion rates are higher than uplift rates, like at Mt. Mitchell, a mountain will shrink in elevation. We figure out: • The relationship between the erosion rates above the surface and the uplift rates below the surface determine the elevation above sea level. • Erosion rates greater than uplift rates result in decreases in elevation, erosion rates less than uplift rates result in increases in elevation, and erosion rates equal to uplift rates result in no elevation change.	

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
⇩ **Navigation to Next Lesson:** Now that we know that there are processes above Earth's surface, as well as processes below the surface that affect how Earth's surface changes, we want to see if we can use both of these sets of processes to explain one of the lingering questions from Lesson 1 (a marine fossil on the top of Mt. Everest), as well as any lingering questions on our Driving Question Board.			
LESSON 14 **2 days** **How is there an exposed marine fossil on Mt. Everest? And, what other remaining questions from our Driving Question Board can we now answer?** Putting Pieces Together	 *Ancient marine fossils can be found at the top of many mountains.*	We revisit our Driving Question Board and determine what questions we have made progress on. We explain our related phenomena. We revisit our mountain cards to determine that we still need to explain the presence of marine fossils on mountains. We gather evidence to help support what is occuring for marine fossils to end up on mountains and take an assessment. We then revisit our Driving Question Board and answer our unit question. We figure out that: • Plate movement has caused uplift to occur at mountains, pushing up rocks that used to exist on ancient seafloors. • Over time, marine fossils from the ancient seafloor are exposed due to erosional processes. • Erosional processes will always be occurring and will continue into the distant future.	
⇩ **Navigation to Next Lesson:** There is no next lesson.			
LESSONS 1-14 **26 days total**			

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstration, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., wearing safety goggles, non-latex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults, and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgement form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle school activities at the following location: (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a non-latex apron, and non-latex gloves during the set-up, hands-on investigation, and take down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip and fall hazard.
3. Follow your Teacher Guide for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.

Specific safety precautions are called out within the lesson using this icon and a callout box.

What is the anchoring phenomenon and why was it chosen?

For the anchoring phenomenon, students read text about how Mt. Everest has increased in elevation over time and analyze data cards about 5 other mountains around the world looking for evidence of other mountains changing as well. This phenomenon around the tallest mountain changing in height is confounding and supports students in beginning to think about how other places on Earth's surface might be changing as well.

Each unit's anchoring phenomenon is chosen from a group of possible phenomena after analyzing student interest survey results and consulting with several external advisory panels. The Mt. Everest and other mountain cases analyzed in this unit were chosen for the following reasons:

- Mt. Everest, as the tallest mountain above sea level, is familiar to students and surprising to read that a mountain can change in height. In addition, the most recent height was determined when scientists from Nepal and China agreed to share data for more accuracy. This was added to the initial article students read to support the Nature of Science ideas that more data leads to more accuracy.
- Students' experience with mountains changing over time is mostly limited so a set of 5 other mountain cases are also part of the anchoring lesson to provide students with additional information about whether mountains change. The addition of these data cards helps students begin making connections to changes in the land around the places they live and visit.

What are the NGSS Dimensions developed in this context?

This unit is guided by two big ideas: (1) processes that build up and (2) processes that wear down Earth's surface. The design of this unit is around the idea that Earth's outer layer, the crust, is constantly changing. It is shaped by internal and external processes working from below and above to both build up and wear down Earth's surface over long periods of time. The unit includes plate movement due to the magma, which is one causal mechanism behind why the plates move in different directions, colliding and spreading away from one another. It also includes processes from above, such as rates of weathering and erosion, that break down rock and landscapes over time. Fossil records, land mass data, and rock strata are used by students to better understand the changes to Earth's surface over time, the spatial and temporal scales of these changes.

In the anchoring lesson, students read a headline claiming that Mt. Everest has grown taller, leading to questions about how a mountain can grow. Students read an article explaining how scientists from both Nepal and China collaborated to share GPS data and survey data to find accurate measurements of Mt. Everest and determine Mt. Everest is taller than the last time it was measured. Students also read that between the first documented measurement of Mt. Everest about 165 years ago, the mountain is 30 feet taller and that, in addition to growing in elevation, Mt. Everest moves towards the NE about 4cm/year. Students wonder if other mountains are also changing in similar ways. Students then analyze five other mountains found around the world and find that there are other mountains changing in elevation and in location. This makes students wonder what could ***cause*** a mountain to change. Students share related phenomena we have experienced or heard/read about and what they think causes their related phenomena to change as well.

The first lesson set uses this anchor to establish that there are multiple potential causes that could be leading to these mountains (and eventually the land beyond the mountains) to change. Through careful investigations driven by the ideas for potential causes, students establish that Earth's crust is not one solid piece of rock, but actually made up of plates—thick slabs of the crust (sediment on top and bedrock below)—that move in different directions. Students use a data visualization tool (Seismic Explorer), maps, informational texts and two hands-on investigations to identify earthquake and landform patterns. These sources of evidence are used to understand the different directions the plates are moving and what happens when these plates interact. Students find out that the crust gets gradually hotter with depth and investigate characteristic changes to Earth materials at higher temperatures through a rock investigation lab. As they build a causal chain of the processes occurring that are related to or causes of the surface of Earth changing, they connect to previous ideas about how temperature can indicate the flow of energy. Using this information, they develop models to explain colliding plates and plates that spread apart. Students also explain that plate movement is one of the causes of changes to Earth's surface. By the end of this lesson set, students have put together key ideas for causes of change over time to the surface of Earth in the current day.

In the second lesson students apply what they have figured out in the first lesson to develop a model of what Earth might have looked like in the past. They analyze and interpret multiple data sets including past mountain locations, past glaciers, past coral reefs, fossil and rock strata. Students use plate movement data they figured out in the first lesson set, along with these sets of data to develop a model of where the continents could have been in the past based on data across the multiple data sets. At this point in the unit, students can explain what causes mountains to move and increase in elevation, but they still wonder about what causes a mountain to decrease in elevation. Students use their prior knowledge from elementary school around erosion and weathering and an informational text to figure out that erosion can affect the height of the land in different areas. Students read about how scientists measure erosion of an area by different processes, like river flow and glacier movement, and put these pieces of data together to calculate an erosion rate for an area. Using this, along with uplift rates (or how much an area is being pushed up from plate movement) students figure out that if erosion rates are higher than uplift rates, an area will decrease in elevation over time. The unit culminates with students using the key ideas of these forces (erosion and plate movement) to explain how a marine fossil from hundreds of millions of years ago could be exposed at a mountain top.

This unit builds toward these performance expectations:		
MS-ESS1-4: Construct a scientific explanation based on evidence from rock strata for how the geologic time scale is used to organize Earth's 4.6-billion-year-old history. MS-ESS2-1: Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process. MS-ESS2-2: Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales. MS-ESS2-3: Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and seafloor structures to provide evidence of the past plate motions.		
Focal Disciplinary Core Ideas	**Focal Science and Engineering Practices**	**Focal Crosscutting Concepts**
ESS1.C: The History of Planet Earth **The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analysis of rock strata and the fossil record provide only relative dates, not an absolute scale.** Students will engage in an analysis of layers to determine that older material is below younger material. Students, using mathematical reasoning, determine the time period from which we should gather data, and analyze rock strata and fossil data to determine the location of past continents from the specified time period. **ESS2.A: Earth's Materials and Systems** • **All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms.** Students determine that the energy derived from the sun is the main driver of erosional forces above the surface of Earth, and the magma is moving due to the energy derived from Earth's hot interior. These processes cause changes to Earth's materials (above and below the surface). • **The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.** Students analyze plate interactions from large spatial and temporal scales and compare them to annual rates of plate movement and erosional forces to determine that the processes of mountain creation and destruction occur over millions of years. Students use the understanding that these interactions have happened in the past and will continue to do so in the future to explain why a marine fossil found on Mt. Everest will not always be there. Students also learn about the causes and why earthquakes are such sudden events, and about how small erosional rates can add up over thousands to millions of years.	**Developing and Using Models:** Students develop, revise, and use models multiple times over the course of the unit to explain the causal relationship between plate movement, erosion forces and changes to the surface of Earth. Student models become more sophisticated over the course of the unit as they continue to collect evidence supporting causal changes to Earth. **Using Mathematical and Computational Thinking:** Students engage with mathematical reasoning as they grapple with what Earth looked like in the past. Using rate of plate movement, students determine where the continents could have been in the past. Students also work with representations of very large data sets through computer interactives and mapped representations.	**Cause and Effect:** This unit follows a thread of causal and correlational relationships in connection with mountain change. Students begin the unit by brainstorming potential causes of mountain movement, such as earthquakes, volcanoes, erosion, etc. Then through the unit they investigate how each of these processes happens and the effect they have on Earth. **Scale, Proportion, and Quantity:** Through the unit, students routinely work with scales that are too small or large to be observed in our given space and over our lifetimes. Students consider how plate movement happens very slowly, but over the course of millions of years, large plates can move great distances and at scales that can be seen globally. Students also learn how erosion happens very slowly and at a small scale, but can make larger changes over geologic time.

Focal Disciplinary Core Ideas	Focal Science and Engineering Practices	Focal Crosscutting Concepts
ESS2.C: The Roles of Water in Earth's Surface Processes **Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.** Students learn about erosional rates on mountains and develop an understanding that the movement of water and wind cause weathering and erosion. These forces add up over time to change the land's surface and can decrease the size of mountains that are experiencing uplift at a lower rate than erosion. Erosion can also cause changes like the rounding out or wearing down of surfaces over time. **ESS1.C: The History of Planet Earth** **Tectonic processes continually generate new ocean seafloor at ridges and destroy old seafloor at trenches. (HS.ESS1.C GBE) (secondary)** Students analyze data from the Mid-Atlantic Ridge and plate movement data to determine that the seafloor and Atlantic Ocean is getting wider in that location. Students generalize this out to determine that over time, as plates move away from each other, new seafloor is created at ridges. Students analyze interactions at the Andes and determine that seafloor is also destroyed over time as plates move together. This occurs at all of our trenches. **ESS2.B: Plate Tectonics and Large-Scale System Interactions** **Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.** Students speculate that Africa and South America were once touching. They use data from their mathematically derived time period of when they might have been touching to explain that there are patterns across continents based upon rocks, fossil, land, and water patterns from before 146 million years ago. Students then wonder if all plates were once in different places, and use the data listed to determine that Earth's land masses have moved great distances, collided, and spread apart.	**Constructing Explanations and Designing Solutions:** As students carry out investigations and analyze data to collect evidence, they construct explanations at pivotal places in the unit to explain causal relationships between changes to Earth's surface and processes being investigated. Initially students are constructing explanations about relationships between earthquakes and mountains changing. Then they construct an explanation about ***plates moving***, and earthquakes and mountains moving. Eventually, at the end of the unit students can explain the relationship between processes above and below the surface and how they shape Earth.	**Stability and Change:** Throughout the unit, students often consider the small changes that occur to Earth's surface yearly (such as the plate movement rate, or rates of erosion versus uplift) to determine that while we cannot see these changes from day to day, we can see these changes over larger temporal and spatial scales. Students also study earthquakes to determine that they are sudden events that are the result of gradual changes that add up over time. **The unit also includes opportunities to practice using Patterns.**

How is the unit structured?

The unit is organized into two main lesson sets, each of which help make progress on a sub-question related to the driving question for the entire unit. Lessons 1-9 focus on developing science ideas behind what causes a mountain to grow and/or move. Lessons 10-13 transition to focusing on what can cause other mountains to change elevation and location. In Lesson 14, students apply what they have figured out about how Earth's surface changes to explain how a fossil can be found on a mountain top.

Driving question: What causes Earth's surface to change?

Lesson Set 1: *What causes mountains to grow and move?*		Lesson Set 2: *What can cause other changes to mountain elevation and location?*	
Lesson 1	**Lessons 2–9**	**Lessons 10–12**	**Lessons 13–14**
Students read an article about scientists discovering that Mt. Everest has increased in elevation. Then they analyze data about different mountains around the world and find others are also growing and moving.	Students investigate what could cause a mountain to form by figuring out more about Earth's surface and what is below the surface.	Students figure out where continents could have been and what mountains looked like in the past.	Students investigate erosion rates and figure out that the elevation of different parts of the Earth is affected by both erosion and uplift rates. When erosion rates are higher than uplift rates, mountains can shrink. Students apply what they have figured out about how Earth's surface changes to explain how a fossil can be found exposed at the top of Mt. Everest.

Where does this unit fall within the Scope and Sequence?

This unit is designed to be taught just after *Storms Unit* in the Scope and Sequence. As such, it can leverage ideas about earth system processes that cause motion above Earth's surface. Students can bring forward ideas about air temperatures and precipitation patterns from *Storms Unit* to bolster their final projects for the unit. The focal DCIs center over changes across large spatial and temporal scales and focus on changes that are seemingly small but add up over geologic time, such as the movement of plates over millions of years and erosion and uplift rates creating the increases and decreases to mountain elevation that can only be seen from a distance over large timescales.

Additionally, another prior unit, *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*, can provide science ideas for students as they investigate how energy transfers between materials and how this transfer of energy results in movement. This means ideas about energy and energy transfer developed in that unit can be leveraged in Lessons 8 and 13 of this unit.

The unit develops or expands students' understanding of energy flows and matter cycling within Earth's systems with an emphasis on time and spatial scales. The emphasized Grade 6-8 DCI elements are listed within a progression of learning across grade bands:

What additional ideas will my students have or know from earlier grades or units?

History of Planet Earth: Students will bring in ideas about events that can cause changes to Earth quickly *and* over longer periods of time. They will also know that rock layers and the location of fossils found in these layers can be used to determine when the different organisms were alive on Earth, with the fossils that are found further down being older than the fossils found closer to the surface. In this unit, students will use these ideas to argue where continents could have been in the past using fossil data and rock layer data.

Earth's Materials and Systems: In prior grades students will have figured out that wind and water can change how the land looks. They will also have ideas about the processes that erode and weather the land. In this unit students will explain why some mountains are shrinking in elevation while others are increasing in elevation using the competing forces of erosion rate and uplift rate data.

Plate Tectonics and Large-Scale Systems Interactions: Students will have had prior experience in early grades with different types of maps and what they represent. In intermediate grades, using maps, they will figure out that different land structures happen in patterns such as earthquakes and mountains. They will also determine that most earthquakes and volcanoes often happen at the intersection of the continents and oceans. In this unit, students use what they have figured out about these patterns as they investigate whether an earthquake could be related to Mt. Everest's increasing in elevation.

What are some common ideas that students might have?

Students will be challenged in this unit to think about processes that occur on very long time scales and also at very large spatial scales. This will likely be the first time they have thought about Earth system processes happening on spatial and temporal scales this large. Students will likely bring with them some knowledge of different geological time periods (e.g., Triassic and Jurassic time = time of the dinosaurs), but it is really not important for them to know the different names and time periods on a geological time scale. This unit challenges students to think conceptually about how long these processes take to occur, but they will not be asked to identify or name time periods.

To represent these spatial scale ideas, students will transition between top-down perspectives and cross-section perspectives to represent movement of magma and the plates of Earth's crust. Some students may readily come to class with a cross-section perspective, but likely many students will need guidance on drawing cross-sections, at least initially.

Many students may come to the unit with some ideas about "plates" and "plate tectonics." It is common for students to think that the continents are the plates and they "float" around slowly in the ocean. This unit purposely uses a global relief map with ocean floor topography (called bathymetry) to help students visualize that the bottom of the ocean is part of Earth's crust too, as the ocean has "plates" that move as well, and many plates include parts of continents and parts of ocean floors. Students may also believe that plates are made of only one kind of crust, such as oceanic crust or continental crust, when in reality many of the plates have a combination of both. Because of that, this unit defaults to the term land masses when talking about places that have a combination of crustal types.

Finally, many students may come to the unit thinking the inside of Earth is liquid lava. This is because all the images they see of hot stuff coming out of Earth is liquified rock, in the form of lava. In actuality, the mantle is made of molten rock (magma) that is more solid than liquid, but it behaves as a very thick semi-solid, similar to putty.

How will I need to modify the unit if taught out of sequence?

This is the fourth unit in 6th grade in the Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier or later in the middle school curriculum. These include:

- If taught before *Cup Design Unit*, students will not have developed ideas about thermal energy being transferred between particles and that particles of a material at a higher temperature transfer energy faster than particles of a material at a lower temperature. This idea is built on in the next unit, *Storms Unit*. Prior to lesson 8, students will need support in visualizing what is occurring to particles as temperature changes so they can figure out what happens to solid rock that gets heated to very high temperatures under the surface of Earth.
- If taught before *Storms Unit*, students will not have developed ideas about density in relation to energy being absorbed by particles and then being transferred between particles. Again prior to lesson 8, students will need some experience with what it means at a particle level when one section of material is denser or less dense than another section of material.

What mathematics is required to fully access the unit's learning experiences?

This unit exposes students to movement data using different measurements and time scales, and, importantly, the movement of two objects in relationship to one another. Students wrestle with GPS movement data in different directions and also visualizing the depth and breadth of earthquake patterns using a visualization tool. Prerequisite math concepts that may be helpful include:

- CCSS.Math.Content.4.MD.A.1 Know relative sizes of measurement units within one system of units including km, m, cm; kg, g; lb, oz; l, ml; hr, min, sec. Within a single system of measurement, express measurements in a larger unit in terms of a smaller unit. Record measurement equivalents in a two-column table.
- CCSS.MATH.CONTENT.5.MD.A.1 Convert among different-sized standard measurement units within a given measurement system (e.g., convert 5 cm to 0.05 m), and use these conversions in solving multi-step, real world problems.
- CCSS.Math.Content.5.NBT.A.3 Read, write, and compare decimals to thousandths.
- CCSS.Math.Content.5.NBT.A.4 Use place value understanding to round decimals to any place.
- CCSS.Math.Content.6.RP.A.2 Understand the concept of a unit rate a/b associated with a ratio a:b with $b \neq 0$, and use rate language in the context of a ratio relationship.

It is important to note that this unit is reinforcing some elementary mathematics standards in a new context and using scales at which students may have not considered before; thus, we anticipate that while some of the mathematics in this unit is aligned to upper elementary math development, it may be a new challenging context for students to apply the mathematics ideas.

What additional strategies are available to support equitable science learning in this unit?

The units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies which are integrated throughout the routines and are intended to increase relevance and provide access to science learning for all students. The units support these equity goals through several specific strategies such as: 1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and provide more accessible ways in which students can engage in learning experiences; 2) developing and supporting classroom norms that provide a safe learning culture, 3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas, and 4) specific strategies to supporting emerging multilingual students in science classrooms.

Many of these strategies are discussed in the teacher guides in sidebar callout boxes titled "Attending to Equity" and subheadings such as "Supporting Emerging Multilingual Learners" or "Supporting Universal Design for Learning." Other callout boxes with strategies are found as "Additional Guidance," "Alternate Activity," and "Key Ideas" and various discussion callouts. Finally, each unit includes the development of a Word Wall as part of students' routines to "earning" or "encountering" scientific language.

For more information about each of these different strategies with example artifacts, please see the Teacher Handbook.

GUIDANCE FOR DEVELOPING YOUR WORD WALL

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have "earned" that word and can add the specific term to the class Word Wall. These "words we earn" should be recorded on the Word Wall using the students' own definition whenever possible. On the other hand, "words we encounter" are "given" to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, words we encounter are helpful just in that lesson and need not be recorded on the Word Wall. However, if a word we encounter will be frequently referred to throughout the unit, it should be added to the Word Wall. As such, the Word Wall becomes an ongoing collection of words we will continue to use, including all the words we earn in the unit and possibly a few key words we encounter.

It is best for students if you create cards for the Word Wall in the moment, using definitions and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the posted meaning of the word, students "own" the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support.

Sometimes creating Word Wall cards in the moment is a challenge. The teacher guide provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate. If you keep one Word Wall in your classroom for several sections of students, you might choose to record each class's definition separately, and then propose an "official" definition to post the next day that captures the collected meaning.

The words we earn and words we encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

Lesson	Words we earn	Words we encounter	Words from previous unit
L1	magnitude, earthquake		
L2		earthquake depth, epicenter, causation, correlation	
L3	magma, (ore) deposits	sediment, bedrock, sedimentary	
L4		crust, mantle, plate	
L5			
L6		oceanic, continental	
L7		volcano, lava, destructive, constructive	
L8			density
L9			
L10			
L11			
L12			
L13		erosion rate, uplift rate	
L14			

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy routine integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things, and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form, and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and well-constructed paragraph.

SCIENCE LITERACY: PREFACE

Put Yourself in This Scene

Literacy Objectives

✓ Initiate thinking about the need to evaluate information in text and images.

Literacy Activities

- Read a brief scenario to pique interest, launch discussion, and begin to frame expectations.

Instructional Resources

Student Reader

Preface

Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigations

The reading of the Preface is appropriate during the first week of unit instruction. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS

Disciplinary Core Ideas ESS2.A: Earth Materials and Systems The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2);

ESS2.C: The Roles of Water in Earth's Surface Processes Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. (MS-ESS2-2)

Science and Engineering Practices: Asking Questions and Defining Problems; Engaging in Argument from Evidence

Crosscutting Concept: Scale, Proportion, and Quantity

CCSS

English Language Arts
RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.8: Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. No Core Vocabulary terms are highlighted in the Preface.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

fracking **science literacy**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the reading.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know that for the Science Literacy routine, they will read independently and then complete short writing assignments. The reading selections relate to topics they will be exploring in their Plate Tectonics and Rock Cycling unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have available class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface about the fracking scenario is written at approximately Lexile 1000–1100, which leans toward the high end of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion.

(FRIDAY)

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Student Reader

Preface

Pages 2–3 **Suggested prompts**	**Sample student responses**
How would you summarize the "scene" referred to in the title?	*It describes a social media post from Olivia, who is worried about the effects of fracking and a reply post from Emily, who thinks her worries are silly.*
What claim made in the first post is challenged in the reply post?	*that fracking will eventually break apart all of North America*
Which of the two people posting appears to have the most facts about this issue?	*the second person posting*
What additional claims does the reply post make?	*The water and sand pushed underground are controlled.* *It's not dangerous.* *The earthquakes are small.* *It's less damaging than digging oil wells.* *We still need oil and gas reserves, and fracking is a good way to get them.*
What questions should Olivia ask Emily to challenge her argument?	*Where did you get your facts supporting the idea that fracking causes less damage to the environment than digging wells?* *What research supports your statement that the earthquakes caused by fracking are not dangerous?* *How do you know that fracking is the best way to maintain oil and gas reserves?*
If you wanted to learn more about how fracking is done and its effects, what reliable sources could you use?	*Ask an Earth science teacher.* *Read articles in science magazines or newspapers.* *Ask a reference librarian for sources.* *Read the U.S. Geological Survey website.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 2–3 **Suggested prompts**	**Sample student responses**
What questions about fracking would you try to answer using these sources?	*Can fracking really break North America into pieces?* *Are water and sand the only materials pushed into the ground?* *How is the oil collected and transported?* *Are there effects on the health of the fracking workers or people who live nearby?* *Does taking water for fracking affect the amount of water available for other uses?* *Do the earthquakes caused by fracking cause damage to people's homes and other community structures?*
What general questions could you ask about continents breaking up?	*Can it really happen?* *Has it happened in the past?* *How fast can it happen?* *If so, what causes a continent to break apart?*
By now you've realized that fracking is controversial. What makes scientific literacy harder when an issue is controversial?	*Everyone feels very strongly about it, and they may be only giving out the facts that support their position.*

KEY IDEA—Point out that, without research into the sources of information in the claims made by the writers of the two social media posts, there isn't really a way to make an informed decision about which side to take about such an issue. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more knowledge to apply to the scenario, and they will circle back to the topic of fracking-caused earthquakes—and whether they can cause North America to break apart—at the end of the unit.

LESSON 1

What is causing Mt. Everest and other mountains to move, grow, or shrink?

Previous Lesson

There is no previous lesson.

This Lesson

Anchoring Phenomenon

4 DAYS

We read about how Mt. Everest is getting taller and moving to the northeast over time. We look at data of four other mountains and find out that they are also changing in elevation, with some shrinking. We model, at a scale larger than we can see, what we think causes a mountain to change in elevation. We brainstorm related phenomena where land near us has changed over time. This leads us to a broad set of questions that we use to form our Driving Question Board (DQB). We brainstorm possible investigations we could do and additional data sources that could help answer our questions.

Next Lesson

We will look at data sources from Ridgecrest, CA before and after an earthquake and determine that there may be a correlation between earthquakes and mountain growth. We will use Seismic Explorer to investigate the depths and magnitudes of earthquakes at our case sites.

Building Toward NGSS

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

What Students Will Do

1.A Develop a model showing what is happening at a scale larger than we can see (patterns) to help explain what happened to the different mountains to (cause) them to change (in elevation and/or location).

1.B Ask questions that arise from our analysis of information showing that Mt. Everest and four other mountain peaks are changing to seek additional information about what caused the changes (effects) we read about.

What Students Will Figure Out

- Some mountains move.
- Mountains can get taller.
- Mt. Everest is growing over time.
- Mountains can also shrink.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	4 min	**EXPLORE AN INTERESTING PHENOMENA** We are introduced to a headline claiming that Mt. Everest is growing. We find where Mt. Everest is located on the world map.	A-B	1 Earth squish ball globe with countries labeled, 1 Earth squish ball globe with no labels, 2 paper coffee sleeves, World Map (large wall global relief map), inflated 16" inflatable globe, 2 sticky notes (or this can be a regular sticky note cut in half)
2	10 min	**READ ABOUT MT. EVEREST** Students read about how Mt. Everest is changing based on data collected by Nepal and China.	C-D	*What is happening on Mount Everest?*
3	6 min	**RECORD WHAT IS HAPPENING AT MT. EVEREST** Students share what they read about what is happening at Mt. Everest and how this was recorded.	E	*What is happening on Mount Everest?*, Mt. Everest Notice and Wonder poster
4	7 min	**DEVELOP INITIAL MODEL** Students develop an initial model to represent what they think is causing Mt. Everest to move and increase in elevation over time.	F-G	*Explain How Mt. Everest Moves and Grows*, *Alternate: Initial Model*
5	3 min	**REVISIT CLASSROOM NORMS** Have students review the classroom norms and set expectations for their work together on a consensus model. Prompt students to pick one norm to focus on for today.	H	*What is happening on Mount Everest?*, *Explain How Mt. Everest Moves and Grows*, chart paper, markers, Discussion Norms poster
6	15 min	**DEVELOP A CLASSROOM CONSENSUS MODEL** The class develops a consensus model to represent what is happening at Mt. Everest and what is causing these changes.	I	*Explain How Mt. Everest Moves and Grows* or *Alternate: Initial Model*, What Is Causing Everest to Move and Grow initial model poster, markers, Discussion Norms poster *End of day 1*
7	5 min	**NAVIGATION** Students share where else mountains can be found on Earth. Then they consider what data from these mountains we would want to look for, to help us figure out what is happening at Everest.	J	

Part	Duration	Summary	Slide	Materials
8	20 min	**COMPARE DIFFERENT MOUNTAIN PEAK INFORMATION CARDS** Students analyze 5 different mountain cases in a jigsaw to look for similar data at other mountains about movement or growth.	K	*Data Cards on Other Mountains and Mt. Everest*, Data Cards for Other Mountains and Mt. Everest, 1 Earth squish ball globe with countries labeled, 1 Earth squish ball globe with no labels, 2 paper coffee sleeves
9	7 min	**COMPARE MOUNTAIN SITE LOCATIONS** Students share with their small group the data they found for their assigned mountain about changes in elevation and lateral movement.	L	*Patterns of Change for Mountains*
10	13 min	**SHARE PATTERNS IN GROWTH AND MOVEMENT BETWEEN DIFFERENT MOUNTAINS** Students share with the class patterns they found that were similar for the different mountains that might also explain how a mountain could move and/or grow.	M	*Patterns of Change for Mountains*, World Map (large wall global relief map), large (4"x6") sticky notes or quarter sheets of paper with tape, sticky notes
				End of day 2
11	10 min	**DEVELOP INITIAL MODEL OF SHRINKING MOUNTAIN** Students will develop a model to represent what causes a mountain to shrink.	N	*Explaining Other Mountains That Shrink*
12	15 min	**ADD TO THE CLASSROOM CONSENSUS MODEL** The class develops a consensus model to represent mountains that are shrinking.	O	*Explaining Other Mountains That Shrink*, What Causes Mountains to Shrink initial model poster
13	15 min	**BRAINSTORM RELATED PHENOMENA** Students think about the land and landforms in the area they live where they have seen changes and brainstorm whether the causes of these changes could be similar to what is causing Mt. Everest to change.	P-R	Related Phenomena poster, sticky notes
14	5 min	**NAVIGATION** Use ideas from the consensus models and related phenomena to develop questions we can investigate.	S	
				End of day 3
15	5 min	**DISCUSS QUESTIONS TO POST ON DRIVING QUESTION BOARD** Provide question sentence stems to help students work on and share their questions from the last time to prepare to post them on the DQB.	T	sticky notes (or index cards and tape), marker

Part	Duration	Summary	Slide	Materials
16	25 min	**BUILD THE DRIVING QUESTION BOARD** Develop the DQB with contributions from all students in the class.	U-V	*What is happening on Mount Everest?*, *Explain How Mt. Everest Moves and Grows*, *Explaining Other Mountains That Shrink*, *Patterns of Change for Mountains*, markers, sticky notes
17	12 min	**BRAINSTORM IDEAS FOR DATA AND INFORMATION NEEDED** Create an "Ideas for Data and Information We Need" poster and record the class's thoughts on how to figure out the answers to our initial questions as we move forward.	W	Ideas for Data and Information We Need poster, DQB (around the two consensus models and related phenomena), markers
18	3 min	**NAVIGATION** Allows students to reflect on the Driving Question Board and offer suggestions for next steps.	X	

End of day 4

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *What is happening on Mount Everest?* • science notebook • *Explain How Mt. Everest Moves and Grows* • *Alternate: Initial Model* • *Explain How Mt. Everest Moves and Grows* or *Alternate: Initial Model* • *Data Cards on Other Mountains and Mt. Everest* • *Patterns of Change for Mountains* • *Explaining Other Mountains That Shrink* • sticky notes (or index cards and tape) • marker	• 1 Earth squish ball globe with countries labeled • 1 Earth squish ball globe with no labels • 2 paper coffee sleeves • Data Cards for Other Mountains and Mt. Everest	• World Map (large wall global relief map) • inflated 16" inflatable globe • 2 sticky notes (or this can be a regular sticky note cut in half) • Mt. Everest Notice and Wonder poster • chart paper • markers • Discussion Norms poster • What Is Causing Everest to Move and Grow initial model poster • large (4"x6") sticky notes or quarter sheets of paper with tape • sticky notes • What Causes Mountains to Shrink initial model poster

	per student	per group	per class
			• Related Phenomena poster • Ideas for Data and Information We Need poster • DQB (around the two consensus models and related phenomena)

Materials preparation (20 minutes)

Online Resources

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

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

Prior to day 1:

1. Put up the global relief map in your classroom where it is viewable by all. We will refer to this as the World Map. You may wish to add a title above it.
2. Inflate the 16” inflatable globe with topography representations. You will use this again in Lesson 11.
3. Look up the location of your town and Mt. Everest, and be ready to point out these locations on the class map.
4. In addition, look up the distance from your school to Mt. Everest.
5. Place each of the *Data Cards for Other Mountains and Mt. Everest* in a plastic sheet protector so they can be reused between classes. Students will revisit these over the course of the unit. Additionally, use *Data Cards on Other Mountains and Mt. Everest* to print a black and white copy for students to annotate and place in their notebooks.
6. A color copy of this reference can also be found in the Student Procedure Guids.
7. On days 1 and 3, pairs of students will need the two squish Earth globe balls and the coffee sleeves to use as they analyze mountain data.

You will need a copy of the global relief map posted in a location in the room that all the students can see and gather around. This map will be used multiple times over the course of the unit.

You will need two sticky notes for day 1. One should be labeled “Our School” with the distance in miles from your school to Mt. Everest. The second should be labeled “Mt. Everest.”

You will need 5 large (4”x6”) sticky notes for day 2, one per mountain case.

Prepare a space for your Word Wall that will include space for “Words We Encounter” and “Words We Earn.” “Words We Encounter” are specialized terminology we encounter in a piece of informational text that we need to know what they mean to comprehend the information. “Words We Earn” are words that we work together to make sense of over time in the context of figuring out the phenomenon. During day 1, add *earthquake* and *magnitude* under “Words We Encounter” from the reading.

Prepare all posters using chart paper and markers:

- Day 1 - Notice and Wonder; Initial Consensus Model for Mt. Everest chart
- Day 3 - Initial Class Consensus for a Shrinking Mountain Model
- Day 4 - Related Phenomena, Ideas for Data and Information We Need

Determine where to set up the Driving Question Board prior to starting day 4.

After your last class on day 4: Organize the questions on your Driving Question Board into categories that emerge across all your classes. After (or as) you reorganize the board at the end of this lesson, make a typed record of all the questions that are on the board so that you can print them out or share with students to reference in groups during future classes. One way to do this is to take a high resolution photo of the board or transcribe the questions on the board into a digital or electronic document.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

Students engage with the phenomenon through a headline claiming that Mt. Everest is growing and an article describing new data that has been collected collaboratively by Nepal and China. After developing an initial model representing what they think could be causing this, students analyze information about four other mountain peaks around the world to look for patterns in potential causes of changes to these landforms. The purpose of the anchor is to probe students' understanding of Earth's geologic processes, and how those processes help shape Earth's surface. It leverages ideas that students may have about how some changes in Earth's surface occur gradually and are almost undetectable at a glance (i.e. the growth of a mountain), while other changes may occur suddenly and are instantly observable (i.e. earthquakes). Additionally, the anchor allows students to ask questions about a single occurrence (Mt. Everest growing in elevation) and a pattern of occurrences (other mountains also changing in elevation around the world over time), and to identify the types of data and information required to answer questions about both the specific phenomenon (Mt. Everest) and the pattern of phenomena (other mountains) they've observed.

Where We Are NOT Going

As students share their ideas, you may hear them mention what they have heard about plates, plate tectonics, weathering and erosion. Encourage students to share their thinking, but avoid giving too much away at this point in the unit. Subsequent lessons will draw upon students' prior knowledge from earlier years and units regarding:

- Thermal energy transfer and convection to explain how Earth's surface is in constant motion due to movement within Earth's mantle. Students will build on their understanding of energy transfer from *Cup Design Unit* and *Storms Unit* in which they figured out energy transfers between particles, areas of high temperature have more particle motion and therefore transfer energy faster to cooler areas, and areas of higher density sink in comparison to areas of lower density (i.e.: less dense air masses rise while more dense air masses sink).
- Geologic events, such as earthquakes and volcanic eruptions, often occur in bands along boundaries between continents and oceans.
- Weathering and erosion as processes that help shape Earth's surface, which helps explain how wind and water slow the effects of uplift. Explaining how landforms get taller or shorter will be the focus of lesson sets 2 and 3.

While we are using the uplift rate of 2 cm, this does not reflect all forces that are contributing to the increasing elevation of the mountain range. Other forces, such as the buoyancy of the plates and isostasy are contributing to this change. These ideas are above grade band. The rate is also variable based upon these forces along with the tectonic processes continually contributing to the changing landscape, and erosional rates, which will be touched on in Lesson 13.

1. Explore an interesting phenomena.

4 MIN

Materials: 1 Earth squish ball globe with countries labeled, 1 Earth squish ball globe with no labels, 2 paper coffee sleeves, World Map (large wall global relief map), inflated 16” inflatable globe, 2 sticky notes (or this can be a regular sticky note cut in half)

Explore an Interesting Phenomenon. Show **slide A.** Say, *Have you ever heard of Mt. Everest? What do you know about it?* Hear from a few students about what they know about Mt. Everest.

Say, *I saw this interesting headline recently about Mt. Everest.* Read the headline off the slide stating it is the tallest mountain and that it grew. Say, *Turn and talk with a neighbor about what might cause a mountain to grow.* Ask a few pairs to quickly share their ideas with the class.

Locate where Mt. Everest is on a map with students. Show **slide B.** Bring students’ attention to the global relief map, which will be referred to as the World Map with students. Say, *Let’s mark on our World Map where Mt. Everest and our town/school is located.* Write “Our School” on one sticky note and “Mt. Everest” on a second sticky note.

Begin by placing a small sticky note, or half of a sticky note, labeled “Our School” to note the location of your town or school. Say, *The distance from our school to Mt. Everest is ______ miles. Let’s record that on our sticky note for our school.* Prior to class, write ___ miles from Mt. Everest on the “Our School” sticky note for your location so that you are ready with this information.

Say, *Mt. Everest is located on the Asian continent between Nepal and China. Does anyone know where the Asian continent is located on the World Map?*

Ask a student volunteer to point out the location of Asia on the map. Then point out the location of the Himalayas and Mt. Everest. Place the sticky note with Mt. Everest at the location. See image to the right.

Orient to the location on the globe.* Distribute both squish ball globes and 2 coffee sleeves to each pair of students. Hold up the 16” inflated globe (or classroom globe if you have one) and instruct students to demonstrate the following with their Earth squish ball globes with their partners. As students find these locations on their small Earth squish ball globe, verify these locations using the larger inflatable globe.

- Place each Earth squish ball globe on its own sleeve so that the northern pole is pointed to the ceiling.
- Ask each person to point to where we live on both Earth squish ball globes.
- Find India.
- Locate China and Nepal.
- Share with students that Mt. Everest is on the border between these two countries.

***Attending to Equity**
Universal Design for Learning:
To support students in map reading during this activity section orient students to your current location on the globe as well as the United States and other notable, meaningful landmarks to students. Providing physical objects and spatial models to convey perspective can help support *representation*, according to the UDL framework.

Additional Guidance

This is the first of many times over the course of the unit that students will be using this class global relief map. This type of map may be a new representation for students and they may have some questions about the different features found on the map. If you have the time, you can field their questions and take time to have students make sense of the map features. But in the next lesson, the class will be spending time making sense of and identifying different features of this relief map. The purpose of visiting the map here is for students to see where Mt. Everest is located and how this location compares to where your town/school is located.

2. Read about Mt. Everest.

10 MIN

Materials: *What is happening on Mount Everest?*, science notebook

Prepare science notebooks to record noticings and wonderings. Display **slide C.** Have students title a new page in their notebooks "Mt. Everest Reading" and make a T-chart below the title to record what they notice and wonder as they read an article about what happened at Mt. Everest.

Science Notebook

This is the first use of the science notebook for this new unit. You may need time to organize a new section in the notebook. It is recommended to have students do the following:

- Reserve a blank page at the start of the unit, to be titled on day 4 of this lesson when the class decides on the unit question after completing the DQB.
- After the title page, reserve 2 pages (4 pages front-to-back) for the table of contents (unless all tables of contents are at the front of the notebook).
- Reserve 8 pages (16 pages front-to-back) for the Progress Tracker.
- Number the pages so everyone begins the first investigation on the same page number (e.g., page 1 for the first page of the table of contents, page 5 for the first page of the Progress Tracker, and page 21 for the first Notice and Wonder chart they are making now).

Remind students that the notebook is their tool for recording their observations, evidence, and ideas to share with the classroom community. They should see it as a space to brainstorm and record their thinking as well as a place to show how their thinking changes as they learn more.

For more information on Science Notebook Management, refer to this section of the Teacher Handbook.

Gather additional information about this phenomenon from a reading. Keep **slide C** displayed. Distribute a copy of *What is happening on Mount Everest?* to each student. Tell students they will read the article with a partner.

Remind students of the close reading strategy. Display **slide D**. Remind students that close reading requires reading more than once and with different purposes and strategies for interacting with the text. Say, *As you read with your partner, remember to use our close reading strategies we have used in prior units. Pause at the end of each paragraph and record anything you have noticed and any questions you have about what you read.*

3. Record what is happening at Mt. Everest.

6 MIN

Materials: *What is happening on Mount Everest?*, science notebook, Mt. Everest Notice and Wonder poster

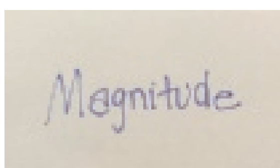
Share noticings and wonderings as a class. Show **slide E.** Have a piece of poster paper ready to record what students share. Say, *What were some things you and your partner noticed and wondered about what is happening to Mt. Everest?* Document students' ideas on the poster paper titled "Mt. Everest Notice and Wonder." These ideas on the poster paper may be helpful for students to refer to when they develop their initial model later in this lesson. Some potential noticings:

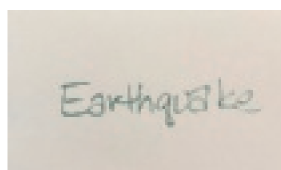
- *Mt. Everest has been recorded as 30 ft taller today than it was in 1856.*
- *Mt. Everest moves 4 cm on average every year to the NE.*
- *Mt. Everest increases in elevation about 2 cm on average per year.*
- *An earthquake occurred at Mt. Everest.*
- *Scientists aren't sure if the earthquake caused a change in height.*
- *GPS data were used to measure changes in Mt. Everest's location and height...like how our phone works with maps.*

Additional Guidance

There are two words introduced in the reading that students will work with in multiple lessons in this unit, "earthquake" and "magnitude". If your students bring these up as noticings and or wonderings, you may wish to add them to your Word Wall under the "Words We Encounter" section. In the next lesson, students will explore different earthquakes and be able to add to and move "magnitude" to the "Words We Earn" section of the Word Wall. In Lesson 6, students will develop a model of plates moving and what happens when they interact, earthquakes being one of these results. In this lesson, they can add to and move "earthquakes" to the "Words We Earn" section. These two words will also be used in the next unit, *Tsunami Unit*, so you might want to keep them up for that unit to support students in continuing to deepen their understanding of these terms.

Add *earthquake* and *magnitude*, if desired, to the Words We Encounter section of the Word Wall.





4. Develop initial model.

7 MIN

Materials: *Explain How Mt. Everest Moves and Grows, Alternate: Initial Model*

Brainstorm possible causes for changes in Mt. Everest. Show **slide F**. Say, *So, we found that Mt. Everest isn't only getting taller or increasing in elevation, but it is also moving. Let's pause and try to picture this.*

Support students in visualizing that the mountain is changing in multiple planes, both vertically and horizontally by modeling these movements using your own body. For example, as you say the mountain is getting taller you could bend your knees and then "grow" your body taller by straightening your knees. To help students visualize what direction northeast is so they can think about Mt. Everest moving this way, orient them to the cardinal directions of north, east, south, west in your classroom. Then face your body towards the north and point your right arm straight out to the east. Tell students northeast would be a point in between north and east. Then turn your body and walk in a direction that is between where you are facing north and where your arm is pointing east.

Say, *Take a couple minutes with your partner and discuss your ideas for what might be causing a mountain to be changing in both of these ways:*

- *Possible causes for the increase in elevation of Mt. Everest*
- *Possible causes for Mt. Everest moving to the northeast*

Develop an initial model for what is causing Mt. Everest to move and grow. Display **slide G.** Distribute *Explain How Mt. Everest Moves and Grows* to each student. Say, *We are going to take a few minutes to develop a model representing what we think could be causing these changes to Mt. Everest. What do we know is happening to Everest?* Use the images on the slide as a way to capture what we have all figured out about Mt. Everest so far from the reading.

- Mt. Everest is moving about 4 cm to the northeast every year.
- Mt. Everest is growing about 2 cm each year.

Say, *As you develop your model, think about where Mt. Everest is located, as seen from a bird's-eye view (from above) like on the map, and think about Mt. Everest the mountain. As you develop your model of what could be causing the tallest mountain to grow and move, why might it be helpful to think about not only where the mountain is located, but also what the area around the mountain looks like from above and from the side?* Sample student responses:

- There might be things under the mountain that are causing it to move.
- There might be things to the side of the mountain.
- Maybe it has to do with what the mountain is made up of.
- It might have to do with where it is located.

Say, *Take a few minutes to develop an initial model representing your ideas for:*

- *What might cause Mt. Everest to increase in elevation by 2 centimeters per year?*
- *What might cause Mt. Everest to move to the northeast 4 cm per year?*

Give students 5 minutes to develop their models.

***Attending to Equity**
Universal Design for Learning: Developing a model for something as large as a mountain to capture how it could be moving may be challenging for some students and they may not know where to begin. In addition, some students may benefit from seeing the location of Mt. Everest on a map as they are developing their model. *Alternate: Initial Model* has a mountain template from a side perspective. This handout can be used as an alternative to *Explain How Mt. Everest Moves and Grows* by providing a representation that allows students access to a place to represent their ideas about how Mt. Everest is changing.

Assessment Opportunity

Building towards: 1.A.1 Develop a model showing what is happening at a scale larger than we can see to explain what happened to the different mountains to cause them to change in elevation.

What to look for/listen for: Students include a variety of mechanisms for the changes to Mt. Everest. We want to get as many student ideas as possible at this point. Included here are some examples of student suggestions, but this list is not inclusive or exhaustive: rocks moving from one side of the mountain to the other, snow building up on the mountain top, strong wind moving the mountain, (tectonic) plates under the mountain, hills colliding causing the mountain to grow, and earthquakes pushing mountains together.

This first initial model represents students' ideas for how Mt. Everest moves to the northeast and increases in elevation. Later it will become a more general model to explain any mountain's change in elevation and movement on Earth. For now, any ideas students have at this point in the unit are acceptable. Over the course of the unit, each of these ideas will be explored by figuring out what tectonic plates are and how they move, weathering factors and erosion factors.

What to do: If a student is struggling to get started on their model, remind them that our initial model is just that—our first attempt at explaining what we think is causing the changes to the mountains. Use *Alternate: Initial Model* to help students begin to develop their model so they have a scaffold to use as they think about the large and small scale causes for Mt. Everest to move and grow.

5. Revisit classroom norms.

3 MIN

Materials: science notebook, *What is happening on Mount Everest?*, *Explain How Mt. Everest Moves and Grows*, chart paper, markers, Discussion Norms poster

Revisit classroom norms to prepare for a whole-class discussion. Show **slide H**. Have all students sit together in a Scientists Circle and bring their science notebooks and *What is happening on Mount Everest?* and *Explain How Mt. Everest Moves and Grows* with them.* Have chart paper ready to develop a consensus model with the question "What is Causing Everest to Move and Grow?" at the top.

Scientists Circle

Your students may be familiar with the Scientists Circle from a previous unit. Remind students of the norms for participation and the logistics for forming and breaking down that space. A Scientists Circle includes these important features:

- students sitting so they face one another to build a sense of shared mission and a community of learners working together
- celebrating progress toward answering students' questions and developing more complete explanations of phenomena
- focusing on where students need to go next and how they might go about the next steps in their work

***Attending to Equity**
This is an important opportunity to emphasize that each individual has contributions to make to their community of learners. It is through differences in thinking that the class will grow their knowledge together. Throughout this unit, students will be asked to be open to sharing knowledge products that depict their current thinking and to be open to learning from classmates who share their knowledge too.

Take this opportunity to remind the class how we listen to one another, press on one another's ideas, and ask questions of one another, and that it's OK to disagree with ideas but it's important to be respectful. You can use **slide H** to remind students of the classroom norms (if you have developed your own set of norms, replace this slide with your norms).

Additional Guidance

This first day of this lesson is a strategic point to have students revisit their class norms. This lesson was selected for this, because it requires students to participate in an extended amount of time in whole class discussion in the Scientists Circle. Days where there is mostly whole class and small group talk are good days to add this norm-focussing launch and wrap up, even if it isn't written into the teacher guide. It is recommended that you add in similar revisiting of classroom norms at such strategic places in each unit you teach, where you envision you could carve out an extra couple minutes being available at the start of that day of the lesson and a few minutes at the end of that day in the lesson to reflect (and debrief as a class as time permits).

Remind students of the Communicating in Scientific Ways sentence starters. Direct students to the *Communicating in Scientific Ways* poster or handout. Tell students that they will be developing a consensus model together.* Ask them which sentence starters they might want to use to help them talk to one another. Examples include these:

Think of an idea, claim, prediction, or model to explain your data and observations:

- My idea is . . .
- I think that . . .
- We could draw it this way . . . to show . . .

Give evidence for your idea or claim:

- My evidence is . . .
- The reason I think that is . . . .

Other examples could come from (1) listening to others' ideas and asking clarifying questions, (2) agreeing or disagreeing with others' ideas, and (3) adding onto others' ideas.

6. Develop a Classroom Consensus Model. 15 MIN

Materials: science notebook, *Explain How Mt. Everest Moves and Grows* or *Alternate: Initial Model*, What Is Causing Everest to Move and Grow initial model poster, markers, Discussion Norms poster

Develop a classroom consensus model of what is causing Mt. Everest to move and grow. Display **slide I.** Ask students to come into a Scientist's Circle with their notebook, *What is happening on Mount Everest?*, and *Explain How Mt. Everest Moves and Grows*. Say, *Last class we developed our initial models for what we think could be causing Mt. Everest to move and grow. Let's synthesize our ideas to develop a classroom consensus model. What do we know is happening to Mt. Everest from our reading that we want represented in our model?*

**Note: Use the prompts below as you develop the consensus model with your students. These are suggested prompts and responses, but use whatever representations your class agrees upon to capture the changes occurring to Mt. Everest.

***Strategies for This Consensus Discussion**
As an instructor, you have two goals for guiding the consensus discussion in addition to the goals listed on **slide I**. Your first goal is to help students: (1) build a positive culture where putting their

Suggested prompts	Sample student responses
Let's begin our class model by representing what we know from the data in the reading. What are some of the data that we want to be able to explain using our class model?	*In 1856 Mt. Everest was 29,002 feet and in 2021 Mt. Everest was reported at 29,032 feet.* *Mt. Everest has grown 30 feet since 1856.* *Mt. Everest grows about 2cm each year.* *Mt. Everest is moving about 4cm each year in the northeast direction.*
Okay so how should we represent that Mt. Everest has grown over time?	*Maybe we could draw a mountain with an arrow labeled with the amount of growth each year.* *Yeah, or maybe we could do a before and after, like draw one mountain at 29,002 feet and then a second mountain next to it at 29,032 feet.*
Now that we have the growth of Mt. Everest represented, how can we add to our model to show that it moves 4 cm to the NE each year?	We should draw a compass rose as a key and then we could add an arrow from the bottom of the mountain to the northeast direction.

ideas out in the public classroom community is valued and (2) to generate a variety of initial ideas to identify that there is a lot we don't understand yet. Highlight any areas of disagreement. Be careful not to favorably respond to any one idea over others as to not "give away" the answer.

Share and record possible causes for these changes. After you have captured what changes the class knows are occurring at Mt. Everest, use the prompts below to capture representations of the mechanisms students think are ***causing*** these changes at Mt. Everest. Here you should anticipate many different mechanisms and include them all in the model with question marks next to each one once you establish that not everyone had this mechanism in their model. For each brief phrase mentioned (e.g. erosion, wind, plates, rocks pushing up, ice), it is OK to ask for clarification such as, *What do you mean by that?* or *Do you have some way you want me to represent this to help illustrate how you picture what is causing this change?* These questions can be followed up with asking students to share their reasoning behind their ideas, but don't push on these questions at this time. The purpose here is to surface as many ideas as students have based on prior conceptions. It is important to make our thinking visible about possible mechanisms, regardless of whether they are accurate or not. One of the main goals of the unit is to figure out what mechanisms cause changes in the topography of Earth.

Say, *Okay, our model now represents what we know is happening at Mt. Everest. Let's add what we think is causing these changes in elevation and movement.*

Suggested prompts	Sample student responses	Follow-up questions
What are some of your ideas for what is causing these changes? What is causing Mt. Everest to grow and move?	*Because it's really cold at the top of Mt. Everest, I think that snow at the top is the cause for Mt. Everest getting taller.*	*Did other people have this included in their model?*
	I think that Mt. Everest is moving each year because rocks break off from one side of the mountain and move to the other side.	*What do others think of this idea?*
	I think we should add in plates under the mountain. I am not sure if they are in the mountain or under the mountain, but I think they have something to do with the mountain moving.	*Was this idea in your model?*
	I think we should add in wind pushing on the mountain above ground. I think this could be moving the mountain.	*How do we want to represent this idea in our model?*
	I think we should add in water under the mountain. There is water under the ground, so maybe there is more water near Everest making it move to the northeast.	*Where should we include this idea in our model?*

Key Ideas

Purpose of this discussion: This initial ideas discussion should be a moment for students to share all the different potential causes they picture that could cause a mountain to move and/or grow. Over the course of the unit, students will investigate different, plausible mechanisms. At this point in the unit, any ideas students have for the causes of mountain changes are acceptable.

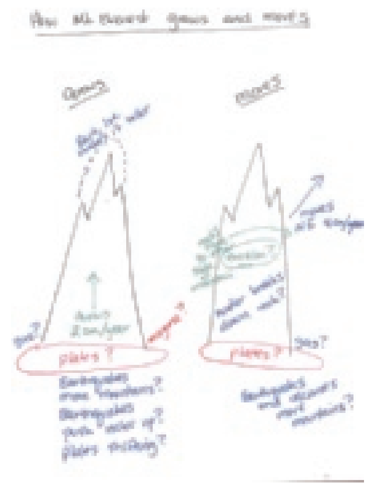
Listen for these ideas: Accept all responses. Possible mechanisms that might be shared:

- Wind
- Moving water
- Temperature differences
- Rain
- Snow
- Plates
- Climate change

Additional Guidance

If students bring up mechanisms such as plate tectonics, don't ignore—write "plates" and put up "arrows to show movement of them" with a question mark. No need to push for it, but if it comes up, say, *We are going to focus on looking for patterns of change similar to Everest in other mountains. We can follow the patterns of change to help us figure out what is causing those changes.*

The classroom consensus model should capture students' ideas for the causes of mountains moving and growing.



End of day 1

7. Navigation

5 MIN

Materials: None

Consider what might be happening at other mountain locations. Show **slide J.** Say, *What about other mountains? There are a lot of mountains on Earth and Mt. Everest is only one of them. What do you think we might see at other mountain peaks and other mountain ranges?* Use the questions on the slide to begin thinking about what we think is happening with other mountain ranges.

- What are some other mountains or mountain ranges you know about?
- Do you think that they are changing in similar ways too?

Follow-up with additional questions as needed:

- *If we looked at other mountains on Earth, would we see similar patterns in mountains changing in height over time?*
- *Do you think we would see other mountains moving to the northeast too?*

Prompt for types of data we need. Say, *So if we look at some additional data about Everest and other mountains, what kind of information would we want that could help us figure out more about what is causing Mt. Everest to change?*

8. Compare different mountain peak information cards.

20 MIN

Materials: *Data Cards on Other Mountains and Mt. Everest*, science notebook, Data Cards for Other Mountains and Mt. Everest, 1 Earth squish ball globe with countries labeled, 1 Earth squish ball globe with no labels, 2 paper coffee sleeves

Find out more about the area that Mt. Everest is located. Show **slide K.** Set up a data table together with students recording it in their notebook. Tell students to open to the next blank two pages so that they have both the left and right hand side available to use. Refer to the image on the slide for an example of this.

Remind students that the ***goal*** of our data analysis is to look for patterns in any changes in height or movement as well as any additional information that gives us ideas about possible mechanisms or causes for those changes. Ask students what kind of data we want to have to help us figure out more about how mountains change over time. When the class agrees on one type of data, students should list that on the far left column of the chart in their notebook. Some examples of types of data students may suggest the class should collect include:

- Height of the mountain
- Movement of the mountain
- Changes in height for the mountain
- Location of the mountain
- Earthquake activity

Once the data table is set up, tell students that the information cards will probably have more information than just whether the mountains are changing. If they see something else that they think might also help explain what is happening at Mt. Everest, add a row to their data table called "other" and include that data (see example below).

Type of data	Data	Causes for changes
Height of mountain		
Movement of the mountain		
Changes in height		
Earthquake activity		
Other data		

Distribute a copy of *Data Cards on Other Mountains and Mt. Everest* to each student and a *Mt. Everest in the Himalayas* card to each group of students as reference. The *Data Cards on Other Mountains and Mt. Everest* reference sheet should be printed in black and white and provided to each student so they can annotate it and include it in their student notebook. In addition, distribute both Earth squish ball globes and 2 coffee sleeves to each pair in a group to use as reference.

In the next part of the lesson, students will read about five different mountain peaks and their ranges. This first one is about the Himalayas where Mt. Everest is located. Analyze this first case site as a class to find the types of data we are looking for to help us figure out more about changes to other mountains besides Mt. Everest.

*Supporting Students in Engaging in Analyzing and Interpreting Data

The mountain case cards include multiple pieces of information about the mountain peaks and the area/ranges they are part of including types of elevation changes, lateral movement that the peaks are experiencing, weather/climate, samples of rocks found in the mountain and other interesting facts. These cards will be revisited and analyzed numerous times over the course of the unit as students build their conceptual understanding of the processes causing changes to Earth's surface. This is the first time students will begin thinking about causal and correlational relationships using data. In this first pass, students are only expected to be thinking about what causes mountains to change. But through the initial discussions in this lesson and the eventual investigations and discussions through the rest of the unit, students will progress in their ability to analyze data and identify causal vs. correlational relationships.

Say, *Mt. Everest is just one mountain that is part of a mountain range called the Himalayas. Let's analyze the data card about the Himalayas to look for any other data that could help us in figuring out more about Everest and why it is changing.* Give students a couple of minutes to look at the different pieces of information on the card. Ask students to share any data they see or read on the card that we should add to the table in our notebook. For each suggestion, probe the student as to why they think this piece of information is important to record and why it might help us figure out what is going on at Mt. Everest.

Additional Guidance

Some students may believe that a mountain range needs to span countries or continents to be considered not just a string of mountains, but a range. A mountain range is simply a series of mountains connected by high ground. In everyday language we tend to refer to structures with names that do not match their actual scientific names, such as the Appalachian Mountain range. In the scientific context, many of these structures are actually orogenic belts composed of smaller mountain systems. It may be worth stopping to operationally define the word mountain range as a class before proceeding with the lesson.

Below are some examples of what students might suggest to underline or annotate from the Himalaya card and add to the data table in their notebook.

Possible student suggestion	Possible student reasoning why to underline
Underlining the location of the Himalayas.	Knowing where the mountain range is located might help us to figure out what is going on around Mt. Everest.
There is another really tall mountain located in the Himalayas called K2.	Maybe all the mountains here are growing taller here since two of the tallest mountains are found in the same area.
There is a lot of snow and ice in this area.	Maybe the new heights are from the snow and ice that is building up here.

As the class agrees on what is important from the Himalayas card, they should add that information to their notebook. An example of a data table is included below:

Type of data	Data	How this data connects to mountains changing
Height or elevation of mountain	Everest is 29,032 feet. Another mountain in the Himalayas is also very tall.	Maybe all the mountains in the Himalayas are tall.
Earthquake activity	There are many large earthquakes in the area.	Maybe earthquakes are connected to mountains moving.
Other data	There is a lot of snow and ice in the Himalayas.	Maybe this is why the height keeps getting taller.

Additional Guidance

The last column is for students to record their initial ideas for how the data could help figure out the causes behind the changes to Earth's surface, specifically mountains at this time. Any ideas students have should be accepted. Notice the examples in the last column are more similar to wonderings. That is okay and you should even encourage students to record those as well. The purpose of asking students to think about what could cause these large changes, or how the data connects to mountain changes, is to get all their ideas shared. Students will continue to look for patterns of cause and effect as they continue through the unit. For example, some students may think that there is less wind in other parts of the Himalayas compared to Mt. Everest since it is the tallest mountain in the world, or they may think that there is less snow on other mountains in the Himalayas that are shorter than Mt. Everest. All of these ideas as causes are acceptable in this first lesson.

Assign one mountain case card to each student within a small group. After reading through the *Mt. Everest in the Himalayas* card together, form small groups of three to four students. Each student within a group will read one of the remaining five *Data Cards for Other Mountains and Mt. Everest*. Organize the assignment of the five mountain cards so that more than one student in the class is reading each mountain card. Direct students to follow the same strategies we just used as a class to find pieces of data from these other mountains that could help us figure out what causes mountains to change over time. In addition to the maps on the front and back of the *Data Cards,* encourage students to use the two Earth squish ball globes to make sense of where the mountain they are analyzing is located on the globe. Give students about 8 minutes individually to read through the card they have been assigned.

During this first analysis of the mountain case cards, students should look for data that could help the class figure out causes for mountains to change by finding potential patterns in the data. It is not necessary at this point for students to record all the data off of the mountain cards. Instead, through their analysis of the material they should pull out only the data that could help explain changes in elevation or lateral movement of mountains.*

Alternate Activity

Though the *Data Cards for Other Mountains and Mt. Everest* are on cardstock and placed in plastic sheet protectors since they will be revisited multiple times throughout the unit, you may wish to provide your students a black and white copy of these. In this first lesson, students may wish to annotate, highlight, or notate different pieces of information as they begin thinking about causes and processes that could be common across different mountain cases for the changes the mountains experience. Use *Data Cards on Other Mountains and Mt. Everest* to make student copies.

9. Compare mountain site locations.

7 MIN

Materials: *Patterns of Change for Mountains*

Share data across mountain cases and look for patterns of change between the different mountains. Display **slide L.** Distribute one copy of *Patterns of Change for Mountains* to each student. Tell students they should each take a turn sharing the data they found for their mountain case. As each person shares they should fill in *Patterns of Change for Mountains* with any data for growth or decreases in height. Then as a group, they should discuss what patterns of change they see between the different mountains and fill in their handout so they are ready to share with the class.

10. Share patterns in growth and movement between different mountains. 13 MIN

Materials: science notebook, *Patterns of Change for Mountains*, World Map (large wall global relief map), large (4″x6″) sticky notes or quarter sheets of paper with tape, sticky notes

Convene in a Scientists Circle and share patterns we noticed between the different mountain peaks. Display **Slide M.** Say, *Let's share what data we found from the different mountain cases and add some of this to our map. We will begin by identifying what other mountains you analyzed and where they are located on our map.* Students should be able to help identify where the mountain is found from what they read on the data card, but they may need help identifying where the location is on the global relief map. Using a small sticky note, mark the different locations of the mountains on the map.

Say, *Now let's share what you found about these different mountains. As different people share and we agree on what data will be important for us as we investigate what is causing mountains to change, we will record this data near the different locations. So, what are some of the data you found for the different mountains that will help us figure out why mountains can change over time?*

Record all of these that the class agrees makes sense to include on a large 4″ x 6″ sticky note. Using the sticky notes or quarter sheets of paper, annotate the different mountain peak locations with similar patterns of data and place it on the map near the mountain peak the data is referring to. These patterns of data should be pieces that we feel will help us figure out Mt. Everest as well. As students share, record the different data on the sticky notes and post them on the map in the location of the mountain range. See the example to the right.

Some examples of data students may suggest to record on the sticky notes for the different mountain peaks is included below:

Mt. Mitchell:

- Mt. Mitchell moves on average 3 cm each year towards the west.
- The Appalachian mountains are ancient.
- They are believed to have been as tall or taller than the Himalayas.
- The peaks are decreasing in height and the valleys are getting deeper.
- There is volcanic rock in these mountains. (Does that mean there are volcanoes here?)
- There are no active earthquakes.

Mt. Cook:

- There are regular earthquakes in the area.
- One earthquake caused part of the ocean floor to rise above the water.
- These mountains are increasing in height 1-2 cm/year.
- This area is moving 6.9 cm towards the north.

Mt. Aconcagua

- These are moving about 3 cm per year to the north.
- The mountains are the tallest mountains after the Himalayas.
- The tallest peak is 22,838 ft tall.
- The tallest active volcano can be found in these mountains.
- These mountains are the same age as the Himalayas.
- These mountains are still increasing in elevation through growth spurts.

Mount Hotaka

- These mountains are younger than the Himalayas.
- There are several active volcanoes in these mountains.

Mount Narodnaya

- These mountains are much older than the Himalayas and about as old as the Appalachians.
- Earthquakes can occur here, but they are small and not common.
- These mountains are moving about 2.5 cm to the east each year.
- This mountain is much shorter than Mt. Everest.

Look for patterns across the different mountains. Say, *Now that we have recorded the pieces of data for each mountain, let's share the patterns of similarities and differences that your group found between the mountain cases.* Use the prompts below to lead a discussion about what patterns students noticed between the different mountains and how they change. You may wish to add some of these to the large sticky notes as students share.

Suggested prompt	Sample student responses
What are some patterns of change you noticed between the different mountains?	*Almost all the mountains are growing except for Mt. Mitchell in the Appalachians and Mount Narodnaya in the Urals.* *Almost all the mountains are moving in one direction or another, but they aren't all moving in the same direction.* *Most of the mountains are moving to the north. But there is one moving west and one moving east.*

Suggested prompts	Sample student responses
What other patterns did you uncover that could be related to how or why a mountain's height or location might change over time?	*The mountains in our cases are all in different parts of the world.* *Some are near the ocean and others are not . . . like the Urals and the Appalachians are both mountains that are not near water and they are both shrinking.* *Besides the Himalayas that are growing and not near water, all the other mountains that are growing are near the ocean.* *The Urals and the Appalachians are much older than the Himalayas, but the rest are younger or about the same age as the Himalayas.* *The mountains have different types of weather depending on where they are located.* *Fossils can be found in most of the mountains.* *Some of the mountains have volcanic rock.* *Some of the mountains have similar types of rock, like sandstone or limestone.*
What potential causes do you see across these cards for the changes in elevation or location? How could this be connected to how Mt. Everest, or any mountain, is changing?	*How close a mountain is to an ocean affects how tall a mountain is because of wind from the water.* *How old a mountain is might affect whether it is growing or not because the Urals and Appalachians are much older than the Himalayas and they are both shrinking.* *If there is volcanic rock on the mountain, maybe volcanoes can cause mountains to change too?* *I saw there were fossils of marine animals in some of the mountains...does this mean the mountain used to be under water?*

Key Ideas

Purpose of this discussion: Surface ideas for causes of change to mountains over time based on patterns students notice. There will be uncertainty about the causal mechanisms shared, but that is okay as these ideas will help motivate us to want to investigate more about the different potential causes of change.

Listen for these ideas:

- Accept all reasonable responses connected to the data in the cards.
- There are other mountains that are getting taller too.
- There are some mountains that are changing in height by shrinking.
- Some other mountains have earthquakes happen too.
- Mountains are different ages, some much older than Mt. Everest and some younger.
- Other mountains also shift in location.

- Some mountains have volcanic rocks on them.
- Some mountains have sedimentary types of rock like sandstone and limestone.
- Some mountains are located near water and others are only on land.

Other ideas that may be shared but are not critical to bring out at this time include: ideas around the fossils found, or the type of weather experienced.

End of day 2

11. Develop initial model of shrinking mountain. 10 MIN

Materials: *Explaining Other Mountains That Shrink*

Distribute a copy of *Explaining Other Mountains That Shrink* to each student. Display **slide N.** Say, *We have developed a model for a mountain that is growing, but now we have found out that some mountains are shrinking. Think back to what we have shown that could be causing our mountains to grow. Do we also think these things could be causing our mountains to shrink? Could it be something else? Take a few minutes with a partner to develop a model to represent what is causing a mountain to shrink.*

Assessment Opportunity

Building towards: 1.A.2 Develop a model showing what is happening at a scale larger than we can see to explain what happened to the different mountains to cause them to change in elevation.

What to look for/listen for: Students including a variety of mechanisms for the changes to cause a mountain to shrink such as: snow melting up on the mountain top, strong wind moving the mountain, (tectonic) plates under the mountain, and earthquakes separating mountains.

Any ideas students have at this point in the unit are acceptable. Over the course of the unit all of these will be explored through figuring out what tectonic plates are and how they move, as well as weathering and erosion factors.

What to do: If a student is struggling to get started on their model, remind them that our initial model is just that—our first attempt at explaining what we think is causing the changes to the mountains. Encourage students to look back at the initial model they developed for Mt. Everest and think about what they would change in the model to represent a decrease in elevation.

12. Add to the Classroom Consensus Model. 15 MIN

Materials: science notebook, *Explaining Other Mountains That Shrink*, What Causes Mountains to Shrink initial model poster

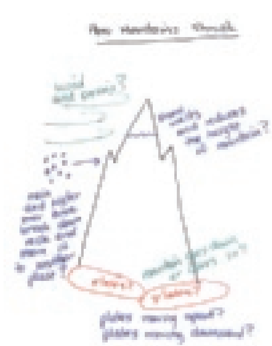
Convene in a Scientists Circle. Display **slide O.** Say, Last class *we found data that some mountains are not growing but are shrinking. So if all mountains aren't growing, then our initial consensus model won't explain what is happening to every mountain. As a class, let's develop a model to capture the ideas we have for what we think might be causing other mountains to shrink.*

Suggested prompts	Sample student responses
Let's begin our class model by representing what we know from data. What are some things we should be sure to include in our class model? How should we begin our model of a shrinking mountain?	*We should include a mountain like we did for Everest, but it should be shorter than our model for Everest.*
	Yeah, both the mountains we read about that are shrinking are shorter than Everest.
So these mountains that are shrinking are shorter than Mt. Everest now, but were they always?	*No . . . it says they were as tall or taller than Everest.*
If we want to model what causes a mountain to shrink, then how can we capture that these mountains were as tall or taller than Mt. Everest but are now shorter?	*We should draw more than one image of the mountain . . . like before and after.*
	Yeah, so we can show what happens over time to the mountain.
Okay, so how should we represent that these mountains have shrunk over time?	*We should have a tall mountain for the before section, then a shorter mountain for now.*
	We could also add an arrow pointing down from the top of the mountain to represent it getting shorter.
What are some of our ideas for what causes these changes? What is causing some mountains to shrink?	*I think maybe there are things happening underneath the mountain, like maybe the plates are moving or breaking.*
	Or maybe the snow at the top of the mountain is melting and that is causing the mountain to shrink.
	I think wind and rain could be causing the mountain to shrink by erosion.

***Strategies for This Consensus Discussion**

Include all ideas at this point in the unit as part of the consensus model. The purpose of developing this model is to surface ideas students have for what could be causing changes to Earth. If everyone doesn't agree with some of the ideas shared, then include the ideas as questions or with question marks. Don't worry about fleshing out every similarity or difference. For example, you can say to the group, *So it sounds like some people have X, but not everyone is totally convinced yet. Let's put it up with a question mark. Does everyone agree that we're not totally in agreement about X? Consensus can mean we agree that we're not in consensus.*

An example of an initial consensus model for a shrinking mountain can be found here:



Key Ideas

Purpose of this discussion: This initial ideas discussion should be a moment for students to share all the different potential causes they picture could make a mountain shrink. The goal is for students to identify common processes that are at play for how Earth's surface changes. Over the course of the unit students will investigate different mechanisms to figure out which ones are causing the changes to the mountains. At this point in the unit any ideas students have for causes of mountain changes, even if they are correlational in nature, are acceptable.

Listen for these ideas: Accept all responses. Possible mechanisms that might be shared:

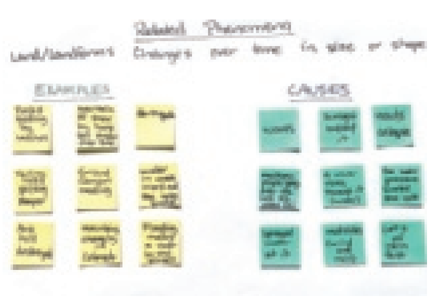
- Wind
- Moving water
- Temperature differences
- Rain
- Snow
- (Tectonic) Plates
- Climate change

In addition to these ideas, students may share ideas around the types of rock the mountains are made of, or the fact that there are fossils on the mountains, but these ideas do not need to be pulled out at this time if they haven't been shared. The inclusion of the presence of these types of rocks could be evidence for some of the processes (e.g. erosion or weathering) that students may want to include in their model. Students will revisit the mountain case cards over the course of the unit to continue to build their models and fully explain what is occurring at the different locations.

13. Brainstorm related phenomena. 15 MIN

Materials: science notebook, Related Phenomena poster, sticky notes

Brainstorm related phenomena. Display **slide P**. Ask students to turn to a new blank page in their science notebook and title it "Related Phenomena." Then they should draw a T-chart on the page. The left column should be titled "Examples" and the right column titled "Causes." Reference image on slide.



Say, *Think back on all your experiences where you've noticed a change in the surface of the land or landforms, such as hills, mountains, shorelines, or other features on Earth's surface. These changes could be over a very short period of time or a long period of time and/or they could be big or small changes to the land. If you can't think of any that happened where you live but you can think of a change that you saw happen somewhere that you visited or that you read about, that is okay too. Take a couple of minutes and record all of the related phenomena you can think of in your notebook and what you think the causes of these changes might be.*

Share with a partner and think about causes. Display **slide Q.** Say, *Take a few minutes to share with a partner your related phenomena examples and potential* *causes. Then together think about the examples you have and whether the causes for these changes would be similar to what could be causing Mt. Everest to change.*

After students have had some time to share with a partner, display **slide R** and bring the class back together. Ask students to share their related phenomena examples and potential causes for these changes. Say, *As you share, tell us how you think it could be related to how mountains change.* As students share their ideas, record the examples and causes on sticky notes. Add these sticky notes onto the appropriate sections on the Related Phenomena poster to be kept in the classroom to reference later.

Additional Guidance

The procedure for developing the related phenomena poster is different here than in other units. We recommend adding ideas to the poster on sticky notes. In subsequent lessons when we revisit this poster, we want to be able to add to it and move things around. As we figure out more about causal and correlational relationships that contribute to mountain and landscape change, causes for some related phenomena may become more apparent for students. Some students may realize an example might belong under causes and vice versa, and the mobility of sticky notes allows for easy rearrangement of ideas.

14. Navigation

5 MIN

Materials: science notebook

Record new questions. Show **slide S**. Have students write down new questions they are now thinking about for what could be causing mountains to change in elevation and move, and other land near them to change. They should write them in their science notebooks before they leave class or on a separate paper to be collected. Students should come to the next class prepared to share those questions with others. If you are short on time, this can be done as home learning. Let the class know that at the next session we will share out all of our questions and build a DQB to help figure out what's causing mountains to change in elevation and move.

Assessment Opportunity

You can read students' questions as a formative assessment prior to the next class and then again later in the unit to see how students' questions are developing. Look for students to be asking questions about what causes could lead to land and landforms, such as mountains to change over time.

End of day 3

15. Discuss questions to post on Driving Question Board. 5 MIN

Materials: science notebook, sticky notes (or index cards and tape), marker

Return to the questions students generated earlier and develop new questions. Say, *Last class, we brainstormed a lot of questions about what could be causing mountains to grow, shrink and move, and other similar phenomena. Today, we're going to post our questions to our Driving Question Board and begin thinking about how we're going to investigate in order to figure out what's happening to cause Mt. Everest and other mountains to grow or shrink and move.*

Share questions with a partner. Show **slide T**. Pull out their questions from the last class or their home learning.

- They should write one or two questions on sticky notes with large, **BOLD** writing so everyone can see. They should write only one question per sticky note.
- Share their questions with one partner in the circle.
- Remind students that the questions do not all have to start with how or why, but they should be questions that (1) we can answer through investigation and (2) will help us explain how a mountain can change.

Collaboration

As students learn to go public with their ideas, it can help to stimulate and support their individual thinking by sharing their questions with one person first, before having to go public with their questions in the large group. If your class is very comfortable sharing ideas in public already, you can omit this step in the lesson.

16. Build the Driving Question Board. 25 MIN

Materials: *What is happening on Mount Everest?*, *Explain How Mt. Everest Moves and Grows*, *Explaining Other Mountains That Shrink*, *Patterns of Change for Mountains*, markers, sticky notes

Record individual questions. Make sure markers and sticky notes are provided. Say, *Let's look back at our noticings and wonderings, What is happening on Mount Everest?, Explain How Mt. Everest Moves and Grows, and Explaining Other Mountains That Shrink, and Patterns of Change for Mountains to capture our questions about what is happening in these different cases where mountains are changing and where other changes are happening to the land around us. We will use these questions to form our Driving Question Board.*

To prompt an array of questions, remind students to think carefully about the changes happening to Mt. Everest, any changes to the mountains described in the cards, and other related phenomena.

Present **slide U**. Give students at least 3 minutes to generate their questions on sticky notes. Encourage students to write more than one question, but only one question per sticky note, and put their initials in pencil on the back of each.

While students write questions, move the Related Phenomena poster to hang next to the Initial Consensus Model posters where all students can see it from a Scientists Circle. These posters together will serve as the space where students can add their questions to build their DQB, and will be referred to as the DQB in subsequent activities and lessons.

Gather in a Scientists Circle around the DQB. Present **slide V**. Have students bring their science notebooks and all of their sticky note questions along with a chair and form a circle in a location where everyone can see the two Initial Consensus Models and the Related Phenomena poster. These three posters will serve as the DQB for this unit.

Remind students that our goal is to capture all our questions to build a DQB. Say something like, *It looks like you have a lot of really good questions about what could be causing changes to different mountains and different locations on Earth. It is important that we hear everybody's questions, and we might find that we have similar questions. To help us group similar questions, let's try to post each question on a spot on one of the Initial Consensus Model posters or on the Related Phenomena poster, or in between them.*

Review these steps for forming the DQB:

- The first student comes up to the DQB with a sticky note, faces the class, and stays standing.
- The student reads their question off the note and then posts it on the DQB near the section of the consensus model or related phenomena it is most related to.
- The student selects the next student whose hand is raised.
- The next student reads their question and posts it on the DQB. This student also says what other posted questions it relates to and explains why or how it relates.*
- The student then selects the next student whose hand is raised.*
- This process continues until everyone has had a chance to post a question.
- Remind students to keep track of whether their question was already asked, put a checkmark on that sticky note if it was, and then select a different question to share.

Assessment Opportunity

Building towards: 1.B Ask questions that arise from our analysis of information showing that Mt. Everest and four other mountain peaks are changing to seek additional information about what caused the changes (effects) we read about.

What to look for/listen for: Students contributing questions about the event on Mt. Everest, about mountains changing in elevation, mountains moving, about earthquakes, and other landforms (e.g.: volcanoes). Look for students' questions to (1) move between different spatial and temporal scales, (2) focus on the Mt. Everest event, and (3) focus on the similar and different patterns of change for other mountains.

What to do: If students are struggling to generate questions in each of these areas, cue them to use the crosscutting concepts of Patterns and Cause and Effect as a lens to help them brainstorm different kinds of questions to ask. (Note: You do not need to use these words explicitly, for example, cause and effect, but can refer to them as the "cause of the mountain getting taller.")

*Supporting Students in Engaging in Asking Questions and Defining Problems

If students forget to explain how or why their questions are linked to someone else's question, press them to try to talk through their own thinking. This is a key way to emphasize the importance of listening to and building off each other's ideas, and to help scaffold student thinking.

Don't worry if some questions raised are not part of topics in this unit. Over time, with practice in this type of activity, students will get better and better at forming testable questions in the scope of the DQB. If students can't figure out which question to connect theirs to, encourage them to ask the class for help. After an idea is shared, ask the original presenter if there is agreement and why, and then post the question.

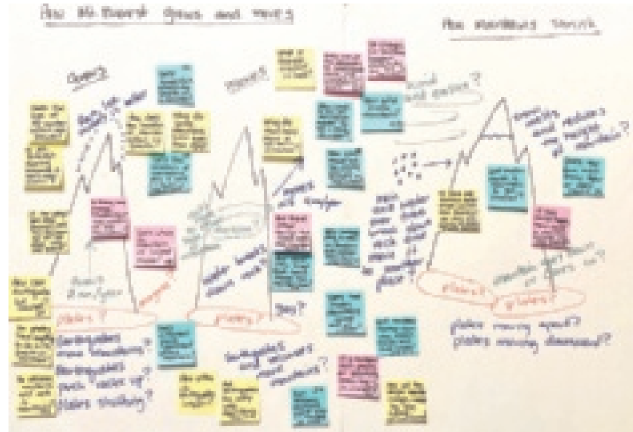
If a question is similar to (or the same as) another one, have the student place it on top of that question so other students can visualize how many questions are identical or related. Emphasize that this provides us with evidence of where many people are thinking about similar things.

*Attending to Equity

Having the student who volunteered and posted a question choose the next student to share

An example of one such DQB is shown here.

Point out that many of the questions are connected to how and why different mechanisms could be the cause of similar changes and how the same mechanisms could cause different things to happen at different places. Suggest that including these questions under a single driving question could remind us of how the work on any one question is in the service of all our questions. Propose that **"What causes mountains to move, grow or shrink?"** could be a single driving question that most of our questions could fit under.



Additional Guidance

In this lesson, students are wondering about the overarching question, "What causes mountains to move, grow or shrink?" Over the course of the unit, as students learn more about the forces and processes that cause mountains to change in location and elevation, this question will be revised to, "What causes Earth's surface to change?" While eventually, students will be wondering this question, this lesson starts off by considering only changes to mountain growth and location. It is important to start with this question to give students agency in later lessons to change this overarching question as we learn more throughout the unit.

Once the class agrees to this, write it in large letters on a half-piece of chart paper and hang this banner over the top of the entire DQB. Remind students that we can revise this question as we continue to figure out new things in future lessons. Ask students to go to the blank page they saved in their notebook for the title of this unit and record this title now.

Additional Guidance

After your last class on day 4: Organize the questions on your Driving Question Board into categories that emerge across all your classes. After (or as) you reorganize the board at the end of this lesson, make a typed record of all the questions that are on the board so that you can print them out or share with students to reference in groups during future classes. One way to do this is to take a high resolution photo of the board or transcribe the questions on the board into a digital or electronic document.

Some examples of categories that might emerge:

- Causes of mountains
- How land moves
- Earthquakes
- Wind, rain, snow
- Volcanoes
- How long it takes for a mountain to change

(from those whose hands are raised) is a great way to turn over the pacing and cadence of this group work to the students. Reuse this technique in future Scientists Circles to encourage increased student agency in the classroom learning community. When you do this, take a seat with the students in the circle to position yourself as an equal member of the learning community who is listening, making sense of questions, and trying to figure this out. If you have questions you want to share with the group, raise your hand and wait for someone to call on you.

17. Brainstorm ideas for data and information needed.

12 MIN

Materials: science notebook, Ideas for Data and Information We Need poster, DQB (around the two consensus models and related phenomena), markers

Brainstorm ideas for data and/or information needed. Display **slide W**. Read the slide aloud. Stay in the Scientists Circle and arrange students into groups of 3. Give students 3 minutes to talk with this small group to generate ideas about the types of data and information they would need to answer their questions on the DQB. Say, *Sometimes when scientists are trying to decide on their next steps, they need to look back at their questions and figure out what data or information they still need. Let's do that now.*

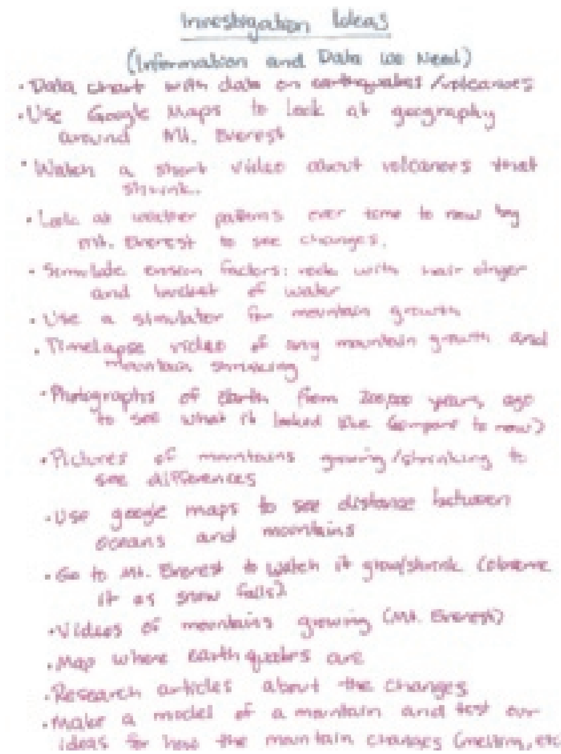
For the next three minutes, have groups of students generate their list. Then, instruct students to take one minute to write their ideas in their science notebooks on a new page titled "Investigation Ideas (Information and Data We Need)" using a table like the one below.

Investigation Ideas (Information and Data We Need)

As students are doing this, hang the Ideas for Future Investigations and Data We Need poster right next to the DQB.

In the remaining 9 minutes, have students reconvene standing in a semi-circle around the Ideas for Future Investigations and Data We Need poster so all can see it. Give each group of students about one minute to report out the data and information that could answer their questions. Record a list of Information and Data Needed that will remain public throughout the unit. Make sure all groups get to share at least one idea.

Build the poster with students' ideas. Tell students you want everyone's ideas to be shared and represented on the poster. Say something like, *To make sure we have your ideas up here, I will pass a marker to the first person on the edge of the circle. That student should share one idea. I will write it up and number it. Once I've almost finished writing it, that student should pass the marker to the student next to them. The second student then shares an idea. If that idea is on the poster already, the student should say which idea it is and how it is similar. I will put a tally mark next to it. The marker is then passed and we continue until we have heard once from everyone in the class. If you have additional ideas that don't end up on the poster, feel free to raise your hand after the marker makes it all the way around the circle. If*



we run out of time, we'll pick up here in the next class. And if you think of new ideas as we go, feel free to jot them down. We should always be thinking of ways we can add to this list.

A sample poster from one class of students is shown above.

Celebrate the formation of a joint enterprise. Once this poster is built, celebrate that they created a joint mission and proposed action plan to guide the work of our learning community for weeks to come. Say something like, *Wow. We have accomplished so much. We now have a mission to accomplish as a class, thanks to all the questions you shared and how you connected them. These questions really represent what we hope to figure out. And we have a lot of ideas for investigations and data sources we can work with. I am very excited for us to start investigating all of these. I have lots of additional data and equipment for us to use that are well matched to the things you've said we need. Let's plan to start exploring some of this in our next lesson.*

Prioritize one set of ideas for investigations. If time permits, say something like, *I noticed we have many different ideas for what could be causing the changes we saw in the different mountains. What cause makes sense to figure out more about first?* Give students a minute or two to turn and talk with a partner.

18. Navigation

3 MIN

Materials: None

Decide where to go next. Display **slide X.** Say, *As you look back at the DQB and think about the ideas shared for investigations and types of data we would want, what makes sense to explore first? Talk with a partner about your ideas:*

- What potential causes did we identify as a class for Mt. Everest changing? What seems the most likely cause to you and why?

In our next class, we will think more about these potential causes and begin investigating them.

Additional Guidance

Remind students to keep their science notebooks organized by writing a title on each page and updating their table of contents. They can do this when they have extra time at the beginning or end of class, or during homeroom or homework time.

ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.6.1.A

Come to discussions prepared, having read or studied required material; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

Students will be reading multiple sources of informational text to pull out data that could serve as causes for change over time of different mountains. They will use the information they have found in the articles in the class discussion to develop initial models representing the changes occurring to different mountains. They will need to draw on evidence they find in these texts and be ready to support the pieces they cite from the reading.

CCSS.ELA-LITERACY.RI.6.3

Analyze in detail how a key individual, event, or idea is introduced, illustrated, and elaborated in a text (e.g., through examples or anecdotes).

Students use close reading strategies to analyze an article to figure out how mountains are measured and what is occurring at Mt. Everest. The article includes information about how Mt. Everest is changing in both height and location over time. Students will use this information that they analyze as they develop an initial model about what could be causing Mt. Everest to change over time.

LESSON 2

How are earthquakes related to where mountains are located?

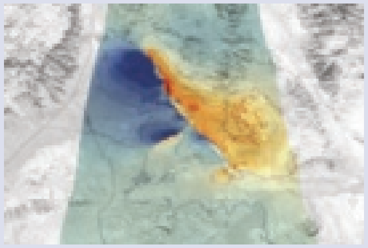
Previous Lesson

We read about Mt. Everest getting taller and moving over time. We find other mountains are changing in elevation too, with some shrinking. We modeled what we think is causing a mountain to change in elevation. We brainstormed related phenomena where land near us has changed over time and formed our Driving Question Board (DQB). We brainstormed possible investigations we could do and additional data sources that could help answer our questions.

This Lesson

Investigation

2 DAYS



NASA

We watch a video of the 2015 earthquake on Mt. Everest. We determine we need more data to understand what is happening during an earthquake. We look at data sources from Ridgecrest, CA before and after an earthquake. We determine that there may be a correlation between earthquakes and mountain growth, and look at our case site locations for data. We use Seismic Explorer to determine that there seems to be a pattern with greater earthquake activity at mountains that are increasing in elevation. We think that earthquakes are correlated to mountain changes in location and elevation, but want to know what is happening underground where earthquakes occur.

Next Lesson

We will develop models to represent what we might find on and below Earth's surface in different places. We will use images, storymap, and a reading to gather information. We will carry out investigations, document and share our observations, and describe what we figure out in our Progress Trackers.

Building Toward NGSS

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

What Students Will Do

2.A Present an oral and written argument that earthquakes either caused or are correlated to the elevation and location changes of the mountain cases and Ridgecrest, California.

2.B Use digital tools to examine a large data set at different spatial and temporal scales to compare global earthquake activity to local activity.

What Students Will Figure Out

- The ground moves back and forth in an earthquake.
- Some parts of the surface crack open with a noticeable difference in between the ground on either side of the crack after an earthquake.

- Earthquakes exist on or near almost all mountain ranges.
- There seems to be a correlation between when mountains were highest or growing and where the earthquakes are the largest or most frequent.
- While earthquakes seem to be correlated to changes in elevation, we are uncertain what is occurring under the surface, and what the land is like under the surface.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Develop a chart showing possible causes and effects of earthquake elevation changes and movement, and determine the meaning of causation vs. correlation.	A-B	Potential Causes for Mountain Movement chart, markers
2	3 min	**NARROW FOCUS TO EARTHQUAKES** Revisit units where many variables were present and determine a systematic process for determining the causes of events in a system. Begin by focusing on earthquake data.	C	Potential Causes for Mountain Movement chart, Ideas for Investigation and Data We Need poster
3	5 min	**DISCUSS EARTHQUAKE EXPERIENCES** Allow students to share prior experiences with earthquakes and what they believe might happen during an earthquake on Mt. Everest.	D-E	6.4 Lesson 2 Experience at Mt. Everest (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	11 min	**INTRODUCE RIDGECREST, CALIFORNIA DATA**	F-O	World Map, sticky notes, 3 meter sticks, 6.4 Lesson 2 Ridgecrest Earthquake (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
5	5 min	**REVISIT MAP TO IDENTIFY POTENTIAL MOUNTAIN LOCATIONS** Revisit the map and determine locations where potential mountains may be located based upon geological features on the map.	P	World Map
6	13 min	**EXPLORE SEISMIC EXPLORER** Use Seismic Explorer to determine what earthquake features can be visualized by the simulation and analyze for earthquake locations.	Q	World Map, Earthquake Data (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

End of day 1

Part	Duration	Summary	Slide	Materials
7	12 min	**ATTEMPT TO DETERMINE CORRELATION OR CAUSATION OF EARTHQUAKE DATA** Write a claim regarding whether earthquakes are correlated with or cause changes in elevation and location of land on Earth's surface. Determine more information is needed regarding earthquake magnitude and frequency.	R-T	*Earthquake Investigations*, Earthquake Data (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
8	10 min	**RECORD DATA FROM EARTHQUAKE INVESTIGATIONS** Record data from investigations on the class map.	U	*Earthquake Investigations*, sticky notes, 4 different color markers
9	5 min	**MAKE SENSE OF NEW DATA ON WORLD MAP** Review the data on the World Map and attempt to find patterns in earthquake depth and magnitude.		World Map
10	5 min	**REVISIT THE POTENTIAL CAUSES FOR MOUNTAIN MOVEMENT CHART** Revisit the Potential Cause for Mountain Movement chart to determine if earthquakes are correlated with or cause mountains to move and change elevations.	V	Potential Causes for Mountain Movement chart
11	5 min	**DETERMINE NEXT STEPS** Reflect on past data collection and determine that in order to figure out what is happening during an earthquake, we have to look at what exists underground.	W-X	
12	3 min	**INTRODUCE HOME LEARNING** Preview and assign home learning.	Y	*Reading: What Do We See on Earth's Surface Where We Live?*
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 2, students are ready to read Student Reader Collection 1 and then respond to the writing exercise.		Student Reader Collection 1: *The Gorgeous Globe*

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • *Earthquake Investigations*		• Potential Causes for Mountain Movement chart • markers • Ideas for Investigation and Data We Need poster • 6.4 Lesson 2 Experience at Mt. Everest (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • World Map • sticky notes • 3 meter sticks • 6.4 Lesson 2 Ridgecrest Earthquake (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Earthquake Data (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 4 different color markers • *Reading: What Do We See on Earth's Surface Where We Live?*

Materials preparation (15 minutes)

Online Resources

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

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

Prior to day 1, look up the location of Ridgecrest, California and be ready to add a large sticky dot on the map for this location on the class map.

Determine distance from your location to Ridgecrest, California. Record this on a sticky note.

Test the interactive, Seismic Explorer Version 1. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

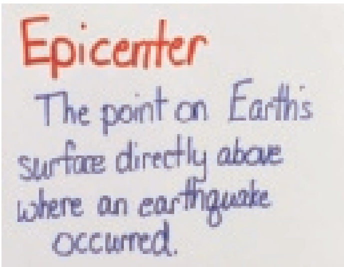
Test the following videos: Experience at Everest and Ridgecrest, CA Earthquake. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

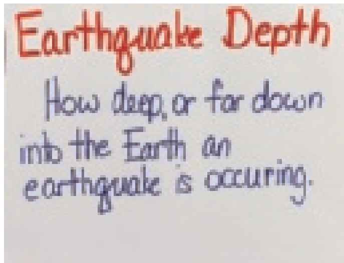
Create a Potential Causes for Mountain Movement chart using a piece of chart paper or other large paper:

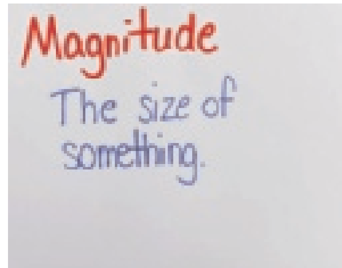
- Label the left hand side "Potential Causes"
- Label the right hand side "Effects"

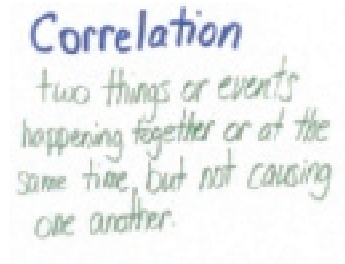
Make sure that the class map and Potential Causes for Mountain Movement chart can be easily accessed and viewed by students. For students that need extra assistance in accessing the information on the maps in this lesson and in future lessons, consider taking high resolution photos of the maps and uploading them on a shareable document with students. This will enable students to be able to zoom in and manipulate the maps in the best way that visually makes sense for them.

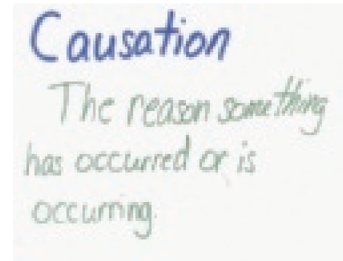
Be sure you have materials ready to add the following words to the Word Wall: *causation, correlation, epicenter, earthquake depth, and magnitude*. Do not post these words on the wall until after your class has developed a shared understanding of their meanings.











Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students created models and identified potential causes for mountain movement and growth. In this lesson, students will create a *Potential Causes for Mountain Movement* chart, where all potential causes from the initial models are listed. Students determine that, like in previous units where multiple variables need to be investigated, one variable will be assessed at a time. Students spend time looking at artifacts and data sources from Mt. Everest and Ridgecrest, California to learn more about what happens before, during, and after an earthquake and the observable changes to Earth's surface. Students also analyze earthquake data across the world and determine that though there are earthquakes occurring where there are mountains, we don't have enough data to conclude that earthquakes cause mountains to change, but we become more confident that there is a relationship between earthquakes and where mountains are located. Students use this information to determine that data, to this point, supports a correlational relationship between earthquakes and mountain growth and movement.

In this lesson, students begin to develop an understanding of the words *correlation* and *causation*. While students may have a superficial understanding of these words at this moment, students will work to conceptually distinguish between these words as they begin to investigate the possible causes for mountain movement. Over the course of the unit students will engage with these words and their meanings in a meaningful way to further develop an understanding of these words. We will be adding these to the word wall in this lesson, but over the course of the unit, we will work to build a deeper understanding of these relationships.

Possible modification to consider: Students list potential causes of changes in mountains. After this, students determine that the class should investigate only one potential cause at a time to see if the potential cause is correlational or actually causing the mountains to change. This discussion leverages students' experiences with single variable investigation decisions during the *Unit 6.2: How can containers keep stuff from warming up or cooling down?*

(Cup Design Unit) to determine which potential cause to investigate first. If you have not taught the *Cup Design Unit*, consider changing the prompts to focus around testing a single variable in an experiment that has been done in science class prior to this unit, and making parallels between the single variable use, to determine if a single potential cause has an effect on our mountains.

Where We Are NOT Going

Lesson 2 is an initial lesson, where students will be listing all of the potential factors for mountain growth and movement. While students begin to investigate earthquakes and their relationship to mountain growth and movement, students will not have an understanding of the mechanisms involved by the end of the lesson to provide evidence of a causal relationship. In future lessons, students will build an understanding of plates and their interactions at a large scale over subsequent lessons.

While students will get a chance to look at earthquake data, they will not begin to develop an understanding of what causes earthquakes or why earthquakes of a greater depth tend to occur at subduction zones, and will learn more about the variance in the average depth of earthquakes along different types of fault lines in a later lesson.

Students' attention will also be drawn to underwater structures that resemble mountains for making earthquake observations. However, we will not explore the reasons why the Mid-Atlantic Ridge exists, or how it was formed, until later lessons.

In this lesson, students will begin to form ideas related to correlation and causation. The justification for these relationships will be limited to qualitative data in this unit, based upon evidence collected and observations made by students. Quantitative analysis of data to show correlation vs. causation relationships involving graphing data is not explored with students until high school, when students learn about statistics and probability, as seen in the Common Core Math Standards.

LEARNING PLAN FOR LESSON 2

1. Navigation

8 MIN

Materials: Potential Causes for Mountain Movement chart, markers

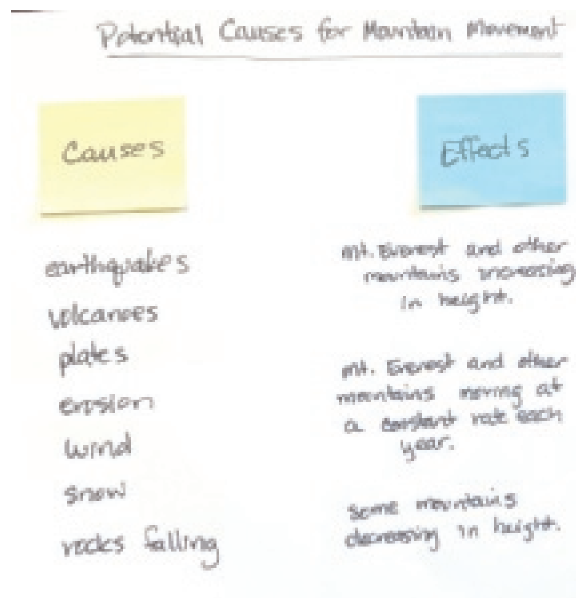
Recall the previous lesson. Display **slide A**. Read the question to students and give them a short period to consider their answers.

- What about these different mountain cases were we trying to explain in our last lesson?

Allow students to share their answers to the question. Students should say that we were trying to determine what caused the movement and changes in elevation to Mt. Everest and other mountains.

Say, *Last class, we had several potential causes on our consensus models that could be leading or contributing to those changes and were wondering about which of these causes was most likely to cause these changes. Let's take some time to remind ourselves about some of our ideas.*

Create a Potential Cause Board. Display the *Potential Causes for Mountain Movement* chart for the class.



Begin by asking students what we found out was happening to Mt. Everest and other mountains from Lesson 1. Say, *We read about changes happening to different mountains in our last lesson. What were these changes?* Students should say that Mt. Everest is growing taller, Mt. Everest is moving, other mountains are growing taller, and other mountains are shrinking.

Say, *Okay, so since we are trying to figure out what is causing these changes, let's think of these as the effects of some potential cause and list these on the right side of our Potential Cause for Mountain Movement chart under "Effects."* Add the three changes under "Effects."

Ask students to look back at their individual mountain models and the class consensus models. Say, *Now let's list all the potential causes we have for these changes. Look back at your initial consensus models. What are some potential causes we included in our models?* As students share their potential causes, ask what effect this potential cause might have on mountains. As students share their potential causes and which effect it could result in, probe students to give evidence for their potential causes and effects. If the potential cause can be tied back to a source from Lesson 1, indicate it by drawing a solid box around the cause. If the potential cause was not mentioned in materials from Lesson 1, such as plates, plate tectonics, rocks moving, ice shaving mountains, etc., draw a dotted line around the cause.

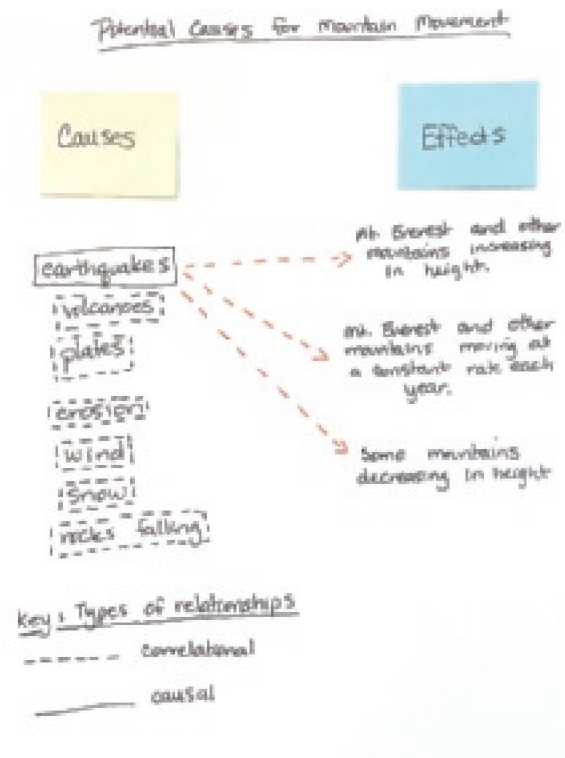
***Supporting Students in Developing and Using Cause and Effect**

As students share their ideas for what could be causing these changes to the different mountains they looked at in Lesson 1, there will be both causal and correlational relationships that they share. At this point in the unit, this is okay and encouraged as we want to get all of our ideas on the Potential Causes for Mountain Movement chart. These ideas will be used and leveraged to help us determine what we want to investigate over the course of the unit. In Lesson 9, this chart will be revised to capture a causal chain of events that occur to lead to a mountain growing in elevation. In Lesson 12, students will revise the Potential Causes for Mountain Movement chart as we determine that underground processes, such as plate movement, isn't leading to any of our mountain cases decreasing in elevation. By the end of the unit, students will also develop a causal chain for erosive processes leading to changes to Earth's surface.

Establish a key with students to use lines that are dotted to represent correlational connections between the potential causes and events. Use solid lines to show causal relationships between the causes and events. An example chart can be found below.

Say, *Let's think about Earth moving or changing. Do we have any experiences with the ground moving, or know of any ways that the ground can move that we might want to add to our Potential Causes for Mountain Movement chart?*

Ask students to share out what evidence they might have of the earth moving on its own. Remind students that one of the reasons the Chinese and Nepalese scientists wanted to collaborate was to collect more accurate data about Mt. Everest after the 2015 earthquake. Encourage students to think about how they think the landscape might change during or after an earthquake. If earthquakes have not been added to the Potential Causes for Mountain Movement chart, do so now. Ask students if they think that the earthquake happens and causes the changes, or if they think the earthquake happens at the same time that the land changes. Allow students to share out their ideas and ask students for their reasoning.



Say, *We have a lot of potential causes for the effects, or changes to the mountains, listed. But as of right now, we aren't sure if these things are just related to, or seem to happen at the same time that a mountain changes or if they actually cause the mountains to change. In the real world, scientists also have to work through determining if potential causes are just related to changes they see or if they actually cause the changes they see happening.*

Introduce correlation vs. causation. Project **slide B**. Look back at the newly completed chart with students. Point out that we have several potential causes listed for the changes we are seeing in our mountains, but at this point, we do not have evidence that any of these potential causes actually led to any of these changes. In order for us to figure out what is happening at our mountains, we need more evidence. Sometimes potential causes can end up either directly or indirectly causing changes that we are observing or they could just be happening at the same time.*

Explain that scientists have special words to describe the relationships between these potential causes and effects that result in changes to the mountains. One word is correlation, and the other is causation. Say, *Think about when you might have heard these two words. Turn and talk with a partner about what you know about these two words.* Have students turn and talk with a partner about the prompt on **slide B**. Ask students to share their ideas regarding the differences between these two words. Determine that the word correlation means that there may be a relationship between the two variables, and that causation means that one variable directly or indirectly causes a change to the other variable.*

***Attending to Equity**

Words such as causation (or cause) and correlation are sometimes used interchangeably despite having distinct scientific meanings. This is similar to using the word theory in everyday language versus how it is used in the scientific context. To help students understand the scientific use of causation and correlation, it may be beneficial to spend time breaking down the words into prefixes, roots, and suffixes to gain a better understanding of the differences between the two words.

Causation- the reason that something is occurring.

Cause- the mechanism or reason why something is occurring

ation- an action or instance of it

Correlation- two things or events happening together or at the same time, but not causing one another.

Co- occurring together or at the same time

relate- connected to

ation- an action or instance of it

Explain that with correlation, there may be evidence of one happening at the same time as the change we are seeing, so they are connected in some way. In order to show that a variable has caused a change, however, we have to look for patterns in our evidence that link the two events together, showing that the variable has actually caused the change.

Additional Guidance

Depending on your students' prior knowledge with these terms, some students may need more support in identifying correlation vs. causation. These two words can feel very similar, and due to spelling similarities, students with dyslexia or students who need greater support with decoding words could benefit from additional practice. Consider pausing and going over a couple examples to help students differentiate between the two concepts. For example:

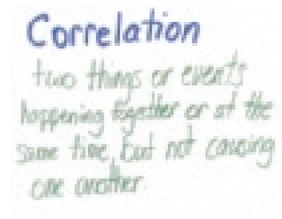
- Ice cream sold in the summer (correlation) vs. ice cream melting faster in the summer (causation; increased temperature).
- Consuming ice cream and the number of sunburns in the USA (correlation) vs. the number of sunburns and time spent in the sun without sunscreen (causation—direct exposure to sunlight unprotected).

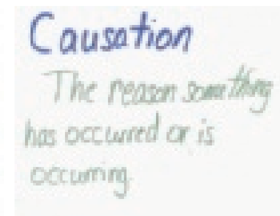
Add these two words, *causation* and *correlation*, to the Word Wall.*

Say, *Now that we know we are looking to determine if events are causational or correlational, and that we need to collect evidence to support any potential connections, what were some of our ideas about which part of our model to explore first?*

***Attending to Equity**

Supporting Emerging Multilingual Learners: When developing new vocabulary, strategies that may benefit emergent multilingual learners are to use student-friendly definitions, make connections to cognate words when possible, and include a visual representation of the word. Use these strategies throughout the unit for both "words we earn" and "words we encounter."





2. Narrow focus to earthquakes.

3 MIN

Materials: Potential Causes for Mountain Movement chart, Ideas for Investigation and Data We Need poster

Say, *We have a lot of potential causes for our mountain phenomena. If we investigate all of them at the same time, will that help us conclude what the underlying cause of the changes is? Should we investigate them all at once?*

Allow students to respond. Students should explain that we cannot investigate all causes at once, or we may have problems determining what evidence of each potential cause could lead to a change in our mountains.

Narrow the focus of study to begin with a single variable. Display **slide C**. Allow students a moment to read the questions on the slide.

- What have we done in previous units when we have several potential causes that could explain observations in a phenomenon on we are investigating?
- How did we investigate those variables to determine whether or not each variable could cause the observed changes, or whether they are just correlated (related to) with the changes?

Discuss the questions as a class and determine that each variable should be looked at individually to assess if it truly has an effect on mountain elevation. Highlight the importance of assessing one potential variable at a time. Example prompts and responses are below.

Suggested prompts	Sample student responses
What units have we experienced prior to this where we have had several potential causes for a change that has occured?	*In Cup Design Unit we had a lot of potential causes for why our cup systems warmed up.*
How did we investigate and decide between these potential causes? Did we investigate all the different possible causes at once?	*We looked at each potential cause one at a time.* *We looked at the different parts that we thought were causing the change to the system individually.* *Examples from Cup Design Unit:* *First we thought there were lots of causes, like the lid, what the cup was made of, and the number of walls based on a lot of cup data we collected. We started after that by looking at the lid, then we looked at other things we thought were the cause of the change in the cup system.*
Why would we want to look at only one potential cause at a time?	*because if we change too many things at once we won't be able to tell which potential cause is really making our system change* *Examples from Cup Design Unit:* *We did make a lot of changes at once in the beginning of the Cup Design Unit, but it showed us that there were a lot of potential causes for the changes to the cup system. We had to look at them one at a time to figure out what was causing the system change.*

Say, *Interesting. In the Cup Design Unit we began by looking at the structure of the lids and how they affected our cup system. We picked lids because we thought the heat might be escaping from the top of the cup and we had evidence that showed that this might be a cause of the change in our cup systems.*

Guide students to look at earthquakes as a potential cause for system change. Direct students to look at the potential causes. Ask students what we have the most evidence for across all of the mountain cards. Say, *Looking at our list of potential causes, where should we start? What cause on our Potential Cause for Mountain Movement chart seems to have connections to multiple mountains?*

Negotiate with the class based on evidence on the World Map and in their notebook from the *Data Cards for Other Mountains and Everest* and *Data Cards on Other Mountains and Mt. Everest*, that we see that earthquakes happen at a number of the mountain ranges on our cards. We also think that earthquakes can cause quite a bit of movement and change in Earth's surface. This seems, at this point, to be the most likely cause of mountain movement or changes in elevation. Students may also have included earthquake data as part of the *Ideas for Data and Information We Need* poster in Lesson 1. If your students also asked for this, you can point to this idea on the poster to reinforce that we use students' ideas to inform our investigations.

Say, *We think earthquake data might help us figure more out about what is happening at Mt. Everest, but we don't have evidence yet to show correlation or causation. We need to collect more data. So let's begin there today by analyzing some earthquake data.*

3. Discuss earthquake experiences. 5 MIN

Materials: 6.4 Lesson 2 Experience at Mt. Everest (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Conduct an informal earthquake experience poll. Say, *Since we are going to learn more about earthquakes, I'd love to hear more about what experiences you have had with earthquakes or what you know about what happens to the Earth or land before, during, or after an earthquake.* Have a couple of students share out what they have experienced or have knowledge about and what changes or effects they have seen happen to the land.*

Make predictions about the Mt. Everest earthquake experience. Project **slide D.** Say, *It seems that some of us have ideas on what it might feel like to experience an earthquake. We learned from our reading and mountain cards that earthquakes can occur where mountains are located, and that a large earthquake occurred on Mt. Everest in 2015. But at this point, we still aren't sure if these earthquakes are just correlated or related to mountains moving, or if they have caused mountain movement.*

Explain that we have a video of hikers that were on the mountain during an earthquake. Ask students to turn and talk to a partner about the question on **slide D**.

- What do you think you would see happening if you were on Mt. Everest during the 2015 earthquake?
- Do you think it would provide enough evidence to support whether the earthquakes caused these mountains to increase in height and change locations?

Allow a couple of students to share their predictions about what they would see happening during the 2015 earthquake, and why or why not they believe the footage might provide evidence for a correlational or causal relationship between earthquakes and changes in mountain height and location. After this, remind students that during the time of the earthquake the two countries, Nepal and China, were not sharing data, so we do not have a lot of data about what happened at the exact moment of the earthquake. We do, however, have a clip of a scientist who was climbing during the 2015 earthquake.*

Watch Mt. Everest earthquake clip. Project **slide E.** Remind students that we are trying to determine what might be occurring during an earthquake on Mt. Everest, and if the earthquake is causing the mountain to change, so as the class views the video, they should pay close attention to what they see happened. Play the clip for students. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Share observations and determine if evidence supports correlation vs. causation. Ask students to share their observations of the clip and what they heard the climbers say happened during the earthquake. As students recall the observations, focus on the movement of back and forth during the earthquake. Emphasize that while we have accounts of the ground moving back and forth, we do not have data to show that the ground is in a new position. Pause and ask students if this potential back and forth motion is enough to show that earthquakes are the cause of the mountain changes we're trying to explain, or if they just happen to occur as mountains are changing in height and location, but do not directly cause those changes to occur. Remind students that in the reading we also learned that

***Attending to Equity**
Experiencing an earthquake first hand can be scary and traumatic. The purpose of asking students about their experiences with earthquakes is to begin activating their ideas around the effects of earthquakes on Earth's surface. To help us figure out if an earthquake can cause a mountain to move or increase height, or if earthquakes are correlated with these changes, we will need to figure out more about earthquakes—both what causes them and what effects they have on the land around them. As you facilitate this step of the lesson, help students to focus on questions related to their effects on the land rather than their effects on people. The Tsunami Unit, which follows this one, investigates ways to protect communities from the effects of natural hazards, like earthquakes.

China and Nepal were uncertain if the earthquake caused any changes to Mt. Everest's height, and at this point as a class, we do not have enough data to support correlation or causation. Guide students to determine that it was also hard to see changes on the mountain surface of such a tall mountain, and that if we could analyze an area of flatter land where an earthquake occurred then maybe we could figure out more about whether earthquakes are causes of mountains changing in height. Example prompts and responses are below.

Suggested prompts	Sample student responses
What observations did we make or the climbers report during the earthquake?	*The climbers felt the ground shaking.* *Things started to move back and forth.*
We had earthquakes as a potential cause for mountains changing elevations and locations. Does moving back and forth mean that the mountain is now taller or that the mountain moved to a different location?	*Maybe. If things move back and forth they can sometimes end up somewhere else.* *It was going back and forth from one location to another, but we don't know if it ended up in a new location or if it made it taller.* *They said it was moving back and forth, but they didn't say if it ended up in a new spot or ended up taller.*
We had earthquakes as a potential cause for mountains changing elevations and locations. So do we think we have enough data to say if the earthquake is correlated with or is the cause for the changes at Mt. Everest?	*Not yet. We can't tell if the earthquake just happened and it moved back and forth then, or if it actually caused the mountain to shift or grow.*
Did anything we read in Lesson 1 say if the 2015 earthquake caused the mountain to grow or move?	*The data from China and Nepal showed the mountain had grown over time and constantly moves 4 cm to the NE yearly, and it had grown since they had last recorded it, but we weren't sure if the earthquake had made it grow or move locations.*
Do we think all earthquakes cause mountains and land to grow and change?	*Maybe they do.* *Maybe they don't.*
Because of its location high above the ground, it may be hard to observe what happens to a mountain during an earthquake. What would happen if we were to look at an earthquake somewhere else, like on flatter land or at a lower elevation? Do we think we would better see the surface of Earth there moving and changing?	*If we look somewhere flatter we can see if there are changes to the surface.* *We could totally see if it was moving because it's not as high up.* *Yeah, we could look at the ground before and after the earthquake and see if the ground changes in height.* *It would be easier to examine changes in the land if it was at a lower elevation.*

Say, *We need to look at more data that might give us a better understanding of what might be happening to the land during an earthquake.*

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Supporting empathy and emotions: In an effort to provide students information about what the Earth is like during an earthquake, we have elected to include a firsthand account from a hiker who was on Mt. Everest during the 2015 earthquake. In asking students to think about and possibly re-experience what an earthquake is like, a stress response could be triggered in students.

You may wish to share with students that we will be discussing what it is like to be in an earthquake and we will be hearing from a person's firsthand account of the earthquake on Mt. Everest ahead of time. You can let students know that all of the people in these video clips we will be watching about earthquakes are okay and survived, but they still may wish to be allowed to not participate in watching the videos. If certain students would prefer not to watch the videos, it will not take away from their learning experience.

4. Introduce Ridgecrest, California data.

11 MIN

Materials: science notebook, World Map, sticky notes, 3 meter sticks, 6.4 Lesson 2 Ridgecrest Earthquake (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Explain to students that we have some location data and videos from an earthquake that occurred in California. The land is more accessible and at a lower elevation than Mt. Everest. Also, this area is more populated, so we are able to collect more data types from more people.

Point out Ridgecrest, California on the World Map. Walk over to the World Map and point out the location of Ridgecrest, California for students. As a class, take note of how far away Ridgecrest is from our location, and note that it is located in the Indian Wells Valley, a Southern Californian desert area between 4 different mountain ranges. Mark the location on the map with a sticky note. Add the distance from your school/town location to the sticky note.

Create a Notice and Wonder chart. Project **slide F**. Tell students that we have video of this earthquake occurring, photos of the location after the earthquake, satellite images, and elevation and location data. Explain that since we are going to look at so many new data sources, we should record our noticings and wonderings so we can try to make sense of what happens to the surface of Earth when an earthquake occurs. Give students a moment to create a notice and wonder chart in their notebooks.

Begin making observations near ground level. Project **slide G.** Explain to students that our first piece of data comes from a hotel surveillance camera located in the area. Play the video clip for students. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) While the entire clip can be played, the video only needs to be shown through the first minute. After the video, allow students to record their observations and any questions they may have. Give students a moment to share some noticings they had about the video before moving on to the next slide.

Continue to **slide H.** Tell students that this image is of the ground near the area of the earthquake, with USGS scientist Beth Haddon standing on the ground. Give students roughly 1 minute to record any observations.

Advance to **slide I.** Explain that this is another picture of geologist Beth Haddon collecting data in the area near where the earthquake occurred, and a larger picture of the ground near where the earthquake occured. Give students roughly 1 minute to record any observations.

Shift to making observations at a larger scale. Continue to **slide J.** Explain that this picture was taken from further above the land than the prior photos. This picture was taken in the desert near where the earthquake occurred. Explain that the road shifted by roughly 7.5 ft, or 2.5 meters. Use 3 meter sticks as a visual to show students how far the road was shifted.

Ask students, *The first two pictures of the ground near where the earthquake occurred were taken roughly at eye level. In this image we are looking at the ground, but from a much higher elevation. How might looking at this area of land, or Earth's surface, from different levels or scales, help us understand what is going on?*

Allow students to respond. Students should be able to point out that by looking at different elevations, we change the scale of what we are able to see at a given time, allowing us to see changes that we might not have seen before.*

Say, *OK. So our last few sets of pictures were taken by satellites above Earth. These images are from a much higher elevation and show a much larger area or scale, than the prior photos.*

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Universal Design for Learning: As mentioned in the Materials Preparation section of this lesson, it may be beneficial for students who have enhanced visual needs to create a high-resolution, digital version of this map to share with them to help them better access the material. This will be especially helpful when adding sticky notes to the map during this lesson. For students that could benefit from additional visual assistance, consider making an interactive version of this map online on a platform such as Jamboard, and adding virtual sticky notes for students to see. Maps can also be printed out and distributed for a number of lessons following this lesson. As you read through the teacher guides, consider what maps would make sense for students to view in this manner and consider making these digital and visual scaffolds for students who could benefit from them.

Make observations of satellite data and compare to our World Map. Project **slide K.** Before having students make observations, pause and go over the scale of the image. Point out the scale at the bottom right-hand corner of the slide. Make a noticing that it represents a distance about 4 miles across this scale shown. Explain that this image was taken by satellite in April, over a year before the earthquake that occurred in July.

Before moving forward, ask students what features are on the map, and how this relates to our larger World Map. Example prompts and responses are below.

Suggested prompts	Sample student responses
At this scale, we are able to see a lot more of the ground. We also see a lot of variation with the grey colors on our map. What do you think those darker grey areas represent?	*I think they show different elevations or heights.* *They are hills or mountains* *They show something that is higher up than the area around them.*
So if we think those are mountains, hills, or something else higher up and we compare to our World Map how do these areas compare?	*On the World Map, the brown areas look like they are where there are mountains, like where we marked Everest, there is dark brown.* *On our World Map, the higher up it is the more brown or white it becomes.* *Our mountain maps have all the mountains as brown or white, and the area below them that is lower elevation is green.*
So on the map on the slide that has the different grey shadings, do the darker grey areas represent mountains? And what do the lighter grey areas represent?	*Yes!* *Lighter grey areas show lower elevation or flatter ground.*

Project **slide L**. Confirm with students that these areas that are darker grey are actually mountain ranges we see that surround Ridgecrest on the class map. The mountain ranges surround a valley in the Mojave desert, and even though it is a valley, it is relatively higher than sea level, about half a mile high. Tell students that we have this image, which is before the earthquake, and another after the earthquake that we can use to figure out if any potential changes to the surface occurred due to the earthquake. Explain that you will toggle between two slides, one with an image taken before the earthquake and an image taken on July 5th, after the earthquake. Students should watch closely as you do this for any changes they see between the two images.

Additional Guidance

As mentioned in Lesson 1, some students may believe that a mountain range needs to span countries or continents to be considered not just a string of mountains, but a range. A mountain range is simply a series of mountains connected by high ground, and even something as large as mountain ranges can vary in scale. If some students are intrigued or confused by the small scale of these mountain ranges, it may be worth stopping to operationally define the word mountain range as a class before proceeding with the lesson.

Toggle back and forth between **slide M** and **slide N**. Repeat this several times until it is clear that some students are observing a change in the surface, predominantly a white line that has emerged towards the center of the picture.

Pause and share noticings and wonderings about how the area around Ridgecrest was affected by the earthquake. Begin by asking students what they observed with the video clip of the vehicles in a parking lot and progress to the satellite images just shown. As students are sharing, listen for students to bring up the following noticings about each artifact. As these ideas are shared, ask students what that noticing has made them wonder:

Video of the parking lot

- Cars and other objects, like the bushes and trees in the area, clearly moved back and forth
- No visible changes other than the movement back and forth on the surface

Image #1 of the crack in the ground

- The ground is at different elevations on each side
- There are layers to the ground
- The ground looks relatively solid, but appears to have cracked
- The ground, although solid, appears to be changed by the earthquake

Image #2 of the crack in the ground w/ scientist collecting data

- The crack looks deep
- The earthquake appears to have separated the ground

Image #3 from above the road

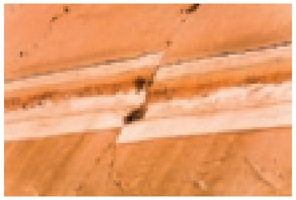
- The road had shifted on one side of another
- A large area had shifted
- The movement was a larger distance
- There may be a crack or a line across the land

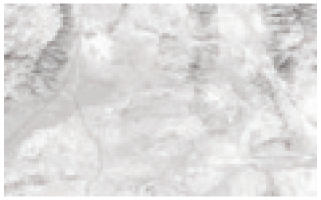
Satellite view

- There is a white crack (line) that has appeared
- The crack (line) seems to be several miles long
- The land around the crack (line) may have also moved
- The changes in Earth's surface are happening all over the observed area

USGS

USGS





NASA

Say, *It seems that looking at the effects of earthquakes at different scales allows us to see different things that may not be observable at other scales. For example, the effects of this earthquake affected a really large area, which was only apparent and observable from a distance above the ground. I have one more artifact for us to look at to help us figure out more about what might have occurred when the earthquake struck.*

Discuss elevation and location changes. Project **slide O**. Give students a moment to look at the newly colored satellite image from before and record their noticings and wonderings. Ask a few students to share out what they notice and wonder about the changes made to this image.

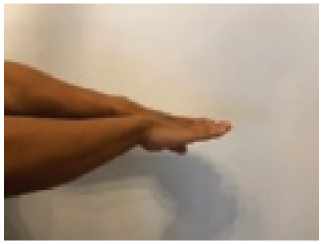
Discuss the features of the map with students and what the features reveal about the impacts of the earthquake on the area. Example prompts and responses are below:

Suggested prompts	Sample student responses	Follow-up questions
This grey map has two different colors placed over it. What do the different colors mean?	*The different colors match up with the scale shown on the bottom of the picture.* *The bottom of the slide says changes in meters and one side is positive and the other negative.* *It must be changes in elevation after the earthquake. The caption under the slide says that.* *The blue means up and the orange means down.*	*What would the positive and negative numbers refer to?*
How large do we think the area is that moved?	*The scale still shows that each one of those units is 4 miles. The area must be a large area.*	*Using this scale, about how large of an area would you predict was affected by this shift?*
In addition to changes in elevation, or changes vertically, what other changes are represented here?	*It says that the blue area is moving northwest and the red area is moving southeast.*	*So this area is moving **and** changing in elevation. How is this similar or different from Everest?*

Say, *So it's clear that some parts of the land have moved, but it is hard to visualize the different movements that have occurred in the area by just looking at the different colors on the map. Let's use our hands to try to better visualize what is happening to the land where the earthquake occurred.*

Model movement with hands. Work with students to model what has happened to the land. You may need to orient students to the cardinal directions here, with north being represented as in front of them, south being represented behind them, east being to the right and west being to the left before beginning to model the land movement.

Ask students to bring both hands together with their palms facing down. Explain that the left hand will represent the blue on the west, or left side of the satellite image, and the right hand will represent the red on the east, or right side of the image.



Have a student read from the slide what occurred to the blue, or west side of the map. Model this movement with students by having them raise their left hand up and shift it away from them in a northwest direction.

Repeat with the right hand, by lowering this hand down and shifting it towards them or in a southeast direction.

Ask students how this hand visualization connects to what we have seen in our other Ridgecrest data sources. Students may mention the following:

- It looked like the road from above might have shifted, but this shows that one side probably sank and another side must have risen.
- This shift in the land could help to explain how the road through the desert could have shifted so much.
- It kind of looks like land in the images of the scientist that is collecting data. The images showed the land had moved vertically. This shows us the land moved horizontally, but we couldn't tell if the land had moved horizontally in that photo.

Say, *OK. It sounds like we have more evidence that earthquakes may be related to mountain motion and that they may be correlated with elevation changes, like we saw with the road and the satellite images. But, are they causing the mountains to change in height and location, or are they just happening at the same time?*

Allow students to respond. Students should say that it seems like they are happening at the same time, but we can't say if they are causing the changes.

Ask students, *If we were to look at other places where mountains are located, what do we think we would see happening to the surface based upon our data?*

Allow students to respond. Students should say that they might see the land is shifting, cracking open, and changing in location or elevation where earthquakes are located.

Say, *So, we've figured out that both Ridgecrest, located in between mountains, and Everest have experienced earthquakes, which seem to be related to changes in elevation and location. I wonder if earthquakes always happen where other mountains are located. Let's look at our map and see where else we think there may be mountains and then see if we can find data about earthquakes in these areas.*

5. Revisit map to identify potential mountain locations. 5 MIN

Materials: World Map

Orient back to the World Map and revisit its features. Project **slide P.** Before identifying potential earthquake locations, orient students back to the map. Ask students to explain the meaning of the different colors on the map. Identify, or re-identify the following features with students:

Colors associated with land vs. liquid water vs. snow/ice

- Blue regions- where liquid water is found, but the water has been removed here
- Green and brown regions- where land is found
- White regions- snow or ice

Elevation changes associated with color variances

- Brown variations- darker brown really high up elevation and lighter brown is further down but not quite at sea level
- Green variations- green and darker green represent from 1 to a few 100 feet above sea level
- White variations- these can also be in some cases between 0 to 10,000s of feet above sea level

Determine locations of potential mountains and ranges. Say, *Using the map's features, where do you think mountains are located?* Allow students to share out potential additional locations of mountains not already listed on our map. If time permits, ask students to approach the World Map or the projected map, and point out specific locations that they believe may be mountainous. As students identify potential locations, ask them if they think earthquakes may occur in those locations, and what potential data they might be referencing to support that the potential earthquakes would be occurring in those locations. If students begin to identify larger potential mountain ranges, probe students to explain why they are choosing those locations.

Consider potential oceanic mountain range locations. If students do not point out locations that are located in the oceans, such as the Mid-Atlantic Ridge or the Mariana Trench, ask students if they think only locations on land have mountains. Direct students to consider the longer lines of higher elevation located in the oceans.

6. Explore Seismic Explorer. 13 MIN

Materials: World Map Lesson 2 Earthquake Data (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Orient students to data visualization tool. Project slide Q. Say, *I have a tool that lets us visualize earthquake data from all around the world for the past few years. It's called Seismic Explorer and it uses daily scientific data from the US Geological Survey, so it has the most recent data on earthquakes and will let us go back in time to see previous earthquakes. Let's use the simulation to see if our predictions of where mountains occur based upon our map match up with where earthquakes actually occur on Earth.*

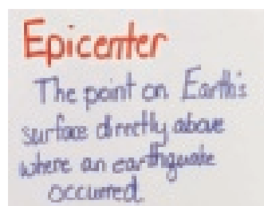
Additional Guidance

Scientists monitor earthquake activity through different scientific organizations, such as the US Geological Survey and the Global Seismographic Network. These efforts mark a shared global scientific endeavor to monitor earthquakes around the world and when possible, mitigate their impact. Some countries also have more detailed monitoring systems to gain an in-depth national or regional look at earthquake activity. It is important for scientific research to monitor and study earthquake activity to gain a better understanding of how Earth's crust shifts over time. But it is also through this detailed monitoring that scientists gain insight into potential impacts of earthquakes on human populations and settlements. Data from this monitoring is updated in real-time and freely available for scientists and citizens to view on different mapping platforms. Seismic Explorer imports this real-time data so that students are viewing accurate and up-to-date earthquake data since 1980.

Open and project Seismic Explorer Version 1. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Change the Map Type on Seismic Explorer to "Relief."

Preview Seismic Explorer and add *epicenter* to the Word Wall.

- Use the date range slider to set the date range, but don't hit "play." Slide the white circle near the bottom of Seismic Explorer from left to right—this represents the starting point for the data. Say, *As I move this slider across the bottom, I'm changing the date range. It looks like I can choose earthquakes from January 1980 to today. What do you notice about the number of earthquakes?* Students should identify that there are a lot of earthquakes on our map.
- Ask students, *What do you think you would see if we zoom in on Ridgecrest?* Students should respond that we would see a dot on Ridgecrest.
- Zoom in on Ridgecrest and reveal that there are many, many small dots in that area. Ask students why the dots are dots, and not lines like we saw in the image of the earthquake that had moved the land. Guide students to determine that the dots are associated with where exactly the earthquake occurred as evidenced by what is seen on the surface of the land. Tell students that scientists call this the **epicenter**. Add the word *epicenter* to the Word Wall.*
- Explain that students can zoom in and out on any area to view the earthquakes. They can also adjust the timescale on the bottom to see earthquakes over time, as we did in the beginning of the demonstration. Students can press play to see the earthquakes populate the map over time.



Concord Consortium

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Supporting Emergent Multilingual Learners: When new scientific words, like "epicenter," are introduced, it can be helpful for emergent multilingual students to see a reference to those words added to a word wall. Add these words to the word wall as they emerge in the discussion, rather than before.

Additional Guidance

If you are planning to teach *Unit 6.5: Where do natural hazards happen and how do we prepare for them? (Tsunami Unit)* directly following this unit, plan to keep up your Word Wall in a place as you transition to that unit so it can still be referred to and used. Students will refer to some of the words from this unit during the tsunami unit, and it will be helpful to have them posted for quick reference.

Explore the Seismic Explorer tool in partner pairs. Ask students to draw a Notice and Wonder chart in their notebooks and distribute a copy of *How Are Earthquakes Related to Where Mountains Are Located?*. Allow students to spend some time in partner pairs using Seismic Explorer either confirming or denying their initial prediction of the earthquake locations based upon the presence of potential mountains and ranges. Give students time to explore the simulation on their own, and ask students to jot down anything that they are noticing and wondering while looking at the simulation, along with whether their predictions were correct. Explain to students that they can use the first map to annotate any interesting patterns or observations that they make. Give students until the end of class to explore the tool.

Additional Guidance

The data visualization tool has earthquake data going back to 1980. However, since distinct patterns will emerge even when looking at a smaller set of data (earthquakes dating back one year), it may be helpful for students to begin by examining less data for now. Students will have an opportunity to select from larger data sets later.

Students will revisit Seismic Explorer on day 2 and have more time to use other tools and notice patterns in the data. At this point, the key is purposefully not being explored. The focus of today's investigation is to look for general connections between our proposed earthquake locations based upon our predicted changes in elevation and location on Earth's surface and where earthquakes actually occur. Magnitude and depth will be more purposefully explored on day 2. If students choose to utilize the key to learn more about these differences in representation of earthquakes on day 1, that is fine, but the data will not be discussed in depth and connections/patterns will not be formally established for this data until day 2 of this lesson.

End of day 1

7. Attempt to determine correlation or causation of earthquake data.

12 MIN

Materials: *Earthquake Investigations*, science notebook Lesson 2 Earthquake Data (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Say, *Last class we had the opportunity to look at a tool called Seismic Explorer that helps us make sense of large earthquake data sets on a world map. This tool allowed us to check our predictions and make more observations about where earthquakes are occurring. We also considered how the earthquakes may be correlated to or cause changes in the elevation or location of Earth's surface. Let's think back to our data that we have collected so far and try to make sense of it.*

Make a claim regarding earthquakes and mountain changes. Project **slide R**. Read the slide to students and allow students 5 minutes to craft an argument. As students work to identify evidence, remind them that we have been recording our ideas and observations in our science notebooks as we have progressed through our last two lessons.

***Supporting Students in Three-Dimensional Learning**
At this point in the lesson, students have analyzed and interpreted large datasets from Seismic Explorer to record data to potentially be used as evidence to determine a causal or correlational

Allow students to share their ideas with a partner. Give students 1-2 minutes to share their ideas with a partner and receive feedback on the evidence they have used to support their argument. Tell students that they are allowed to, and even encouraged to revise their evidence as they share with their partner.

Discuss prompts as a class. Bring the class together and ask students if they think the events are correlated or caused by earthquakes.* At this point of the unit, students should be able to identify that earthquakes are occurring in areas that we have identified the mountains as growing, and that few earthquakes are occurring at the Urals and Appalachian ranges. We may also see earthquakes happening in other areas that we have identified as there being mountains, but some locations such as the mountain range off of the western coast of Norway are not very active.

Ask students, *While we see the earthquakes occuring at the places where we have data that mountains are growing from our mountain case cards, does it mean that changes in mountain elevation and location are* ***correlated*** *with earthquakes, or* ***caused*** *by earthquakes?*

Students should identify that the earthquakes seem to be happening at areas where mountains appear to be growing in elevation according to our mountain case cards, and that earthquakes are occuring at a lot of other locations on the surface of the globe, but we aren't sure yet if these other locations are also changing. We can say at this point that they seem correlated, but we cannot say that they are causing these mountains and other areas to change in elevation and location.

Assessment Opportunity

Building Towards: 2.A Present an oral and written argument that earthquakes either caused or are correlated to the elevation and location changes of the mountain cases and Ridgecrest, California.

What to look/listen for:

- Look and listen for students to write and orally argue that data and observations support a correlation, not a causal relationship, between earthquakes and mountain growth and movement.
- Students should cite changes to the surface after an earthquake as evidence of a correlational relationship, and evidence from the videos as not showing direct changes occurring during the earthquakes to make a causal relationship.

What to do:

- If students try to create a causal relationship between the events, ask students if any ground cracked or changed in elevation or location during the videos watched.
- Students should state that the ground momentarily moved, but did not visibly change.

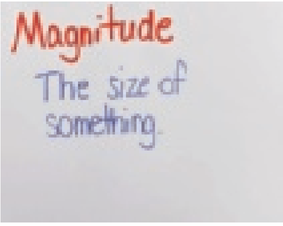
Point out that while we were looking for potential connections between the surface changes and earthquakes, we also found some interesting earthquake patterns. Ask students to share out any patterns and new questions that they have related to those patterns, and what we might learn by investigating earthquake location, size, and depth. Example prompts and responses follow.

relationship between earthquakes and mountain changes. While this work to determine correlation vs. causation is starting in this lesson, students will engage in using data as evidence to determine the relationships between our potential causes for mountain movement and the effects we have observed in multiple places throughout our unit. As students progress through the unit, this SEP is utilized as students in turn engage in the Crosscutting Concept of Cause and Effect at a middle school level. As students figure out these relationships, at many points, this practice and crosscutting concept will work hand-in-hand to aid student understanding and development of ideas related to causation and correlation based upon data being used as evidence to support our ideas. Inherently throughout the unit this practice of Analyzing and Interpreting Data will have to occur for students to engage in this Crosscutting Concept of Cause and Effect that is referenced in many lessons going forward in the unit. Due to the nature and scale of the data and data sources this practice and crosscutting concept will be used in conjunction with each other for students to make sense of their ideas throughout the unit about what causes changes to Earth's surface.

Suggested prompts	Sample student responses
What other patterns or observations did we identify as we looked at the earthquake data?	*The earthquakes happen in lines.* *The earthquakes happen at different depths.* *Some earthquakes are bigger than others.*
What did those observations and patterns make you wonder about?	*Why do they happen in lines?* *What causes the earthquakes to be bigger in some areas?* *What is happening to start an earthquake?* *Is this line related to lines of mountains? Is this how they are growing?* *What type of earthquakes are where the ground changes the most?* *How deep do some of the earthquakes go?*

***Attending to Equity**
Small group labs and investigations are designed to ensure that all students are positioned to intellectually engage during the activity. While it may be more convenient to have students investigate each factor as a partner pair or small group, this does not necessarily position all students to intellectually engage in the activity. By having each member of the group investigate a different variable, each student will have to analyze the associated data and provide insight to the rest of the team and engage in a collaborative learning process.

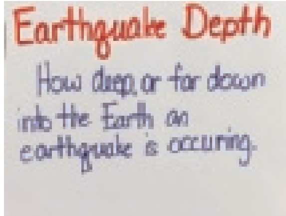
Go over the Seismic Explorer Key and add *depth* and *magnitude* to the Word Wall. Reopen Seismic Explorer for students. Ask, *Did everyone make sense of what these different circle sizes and colors mean?*



As a class, go over the Key and what each of the features means.

- Click the “Key” in the upper right hand corner. Discuss briefly what the circles and colors represent.
- Compare the larger and smaller circles—students should explain that the larger circles have a larger magnitude, according to the key.
- Ask students what **magnitude** means. Students should make the connection that a larger circle is a greater magnitude, and that it represents an earthquake that was bigger or affected a larger area. Explain that magnitude is a word used to describe how big the earthquake is.

Add *magnitude* to the Word Wall.



- Look at the different colors of earthquakes, and ask students what they think the different colors mean. Students should identify that the colors correspond with the depth of the earthquake.
- Ask students what **depth** means. Students should identify that the depth is how far down into Earth the earthquake is occuring.

Add *earthquake* and *depth* to the Word Wall.

Use Mt. Everest to make a prediction. Zoom in on Mt. Everest. Ask students what earthquake depth and magnitude data we would expect to see at Mt. Everest if it were to display the large earthquake from 2015. Project the 2015 map data for students. Ask students what they notice about the depth and magnitude of the earthquake. Students should note that the earthquake was large, but shallow. Ask students what they think they will find if they were to look at other mountains and the earthquakes around them. Example prompts and responses are below.

Suggested prompts	Sample student responses
It looks like Mt. Everest experiences a range of earthquakes, and some of them are higher in magnitude. Do you think we would find the same data at all the mountains in our case sites that are moving or growing?	*I think so. We see earthquakes happening and also signs of movement at those locations.*
Do we think there will be a relationship between how large the earthquakes are and the locations where our mountains are moving?	*Possibly?* *I think some of the earthquakes in lines were the same color.* *Maybe in areas where it is growing they are really high magnitude.*
Mt. Everest's earthquakes were also shallow. Do you think that all earthquakes around our mountains are shallow?	*I don't think so. We saw some darker colors on our map.* *Maybe they are next to the mountains, and the deeper ones happen in places that are just deeper to begin with.*
Would the depth of the earthquake be related to where mountains are growing?	*Maybe?* *Some seemed to be deeper than others when I clicked on them, but the 2015 earthquake near Mt. Everest was really shallow.*

Say, *We have questions about how the depth and magnitude of earthquakes might affect mountains. It also sounds like we need to look directly at locations where we have movement and growth data. Let's divide these things up among our groups so we can investigate all 4 at the same time.*

Distribute maps and go over investigations. Project **slide S**. Distribute *Earthquake Investigations* to students. Instruct students to add the maps to their notebooks facing the same direction as the other map on *How Are Earthquakes Related to Where Mountains Are Located?*.

Divide the class into groups of 4. Explain that each person in a group will do a slightly different investigation to determine how earthquake magnitude and depth might be related to mountain growth and movement. As students investigate their variables, explain that they can use the map to annotate where they find any patterns between earthquake magnitude or depth, and mountain growth or movement.

Additional Guidance

Depending on the science notebook style used in your classroom (e.g., binder, spiral notebook, or composition notebook), adjust the information on slide S to reflect the procedures you have in place for attaching handouts to the notebook, titling pages, and updating the table of contents.

Conduct investigations. Project **slide T.** Give students a moment to determine who in each group will conduct each investigation.* Once each group member has an assigned investigation, allot 8 minutes to explore Seismic Explorer and look for patterns. If groups finish early, ask students to begin to compare their findings in their groups of 4. Students should make observations similar to what can be found on *Student Mountain Observations Key*.

Additional Guidance

Some mountain locations can have a lot of earthquake data to filter. While depth is color coded, magnitude can be harder to decipher for some students. If students are having issues clicking on specific earthquake events, or determining the basic range of magnitude for the earthquakes in the region, direct students to use the magnitude slider tool at the bottom of the interactive. As the tool is slid back and forth, the earthquakes show up as white when the range that they are categorized into is passed before they change to a color and layer on the map. This can create a quick reference visual to the magnitude of the earthquakes in the region for students.

Assessment Opportunity

Building Towards: 2.B Use digital tools to examine a large data set at different spatial and temporal scales to compare global earthquake activity to local activity.

What to look/listen for:

- Look for students to locate mountain regions identified in case site information and narrow focus to earthquake data that applies to those areas that would not be discernible at a larger scale.
- Students should filter through earthquake data and analyze the large sets of earthquake data for any patterns in depth, location, frequency, or magnitude at the regional scale for evidence of earthquakes being causal or correlational to mountain movement and growth.

What to do:

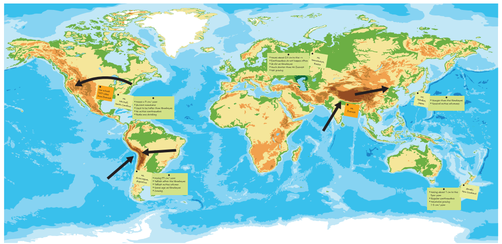
- If students are not able to narrow the focus of their research to specific mountains, guide students to identify each mountain and range, and help students zoom into the data specific to those ranges.
- If students are having trouble discerning the data, help students adjust the earthquakes by magnitude to limit the amount of data shown, and reference the key to show differences in magnitude and depth.
- If there is too much data for students to analyze, instruct students to narrow the year range for their data by only playing a certain portion of the data slider.

8. Record data from earthquake investigations.

10 MIN

Materials: *Earthquake Investigations*, sticky notes, 4 different color markers

Share data and establish a map key. Project **slide U.** After 8 minutes, ask students to show their maps and discuss any patterns they found in their small groups. Once students have had a chance to share with their groups, bring the class back together to share their information. Start with Mt. Aconcagua in the Andes Mountains. Allow students to share what depth and magnitudes are found around the mountain and mountain range. As students share their data, point out that it seems we may have some places that are more shallow, like Mt. Everest, and some places that are deeper, like Mt. Aconcagua in the Andes Mountains. Also note that it may help us see any patterns if we use different colors to record deep and shallow, and use representations to show if they are high magnitude or lower magnitude in general. Bring out 2 different color markers and work with students to determine which marker should represent deep earthquakes and which color should represent shallow earthquakes. Record the colors chosen for the map by making a key on a scrap piece of paper or small sticky note and post it next to the larger map.* An example of a map with completed sticky notes on it is shown here



Record class data on map. Return to the data at Mt. Aconcagua. Make a sticky note using the class-designated key for the Mt. Aconcagua depth, and a sticky note in the designated color for the depth, and work with students to make a circle that is representative of the magnitude of the earthquakes felt there. Since the earthquakes are deep and higher magnitude, make the circle large on the sticky note in the color that represents deep earthquakes. Make a sticky note with the information for each location as students share. If students also note locations above or below the mountain location within the mountain range, these can also be added at this time. Work together to compile information about each range. A sample of data that students may want to record for each mountain and range is in the table below. Note that this table is for teacher reference only, and not expected of students.

Mountain	Magnitude	Depth
Mt. Mitchell, Appalachian Mountains	EQs are low magnitude Almost all EQs are magnitude 3 or below	EQs are shallow 30km or less
Mt. Aconcagua, Andes Mountains	Most EQs are 3-6 in magnitude Some EQs up to magnitude 9 around it	EQs are 100-200km deep Some EQs are much deeper to the NE
Mt. Narodnaya, Ural Mountains	4.4 magnitude only 1 earthquake happened near it	EQ was shallow 30km or less
Mt. Everest, Himalayan Mountains	Most EQs are 2-5 magnitude Up to 8 magnitudes can occur around it	Most EQs are 0-100km deep Some larger earthquakes are shallower
Mt. Hotoka, Japanese Alps	Most EQs are a magnitude of 3 Larger EQs can be found N and S on range	0-30km deep around the mountain Some are 300-500km deep to the N and W of the mountain, sometimes deeper
Mt. Cook, Southern Alps	Most EQs are 3-5 in magnitude Only 1 6 magnitude has happened at the mountain Magnitude 7-8 occur along the range	Mostly shallow at the mountain, above 30km Deeper earthquakes occur along the range

***Attending to Equity**
Although color coding is discussed and suggested as a useful way to quickly reference the potential patterns found on the class map, letter or number coding helps ensure accessibility for any student who may be color-blind. Consider creating a key that also assigns numbers or letters with the colors (such as all red text has an A or 1 next to it) to track what colors, symbols, numbers, or letters represent different data points.

9. Make sense of new data on world map. 5 MIN

Materials: World Map

Discuss data as a class. Begin by saying, *OK, what patterns or observations can we make about the data we have added to our class chart?*

Allow students to share their general patterns or observations with the class. Ask students what they notice regarding the number of earthquakes, location of earthquakes, and the depth and magnitude on our class map. Guide students to make the following observations about the data public:

- Mountains that are changing location and elevation all have earthquakes around them.
- Mountains that are not increasing in elevation also have at least 1 earthquake that has occurred near the location in the past 30 years.
- The mountains that are increasing in elevation have more earthquakes that occur around them.
- Some mountains have larger earthquakes than others, although at this point there isn't a clearly defined pattern with magnitude.
- Some mountains have earthquakes that are deeper than others, but at this point there isn't a clearly defined pattern with depth.

Say, *Now that we have added what we found out about where earthquakes occur and their magnitude and depth to our map, let's see if we can make progress on our Potential Causes for Mountain Movement chart.*

10. Revisit the Potential Causes for Mountain Movement chart. 5 MIN

Materials: Potential Causes for Mountain Movement chart

Discuss potential causation or correlation to mountain changes. Project **slide V**. Direct students to look back at the Potential Causes for Mountain Movement chart and remind students that earthquakes were the first potential cause we investigated. Lead a discussion with the class regarding earthquakes and the nature of their relationship with the changes in mountain height and location. Remind students that we have seen videos and some pictures from Mt. Everest, Ridgecrest, and the surface of Earth at Ridgecrest before and after earthquakes. Although we have evidence that earthquakes could have caused the observed changes on the surface of Earth at Ridgecrest, we could not definitively say that the earthquakes are causing mountains to change in elevation or location. We have also looked at data regarding magnitude and depth. Example prompts and responses are below.

Suggested prompt	Sample student responses
Let's think back to the data we have collected from this lesson. What did we see from our Ridgecrest data?	*During an earthquake the ground moves back and forth.* *The satellite images of Ridgecrest showed that the land was in a different place after the earthquake, and that it was at a different height too.*

Suggested prompts	Sample student responses
While we saw those changes on Earth's surface, did we see any proof that earthquakes caused the land near Ridgecrest to change?	*While we saw that the cars moved back and forth, we didn't actually see anything crack or move locations in the video.* *We didn't see the land crack and move at Mt. Everest either.* *We did see the land change locations in our satellite images, but I don't know if the earthquake caused the land to change elevations or locations or if the land moving caused the earthquake.*
What did we discover with this investigation that helps us determine if earthquakes are correlated with or cause mountains to change?	*We noticed more earthquakes at locations where the mountains were increasing in elevation, but we also saw some at places where the land was just moving, not growing like Mt. Mitchell.* *We also noticed that there were different magnitudes. The higher magnitudes seemed like they were in areas where mountains are increasing in elevation, but we aren't sure if that is a pattern.* *We noticed the same thing with depth. Some were deeper, and some were shallower, but we can't tell if deeper or shallower earthquakes cause mountains to grow, just that they were at the same places where mountains grow.*
So would you say we have enough evidence to say that earthquakes cause mountains to change, or do we just have enough information to say that they are correlated, or related, to each other?	*We don't have enough information to say that earthquakes cause mountains to change, but they are definitely related!* *Earthquakes are correlated to mountain change.*

11. Determine next steps.

5 MIN

Materials: science notebook

Determine what data we still need to investigate. Say, *So far we have looked at several data sources to try to understand if earthquakes are causing or are just correlated to changes in mountains. At this point, we only have evidence to support a correlational relationship. Maybe this is because of our data. Let's consider the data we have collected so far.*

Turn and Talk about data collection. Project **slide W.** Give students time to share with a partner, then spend time discussing each question as a class.

- Where have we collected data from?
- What perspectives did we use to look at that data?
- Is there still some data that we cannot explain, or have questions about?

Students should say that we have collected data from Mt. Everest, Ridgecrest, and from our other mountain locations on Seismic Explorer and through videos and images. We have looked at data at ground level and pictures from above Earth's surface. We have also looked at data from below the surface. Ask students if there is any data that we are still uncertain about. Students should identify that while we may see earthquakes of different magnitudes and depths, we still don't understand why we see those occurring, or what is happening to the mountains as the earthquakes occur.

Say, *OK, so we still have questions about what is occurring under the surface, and if that is correlated with or causing our mountains to change in elevation and location. We still think there is something happening underground that might be contributing to the changes we see happening to mountains above ground. What would we even find down there if we were to look underground?*

Consider what is underground. Project **slide X**. Ask students to turn and talk about the prompts on the slide. After about 2 minutes, bring students back together and explain that we will get a chance to consider what is underground.

12. Introduce home learning.

3 MIN

Materials: *Reading: What Do We See on Earth's Surface Where We Live?*

Distribute and go over home learning. Project **slide Y.** Pass out *Reading: What Do We See on Earth's Surface Where We Live?* to students. Explain that for home learning they will read the information and consider what the land is like where they live. Next class period we will revisit these ideas as a class, so they should be ready to share their ideas.

Attending to Equity

This home learning is used to broaden students' thinking beyond the classroom to the world around them through related phenomena and leverage these everyday science experiences they have outside of school to augment the learning that happens in the classroom. Locating phenomena in the context of their community helps the phenomena become more personally meaningful to each student and provides students an opportunity to talk about the phenomena with family members and other community members.

ADDITIONAL LESSON 2 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

Students work with digital informational data to look for earthquake patterns for all six of our mountain locations in terms of four research questions:

- How is Earthquake Depth Related to Where Mountains Are Moving?
- How is Earthquake Strength (Magnitude) Related to Where Mountains Are Moving?
- How is Earthquake Depth Related to Where Mountains Are Growing?
- How is Earthquake Strength (Magnitude) Related to Where Mountains Are Growing?

Once they have worked independently to collect their data, they work with a small group to jigsaw this data. They build on each other's ideas and express their ideas clearly by looking for and communicating patterns and connections to the elevation of the different mountains and the types of earthquakes that occur there.

The Gorgeous Globe

1 **Vivid Vacation Pics**
2 **Earth's Famous Events**
3 **How Deep Can You Go?**
4 **Seeing the Unseen**
5 **It's Not Their Fault**

Literacy Objectives

✓ Summarize key points related to Earth's crust.
✓ Translate text to visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 1 and 2.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a four-panel comic in response to the reading.

Instructional Resources

Student Reader
Collection 1

Science Literacy Student Reader, Collection 1
"The Gorgeous Globe"

Exercise Page
EP 1

Science Literacy Exercise Page
EP 1

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: What is causing Mt. Everest and other mountains to move, grow, or shrink?
- Lesson 2: How are earthquakes related to where mountains are located?

Standards and Dimensions

NGSS

Disciplinary Core Idea ESS2.A: Earth Materials and Systems: The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

Science and Engineering Practice(s): Asking Questions and Defining Problems; Obtaining, Evaluating, and Communicating Information

Crosscutting Concept(s): Systems and System Models

CCSS

English Language Arts
RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

LITERACY.W.6.3.A: Engage and orient the reader by establishing a context and introducing a narrator and/or characters; organize an event sequence that unfolds naturally and logically.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

crust **fault**

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

sedimentary **seismic waves**

seismometer **tectonic plates**

transform fault

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Plate Tectonics and Rock Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read a simulated vacation photo journal that shows unusual rock formations from China, Indonesia, Australia, and Greece.*
    - *Next, you'll look at a map showing that violent volcanic eruptions and earthquakes affect people in many parts of the world.*
    - *Then, you'll read a science-magazine-style article about digging and boring deep into Earth's crust and see two record holders.*
    - *After that, you'll interpret a detailed diagram showing two kinds of waves produced by earthquakes, how they travel differently through Earth's layers, and what they reveal.*
    - *Finally, you'll read a science comic that will explain where faults occur and how three types differ.*
- Distribute Exercise Page 1. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
- *For this assignment you will be expected to generate a comic of your own, similar to the one in the fifth selection, to explore one interesting idea from the first four selections.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

Exercise Page

EP 1

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What kind of rock sometimes appears striped?	*All sedimentary rocks frequently occur in layers overlying and underlying other types of sedimentary rocks.*
How does one kind of bacteria living two miles below Earth's surface in a gold mine get energy?	*It gets energy from radioactive materials in the mine.*
What do scientists use seismometers for?	*to detect and measure waves produced by earthquakes*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
In Lesson 1, we discussed whether earthquakes might be a cause of Mt. Everest's change in height. What evidence do you have from the readings that earthquakes are very powerful?	*The callouts on the map in the second reading explain that earthquakes cause tsunamis and landslides, both of which have killed thousands of people.*
What are two types of seismic waves that travel away from an earthquake's epicenter?	*P-waves and S-waves*
After reading the comic about faults in the fifth selection, what would make you think that there are faults on Mt. Everest?	*Faults have something to do with the movement of Earth's rocks, and we learned that Mt. Everest is moving.*

- Refer students to the Exercise Page 1. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to draw a four-panel comic to highlight some unexpected, interesting, or challenging science idea from the first four readings in Collection 1.*
  - *That means you will have to choose one idea to focus on, but you don't have to be an expert in the idea. Your strip could explore all the things you wondered about when you read it.*
  - *You don't have to draw well to make an effective comic, but be creative and engage readers by giving your characters interesting personalities and emotions—funny, bored, enthusiastic.*
  - *Use a single storyline across all four panels of your comic.*

Exercise Page

EP 1

    - *Use word balloons, or place the dialog under your drawings.*
    - *The important criteria for your work are that you show your interest or understanding of one science idea from this collection and that you use the comic format to engage your readers.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion. (Friday)

Facilitate class discussion about the reading collection and writing exercise. The first three selections take the student on an easy-to-read fact-filled tour around the globe. The final two selections introduce concepts basic to understanding plate tectonics: two kinds of seismic waves and three kinds of tectonic plate boundaries.

Pages 4–13 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Vivid Vacation Pics"?	*It displays, with photos, beautiful rock formations from around the world, paired with text that explains how the rocks came to be that way.*
Which rock formation did you find the most interesting, and why?	*the Rainbow Mountains in China, because it just doesn't seem possible that rocks can have such colorful stripes like that*
Compare the "Science in Here" boxes. What do the formations showing sedimentary rock have in common?	*They both have stripes, or layers.*
What is the general purpose of the second selection, "Earth's Famous Events"?	*It provides examples of past earthquakes and volcanic eruptions that are famous.*
What conditions might make an earthquake or volcanic eruption "famous"?	*if it killed many people, the sound was heard far away, or the ash affected people far away* *if people saw it and recorded it in books, with stories, or in songs*
Which event was closest to Mt. Everest? How does knowing about it affect your thinking about what is causing the mountain to get taller?	*The Assam-Tibet Earthquake in 1950 was very close and leads me to think that very big earthquakes might be related to the mountain changing height.*
What is the general purpose of the third article, "How Deep Can You Go?"	*It describes two places where people have dug or drilled deep into Earth's crust.*
From the article, what can you infer about the characteristics of Earth's crust?	*It can be at least 7 miles thick; it seems to be mostly solid rock, but there are also gases and water in it; it is hotter than the air on Earth's surface.*

Student Reader

Collection 1

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

CHALLENGE—The map of famous events does not show examples from North America or Africa. Ask students to do research to find out if there have been any "famous" earthquakes or volcanic eruptions on these two continents. Give students a world map onto which they can transfer the six events from the reading. Then challenge them to do online research to find other examples that were either very deadly or very powerful to add to the map, writing details on the back of the sheet. Have them list their online sources and be ready to explain why they are reliable.

Pages 4–13 **Suggested prompts**	**Sample student responses**
What questions do you have after reading this article?	*How dangerous is it to work the gold mine?* *Is gold only found deep in the crust?* *Is the radioactivity in the mine bad for people?* *How long did it take to drill the Kola Superdeep Borehole?* *How wide is the borehole?* *How much deeper is the crust?* *What's under the crust?* *Why don't they drill the borehole all the way to the center of Earth?*
What is the general purpose of the fourth article, "Seeing the Unseen"?	*It compares the behavior of two kinds of seismic waves—P-waves and S-waves.*
How does the fourth selection help you build knowledge on top of what you learned in the third selection?	*In the third selection, I learned that holes can be dug and bored into Earth's crust—meaning that it is mostly solid rock. In this selection, I learned that there are other layers below Earth's crust and that they are not all solid.*
Take a look at the "Connection" box. Do you think one type of wave from an earthquake changes the landscape more than the other?	*It's hard to say from the clues here, but maybe the S-waves cause more damage because they move the ground up and down and that might knock down buildings.*
As you read this selection, what did you find that you could explore in your comic writing?	*I thought about asking questions about the differences between P-waves and S-waves.* *I wondered if scientists could predict earthquakes so people can prepare for them.* *I wondered how Earth came to have layers and what each layer is made of.*
What is the general purpose of the fifth article, "It's Not Their Fault"?	*It explains where faults are found.*
How do the faults at plate boundaries differ?	*by how the crust moves on either side of the fault and if volcanoes are involved or not*

SUPPORT—If students find the diagrams of faults confusing, have them model how each type moves using their two hands touching to represent the crust on either side of the fault.

SUPPORT—While looking at the illustration of the three kinds of plate boundaries, point out that the names all have common prefixes that can help readers understanding their movement. *Di* means "apart," and divergent boundaries are where plates move apart. *Con* means "together," and convergent boundaries are where plates move toward one another. The prefix *trans* has several meanings, but the one closest to this usage means "to change or transfer"; plates along transform boundaries slip past one another, tearing apart rocks alongside the boundary.

Pages 4–13 Suggested prompts	Sample student responses
The kid in the cartoon mentions "plate boundaries" and "tectonic plates." We haven't discussed these yet, but you may have heard of them. What do you think they are?	*From the diagrams, Earth's crust seems to be thin like a plate you eat on. The boundaries must be where one plate touches another.*
If you used the model that the crust is made of dinner plates and the boundaries are where they overlap or touch, how would faults that are away from boundaries be represented?	*cracks in the dinner plates*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 1, students should create a four-panel science comic using the template on their Exercise Page. Modeling their comic on the one in the fifth reading, they should have two characters who converse in an engaging way about some aspect of the science presented in one of the four previous selections. Sample topics may include the following.

- Sedimentary rocks often, but not always, appear striped.
- Has North America, Africa, or Australia experienced famous earthquakes or volcanic eruptions?
- Why is it so hot in deep mines?
- Radioactivity exists due to natural or human-made phenomena.
- Earth is not solid rock all the way through.

Consider displaying students' comics around the room and having students take a gallery walk to tour the work. Allow students to use sticky notes to leave helpful comments next to each comic.

Use the rubric provided on the Exercise Page to supply feedback to each student.

EXTEND—Remind students that there are websites and applications they can use to create more polished comic strips. Most of these tools allow teachers to leave feedback for students and have tips and samples related to school topics. Before using with students, preview the tool or app to determine that it conforms to your school's internet-use policies.

LESSON 3

How does what we find on and below Earth's surface compare in different places?

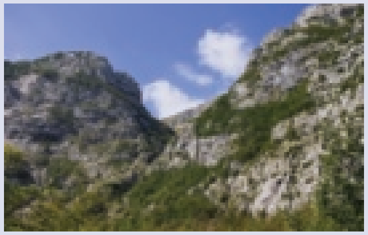
Previous Lesson

We looked at data sources from Ridgecrest, CA before and after an earthquake and analyzed our case site locations in Seismic Explorer. We determined that there seems to be a pattern with greater earthquake activity at mountains that are increasing in elevation. We thought that earthquakes are correlated to mountain changes in location and elevation, but wanted to know what is happening underground where earthquakes occur.

This Lesson

Investigation

2 DAYS



Last class, we figured out that earthquakes are correlated to mountain changes and wondered about what is happening underground where earthquakes occur. We develop models to predict what we would find on and below Earth's surface in different places. Then we look at underground images and watch a storymap to learn more about what we will find below the surface. We document and share what we notice and wonder, then gather additional information from a reading. We carry out investigations about different types of earth materials found at and below the surface.

Next Lesson

We will develop a profile view model of the topography at Ridgecrest including what we know about the ground underneath these different parts of Ridgecrest. We will use a 3D cross section tool in Seismic Explorer to analyze where we saw long lines of earthquakes to the east and west of Ridgecrest. We will figure out that these big sections of Earth between long fault lines are called plates.

Building Toward NGSS

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

What Students Will Do

3.A Develop and use models to describe the structure, composition, and temperature of materials below the surface of Earth, and some of the processes (pressure and heat) that cause changes to those earth materials.

3.B Construct a scientific explanation based on evidence from text, media, and investigations to explain changes that occur to materials below the surface of Earth that are not directly observable.

What Students Will Figure Out

- The surface is often covered with sediment (broken rock, dirt, gravel, sand).
- Sediment and solid rock make up Earth's surface.
- Rocks have different properties, including density and melting point.

- Everywhere we look, solid rock, known as bedrock, is found on, near, or below the surface of Earth.
- The characteristics of rocks change the deeper underground they are.
- As we move deeper underground, temperature increases and rocks are more compressed.
- As rocks become hotter and more compressed, their behavior changes—they change state, and tend to begin to move and shift.
- The rock deep below the ocean bottom is more dense than the rock deep below the continents.

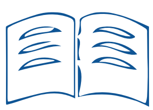
Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	4 min	**NAVIGATION** Revisit the possible relationship between earthquakes and some of the changes that happen to mountains to motivate the need to figure out what is happening deep underground during earthquakes.	A-B	
2	10 min	**DEVELOP, SHARE, AND COMPARE MODELS** Use initial predictions to develop a model of what might be found on and below the surface at the top of Mt. Everest. Share models and look for similarities and differences.	C-D	
3	27 min	**GATHER AND ANALYZE ADDITIONAL DATA** Gather and analyze information about what is found below the surface of Earth. Modify our models, summarize, and document what we have figured out.	E-P	*Materials Found at and Below the Surface*, colored markers or pencils, paper, tape, Earth Materials Found at the Mountain Sites cards, Data Cards for Other Mountains and Mt. Everest, hand lenses, Digging and Drilling Storymap (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), markers, Materials Found At and Below the Surface of Earth chart
4	4 min	**INTRODUCE HOME LEARNING** Preview the home learning.	Q	*Reading: What do people dig or drill deep underground for and what do they find?*
				End of day 1
5	5 min	**NAVIGATION** Students share ideas they got from family and community members.	R-S	*Reading: What do people dig or drill deep underground for and what do they find?*, chart paper, markers, Materials Found At and Below the Surface of Earth chart
6	32 min	**INVESTIGATE PROPERTIES OF ROCKS** Investigate properties of different types of rock commonly found below the surface.	T-U	chart paper, markers, Materials Found At and Below the Surface of Earth chart, Rock Investigations

Part	Duration	Summary	Slide	Materials
7	8 min	**UPDATE THE PROGRESS TRACKER AND CONSIDER NEXT STEPS** Use evidence to update our Progress Trackers. Determine our next steps in figuring out what is happening at Mt. Everest.	V–W	tape, markers, paper for Word Wall words

End of day 2

Lesson 3 • Materials List

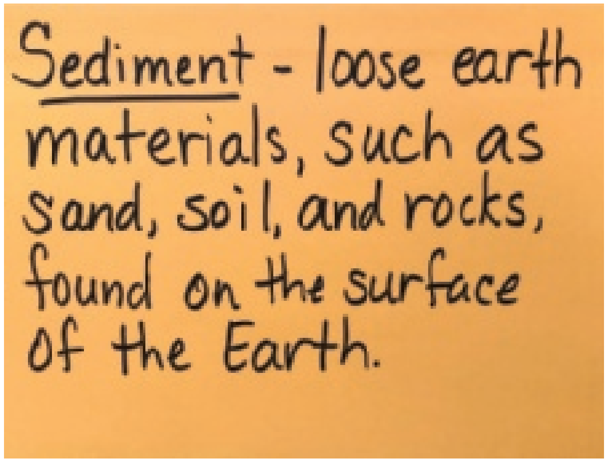
	per student	per group	per class
Rock Investigations materials	• *Rock Investigations Data Chart* • science notebook	• *Rock Investigations Cards* • hand lenses • safety goggles • rock samples • device to access 6.4 Lesson 3 Glass Blowing (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)	• aluminum foil • heating pad • tongs or silicone hand mitts • small ice chest • ice packs or zipper bags of ice • 6-8 cement bricks
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Materials Found at and Below the Surface* • colored markers or pencils • paper • tape • *Reading: What do people dig or drill deep underground for and what do they find?*	• Earth Materials Found at the Mountain Sites cards • Data Cards for Other Mountains and Mt. Everest • hand lenses	• Digging and Drilling Storymap 6.4 Lesson 3 Glass Blowing (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • markers • Materials Found At and Below the Surface of Earth chart • chart paper • paper for Word Wall words

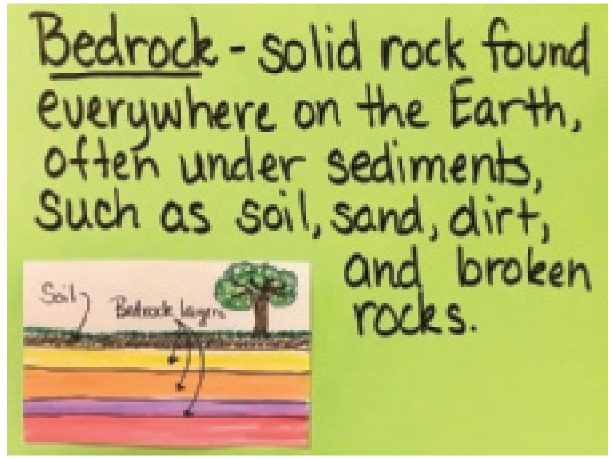
Materials preparation (30 minutes)

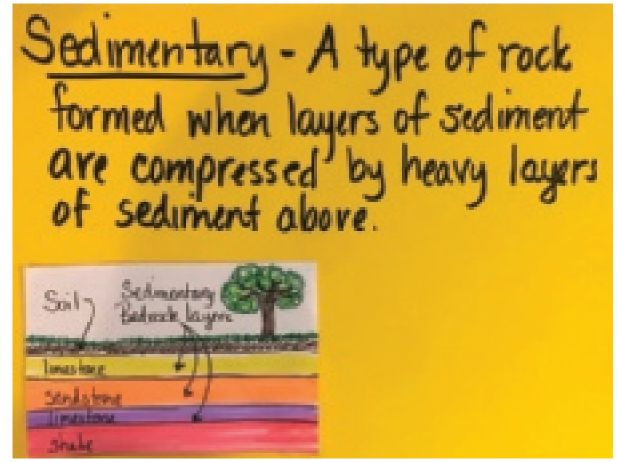
Online Resources

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

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







Be sure you have materials ready (e.g., blank piece of paper, large sticky note, or note card) to add the following words to the Word Wall: *sediment, bedrock, sedimentary*. Do not post these words on the wall until after your class has developed a shared understanding of their meanings.

You may wish to prepare a piece of chart paper titled *Materials Found At and Below the Surface of Earth* prior to the lesson.

Rock Investigations

- **Group size:** Obtain enough bins and materials to accommodate pairs or groups of 3 students.
- **Setup:** Gather and organize the materials for all three investigations so that each bin has the materials needed for pairs or small groups of students to conduct the Rock Investigations. Each bin will need the following materials:
  - **General materials/equipment (per group):**
    - 2-3 Hand lenses
    - Safety goggles - 1 per student
    - 1 set of *Data Cards for Other Mountains and Mt. Everest* from Lesson 1
    - 1 set of *Rock Investigations Cards*
    - Balls of clay - each group needs 3:
      - 1 wrapped in aluminum foil and placed on a heating pad at low heat
      - 1 wrapped in aluminum foil and placed in a freezer if available, or small ice chest with ice packs
      - 1 kept at room temperature

- **Station A**
    - One of each of the following rock samples:
        - Sample A: Sandstone
        - Sample B: Limestone
        - Sample C: Granite
        - Sample D: Basalt
- **Station B**
    - 1 sheet of paper
- **Station C**
    - Sample of sand
    - Laptop or tablet
- **Additional Class Materials**
    - Aluminum foil
    - 1-2 heating pads
    - 2-3 pairs of hot mitts
    - 6-8 cement bricks
    - Locally sourced:
        - 2-3 ice packs or zipper bags of ice
        - Freezer to store small balls of clay or small ice chest if a freezer is not available

It might be helpful to put the *Data Cards for Mountain Cases and Mt. Everest* (from Lesson 1) and the *Rock Investigations Cards* in sheet protectors so that the cards stay clean and can be used with multiple groups of students.

For **Station B**, each group of students will need 3 balls of clay—one cold, one at room temperature, and one that is warmed. Prior to conducting these investigations, make sure you have enough balls of clay for each group. Wrap ⅓ of the clay balls individually in foil and place in a freezer or a small cooler of ice. Wrap another ⅓ of the clay balls individually in foil and place on a heating pad set to low. The remaining ⅓ of the clay balls should be kept at room temperature. Groups can collect the clay balls they need when they are ready to conduct investigation B. In between classes, you will need to refreeze and/or reheat the clay balls so they will be ready to be used again. **Note: If you have back to back classes, you will want to make two sets of these as the clay in the freezer and on the heating pad may not have enough time to change temperature.**

- **Notes for during the lab:** Have a few groups begin with Investigation A, have a few more begin with Investigation B, and have the remaining few groups begin with Investigation C. This will ensure that all groups have access to 2 cement bricks for Investigation B when needed.

- **Safety:**
    - Students will work with clay warmed on a heating pad. Make sure the heating pad is set on low, which should keep the clay at a temperature that allows students to easily handle the warmed clay with their hands. However, if you determine that this is not the case, provide hot mitts for students to use to handle the warmed materials safely.
    - Students will also need to wear safety goggles while handling the different materials in their bins.
- **Disposal:** Students should dispose of the aluminum foil and sheets of paper after their group has completed the investigations. Keep all other materials for future use.
- **Storage:** Store rock samples and modeling clay in containers in a storage closet or cabinet. Unplug the heating pad and store it after it has cooled down.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In Lesson 3, students develop and use a model to represent what they think they will find at and below the surface of Mt. Everest. This model is iteratively revised throughout the lesson, giving students the opportunity to use evidence to describe the structure, composition and temperature of materials at and below the surface of Earth. Students gather data to use as evidence from multiple sources: storymap video, images, readings, and investigations. Using these resources, students observe that sediment is often found on the surface of Earth, and that sediment can include soil, sand, dirt, and broken rock. The layer of sediment can range in depth from a few inches to hundreds of feet thick, and there are some places where this layer is completely absent. Students also notice that everywhere on Earth, solid rock, known as bedrock, is found on, near, or below the surface of Earth. This bedrock can be made up of different types of rock, and the properties of bedrock change as we move deeper underground. Students learn that pressure and heat increase as we move deeper and deeper beneath the surface, and that heat and pressure cause changes to the bedrock—it begins to change state, becoming soft and more pliable, and begins to shift and move. Students also learn that bedrock beneath the ocean tends to be more dense than the bedrock beneath the continents.

Where We Are NOT Going

The purpose of this lesson is for students to begin thinking about and analyzing the properties of different types of rock at and near the surface of Earth, and how those properties can change deep underground due to pressure and heat. This lesson does not focus on other processes that cause changes to Earth, such as weathering, erosion, and deposition. We will focus on the impacts of such forces in Lesson 13.

LEARNING PLAN FOR LESSON 3

1. Navigation

4 MIN

Materials: science notebook

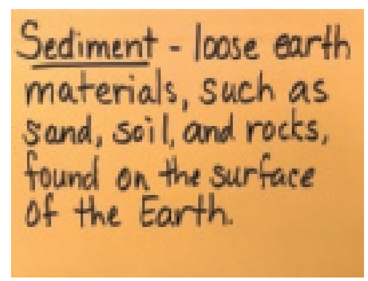
Revisit what we figured out and determine next steps. Show **slide A** and say, *In our last class, we figured out that there are earthquakes in patterns around the world and that these earthquakes can range in strength, or magnitude, and depth. We also noticed that most of these earthquakes happen near mountains. When we analyzed the images from the earthquake that happened at Ridgecrest, what did we see happen to the surface when there is an earthquake?* Students should say that the surface can crack apart and open.

Say, *So based on our analysis of data in the last lesson, do we think earthquakes are related to changes in mountain location and elevation?* Students should say they are related, but we aren't sure if they are the cause of the changes. Say, *So we need to gather more information about what is going on deep underground, in order to figure out if the relationship is causal or correlational.* But first, let's think about the predictions you made at the end of the last class and about what you did for home learning.*

Ask students to turn to the next page in their notebooks and show **slide B**. Say, *Last class, you shared with your partner what you thought you might find underground if you were to dig where you live. For home learning, you made some observations about what you found on the surface around where you live. What were some examples of things you recorded as finding on the surface near where you live?*

Accept all answers, but remind students we want to focus on the materials that are natural and not man-made. Examples of what students might share: dirt, rocks, trees, plants, grass, sand, gravel, and bugs.

Say, *Some of these materials found at the surface—dirt, sand, soil, or gravel—have a term that scientists use. It was in your home learning, and we might want to begin using this term in our unit as we work to figure out how mountains change. The term that refers to these loose types of material found on the surface is **sediment**.*



Put this word up on the Word Wall under "Words We Encounter." Tell students that we will continue to develop and use this word over the course of the lesson so that we can move it to "Words We Earn" at the end of the day.

Say, *Do you think you would find the same types of materials, or sediments, on the surface at the top of Everest? What about if you could dig down below the surface at the top of Everest?*

Have students title the left page in their science notebooks "Earth Materials On and Below the Surface at the Top of Mt. Everest", then give them two minutes to document their predictions.

***Attending to Equity**

Universal Design for Learning: Remember, words such as causation and correlation can be misrepresented and sometimes incorrectly interchanged with one another even though they have distinct scientific meanings. This might be a good time to revisit these two words to ensure students understand the meaning of each and how they fit into the context of this discussion. Revisit the conversation from Lesson 2 and remind students that both causation and correlation describe types of relationships between events, but that the relationship is different for each:

- **Causation** - a relationship in which one event directly causes another event to occur.
- **Correlation** - a relationship in which two events occur together, but one does not cause the other.

If we cannot find evidence to confirm that one event directly or indirectly causes the other event to occur, then we cannot claim a causal relationship between the two events.

2. Develop, share, and compare models.

10 MIN

Materials: science notebook

Develop initial models. Show **slide C** and ask students to use their predictions to develop an initial model that represents their thinking about what they would find if they were at the top of Mt. Everest and they could examine earth materials found:

- On the surface, and
- Below the surface—
  - A couple of inches down
  - In the first hundred feet down
  - Thousands of feet down, knowing that 1 mile = 5,280 feet

Ask students to use symbols and words to label what they are representing in their models, including what they might find, and to indicate the depths at which they might find different materials. Have them create their models in their notebooks right below their predictions. Give them 3-4 minutes to work.

Share models and look for similarities and differences. As students finish, show **slide D** and have students share their models with a partner. Tell them to look for similarities and differences between their models and to be prepared to share what they observed as they compared their models.

Give students a couple of minutes to share with their partners, then use the questions on the slide to guide a quick share out. Encourage students to show their models to the class as they share similarities and differences they noticed.

Suggested prompts	Sample student responses
What similarities do you notice as you share your models?	*We do not have plants on the surface at the very top of Everest. It is way too cold for plants to live there.* *We do not have dirt or sand on the top of Everest, it just looks like snow or ice is there.* *We think we will find rock as we dig down, and that we will continue to find rock the deeper we go.* *We think that at some point deep down we would find magma or melted rock.*
What differences do you observe?	*We didn't agree about everything we would find on the surface at the top of Everest. Some of us have loose rocks and soil at the very surface, while some of us have solid rock.* *We didn't agree on the type of rock we would find at different depths as we dig down from the top of Everest.* *Some of us think we would find snow, ice, or water as we dig down.* *We didn't necessarily agree about how deep we would have to go to find melted rock.*

Supporting Students in Engaging in Developing and Using Models

Tell students that these models they initially develop will be revisited and revised at strategic points throughout the lesson. This will give them the opportunity to engage in the Science Practice of Developing and Using Models in the same way as scientists as they investigate a phenomenon. Students' initial and revised models will become a record of how their thinking develops and changes over time, which is one of the purposes of engaging in this particular Science practice. This record can also help you, as a teacher, assess their learning throughout the lesson.

3. Gather and analyze additional data.

27 MIN

Materials: *Materials Found at and Below the Surface*, science notebook, colored markers or pencils, paper, tape, Earth Materials Found at the Mountain Sites cards, Data Cards for Other Mountains and Mt. Everest, hand lenses, Digging and Drilling Storymap, markers, Materials Found At and Below the Surface of Earth chart Lesson 3 (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Frame the task. Say, *Now that we have made some predictions about what we think is below the surface of Everest, we need to gather evidence to figure out what parts of our models are accurate and what parts might need to be revised. What are some ideas you have for where we could get this data or evidence from?*

Sample students responses:

- We could dig deep underground at the top of Mt. Everest, or find data from someone who has dug there.
- We could dig down deep in our area to see what we could find.

Show **slide E** and say, *These are some great ideas for ways we could get some data if we could get the right tools. Who else might want to dig down deep underground that might have data we could analyze? Turn and talk to your partner about the two questions on the slide:*

- *Who might want to dig deep underground?*
- *Why do you think people dig deep down underground?*

Give students a minute to talk, then use the questions on the slide to surface students' thinking.

Suggested prompts	Sample student responses
Who might want to dig deep underground?	*scientists* *miners* *people looking for gems, like gold or diamonds* *people putting in pipes for cities or towns* *people looking for oil or water*
Why would anyone want to know what is underground?	*We need to know what is below the surface so that we can get some of the things we need, like oil, gas, and water, and to get things we want, like gold and diamonds.* *We also need to know where those things are, so that we aren't just digging in random places. That would be a waste of time and money, as well as not good for Earth.*

Distribute *Materials Found at and Below the Surface* to students, then show **slide F**. Tell students that they will gather and document information about the materials that can be found on and below the surface of Earth at a number of different sites.* They will watch a storymap and examine images that come from people who have mined or dug deep below the surface of Earth. They will also revisit their *Data Cards for Other Mountains and Mt. Everest* from Lesson 1 for

***Attending to Equity**
If students need additional support as they examine the given sources of information—video, images, and information on *Data Cards for Other Mountains and Mt. Everest* and in the *Drilling and Digging Underground* Storymap—you can have them work in pairs or triads to discuss and document information they gather from the data sources.

Supporting Emergent Multilingual Learners: This would be especially helpful for emergent multilingual students and those who need additional scaffolding for reading and/or writing.

***Attending to Equity**
Providing color copies of the *Earth Materials Found at the Mountain Sites cards* (which have the same images as **slides I-M**) and making them available to students to look at closely may allow students to make better observations of the size of the mountains based on the scale of the mine in comparison to the people or equipment in the mine. This could help students further develop a sense of the spatial scale of the changes occuring on and below Earth's surface.

additional information. For each site listed in the data table, students should (1) identify the source or sources of data used, and (2) document earth materials that are found on and below the surface.

Document observations in the data table on the handout. Show **slide G** and say, *We will begin by watching a storymap developed about digging and drilling underground. On your data chart, fill in the source of data as "storymap." Remember, as you work through the storymap, look for evidence of the materials on and below the surface, then document your observations in the data chart.*

Show the storymap at the web page. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) After going through different parts of the storymap, give students a minute or two to document their observations after each part of the storymap in their data charts. Then say, *There are different ways that mining is done. Sometimes mines are drilled straight down into the ground or they can be dug as tunnels running horizontally into a mountain, or diagonally downward. Sometimes resources, like coal or copper, are mined by clearing more and more material from the surface, resulting in a large, deep, open hole at the surface. This type of mining is called surface mining.*

Additional Guidance

An alternative, if you have the technology available, to watching the storymap as a whole class is to provide the link to pairs of students and provide them time to work through the different parts together while documenting what they notice and wonder.

Next, show **slide H** and tell students that the next 5 slides have images for the remaining sites on *Materials Found at and Below the Surface*. Distribute a set of *Earth Materials Found at the Mountain Sites* cards for each group. These cards have the same images as the slides. Tell students they can look at the images on the slides and use the cards for a closer view. Remind them that they are to look for evidence of the materials on and below the surface. They should document their findings in *Materials Found at and Below the Surface*. In addition to the images on the slides and cards, students can also look back over the *Data Cards for Other Mountains and Mt. Everest* from Lesson 1 for additional information about the types of earth materials found at the different locations. Some examples of what students may notice on the *Data Cards* include:

- Sandstone and limestone are found at many of the mountain locations.
- Granite and other types of volcanic rock are found at some mountain locations.

Slowly move through **slides I-M**, giving students time to document the information they need for the remaining 5 mountain sites in their data charts on *Materials Found at and Below the Surface*. Encourage students to revisit their *Earth Materials Found at the Mountain Sites* cards and the *Data Cards for Other Mountains and Mt. Everest* from Lesson 1, as needed.*

Share evidence from multiple sources and document key ideas. When students finish documenting their observations in their data charts, project **slide N.** Read the questions on the slide with the class:

- How does what we find on the surface at these different sites compare?
- How does what we find below the surface at these different sites compare?

***Supporting Students in Developing and Using Scale, Proportion, and Quantity**
As students respond to the questions on **slide N**, ask students to think about and discuss the concept of spatial scale as they share their observations of the storymap and images on the slides. Scale is evident in a number of images that show people and/or other relatable objects deep in Earth. Use questions to get students to think about scale in terms of making comparisons between:

- The size of people or other items to a space within a mine;
- The size of a mine space to an entire mountain;
- The depth of a mine to the depth of bedrock itself.

Use the questions on **slide N** to guide students as they share the data they have collected. Encourage them to share data collected from: the storymap, the images on the slides and on the *Earth Materials Found at the Mountains Sites* cards, and the information and images on the *Data Cards for Other Mountains and Everest*.

Suggested prompts	Sample student responses
How does what we find on the surface at these different sites compare?	*On the surface at a few locations, we see evidence of sediment—dirt, soil, and broken rocks of various sizes.* *Some of the sites, especially the very tall mountains, look like they have solid rock at the surface.* *As you move lower on the mountains, you can see loose rocks and some sediment in a few of the pictures.* *If you look at some of the pictures closely, you can also see that some mountains, like Mount Mitchell in the Appalachians, have trees. We can't see if there is sediment in those places, but where there are lots of trees, there might be some sediment beneath them.*
How does what we find below the surface at these different sites compare?	*At every site, we see solid rock in the mines and cavities dug deep below the surface.* *We also see some layers or layering in the rock at a few sites, like Mount Everest and Mount Aconcagua.* *The Data Cards for Other Mountains and Mt. Everest helped us know the type of rock below the surface can be different at different sites.* *We know from the storymap that the temperature of the rock increases (gets hotter) as people dig deeper.* *It looked like there was water deep in Earth in the Resolution Mine, but we aren't sure if the water came from the surrounding rock or if it was the water pumped down into the mine to keep the temperature cool.*

As students share, write key ideas on a sheet of chart paper titled "Materials Found At and Below the Surface of Earth." Key ideas include:

- Sediments—dirt, soil, sand, broken rocks—can be found at the surface in some places on Earth.
- As we dig down below the surface, we often find solid rock.
- Sometimes solid rock is found at the surface.
- The type of solid rock we find varies in different places.
- As we dig deeper underground, the temperature inside Earth increases.

***Attending to Equity**

Universal Design for Learning: To optimize challenge and promote high expectations for your students, you may want students to revise their models prior to having them share the data they collected from the Digging and Drilling storymap, the images on the Earth Materials Found at the Mountain Sites cards, and the information and images on the Data Cards for Other Mountains and Mt. Everest from Lesson 1. This will give students the opportunity to think critically about their observations and apply what they learned. This, in turn, will give you the opportunity to see what kinds of earth materials each student observed in the various resources and how they are applying the data they gathered individually. If you choose to do this, you can also choose to let students revisit their models a second time after the class share-out and documentation of key ideas from the various sources of data.

Revise initial models. Show **slide O**, and tell students to think about the evidence we have collected about the materials we find at and below the surface of Earth. Have them revisit their models and use a colored marker or pencil to make any changes to their models to better reflect what we have learned about the materials found at and below the surface of Earth.

Give students a few minutes to revise their models, then have them turn to a partner and share what they changed on their models based on the evidence we collected. Walk around and make note of the types of changes that students made to their models and the evidence they used to support the changes made. If students do not share evidence for the changes they made to their models, ask them to do so.

Alternate Activity

If students do not want to make changes and/or adjustments to their models, have students draw a revised model on the next page in their notebooks. This option gives students an opportunity to share and compare their initial thinking and their current thinking, which annotating their current models may not.

Assessment Opportunity

Building toward: 3.A.1: Develop and use models to describe the structure, composition, and temperature of materials below the surface of Earth, and some of the processes (pressure and heat) that cause changes to those earth materials.

What to look for: Look for students to adjust their models to include solid rock at or just below the surface of Mt. Everest, and they should also indicate that the temperature of the rock deep below the surface is increasing with depth. They might include a thin layer of loose sediments (soil, dirt, broken rocks) at the surface, but may not, since the image they have seen of Mt. Everest shows exposed rock at the surface.

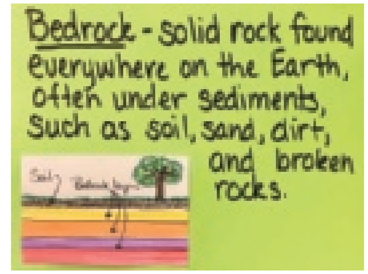
What do do: If students' revisions to their models do not reflect things figured out from the information gathered from video, images, and readings from the storymap and the slides, have them revisit: *Materials Found at and Below the Surface*, images on **slides I-M** or *Earth Materials Found at the Mountain Sites* cards, and *Data Cards for Other Mountains and Mt. Everest* from **Lesson 1**.

Add key ideas to *Materials Found At and Below the Surface of Earth*. After students finish sharing their revisions with their partners, ask if anyone would like to summarize what we figured out from the data we collected from the storymap, the images on the slides and on the *Earth Materials Found at the Mountain Sites* cards, and the information and images on the *Data Cards for Other Mountains and Mt. Everest*. Look for the following ideas to surface and document on a sheet of chart paper titled *Materials Found At and Below the Surface of Earth*.

- Sediments—dirt, soil, sand, broken rocks—can be found at the surface in some places on Earth.
- As we dig down below the surface, we often find solid rock.
- Sometimes solid rock is found at the surface.
- The type of solid rock we find varies in different places.
- As we dig deeper underground, the temperature inside Earth increases.

Add to the Word Wall. Say, *We need to take a few moments to add to our Word Wall. We were introduced to the word* ***sediment*** *in our home learning from Lesson 2, and we have used the word today to refer to the soil, sand, dirt, and broken rock that we find at the surface in many places on Earth. So, let's move* ***sediment*** *from "Words We Encounter" to "Words We Earn" on the Word Wall.* Move the sediment card with the term, definition, and a simple diagram to the appropriate part of the Word Wall.

Then say, *The solid rock we sometimes see at the surface or come across as we dig below the surface is called* ***bedrock***. Write the word and its definition and draw a simple diagram on a piece of paper. Add the word to the class Word Wall.



Complete the exit ticket. Distribute a piece of paper to students and have them write their names at the top of the cards. Show **slide P** and say, *All the sites we analyzed showed evidence of solid rock—or bedrock—at some point below the surface of Earth. Think about where you live.*

- *Do you see any evidence of solid rock, or bedrock, at the surface where you live? If so, describe the evidence.*
- *Do you think we would find solid rock, or bedrock, below the surface where you live? Why or why not?*

Take a few minutes to write down your responses to the questions on the index card. Don't forget to use evidence to support your thinking.

Collect the exit tickets and tell students to tape their data table on the page opposite their predictions in their science notebooks.

4. Introduce home learning.

4 MIN

Materials: *Reading: What do people dig or drill deep underground for and what do they find?*

Preview the home learning. Say, *To help us gather more information about the materials found at and below the surface in our community, go home and poll your trusted family and friends. Our friends and family may have seen things or heard about materials underground that we haven't experienced or figured out yet. There might be stories our family or community know about the bedrock in our area. Let's pull in those resources.**

Distribute *Reading: What do people dig or drill deep underground for and what do they find?*. Display **slide Q.** Say, *Tonight, go home and poll your friends and family members. First, share with them what we have been figuring out in class and why we want to know more about what it is like underground. Let them know what we have figured out about bedrock. Then ask them these questions:*

1. *What do you know about what it is like underground in our community?*
2. *Have you ever dug far underground in our area and reached solid rock, or bedrock? What is it like? What kind of solid rock or material is it?*

Encourage students to bring in photos or drawings of bedrock if they find out there are areas in their community where the solid bedrock can be seen.

End of day 1

***Attending to Equity**
Universal Design for Learning: Framing students' families and communities as legitimate funds of knowledge can serve multiple purposes for student engagement. It can: (1) help students feel like they belong in the science classroom by situating their family and community knowledge as productive resources for science; (2) engage students' families in conversations about what is happening in the classroom; and (3) help students make connections between the science classroom and their everyday lives.

5. Navigation

5 MIN

Materials: *Reading: What do people dig or drill deep underground for and what do they find?*, chart paper, markers, Materials Found At and Below the Surface of Earth chart

Return to home learning and add key ideas to *Materials Found At and Below the Surface of Earth*. Ask students to take out *Reading: What do people dig or drill deep underground for and what do they find?*, then show **slide R**. Have students share the ideas they got from their family and community with the people at their table and be ready to share with the whole class. Say, *In our last class we recorded what we figured out about the materials we find at and below the surface at different locations, and we used evidence we collected to support our thinking. Turn to your partner and share what you figured out about the materials we find on and below the surface in our community from what you learned from your poll.*

Give students a minute or two to share, then say, *Let's add to our chart from yesterday.*

As students share, document key ideas on *Materials Found At and Below the Surface of Earth*. Record any ideas students bring with them from their poll. Some examples are included below, but this will vary greatly depending on your location as to whether there is bedrock exposed in the area and whether their friends and family have any experiences with this.

- The types of rock that make up the bedrock in the area
- Sometimes the bedrock is exposed.
- How shallow or deep the bedrock is in the area
- Experiences with bedrock cracking or shifting or moving

After students have had a chance to document these ideas, ask students, *Do you think that the rock at Mt. Everest is similar or different from what we have found locally?*

Accept all responses.

Show **slide S** and give students a minute or two to read the questions on the slide:

- What do we know about the materials on and below the surface at
  - Mount Everest?
  - Ridgecrest, California?
- What kinds of changes occur at Mount Everest every year?
- What kinds of changes occurred at Ridgecrest in 2019?
- How does this information influence our thinking about what it would take to cause these kinds of changes at Mount Everest and at Ridgecrest?

Let them know that the first few questions will help them review what we have already figured out from all the resources we have used up to this point, and that the last question is really where we will begin our discussion. Have students first turn and share their initial thinking with a partner, then ask them to share with the class. Use the questions on the slide, as well as the additional questions below to help you guide the discussion.

Suggested prompts	**Sample student responses**
What do we know about what we find on and below the surface at Mt. Everest and Ridgecrest?	*At Mount Everest, we didn't see sediments on the surface, but we did see solid rock.* *We also know that there is solid rock below the surface.* *In Lesson 2, we saw pictures of Ridgecrest that showed evidence of sediments on the surface, and solid rock below the surface where Earth cracked.*
What kinds of changes occur at Mt. Everest every year?	*In Lesson 1, we read that Mt. Everest increases in elevation about 2 cm and moves to the northeast about 4 cm each year.* *We also know that earthquakes happen on and around Mt. Everest, but we don't know if the earthquakes actually cause the movement that occurs at Mount Everest every year. We only know that these events are somehow related.*
What kinds of changes occurred at Ridgecrest in 2019?	*There was an earthquake in 2019 that caused the ground to shift and there was a change in elevation, too. We used our hands to help us see the kinds of changes that happened.* *The ground actually cracked open and shifted. We saw images that showed a road shifting about 7.5 feet—most of us are less than 5 feet tall!* *So the ground shifted and changed in elevation, like at Mount Everest!* *We also figured out that the size of the area affected was large, based on the maps we looked at and the scale on the maps.*
How does this information influence our thinking about what it would take to cause these kinds of changes at Mt. Everest and at Ridgecrest?	*All that solid rock below the surface must weigh a lot, so it would take a lot of force to crack, shift, and push upward.* *And we don't know that earthquakes—even very strong earthquakes—actually cause these changes.* *But, the changes are similar—shifts and changes in elevation. And earthquakes occurred at both locations when this happened.* *I think we have more to try to figure out regarding these kinds of movements that happen at different places on Earth.*
So we know that earthquakes are in some way related to the changes at Mt. Everest and Ridgecrest. We also know that the changes were similar—but not exactly the same—in each place. What might explain the differences in how the bedrock cracks and moves differently in different places?	*We know that there are different types of rock found in bedrock, so maybe some types of rock crack and move easier than others.* *Maybe some types of rock are harder than others and would not crack or break as easily as rocks that are not as hard.* *Maybe the bedrock is thicker in some places than others, which might make it heavier, too. That might be why Mount Everest doesn't crack and move as far as the land at Ridgecrest.*

Summarize the discussion by saying, *Maybe we need to learn more about the types of rock that we find deep under the surface of Earth. That might give us some additional information that would help us figure out what is happening at Everest and other places, like Ridgecrest, California.*

6. Investigate properties of rocks. 32 MIN

Materials: Rock Investigations, chart paper, markers, Materials Found At and Below the Surface of Earth chart

Conduct rock investigations. Distribute *Rock Investigations Data Chart*. Show **slide T** and say, *We have figured out some things about the materials below the surface of Earth. Let's investigate some of these materials close up to see what more we can figure out.*

Tell students that they will work in small groups, and that each group will have a bin of materials. Tell them that they will have about 8 minutes to complete each investigation.

There is a set of *Rock Investigations Cards* with procedures that they will use to guide them in the investigations. As they work, they should record their observations and responses to questions in the *Rock Investigations Data Chart*. Consider displaying a timer so that students can pace themselves through the investigations. Answer any questions they have, then set them to work.

Additional Guidance

To keep students focused on their observations, it is recommended you use a visual and/or audible timer to cue students as to when they should move from one investigation to the next. Timers that can be displayed on your computer can be found online and projected for the class to view. You might look for one that allows you to set multiple timers that can be started in a sequence, each with its own signal.

As groups work, walk around the classroom, listen to their discussions, and use questions to help guide them, if needed. Encourage them to work through the investigations within the time frame allotted, and to focus on thinking about the properties of the rocks they are investigating.

Additional Guidance

There are a number of strategies that could be used to help students move smoothly through the investigations.

- Carefully consider how you group your students, especially if you have some who might need additional time or support.
- If your students need more time to work through the investigations, consider extending the time across two class periods, rather than one.
- Students can work in pairs rather than small groups to help ensure that every student is more actively engaged in the investigations. If you choose to do this, you will need to prepare additional bins of materials so that students are not waiting on others to finish with materials they might need.

- If you do not have enough materials for each group, consider setting up 3 stations around the classroom—one for each investigation. Set up enough materials for 3 or 4 groups at each station, so groups can work through the investigations at their own pace.

Share observations and add key ideas to our *Materials Found at and Below the Surface of Earth* chart. Ask students to return all materials to their bins and clean up their area. When students are ready, say, *We have been recording key ideas about the materials we find at and below the surface at different locations, and we are using the evidence we gather from our observations as evidence to support our thinking. Let's talk about what we have figured out during these investigations and add our ideas to our chart. Keep in mind that we are trying to determine how what we find on and below Earth's surface compares at different sites so that we can eventually figure out what causes the kinds of changes that happen at Mt. Everest.*

Show **slide U** and use the questions on the slide to guide this Building Understandings Discussion.

- What are some things you figured out about the different types of rock found at the mountain sites?
- What happens to rock when it experiences high temperature and pressure deep below the surface of Earth?
- Why might these ideas be important in helping us figure out the changes happening at places like Mount Everest?

Key Ideas

As you conduct this discussion, consider that a **Building Understandings** Discussion gives students the opportunity to arrive at tentative conclusions, knowing that they still need more investigation and data to fully explain a phenomenon. At this point in the lesson, students have gathered data from a variety of sources, and this data can and should be used as evidence to support their ideas.

Your role in this discussion is to:

- Use questions to maintain the focus of the discussion.
- Invite students to share ideas, and push them to use evidence and reasoning to support their thinking.
- Encourage critique and alternative explanations.
- Help the group come to tentative conclusions and next steps.

You can use questions, such as the following, to help guide students during the discussion:

- What phenomenon are we trying to explain?
- What have we already figured out?
- What evidence do you have to support your ideas/claim?
- Is there any other evidence that either supports or challenges that idea?
- What else do we still need to figure out in order to explain the phenomenon?

Suggested prompts	Sample student responses
What are some things you figured out about the different types of rock found at the mountain sites?	*Limestone and sandstone are both sedimentary rocks, while granite and basalt are volcanic rocks.* *Some types of rock are more dense than others. Basalt is more dense than granite.* *Some rocks, like sandstone, melt at higher temperatures than others.* *Granite is a more common type of bedrock found below the surface on the continents.* *More dense rock, like basalt, is more commonly found in the bedrock below the oceans than the bedrock below the surface on the continents.*
What happens to rock when it experiences high temperature and pressure deep below the surface of Earth?	*Heat deep in Earth and pressure from the weight of the materials above cause rock to change.* *A lot of heat and pressure will cause the rock to soften and move, like the warm clay. This can make drilling deep in Earth difficult.* *Heat and pressure can also cause rocks to change to different types. For example, we learned from the reading that limestone changes to marble with lots of heat and pressure.* *We think that maybe rock becomes so compressed that it changes and becomes more dense the deeper it is below the surface.*
Why might these ideas be important in helping us figure out the changes happening at places like Mt. Everest?	*We now know that the bedrock that makes up Mount Everest, or any other mountain, and the land below it is very, very thick and heavy.* *We think it will take a great deal of force to move a mountain like Everest, even just a little bit.* *This makes us think that Mt. Everest is only going to change a little at a time—and these changes are most likely not really noticeable to us.*

As students share what they observed and what they have figured out about the materials found below the surface, look for and document the following key ideas on *Materials Found at and Below the Surface of Earth.* If any of the ideas students share are already on the chart, do not write them again. Just point them out and continue the discussion.

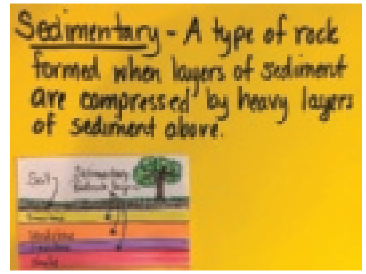
- Different areas on Earth have different materials at and below the surface.
- When rock deep below the surface is heated, it can change.
    - It can become soft and tends to move or shift.
    - With enough heat and pressure, it can become a different type of rock. For example, limestone can become marble.
- The rock deep below the ocean bottom is more dense than the rock deep below the continents.

7. Update the Progress Tracker and consider next steps.

8 MIN

Materials: science notebook, tape, markers, paper for Word Wall words

Add to the Word Wall. Tell students, *We need to add another word to our Word Wall that is related to one we added yesterday.* ***Sedimentary*** *is a type of rock made when sediments—soil, sand, dirt, and broken rock—are deposited by wind or water and then compressed into rock over time by heavy layers of sediment above them.**



Display the definition on a piece of paper along with a simple diagram. Add the word to the Word Wall.

Revisit our models and document in the Progress Tracker. Show **slide V** and say, *Think about all the data we have collected about the materials found at and below the surface of Earth. Take a few moments to revisit your model, which you developed and revised during our last class. What, if anything, would you revise in your model? Why? Think about this as we document our current thinking in our Progress Trackers.**

Show **slide W** and direct students to the Progress Tracker section of their notebooks. Have them turn their notebooks to landscape orientation and draw a 3-column progress tracker like the one on the slide. By using a landscape orientation and having no structured box, students can take up a lot of space or a little space on their Progress Trackers. Remind students that the Progress Tracker is a space for them to document their current thinking. Have them write the lesson question in the first column of the Progress Tracker, then use pictures, words, and symbols to develop a model that represents their thinking about the lesson question, "How does what we find on and below Earth's surface compare in different places?" Give students time to add to their Progress Trackers.* Whenever a student is done writing, they can draw a line after their work to make space for the next time a teacher instructs them to write in their Tracker.

After students finish, ask them to tape *Rock Investigations Data Chart* into their science notebooks.

An example of the Progress Tracker is included below:

Question	Sources of Evidence
How does what we find at and below Earth's surface compare in different places?	• The Digging and Drillling storymap. • The images, the *Data Cards for Other Mountains and Mt. Everest.* • Data collected from the *Rock Investigations Cards.*

***Attending to Equity**

Universal Design for Learning: When adding the science term **sedimentary** to the Word Wall, you can provide options for language and for comprehension by:

- Pointing out, highlighting, or underlining the root word **sediment** and referring to its definition that was added to our Word Wall earlier today.
- Pointing out, highlighting, or circling the suffix *-ary* and telling students that it means "of, relating to, or connected with." Then you can further explain that **sedimentary** rock is made "of **sediment**."
- Making an explicit connection between the two terms—**sediment** and **sedimentary**—and the relationship between the concepts, such as the example statement, ***Sedimentary*** *is a type of rock made when* ***sediments****—soil, sand, dirt, and broken rock—are deposited by wind or water and then compressed into rock over time by heavy layers of sediment above them.*

What We Figured Out in Words and Pictures

- The temperature of the rock increases (gets hotter) as we go deeper down into Earth.
- The surface is often covered with sediments (i.e.: broken rock, dirt, gravel, sand).
- Sediments and solid rock make up Earth's surface.
- Everywhere we look, solid rock, known as bedrock, is found at some point on, near, or below the surface of Earth.
- Rocks have different characteristics, including density and melting point.
- As we move deeper underground, rocks become increasingly hotter and compressed.
- As rocks become hotter and more compressed, their behavior changes—they change state and tend to more readily move and shift.
- The rock deep below the ocean bottom is more dense than the rock deep below the continents.

ASSESSMENT OPPORTUNITY

Building towards 3.A.2: Develop and use models to describe the structure, composition, and temperature of materials below the surface of Earth, and some of the processes (pressure and heat) that cause changes to those earth materials.

What to look for: Students revise the models in their Progress Trackers to represent their current understanding of the structure and composition of materials at and below the surface and the changes that occur due to pressure and heat deep in Earth's bedrock. Students' Progress Trackers should include the ideas called out in the sample Progress Tracker above.

What to do: If students' models have incomplete or missing ideas or are missing sources of evidence, there are a number of resources that they can review:

- Readings (with images):
  - Materials Found at and Below the Surface
  - Rock Investigations Cards
  - Data Cards for Other Mountains and Mt. Everest
- Images on **slides I-M**
- Observations documented on *Rock Investigations Data Chart*

Students can also use the list of key ideas on the *Materials Found At and Below the Surface of Earth* chart for additional support.

Building towards 3.B Construct a scientific explanation based on evidence from text, media, models, and investigations to explain changes that occur to materials below the surface of Earth that are not directly observable.

***Supporting Students in Engaging in Developing and Using Models**

Remind students that we often revisit and revise models whenever we figure out new ideas and concepts that help us better explain a phenomenon. This is a practice that scientists use quite often, and it should not be viewed as "correcting" our models. Scientists revise their models because they should accurately reflect what they are figuring out over time as they investigate different components, interactions, and mechanisms within the system they are currently studying. In addition, an initial model, along with revised versions, gives a view of what we are learning over time and how our understanding has changed as we continue to investigate a phenomenon.

***Supporting Students in Engaging in Constructing Explanations and Designing Solutions**

Constructing a scientific explanation is an important part of students' work in this lesson. Documenting in the Progress Tracker gives students the opportunity to construct an explanation that answers the Lesson 3 question, "How does

What to look for : Students' completed Progress Trackers give an opportunity to assess what they have figured out during this lesson. In students' models, you should look for representation of the ideas and supporting evidence called out in the sample Progress Tracker above.

What to do: If students' models have incomplete or missing ideas, or if sources of evidence are not complete, students can review the same resources previously listed. Encourage them to add new ideas or information from those resources.

Navigate to the next lesson. Quickly close the lesson by saying, *We wanted to know what is on and under the surface of the earth. We have figured out that there is bedrock everywhere below the surface of Earth. We've revisited and revised our model of Everest, and we developed a model and documented evidence in our Progress Trackers to explain how what we find at and below Earth's surface compares at different places. We next need to think about what might be happening to the bedrock when an earthquake occurs.*

what we find on and below Earth's surface compare in different places." Encourage students to answer the lesson question using a claim supported by evidence from the images, videos, reading, and lesson investigations. The Progress Tracker could also include a model that represents students' thinking using pictures, words, and/or symbols.

ADDITIONAL LESSON 3 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-Literacy.SL.6.1

Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

There are a number of opportunities in this lesson for students to engage in discussions in pairs, small groups, and as a class. Some discussions are teacher-led, but not all. Students should be encouraged to share their prior understandings, observations, and current thinking while working collaboratively with their peers to figure out the structure, composition, and temperature of materials found at and below the surface of Earth, as well as the changes that pressure and heat cause to bedrock deep below the surface. As much as possible, questions and prompts are used by the teacher, and students are given multiple opportunities to share their current thinking and build on the thinking of others. Additional strategies that can be used include:

- Strategically pair and group students, keeping their individual needs in mind.
- Supply several opportunities for students to respond to questions and share their thinking (e.g., in pairs or small groups before class discussion).
- Allow students to use drawings, symbols, writing, and gestures to express their ideas.

CCSS.ELA-Literacy.SL.6.1.A

Come to discussions prepared, having read or studied required material; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

In this lesson, students obtain information from a home reading and are expected to use that information to support their thinking. At the opening of day 2, students are asked to share information in that text about the structure, composition, and temperature of materials at and below the surface of Earth. To support students in sharing and using the information they gather from the reading, key ideas are documented on a chart that students can reference when needed.

LESSON 4

What is happening to Earth's surface and the material below it during an earthquake?

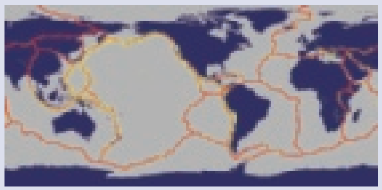
Previous Lesson

We developed models to represent what we might find on and below Earth's surface in different places. We looked at underground images and watched a storymap to gather data. We documented what we noticed and wondered, then gathered additional information from a reading. We carried out investigations about different earth materials found at the mountains.

This Lesson

Investigation

2 DAYS



We develop a cross section model of the topography at Ridgecrest including what we know about the ground at and underneath these different parts around Ridgecrest. We add in the break in the ground that formed from the earthquake at Ridgecrest. We use a foam board to model changes in the bedrock to determine this break must go all the way through the bedrock. Using data from a 3D cross section tool in Seismic Explorer, we develop a cross sectional model of the North American plate that runs through Ridgecrest, including the bedrock from the surface to far below the surface. We figure out that scientists call these big sections of Earth between long fault lines, plates. We look at the whole world map and look for where there could be other plates on the map.

Next Lesson

We will use GPS data from the North American plate to demonstrate how it moves over time. We will further revise a cross section model of the North American plate to try to explain how its movement is connected to the characteristics of the underlying bedrock. We will use Seismic Explorer to investigate the movement of all plates on Earth's surface in order to help explain the movement of Earth's mountain formations.

Building Toward NGSS

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

What Students Will Do

4.A Develop a profile model across the North American plate to explain the changes seen in bedrock after an earthquake by showing what is found at and below the observable surface.

4.B Construct an explanation using qualitative evidence from class investigations to explain what is happening to the bedrock below the observable surface when an earthquake causes a shift or break in the land.

What Students Will Figure Out

- Sections of bedrock in between these fault lines of cracks from earthquakes are called plates.
- These cracks must go really far down into and through the bedrock to where the rock begins to creep, shift, and move.

- There is evidence of at least two really large and long crack lines on either side of most of the United States.
- There are other plates in the world that can be found in between long lines of fault lines.
- Models of our crust and mantle have scale limitations due to the size of the Earth and its layers.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Consider similarities between Mt. Everest and Ridgecrest after an earthquake and how analyzing what happened to the land at Ridgecrest could help us figure out more about the changes at Mt. Everest.	A-B	World Map
2	3 min	**LOOK BACK AT SATELLITE IMAGES FROM RIDGECREST** Revisit images of what the surface of Ridgecrest looked like before the earthquake.	C-D	
3	6 min	**DEVELOP CROSS SECTION OF RIDGECREST** Construct a cross section model of the land at and below the surface of Ridgecrest and surrounding area.	E	1–2 pieces chart of paper, markers
4	8 min	**REVISITING IMAGES OF RIDGECREST AFTER THE EARTHQUAKE** Revisit images to describe the changes observed in the structure of Earth after the earthquake at Ridgecrest.	F-H	
5	15 min	**ARGUE FOR WHAT HAPPENED TO BEDROCK UNDER THE SURFACE AT RIDGECREST** Small groups develop an argument for what is happening to the bedrock at Ridgecrest. The class comes to consensus on how to represent the land cracking open using a square foam piece to represent the bedrock.	I	piece of pink insulation foam (12”x12”)
6	5 min	**NAVIGATION** Make predictions about how far the bedrock on either side of the crack extends and how it was affected by the earthquake.	J	broken pieces of pink foam insulation
				End of day 1
7	3 min	**NAVIGATION** Discuss looking at earthquake data to figure out where there are other fault lines.	K-L	broken pieces of pink foam insulation
8	8 min	**DEVELOP A PROFILE MODEL OF THE UNITED STATES** Review earthquake data and surface data on a North American region map to summarize what we already know and identify potential fault lines across the region.	M-N	*Constructing Profile Model West and East of Ridgecrest*

Part	Duration	Summary	Slide	Materials
9	12 min	**DEVELOP A CLASS PROFILE FOR THE NORTH AMERICAN REGION** Create a consensus profile model for a cross-section of the North American region including what is on the surface and below.	O-Q	
10	6 min	**REVISE OUR MODEL WITH DATA FROM SEISMIC EXPLORER** Use Seismic Explorer to look for data about where fault lines are found, how deep they are, and where they are hundreds of miles long.	R-U	Seismic Explorer
11	5 min	**UPDATE PROGRESS TRACKER** Record in Progress Tracker how earthquakes affect the land, both at the surface and far below the surface.	V	
12	5 min	**LOOK AT EARTHQUAKES ON MAP TO PREDICT WHERE OTHER PLATES ARE LOCATED** Use earthquake patterns to visualize where other plates might be located across the globe.	W-X	*10-Year and 30-Year Earthquake Data*
13	4 min	**REFLECT ON THE PRACTICE OF DEVELOPING MODELS** We reflect on the challenges of developing a model of a large section of the Earth on a small piece of paper.	Y	
14	2 min	**NAVIGATION** Brainstorm with a partner what could be happening to the bedrock below Mt. Mitchell, which is part of the same plate on Earth that Ridgecrest is part of, if it is moving 2 cm per year.		Potential Causes for Mountain Movement chart

End of day 2

Lesson 4 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Constructing Profile Model West and East of Ridgecrest* • science notebook • Seismic Explorer • *10-Year and 30-Year Earthquake Data*		• World Map • 1-2 pieces chart of paper • markers • piece of pink insulation foam (12"x12") • broken pieces of pink foam insulation • Potential Causes for Mountain Movement chart

Materials preparation (15 minutes)

Online Resources

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

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

Be sure you have materials ready to add the following words to the Word Wall: plate, crust, and mantle. Do not post these words on the wall until after your class has developed a shared understanding of their meaning.

On day 1, you will need to have one 12 x 12 inch piece of foam board ready to use for each class. After these pieces are broken to represent how pieces of Earth can break open, keep these broken pieces around for later use in the unit.

Ensure the web page loads and can be used by you and/or your students depending on whether you decide to demonstrate this simulation or have small groups explore together. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students build on their model of what it is like under the surface of Earth by revisiting the earthquake that occurred in Ridgecrest, California in 2019. Using the data about the land here and what we have figured out about the materials under the surface of Earth, students develop a cross section model of the area around Ridgecrest before and after the earthquake, spanning from the mountains to the west, through the valley Ridgecrest is located in, and to the mountains just to the east of Ridgecrest. Added to this model is the shift in the land half a meter vertically.

Students construct an oral explanation with their small group for what happens to the bedrock below the surface when there is a vertical shift to the land at the surface. Students will conclude that the land cracks through the bedrock to allow a shift like this to happen. Then this model is expanded to the west and east of this break in the land, to represent the North American plate using the long lines of earthquakes along the west coast and in the Mid Atlantic, as the boundary of the plate. Through developing this model, we figure out that these large sections of bedrock in between these long lines of faults are called plates. We look for other similar patterns on the world map from Seismic Explorer that we analyzed back in Lesson 2 to argue for how many other plates we think there are on Earth.

Where We Are NOT Going

In this lesson, students figure out there are sections of land that scientists call plates on Earth's surface, and these plates are bounded between long lines of earthquake fault lines. Beyond discovering that North America is on a plate that is bounded between earthquakes in the Pacific and earthquakes in the Mid Atlantic, students do not explore the mechanisms involved in plate movement. In a later lesson, students will synthesize what they have figured out about how rock further down under the surface begins to shift, move, and melt due to both temperature and pressure increases, and how this could cause plates to move. This lesson and unit, will not address how the thermal convection of solid materials is the cause of plate movement, as this is above grade band.

Though students will figure out that plate boundaries are found between long lines of earthquakes and that these boundaries are separations through the bedrock, we will not dive deep into how earthquakes affect the land every time. The purpose at this point in the unit to see the pattern between fault lines of earthquakes and the plate boundaries.

1. Navigation

8 MIN

Materials: World Map

Brainstorm similarities between Mt. Everest and Ridgecrest several miles down. Display **slide A**. Say, *Last class we investigated different materials that are found under the surface and found out some things about what happens to these materials the further down you go. And you developed and revised a model of what materials could be found under the surface at Mt. Everest. Take a minute to turn and talk with a partner about the question. If we could analyze a sample of the materials under the surface a couple of miles down from both Everest and Ridgecrest, based on your previous investigations, what would you expect to be similar at both of these locations?*

Students should say some similarities would be: solid rock below the surface, temperature increases far under the surface, really hot temperatures cause the rock to begin to creep (move and shift) and there could be common types of rock far under the surface.

Briefly discuss how analyzing the Ridgecrest earthquake could help us figure out more about Mt. Everest. Display **slide B**. Say, *We know an earthquake happened at both Mt. Everest and near Ridgecrest, CA. As we saw in Lesson 2, there is a lot of data available from the earthquake that happened at Ridgecrest. If we could use the information we have from Lesson 2 about the Ridgecrest earthquake to develop a model of what the land looked like before and after the earthquake, how might that help us figure out what is happening at Mt. Everest to cause it to be growing?* Accept all responses.

2. Look back at satellite images from Ridgecrest.

3 MIN

Materials: None

Revisit the Ridgecrest images from Lesson 2. Display **slide C**. Reconfirm with students that the different grey shadings represent the topography of the land, with mountains to the west and east, and a valley in between.

Display **slide D.** Re-orient students to the mountain ranges surrounding the valley in the Mojave Desert, and even though it is a valley, it is relatively higher than sea level, about half a mile high. Tell students that we will begin with this image of the area before the earthquake that occurred in 2019 as we develop a cross section model of the land here.

3. Develop cross section of Ridgecrest.

6 MIN

Materials: 1-2 pieces chart of paper, markers

Develop a cross section view for the defined section of the map.* Display **slide E**. Say, *This blue rectangle identifies the area where we had satellite data showing how the ground shifted. The area in the blue rectangle represents about 10 miles across from west to east. Let's think about what the surface looks like across this area.*

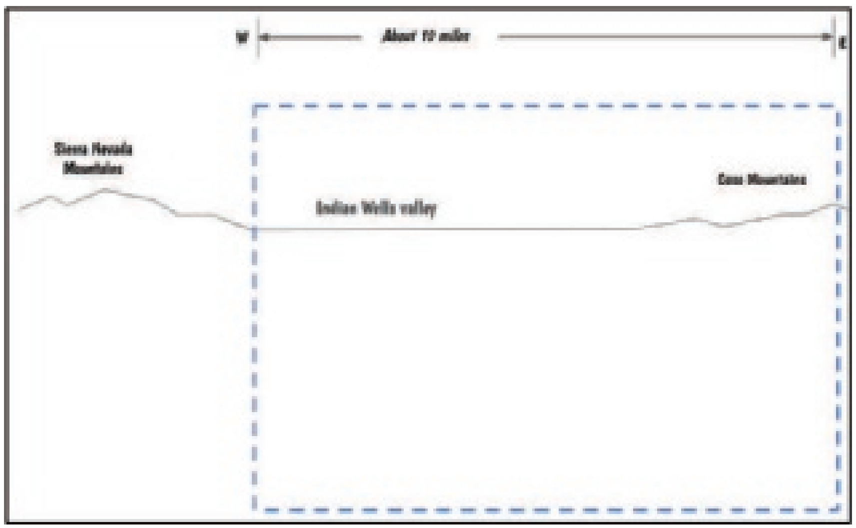
Continue by saying, *Let's get ready to draw a cross section, or side view of the area within the rectangle, showing the elevation changes at the surface and what we would find below the surface, much like you did for your Everest model in Lesson 3.*

Additional Guidance

In this unit, students leverage this experience with Mt. Everest to develop a cross section perspective of another large-scale phenomenon: what happens when a 10-mile section of land on Earth cracks apart after an earthquake. If they are struggling with how to construct their cross section models in this lesson, you may want to remind them of their previous experiences constructing cross sectional models. If your students experienced *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* prior to this unit, they will have had experiences developing models from a cross section perspective. In *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*, the models developed of large air masses helped students visualize how the different components of the atmosphere interact leading to different types of weather. Because these interactions happen on such a large scale, students used qualitative data to develop these air mass systems and make sense of how they develop, move, and interact. For example, you might say something like, *Just like how in Storms Unit, where we developed a model of a phenomenon that was at a scale either too large to see (huge air masses) or unobservable (the changes to the water or air particles due to temperature), this model will represent unobservable interactions and materials as well what is happening on and under the surface of Earth to cause changes to the land.*

Say, *Let's begin by representing the elevation changes from the side starting on the west side.* With students' help, begin to draw a cross sectional model on the poster paper to represent the different elevations. This model will be developed incrementally with students. A suggested plan for developing this model, along with example images showing its incremental co-construction, is provided below. Ensure that the model you develop with your students represents their shared thinking. Different classes may develop this model in a different order or way.

Begin by drawing a line from the left side of the poster paper to the right side of the poster paper to represent heights, or profile of the land. You may want to orient your poster paper landscape if using one piece. If using two pieces, place them next to each other, and this line can extend across both pieces.

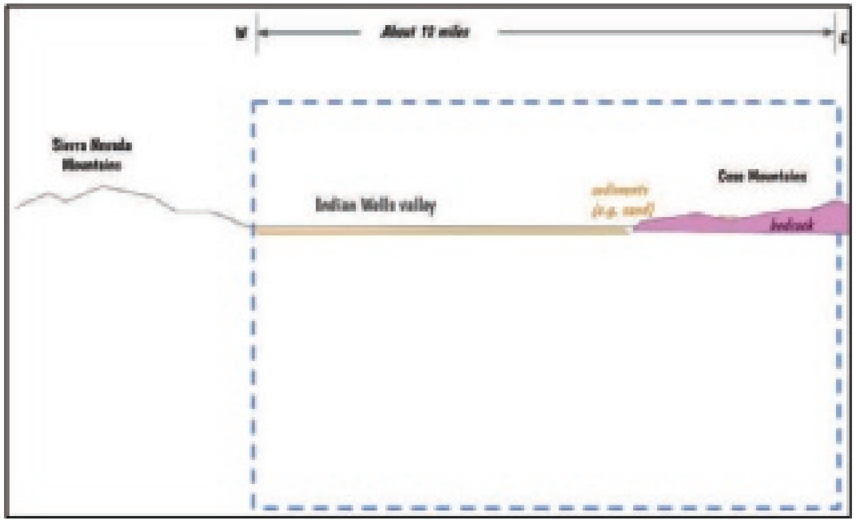


***Supporting Students in Developing and Using Scale, Proportion, and Quantity**

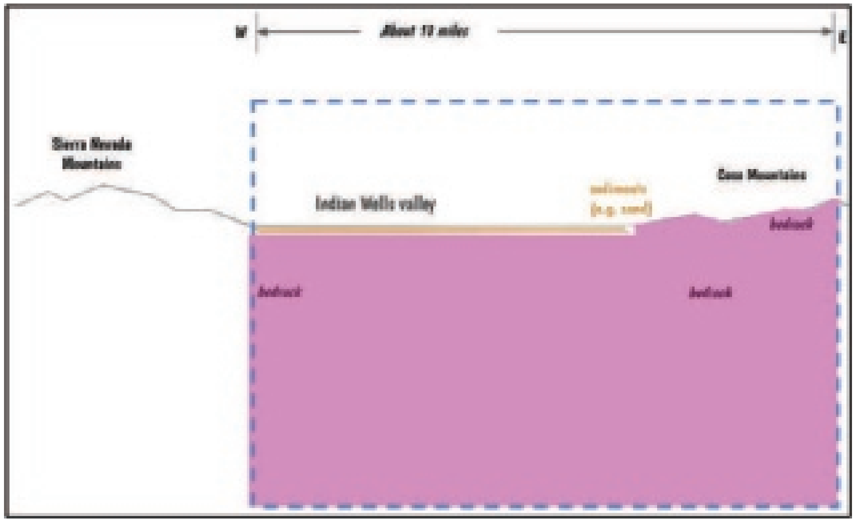
The distance represented on the satellite image of Ridgecrest is over a distance that is too large to visualize without using representations, images and models. As we work through this lesson to develop a model to represent what is happening at and below the surface over a span of miles, remind students that the scale we are modeling is much larger than what they are seeing on the slides (or poster if you decide to make a hardcopy in your classroom on poster paper). Distances at the scale of miles can be difficult for students to visualize. To support students working at and understanding this scale, create relevance by referencing a common landmark that is located at a 10 mile distance from the school in your town and compare to this map cross section.

Say, *Now let's consider what type of material is on the surface. We know that the surface can have sediments on it or it can have bedrock exposed. Let's start with Indian Wells Valley. Think back to the images we saw of Ridgecrest. What did the material on the surface look like?* Students should say it looked sandy, or like a desert. Ask, *Based on what we read about in our mountain cards, our mining reading, and the rock investigations, what would we see at the surface most of the time when we are looking at mountains?* Students should say bedrock. They may also want to include some sediments in between the mountain tops.

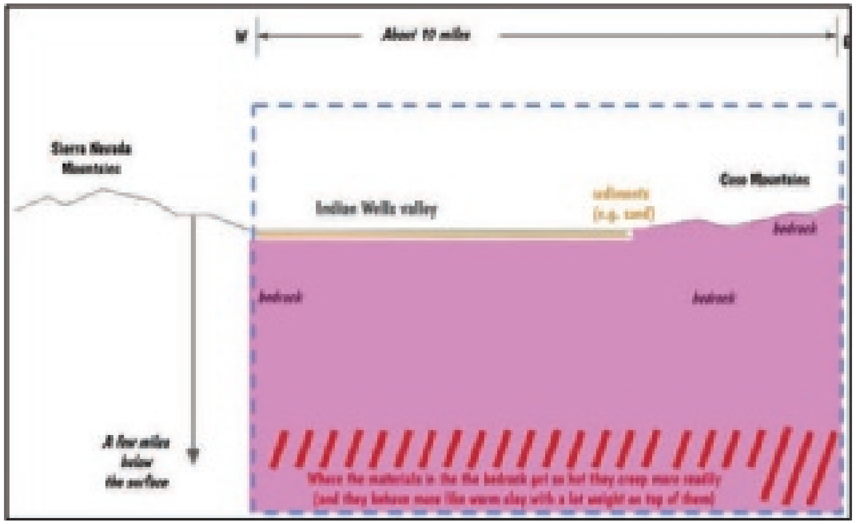
Add these to the model.



Ask, *What type of material do we eventually find everywhere below the surface?* Students should say bedrock. Draw this in, connecting the bedrock of the mountains to the bedrock further down.



Ask, *How does the behavior of that solid bedrock change as we go several miles down?* Students will say it gets warmer the further down you go and that the rocks begin to move and shift more easily. Add an arrow facing downward labeled "a few miles below the surface" going from a spot on the surface of the Sierra Nevada Mountains downward. Add red surface of the Sierra Nevada Mountains downward. Add red hatch marks toward the bottom of the bedrock and label this as "where the materials in the bedrock get so hot they begin to move or shift more readily (and they behave more like warm clay with a lot of weight on top of them)."



Say, *If we were to develop a similar profile model of Mt. Everest, what would we expect to be similar?* Examples of what students might say:

- there would be some sediment in between mountains and in lower areas
- bedrock sticking out of the surface at the mountains with bedrock below everything
- a few miles below the surface, the material would get so hot that the bedrock would begin to move or shift
- there might be differences in the height of the mountains, or the type of sediments found on or around them

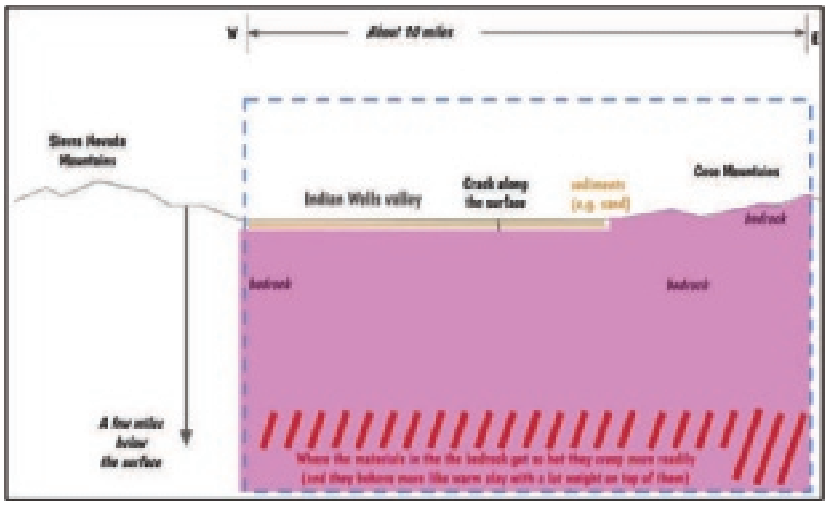
4. Revisiting Images of Ridgecrest after the Earthquake — 8 MIN

Materials: None

Revisit images of the surface of Ridgecrest after the 2019 earthquake. Display **slide F**. Say, *Now that we have a model of Ridgecrest before the earthquake, let's add to our model to represent the type of changes we saw in the structure of Earth after the earthquake.* Ask students to describe the changes shown in the images on the slide that we should include in our model. Students should say there were breaks and shifts in the ground. Ask students how long the break was again. They should say several miles long.

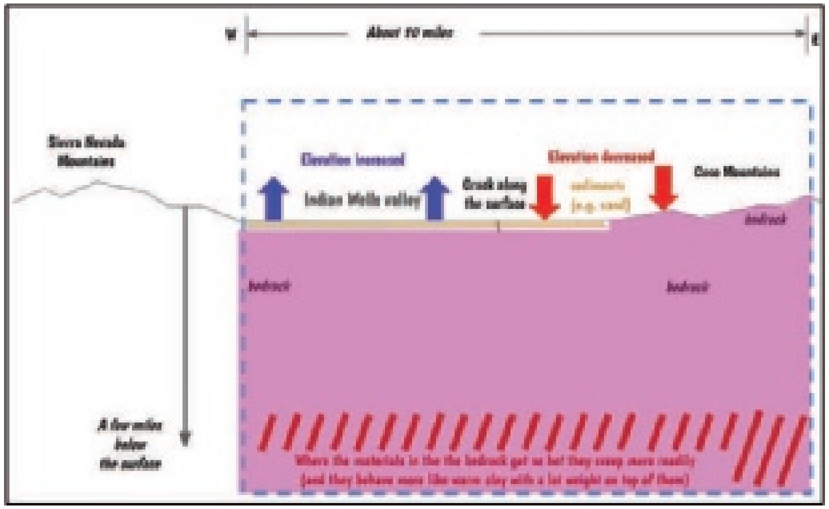
Characterize the changes in Earth's surface as a result of the earthquake in detail. Show **slide G.** Say, *We can see the break formed along the line between these two regions on the map. We saw that along one side of the break, the surface* *shifted in one direction, and along the other side of the break, the other surface shifted in an opposite direction. Show me with your hands again how each region shifted.* Display **slide H** and say, *Let's get ready to revisit our cross-section we drew of this region shown in the blue rectangle to think about how we can represent the changes in the surface. Let's begin with representing the crack we saw along the surface.* Again, a suggested plan for adding to the model, along with example images showing its incremental co-construction, is provided below. Ensure that the model you develop with your students represents their shared thinking.

Add a vertical line in the valley area to represent the crack at the surface that we saw in the images from Ridgecrest. We aren't sure at this point how far this crack goes down. Students may argue that the crack goes all the way down, but not everyone may be in agreement with this yet. We will consider how far the crack must go in this lesson. So for now, just make a small line for the crack.



Say, *Next, let's show the elevation change that happened to the land in this area where it cracked open. Where in the model should we represent a change in elevation?* Students should say that to the left, the land increased and to the right of the crack, the land decreased.

Add in arrows and labels to represent which way the land moved on either side of the surface crack. Use blue arrows to represent the rise in elevation shown on the satellite image and red arrows to represent a decrease in elevation as shown on the satellite image.



5. Argue for what happened to bedrock under the surface at Ridgecrest.

15 MIN

Materials: piece of pink insulation foam (12″x12″)

Brainstorm how the solid bedrock is affected during an earthquake. Display **slide I**. Hold up the piece of pink insulation foam. Say, *Let's imagine this is the bedrock that stretches across this 10-mile wide region. Talk with a partner. What do you think happened to the solid bedrock just under the surface across this entire area that could help explain why we saw a shift and change in elevation in the surface of the land at the time of the earthquake?* Give students about 8 minutes to turn and talk with a partner, or in a small group.

Assessment Opportunity

Building towards: 4.B.1 Construct an explanation using qualitative evidence from class investigations to explain what is happening to the bedrock below the observable surface when an earthquake causes a shift or break in the land.

What to look for/listen for: Students arguing using a chain of logic to make the connection between the crack at the surface and what must be happening under the surface. Some arguments you may hear them debate with their partner:

- That the break looks like it is pretty far down.
- If the land was broken pretty far down below the surface, the bedrock was also broken apart here.
- The land at Ridgecrest not only broke apart, but it shifted up half a meter.
- The section of land that shifted up was about 10 miles long.
- For such a large section of land to shift up so much, it must mean the break is all the way through the bedrock to where the rock begins to move or melt.

***Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Students will experience the changing of the Ridgecrest landscape by utilizing the pink foam model in the instructions below. As students are working on this model, emphasize how the landscape might be changing or what changes would be felt or visible during the interaction of the foam pieces. Using this representation will allow students to study this interaction at a scale much more manageable for classroom purposes, and create a mental representation of what can happen to cause an earthquake, as well as subsequent potential changes that occur on the land.

What to do: As students are constructing their explanation with their small group, and if they are struggling to come to an agreement, encourage them to think back through the images they saw of the crack near Ridgecrest, how much the land shifted here, and what they have figured out about what it is like under the surface. In addition, using an analogy to help them visualize a break of this size in something solid might help. For example, you might ask the students to think of a large solid food like a pizza, or a pan of brownies or cake. We can use a knife to create an opening in the surface of the brownie, like we saw at the crack in the land near Ridgecrest, but if we want to remove a piece (like shifting it vertically), we need to cut all the way through the brownie. Encourage them to think about this in relation to the land at Ridgecrest shifting half a meter upward.

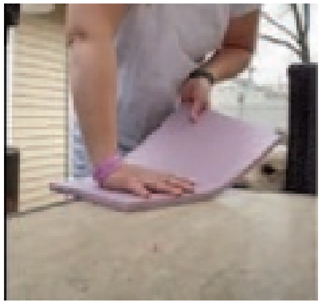
Reconvene the class. Explain that we will use the pink foam to represent the bedrock. Ask students how this is different from the bedrock we see on the surface of the Earth. Probe students to consider how this is spatially and structurally similar and different.

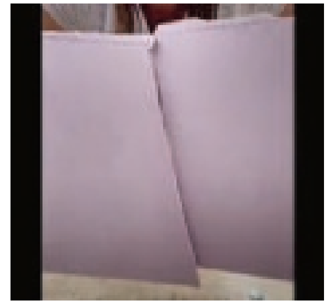
Suggested prompts	Sample student responses
We are using this piece of pink foam to represent the bedrock that makes up this section of Earth where Ridgecrest is. How is this similar to the bedrock?	*It is solid.* *It is kind of bendy.* *It is kind of thick.* *It can probably still crack like what happened at Ridgecrest.*
How is this different than the bedrock that we find on Earth's surface?	*It's definitely smaller—Ridgecrest is a much larger area.* *It's a different color.* *It may be softer or more bendy.* *The bedrock is made of rock—I wonder if that makes a difference?*
So it is much smaller than Ridgecrest. How might using something smaller like this to model that area help us in our investigation?	*Sometimes we can't make changes on something as big as pieces of land. But we can use this to model what might happen at a different scale.* *We can see it without having to go to Ridgecrest or get heavy machinery or cause an earthquake, and still figure out what might be happening using this smaller item.*
If we want to use this to help us make sense of what happens to the bedrock when there is an earthquake like near Ridgecrest, do you think this will provide us some evidence that we can use to help us figure this out?	*Yes… it is way smaller and it doesn't have sediment, like sand on it, but we can use it to see how it breaks.* *It can still probably crack and move like the ground at Ridgecrest.* *It's smaller, but we can't move the ground at Ridgecrest on our own. We can move this and see what happens.*

Ask students to share what they discussed with their partner(s). Students should argue that the bedrock either broke or was already broken before the earthquake occurred.*

Use the foam board to demonstrate this by slowly pulling up on one corner of it and bending it up on a diagonal. Say, *OK, I am starting to bend the foam board (bedrock) slightly… which in reality is something that rocks can do up to a point before they break. Typically it's hard to see such bending unless the forces on them are very great or the size of the rock being bent is very large.*

Snap the board in half and then say, *OK, so that is one thing that could have happened from the earthquake, the solid bedrock broke. But what if the bedrock was already broken along this line, can someone show me how these two pieces of bedrock would have shifted from the earthquake to result in the motion and change in elevation?*

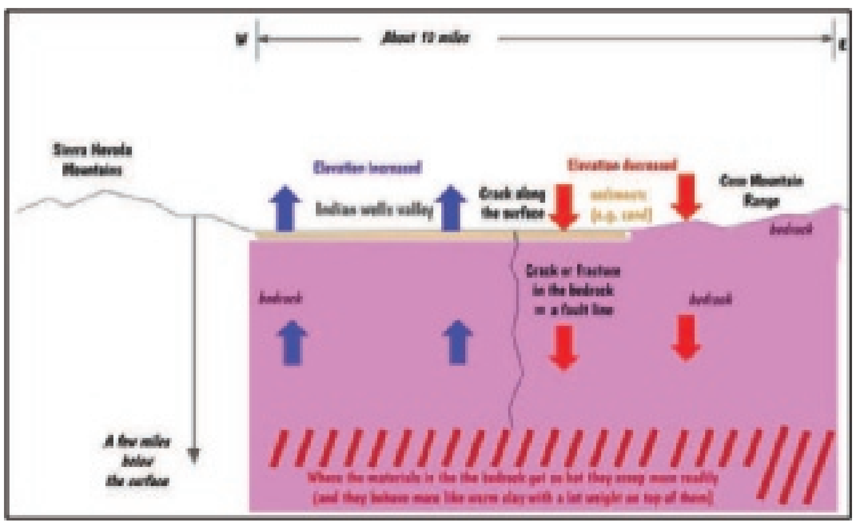




Students should conclude that a break all the way through the bedrock would have to happen during the earthquake, or would have had to exist before the earthquake happened in order to explain what they observed at the surface of the land: shifting half a meter upward and moving northwest and southeast.

Say, *Let's add to our model to represent what we just determined.*

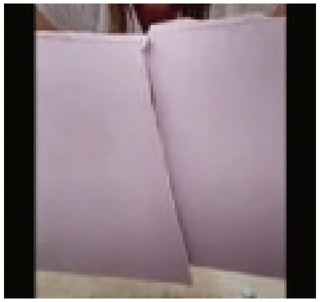
Add the representation of a crack below the surface all the way through the bedrock until it reaches the region where the bedrock gets so hot that it begins to move or shift more readily. Students may suggest that the crack could go down lower too, though it would probably fill in quickly with this moving rock shortly after the break occurred. Tell students that the name of a large fracture all the way through the solid bedrock is sometimes called a fault line.



6. Navigation

5 MIN

Materials: broken pieces of pink foam insulation



Consider how the bedrock to the east and west of the crack is affected. Display **slide J**. Hold up the broken piece of pink foam. Point out that we only modeled the bedrock under a 10-mile wide region, but we haven't yet considered how big each piece of bedrock is on either side of the fault line. Ask students to consider how far the piece of bedrock to the west of the fracture (fault line) extends. Ask the same about the piece of bedrock to the east of the fracture and how far it extends to the east. Accept all predictions.

Say, *Do you think these cracks in the bedrock occur anywhere else?* Ask students to share ideas for what sort of data we would need to determine where else on Earth there might be breaks like this in the bedrock. Students should suggest that we need to look at our earthquake data again because those locations will show us where other fault lines are likely located.

Additional Guidance

Keep the pieces of the pink foam for use later in this lesson and again in Lessons 4 and 6.

End of day 1

7. Navigation

3 MIN

Materials: broken pieces of pink foam insulation

Decide as a class how earthquake data can help us figure out how far the chunks of bedrock extend. Display **slide K**. Hold up the broken piece of pink foam. Remind students that last time we only modeled the bedrock under a 10-mile wide region and just started wondering how big these chunks of bedrock are. We began to consider how much further each piece of this bedrock under Ridgecrest may extend to the east and to the west. Ask students if there is agreement on how big we thought each piece of bedrock was on either side of the fracture in the bedrock (fault line) near Ridgecrest. They will most likely say there is no agreement. Remind students that last time we decided we wanted to look back at earthquake data. Ask students to summarize: *How could looking back at our earthquake data help us determine where else on Earth there might be long fractures in the bedrock (fault lines)?* Students will say that earthquake locations will show us where other fault lines are likely located.

Display slide L. Orient students to the map on the slide. Say, *Here is 10 years of earthquake data, from 1980-1990, to the west and to the east of Ridgecrest to help us figure out how far the bedrock might extend east or west of the fault line at*

Ridgecrest. The red markers are like the ones we saw in Seismic Explorer to represent locations of earthquakes. This smaller data set may help us visualize where we think these fractures or fault lines in the bedrock are located. Discuss the questions on the slide as a class:

- What parts of the United States on this map would have relatively few or no fault lines?
  - Anticipated responses include:
    - The middle and eastern part of the United States
    - The Gulf of Mexico and the Atlantic Ocean bottom off the East Coast, all the way to the Mid-Atlantic Ridge
    - In the middle of the Pacific Ocean to the west of California
- Where do you think you would find fault lines?
  - Anticipated responses include:
    - Along the West Coast up through part of California and into the Pacific Ocean
    - Near Ridgecrest
    - In some small areas in the Rocky Mountains
    - Along the Mid-Atlantic Ridge

8. Develop a profile model of the United States.

8 MIN

Materials: *Constructing Profile Model West and East of Ridgecrest*, science notebook

Prepare to develop a profile model of land to the west and east of Ridgecrest. Display **slide M**. Say, *So if we're going to understand where these fault lines are and how they are related to the land in the area, let's start like we did before, by making a model of this whole area from the long line of earthquakes in the west (where we think there is a long line of fault lines), through Ridgecrest to the Mid Atlantic where there is another long line of fault lines. Let's start by thinking about the surface of the land, and then we can think about what's happening underneath. Using what we know about what the different colors on the map represent, what does the land look like at different locations in the blue rectangle?*

Discuss the question on the slides as a class:

- How does the surface of the land compare in the locations shown in the light blue dash-lined box on the slide?
  - Anticipated responses include:
    - The West Coast, Ridgecrest, and the Rocky Mountains are all mountainous, though there may be some valleys in those mountains too.
    - The Great Plains are relatively flat.
    - The Mississippi River Basin is also relatively flat and maybe a little lower than the Great Plains.
    - The Appalachian Mountains are all mountainous, though there may be some valleys in those mountains too.
    - The East Coast (near North Carolina) is relatively flat.
    - The Mid-Atlantic Ridge is mountainous (underwater).

***Supporting Students in Engaging in Developing and Using Models**

Some prompts to help students develop their cross section model:

- How are you representing the differences in elevation across the country?
- Can you label the different locations on the map that are in your model?
- How can you use the colors on the map in the section you are modeling to help you figure out what the elevations should be on land and in the ocean?

Say, *Where do you think some of the longer lines of fault lines are located on the west side of this map? On the east side of this map?*

- Anticipated responses include:
  - In Lesson 2 we saw lots of earthquakes on the West Coast and in the middle of the Atlantic Ocean.
  - On the map in the previous slide, we also saw a long line of earthquakes in these two locations.
  - Along the West Coast up through part of California and into the Pacific Ocean.
    - Near Ridgecrest
    - In some small areas in the Rocky Mountains
    - Along the Mid-Atlantic Ridge

Display slide N and organize students into small groups. Pass out a copy of *Constructing Profile Model West and East of Ridgecrest* to each student and tell them not to put it in their notebook yet. Tell students they will construct a cross sectional model across the whole United States on *Constructing Profile Model West and East of Ridgecrest*. They are representing the section in the blue dash-lined rectangle to represent the differences in elevation of the land as they move from the west to the east. Remind them we already have some of the profile of the land around Ridgecrest, so they could start by modeling that first on their handout, and then add to their model what the profile would look like to the west and then to the east. Once they have the elevations represented for the different locations, they should think about how the land would look on the surface and below the surface and add that to their model.*

Assessment Opportunity

Building towards 4.A Develop a profile model across the North American plate to explain the changes seen in bedrock after an earthquake by showing what is found at and below the observable surface.

What to look for/listen for: Students to include

- differences in elevation across the North American plate
- some type of sediment at the surface in the lower elevation areas
- bedrock exposed on some of the higher elevations
- bedrock underneath everything going down deep
- additionally, they may represent rock beginning to shift or move far under the surface due to temperature

What to do: Encourage students to come up and look at the class relief map if they are not sure about the elevation of certain areas on the map. If students can't remember what the different colors on the map represent, remind them what the class shared in Lesson 2.

9. Develop a class profile for the North American region.

12 MIN

Materials: None

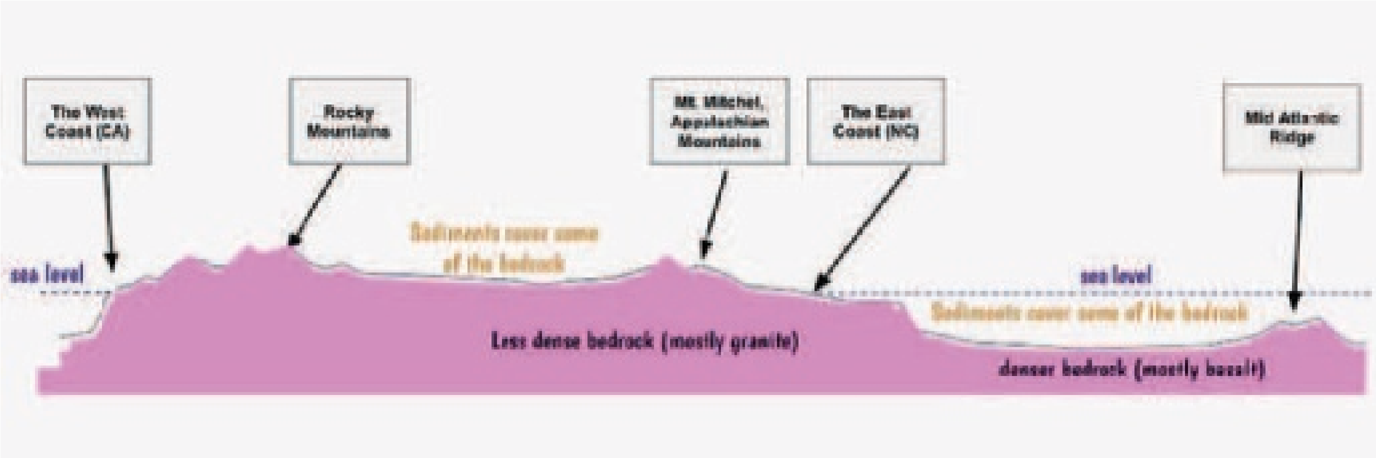
As a class, develop a consensus model. Bring the class back together and talk through the different components that should be included in our cross section models. Tell students that we are going to share our cross sectional models as a class.

Additional Guidance

You will notice that the discussion around and development of a model for this profile view of the North American region is developed through the slides instead of on poster paper. The reason for this is that the class has already developed a cross section model of the Ridgecrest area, and this model is basically the same model except it is a larger area. In addition, on *Constructing Profile Model West and East of Ridgecrest*, students have been provided the beginning of the model—the profile of the surface of the land. Students have also worked with their small group to co-develop what is under the surface. The slides can serve as confirmation of what they co-developed. If you have the time, you can choose to develop this on poster paper instead.

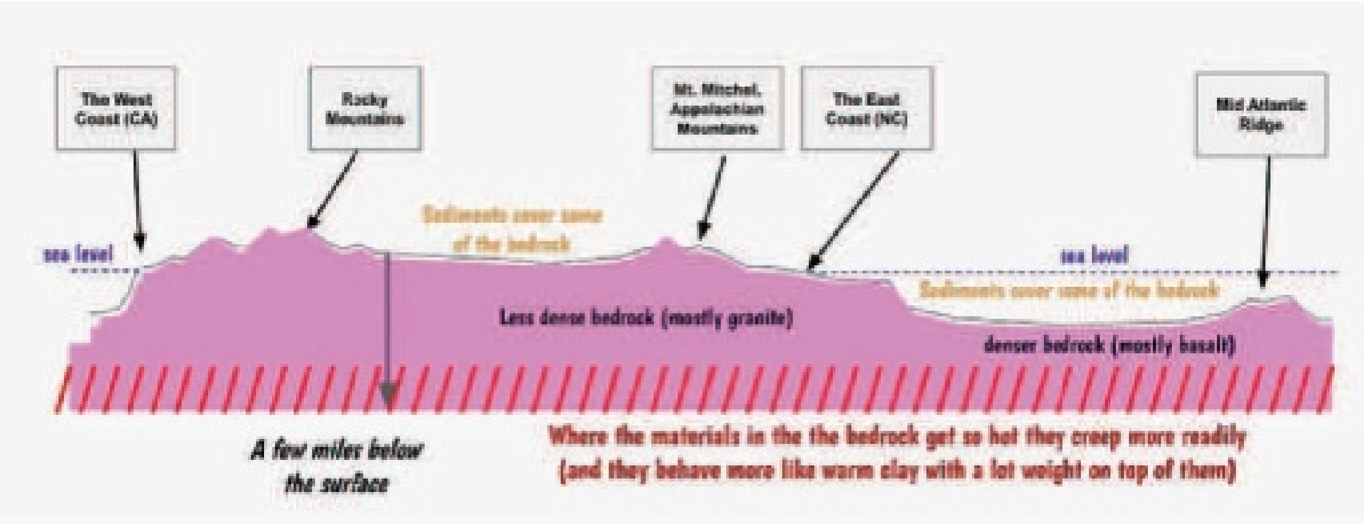
Suggested prompts	Sample student responses
*(**Display slide O**.) On the slide, there is a profile model at the top that will look similar to what you and your small group developed. Notice there is a dashed line marking sea level on the profile model, what does this represent?*	*This is where the land meets the water, so anything under the sea level line means it is under water.*
Besides sea level, what else did others include in their models at the surface and just under the surface?	*Sediments in between mountains and bedrock under everywhere.*
What did we figure out in Lesson 3 about the bedrock that is under the land versus under the ocean?	*The bedrock under the land is less dense and mostly granite while the bedrock under the ocean is more dense and mostly basalt.*
(Optional - if students haven't included sediment.) What do you think is on the surface between the East Coast and the Mid-Atlantic?	*sediments or sand* *Sand is on the bottom of the ocean.*

Show **slide P** at this point.



Suggested prompt	Sample student response
What else can we add to our model about what the materials are like far underground?	*We need to add that the bedrock gets much hotter and begins to move and shift.*

Show **slide Q** at this point.



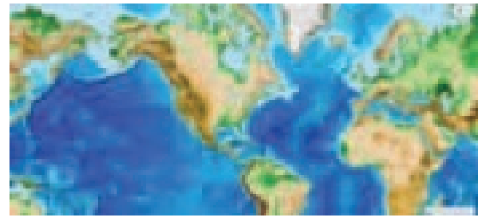
Suggested prompts	Sample student responses
We know there is a fault line where the earthquake in Ridgecrest happened and this crack went down through the bedrock. Do you think there are other areas on our map where there may be fault lines?	*Yes! Since we saw there are other areas where earthquakes happen when we looked at Seismic Explorer.*
What do you think is happening to the bedrock and Earth where there are long lines of earthquakes like we saw in Lesson 2?	*The land could be cracked open in these locations too and might also go down through the bedrock.*

10. Revise our model with data from Seismic Explorer. 6 MIN

Materials: Seismic Explorer

Orient students to the cross section feature of Seismic Explorer. Display **slide R**. Say, *In Lesson 2, when we explored where earthquakes happen in the world using Seismic Explorer, many of you noticed that we could see where they happen and that there are different depths and strengths of earthquakes. We are going to return to Seismic Explorer to use a feature that will provide us with a new piece of data, a cross section view of the earthquake data. Let me show you how to use this* *feature in Seismic Explorer, then you will have some time to explore it on your own.* Use the steps below to demonstrate to the whole class and orient the students as to how to use the cross section tool.

1. Open Seismic Explorer. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Make sure you are seeing the relief map. The link should open there, but if not, use the “Map Type” button at the button to toggle to the relief map.



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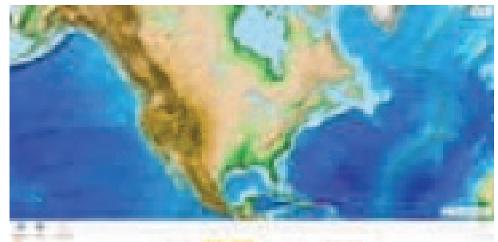
2. Click and hold on the map so that you can drag North America to the center of the map.



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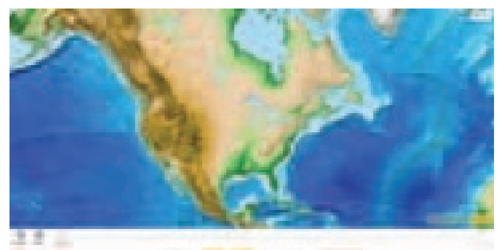
3. Click on the “+” sign in the top left of the map to zoom in. You should only need to click on this one time to have the United States centered with the Pacific Ocean on the left and the Mid-Atlantic clearly visible on the right.



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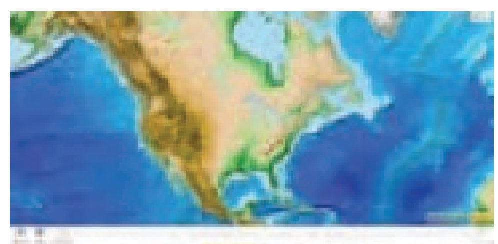
4. Click on the “Draw Cross Section” button in the bottom right of your screen. This button will go away and you will see two buttons pop open, one that reads “Open 3D View” and one that reads “Cancel.” You will notice the “Open 3D View” is transparent looking at first. This is because you need to identify what section of the map you want to see a cross section of.



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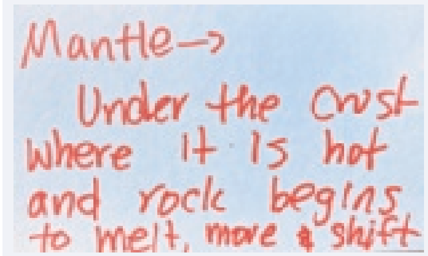
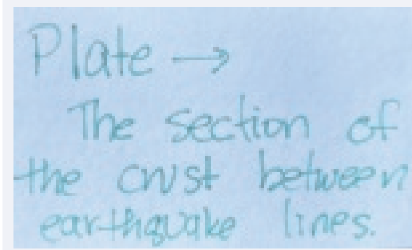
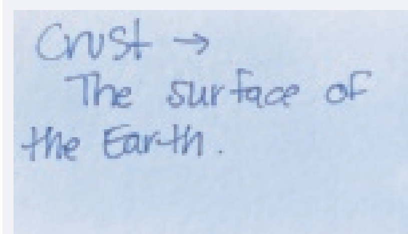
5. We want to choose a section on the map that reflects the cross section we just developed a class model of. You will want to click at first on the west side slightly into the Pacific Ocean like we have on our World Map. When you click here, you will notice a P1 show up on the map where you clicked.

***Attending to Equity**

When adding the words **plate, crust,** and **mantle** to the Word Wall, use both words and pictures when adding the meaning of these words to the card for the Word Wall. Students will be using and referring to these words throughout the unit. An example of what these might look like is included here:

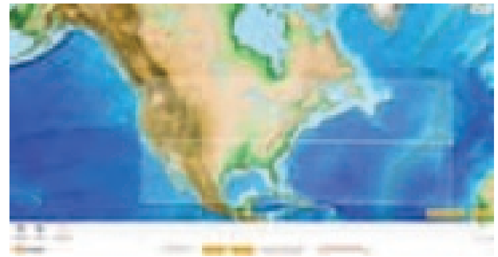






Supporting Emergent Multilinguals: These three words have multiple meanings in English depending on how they are used,

6. Keep holding and drag across the map from P1 in a straight line just past the Mid-Atlantic Ridge, like we have in our model. You will see a P2 appear where you let go of your mouse with a line connecting P1 and P2, as well as a shaded rectangle around the area around this line. If you let go of your mouse or trackpad after P1 has been placed on the map, just click on the spot P1 to draw the line across.



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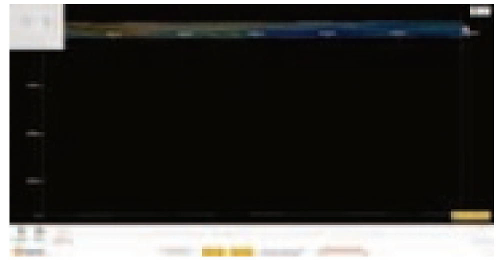
7. Now that an area on the map is designated, you should see that the "Open 3D View" button will be darker and accessible. Click on it and you will see the map change to a profile view.



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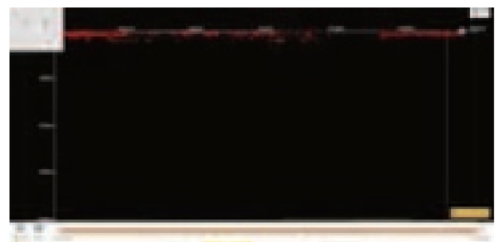
8. Help students make sense of what is being shown here. There are distance markers running horizontally and vertically. Ask students what these are representing. The horizontal measurements represent the distance in kilometers from one end of the selected area to the other across Earth. The vertical measurements are how deep under the surface the earthquake happened. There will not be any earthquake data in the cross section until you click on "Start" on the bottom left of the screen. Click on "Start" now.



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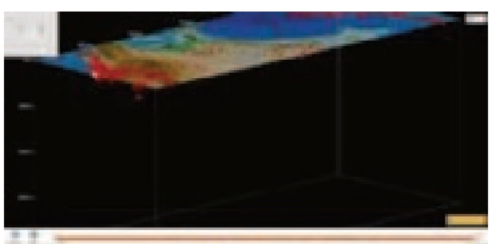
9. At first, the data will just be at the top of the screen and somewhat difficult to analyze to look for long lines of fault lines. If you click and hold on the screen anywhere, you will be able to move the image around so that you can see the earthquakes from different views. Do this now and show students how this can be done.



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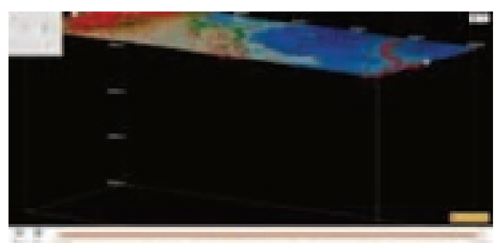

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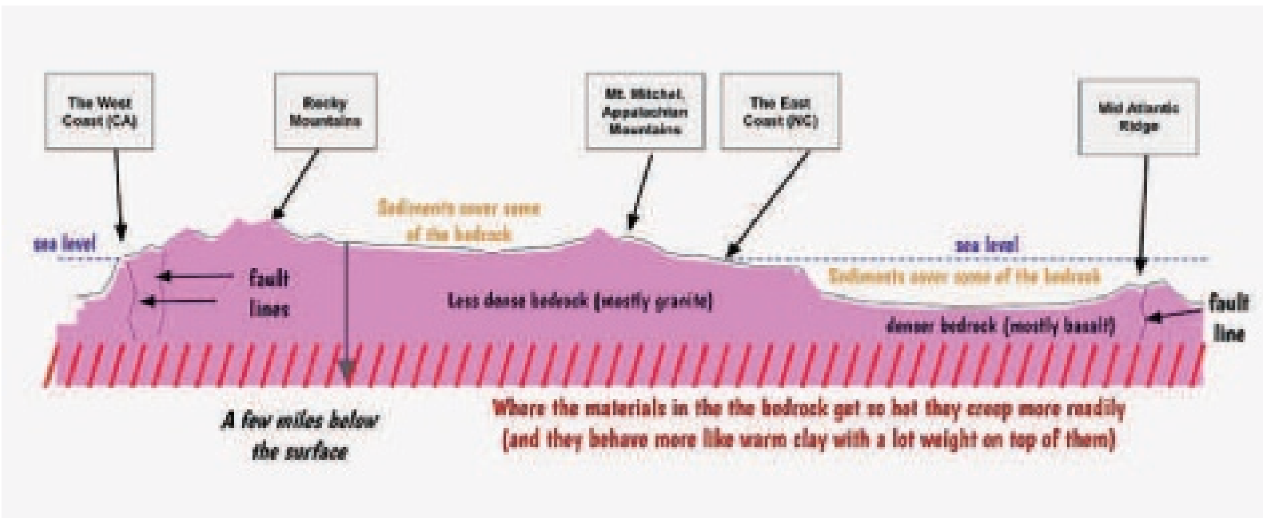
therefore including an image on the Word Wall card will support emergent multilingual students. To take this support one step further, you could ask for a student to add a definition for these three words in their native language. Teachers can support all students, particularly emerging multilingual students, in forming a deeper understanding of newly "earned" vocabulary by representing the new term in multiple ways. For example, students can 1) write the term, 2) draw a representation of the term, 3) use their own words to write an explanation for what the term means, and 4) use the new term in a sentence.

10. Tell students when they explore this on their device, they should rotate the land around in the 3D cross section view to see what they can discover about where earthquakes occur and what this means for the bedrock in these areas. When finished, you can click on the button on the bottom right, "Close 3D View."

Say, *Now that you have seen how to set this up, open up Seismic Explorer on your device, and look for evidence of any long lines of fault lines in the cross section that matches the model we just finished developing*. Give students about 5 minutes to explore this data in Seismic Explorer, then bring the class back together.

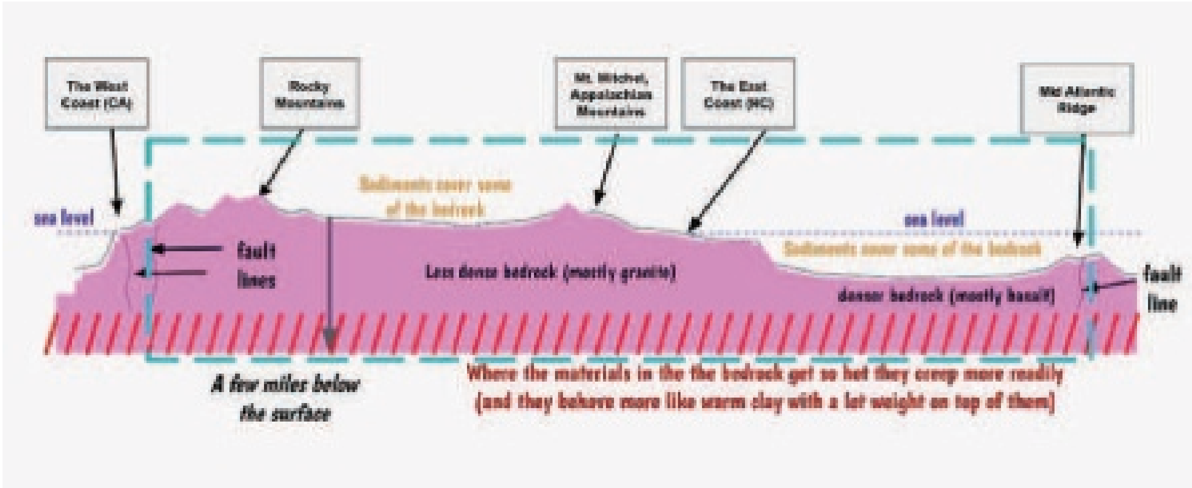
Ask, *Did you find any long lines of earthquakes? Where?* Students should say yes, along the west coast and down the Mid-Atlantic. Ask, *So if there are long lines of earthquakes, would there be fault lines there?* Students should say yes they think so, just like Ridgecrest. Suggest everyone add these locations to the profile model on *Constructing Profile Model West and East of Ridgecrest*. Show **slide S.**

Point out the added fault lines on the west and east of the cross sections.

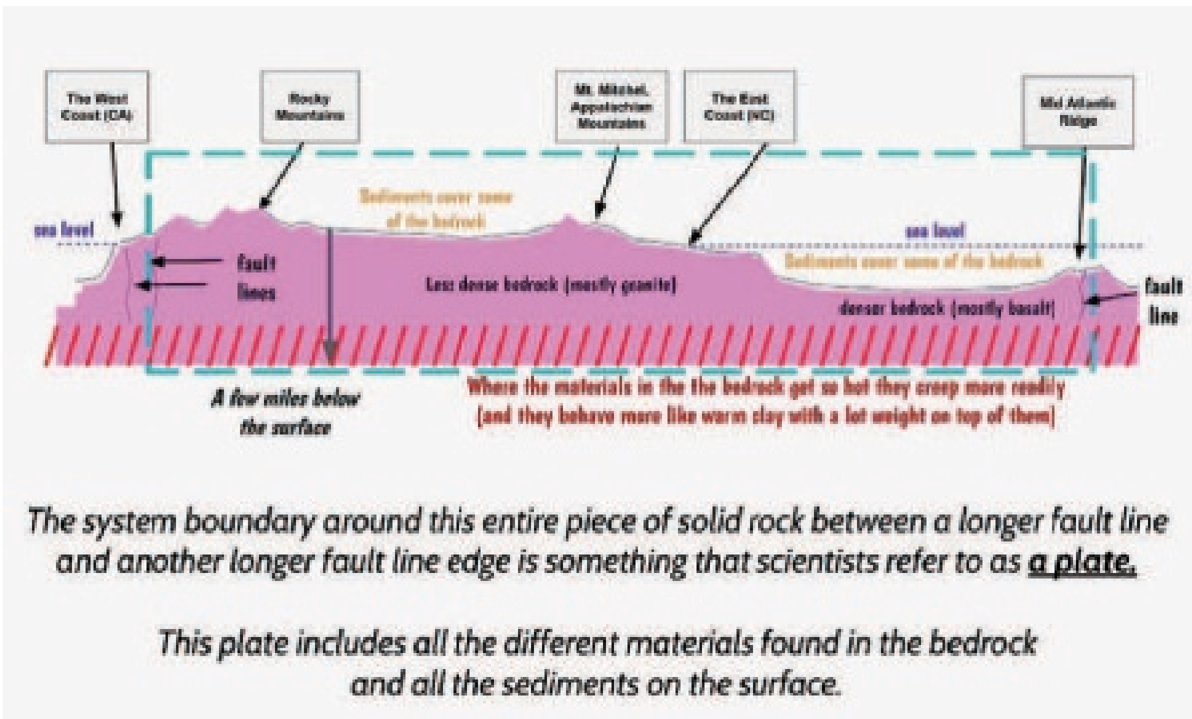


Say, *So if there are long lines of fault lines at these places on the map, and we saw that these fault lines can represent where the bedrock has cracked apart, then let's think about what is going on from the fault lines on the west coast to the fault lines on the east in the Mid-Atlantic.* Help students add any other details they notice on their profile model. Point out that the fault lines at the edges of the model seem to be many and run in long lines with there being only a few earthquakes in the center of the country. Ask, *What do you think the bedrock is like in between those long lines of fault lines?* Students should suggest that it is most likely big solid sections of rock with a few other cracks like we saw at Ridgecrest.

Display slide T and say, *In Storms Unit, when we were trying to figure out what caused storms, we learned that when scientists are working with phenomena that are at a very large scale, they will look at different sections with similar characteristics or systems, to help them figure out what is happening on a larger scale. On the slide, the light blue rectangle represents our system boundary between fault lines.*



Show **slide U.** Tell students that this system boundary between fault lines, with mostly unbroken bedrock in between the broken edges of the bedrock at the fault lines, is a system that scientists call a **plate.** Add the word **plate** to the Word Wall. Also share with students that scientists call the part of Earth with the plates, the **crust** of Earth and the part of Earth under the crust where rock gets hot enough to melt, the **mantle**.*



The system boundary around this entire piece of solid rock between a longer fault line and another longer fault line edge is something that scientists refer to as **a plate.**

This plate includes all the different materials found in the bedrock and all the sediments on the surface.

11. Update Progress Tracker. 5 MIN

Materials: science notebook

Help students synthesize what they have figured out by using the Progress Tracker. Tell students to open to the Progress Tracker section of their notebook. Present **slide V**. Have students draw a two-column chart in their science notebooks in the section set aside for Progress Trackers. Remind students that the Progress Tracker is a space for them to document their current thinking. Have them write the lesson question in the first column of the Progress Tracker, then use pictures, words, and symbols to develop a model that represents their thinking about the lesson question, "What is happening to Earth's surface and the material below it during an earthquake?" Give students time to add to their Progress Trackers.*

Assessment Opportunity

Building towards 4.B.2 Construct an explanation using qualitative evidence from class investigations to explain what is happening to the bedrock below the observable surface when an earthquake causes a shift or break in the land.

What to look for/listen for: Look for students to explain using words and/or pictures that when there is an earthquake, the land at and below the surface can be affected. Some ways it can be affected include:

- The land cracks apart or breaks open.
- The land shifts in elevation with part of the land increasing and/or decreasing in elevation.
- The land moves horizontally to be in a different location.
- The bedrock below the surface is also cracked or broken.
- The long breaks in the bedrock are called fault lines.
- The large sections or chunks of bedrock in between these fault lines are called plates.

What to do: Use this Progress Tracker entry as a formative assessment to see what students are able to synthesize from this lesson. If students struggle to get started answering this, encourage them to look back over the profile models that have been developed over the last two class periods, and use them to answer this question.

***Attending to Equity**
It is important that what the students write in the two-column tracker reflects their own thinking at that particular moment in time. This is an opportunity for students to express their understanding and reasoning in their own way. Encourage students to express what they've learned using a mode that makes sense for them. For some emergent multilingual students, encourage them to use this space to make sense in the language that they feel most comfortable using. The individual Progress Tracker is a space for students to be creative and to synthesize learning in their own words. It is not supposed to follow a prescriptive plan or structure and should be a low-stakes opportunity for students' to make sense of what they are learning without the worry and anxiety that comes with knowing their work will be graded. Use the Progress Tracker for formative assessment only.

12. Look at earthquakes on map to predict where other plates are located. 5 MIN

Materials: *10-Year and 30-Year Earthquake Data*

Return to the map of earthquake locations to predict where else there are plates located. Display **slide W**. Say, *Scientists are not in agreement about how many plates there are on the earth. Take a moment to look at the map on the* *slide from the Seismic Explorer earthquake data. Why do you think scientists are in disagreement?* Accept all responses suggesting it is difficult to clearly identify everywhere there are long lines of fault lines. Say, *So if plate system boundaries are long lines of fault lines and fault lines exist where there are lines of earthquakes, will our earthquake data help us define where the plates are?* Distribute *10-Year and 30-Year Earthquake Data* to each student. Tell them to work with a partner to identify how many plates they think there are over the whole Earth.

Show **slide X.** After a few minutes, ask students to share their ideas with the class. There should be some disagreement, but for areas where students are in agreement about representing a plate, ask a volunteer to label it by placing a sticky note in the middle of the plate with the label "plate." Help them articulate that some of the fault lines are pretty clear, but others are not as clear, so it is not always clear where the edges of each plate are.

Additional Guidance

10-Year and 30-Year Earthquake Data can be printed in black and white. There is a color copy included in the Student Procedure Guide for reference if needed.

13. Reflect on the practice of developing models.

4 MIN

Materials: science notebook

Self-reflect on the use of different models. Project slide Y. Tell students to open to the next page in their science notebook. Say, *Today on Constructing Profile Model West and East of Ridgecrest you developed a profile model of the land on either side of Ridgecrest from the Pacific Ocean to the Atlantic. Then we used your models to create a class consensus model. We use models in science all the time to capture what we have figured out and to help us identify what we still need to figure out. Take a moment to reflect back on when you were developing this cross section model and answer the two questions on the slide in your notebook:*

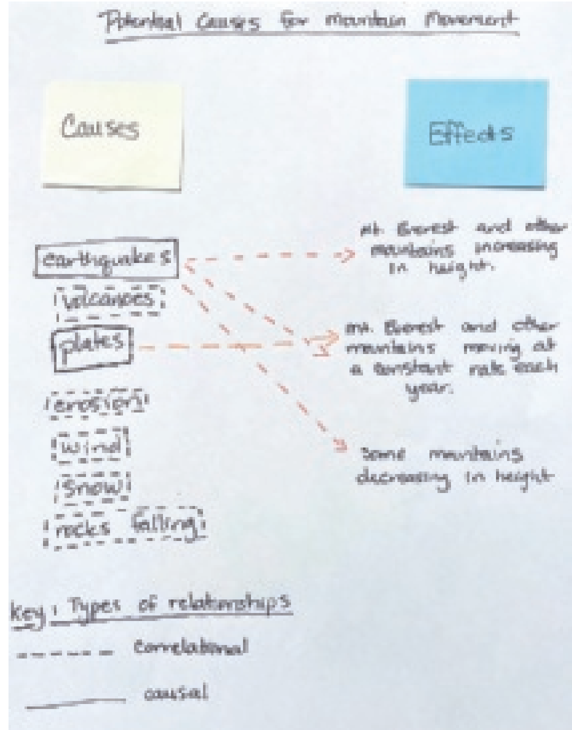
- What were the challenges for you of developing this representation of such a large section of land on the Earth?
- What are some ideas you have for materials or layout to use in future models like this that would make representing the system easier?

Materials: Potential Causes for Mountain Movement chart

Return to Potential Causes for Mountain Movement chart. Reference the two potential causes of earthquakes and plates. Ask, *What have we figured out about earthquakes and plates?* Students should summarize:

- earthquakes mostly happen near mountains where there are different plates next to each other,
- when earthquakes happen the land can crack all the way down through the bedrock,
- and when this happens, the land moves,
- plates are on the surface of Earth between fault lines, and
- since earthquakes happen at the edges of plates, and mountains are also in the same area, then maybe this somehow affects how mountains grow or move.

Say, *So can we add anything to or revise anything on our Potential Causes for Mountain Movement chart?* Students should say, we can make the dashed box around the word "plates" solid now because we have figured out that there are plates. Also, they should say we are more sure now that earthquakes are related to mountains moving and growing, but we need to figure out more about plates, like do they move? And if they do move, how does this happen?



ADDITIONAL LESSON 4 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.6.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas, and expressing their own clearly.

Students will engage with both a small group discussion and a whole-group discussion. In this lesson, students use data images of how the land at Ridgecrest broke apart after an earthquake to co-develop an argument with a partner for how the bedrock below this crack is affected. The students come together as a class and share what they and their partner think happens to the bedrock. Through this discussion, the students work together to come to a consensus idea for what must happen to the bedrock—that it must also break apart since the land shifted in elevation.

How does plate movement affect the land around mountains such as Mt. Everest?

Previous Lesson

We developed a cross sectional model of the topography at Ridgecrest including what we know about the ground underneath these different parts of Ridgecrest. We added a break in the model to represent the earthquake at Ridgecrest. We used foam board to model changes in the bedrock to determine this break must go all the way through the bedrock. We figured out that these big sections of Earth between long fault lines are called plates.

This Lesson

Investigation, Putting Pieces Together

1 DAY

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We look for patterns in GPS data to examine land movement around Mt. Mitchell, and use a physical model to demonstrate that the entire North American plate moves at a constant speed and in a specific direction. We further revise a cross section model of the North American plate from the previous lesson to connect its movement to the behavior of the deeper, hotter bedrock. We use Seismic Explorer to investigate the movement of all plates on Earth's surface. We figure out that most plates move at constant speeds and in specific directions. In conclusion, we claim that most mountain movement is caused by plate movement.

Next Lesson

We will use models of plate movement to identify and describe the results of plate interactions. We will develop models of the interactions to help explain what caused the elevation and other changes at Mt. Everest, and will consider how earthquakes could be caused.

Building Toward NGSS

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

What Students Will Do

5.A Analyze a graphical display of a large data set of plate movement in order to determine whether a causal or correlational relationship exists between plate movement and mountain movement.

What Students Will Figure Out

- All plates are constantly moving in different directions and at different speeds.
- Plates move because they sit on top of deeper, warmer rock layers which move, or creep.
- When creep occurs, mountains and all other features on the plate above also move.

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	2 min	**NAVIGATION** Revisit the *Potential Causes for Mountain Movement* chart to consider potential relationships between the movement of both Mt. Mitchell and the North American plate.		Potential Causes for Mountain Movement chart
2	3 min	**SHARE PREDICTIONS** Use a model of the North American plate to predict what happens to the land to the east and west of Mt. Mitchell.	A-C	
3	10 min	**ANALYZE GPS DATA** Use GPS data from Seismic Explorer to observe movement of the North American plate.	D-F	*North American Plate Manipulative*
4	10 min	**USE A MODEL TO EXPLAIN WHY THE LOCATION MOVES** Use the cross section model of the North American plate to explain why it moves.	G-I	
5	10 min	**INVESTIGATE PLATE MOVEMENT** Use GPS data from Seismic Explorer to investigate the movement of plates.	J	computer, Plate Movement map (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
6	6 min	**PUTTING PIECES TOGETHER** Discuss patterns from Seismic Explorer data. Revisit the *Potential Causes for Mountain Movement* chart to account for mountain movement.	K-L	Potential Cause for Mountain Movement chart, markers, World Map
7	2 min	**UPDATE PROGRESS TRACKERS** Allow time to update Progress Tracker with ideas from Lesson 5.	M	
8	2 min	**NAVIGATION** Foreshadow next lesson by problematizing the connection between plate movement and mountain growth	N	Potential Causes for Mountain Movement chart
				End of day 1
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 5, students are ready to read Student Reader Collection 2 and then respond to the writing exercise.		Student Reader Collection 2: *A Historical Perspective*

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *North American Plate Manipulative* • science notebook	• computer • Plate Movement (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)	• Potential Causes for Mountain Movement chart • Potential Cause for Mountain Movement chart • markers • World Map

Materials preparation (10 minutes)

Online Resources

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

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

Make certain that the web page used in this lesson only displays "Plate Boundaries" and "Plate Movement" under the button "Data Type" located at the bottom of the screen. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Display these by checking the appropriate boxes. During the lesson the additional checkbox of "plate Movement - (Detailed)" will also be utilized. Have the simulation available and running on a computer or internet enabled device for groups of students.

Have at least one copy of *North American Plate Manipulative* and one pair of scissors, for each set of partners or groups. Ideally, print this handout in color. The document as a pdf will keep the maps the size needed so that when the students cut out the North American plate image it will "fit" on top of the world map image. If printing from a different format and the images are not fitting, the first image should be printed at 75% size of the second image.

Be sure to have the *Potential Causes for Mountain Movement* chart ready to use at various points during this lesson.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students first revisit the cross sectional model of the North American plate and wonder whether the land around Mt. Mitchell also moves along with the mountain. Using GPS data from Seismic Explorer, students discover that the entire North American plate moves at a consistent speed and in a specific direction. Students refine their cross section model of the North American plate to include its overall movement. Thinking more broadly about other mountains around the world, students then explore a larger set of GPS data to discover that all the plates on Earth's surface move at constant speeds and in different directions. After reaching consensus that mountain movement around the world is caused by plate movement, students revisit and refine the *Potential Causes for Mountain Movement* chart to change the relationship between plates and mountain movement from a correlational link to a causal link.

Where We Are NOT Going

This lesson helps students see that the movement of mountain peaks and ranges on Earth is caused by plate movement. Though some students may ask, the fact that some mountains can also grow taller, while others shrink, is addressed in a later lesson. Also, though students may begin to infer that plate movement is due to temperature variation and bedrock creep, this concept will not be explored now as it is further developed in a later lesson.

LEARNING PLAN FOR LESSON 5

1. Navigation

2 MIN

Materials: Potential Causes for Mountain Movement chart

Revisit the *Potential Causes for Mountain Movement* chart. Display the *Potential Causes for Mountain Movement* chart. Say, *Let's revisit our chart and remember what we had concluded at the end of our last class. We listed a number of potential causes for mountains moving, growing, or shrinking on our chart. One of the potential causes we listed was plates.*

Suggested prompt	Sample student responses
In our last lesson we concluded that the box around "plates" should be solid instead of dashed. What did we figure out that led us to decide this?	*We know from the reference cards that some mountains move a certain amount every year, even without earthquakes.* *We figured out that there are large sections of land between areas where earthquakes happen called plates.* *We know what plates are, but we aren't sure how they are related to mountains changing.* *We wonder if earthquakes, mountains, and plates are related.*

After several students share their thoughts, focus on the potential connection between mountain movement and plates by reminding students that we have evidence of mountain movement from the reference cards. Say, *We know that several mountains around the world are moving. In fact, we know specifically that Mt. Mitchell is moving at about 3 cm per year towards the west. And, it's located on the North American plate. So what do we think is happening at other places on the plate? Do we think they are moving too?*

2. Share predictions.

3 MIN

Materials: None

Recall the cross section model of Mt. Mitchell. Display **slide A**. Using the slide, remind students that Mt. Mitchell is moving westward 3 cm per year. Reorient students to Mt. Mitchell's location with respect to the North American plate using the cross section model developed in the previous lesson. Say, *Let's look back at our model of the North American plate. Let's also remember that Mt. Mitchell moves 3 cm to the west each year. What material is under the surface of the entire North American plate, including under Mt. Mitchell?*

Suggested prompts	Sample student responses
What material makes up the entire North American plate and including under Mt. Mitchell?	*bedrock*
Previously, we found out some things about the different types of rock bedrock is made of. What is most likely the type of rock we could find if we were to dig down deep into the bedrock of the North American plate?	*Most of the bedrock is granite, unless it's under the ocean where it's mostly basalt.*

Display **slide B**. Ask students the first prompt, and guide students to think next about what is happening to the bedrock below Mt. Mitchell. Say, *Thinking back to what we figured out about what it's like deep below Earth's surface, what changes would you expect to see as you go deeper below Mt. Mitchell, if we were to dig miles down?*

Push students to then think more about what happens to some of the bedrock when it gets warmer. Ask, *What happens to some of the bedrock as it gets warmer?* If students struggle to respond, continue to use the image of the model from **slide B** to encourage them to think about what we figured out in Lesson 3, specifically about how the temperature increases the further below the surface we go.

Suggested prompts	Sample student responses
Thinking back to what we figured out about what it's like deep below Earth's surface, what changes the deeper you go below Mt. Mitchell?	*I remember the video and reading in the mining lesson saying that it gets hotter as you go deeper into Earth.*
What happens to the bedrock as it gets warmer?	*In our model, we said that the hotter, deeper bedrock can behave like warm clay. It begins to slide or shift as it gets hotter and when you push down on it.*

Make and share predictions. Display **slide C**. After students recall that Mt. Mitchell is moving, and that the bedrock beneath the mountain and land surface may also be moving, guide students to consider what may happen to the land far away and on either side of the mountain. Ask, *What about the land on either side of Mt. Michell? What do you think is happening to the land at Earth's surface* ***many*** *miles to the east and west of Mt. Mitchell?*

Prompt students to turn to a neighbor and discuss the second prompt on the slide. Give students one minute to discuss the prompt. Then, for the next minute, ask for volunteers to share something their partner mentioned. Listen for some students to say that the land could be moving, and for others to wonder how the land could always be moving if we don't feel it, particularly in locations that don't typically experience earthquakes.

Supporting Students in Developing and Using Scale, Proportion, and Quantity

Students begin to think about the movement of the plates on Earth. As they consider the movement of the North American plate at a rate of 3 cm/year, reflect on how, though the plate is moving at a constant rate (verified by GPS data), they can't feel this movement. In order to begin to make sense of how this movement affects the Earth on a larger scale, students use scaled down manipulatives of both the North American plate and the world with the plate boundaries noted. This understanding helps to reinforce that small changes over a large scale are harder to perceive, but still contribute to larger change over spatial and temporal scales.

Suggested prompt	Sample student responses
What about the land on either side of Mt. Mitchell? What do you think is happening to the land at Earth's surface many miles to the east and west of Mt. Mitchell?	*I don't think it's moving far from Mt. Mitchell because I'm far from the mountain and I don't feel or see the ground moving.* *Maybe it's not moving as much towards the east because you get to the ocean where there is less bedrock.* *Maybe in the west where there are more mountains, the land moves more because the weight of the mountain pushes down and makes the bedrock creep more.* *I think it moves the same way whether you move east or west because there's bedrock everywhere, and bedrock will move when it gets warmer.* *Our model shows that the bedrock is everywhere under the entire plate, so maybe the whole plate moves together when the mountain moves?*

Close the discussion. Guide students to consider what type of information or data might be useful to see what is happening to the land around Mt. Mitchell. End the discussion once one or more students mention GPS data or using Seismic Explorer.

Suggested prompt	Sample student responses
We have some different ideas about what could be happening to the rest of the land around Mt. Mitchell. What information could we look at if we wanted evidence of movement around Mt. Mitchell?	*Maybe we can use the same tools or instruments scientists used to measure mountain movement, like what they did with Everest.* *Can we look at GPS data, like we read about, to see if other parts of the land also move?*

3. Analyze GPS data.

10 MIN

Materials: *North American Plate Manipulative*

Analyze GPS data. Transition from the previous discussion by telling students that Seismic Explorer has additional data for review. Some of the data that is included in Seismic Explorer is assembled using GPS tracking data. Say, *Remember we used Seismic Explorer to analyze data about earthquakes. There are other types of data we can analyze besides earthquake data, such as using GPS to track earth movement. We can also use this same GPS data to look at what is happening with the plates.*

Display **slide D**. Orient students to the map by explaining that it shows the part of the North American plate that spans the cross section model of the North American plate from the previous slide. Note similarities between the cross sectional view of the plate from the previous slide and the overhead view on this slide. Say, *Some of you may recognize this map as part of the North American plate. In the last lesson we developed a cross section model of part of the North*

American plate. Here, what we see instead is an overhead view. You can even see the Appalachian Mountains near the center of this map, just as we saw Mt. Mitchell and the Appalachian Mountains are near the center of our cross section model as well.

Explain that the small arrows on this map represent the relative movement of a particular location as calculated using data from GPS tracking instruments. Taken together, it infers overall, or average movement of a plate at different locations. Say, *In looking closely at the GPS data from Seismic Explorer, the North American plate is calculated to move approximately 3 cm per year.*

Facilitate a whole class discussion. Ask students the first prompt. Say, *What evidence is there that the plate may be moving?* Listen for students to say it looks like the entire plate is moving since there are arrows everywhere. Ask students the second prompt from the slide and elicit student ideas.

Suggested prompt	Sample student responses
What do you notice about the direction of movement at different locations on the plate?	*It looks like the plate is moving in different directions depending on your location.* *The eastern part of the plate, over the ocean, seems to be moving north and west (up and left).* *The western part of the plate seems to be moving mostly west and a little south (left and down).* *In the middle of the plate, it all seems to be moving west (left).*

Display **slide E**. Explain that the previous slide only showed part of the North American plate, but that this slide shows the entire plate. In the previous lesson we figured out that the edges, or boundaries of a plate are identified by where there are earthquake fault lines extending in long lines. Here we see the lines we identified in the previous lesson extend even further north and south. The portion of the plate from the previous slide is highlighted in the red oval. Say, *On the previous slide it was useful to look closely at the part of the North American plate that fit over our cross section model. But since we're interested in seeing if plate movement is connected to mountain movement, we'll need to zoom out to look at the entire North American plate.*

Ask, *As we zoom out to look at the entire North American Plate, what do you notice about plate movement?* Students should notice that the entire plate appears to be moving similarly to the segment of the plate shown in the previous slide. Students may also notice that the overall counterclockwise movement of the plate seems clearer when looking at the entire plate than when looking at the plate segment.

Make a prediction. Display **slide F**. Summarize the types of movement described by students from the previous slide. Say, *It seems as though we noticed movement across the entire North American plate, and that different parts of the plate are moving in different directions.* Pass out *North American Plate Manipulative* to each pair of students. Prompt students to work with a partner and use the handout to show where they predict the North American plate will be located many years in the future.

Explain that the handout contains a world map highlighting all the lines of earthquake fault lines where there are plate boundaries on Earth's surface. Tell students to cut out the small colorful piece representing the North American plate—the same image that was on the previous slide. Say, *Based on how fast the North American plate moves each year, and the direction it seems to move as seen in the previous slide, predict where you think the plate will end up many years into the future.*

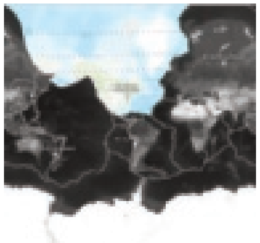
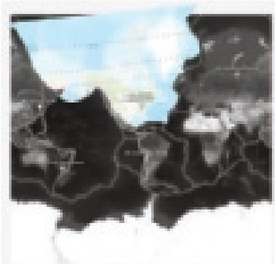
Give students 5 minutes to work with their partner. Ask for volunteers to describe or show their predictions to the class. Push for volunteers to also provide a brief explanation for their prediction.

Supporting Students in Developing and Using Scale, Proportion, and Quantity

In prior lessons, representations of smaller areas of land have been studied, such as the land at Ridgecrest. While studying smaller areas, lines of earthquakes have been dissected and small areas of movement have been analyzed, including the development of cross-sections, from the surface level to understand that a large area on Earth can move. At this point in the lesson, this movement is being analyzed on a much larger scale. By looking at the earthquake lines and determining that these are plate boundaries, we can scale up the movement from an individual location or line to the section of entire tectonic plates, moving from the analysis of events, such as earthquakes, to the larger scale movement of entire plates.

Additional Guidance

The purpose of this activity is for students to use a manipulative to model general movement of a plate segment over time. In this case, the North American plate twists slightly counterclockwise. Below are current/future images of where the North American plate segment will start at the beginning of the activity, and where it might be located in the future.

Current location of NA plate	Predicted future location of NA plate
 Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.	 Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.

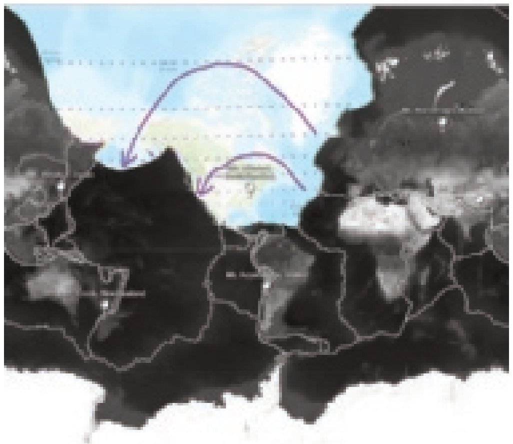
This prediction is not meant to be precise. Even with sophisticated mathematical modeling, the precise movement of plate tectonics is difficult to predict. Additionally, most students will likely move the plate segment at least 2-3 cm away from the starting location. Pointing out that 3 cm on this map is not the same as 3 cm of actual plate movement on Earth will be important as students grapple with making sense of the scale of this movement on Earth as compared to on our paper map. Therefore, the scale of movement will not be accurately represented on this map when moving part of the North American plate.

Assessment Opportunity

Building towards: 5.A.1 Analyze a graphical display of a large data set of plate movement in order to determine whether a causal or correlational relationship exists between plate movement and mountain movement.

What to look for/listen for: Using *North American Plate Manipulative*, students place the North American plate slightly to the west of its original location, and rotate it slightly counterclockwise. Students should be able to support this prediction by referring to the arrows shown on the Seismic Explorer map of the North American plate.

What to do: As students work with a partner, they will use GPS data regarding the North American plate (after **slide F**) to predict that the North American plate will twist counterclockwise. The exact amount of rotation is not important since no numerical values have been attached to the arrows on the map. If students are struggling to see how the arrows on the plate indicate a general counterclockwise rotation, ask



Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.

students to use a pencil or dry/wet erase marker to connect adjacent arrows in a dot-to-dot fashion, starting to the east of Mt. Mitchell and moving towards the west. The end result should resemble a semicircle moving from west to east.

Alternate Activity

There are numerous ways for students to physically or digitally show where the North American plate segment may be located in the future. Aside from using the provided handout, you might consider one of the following:

- Option A - Use the foam board pieces cut during Lesson 4 to represent the North American plate, and ask students to move or position it across a projected map.
- Option B - Students can point on a projected map to where the North American plate is currently located, and then to where they predict it will be in the future.
- Option C - Students can digitally manipulate an image on a slide by rotating or sliding the image of the North American plate over a projected world map.

4. Use a model to explain why the location moves.

10 MIN

Materials: None

Use a model to develop an explanation. Display **slide G**. Guide students to think about what could be causing the plate movement they predicted in the previous activity. Prompt students to discuss the prompt from the slide in small groups for the next 2 minutes. Say, *Using our model for the behavior of bedrock many miles below Earth's surface, explain what is* ***causing*** *the North American plate to move 3 cm per year.*

For the next 2 minutes, ask for volunteers from different groups to share their ideas. Encourage students to use the image of the model from the slide while sharing their explanations.

Additional Guidance

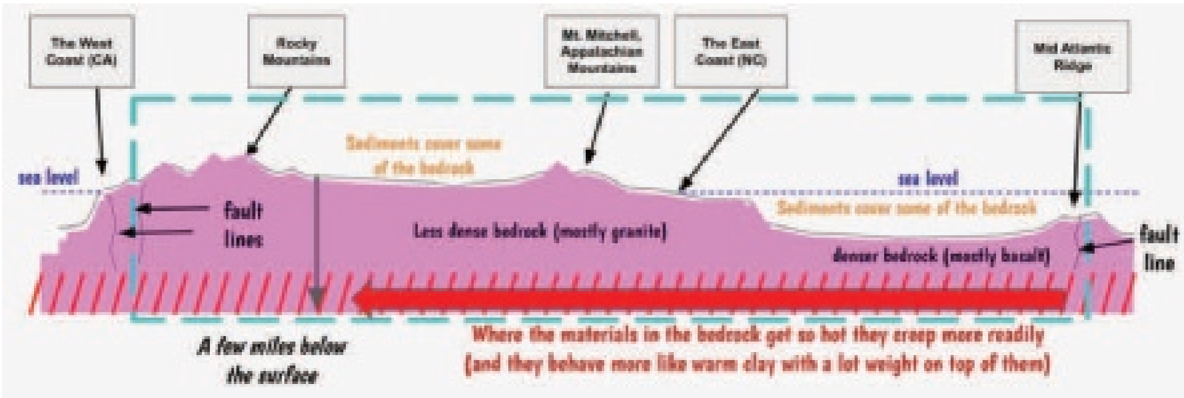
Students should be thinking that the bedrock miles below Earth's surface is warmer and thus tends to shift and move. As the lower bedrock moves, the bedrock above it also moves, thus moving the entire North American plate.

If students struggle to connect the idea of the deeper, warmer bedrock creeping and everything sitting on this bedrock moving as a result, remind students of what they saw happen with the cooler and warmer clay. Ask them what they suspect would happen if cooler clay pushes down on warmer clay. Explain, or show, that the cooler clay pushing down from above begins to deform the warmer clay below, causing the entire clay block to move or slide in one direction. You may wish to have some clay at room temperature and some more clay wrapped in foil on the heating pad from Lesson 3 set up ahead of time in case this is needed as the class discusses what happens to cause plates to move.

Update plate profile model. Display **slide H**. For the next 3 minutes, facilitate a whole-group discussion to reach consensus on how to represent plate movement on the profile model of the North American plate.

Suggested prompt	Sample student responses
*Based on what we have figured out about how the North American plate is moving, what should we add to our class model of the North American plate profile that could help explain what is **causing** Earth's surface to move?*	*We need to show the whole plate moving somehow.* *We should put a large arrow underneath the whole profile pointing to the left (west).* *The arrow should be drawn inside the layer of hot creepy bedrock shaded with the red lines in this model.*

Add a large arrow in the deep, hot layer of bedrock, as seen below.



Alternatively, you may consider refining the model with a different agreed upon representation.

Consider the movement of other plates. Display **slide I**. Guide students to think about the possible movement of other plates based on the revised cross section model of the North American plate. Give volunteers 3 minutes to respond. Once you hear a student mention needing GPS data, move to the next slide.

Suggested prompts	Sample student responses
We just came up with an idea to help explain how the North American plate moves slightly each year. Do you think other plates move in the same way?	*Yes, because otherwise all the plates would just pile up in different places.* *No, because every plate has different mountains and other features.* *I'm not sure.*
What kind of data might help us figure this out?	*We could look at GPS data for the other plates around the world.* *Let's use Seismic Explorer again to look for GPS data showing us if the plates move.*

5. Investigate plate movement.

10 MIN

Materials: science notebook, Lesson 5 Plate Movement map (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Return to Seismic Explorer. Reorient students to Seismic Explorer using the web page (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Point out that in this version there are options to turn on plate boundaries and detailed plate movement. Say, *This map should look familiar. We can see the six mountain peaks we've discussed in previous lessons. This version of Seismic Explorer makes it easier to focus on the plates and their boundaries.*

Demonstrate for students how to select the button "Data Type" to see new viewing options. Selecting the checkbox "Plate Boundaries" displays the borders of each plate. Selecting the checkbox "Plate Movement (Detailed)" displays the same movement arrows seen previously for the segment of the North American plate. To help make the arrows more visible, select the checkbox "Street" option under the "Map Type" button near the bottom.

Investigate plate movement. Display **slide J**. Prompt students to set up a Notice and Wonder chart on a new page in their notebook. Say, *You will work in groups to investigate what is happening with different plates on Earth's surface. While using Seismic Explorer, be sure to record things you notice and wonder about in your notebook.*

Prompt students to begin by investigating plate movement at different locations and at different scales, by zooming in and out. Ask students to record what they notice and wonder about in their notebooks.

Tell students to be prepared to share their noticings and wonderings with the class. Allow students to use Seismic Explorer for 2 minutes. After 2 minutes, ask students to explain what the different size arrows represent. Ask, *Can someone tell us what the arrows represent on this map?*

Students will likely notice that there are larger and smaller arrows, and that larger arrows in a given area may represent greater plate movement in a specific area. Allow students to continue using Seismic Explorer for another 6 minutes.

6. Putting Pieces Together

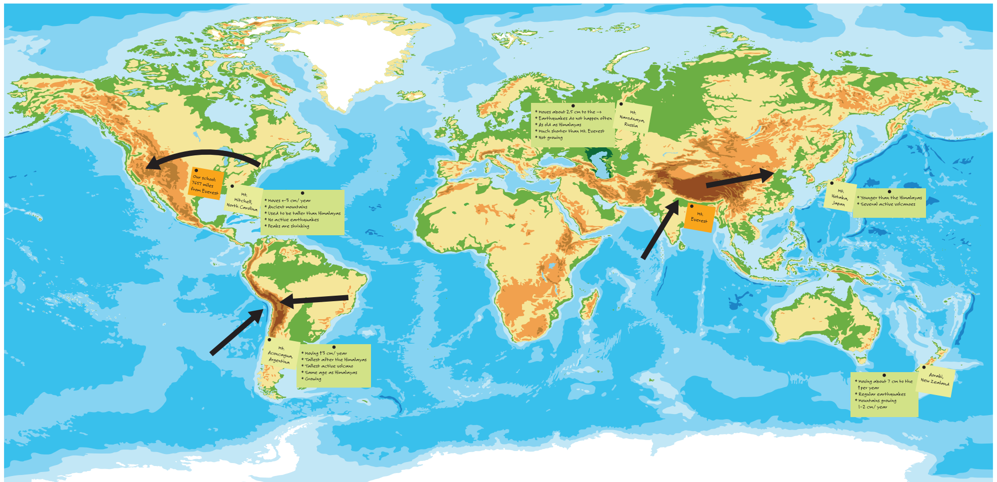
6 MIN

Materials: Potential Cause for Mountain Movement chart, markers, World Map

Discuss findings from plate investigation. Display **slide K**. Show only the first two prompts on the slide. Facilitate a whole-group discussion for the next 6 minutes. Ask for a volunteer from several groups to share one thing they noticed and wondered about from their Seismic Explorer investigation.

Suggested prompt	Sample student responses
What are some things you noticed about the plates on Earth's surface? How do they compare with the area around North America?	*The other plates around the world are moving at different speeds, some of them seem to move faster than the North American plate.* *The plates seem to be moving in different directions.* *Some plates seem to move towards each other, while others seem to move away from each other.* *There are alot of big arrows in the Pacific Ocean!* *Some plates are moving in the same direction, but at different speeds.*

As students share, record their noticings on a sticky note of the movement of the different plates using arrows. Larger and/or thicker arrows can represent faster movement with thinner and/or smaller arrows representing slower movement. The arrows should also represent the direction the section of plate is moving on average based on what students saw in Seismic Explorer. Alternatively, rather than use sticky notes, student noticings can be recorded directly on the map using wet or dry erase markers. See below for an example of how this may look on the World Map.



After students describe how every plate seems to be moving, and that some move faster than others and in different directions from each other, display **slide L**. Say, *We've noticed some interesting patterns in plate movement. What might be causing this movement?*

Listen for students to connect plate movement to what the class decided is causing the North American plate to move, the movement (creep) of deeper, warmer bedrock below Earth's surface. If students struggle to make this connection, display **slide H** again and ask students to explain what the large arrow in the deep layer of bedrock represents. Students should remember that the arrow represents the westward movement of the North American plate, and that the movement is likely caused by bedrock creep.

Revisit *Potential Causes for Mountain Movement* chart. Discuss with students what we can now explain about why Mt. Everest and Mt. Mitchell move.

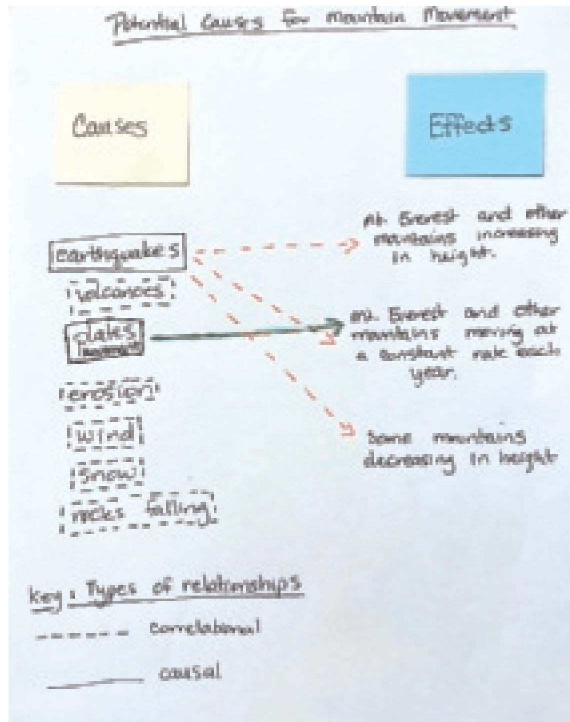
Display the *Potential Causes for Mountain Movement* chart. Say, *Remember that before this lesson we changed the box around plates from a dashed box to a solid box because we thought that plates could explain why mountains move. Can we change or add anything new to our* Potential Causes for Mountain Movement *chart based on what we figured out today?*

Suggested prompts	Sample student responses
Is there anything we can update or revise on our Potential Causes for Mountain Movement chart?	*I think we can change the dotted line connecting "plates" to "Mt. Everest moving" to a solid line because we could see the plate(s) where Mt. Everest is located was moving in Seismic Explorer.* *We can probably change the line connecting "plates" to "other mountains moving at a constant rate" from the dashed line to a solid line because we saw that all the plates where the other mountains are located are also moving.*
Originally, we simply had the term "plates" on our Potential Causes for Mountain Movement chart, and then connected this to mountain movement. Can we refine the term now to be more specific about what is happening with the plates?	*Well, the plates are moving, and that's why the mountains are moving.* *So, can we just change it from "plates" to "plate movement?"*

Students should suggest changing the lines connecting "plates'' to the movement of Mt. Everest and all other mountains, from dashed lines to solid lines. Push students to then explain what this change represents by asking, *Why is it important that we change this from a dashed line to a solid line? What does this say about our thinking at this moment?*

Students should explain that changing the type of line represents a change in how we classify the relationship from one in which two ideas may only be happening together (correlational), to a relationship in which one thing causes another (causal). If students struggle to make this distinction, consider asking if we have any information about plates that helps us explain mountain movement.

Students should also suggest changing the term "plates" to "plate movement" pointing to the GPS data as evidence that the plates move, and that this movement causes the mountains to move.



Assessment Opportunity

Building towards: 5.A.2 Analyze a graphical display of a large data set of plate movement in order to determine whether a causal or correlational relationship exists between plate movement and mountain movement.

What to look for/listen for: Students use Seismic Explorer data to make the claim that all plates are moving, and conclude that each case of mountain movement is due to plate movement. On the *Potential Cause for Mountain Movement* chart, students will change the link between plate movement and mountain movement from a dashed line (representing correlation) to a solid line (representing causation).

What to do: After students revisit Seismic Explorer to explore a larger set of GPS data (**slides K-L**), they should uncover patterns **establishing a causal link** between plate movement and mountain movement. If students struggle to make this connection, consider giving students more time to investigate plate movement using Seismic Explorer. Prompt students to pay particular attention to the direction of the arrows near the specific mountain peaks from the case studies. Ask students whether it seems like the mountain peak is moving in the same direction indicated by the arrows on the map. Students should see that in each case the mountain peak seems to move in the same direction as the arrows immediately nearby, further reinforcing the causal link that plate movement is causing the corresponding mountain to move.

7. Update Progress Trackers.

2 MIN

Materials: science notebook

Update Progress Trackers. Project **slide M**. Ask students to open their science notebooks to their Progress Trackers and draw a line across the page to denote a new lesson. As students update their trackers, have them focus on answering our lesson question:

- How does plate movement affect the land around mountains?

Allow students 2 minutes to consider what new ideas we have developed in our lesson. As students complete their Progress Tracker, circulate to help students consider what we have learned during our Building Understandings Discussion, and what can now be added to our Progress Tracker.

8. Navigation

2 MIN

Materials: Potential Causes for Mountain Movement chart

Problematize findings. Continue displaying the *Potential Causes for Mountain Movement* chart. Say, *It seems like we've figured out some things about how plates are related to the movement of Mt. Everest and mountain movement in general. But we also see that based on today's investigation, there are still some things we cannot quite explain. There are still some effects that we don't yet know the causes for.*

Present exit ticket. Display **slide N**. Prompt students to respond to the prompts on the slide, and turn these in before leaving class:

- What new questions do you now have?
- By looking at plate movement near Mt. Everest and other mountains, how can we explain what is happening to them?

A Historical Perspective

1. **Wegener: A Science Outcast**
2. **Journey to the Center of the Earth**
3. **Wartime Discoveries**
4. **Tools of the Trade**

Literacy Objectives

- ✓ Summarize key points from readings related to Earth's structure.
- ✓ Organize related details about understanding Earth's structure.
- ✓ Differentiate fact, reasoned judgment, speculation, and opinion.
- ✓ Translate text to visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 3–5.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a concept map in response to the reading.

Instructional Resources

Student Reader

Collection 2

Science Literacy Student Reader, Collection 2
"A Historical Perspective"

Exercise Page

EP 2

Science Literacy Exercise Page
EP 2

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 3: How does what we find on and below Earth's surface compare in different places?
- Lesson 4: What is happening to Earth's surface and the material below it during an earthquake?
- Lesson 5: How does plate movement affect the land around mountains such as Mt. Everest?

Standards and Dimensions

NGSS

Disciplinary Core Ideas
ESS1.C: The History of Planet Earth Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.

ESS2.B: Plate Tectonics and Large-Scale System Interactions Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

Science and Engineering Practice(s): Obtaining, Evaluating, and Communicating Information

Crosscutting Concept(s): Structure and Function; Patterns; Systems and System Models

CCSS

English Language Arts
RST.6-8.3: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

theory of plate tectonics

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

continental drift
ferromagnetic
magnetometer
seafloor spreading
seismometer
theory

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations.

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Plate Tectonics and Rock Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you will read how a scientist trained to study weather and climate made the first major contribution toward understanding that Earth's crustal plates move.*
  - *Then, you'll read a work of science fiction, published in 1864, that speculates what the inside of Earth is like and compare it to the 1936 discovery of scientist Inge Lehmann.*
  - *Next, you'll read the true story of how a tool developed by scientists was used by the military during war and then later again used to make scientific discoveries.*
  - *Finally, you'll read a group text that includes five students sharing how they each completed a class assignment to research tools used to investigate plate tectonics.*
- Distribute Exercise Page 2. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a concept map that shows contributions to scientists' understanding about the structure of Earth.*

Exercise Page

EP 2

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions.

(WEDNESDAY)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What do the maps in the reading about Alfred Wegener show?	*that all the continents were once one big continent*
What were portable fluxgate magnetometers used for in World War II?	*to find enemy submarines*
What tool do scientists use to detect the shaking and other ground movements of moving plates?	*seismographs*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What did Jules Verne's story get wrong about the temperatures deep below Earth's surface?	*In the story, he says it wasn't hot, but in reality, it does get hotter the deeper you go.*
In Lesson 4, we talked about bedrock. How is that related to the tectonic plates that scientists use computer models to investigate?	*Tectonic plates are made mostly of bedrock.*
What tool do scientists use to track the movement of the plate that Mt. Everest sits on?	*GPS satellites*

- Refer students to the Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to draw a concept map showing your understanding of the contributions to understanding Earth's structure, as described in this collection.*
  - *Don't worry about understanding the theory of plate tectonics in its entirety—future lessons will explore it in greater detail.*
  - *Just focus on finding examples of contributions to it and understanding what's inside Earth in all four readings.*
  - *Also, spend some time planning the visual impact of your concept by thinking about colors, connecting lines, and making the text readable.*
  - *The important criteria for your work are that you draw connections between the readings and show them clearly in your concept map.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page

EP 2

4. Facilitate discussion.

(Friday)

Facilitate class discussion about the reading collection and writing exercise. The historic theme in this collection extends to the photos of scientists, maps, and the literature excerpts from Jules Verne's *Journey to the Center of the Earth*, first published in 1864. Draw students' attention to the timelines at the bottom of the pages that pinpoint the year of each contribution to the theory of plate tectonics and understanding Earth's inner structure.

Student Reader

Collection 2

Pages 14–23 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "Wegener: A Science Outcast"?	*It describes the contributions of Alfred Wegener to understanding the movement of tectonic plates.*
Summarize two ideas Wegener said about continental drift.	*He said that the continents used to be all connected in one big continent but that they had moved apart. He also said that the continents moved but that the crust that made up the oceans did not.*
Which idea turned out to be incorrect, making Wegener an outcast?	*that the crust under the oceans did not move*
What about Wegener's background made him an unusual scientist to propose a theory of continental drift?	*He was trained as a scientist to study weather and climate and was not trained to study Earth's rocks and fossils.*
What have we explored in class about how tectonic plates likely move that Alfred Wegener did not know?	*that the bedrock gets so hot near the bottom that the material is like warm clay and can creep across the top of the mantle*
What is the general purpose of the second selection,"Journey to the Center of the Earth"?	*It compares and contrasts a work of fiction with the scientific work related to discovering what Earth is like below the crust.*
What clues from the story suggest that Jules Verne had a passion for science?	*He wrote about the scientific laws related to heat.* *He talked about evidence from the senses.* *He explained the source of light underground as something electric, like the aurora borealis.* *He referred to atmospheric pressure and "physical laws" that could explain the clouds underground.*
How does this selection help you build knowledge on top of what you learned in the first collection about P-waves and S-waves?	*The Collection 1 article revealed how these two types of waves differ and that they were used to locate liquid and solid layers inside Earth. This article identifies the scientist who made the discovery—Inge Lehmann.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

CHALLENGE—Have students watch the 3-minute online trailer for the 1959 movie *Journey to the Center of the Earth* Discuss how the scenes compare to those captured in the excerpt in the second selection. Then challenge students to manipulate the story elements they saw by making notes for the movie director. Guide thinking by suggesting that some suggestions make the story more in line with what scientists later discovered about Earth. Others can make it more fantastic. Caution: Preview for appropriateness for your students—one scene involves the use of a gun.

Pages 14–23 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article,"Wartime Discoveries"?	*It tells the story of how tools developed for military use led to the discovery of seafloor spreading.*
How was the invention of a fluxgate magnetometer that was portable important to understanding the structure of Earth?	*It meant the tool was light enough to carry on a plane, where it could detect stripes of magnetic materials on the seafloor.*
This selection ends by naming a phenomenon called "seafloor spreading." From a close look at the diagram, how do you think seafloor spreading works, and what is one question you have about it?	*The illustration makes it look like liquid rock might be coming out of the mid-ocean ridge. Does the magma pushing up help push the plates on either side of the ridge?*
What is the general purpose of the fourth article,"Tools of the Trade"?	*It identifies five tools used to make discoveries related to plate movement.*
What part of Alfred Wegener's ideas could not be explained with his maps?	*what actually caused the continents to move apart*
Take a look at the "Connection" box. What questions do you have about fluxgate magnetometers in space?	*What do NASA scientists want to know about magnetic fields in space?* *Do magnetic fields in space affect spacecraft?* *Could the magnetometers be used to find and collect space junk?*

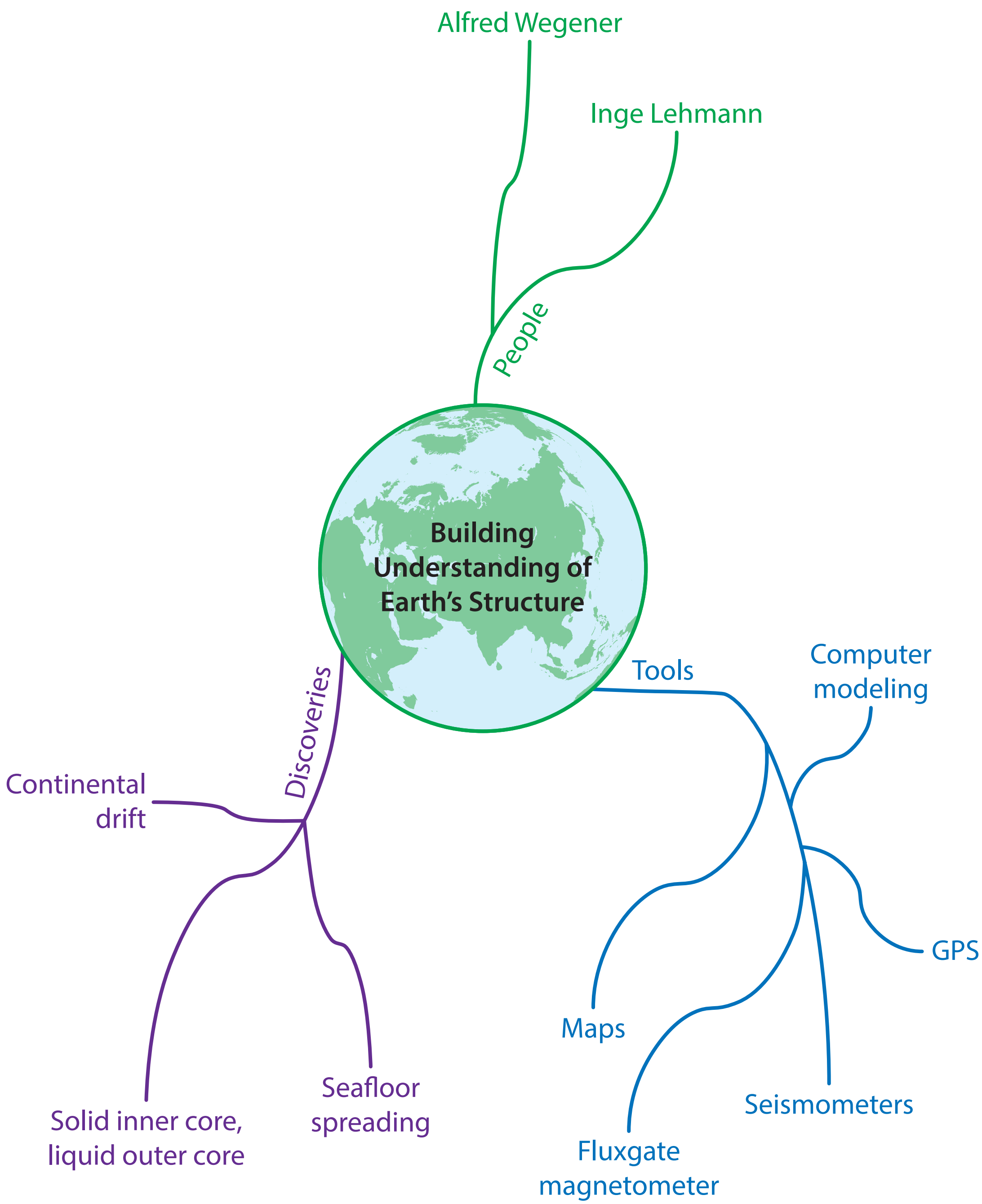
SUPPORT—Explain to students that ferromagnetic objects are attracted to magnets and usually made of iron, nickel, or cobalt. They can also become permanent magnets when exposed to a strong magnetic field. Earth's core contains a large amount of iron and produces a magnetic field. Ordinarily, iron loses its magnetic properties at high temperatures, and the core is very hot. Scientists have discovered that motion in the liquid core generates electric current that produces Earth's magnetic field.

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 2, students should complete a concept map summarizing the contributions to understandings about Earth's structure, as described in Collection 2 readings. Using the provided template as a guide, the contributions should be organized in three categories: people, tools, and discoveries. Look for evidence that they were able to find details about contributions from all four reading selections. An example of a thorough concept map is shown on the following page.

EXTEND—Some students may prefer to produce concept maps using drawing or mind-mapping apps, rather than hand-drawing them. Any productivity suite they already have on classroom tablets or other devices will likely meet their needs. If not, consider online mind-mapping websites, especially those that allow students to share or publish their work. Preview web-based tools to make sure they conform to your school's internet policies.



Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 6

How could plate movement help us explain how Mt. Everest and other locations are changing in elevation?

Previous Lesson

We looked for patterns in GPS data around Mt. Mitchell, and used a physical model to demonstrate that the entire North American plate moves at a constant speed and in a specific direction. We revised our cross section model of the North American plate to connect its movement to the shifting, deeper, hotter bedrock making up the plate. We used Seismic Explorer to investigate the movement of all plates, and we figured out that they move at constant speed and in specific directions. We concluded that mountain movement is caused by plate movement.

This Lesson

Investigation, Putting Pieces Together

3 DAYS

Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.

We use models of plates and plate movement to identify and describe in detail the results of plate interactions between plates of similar or differing densities, and develop diagrammatic models to communicate our findings. We use our models to help explain what might cause the elevation changes and other changes we know about at Mt. Everest. We consider how earthquakes could be a result of uneven plate movement. We celebrate how many questions we can now answer from the DQB.

Next Lesson

We will use map images to determine where volcanoes occur, and observe a model to describe the effects of a collision between oceanic and continental plates. We will use a reading to determine the effects of volcanic eruptions, then draw conclusions about the relationship between volcanic eruptions and changes at the mountain sites.

Building Toward NGSS

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

What Students Will Do

6.A. Develop and use models showing what is happening at varying spatial and time scales to describe how plates interact at plate boundaries.

6.B. Construct an argument supporting a model of how plate interactions could cause mountains and earthquakes.

What Students Will Figure Out

- When plates move towards each other, they collide and mountains can get taller.
- Plates can move next to each other in opposite directions.

- Plate boundaries or edges are rough; when plates interact, they can get stuck against or slip against each other, which we can feel as earthquakes.
- Plate movement causes earthquakes.
- Plate movement can cause mountains to get taller.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Motivate how modeling can help us put together what we've figured out about plate movement and mountains changing.	A	Data Cards for Other Mountains and Mt. Everest from Lesson 1
2	15 min	**IDENTIFY NECESSARY MODEL COMPONENTS** Determine what components of plates and their movement will be necessary to include in our models.	B-E	
3	10 min	**MAKE SENSE OF MANIPULATIVES AND WHAT THEY REPRESENT** Make sense of any relationships between plate boundaries and mountains.	F-H	highlighter or marker or other type of writing utensil, Optional 6.4 Lesson 6 How Plates Move (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	15 min	**MODEL PLATE INTERACTIONS** Investigate the movement and interactions of plates.	I-J	Physical Modeling of Plate Interactions
				End of day 1
5	20 min	**CREATE DIAGRAMMATIC MODELS** Capture representations of the details of the types of plate interactions observed.	K	*Record Your Observations*, tape or push pins, 3-5 pieces of 8.5x11 paper, pens, scratch paper
6	10 min	**GALLERY WALK** View others' models and identify similarities and differences.	L	sticky notes, pens
7	15 min	**CONSOLIDATE CLASS MODELS** Collect and represent models of all the different types of plate interactions observed.	M	Different Plate Interactions chart, markers
				End of day 2

Part	Duration	Summary	Slide	Materials
8	20 min	**EXPLAIN MT. EVEREST** Write an argument supporting a claim of which model best represents what is happening at Mt. Everest.	N-Q	Different Plate Interactions chart
9	15 min	**EXPLAIN EARTHQUAKES** Describe how plate interactions can explain what happens during an earthquake and sudden events that occur over time.	R-T	Different Plate Interactions chart, two pieces of white foam with medicine cups attached, water, food coloring (optional)
10	8 min	**REVISIT THE DRIVING QUESTION BOARD** Identify what questions from the DQB can be answered and look at what kinds of questions remain to be answered.	U	sticky dots, ALTERNATE material: one printed copy per pair of students of the digital version of DQB questions if you made one in Lesson 1, sticky notes, Driving Question Board
11	2 min	**NAVIGATION** Consider whether our models could help explain other mountains, or other surface phenomena we've seen.	V	

End of day 3

Lesson 6 • Materials List

	per student	per group	per class
Physical Modeling of Plate Interactions materials	• *Record Your Observations*	• pan • gloves (optional) • water • aluminum pan • 2 precut foam pieces • food coloring • *Blank World Map* • science notebook	

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• highlighter or marker or other type of writing utensil • sticky notes • pens • science notebook • sticky dots • ALTERNATE material: one printed copy per pair of students of the digital version of DQB questions if you made one in Lesson 1	• *Record Your Observations* • tape or push pins • 3–5 pieces of 8.5x11 paper • pens • scratch paper	• Data Cards for Other Mountains and Mt. Everest from Lesson 1 • Optional 6.4 Lesson 6 How Plates Move (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Different Plate Interactions chart • markers • two pieces of white foam with medicine cups attached • water • food coloring (optional) • Driving Question Board

Materials preparation (60 minutes)

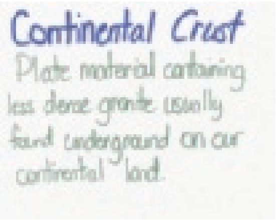
Online Resources

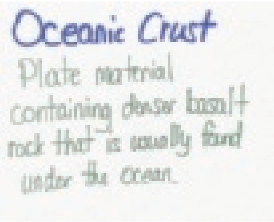
Review teacher guide, slides, and teacher references or keys (if applicable).

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

Prior to day 1:

- Retrieve *Data Cards for Other Mountains and Mt. Everest.*
- Be sure you have materials ready to add the following words to the Word Wall: *oceanic crust* and *continental crust*. Do not post these words on the wall until after your class has developed a shared understanding of their meaning.
- Practice holding and moving the model pieces so that you can effectively demonstrate them for students. This is illustrated. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- If video will be shown to students, test video. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)



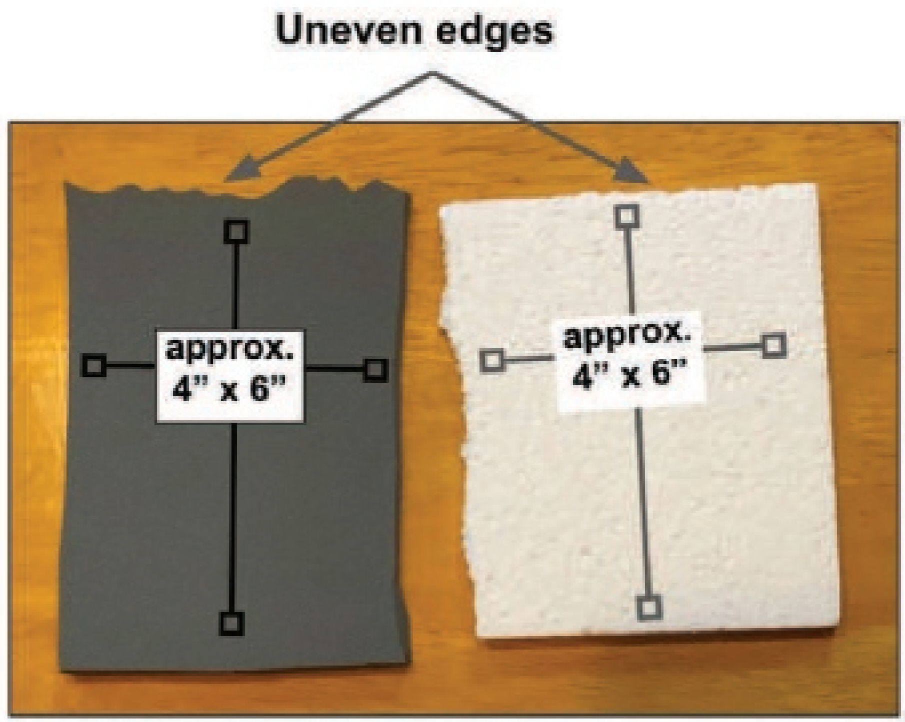


Prior to day 2:

- Title a piece of poster paper Different Plate Interactions for use during the discussion.
- Designate three separate areas in the classroom for displaying models. One each for: models showing moving apart, models showing sliding past each other, and models showing moving together.

Day 1: Physical Modeling of Plate Interactions Lab

- **Group size:** Up to 3 students
- **Setup:**
  - Prepare continental plate rock model pieces by cutting flattened KCEL Crafts Extra Stiff Grey Cosplay Craft Roll (54″long x 12″wide x ¼″thick) into 15 - 4″x6″ shapes and making one of the 4″ long edges of each piece uneven by cutting in a wavy pattern or cutting with patterned scissors if available.
  - Prepare oceanic crust rock model pieces by bending and breaking the white foam panel boards into 15 - approximately 4″x6″ shapes. The broken edges should be somewhat uneven.
  - Set aside one aluminum pan for each group of 3 or fewer in a classroom (12).
  - Review *Guidance for Physical Modeling Activity* prior to the day of the lab for guidance on how to facilitate this.
  - Review to ensure it will play if you plan to use it. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)



- **Notes for during the lab:**
  - Add food coloring to a sufficient amount of water for all labs if desired so that the layer that represents softer, more moveable rock in the model is more easily visible.
- **Safety:**
  - If using food coloring, you may wish to provide gloves for students to wear to prevent staining of fingers. As students transport their baking pan of water, have towels or other absorbent materials on hand to clean up any spills and prevent students slipping on a wet floor.
- **Disposal:**
  - The water can be poured down the sink when finished with the lab. If sinks aren't available you may need to obtain a pan or bucket to collect water after each lab.
- **Storage:**
  - Foam boards, craft rolls, and baking pans can be dried and stored for future use.

Prior to day 3:

- Prepare two 12″x12″ pieces of white foam panel boards with rough edges on all sides by breaking off pieces to create the rough edges. Glue a see-through material about an inch away from the rough edge of each piece of foam. Hot glue or white glue can be used, just be sure it is dry prior to this demonstration on day 3.

- Have a small amount of water available for the demonstration. Colored water prepared with a little food coloring helps students easily see the motion of the water.
- If the video will be shown to students instead (or in addition), test the video to ensure it will play. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

This lesson digs deeply into the practice of modeling to allow students to investigate the effects of various types of plate interactions. In this lesson, students' models will inform arguments for how mountains form and increase in elevation, and how earthquakes happen. The same set of models will be used in subsequent lessons to explain other phenomena that are global in scale, and operate over many different time scales (specific mountains, mountain ranges, volcanoes, ocean ridges, trenches, continental drift, etc.). Components and interactions captured in these models will inform the investigations of changes to Earth's surface in the past and future in Lesson Set 2 (lessons 10-14).

The emphasis in this lesson is on developing the models, by first investigating plate movement using a physical model that functions much like a simulation of a system at a scale beyond what we can directly perceive, and then creating representative models using text and diagrams.

Where We Are NOT Going

Students will use their models to support an argument for the change in elevation of a particular mountain (Mt. Everest) and associated phenomena. However, there will be no attempt to generalize these ideas to explain how all mountains form. We will address the effects of large-scale movements of plates over long periods of time in the next lesson set.

The arguments that are constructed in this lesson rely on evidence from working with physical models of plate movement. Arguments based on empirical evidence will be the focus of future lessons.

While two different types of foam are being used in this lesson, the authors recognize that this is not a direct comparison to the granite and basalt seen in different plates with these compositions. As with all models, scaling this demonstration has this limitation, but the benefit in this lesson of having a representation of two materials of different densities is seen to far exceed the potential material limitations of this representation to support students in developing a conceptual understanding around the interactions of solid rocks and subduction and convergence of rocks of different or similar densities.

In addition, since most of the plates students will be investigating to figure out what happens when they move and interact will include both oceanic and continental materials, we are consciously choosing to use the term "oceanic crust" and "continental crust" in lieu of "oceanic plate" and "continental plate" with students in this lesson and future lessons to support them in figuring out the different properties and behaviors of each. While these terms have been used by others interchangeably, we believe it is important to help students understand that a plate can have both material (oceanic and continental crust) present, and when they are part of a plate they move together. With this understanding, it will also help students in future lessons (Lessons 10-11) to understand that the size and location of plates change due to the creation and destruction of plates, and that when oceanic crust is created or destroyed, it adds or removes from the current plate, as seen with Africa and North America. We used recommendations around these terminology as suggested. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

LEARNING PLAN FOR LESSON 6

1. Navigation

5 MIN

Materials: Data Cards for Other Mountains and Mt. Everest from Lesson 1

Revisit the anchoring phenomena. Display **slide A**. Ask, *What have we figured out that might help us explain what caused our mountains to change?* Ask students to articulate what we've figured out so far in this unit that could help us explain how mountains change and move. Write this list on a white board or other publicly visible space. Listen for student responses:

- There are big plates made of mostly solid bedrock.
- Sometimes the plates are made of rock that is very dense, like basalt rock that is usually under the ocean, or less dense, like granite rock that is usually under the land.
- The plates move on top of softer, warmer rock underneath that tends to shift and move like warm clay.
- The plates move in lots of different ways in relation to each other.
- Lots of mountains are found near the edges of plates.

If students do not mention some of these, prompt them to look back at what they found in earlier lessons about where plates are found on Earth, how they move, and how this connects to where mountains are located.

Revisit the general characteristics of the mountains from the *Data Cards for Other Mountains and Mt. Everest*. Direct students' attention to the examples of mountains changing in elevation and ask whether they think plate movement could cause mountains to get taller or shorter.

Motivate the need to do some modeling. Continue to display **slide A**. Say, *So, we have been figuring out a lot about what plates are and how they move, and we've seen that mountains are near the edges of plates. We need some evidence to figure out whether plate movement causes mountains to get taller or shorter.*

Suggested prompts	Sample student responses
Can we observe actual plate movement?	*No, because they are too big to see, and they move a very small amount over a year.*
How could we investigate and gather some evidence to help us answer our question?	*We could use something to model the plates that are kind of like the plates and then observe how these materials representing the plates interact at the edges.*

If students are having trouble coming up with this suggestion, prompt them to think about what we could do in the classroom, or whether there is any good way to represent those movements.

2. Identify necessary model components.

15 MIN

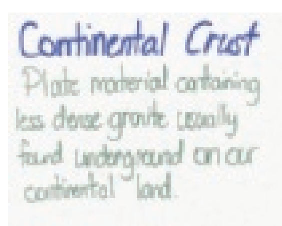
Materials: None

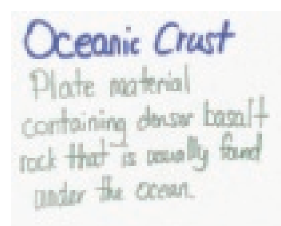
Facilitate a class discussion to identify the components of models that we could use to try to answer our question. Display **slide B**. Have students turn and talk for a couple of minutes to articulate some ideas. Then have them share and capture a list of student ideas on the white board or other publicly visible space. Students will use these lists as a guide as they develop their models.

Suggested prompts	Sample student responses
What are the parts that we want to be sure to include in our model?	*crust and mantle* *plates* *bedrock* *softer, more moveable rock underneath the bedrock (mantle)*
What do we know about each of those parts?	*The crust is on top of the mantle.* *The plates are made up of bedrock on top of the softer rock.* *Different kinds of rock make up the plates: some are made of basalt and some are made of granite.* *The hotter, more moveable rock is warmer and moves like a liquid underneath the plates.*
What kinds of plate movement do we want to include in our model?	*Some plates move fast and some move more slowly.* *We saw on Seismic Explorer that plates can move in all different directions, and sometimes they move at different speeds.*
How are the plates able to move?	*The bedrock can move because of the more moveable, softer, liquidy rock underneath it moves easier.*

Define the types of crust. Display **slide C.** Say, *You said that in our models, we'll need to have something that represents the plates and the types of rock that make up that plate.* Ask, *What are the major types of rock the plates are made of?*

Students should recall from Lesson 3 that the main types are basalt rock that's usually found under the ocean, and granite rock that's usually found under the ground. They may also mention that these rocks have different densities. Tell students that you have materials that can represent how the oceanic plate material and the continental plate material can move and interact.





Display **slide D**. Tell students that scientists distinguish between these two plate rock types. Parts of the plate material that are made of the denser basalt rock that's usually found under the ocean are called "oceanic crust". While plate sections that are

***Attending to Equity**

Supporting Emergent Multilingual Learners: It is important to support all students, particularly emerging multilingual students, in forming a deeper understanding of newly "earned" vocabulary by representing the new term in multiple ways. For example, students can 1) write the term, 2) draw a representation of the term, 3) use their own words to write an explanation for what the term means, and 4) use the new term in a sentence. All of these representations would be appropriate to add to the Word Wall.

This is especially important when the vocabulary is complex or the definition requires referencing multiple concepts. For instance, defining "oceanic" crust requires knowing the characteristics of the type of rock (dense basalt) as well as the location of the plate (under the ocean), only part of which is captured in the term "oceanic." A pictorial representation could capture all the relevant characteristics in a way that is more accessible to emergent multilingual students and others.

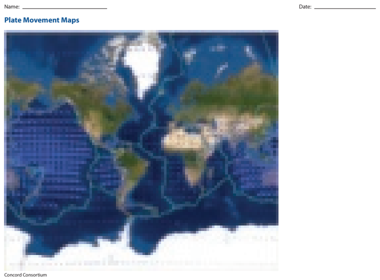
made of the less dense granite type that is found under the ground are called “continental crust” because they are found where the continents are found on Earth. Add oceanic and continental crust to the Word Wall.*

Additional Guidance

Since many of the plates students will be investigating to figure out what happens when they move and interact will include both oceanic and continental materials, we are consciously choosing to use the term “oceanic crust” and “continental crust” with students from this lesson and going forward to support them in figuring out the different properties and behaviors of each type of rock. See the Where We Are Not Going section at the beginning of this lesson for more information on the reference we used to make this decision.

Brainstorm and identify the types of plate interactions we want to model. Say, *Since we’re trying to figure out whether plate movement causes mountains to change height, let’s make sure we are clear about the different ways that plates can move and interact*. Distribute *Plate Movement Maps* to each student, then take a few minutes to make sense of the three maps on the handout.

Say, *Let’s take a few minutes to make sense of what is on your handout. Look at the two maps. What is being represented here?* Students should recognize the first image from Lesson 5, when we investigated GPS plate movement. The second map is a more simplistic version of the plate boundaries map they have encountered in Lesson 5. Students should notice that overall plate movement is being represented in the first map along with plate boundaries. In the second map the blue arrows representing overall plate movement have been removed. Tell the class that this handout has been put together for them so that they can focus on the interactions of the plates since we are trying to figure out if plate movement can cause mountains to change.



Say, *Okay, take a moment and, using the key on the 2nd map, what types of movement do you notice is happening at different plate boundaries?*

Listen for student responses and record them on the white board or other publicly visible space as described below:

- They move away from each other in opposite directions - *write Moving Apart.*
- They move sideways, or in different directions like they do at Ridgecrest - *write Sliding Past Each Other.*
- They move toward each other, or crash into each other - *write Moving Together.*

Once defined, number the three types of plate interactions on the white board or other publicly visible space. These will be referred to repeatedly as students develop their various models in the next activities. For example:

1. moving apart
2. sliding past each other
3. moving together

Additional Guidance

The purpose of using the images from Seismic Explorer that students have seen in the previous lesson is to help them develop a deeper conceptual model of what is being represented here through investigating what happens when plates collide and interact or move apart. In Lesson 5, students figured out that the North American plate is moving and began thinking about what this means for the other plates all around it. In this lesson students will use these maps to identify where the plates are moving towards each other, where they are moving away from each other and where they might be sliding past each other as they work with their small group to model the possible effects of these plate movements on the Earth.

Distribute *Blank World Map* to small groups. Display **slide E.** Say, *Now look at the map on the second handout. What is represented there?* Students should notice that it is a map with dark black lines that seem to match up to the plate boundaries from the first two maps.

Tell students this map is included for them to use to annotate areas they want to model and observations they make as they model. Say, *Each group will work with different pieces of foam representing different plate materials so we can figure out across the class how the different types of plate materials act when moving in these various ways. Your group may have two of the same type of material, or you may end up with different materials. As you are working with your group to figure out plate interactions, use the map on the second page of your handout to identify what area you are trying to model using the manipulatives you will work with and use the space to record what you see happening in each case. The more detailed you can be when making your observations, the more we will be able to make sense of what happens when plates move and how this movement affects the Earth's crust.*

Additional Guidance

Moving apart, or diverging plates, happen when plates are moving in opposite directions, but also when a slower moving plate is behind a faster moving plate going in the same direction. In this case, the distance between the plates is increasing, hence the plates are moving apart.

Moving the manipulatives together, or simulating the collisions between plates, is seen happening in this demonstration when plates are moving directly toward each other from opposite directions. As students engage with the manipulatives that represent the plates during the lab, they most likely will notice that there are different types of these collisions, particularly if they are trying to represent the different speeds and directions at which the various plates are moving. Later in the lesson, students will gain experience with plates that are moving in the same direction at different speeds and discuss how this can create features such as mountains.

The goal for students as they engage in the lab is to brainstorm, and model, the different types of plate movements that are represented in what they figured out in Lesson 5—plates moving in various directions and at various speeds resulting in collisions, moving apart, and slipping past each other.

3. Make sense of manipulatives and what they represent. 10 MIN

Materials: highlighter or marker or other type of writing utensil, Optional: Lesson 6 How to Make a Model of Tectonic Plates for Elementary Students: Plate Tectonics (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Set up groups and assign plate rock types. Divide students into groups of no more than three students. Distribute the appropriate pieces of foam to represent their assigned type of plate rock (grey foam for denser oceanic crust and white foam for less dense continental crust). Assign an approximately equal number of groups to each of three options:*

- oceanic plate material (grey foam) interacting with oceanic plate material (grey foam)
- oceanic plate material (grey foam) interacting with continental plate material (white foam)
- continental plate material (white foam) interacting with continental plate material (white foam)

Distribute *Record Your Observations*. Ask students to write their plate material types on their handouts. Explain to students that each group will use their representative plate material pieces to develop a model of each of the three patterns of movement using the physical pieces that represent their plate type(s):

- moving apart
- sliding past each other
- moving together

Consider what areas and interactions they represent. Display **slide F**. Direct students to look back at *Plate Movement Maps* and *Blank World Map*. Using *Plate Movement Maps*, tell them to identify areas where the two assigned plate materials are next to each other on the map. Once they have identified these locations, ask students to mark these locations where the plate materials are interacting on *Blank World Map* by circling or shading the areas of interaction. Stress to students that interactions could be any of the following and they will be modeling all of these using the representative plate materials they were assigned:

- moving away from each other
- coming towards each other
- sliding past each other

*Attending to Equity

Universal Design for Learning: Whichever set of plate/crust rock types they are modeling, each group will observe basically the same patterns of movement when the plate sections are moving apart or sliding past each other. However, there may be multiple distinct patterns when plate sections move together. This is especially true for groups that are working to model the two different types of plates interacting, continental crust material and oceanic crust material. Because groups using two different types of plates will have more complex interactions to observe and record, consider assigning this model type to groups of students that have greater *comprehension* of developing and using models. This will provide them with a more challenging activity while allowing students in other groups to focus more directly on the practice of modeling itself, since they will have fewer variables to *represent*.

Additional Guidance

In this unit, as students figure out the different ways plates move and interact we have intentionally used student friendly language to describe these interactions, such as “moving apart”, or “moving towards each other”. There are scientific terms for these movements—divergence and convergence. We will not be including them as words for the Word Wall as words to link to these processes. These are challenging conceptual models for students to develop so we decided to keep the labels describing these interactions student friendly. You should feel free to add these labels if it is something you feel your students can do and will appreciate.

Make predictions about what might happen. Project **slide G**. Ask students to consider what might occur as different plate materials interact in one of the three ways we have identified. Ask for students to share a variety of possibilities with the class to give everyone a chance to think about or visualize many possible interactions.

Potential student responses:

- They might crash or break on each other.
- One or the other, or both might bend when they move together.
- They might bend in different directions.
- They might go over or under each other.
- There might be a big hole between them when they move apart.
- The softer, warmer (liquidy) rock layer might move around a lot.
- They might rub together when they slide past each other.

Facilitate a brief discussion about the model parts. Say, *We are most interested in how the plates move and interact. We are using these two kinds of foam to represent the two crust types not because they are made of the same material as the crust making up the plates, but because these two types of foam will interact with each other similarly to the way the two types of plate rock actually interact along the edges of plates. Notice that the edges of the foam that will be interacting are rough like the edges of plate rock would be. Similarly, the water that we will float the plate models on is not the actual material that the softer, warmer rock layer is made up of. But it will move and interact with the plate models similarly to the way the mantle interacts with the crust.**

Use the example prompts and responses below to discuss what each part of the model represents, and the data we would like to collect.

Suggested prompts	Sample student responses
We are using pieces of foam. What are these foam pieces representing?	*the crust* *the plate material*
Why do we have two different types of foam?	*because we have two different plate materials, basalt and granite* *to represent the oceanic crust and continental crust of the plates*
We are representing basalt and granite. Where are these materials mainly found?	*Basalt is found under the ocean in oceanic crust.* *Granite is found in continental bedrock. It's in the crust of the continents.*
What is the water representing in our aluminum pan?	*The water represents the warmer rock.* *The water represents the shifty rock material that moves more as it gets hotter.*

***Supporting Students in Engaging in Developing and Using Models**

The foam provided is of two types: a grey pliable type and a white stiffer type. These foam types will behave in the model similarly to the way that the two plate rock types behave when they interact. However, while oceanic plate material is more dense than continental plate material, the white foam type is actually less dense than the grey foam type. Components of models are chosen because they are the most useful in illustrating the phenomena being modeled. The interactions between the components is the most important aspect of the model here, so components have been chosen to represent what happens when plates interact even though they don't accurately represent the actual material making up the plates.

Suggested prompt	Sample student response
Okay so we are using these materials in our classroom to represent different components in the real world so we will want to be making some close observations. What kind of data do we hope to get from this investigation?	*We want to know what happens at the locations where plate edges interact so we can figure out if plates moving can cause changes to the land.*

Say, *Okay so if we are wanting to focus on the interaction between our foam pieces that are representing the plate materials and we immediately put these pieces in the water that is representing the warmer shifting rock below, then what might be tricky as we try moving the foam pieces on the water?* Students should say it will be important and challenging to keep the foam pieces floating on the water as they move them. Tell them they should try some dry runs on the table moving the foam pieces so they can see the interactions before also trying to carefully move them on the top of the water in the pan. Remind them that we know the plate material we are trying to model doesn't sink into the warmer softer rock on Earth, so their foam pieces shouldn't be sinking either.

At this point, you may wish to demonstrate for students how they should move the foam pieces by holding them at the edge farthest away from the uneven, interacting edges, and allowing them to float on the top of the water. You may want to show them the video that was provided in the Materials and Preparation section, and reference *Guidance for Physical Modeling Activity* as an illustration. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) This will avoid most of the impact of their handling the "plates/pieces of crust" and allow them to observe the movement and interaction of the edges of the plates in the model more authentically. Allow them to handle the foam pieces, but ask them to wait until they get the softer, warmer rock (water) layer to start making observations about their interactions.*

Review instructions. Display **slide H**. Review the instructions on the slide with the class. Leave the slide up as they work. Be sure you have reviewed the guidance on *Guidance for Physical Modeling Activity* to help you facilitate the next activity.

***Attending to Equity**

Classroom culture and norm building: In order to support students in utilizing their time in their groups efficiently, and to assure that everyone is supported in their ability to participate, you may choose to assign students roles in the groups so they will have a defined role as they work together to make sense of what is happening when the plates move. It may be helpful to have each student get a chance to move the plate models so as to maximize the different types of interactions they might observe. Other useful roles for this activity would be someone to record all the observations, a progress tracker to help keep students on task, and a clarifier to help refine and categorize the patterns of movement that will be observed.

4. Model plate interactions.

15 MIN

Materials: Physical Modeling of Plate Interactions

Have students create and investigate their physical models. Display **slide I**. Distribute the pan and water representing the softer, warmer, shifting (liquidy) rock to each group. Supply enough water to cover the entire bottom of their pans about ¼ to ½ inch deep. Allow students to start working with their plate rock models. You may wish to use food coloring to lightly color the water prior to distributing to small groups. This may allow them to more readily see what is happening under the foam pieces. As they work, circulate among the groups and encourage them to repeat each movement several times, and to look carefully at the details of what is happening as they recreate each of the three different types of movement (moving together, moving apart, and sliding past each other). They should record observations in each section of *Record Your Observations* as they work.

Use these suggested prompts to probe small groups as they work:

- Are the plates changing as they interact?
- How would you describe how the plates are changing as they interact?
- Is that the only thing that can happen when the plates interact that way?
- If you do it more than once, does the same thing happen each time?
- What words could you use to describe the movement of the plates?
- Does the exact same thing happen all along the whole edge of the plate as it moves?
- Do you notice anything about the edges of the plates that might make that happen?
- Does it make a difference if they're right up next to each other, or further apart as they slide past each other?
- What's happening with the liquidy rock (water) as the plates move?
- What does speed have to do with it?
- What would happen if the plates were moving faster? Slower?
- Are you recording your observations so you could describe them to someone else who hasn't seen what you saw?
- Do any of the results of your investigation with the foam pieces look similar to any of our mountain cases?

In addition, some groups may notice that sometimes two plates are moving in the same direction. If they mention this as you are checking in with groups, reflect with students that in some of those cases (e.g. the Himalayas, parts of the Antarctic plate boundaries), we have evidence that one plate is moving faster than the other. We can check this by looking at the first map on page one of *Plate Movement Maps*. Help students to understand that if two plates are going in the same direction, but one is moving faster than the other, that is like two plates moving together, or two plates moving apart—because if the faster one is ahead, the distance between the plates will be increasing (moving apart), and if the faster one is behind, then it will be colliding with the slower one (moving together).

Additional Guidance

Students will use their models as evidence in future lessons. Therefore, it is important that at least one group in the classroom observes the following types of plate interactions (see Guidance for Physical Modeling Activity):

- An oceanic plate rock type moving underneath a continental plate rock type (convergent subduction will help explain increases in mountain elevation and oceanic trenches)
- Two plates colliding and both plates moving upward (convergent collision will help explain increases in mountain elevation)
- Two plates moving apart leaving space with no plate between them (divergence will help explain oceanic ridges and creation of new plate)
- Movement of the liquidy rock layer (will help explain volcanoes and magma moving in the mantle)
- The rough edges of plates catching on each other as they move together or slide past each other then snapping quickly out as they continue to move past each other (will help explain earthquakes and other sudden changes to Earth's surface)

Have students collect and record their observations. Allow students sufficient time to investigate all three types of movement with their physical models, make careful observations of the effect of the movement on the two types of crust the plates are made of, and record their observations in note form or with sketches. Encourage each student to add some observations to the handout that the group is working on. They will use these recorded observations at the beginning of the next class period to create models of what they saw.

Additional Guidance

At the start of day 2 of the lesson, students will represent diagrammatically what they physically modeled. If your students have access to technology that gives them the ability to take photos of the kind of shapes they observe, and allows them to annotate those photos with text and symbols, this option might save some time as they create their models during the next class period. The three (or more) models that each group creates will be displayed along with other groups' models for a gallery walk, so be sure there will be a way for other students to easily view and comment on the models that students create.

Assessment Opportunity

Building towards: 6.A. Develop and use models showing what is happening at varying spatial and time scales to describe how plates interact at plate boundaries.

What to look/listen for: As students use their physical models, listen for them to make connections between the components and relationships in their models and the real-world phenomena they represent, such as the following:

- Referring to the foam pieces as "plates" as they work with them
- Describing a change in height of a foam piece as a "change in elevation"
- Proposing surface phenomena that might be explained by the observations they are making as they manipulate their models
- Wondering about how the model interactions they are observing would look (or feel) at an Earth-sized scale
- Labeling and describing components of their models with the real-world phenomena they represent (e.g. plate rather than foam piece; liquidy rock layer rather than water; arrows labeled as plate movement)

Alternatively, if you collect and assess *Record Your Observations* with the observations that students recorded, look for similar indications in their observations that they are connecting the model parts and movements with what actually happens on Earth's surface.

What to do: If students do not readily make the connections, cue them to tell you what is represented by the parts they are handling, and the movements they are making with them (or comment on those in the observations they recorded). Use the names of the real-world objects as you talk with them about their models (e.g. *How are you moving the plate?*, rather than, *How are you moving the foam?*)

Display **slide J**. Allow sufficient time to clean up the lab by rinsing and setting the foam pieces out to dry and disposing of the water in the aluminum pans. It can be very difficult to carry the shallow pans without spilling. You may want to circulate with a large tray or bucket to collect the water and then have students set the pans up to dry as well. Or if available, have students do this investigation near a sink.

Begin to plan their models. If time permits after groups have cleaned up the materials from the investigation, have students take a few minutes to start to identify which components and interactions they need to include and how they will represent them in each of their models in note form or with sketches on *Record Your Observations* or in their science notebooks. If you are assessing the observations they recorded, collect *Record Your Observations*.

Home Learning Opportunity

If you run out of time to have students start to think with their groups about how they will represent what they observed in their models, let them know that during the next class period, they will be developing diagrammatic models of everything they observed. Ask them to make some notes and sketches in their science notebooks showing how they might represent what they observed. This will give them a bit of a head start on the activity in the next class period.

End of day 1

5. Create diagrammatic models.

20 MIN

Materials: *Record Your Observations*, tape or push pins, 3-5 pieces of 8.5x11 paper, pens, scratch paper

Remind students of what they did the previous class period. Ask a student or two to describe what we did during the previous class period. Have everyone retrieve their group notes on *Record Your Observations* about what they observed while working with their models.

Develop three different diagrammatic models. Display **slide K**. Have students reassemble in the groups they were working with during the previous class. Distribute at least 3 sheets of paper to each group for final models—one each for plates moving together, plates moving apart, and plates sliding past each other—along with additional scratch paper for sketching and planning. Review the instructions on the slide. Remind students that they will be displaying their diagrammatic models for a gallery walk with their classmates. Be sure to have them put a title or their names on each model so that students can refer to individual models specifically in the next step.

Additional Guidance

Students who used technology to capture the shapes and appearance of the plate model material that they saw when they observed their interactions during the last class activity will work on annotating their photos and preparing them for display.

Display models for the gallery walk. As students finish their models, have them display them in designated areas around the room for the three types of diagrammatic models that students will develop:

- moving apart
- sliding past each other
- moving together

The area for models of plates interacting as they are moving together should be the largest as there are likely to be more different interactions represented in these models.

Have students who worked with the same sets of plate rock types group their models near each other within the areas defined for each type of movement. This will result in three distinct areas in the room that models are posted—one for models representing moving apart, one for sliding past each other and one area for moving together. Students should use tape or pushpins to attach or arrange their models so that they will be easily viewed by other students during the next activity.

6. Gallery Walk

10 MIN

Materials: sticky notes, pens

Give instructions for gallery walk. Display **slide L**. Review instructions on the slide with students. Distribute three or more sticky notes to each student and make sure they have something to write with.

Have students circulate to view and compare all the models in all three areas. Students will be circulating and noting models that are essentially the same in what they show about how plates interact in each area in the room. They should identify models representing each type of interaction (moving together, moving apart, sliding past each other) that seem mostly the same as other models. Have them write the titles of the models that they think are mostly the same on a sticky note and post it near the models in the area they are examining. As students circulate, they may need help defining what makes models "mostly the same". A brief discussion with the whole class before starting the gallery walk could help define what makes models mostly the same for students who struggle to identify similarities. Students should focus on broad, general patterns of shape and movement (bending up, going under, staying flat, smooth vs. jerky sorts of movement, fast vs. slow movement, etc.), rather than on stylistic similarities or use of the same symbols across different models.

As they work, circulate among them and probe their thinking regarding what makes two models mostly the same. Focus them on what the model shows rather than how the model looks. If some students finish early, you could ask them to circulate around to the different areas in the room and determine how many different distinct models there actually are in the classroom.

Agree as a class on the number of distinct model types. Have students return to their seats. If some students made a count of the number of different model types, have them share and explain why they think certain models are the same. Allow students whose models are described as the same to comment on any distinctions in their model that they think are important. The class should come to an agreement about which models to combine and represent as one because they are mostly the same, and how many distinct model types there are. You may need to circulate among the model displays yourself and group together those that are mostly the same according to the sticky notes (and any obvious mechanistic similarities).

Key Ideas

Students may come up with many distinct model types, or only a few based on what they think are the most important distinguishing features of the models that were created by different groups. Follow their lead in categorizing models. ***Please note that the terms in parentheses here and throughout this lesson are not terms we expect students to***

know or use. They are provided only as a cue for teachers regarding which class of plate boundary/interaction is being indicated by the description.

It is important for the rest of this lesson and for future lessons that the following four types of models are represented among the group of models that students decide on:

- Two flat plates moving away from each other (divergent interaction)
- Two plates meeting in the middle and forcing each other up in an inverted V-type structure (convergent collision interaction)
- One plate going over the top of another—with or without bending of either plate (convergent subduction interaction)
- Two plates sliding past each other with the rough edges of the plates catching on each other as they slide past (transform interaction)

7. Consolidate class models.

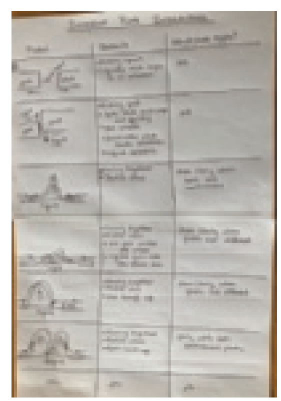
15 MIN

Materials: Different Plate Interactions chart, markers

Set up a class chart. Display **slide M**. Put up one or two pieces of poster or chart paper that you have titled *Different Plate Interactions* and draw enough sections to capture the number of different models that the class identified. Each section should have a space for a drawn model, a space for descriptive details, and a space to record which plate types show that kind of interaction.

Represent the different model types on the class chart. Capture the major characteristics of each different model in the chart. Draw the model in the first column (Model) with components, motion and interactions labeled. Record important information (Details) about the movement and the effect on the plates in the second column. Record which plates show this kind of interaction (What plate types?) in the third column.

You could do this by having a student who created a clear representation of a particular model type describe it to you as you draw, label and write. If some students have done a good job of creating a clear, simple model of each type, you could have several students fill out sections of the class chart, or some combination so that the chart gets filled in neatly, and completely, using as little class time as possible. Number or name the different model types for easy reference in later activities.



Pause to discuss the types of interactions described. As you build the chart, or after the chart is complete, be sure to clarify the details in the center column. It is especially important that students all have a clear grasp of the movement represented most clearly in the model of plates sliding past each other. This characteristic of plate movement will be necessary for students to explain earthquakes later in the lesson. Ask several students to describe what happened in that model. Listen for student responses:

- The plates got stuck on each other, then snapped out of it.
- The plates built up tension as we were trying to move, then the tension was suddenly released.
- There was friction between the plates because the edges were rough, and then they jumped past each other.

Ask students whether they think this kind of sudden movement could happen other times, like when plates move together and come in contact with each other and their rough edges rub against each other. This type of movement will be reconsidered in more detail later in the lesson.

End of day 2

8. Explain Mt. Everest.

20 MIN

Materials: science notebook, Different Plate Interactions chart

Remind students we want to use what we figured out to explain some of our anchor phenomena. Ask students why we created these models.

Suggested prompts	Sample student responses
What were we trying to figure out?	*We had a question about whether plate movement and plate interactions could explain how mountains change.* *Yeah, we wanted to see if plates moving could cause mountains to grow.*
What do you think now? Do you think plate movement could cause mountains to change in elevation?	*Yes! I think plate movement is what causes mountains to change in elevation and get taller.*
Why do you think plates cause mountains to change in elevation?	*Because we saw with our foam representations that when they were pushed towards each other, they tended to "grow" or push upwards.*

Display **slide N**. Say, *Let's try it out, and see if we think plate movement and plate interactions could explain what we know about Mt. Everest and how it's changing.* Direct students' attention to the slide and distribute copies of the data card for Mt. Everest from *Data Cards for Other Mountains and Mt. Everest* to students as needed so that they can find out what information needs to be explained. You may also refer them to the reading about Mt. Everest that they did in Lesson 1 (*What is happening on Mount Everest?*).

Make a list of what needs to be explained. Say, *Looking back at the reading and data cards from Lesson 1, what are we trying to figure out and explain about Mt. Everest using evidence from our models?* Record the list on a white board or other publicly visible space for students to access as they do the activity.

Suggested prompt	Sample student responses
How is Mt. Everest changing?	*Mt. Everest is moving to the northeast [1.6 inches (4 cm) per year].* *Mt. Everest is getting taller [by 0.79 inches (2 cm) per year].*

***Supporting Students in Engaging in Developing and Using Models**

This discussion is an opportunity for students to evaluate the limitations of a model for explaining a particular phenomenon: Mt. Everest. The best model of any phenomenon has these characteristics:

- It represents all the important components of the phenomenon.
- It represents the characteristics of those components accurately.
- It represents the relationships between those components accurately.
- It does not include components, characteristics or relationships that the phenomenon doesn't have.

As students consider which model is best, they are identifying the limitations of the models that are not best, whether a model is limited in that the possibility of multiple mountains are not represented, or limited in that a trench is represented in the model that does not (apparently) exist near Mt. Everest.

Suggested prompts	Sample student responses
What do we know about the area around Mt. Everest?	*Mt. Everest is in the Himalayas which is a very big mountain range (almost 1500 miles long with lots of mountains).* *There are other tall mountains in the Himalayas.* *There are lots of earthquakes in the Himalayas.*
And what did we notice about how the plates near Mt. Everest are moving in Lesson 5? What did we add to our World Map?	*We saw that there are two plates where Mt. Everest is located.* *Yeah and these two plates are moving in the same direction, but one is moving faster than the other.*
And if they are both moving the same direction but one is moving faster than the other, then how might this be affecting what is happening at Mt. Everest?	*I think since the one moving faster is pushing into the one moving slower, it would maybe push up over the other plate.* *Yeah or maybe the faster one pushes the slower moving one up.*

Additional Guidance

When a slower moving plate interacts with a faster moving plate behind it that is going in the same direction, collisions happen. This is the type of plate movement that students may have seen happening in the Himalayas in Lesson 5 when they analyzed the plate motion GPS data. If students struggle to understand that this is an example of plates moving together, share with them the analogy of two cars crashing into each other. If a car is moving slowly and another car comes up behind it going more quickly, the cars will crash into each other, or collide, even though they are both moving in the same direction.

Work individually to identify the best model to use to explain what's happening at Mt. Everest. Display **slide O**. Have students open their science notebooks. Ask them to decide for themselves individually which model from the class *Different Plate Interactions* chart they think is the best one to use to explain the changes happening at Mt. Everest. They should record which model they choose in their science notebook, and then make a list of why they think that is the best model to help explain what's happening. Remind them they will be sharing their ideas with others. Allow sufficient time for students to record their ideas in their science notebooks in whatever format is most helpful for them (writing or drawing, listing or labeling, etc.).

Share ideas with a partner. Display **slide P**. Have students turn and talk with a partner to share and listen to ideas. Say, *Discuss with your partner why you think the model you chose is the best one to help explain what's happening at Mt. Everest. Listen carefully to your partner's ideas. If you are not in agreement, work together to try to agree on one model which best represents what is happening at Mt. Everest.* Allow students time to share and discuss their ideas.

Share ideas with the whole group. After 3 minutes of partner talk, ask each pair to indicate which model they thought was best. Help the class come to consensus about which model best represents what is happening at Mt. Everest by agreeing on which one most accurately represents more of the characteristics of Mt. Everest. Make a list of why students think the chosen model is the best one on the white board or other publicly visible space for students to access as they continue the activity.

Suggested prompts	Sample student responses
What model did you and your partner decide best represents what is happening at Mt. Everest?	*We think the model that shows the plates moving together and colliding shows how a mountain could get taller.* *We think the model of colliding plates that are the same plate or crust types is the best.*
*Why does this model best represent what is happening at Mt. Everest?**	*This model shows how the mountain could move as the plates move, and we know Mt. Everest moves.* *This model shows part of a plate getting pushed up and taller, and we know Mt. Everest is getting taller.* *This model shows more than one tall or growing part in the same area, and we know there are lots of mountains in the Himalayas.* *This model shows lots of activity or effects at the edge of the plate that could represent earthquakes, and we know there are lots of earthquakes in the Himalayas.* *This model shows how Mt. Everest could move, and get taller, and be around lots of other mountains, and have earthquakes.*

Key Ideas

Purpose: to agree on one model from the *Different Plate Interactions* chart that can best be used to explain the changes happening at Mt. Everest.

Any of the models could represent a mountain moving laterally as plates move. However, only the models in which plates were moving together (convergent) are accurate representations of how mountains could increase in elevation.

Listen for students to agree that:

- The model must be one that shows plates moving together.

They may also make a further distinction:

- The best model is more likely to be one in which the plates moving together are of the same density since they collide and can squash together (collision), sometimes making very high mountains, or multiple mountains.
- The best model is less likely to be one in which, when the plates move together, one goes underneath the other (subduction) since that creates a kind of valley on one side, and Mt. Everest / the Himalayas doesn't have that.

If they do not make that distinction on their own, push them to consider which of the moving together models best represents all that they know about Mt. Everest, how it is changing and the area around Mt. Everest. It is not critical that they identify that the best model is the collision model, but it is important that they be able to articulate why one is better than the other as a representation of Mt. Everest.

Write an argument. Display **slide Q**. Have students open their science notebooks to a fresh page. Say, *Now that we've worked together as a class and agree on the argument that model X is the best one, what claim can we make about* *the model that we've chosen in relation to Mt. Everest?* Agree as a class on a claim that is similar to "Model (X) is the best one to show what's happening at Mt. Everest to cause it to get taller" and have them record it at the top of the page. Then ask students to write a few sentences explaining why this model best represents what is happening at Mt. Everest. Tell them to be sure their writing includes evidence from their notebook and/or artifacts in the classroom as part of their explanation to support the claim. If students are having trouble getting started, refer them to the list of the characteristics of Mt. Everest that was recorded on the white board of a poster paper at the beginning of this class period, and the list of why they think the chosen model is the best one.

Assessment Opportunity

Building towards: 6.B.1 Construct an argument supporting a model of how plate interactions could cause mountains and earthquakes.

What to look/listen for: Students' written arguments should include multiple examples of evidence from specific models that directly supports the claim that increases in the elevation of Mt. Everest can be caused by plate movement and plate interactions. The evidence should come from the ways that plate shape and elevation was affected in their models, and what they know about the real characteristics of surface phenomena involving Mt. Everest. These pieces of evidence will have been discussed or referenced in the lesson before students are called to use them in their writing. Through writing their written arguments, they are identifying those pieces as evidence and articulating why the evidence supports the claim of causation.

What to do: If students struggle to put the pieces together, refer them to the model that the class agreed on, the list of reasons why that model best represents what's happening at Mt. Everest, and the list of characteristics of Mt. Everest that need to be explained, and encourage them to articulate how those ideas are connected.

9. Explain earthquakes.

15 MIN

Materials: science notebook, Different Plate Interactions chart, two pieces of white foam with medicine cups attached, water, food coloring (optional)

Facilitate a discussion to think about what might cause earthquakes. Display **slide R**. Say, *Are there any characteristics that we described about Mt. Everest that we maybe didn't fully explain with our model? We said that earthquakes happen frequently near Mt. Everest. In a reading we did in Lesson 1, we found out that a major earthquake happened very close to Mt. Everest in 2015. Could our model help us explain the earthquakes, too?*

Suggested prompts	Sample student responses
What do we know about where earthquakes happen?	*They mostly happen at the edges of plates.*
What do we know about how the land is moving during an earthquake?	*It can move sideways like we saw at Ridgecrest. We also saw that it had moved up or down after the earthquake.* *It happens where plates are moving past each other.* *It happens suddenly, not slowly.*

Suggested prompts	Sample student responses
Was there any kind of movement in our models, especially at the edges of the plates, that was like that?	*We saw that sometimes when plates moved past each other, they got stuck a little bit if the edges were rough.* *There was rubbing or friction between the plates as they moved past each other. If the edges were rough or uneven it was harder to move them.*
Do you think the edges of the plates that are moving near Mt. Everest are likely to be rough or very smooth?	*Rock is usually rough.* *Plates are big. They can't be totally smooth at all the edges.* *If the edges of plates are like the crack in the land that we saw at Ridgecrest, then it is probably pretty rough.*
Was there ever a point where the edges of the plates in your models moved sort of suddenly?	*When they got stuck on a rough spot, and then they'd sort of snap past it as we kept pushing.* *Sometimes a little piece would break off the edge and then it would suddenly move much faster.*

Make a list of the main ideas they articulate on the white board or other publicly visible space.

Demonstrate this kind of plate movement. Ask students to gather around you so they can see what's happening as you demonstrate the plate movement. Take the two pieces of white foam that you've prepared with uneven edges and medicine cups attached (explained in the Lab Preparation section of this lesson), and show the students their rough edges. Demonstrate how they would move past each other, alternately catching on some spots and then snapping past that spot as you continue to push very slowly. Demonstrate this movement both side by side laterally (⇄), and when one is moving over the top of the other (down↓↑up). Then add a little bit of water to each medicine cup to allow students to see when the surface of the plate is moving, and have students observe when the water in the cups moves the most as you move the plates. Repeat the side by side lateral movement and the up and down movement to demonstrate. They should notice that the water (like the surface of the land in an earthquake) moves the most when the edges of the plates snap out of a spot where they were stuck.

Additional Guidance

You may want to rehearse this demonstration before presenting it to students. The way you move the plates as they interact is important for making the demonstration work. Move the plates smoothly, but allow them to get stuck as you keep pushing when the rough edges interact. The video shows how to move the plates. Be sure you demonstrate both a lateral sliding past each other motion, and a movement in which one of the plates is moving over the top of the other. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) The important observation for students to make during this demonstration is that when the "plates" snap rapidly past a rough place on the interacting edges, the water in the cups moves a lot, whereas when the plates move smoothly

*Supporting Students in Developing and Using Stability and Change

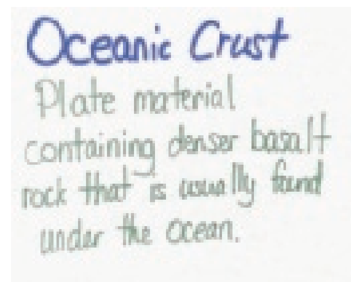
In this moment of the lesson, after students have made the connection between plate movement and earthquakes, the class pauses to reflect on how the event of an earthquake is usually sudden yet is a result of changes that have been occurring over a longer period of time (plate movement). This idea of sudden events we experience and see change the Earth that are due to mechanisms that happen over a longer period of time at a scale that we can't always see is new for students in middle school. This discussion will help begin to set the foundation for students to think in this new way.

past each other, the water barely moves at all. Make the connection for them that the surface of the land moves a lot very suddenly in an earthquake, similarly to what the water is doing in the demonstration.

Facilitate a brief discussion about how this sudden movement is likely to occur. Display **slide S**. Ask students to consider when this movement (of building tension and then snapping suddenly out of it) is likely to occur. Ask, *Besides plates that are sliding past each other, we modeled other ways plates move. Do you think any of these other types of plate movement could also cause earthquakes?* Have students turn and talk with a partner to share ideas about the answer to this question. Students should be able to articulate that it could occur whenever two plates are moving against or past each other in any direction, since rock edges are always rough and any interaction could create the tension that would resolve suddenly. Note for students that this is likely to happen not only when plates are sliding past each other laterally, but also when plates are moving together and run into each other or move over each other in any direction.

Make a claim about how plate movement could cause earthquakes. Ask, *Based on what you've seen, what claim do you think we could make about what causes earthquakes?* Agree as a class on a claim that is similar to "Earthquakes are ***caused*** by plates moving against each other and getting stuck on their rough edges, then snapping out of it suddenly." Have the foam pieces from the lab available to use to demonstrate this if needed. Say, *We have been using the word earthquake since lesson 1, but we haven't yet added it to our word wall. Now that we know what causes earthquakes and have an understanding of the process that causes earthquakes, add earthquakes as a word we have earned on our word wall.*

Add earthquake to the word wall, or if it was added to "words we encounter" in lesson 1, update the card to reflect our current understanding of the word and move the card to "word we earn."



Consider the changes that lead to earthquakes. Discuss the sudden movement of earthquakes with students, and determine that the earthquake is the result of constant plate movement that is felt suddenly after the plates have adjusted to this constant movement. Use this moment to support students in the relationship between slow, constant plate movement (that we can't see or feel) to earthquakes that are felt suddenly (and can be seen or felt). Example prompts and responses are below.

Suggested prompts	Sample student responses
We only feel earthquakes occasionally. Why would we only feel them occasionally?	*Because they only happen when the plates slip past the point where they were caught on each other.* *If the plate catches then it keeps pushing until it snaps or breaks, and then we feel the break.*
So we only feel the earth move when it snaps or breaks. But is that the only time the land is moving?	*No, it is always moving.* *The plate is always building up pressure as it constantly moves. We just feel it when the pushing of the plate makes it break. But it's always moving.*

Suggested prompts	Sample student responses
So this movement, is it happening quickly, or slowly?	*It has to happen pretty slowly.* *If the plate is moving then it is moving slowly. We don't feel the gradual movement.*
So would this also explain why we don't feel the movement as the entire plate moves with us on it?	*Yeah, the movement is so small that we just don't feel it.*
But why do we still feel earthquakes so suddenly? How would that little movement of a plate add up to something like an earthquake?	*It's the little movements over a large time that add up. That's why we feel them so suddenly and sometimes violently.* *If something happens every day, and it's small, over the course of a year it can add up. So when it does slip or snap we feel it.* *The earthquake is the result of those small changes adding up over time.*
So those small changes we can't feel like plate movement can cause sudden events like earthquakes over time?	*yeah*

Write an argument. Display **slide T**. Have students record this claim, "Earthquakes are caused by plates moving past each other and getting stuck on their rough edges, then snapping out of it suddenly," on a fresh page in their science notebooks and add a few sentences supporting the claim using evidence from their models, this demonstration, and/or artifacts in the classroom. If students are having trouble getting started, refer them to the list of characteristics of earthquakes and the demonstration they just observed. If you are assessing their written arguments, collect students' science notebooks.

Assessment Opportunity

Building towards: 6.B.2 Construct an argument supporting a model of how plate interactions could cause mountains and earthquakes.

What to look/listen for: Students' written arguments should include clear descriptions of specific evidence from models that directly supports the claim that earthquakes can be caused by plate movement and plate interactions. The evidence should come from the ways that the rough edges of plates catch on each other as they move by each other, building tension that resolves when the edges suddenly slip past each other. These pieces of evidence will have been discussed in the lesson before students are called to use them in their writing. Through writing their written arguments, they are identifying those pieces as evidence and articulating why the evidence supports the claim of causation.

What to do: If students struggle to put the pieces together, refer them to the discussion about how sudden movements occur, and the demonstration of when the surface of the plates moved the most, as well as the characteristics of earthquakes that they are familiar with from Lessons 2 and 3, and encourage them to articulate how those ideas are connected.

10. Revisit the Driving Question Board.

8 MIN

Materials: sticky dots, ALTERNATE material: one printed copy per pair of students of the digital version of DQB questions if you made one in Lesson 1, sticky notes, Driving Question Board

Revisit the Driving Question Board and review questions that have been answered and that remain to be answered. Show **slide U,** and say, *Now, let's revisit the Driving Question Board and see what questions we can answer based on what we have learned in this unit so far. Take a few minutes to look through the questions on the Driving Question Board and put a sticky dot on any that you think we can now answer based on what we have learned about plates and plate movements up to this point.*

Ask students to gather around the DQB, then give them 2-3 minutes to place sticky dots on questions. Have them step back and take a look at the selected questions, as well as at the questions that remain unaddressed at this point in the unit. After students have had time to look through the questions, ask students to share their selections.

Suggested prompts	Sample student responses
Under which categories did we find questions that we can now answer?	*Some of the questions we tagged are under the category of "Causes of Mountains."* *Some of the questions that ask "How Land Moves."* *Some are about "Earthquakes."*
What kinds of questions do we still not have answers for?	*questions about mountains getting shorter* *questions about volcanoes and other kinds of things we see happening on the surface* *questions about how long this all took to happen* *questions about what wind and snow and other things like that are doing to mountains*
Do you have any new questions?	*We have new questions about what's going on when plates move away from each other.* *Accept all answers and add new questions to the DQB.*

Celebrate with students that they have explained a lot about the anchor phenomena. Take a moment to celebrate that we have answered a lot of our questions already.* We have learned a great deal about what is happening under the ground and how plate interactions are causing many of the changes we see happening all over the world.

Additional Guidance

The categories on your DQB and the questions selected may differ slightly from those in the sample responses. However, students should select questions that focus on large scale movements of landmasses and plates as causes

***Attending to Equity**

Part of making learning accessible to all students is acknowledging that each student contributes to sensemaking and knowledge building in potentially different ways.

Emphasizing what has been achieved by the collective efforts of the entire class includes all students in the celebration of achievements.

of those movements. The questions they have not yet answered should be relevant to the amount of time it takes for these changes to happen, and to the surface causes, like weather and water, that can impact landmasses.

Alternate Activity

Alternatively, you can pair students and distribute a copy of the digital copy of DQB questions that you prepared in Lesson 1. Have pairs work together to identify which questions we now have answers for and what kinds of questions we do not have answers for.

If you do not have enough time to complete this activity in class, each student can individually use the digital copy of DQB questions to identify the questions we have answers for and the kinds of questions we do not have answers for as a home learning assignment.

11. Navigation

2 MIN

Materials: None

Focus attention on the questions that remain to be answered. Display **slide V**. Ask students what else they think the models they developed in this lesson might help explain. Do they think that a different model might help explain a different mountain? Are there other surface phenomena that these models might help explain? Accept all answers.

LESSON 7

What happens at mountains where we see volcanic activity?

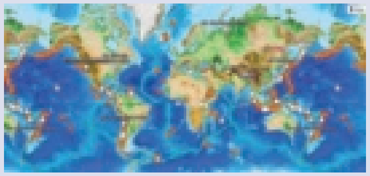
Previous Lesson

We used models of plate movement to identify and describe the results of plate interactions. We used models of the interactions to help explain what caused the elevation and other changes at Mt. Everest. We considered how earthquakes could be caused by uneven plate movement.

This Lesson

Investigation

1 DAY



Concord Consortium

We use map images to determine that most volcanoes occur along the boundary between oceanic and continental plates. We use a model previously developed to observe and describe the interaction and resulting effects of a denser oceanic plate colliding with a less dense continental plate. We revisit the Data Cards for Other Mountains and Mt. Everest from Lesson 1. We use a reading to figure out that volcanic eruptions can add new earth material to existing landforms or can destroy them. Using what we have figured out, we draw conclusions about the relationship between volcanic eruptions and changes that occur at Mt. Everest and the other five mountain sites.

Next Lesson

We will share and record claims about what occurs where two plates are moving away from each other and investigate the Mid-Atlantic Ridge to analyze evidence for our claims. We will determine what is happening at the Mid-Atlantic Ridge and update our Potential Causes for Mountain Movement chart.

Building Toward NGSS

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

What Students Will Do

7.A Apply scientific ideas and evidence to construct an explanation for the processes that cause some of the large scale interactions of Earth's plates that result in the effects (volcanoes) of those interactions.

What Students Will Figure Out

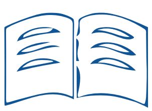
- Volcanoes occur in some of the same places where earthquakes occur.
- Volcanoes occur in lines where an oceanic plate collides with a continental plate.
- When a more dense oceanic plate collides with a less dense continental plate, the oceanic plate moves under the continental plate.
- The portion of the oceanic plate that moves below the continental plate begins to heat up, causing the bedrock and sediments to melt and the water in the sediments to boil.
- The melted earth materials and steam move upward through openings called volcanoes, in the continental plate.
- Volcanic eruptions can cause mountains to grow in height when new earth material is added, or shrink when existing earth material is scattered.

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	6 min	**NAVIGATION** Revist the *Possible Causes for Mountain Movement* chart, review what we have figured out, and determine our next steps.	A-B	Possible Causes for Mountain Movement chart
2	15 min	**GATHER ADDITIONAL DATA FROM ARTIFACTS** Use Seismic Explorer to determine why and how we will investigate the possible role of volcanoes in changes that occur to mountains.	C-J	*Volcano and Earthquake Data Chart*, *Gathering Data from Maps*, Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, markers
3	3 min	**REVISIT OUR DIFFERENT PLATE INTERACTIONS CHART** Revisit the *Different Plate Interactions* chart to observe and describe the interaction between oceanic plate material and continental plate material.	K	optional: different foam pieces from Lesson 6
4	13 min	**GATHER INFORMATION FROM A READING** Use a close reading protocol to gather information about how volcanoes are formed and the types of changes volcanoes cause to the surface of Earth.	L-R	*Reading: How are Volcanoes Formed and What Kinds of Changes Do They Cause?*, highlighter, Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, 2 5x8 index cards or half sheets of paper, markers
5	5 min	**SUMMARIZE THE CHANGES CAUSED BY VOLCANOES** Summarize what we have figured out about the changes that volcanoes can cause. Add to the Word Wall, and complete an exit ticket.	S-T	5 x 8 index card or half sheet of paper, markers

End of day 1

Lesson 7 • Materials List

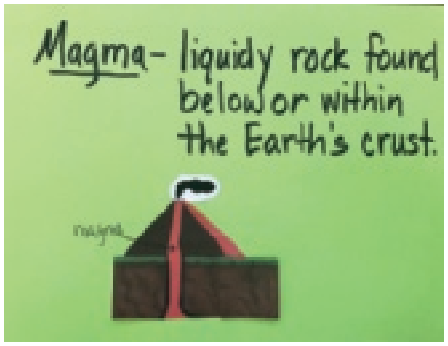
	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Volcano and Earthquake Data Chart* • *Gathering Data from Maps* • *Reading: How are Volcanoes Formed and What Kinds of Changes Do They Cause?* • highlighter • 5 x 8 index card or half sheet of paper	• Data Cards for Other Mountains and Mt. Everest from Lesson 1	• Possible Causes for Mountain Movement chart • chart paper • markers • optional: different foam pieces from Lesson 6 • 2 5x8 index cards or half sheets of paper

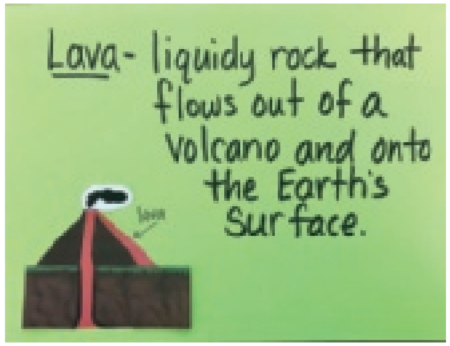
Materials preparation (30 minutes)

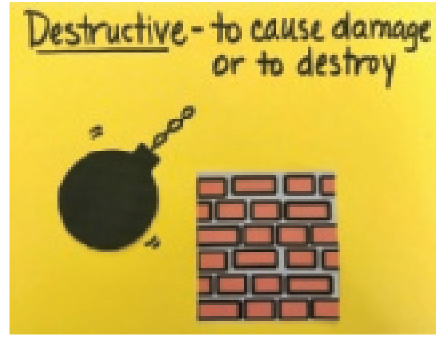
Review teacher guide, slides, and teacher references or keys (if applicable).

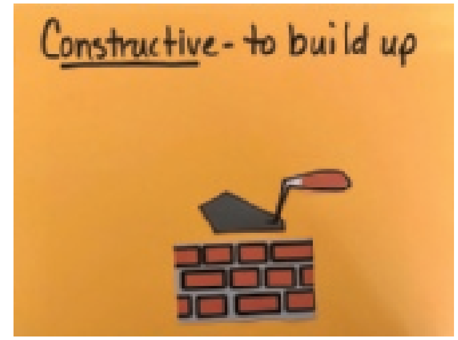
Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Online Resources









Be sure you have materials ready (e.g., blank pieces of paper, large sticky notes, or note cards) to add the following words to the Word Wall:

- Words We Earn: *magma, lava*
- Words We Encounter: *destructive* and *constructive*.

Do not post "Words We Earn" on the Word Wall until after your class has developed a shared understanding of their meaning. "Words We Encounter" will be posted to the Word Wall after students read *How are Volcanoes Formed and What Kinds of Changes Do They Cause?*

Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students make observations and analyze data from a number of sources to determine if volcanic eruptions cause the changes in elevation and location that Mt. Everest and the five other mountain sites regularly experience. Students first use images of seismic maps to determine that most volcanoes are located along the boundary between oceanic and continental plates. They make observations (through video) of one model developed in Lesson 6 to describe the interaction between an oceanic plate and a continental plate. They observe that the denser oceanic plate moves under the less dense continental plate. From a reading, students further develop their understanding of how a denser oceanic plate moves under the continental plate when they interact with the leading edge of the oceanic plate moving towards the hot mantle. The earth materials (bedrock and sediments) that make up the plate melt and the water saturated into the sediments of the plate boils. The melted rock, or magma, and steam move upward and escape to the surface of Earth through cracks in the crust known as volcanoes. As volcanoes erupt, a steady flow of lava from a volcano can add new earth material to the volcano and the land around it. Violent eruptions, however, can cause destruction to the volcano and the surrounding area. Students use the information and data they analyze in this lesson to describe the changes caused to the surface of Earth by volcanoes. Students determine that the only possible change that might be caused by volcanoes is the increase in Mt. Hotaka's elevation from our mountain cards, which is an active volcano.

Where We Are NOT Going

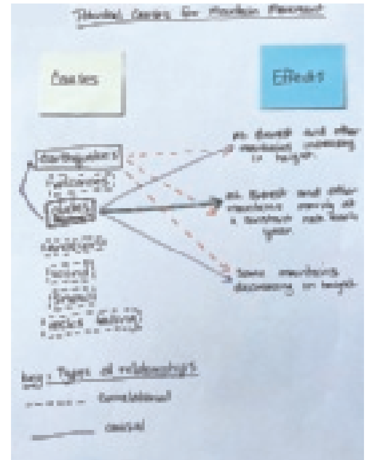
There are a number of concepts and skills related to the content of this lesson that are beyond the scope of this lesson and the unit. Students describe the interaction and the resulting effects of an oceanic plate colliding with a continental plate; however, students should not be required to use scientific terms to name this type of interaction. To understand why an oceanic plate moves below a continental plate when they interact, students focus on the relative density of the bedrock that makes up each type of plate, and not on the composition. The mechanisms (increasing pressure) that cause the upward push of molten rock and steam through Earth's crust and out onto the surface is another concept that is beyond the scope of the lesson. Instead, students focus on describing the effects of volcanic eruptions on the surrounding area and determining whether or not those effects cause the changes in elevation and location that Mt. Everest and the five other mountain sites undergo on a regular basis. Students also do not look at volcanoes changing landscapes at regions that are not on tectonic boundaries, as the understanding of hotspots is above grade band.

LEARNING PLAN FOR LESSON 7

1. Navigation

6 MIN

Materials: science notebook, Possible Causes for Mountain Movement chart



Update the Potential Causes for Mountain Movement chart. Say, *Last class we decided there is a connection between earthquakes and mountain movement. Let's revisit our* Potential Causes for Mountain Movement *chart and revise it to represent what we figured out.*

Guide students to look at the chart and ask, *How are earthquakes related to mountain movement?* Students should respond that the earthquakes are caused by plate movement when plates collide or slip past each other, but do ***not*** cause mountains to grow or move in location. The mechanism that causes mountains to grow and move **and** also causes earthquakes is plate movement. Plate movement is causing earthquakes and mountain movement.

Say, *Let's show this causal link on our chart.* Take a moment to recap with students what the role of plates is in relation to earthquakes. Draw an arrow between plate movement and earthquakes to represent a causal link between the two. As you are drawing, make sure to ask students to verify each link and that it represents their current understanding. Also draw a line between plate movement and mountain growth and mountain movement to represent that plate movement causes mountains to grow and plate movement causes mountains to move.

Consider other potential causes for mountain movement. Show **slide A** and say, *Over the last few lessons, we have gathered evidence and have documented what we have figured out using that evidence. Take some time to review the Possible Causes for Mountain Movement chart, then turn and talk with your partner. What do we know about what causes mountains, like Mt. Everest, to change? Look back at your notes and your Progress Tracker, if you need to.*

Additional Guidance

Prior to the start of the lesson, you may want to take a picture of the *Possible Causes for Mountain Movement* chart and insert the image on **slide A** and **slide B** with the image of the chart your class created.

Give students time to talk, then ask a few to share with the class. Look for the following ideas to surface:

- When plates move towards each other, or collide, mountains at the plate boundaries can form and increase in elevation.
- Plate collisions can also cause mountains at the plate boundaries to move.
- When plates interact, they often get stuck against one another. Over time, they eventually slip, which causes earthquakes.
- Earthquakes do not cause mountains to increase in elevation—the interactions between plates do.

Summarize by referencing the *Possible Causes for Mountain Movement* chart and saying, *We know that when plates move towards each other, or collide, the mountains found along the plate boundaries can change in size and location. As we figured out in our last lesson, the increase in elevation and the movement to the northeast that happens at Mt. Everest yearly are examples of this kind of cause-and-effect relationship. We also figured out that as plates move against one another, they catch and slip, which causes earthquakes. So we figured out that earthquakes do not cause mountains to move or increase in elevation, instead the interactions between plates do.*

Motivate the need to investigate volcanoes. Show **slide B** and say, *We have investigated two of the potential causes for the processes that could be causing changes to mountains like Mt. Everest—plates moving and earthquakes. But sometimes there can be more than one cause for something to change. There is another potential cause that we still have on our chart and need to investigate—volcanoes. We originally thought that volcanoes might cause some of the changes that occur to mountains. What do we know about volcanoes, and where they occur? Once again, turn and talk with your partner, and be prepared to share your thinking with the class.*

Give students time to talk, then ask a few to share what they discussed.

Suggested prompts	Sample student responses
What do we know about volcanoes?	*Volcanoes can erupt suddenly and can be very dangerous.* *When volcanoes erupt, ash sometimes goes into the air, and melted rock comes up and flows onto the surface.*
Where do they occur?	*Hawaii has volcanoes, so maybe there are volcanoes wherever there are islands.* *Mt. Hotaka is a volcano, but it isn't active anymore.* *The Andes mountain range has the biggest active volcano.*

After students share, tell them that we need to think about how we might investigate volcanoes.

2. Gather additional data from artifacts.

15 MIN

Materials: science notebook, *Volcano and Earthquake Data Chart*, *Gathering Data from Maps*, Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, markers

Explore maps from Seismic Explorer. Distribute *Gathering Data from Maps* and show **slide C.** Tell students, *Let's take a look at a few artifacts that can help us figure out whether or not volcanoes cause mountains to move or change in height or elevation. On the slide, you see a map showing the sites of volcanoes around the world. You see the same image on the first map on Gathering Data from Maps. The white triangles indicate active volcanoes, and the orange triangles indicate volcanoes that have erupted since January 1980. What do you notice about where these volcanoes are located?*

Give students two minutes to talk with those in their small groups, then show **slide D.** Say, *On **slide D,** and on the second map on Gathering Data from Maps, we have added red circles that indicate earthquakes that have occurred since January 1980. What do you notice about where volcanoes are located in comparison to where earthquakes occur?* Give small groups another two minutes to talk. Then ask groups to share their ideas with the class.

***Strategies for This Initial Ideas Discussion**

The purpose of this type of discussion is to surface students' initial ideas and to provide support for students to make sense of their ideas, which might not be fully formed. Students will also need help to figure out what they can do next to determine

Suggested prompts	Sample student responses
What do you notice about where volcanoes are located?	*Many volcanoes occur in lines along the edges of some continents or between two continents. These look like they are located at plate boundaries.* *Some volcanoes are out in the ocean.* *Some volcanoes are scattered on and around the continent of Africa.* *There are very few in the continental United States.*
What do you notice about where volcanoes are located in comparison to where earthquakes occur?	*Most of the volcanoes, especially those in lines along the plate boundaries are located in places where earthquakes occur.* *Volcanoes seem to be where there are earthquakes, but there are many places where there are earthquakes and no volcanoes.*

Make connections to Mt. Everest and other mountain sites. Distribute *Volcano and Earthquake Data Chart*. Show **slide E**, and ask students to use the information from the maps in *Gathering Data from Maps* to document whether or not volcanic activity and/or earthquakes occur near each of the six mountains listed on the *Volcano and Earthquake Data Chart*. Give small groups a few minutes to document the information in their charts. Remind students to use the first two images on *Gathering Data from Maps* to help them determine whether or not volcanic activity and/or earthquakes occur near each of the six mountains listed on *Volcano and Earthquake Data Chart*.

When students are finished, distribute one set of *Data Cards for Other Mountains and Mt. Everest* from Lesson 1 to each group, and show **slide F**. Tell students to use the set of *Data Cards for Other Mountains and Mt. Everest* from Lesson 1 to find the amount of change that occurs in both the location and elevation for each mountain. Students should document the data in the *Volcano and Earthquake Data Chart*.

Give students a few minutes to work. When they are ready, show **slide G** and ask students to take a moment to read the questions on the slide:

- What do you notice about the location of our mountain ranges as compared to where volcanoes are located?
- What does this tell us about the changes that occur at Mt. Everest and at our other mountain sites?
- What other data do you think we need to help us figure out whether or not volcanoes cause mountains to move and change in height?

Have students discuss the questions with those in their small group using the information they have documented in the *Volcano and Earthquake Data Chart* as evidence to support their thinking. Tell them to be ready to share their responses to the questions and their supporting evidence with the class. Be prepared with chart paper and markers to document students' thinking.

Suggested prompt	Sample student response
What do you notice about the location of our mountain ranges as compared to where volcanoes are located?	*We see volcanoes located at or near some of the mountains.*

the relationship between where volcanoes are found, the type of plate interactions that occur, and the changes that occur to mountains at those same locations. To accomplish this, you can:

- Encourage student-to-student talk focused on raising questions, clarifying, or adding on to what someone has said rather than debating or arguing. Students can find support for this conversation by using the *Communicating in Scientific Ways* chart, which gives students prompts to use to help them communicate with others during science discussions.
- Ask for or provide a synthesis of the ideas that have emerged from the discussion.
- Ask students how they might test or further explore their ideas.

Suggested prompts	Sample student responses
What evidence do you have to support that claim?	*We see volcanoes on our map and in our mountain cards at Mt. Aoraki, Mt. Aconcagua, and Mt. Hotaka.*
What does this tell us about the changes that occur at Mt. Everest and at our other mountain sites?	*We don't see any volcanoes at or near Mt. Everest on our cards and maps. There are earthquakes, but no volcanoes. That means the changes in location and elevation must not be caused by volcanoes.* *The same seems to be true for Mt. Mitchell that's moving west 3cm every year, and Mt. Narodnaya that's moving east 2.5cm every year. We don't see volcanoes at or near them, but they are still moving.* *We still do not know whether or not volcanoes that are near other mountains cause them to move and/or increase in height like Mt. Aoraki, Mt. Aconcagua, and Mt. Hotaka.*
Can we now document what we know about the relationship between the movements on Mt. Everest, Mt. Mitchell, and Mt. Narodnaya in the last column of our Volcano and Earthquake Data chart?	*Yes, definitely!* *We know that volcanoes did not cause any of the changes we noted for those three mountains because there are no volcanoes near them!*
What other data do you think we need to help us figure out whether or not volcanoes can cause mountains to move and change in height?	*Well, we noticed that where volcanoes are found, there are also earthquakes and plate boundaries. We might need to see the maps that show where the plates meet.* *We also might need to see how the plates are moving or interacting, because there might be something similar happening where the volcanoes occur.*

As students share data and are able to draw conclusions about the relationship between volcanic activity and the changes that occur at each mountain site, document students' data and conclusions on the data table projected on **slide H**. Also, give students an opportunity to document conclusions for Mt. Everest, Mt. Mitchell, and Mt. Narodnaya on their copies of *Volcano and Earthquake Data Chart*. An example of the information that will be filled in on **slide H** is included here.

Site	Types of Changes (yearly)		Event (yes or no)		Are the changes to the mountain caused by volcanoes?
	Location	elevation	Volcanoes	Earthquakes	
Mt. Everest	4cm NE	3cm increase	no	yes	No, there are no volcanoes nearby
Mt. Mitchell	3cm W	decreasing	no	very few	No, there are no volcanoes nearby
Mt. Aoraki	7cm N	1-2cm increase	yes	yes	
Mt. Aconcagua	3cm N	10cm/10yrs avg. increase	yes	yes	
Mt. Hotaka	1cm SE	4mm increase	yes	yes	
Mt. Narodnaya	2.5cm E	none	no	no	No, there are no volcanoes nearby

Alternate Activity

If it is more convenient, recreate the chart on *Volcano and Earthquake Data Chart* on chart paper and use the chart to document students' data and conclusions.

Summarize this part of the discussion by saying, *So, we know that the changes at three of the six mountain sites—Mt. Everest, Mt. Mitchell, and Mt. Narodnaya—are not caused by volcanoes, since there are no volcanoes near these three sites. We still need to figure out the relationship between the changes that occur at the other three mountains—Mt. Aoraki, Mt. Aconcagua, and Mt. Hotaka—and the volcanic activity that occurs at or near each of these sites.*

Gather additional information about plate movements and interactions. Have students tape the *Volcano and Earthquake Data Chart* into their notebooks on the next available page, and label that page "Volcano and Earthquake Data." When students are ready, say, *We know that volcanoes are located at three mountain sites. To help us figure out if plate movement relates in some way to the location of active volcanoes, and if those volcanoes play a role in the changes that happen to mountains at those same locations, we have two maps that might give us important information.*

Show **slide I** and say, *The map on this slide shows the plate boundaries and the direction that the plates move. You have a picture of this map on Gathering Data from Maps. With your small group, examine the map. What do you notice about the plates and how they move and interact? Which mountain sites are on or very near to plate boundaries?* Give students time to talk with those in their small group.

Additional Guidance

The map on **slide I**, which is in *Gathering Data from Maps* is more complicated and has more data to process than the maps used in previous lessons, so students may need additional support and guidance as they analyze the information on the map.

You may want to guide this analysis by pointing out individual components on the map to focus students' attention on one component at a time. This includes:

- Blue-green boundaries between oceanic plates
- Blue-green arrows indicating movement of oceanic plates
- Yellow boundaries between oceanic plates and continental plates
- Yellow arrows indicating movement between oceanic plates and continental plates

Students should notice the following relationships:

- Along the blue-green boundaries, oceanic plates tend to move away from one another.
- Along the yellow boundaries, we see oceanic plates and continental plates moving towards one another.

This distinction is important for students to notice since volcanoes tend to line up along the boundaries between oceanic and continental plates, where oceanic plates move towards continental plates.

Next, show **slide J.** Say, *Let's look at where volcanoes occur in relation to the plate boundaries. What do you notice about how the plates move and interact at the places where volcanoes occur? Remember, you have a corresponding image of this map on Gathering Data from Maps.* Tell students to examine the map and discuss the question with their small groups and to be prepared to share their responses to the questions on **slides I** and **J**.

When students are ready, use the questions on the two slides as well as the additional questions below to guide an Initial Ideas discussion.*

Suggested prompts	Sample student responses
What do you notice about the plates and how they move and interact?	*Portions of each plate boundary are outlined in green, pink, or yellow.* *The portions of the plate boundaries colored green show where the plates are moving apart from one another. We notice that the plates tend to move apart out in the ocean, but this type of plate movement sometimes happens on a continent, like in Africa or Asia.* *We noticed that the portions of the plate boundaries colored pink indicate places where the plates are sliding along one another. These types of interactions tend to occur in small areas of all plate boundaries.* *The portions of the boundaries colored yellow show where the plates are moving towards one another. These types of interactions seem to happen where oceanic crust material meets continental crust material.*
What do you notice about how the plates move and interact at the places where volcanoes occur?	*We noticed that volcanoes tend to be along yellow boundaries where the plates are moving toward one another.* *There are a few volcanoes that are not close to any plate boundary, but the majority are along the yellow plate boundaries.* *We also notice that volcanoes tend to be located near coastlines where oceanic plates are moving toward land or continental plates.*
What do we already know about how oceanic parts of plates interact with continental parts of different plates?	*The oceanic plate material moves under the continental plate material. One of our models showed that!*
How can we check our thinking about the results of the interaction when oceanic crust on a plate collides with continental crust on another plate?	*We can revisit our models from the last lesson.* *The model can help us understand what is happening as an oceanic plate crust collides with a pieces of continental plate crust.* *The model might also help us figure out why volcanoes are found in the same area where an oceanic plate and a continental plate collide.*

Summarize the discussion and motivate next steps. After working through the questions on the slide and the additional prompts, say something like, *We noticed that volcanoes tend to be located where oceanic plate boundaries are moving toward land or continental plate boundaries. So, we are now wondering if what we learned during the last lesson about plate interactions can help us better understand this type of interaction between oceanic crust at a plate boundary and a continental crust at a plate boundary, and if this might also help us figure out why volcanoes are found where this type of plate boundary interaction occurs. Sounds like we might need to revisit our models from the previous lesson!*

3. Revisit our Different Plate Interactions chart. 3 MIN

Materials: science notebook, optional: different foam pieces from Lesson 6

Observe and describe the models from the *Different Plate Interactions* chart that could represent where volcanoes occur. Show **slide K** and make sure the *Different Plate Interactions* chart is in a place that all the students can see it. Then tell students, *In our last class, we developed models to represent the different ways plates can interact based on the investigations we did with the foam pieces and the water in the aluminum pan. Let's take a moment to look back and see if any of these models we developed could be representative of the kind of plate interactions that would lead to a volcano.*

Elicit responses from students about these representations. Examples of prompts and responses are below.*

Suggested prompts	Sample student responses
What happened when the grey foam representing the oceanic plate material and the white foam representing the continental plate material collided?	*When they were pushed together, we noticed that the foam that represents the oceanic plate material went under the foam that represents the continental plate material.* *We also noticed that a thin layer of water is pulled downward with the oceanic plate part.*
We know our representations had limitations. What limitations do you expect that this representation might have?	*Maybe the pan stopped the plate from going down. Maybe the plate goes all the way down and circles back up eventually.* *Maybe one slides under the other and just slides under it all the time, making earthquakes like they have in Oklahoma where there aren't plate boundaries.* *It was hard to keep the foam above the water. Sometimes the back sides of the plate material would fall under water. Maybe the other side of the plate in real life doesn't sink below the water, or magma.*

If time permits, allow students to add any new questions to the Driving Question Board. Tell them that we might not answer all their questions in this lesson, but as we continue to figure out more about the changes that happen to the surface of Earth, they will be able to answer many of their questions.

***Attending to Equity**
Universal Design for Learning: While some students may be able to refer back to the chart and make connections, some students may benefit from an alternative physical *representation* of the two plate materials colliding. Consider reusing the two foam materials from Lesson 6 to replicate the interactions seen on the chart for students. This representation can be done by colliding the materials with or without water, and is to help students make connections between the learning from Lesson 6 and what we know about the interactions between continental crust colliding with oceanic crust.

4. Gather information from a reading. 13 MIN

Materials: science notebook, *Reading: How are Volcanoes Formed and What Kinds of Changes Do They Cause?*, highlighter, Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, 2 5x8 index cards or half sheets of paper, markers

Set the purpose for the reading. Tell students, *So we have some questions about what happens as an oceanic plate moves under a continental plate. We still have not figured out why volcanoes are found where these two kinds of plates interact and whether or not they can cause the kinds of changes we see at Mt. Aoraki, Mt. Aconcagua, and Mt. Hotaka.*

***Attending to Equity**
Universal Design for Learning: It is important to support students to clarify academic language they encounter in the text to

We also have questions about the actual limitations of our models. To help us, let's take a few minutes to gather more information from a reading.

Project **slide L.** Distribute a copy of *Reading: How are Volcanoes Formed and What Kinds of Changes Do They Cause?* to each student. Using the handout version of this reading gives students the opportunity to annotate the reading, and later tape it into their notebooks. There is a color copy of this reading in the Student Procedure Guide for reference. Tell students that they are to read *Reading: How are Volcanoes Formed and What Kinds of Changes Do They Cause?* and look for information that will help us better understand how volcanoes are formed and how they change the surface of Earth.

Preview the close reading strategies. Show **slide M** and tell students that they will need to follow the close reading protocol outlined on the slide to help them gather the information they need. Remind them that they have used this protocol before in *One-way Mirror Unit*, then walk through the protocol with students:

Individually, students:

1. Identify the question(s) we are trying to answer with the reading.
2. Read once for understanding to see what the reading is about.
3. Read a second time to highlight a few key ideas that help answer our question(s).

With a partner, students:

4. Summarize the key ideas in their own words.
5. Jot down any new questions they have.

Work together to identify the questions we are trying to answer with the reading:

- Why are volcanoes found where an oceanic plate collides with a continental plate?
- Can volcanoes cause the kinds of changes we see at the remaining 3 mountain sites in our chart—Mt. Aoraki, Mt. Aconcagua, and Mt. Hotaka?

Document these questions at the top of a sheet of chart paper, which will be used after students finish the reading.

Remind students to be selective about what they highlight—we are looking for those key ideas that help us answer our questions. Also, point out that there are a few terms that students might or might not recognize or understand, even in the context of the reading. Tell them to circle unfamiliar terms and that we will discuss those terms after students finish reading.

Once students feel comfortable with the close reading protocol, give them time to read the text on their own.

When they finish, they should work with a partner to summarize the key ideas from the reading and jot down any new questions they might have.

Use strategies to determine the meaning of unfamiliar science words. When students are ready to discuss the reading, show **slide N** and ask them to first share any unfamiliar words they circled in the reading. Take a few minutes to discuss these terms. Use context clues from the reading, words that are from the same root as the circled word, or examples from students' personal lives to help them understand the meaning of unfamiliar words.*

develop their ability to learn and use linguistic *representation*. Most of these terms are words we encounter that students need only understand to make sense of the text at this moment. However, a few terms, such as "solidified," "destructive," and "constructive" can become words we earn if students continue to use and develop an understanding of those terms beyond this reading.

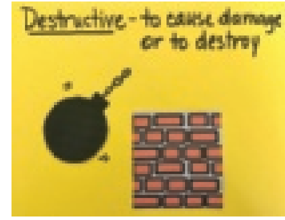
Supporting Emerging Multilingual Learners:

Provide opportunities for emerging multilingual students to break down the meaning of scientific terms used in the lesson. Provide an opportunity to discuss any preconceptions about the meaning of each term and draw upon their personal experiences to make sense of them.

For example:

- Use students' prior knowledge of the word **solid** to help them understand that **solidified** means to become solid, and use examples, such as water **solidifying** into ice when it is placed in a freezer.
- Use students' personal experiences with words such as **construct** and **construction** to help them make sense of **constructive** processes, which build up or create new land or landforms.

Add to the Word Wall. Say, *As we read about ways in which volcanoes can change the surface of Earth, we were introduced to a few unfamiliar terms. We have worked together using a variety of strategies to determine what these words mean, and I think we can add two of these terms to the Word Wall as "Words We Encounter," because we will come across these words again.* ***Destructive*** *means to cause damage or destroy, and* ***constructive*** *means to build up.*



Write each word and its definition on a half sheet of paper or 5x8 index card, and draw a simple diagram for each. Add the half sheets of paper or index cards to the "Words We Encounter" section of the class Word Wall.

- Use students' experiences with words like **destroy** and **destruction** to help them understand that **destructive** processes are those that break down landforms and earth materials.

Additional Guidance

Though we are using the words "constructive" and "destructive" as a way to describe what events that occur at and below Earth's surface, such as volcanoes, can do to land, we are not going into the full mechanism that explains constructive forces and destructive mechanisms that occur on other places than mountains. We don't talk about mass wasting, seamounts, valleys, etc. We also don't address that these processes (constructive and destructive) happen at different rates and scales from continental masses comparative to ocean floor masses.

Share key ideas from the reading and revisit the class data chart. Show **slide O** and point to the chart paper that has our two questions written at the top. Remind students that we want to share key ideas from the reading that will help us answer these two questions:

- Why are volcanoes found where an oceanic plate collides with a continental plate?
- Can volcanoes cause the kinds of changes we see at the remaining 3 mountain sites in our chart—Mt. Aoraki, Mt. Aconcagua, and Mt. Hotaka?

As students share, document the key ideas as a bulleted list below the two questions on the chart paper. Look for the following key ideas to surface:

- Volcanoes are openings in Earth's crust (or plates) that allow melted rock, steam, and other gases from below the plates to be released.
- They are most often found close to a boundary between oceanic and continental plates.
- Oceanic plates have water soaked into the sediments at the top of the plate.
- Oceanic plates are more dense than continental plates, so when they collide, the oceanic plate will move below the continental plate.
- As an oceanic plate moves under a continental plate, the rock and sediments melt and the water boils and becomes steam. These melted materials and steam from the oceanic plate move upward through the openings in the continental plate and out of Earth through volcanoes.
- Volcanoes can slowly create new land or land forms as lava pours out and solidifies into new layers of rock. These layers build up over time as eruptions continue to bring lava to the surface.
- Volcanoes can also quickly destroy mountains and other landforms when lava, steam, and gases explode with great force from within Earth.

*Supporting Students in Developing and Using Scale, Proportion, and Quantity

In lesson 6 and the current lesson, students have engaged with models that represent larger scales that would otherwise be unobservable for students due to their spatial or temporal limitations in the classroom. At this point, pause to reflect on the usefulness of these models representing these larger scales and how they helped students see and make sense of the relationship between these otherwise unobservable events of plate movement and volcano formation. After the exit ticket it is recommended to have students share out their ideas on how this scale representation has aided their understanding.

After key ideas are documented on the chart, ask students how this reading has helped them better understand the process of oceanic plate material colliding with continental plate material, and what new parts helped them build upon the limitations of the foam model. Students may mention ideas such as the foam model did not allow for melting of the plate, which we saw in the reading. After revisiting the limitations of our past model, ask students if there are any other things we can now better explain, such as other specific mountains with volcanoes present.

Show **slide P** and tell students to have small group conversations about the questions on the slide:

- Are any of the remaining 3 mountains—Mt. Aoraki, Mt. Aconcagua, or Mt. Hotaka—actually active volcanoes?
- Can an eruption of a volcano increase the elevation or size of surrounding mountains? Why or why not?
- Can a volcano cause a mountain to move? Why or why not?

Remind students to use the *Data Cards for Other Mountains and Mt. Everest* from Lesson 1 to help them with the first question. Give them time to find the information they need and to discuss the questions. Encourage them to use evidence and reasoning to support their responses to the questions.

After a few minutes, revisit the class data chart and say, *Let's revisit our class data chart and look at the data we have recorded for the remaining 3 mountain sites—Mt. Aoraki, Mt. Aconcagua, and Mt. Hotaka. Do volcanoes cause the changes in location and elevation that occur at these three sites? Turn and talk with your small group and be prepared to share a claim with supporting evidence.*

Let students again talk with their small group, then use the questions on **slide Q** to give students the opportunity to share their thinking and their final claim. Remind them that they should use evidence and reasoning to support their ideas.

Suggested prompts	Sample student responses
Are any of the remaining 3 mountains—Mt. Aoraki, Mt. Aconcagua, or Mt. Hotaka—actually active volcanoes?	*Only Mount Hotaka is an active volcano.* *There are active volcanoes near Mount Aoraki and Mount Aconcagua, but neither is an active volcano.*
Can an eruption of a volcano increase the elevation or size of surrounding mountains? Why or why not?	*We don't think that a volcano can increase the elevation or size of surrounding mountains, because the lava would first flow down the volcano and then would have to flow up the surrounding mountains to increase their size or elevation.* *A volcano can only add new material to itself and to the land below it.*
Do volcanoes cause mountains to move?	*Volcanoes can be destructive. A volcano can erupt violently and blow away parts of itself, but it doesn't move or change location.* *We did not find any evidence that an eruption from a volcano could move itself or any other mountain.*

***Attending to Equity**

Universal Design for Learning: Some students may be ready to write a more extended response to question 2 at this point. The question refers to manipulables students used in both Lesson 6 and this lesson to allow those students who are ready to extend their *engagement* beyond just this lesson to synthesize what they have figured out up to this point in the unit in regards to causal and correlational relationships. If students are ready to make this connection, add in another question after Question 2 that asks how the changes that occur to cause volcanoes are similar or different than the processes that cause earthquakes to occur, and how this is related to the scale of the changes observed. Extend the existing second question on the slide to encompass earthquakes as well.

As students share their thinking, complete the class chart. A completed example is below:

Site	Types of Changes (yearly)		Event (yes or no)		Are the changes to the mountain caused by volcanoes?
	Location	Elevation	Volcanoes	Earthquakes	
Mt. Everest	4cm NE	6-7cm increase	no	yes	No, there are no volcanoes nearby
Mt. Mitchell	3cm W	decreasing	no	very few	No, there are no volcanoes nearby
Mt. Aoraki	7cm N	1-2cm increase	yes	yes	No
Mt. Aconcagua	3cm N	10cm/10yrs avg. increase	yes	yes	No
Mt. Hotaka	1cm SE	4mm increase	yes	yes	The change in location is not, but the increase in elevation might be, since Mt. Hotaka is an active

Consider the role of volcanoes in mountain movement. Project **slide R**. Ask students to turn to a new page in their science notebooks. Label this page, "Volcanoes and mountain movement." Read over question 1 on the slide with students and explain that students should use our sources of evidence from our current and previous lessons to support an argument for whether volcanoes do or do not contribute to mountain movement. Read question 2 with students and ask students to consider how the smaller scale of the manipulatives they used to figure out what is happening when plates moved has helped them answer their first question relating the causal relationship between plate movement and volcanoes. Ask students to reflect on the usefulness of the manipulatives to better understand the larger scale processes of plate movement and volcanoes. Students may also include the relationship of earthquakes from the prior lesson as they reflect on this question, but it is okay if they only reflect on volcanoes.**

Assessment Opportunity

Building towards 7.A: Apply scientific ideas and evidence to construct an explanation for the processes that cause some of the large scale interactions of Earth's plates that result in the effects (volcanoes) of those interactions.

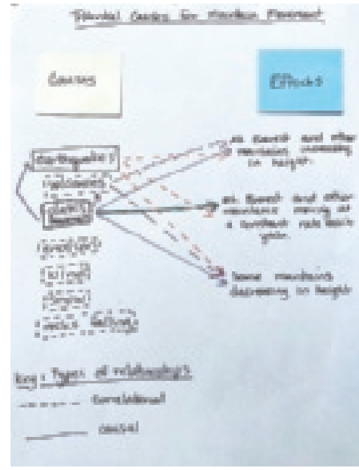
What to look for: Look for students to use evidence from the Seismic Explorer map images, the *Data Cards for Other Mountains and Mt. Everest* from Lesson 1, and *How are Volcanoes Formed and What Kinds of Changes Do They Cause?* to describe the processes that play a role in the development of volcanoes and the changes that volcanoes cause to the surface of Earth. (See the key ideas listed above.) Some examples of what students might argue:

- We know that volcanoes do not cause mountains to move, so we can claim that none of the changes in location were caused by volcanoes at or near any of the mountain sites.
- We also know that volcanoes can create new landforms or build up existing land when lava flows out and over the top of a volcano.
- But a volcano can only add to its own height, not the height of surrounding mountains.
- So, the only mountain that might possibly be increasing in elevation because of volcanic eruptions is Mt. Hotaka because it is the only active volcano in our list of 6 mountain sites.

What do do: If students do not correctly describe the interaction between the oceanic plate and the continental plate, you can:

- Have students work with partners or in small groups to review the reading and look for evidence of the processes that play a role in the development of volcanoes and the changes that volcanoes cause to Earth's surface.
- Have partners or small groups develop models using pictures, words, and/or symbols that show:
  - how volcanoes are created from the collision between a denser oceanic plate and a less dense continental plate; and
  - the constructive and destructive changes that volcanoes cause at the surface.

Materials: 5 x 8 index card or half sheet of paper, science notebook, markers



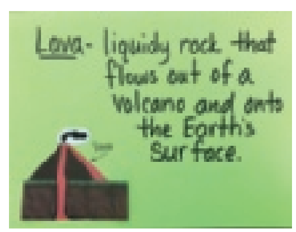
Summarize what we have figured out. Show **slide S** and ask students to think about the lesson question on the slide: What happens at mountains where we see volcanic activity? Have them turn and talk to a partner, then ask someone to summarize what we have figured out. Look for the following ideas from students:

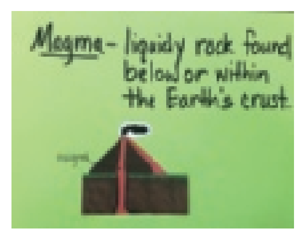
- Volcanoes occur in some of the same places where earthquakes occur.
- Volcanoes occur in lines where an oceanic plate collides with a continental plate.
- When a more dense oceanic plate collides with a less dense continental plate, the oceanic plate moves under the continental plate.
- The portion of the oceanic plate that moves below the continental plate begins to heat up, causing the bedrock and sediments to melt and the water in the sediments to boil.
- The melted earth materials and steam move upward through openings in the continental plate. These openings are called volcanoes.
- When the melted earth materials and steam move through the bedrock and break through the surface, this is a volcanic eruption.
- Volcanic eruptions can cause mountains to grow in height when new earth material is added, or shrink when existing earth material is scattered.

Update the Potential Causes for Mountain Movement chart. Say, *Let's revisit our* Potential Causes for Mountain Movement chart *and revise it to represent what we figured out in this lesson about the relationship between volcanoes, plate movement and mountains moving or growing.*

Guide students to look at the chart and ask, *How are volcanoes related to mountain movement?* Students should respond that volcanoes can be caused by plate movement when plates collide, but do ***not*** cause mountains to grow yearly or move in location. Some mountains do grow or shrink in elevation when there is a volcanic eruption, but this is not a regular occurrence at the mountains we are investigating. Say, *Let's add a link between plate movement and volcanoes. Let's also draw a dotted link between volcanoes and mountains growing and shrinking since we are saying we figured out that there is a correlation with some mountains or land growing or shrinking in elevation when a volcano erupts.*

Add to the Word Wall. Say, *We have used a number of new science terms during this lesson, and we need to add these terms to the word wall.* ***Magma*** *refers to the liquidy rock that is found below or within Earth's crust. We know that the plates that make up Earth's crust are able to move because they rest on top of this layer of liquidy rock.* ***Lava*** *is the term we use to refer to the same liquidy rock when it breaks through and flows out onto the surface of Earth. We usually see lava during a volcanic eruption. We can add these two terms to "Words We Earn" on the Word Wall.*





Write each word and its definition and draw a simple diagram for each. Add the cards to the “Words We Earn” section of the class Word Wall.

Complete an Exit Ticket. Distribute a half sheet of paper or a 5x8 index card to students, and show **slide T**. Use the slide to explain the task to students, and give them two minutes to respond to the prompt on the slide. When students finish, collect the exit tickets, and ask them to tape *Reading: How are Volcanoes Formed and What Kinds of Changes Do They Cause?* into their notebooks.

ADDITIONAL LESSON 7 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.6.1.A

Come to discussions prepared, having read or studied required material; explicitly draw on that preparation by referring to evidence on the topic, text, or issue to probe and reflect on ideas under discussion.

In this lesson, students obtain information from a reading and use that information to describe the mechanisms that cause the formation of volcanoes and the changes that volcanoes make to Earth’s surface. To support students in obtaining the information they need, they use a close reading protocol to highlight key ideas in the reading. To support students in sharing and using the information they gather from the reading, key ideas are documented on a chart that students can reference when needed.

LESSON 8

What is occurring at locations where two plates are moving away from each other?

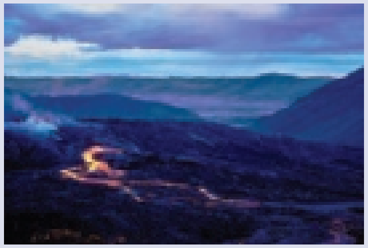
Previous Lesson

We used map images to determine where volcanoes occur, and we observed a model to describe the effects of a collision between oceanic and continental plates. Using a reading, we figured out that volcanic eruptions can add to or destroy existing landforms. We drew conclusions about the relationship between volcanic eruptions and changes that occur at the six mountain sites.

This Lesson

Investigation

2 DAYS



We establish claims about what is occurring where two plates are moving away from each other. We investigate artifacts from the Mid-Atlantic Ridge to analyze evidence to support or refute our claims. We evaluate our claims as a class to determine whether our evidence supports or refutes each claim. We discuss what is occurring at the Mid-Atlantic Ridge and determine that magma from the mantle is slowly creating new plate material at the ridge. We update our Potential Causes for Mountain Movement chart to show that pressure from the mantle is pushing on the plates, causing them to move, which causes the observed mountain changes.

Next Lesson

We revisit our Potential Causes for Mountain Movement chart and develop a causal chain of events that lead to a mountain moving or growing. We revisit the DQB to see what questions we can answer. We make predictions about what we think the Andes Mountains and the Mid-Atlantic Ridge would look like in the future and what it looked like in the past.

Building Toward NGSS

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

What Students Will Do

8.A.1 Support or refute a claim orally and in writing, based on evidence from multiple locations over a large distance along the ridge to explain what is happening where two plates are moving apart.

8.B Compare data and evidence from the case cards and the Mid-Atlantic Ridge to determine that volcanoes are correlated with some cases of mountain change, but not the cause of all mountains changing.

What Students Will Figure Out

- Plates are moving apart along the Mid-Atlantic Ridge.
- Scientists call the place where two plates are moving apart a ridge.

- Magma from the mantle is pushing up from under the plate, which can be seen in places like volcanoes and fissures in Iceland and along ridges.
- New oceanic plate material is being formed at ridges.
- The pushing of magma on the plates causes the plates to move, which causes changes to mountain elevation and location over time.

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**ESTABLISH CLAIMS ABOUT PLATE SEPARATION AREAS** Look back at the last lesson and predict what is occurring at places where two plates are moving apart.	A	chart paper, markers
2	10 min	**DETERMINE LOCATION FOR EVIDENCE COLLECTION** Identify the Mid-Atlantic Ridge as a place to collect evidence to support or refute our claims.	B	*Seismic Explorer Plate Movement Map*, Mid-Atlantic Ridge Plate Boundary Line (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	6 min	**INTRODUCE MID-ATLANTIC RIDGE STORYMAP** Go over the storymap layout and *Evidence Tracker* as a class.	C-D	*Evidence Tracker*, Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	15 min	**USE MID-ATLANTIC RIDGE STORYMAP TO COLLECT EVIDENCE** Work in partners to analyze artifacts and record evidence from the Mid-Atlantic Ridge storymap. Consider whether the evidence helps to support or refute our claims.	E	*Evidence Tracker*, Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), optional: *Mid-Atlantic Ridge Storymap Images*
5	6 min	**REVISIT CLAIMS ABOUT THE MID-ATLANTIC RIDGE** Reflect on the evidence from the Mid-Atlantic Ridge storymap to determine if the evidence supports or refutes our initial claims.	F	*Evidence Tracker*
				End of day 1
6	6 min	**REVISIT CLAIMS FROM LAST CLASS** Revisit claims made on *Evidence Tracker*. Share ideas with a partner.	G	*Evidence Tracker*
7	10 min	**REVIEW EVIDENCE AS A CLASS IN A SCIENTISTS CIRCLE** Share out important evidence from each artifact on the Mid-Atlantic Ridge Storymap.	H-J	*Evidence Tracker*, Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), *Mid-Atlantic Ridge Artifact Evidence*

Part	Duration	Summary	Slide	Materials
8	10 min	**DISCUSS EVIDENCE AND HOW IT RELATES TO CLAIMS** Go over evidence collected to support or refute claims made by the class. Make connections between what we see happening at the ridge and what is occurring when two plates move apart.		*Evidence Tracker, Potential Ridge Claims and Evidence*, Class Claims for What is Happening at the Ridge chart
9	10 min	**UPDATE POTENTIAL CAUSES FOR MOUNTAIN MOVEMENT CHART** Revisit the *Potential Causes for Mountain Movement* chart to determine that magma is the cause of plate movement, but not always a cause of changes in mountain elevation and location.	K	Potential Causes for Mountain Movement chart, markers
10	6 min	**DETERMINE REASON FOR MAGMA MOVEMENT** Revisit learning from previous units *Cup Design Unit* and *Storms Unit* to determine the mantle is rising and pushing on the crust due to density changes in the mantle.	L-N	*Storms Unit* consensus model if available
11	3 min	**UPDATE PROGRESS TRACKER AND NAVIGATE TO NEXT LESSON** Update the Progress Tracker and consider what is happening on the other side of the South American plate.	O	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 8, students are ready to read Student Reader Collection 3 and then respond to the writing exercise.		Student Reader Collection 3: *The Rocking Rock Cycle*

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebooks • *Seismic Explorer Plate Movement Map* • *Evidence Tracker*	• Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • optional: *Mid-Atlantic Ridge Storymap Images*	• chart paper • markers • Mid-Atlantic Ridge Plate Boundary Line (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Mid-Atlantic Ridge Artifact Evidence* • *Potential Ridge Claims and Evidence* • Class Claims for What is Happening at the Ridge chart • Potential Causes for Mountain Movement chart • *Storms Unit* consensus model if available • science notebook

Materials preparation (15 minutes)

Online Resources

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

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

Day 1:

- Test both to make sure they are compatible with both student and teacher devices. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- Optional: Print a copy of *Mid-Atlantic Ridge Storymap Images* for students who cannot access the storymap. A copy of this document can also be found in the student procedures.

Day 2:

- Make sure the *Potential Causes for Mountain Movement* chart is located in an easily viewable location.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will explore the Mid-Atlantic Ridge to determine what occurs in places where two plates are moving apart. Students will observe artifacts from the Mid-Atlantic Ridge that will help students visualize plate building processes and understand that the creation of new oceanic plate material happens over a long timespan. Students are guided to specifically identify Iceland as a source of evidence because the plate boundaries and ridge are visible without being underwater in this location. Students will observe areas that are seemingly actively changing and moving, while others, such as artifact #1, have not visibly changed in a while. Students will also be able to observe magma and lava making changes to the surface in the form of new plate material, and compare this to what they already know about volcanic activity.

Over the course of the lesson, students will develop an understanding that new plate material forms as magma surfaces from the mantle. The mantle pushes on the plates, which causes them to move, leveraging learning from *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)* and *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* to better understand this process of how heating and cooling affects the movement of the magma and plates. As plates move, mountains change in elevation and location. Students connect the formation of new plate material with plate movement, which causes changes in elevation and locations of mountains.

Where We Are NOT Going

Hotspots will not be discussed until high school, as the mechanisms for explaining them are above grade band. Scientists debate whether Iceland could be designated as a geological hotspot, or whether its geologic activity is due to the plate boundary. We focus on activity that can be associated with plate boundaries, which tend to occur on the surface in the southern region of Iceland.

This lesson will also discuss the role of the convection in Earth's interior as a driving force for plate movement. While the majority of the mantle is solid and convecting, this lesson will only focus on the observable liquidity of the extruding mantle and its interactions with the crust. This lesson will not go into detail about why portions of the mantle are liquidy. Pressure and water help cause the liquidity of the materials coming out of the mantle through the crust. The role of pressure in this interaction and how the pressure can be altered by the presence of water is a high school grade band idea.

This lesson will also not explain why areas such as the space between the plates at the Bridge Between Continents artifact have sand-like material. The processes that contribute to this (weathering, erosion, deposition) will be explored in later lessons after students have developed an understanding of the processes that contribute to increases in elevation or plate material. The processes that contribute to the destruction or breaking down of material will be encountered in Lesson Set 2.

1. Establish claims about plate separation areas.

8 MIN

Materials: science notebooks, chart paper, markers

Revisit claims about what is occurring between plate edges that are moving apart. Project **slide A**. Give students a moment to re-read their claims about what happens at the place where two oceanic plates move apart, and make any changes they want to their ideas.

- Look back at your claims from last class.
- Make sure your claim explains what you think is happening between the two plate edges as the plates are moving apart. You can revise your claim as needed.

Additional Guidance

During this lesson, students will use evidence to evaluate their claims about what is happening between the two plate edges at the Mid-Atlantic Ridge. Common ideas from prior lessons that can be used in students' claims can be found below. Note that these are potential student ideas, and not all are accurate descriptions of what is occurring at the Mid-Atlantic Ridge, as we will learn in this lesson.

- Magma from the mantle/lava could be escaping or filling in the space between the plates (from Lesson 7).
- Volcanoes are forming along the ridge (from Lesson 7).
- New mountains are being formed (from labeling potential mountain ranges in Lesson 2).
- Earthquakes are breaking apart the plates, but nothing is filling with magma, just creating a canyon or gap (from Lesson 2 and Ridgecrest findings).

Determine how to decide which claims are accurate. After 2-3 minutes, bring the class back together. Point out that the class shared a variety of claims. Say, *Up to this point, we have figured out what happens when plates move towards each other or slide past each other, but we still don't know what happens when plates are moving apart. Last class, we figured out that in areas on Earth where there are volcanoes, there are openings in Earth's crust.*

Ask a few students to share their claims. Lead a discussion to motivate the need to collect evidence for what is occurring at the ridge. Example prompts and responses are below.

Suggested prompt	Sample student responses
As I read your exit tickets I noticed many of you had claims about what you expect would be happening where two plates are moving apart related to volcanoes and there are also a few different claims about what could be occurring at the places where plates are moving apart. How could we figure out if our specific claims are accurate? What evidence would we need?	*My claim is that we would be able to see the mantle there. If they are moving apart, then there is probably an opening in Earth. If the gap goes all the way down through the bedrock in the plate, we would see the mantle.* *I think there are volcanoes where plates move apart because there would be an opening in Earth, so we should see volcanoes up and down the plate edges.* *I think there is a gap in Earth, so we would need to get evidence on what is happening to the land inside or around the gap so we could figure out how Earth's surface might look there.*

Say, *We figured out that when plates move and collide, volcanic eruptions can occur. On our* Potential Causes of Mountain Movement *chart, we connected plate movement to volcanoes. We also figured out that when this happens magma comes up to the surface. So now we are wondering what is happening when plates move apart.*

Suggested prompt	Sample student responses
What would we expect at the opening between two plates moving apart if volcanoes are actually a cause of mountain formation?	*We would see mountains being made or growing.* *We would see long lines of volcanoes where the mountains are located.*

Say, *Okay, it sounds like we should go analyze some data about what is happening where two plates are spreading apart.*

2. Determine location for evidence collection. 10 MIN

Materials: *Seismic Explorer Plate Movement Map*, Lesson 8 3D Mid-Atlantic Ridge Plate Boundary Line (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Say, *Let's look back at our map and see if we can locate a place that appears to have mountains where two plates are moving apart to see if volcanoes are also there.*

Project **slide B**. Distribute a copy of *Seismic Explorer Plate Movement Map* to students. A colored copy of this material can also be found in the Student Procedure Guide. Give students a moment to orient themselves to the image of plate motion from Seismic Explorer. Explain that this map shows general directions of plate movement from the plate boundaries. Ask students to turn and talk to a partner about the prompts on the slide.

- Do we see any locations where there are plates moving apart?
- Do any of these locations also appear to have mountains?

Locate an area of plate separation with potential mountains. Allow students to share their ideas of where plates are moving apart using the arrows on the map, and locations for where mountains also form. Two areas of interest to students might be the plates moving apart in the South Pacific Ocean and the Atlantic Ocean. Guide students through a discussion to conclude that the place of interest is called the Mid-Atlantic Ridge by referencing past noticings of potential mountains underwater. Example prompts and responses are below.

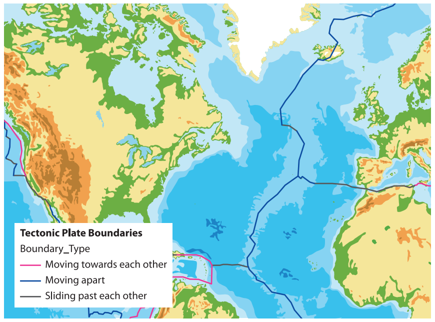
Suggested prompts	Sample student responses
Where do you notice plates are moving apart, or away from each other?	*in the area in the South Pacific* *between North America and South America and Africa and Europe* *between North America and Europe*
Do we have data from previous lessons that may indicate mountains at any of these locations?	*between North America and South America and Africa*
What have we called this location between North America and South America and Africa where plates are not only moving apart, but also where mountains form?	*the Mid-Atlantic Ridge*

Explain that since this is a large feature on Earth's surface, scientists and geographers have a specific name for this feature, the Mid-Atlantic Ridge.

Additional Guidance

Some students may wonder why this location is called a ridge. At this point, students have not discussed the connection between ridges and mountains. You can ask students why this feature may be called a ridge, and where we might find ridges on land. Listen for students to make connections to mountain ridges. Ask students why they think scientists and geographers have called this a ridge. Students should mention that this location may have mountain-like features.

Use a map to determine potential data collection areas. Display the map located at the web page (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Make sure all students can see the projection. Open up the key and allow students to see that the yellow line shows the area where the two plates are moving apart. Explain that we need to identify places where we might be able to easily collect evidence to support or refute our claims, just like at Ridgecrest. Zoom in and out of the map as the class looks along the ridgeline. Allow students to share their ideas of where we should investigate.



Guide students to determine that while most of the ridge is under water, Iceland is on the ridge and above sea level. And since it is above sea level, we will be able to see if there are mountains there. Examining Iceland could allow us to easily see what is happening at the ridge, since people live there and have been observing the land for a long time. There are also some more shallow ocean areas that are closer to the surface that might be easy to collect data from. By examining this region of the ridge, we can potentially collect a lot of data to support or refute our claims. Example prompts and responses are below.

Suggested prompts	Sample student responses
Let's look at the ridge together. What features do we see along the ridge?	*We see a lot of water and the ridge itself.* *There's an island or country up towards the top.*
What do we know about the ocean?	*It's really big.* *It's deep in places.* *There's a lot of water there.*
So if the ocean is really big, and this ridge in the middle of the ocean is too, is there a place that we can look at where data might be easier to find? Just like we looked at Ridgecrest, is there another area that may be closer or easier to observe than others?	*There might be some shallow places in the water—maybe we can look there.* *There's an island or country. Maybe we can check that out.*
Great. Let's look at the area on and around that island, which is the country of Iceland.	

Say, *Now that we have identified an area to observe, let's use that area to collect data to either support or refute our claims.*

3. Introduce Mid-Atlantic Ridge storymap.

6 MIN

Materials: *Evidence Tracker*, Lesson 8 Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Orient to the Artifacts from the Mid-Atlantic Ridge storymap. Project **slide C**. Say, *Iceland is a popular destination for many people, including tourists, scientists, naturalists and people wanting to live there. Because of this there is a plethora of artifacts from the area that we can analyze to help us in figuring out what is happening where these two plates are separating.*

Say, *Thinking back to the claims we have about what we think is happening at the place plates are moving apart, talk with a partner about the questions on the slide.* Give students a moment to turn and talk to a partner about the prompts on the slide. Since the term *refute* may be new to students, take a moment to explain what the word *refute* means.

- What type of evidence might we look for to support or refute our claims?
- Why would we look for evidence that could possibly refute a claim?

Allow students to share their responses with the class. Guide students to determine the following:

- We are looking for evidence to support or refute our claims about what is occurring at the ridge when two oceanic plates are moving apart and whether there is a link between volcanoes and mountains changing.

- We need to look for evidence that refutes claims because it will help us know if we should revise our thinking.
- We need to look for evidence that refutes claims because we are trying to figure out what is actually happening at the ridge, and if we find evidence that refutes our claim we might need to revise it.
- We are not looking just for evidence that supports our claim, we are looking for any evidence about changes happening at the ridge.

Ask students, *What do we consider to be good evidence to either support or refute our claims? What would not be considered good evidence?*

Students should identify that evidence is anything like images or data we analyze, that helps to support or refute our claims, like what the ridge landform looks like underwater. Something that is not evidence is anything that is not related to the supporting or refuting of our claims, such as what animals or people are doing in the images, or what the sky might look like.

Preview the storymap with students. Open up the Mid-Atlantic Ridge storymap at the web page (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Walk through the first map at the top of the storymap that shows where each artifact is located. Point out that we have many artifacts from Iceland, and a few from different areas in the Atlantic Ocean. Zoom in on Iceland and show students that while the artifacts appear to be close together, they are from different places so students will want to zoom in and out as they explore.

Additional Guidance

This storymap utilizes a flat map that can distort actual sizes of locations, leading some students to believe that some continents, countries, or regions are larger or smaller than in reality. This map represents Iceland being as large as the entire Northeastern part of the US, when in reality, Iceland is slightly smaller than Kentucky. To support students in understanding how the form of the representation can change depending on whether it's 3D or 2D, distribute small handheld globes to your students and ask them to compare how Iceland is represented on the 3D globe compared to the 2D map. Explain that our storymap was formed by taking the map of Iceland, which is located on a round globe, and was flattened to make it 2D, which may cause parts to be stretched.

Introduce *Evidence Tracker*. Display slide D. Explain to students that we have an organizer that will help us record evidence to support or refute our claims we have made about what is occurring at the ridge as we gather evidence from our storymap. Explain that *Evidence Tracker* has a row for each artifact. Point out each row has different columns. Show students that the first column reflects the artifact number, the second column reflects the evidence we will record, and the third column can be used to give initial ideas on whether the evidence supports or refutes our claims.

Say, *As you work through this handout, look at the evidence you recorded from each artifact and think about whether the evidence supports your claim. If it does, then mark the box next to support. If the evidence does not support your claim, then it refutes your claim. If that is the case, then mark the box next to refute.*

Before starting, give students a moment to write their claims from the last class at the top of the page for quick reference as they work through this task. Tell them it is okay if they don't remember the exact wording they used in the previous class or if they have revised their thinking and therefore their claim since then.

4. Use Mid-Atlantic Ridge storymap to collect evidence. 15 MIN

Materials: *Evidence Tracker*, optional: *Mid-Atlantic Ridge Storymap Images* Lesson 8 Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Collect evidence in partner pairs. Project **slide E.** Organize students into partner pairs and allow students to analyze the evidence from the Mid-Atlantic Ridge storymap. Note: If using paper materials in lieu of the virtual storymap, you will need to project the Artifact 7 video from the storymap website.

Circulate as students view each artifact. As students are working together, encourage students to consider the questions below the description of each artifact. While students are working, go from pair to pair to ask students about the evidence they have collected and whether it supports or refutes their claims and why. Students should be able to make the following general observations:

- A gap exists between the two plates, but this gap has been filled in with rock.
- Some gaps look like they have been around or stable longer due to the presence of plants and other features.
- Some areas show magma coming up through cracks or gaps in the ground.
- The rocks between the plates is basalt, which is what our oceanic plates are made from.
- It is much hotter where the plates seem to be active and we see hot steam or hot springs or magma coming up.
- Parts of the underwater ridge are higher in elevation and look like a mountain range.

For further guidance, specific observations for each artifact can be found in *Mid-Atlantic Ridge Artifact Evidence*.

Additional Guidance

To help students identify relevant evidence, try asking the following questions:

- Do you see evidence of two separate plates?
- What is happening in between the two oceanic plates?
- Do you see anything new or old between the oceanic plates?
- Is there any evidence of change to Earth's surface that can support your ideas for what happens when two oceanic plates move apart?
- How is this artifact evidence similar or different from the evidence you collected in another artifact?

5. Revisit claims about the Mid-Atlantic Ridge. 6 MIN

Materials: *Evidence Tracker*

Revisit individual claims. Project **slide F**. With roughly 6 minutes remaining, ask students to individually look back at their claims on the top of their handout. Give students a moment to consider their claim and write whether the evidence they have recorded supports or refutes their claim and why.

Direct students to look at the last question on *Evidence Tracker* and give their reasoning. Say, *Look back over the evidence you analyzed from each artifact and whether the evidence helps to support or refute your claim about what happens when two oceanic plates move apart. On the last question explain what evidence helped you support* ***or*** *refute your claim, and why.*

Additional Guidance

Some students may not be comfortable with having evidence that refutes their initial claims. Remind students that just like we continue to revise our models and thinking in class, scientists too, make and revise their claims based on evidence they've gathered. Explain that at the end of this lesson we will have the opportunity to review the claims as a class and see how our new learning has revised our understanding of what is occurring at the ridge.

Assessment Opportunity

8.A.1 Support or refute a claim in writing and orally, based on evidence from multiple locations over a large distance along the ridge to explain what is happening where two plates are moving apart.

What to look/listen for: Look for students to cite evidence that is relevant to their claim and use the evidence to explain whether their claim is supported or refuted. See *Individual Potential Claims and Evidence* for further guidance on what evidence to look for to support and refute claims.

What to do:

- If students have cited evidence that incorrectly supports or refutes their claim, press students to explain how the evidence is related to their claim. Point to specific evidence that would help students support or refute their claims, and ask them to critically consider how the collected piece of evidence helps them to explain the validity of their claim.
- If students have listed irrelevant evidence in their chart, revisit the evidence collected with the student, and ask if the evidence helps the student try to explain what is happening at the ridge, or if it is a disconnected observation. Push students to explain the connection and how it could be used to support or refute a claim.

Collect *Evidence Tracker* from students prior to day 2 to formatively assess their claims. This assessment can also occur quickly at the beginning of day 2 as students are orally sharing their claims with a partner and the teacher circulates to question students and observe their thinking.

End of day 1

6. Revisit claims from last class.

6 MIN

Materials: *Evidence Tracker*

Share claims and evidence with a new partner. Project **slide G.** Distribute *Evidence Tracker* back to students that was collected at the end of the last class period. Direct students to turn to a partner that they were not working with the previous class period. Ask students to share with their partner if they felt their claim was supported or refuted by any specific evidence from the storymap and how that evidence helped to support or refute their claims.

Use the protocol listed on **slide G** to help students structure their conversation.

- Partner A will share their claim and their evidence used to support or refute their claim.
- Partner B will listen and give feedback to Partner A about:
    - Whether their evidence supports or refutes the claim.
    - What evidence could also be used by Partner A to help make their argument stronger.
- After partner A has shared, Partner A and Partner B will change roles. Partner B will share their claims and Partner A will give feedback.

Update evidence and reasoning on handouts. Allow students to modify their evidence and reasoning as needed on their handouts.

Assessment Opportunity

8.A.2 Support or refute a claim in writing and orally, based on evidence from multiple locations over a large distance along the ridge to explain what is happening where two plates are moving apart.

What to look/listen for: Listen for students to explain whether the evidence supports or refutes their claims, and give feedback to their partners on whether their evidence is sufficient for supporting or refuting their claims. See *Individual Potential Claims and Evidence* for further guidance on what evidence to look for to support and refute claims.

What to do:

- As students are sharing their claims, ask students if their partner's cited evidence would help to support or refute their claim, and to explain why.
- Point to specific evidence that would help students either support or refute their claims and ask them to critically consider how the collected piece of evidence applies to their claim.

7. Review evidence as a class in a Scientists Circle. 10 MIN

Materials: *Evidence Tracker, Mid-Atlantic Ridge Artifact Evidence,* Lesson 8 Artifacts from the Mid-Atlantic Ridge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Revisit each artifact and share evidence. Project **slide H.** Bring students together in a Scientists Circle with their copies of *Evidence Tracker.* Ask students to share any evidence that they collected about what is happening where the plates are spreading apart. As students share, guide the class to bring out ideas listed in *Mid-Atlantic Ridge Artifact Evidence* during this step. After evidence has been shared for items on **slide H**, proceed to show **slides I-J** and allow students to share evidence from those artifacts as well.

Additional Guidance

At this point in the lesson, students are not asked to explain how each piece of evidence they are sharing supports or refutes their claims. Evidence is being shared to make sure all students are able to see and understand the key features from each artifact. This broad sharing of evidence will aid in the next step as students create a *Class Claims for What is Happening at the Ridge* chart and identify how some of our claims are supported by our evidence.

Sample questions to ask students:

- What evidence did you see happening in between the plates in artifact X?
- Was anything changing in this artifact, or did we see any evidence of change?
- Was there anything that you expected or that was unexpected in the artifact that you might have cited as evidence for your claim?
- What type of landforms do we see in this artifact? What are they made of? Are they old or new?
- Is there any evidence of change or movement that might be important to what is occurring at the ridge?

8. Discuss evidence and how it relates to claims.

10 MIN

Materials: *Evidence Tracker*, *Potential Ridge Claims and Evidence*, Class Claims for What is Happening at the Ridge chart

Review claims made by partners and create a class record of claims. Ask students to turn and talk with a partner about their claims, and whether they think we are able to support or refute the different claims made by their partners. After students have had a chance to share and discuss their claims with a partner, ask students to share any claims they just discussed with their partner that they think can be supported by our evidence with the class. Make a record of the claims as students share them, either on chart paper or on a white board, and label this record the *Class Claims for What is Happening at the Ridge* chart.

Some examples of claims students will argue at this point include, but are not exhaustive:

- Magma is coming up at the Ridge.
- The plates are moving apart at the Ridge.
- A canyon is forming at the Ridge.
- The Ridge is made of a long line of volcanoes.

See *Potential Ridge Claims and Evidence* for more extensive guidance on potential student claims and ideas.

Additional Guidance

Even though students have been working with their individual claim and analyzing data to be used to support or refute their claim individually and with a peer, students have not yet had a chance to revise our claim based on the evidence they have collected. These prior steps of collecting evidence and evaluating claims have been built in incrementally for students because the data they are working with is complicated and the practice of identifying how

*Supporting Students in Developing and Using Stability and Change

Students may view volcanoes as a sudden change to Earth's surface that occurs very quickly and is short-lived, and many may believe that the only way magma comes to the surface is through these more sudden events. Evidence from the storymap allows students to see that the process of magma coming to the surface can happen over different timescales and quantities, and can make changes to the surface at varying speeds. While this surfacing of magma may seem to occur slowly at the openings in the ground seen in Iceland, this is a relatively short time when compared to the forming of to use data as evidence for a claim is a practice students are still developing. At this point, now that they have had multiple opportunities to work with their claim and the data pieces, students will work together as a class to evaluate each claim with the evidence we have to develop a class explanation of what is occurring at the Ridge.

Share evidence that supports or refutes each claim. Direct students to look again at the first claim on the *Class Claims for What is Happening at the Ridge* chart. Explain that now that we have reviewed some evidence, we can go back and evaluate our claims. Ask students to share if they think the evidence supports the first claim or refutes the claim. Allow students to discuss whether they agree or disagree with their classmates based upon the evidence. See *Potential Ridge Claims and Evidence* for potential claims made by students, evidence students may use to support or refute those claims, and suggested questions to guide the conversation with students. Note that this table does not include all potential claims that students may make, but it can serve as a starting point to help guide discussion.

Determine what is occurring at the ridge. Once all claims have been evaluated, lead a discussion with students to create an explanation about what is occurring at the ridge. Ask students to use evidence from the storymap to support their ideas as they come to consensus on what is happening at the ridge. Some ideas from below may have already been discussed during the review of the claims shared by the class. Before moving on to the next portion of the lesson, make sure that students have come to consensus that the ridge is a place of plate growth (as seen in the plate boundaries across New Zealand, both active and inactive volcanically), and that rock is filling the space between the two plates, sometimes slowly (as in the locations that appear to be more settled) and sometimes very quickly (such as the volcanic locations).*

mountains and plates. Connections to stability and change can also be made through this discussion by supporting students in understanding that magma can move slowly, as seen at fissures, and can change the surface much slower than a sudden eruption, but still occur much quicker than plates being formed or moving.

Key Ideas

Purpose of this discussion: Identify that while magma or lava may be present at the ridge, it does not mean that a line of new volcanoes or mountains are forming at the ridge. Conclude that at the ridge, magma is coming up to fill the space in between the plates that are moving apart. The plates move very slowly, and over time, the magma cools into new plate material.

Listen for these ideas:

- The ridge itself does not have large gaps that are completely open to the center of Earth.
- The ridge has areas of active movement, which can be seen from the presence of magma, and other areas that seem less active or dormant.
- The magma or lava that is coming up between the new plates is made of basalt, signaling that there is new seafloor being made.
- This process of plates moving apart is slowly changing Earth at the ridge, while over the same timescale, volcanoes are quickly changing the surface of Earth in other locations.
- Sometimes it appears that the pressure from underground forces material (water or volcanic material) up and out of the ridge.
- Volcanoes can form at the ridge, but the presence of a ridge does not mean that there will be volcanoes all along the ridge.

9. Update potential causes for mountain movement chart.

10 MIN

Materials: Potential Causes for Mountain Movement chart, markers

Say, *OK. We have discovered that there is magma coming up at the ridge and forming new oceanic plate material where the plates are moving away from each other. We also found that volcanoes can be found there, but there aren't really any new mountains formed by volcanoes at the ridge. Based on this and our mountain cases, let's look back at our* Potential Causes for Mountain Movement *chart and see if we can determine if volcanoes or magma or lava flows are linked to changes in mountain location and elevation.*

Consider the role of volcanoes and magma in mountain changes. Project **slide K.** Ask students to turn and talk briefly to a partner about the following questions:

- Do we see evidence of volcanoes or magma or lava flows causing changes to elevation and location of mountains for all of our mountain cases from our cards?
- Does this help us explain any, all, or none of our mountain cases?
    - If so, how are they causing these changes?
- What do we see the volcanoes or magma doing to the areas where they are located?

Allow students to share their ideas. Students should determine that we do not see active volcanoes or magma or lava flows at our mountain locations that could be contributing to the changes in all mountain cases. We do, however, see this at Mt. Hotoka and in the Andes, and this could be a potential cause of the changes to that mountain. We also see changes to the surface at areas where volcanoes are located, and places where we see magma, such as the Mid-Atlantic Ridge, have new plate material forming.

Revisit the role of volcanoes in mountain changes on the class Potential Causes for Mountain Movement chart. Look back at the *Potential Causes for Mountain Movement* chart as a class and point out volcanoes. Explain to students that we should update our connections to reflect what we have now figured out about volcanoes. Begin by pointing to the changes in the mountain elevation box.

Say, *Last class when we investigated volcanoes, we added a dotted line here to represent the correlation we found between plate movement and volcanoes. And in that lesson we were only looking at locations where plates collided. Now we have analyzed volcanoes in areas where plates are moving apart and our mountains are not located. Do we still feel volcanoes are correlated to changes in our mountains? Or do we think they are a cause of these changes?*

Assessment Opportunity

8.B Compare data and evidence from the case cards and the Mid-Atlantic Ridge to determine that volcanoes are correlated with some cases of mountain change and landscape change, but not the cause of all mountains changing.

What to listen for: Students should state that while there is evidence of volcanoes at some of our mountain cases, this evidence does not exist at all of the class mountain locations. We also see magma and volcanoes at some locations at the Ridge, but it is not always correlated with increases in elevation in the landscape that it is currently in. While volcanoes can cause changes to mountain elevation, this is not seen at all of our mountain cases or in all cases on our Ridge. Students should confirm with this evidence that volcanoes are correlated, but not causing changes in location and elevation to all mountain cases.

What to do:

- If students are uncertain about the evidence from each mountain supporting volcanic activity, revisit the cards for evidence of volcanic activity at each mountain card.
- If students are not sure if volcanoes are correlated or causing changes, revisit the data from the cards and what correlation and causation mean.
- Revisit this completed chart to determine that we cannot say that volcanoes cause these mountain changes at all locations, so volcanoes must be correlated.

Reflect on the correlation shown on our *Potential Causes for Mountain Movement* chart. Say, *Let's look back at our chart now that we have confirmed the dotted line between volcanoes and plate movement.*

Suggested prompts	Sample student responses
Where else do we have a dotted line to plate movement that represents a correlation?	*We see a dotted line showing earthquakes are correlated to plate movement.*
Why are we certain that earthquakes are correlated to plate movement?	*Because in Lesson 6 we figured out that when plates run into each other, it causes the ground to shake, or an earthquake to happen.*
So, if we have a dotted line for volcanoes too, then do we think the correlation is the same—that when plates run into each other a volcano happens?	*No… it seems like volcanoes happen when there is an opening between the plates and the magma comes up.*
If both are due to plate movement, what could be causing those plates to move? Do we see anything moving that could move these plates at these locations?	*The difference is that with volcanoes we see magma coming up... so maybe that has something to do with this?* *Yeah… and isn't magma rock that is really hot and melty?*

Determine the reason for the correlation between volcanoes and plate boundaries. Lead a brief discussion to determine that volcanoes signify the presence of magma from the mantle pushing on and up through the plates causing the plates to move, which in turn causes mountains to change in elevation and location. Example prompts and responses are below.

Suggested prompt	Sample student responses	Follow-up questions
What do we see happening to the surface of Earth where we see volcanoes and earthquakes changing the surface?	*At volcanoes we see magma coming out of the ground as lava.* *Sometimes we see magma exploding/coming out of the ground, like we did last lesson.* *At places with earthquakes we see cracks and damage.* *At some earthquake places we see cracks really far down.*	*Besides where we find volcanoes, where else did we see magma coming to the surface? Is this the only place we see magma coming out of the ground?* *Do we have any evidence from Lessons 6 and 7 on what could be under those earthquake locations causing them to move?*

Suggested prompt	Sample student responses	Follow-up questions
We saw magma and lava come out at some places where there are volcanoes. We also used a liquid under our plates to recreate plate movement in Lesson 6 like the liquidy rock the plates are on. Think about what we know happens to solids or liquids as they heat up. How do you think that liquidy rock behaves? What could that liquidy rock be doing to our plates?	*Maybe it's pushing on them.* *The rock and magma spews up at volcanoes that explode, so there's something with a lot of pressure to make it squirt up.* *We know that as the rock heats up it shifts and moves, so if it gets even hotter further down it might begin to flow?*	*So do things like magma just rise to the surface from the mantle? Or do you think that it has to get pushed up?*

Students should determine that we see the magma moving at these locations where we have volcanoes, and that the magma comes from underneath the crust material.

Key Ideas

Purpose of this discussion: Determine that magma from the mantle pushing on the plates causes them to move. This causes changes in mountain location and elevation. **Listen for these ideas:**

- Magma from the mantle is emerging from the ground where there are plate boundaries, and coming up with visible force in some locations, as seen in Lesson 7 and with our Ridge artifacts from Lesson 8.
- The mantle's magma is moving the plates by pushing on them, and we see that pushing happening when the magma pushes up through the surface in the form of volcanoes and fissures.

10. Determine reason for magma movement. 6 MIN

Materials: *Storms Unit* consensus model if available

Turn and talk about reasons for magma moving. Project **slide L**. Say, *We've seen magma pushing on the surface, but why do you think it is pushing on the surface? What could be causing it to push?* Allow students to turn and talk about the following question:

- What could be causing magma to push out of the surface of Earth?

Allow students to share their ideas with the class. Listen for students to say that something must be pushing on it, or making it move. Use these answers to transition the discussion to helping students think through what could be causing magma deep below the surface to rise to the surface. Draw on ideas about thermal energy transfer and conduction from earlier units, *Cup Design Unit* and *Storms Unit*.

Engage in a discussion regarding magma movement and density from previous units. As students engage in the discussion of what happens in prior units that can explain what is occurring with the magma, make connections back to instances when students have learned about or experienced movement due to density differences. Below is an example of how to lead this discussion. **Slides M-N** have been added to support students in linking prior models and ideas to their current understanding of the movement of magma. If the slides and explanation are not needed, and students have explained that this movement is due to density, ask students how this relates to prior units to help them make connections across different science content areas and ideas.

Additional Guidance

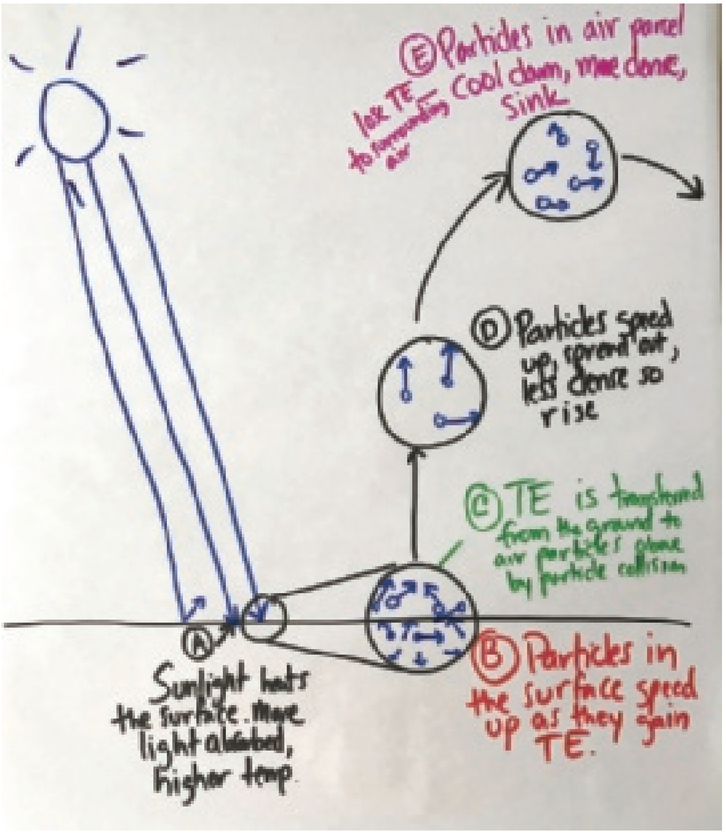
This next section of the discussion pulls heavily on what students have figured out in two units prior to this one in the 6th grade scope and sequence of the program. If your students have not experienced Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit) and/or Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit), you may need to add a little time to this discussion to support your students in developing the key ideas.

- In *Cup Design Unit*, students figure out that things on Earth are made up of particles. When these particles have energy transferred to them, they increase in speed (an increase in temperature for the material or object the particles make up). Students also figure out that particles are always moving whether part of a solid, liquid, or gas, but the movement of the particles is related to the material's state of matter. If an object is heated enough to melt, then the particles have sped up and spread apart. In addition, particles can collide with neighboring particles, transferring energy back and forth.
- In *Storms Unit*, students build on this model of particles to figure out what causes storms. They find that the sun is the source of heating the ground which in turn heats the air above it. This heating is uneven due to the materials the ground is made of, which causes the air above the ground to be heated unequally. When this happens, it results in different sections of air, or air masses, being heated differently and having different densities. Less dense air masses rise until they begin to cool down the further from Earth's surface they get, and then they become denser and sink back to the ground.
- In this discussion, students will be supported through questions to think about how a similar model could help us explain the movement of the plates due to heating of the rock from deep underground.

Suggested prompt	Sample student responses
Think back to our past units. Did we ever see evidence of something else rising to the top or surface, like we have seen the magma coming up and rising or pushing on the surface?	*We saw the food coloring rising up in the cups warmed from the bottom in the Storms Unit.* *We saw a balloon rise up when it was heated during the Storms Unit.* *We saw steam rise out of a cup in the Cup Design Unit.*

Suggested prompts	Sample student responses
What did we figure out in Cup Design Unit was happening to cause a liquid to warm up inside of a cup? *This prompt can be tailored to examples given by the class.*	*In Cup Design Unit we figured out that when particles are heated up, they transfer energy to each other and some move faster and some move slower.*
What did we figure out in Storms Unit happened to cause air to heat up?	*Sunlight heated up the ground which then heated up the air particles above it.*

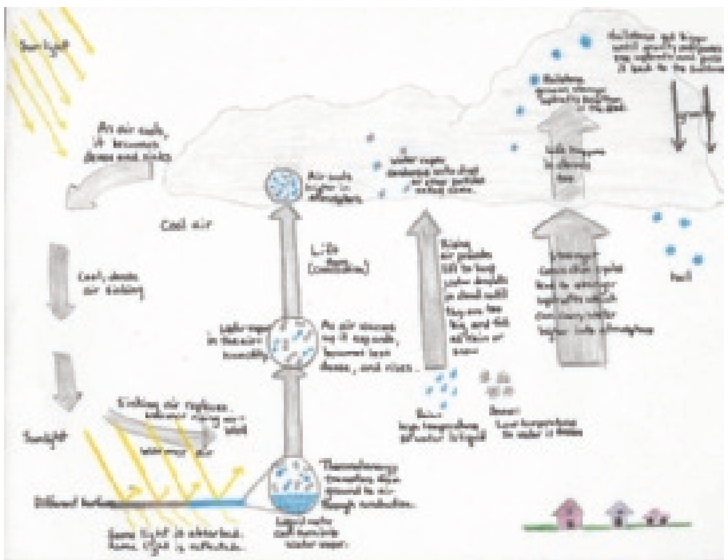
Display **slide M**. Say, *And what did we figure out was the source of that sunlight?* Students should say the sun.



Suggested prompt	Sample student responses
If the sun is the source of sunlight which is the energy that heats up things above Earth's surface, where must the source of energy that heats up things below Earth's surface be located?	*deep inside Earth* *Many many miles below the surface because it gets hotter the further down we go.*

Suggested prompts	Sample student responses
So we know the energy from sunlight causes air and water to move above Earth's surface. What does this source of thermal energy from deep below Earth's surface end up moving?	*the melted rock* *that then moves the plates*
Okay, so we also figured out in Storms Unit what happens when different parts of the ground that are different colors and were made up of different materials were heated by sunlight. What did we figure out?	*The areas of the ground that were darker, heated up faster and hotter because it absorbed more sunlight.* *Yeah and lighter colored ground heated up slower than darker because some of the light was reflected.*
And when this happened, how did it affect the air above it?	*Some sections of air would heat up faster and become less dense than other sections of air.*

Display **slide N** (or refer to the poster in the classroom from *Storms Unit* if you still have it around). Use the image of the model to remind ourselves of what we figured out happened as different sections of air heated up at different rates with less dense air masses rising and more dense air masses sinking.



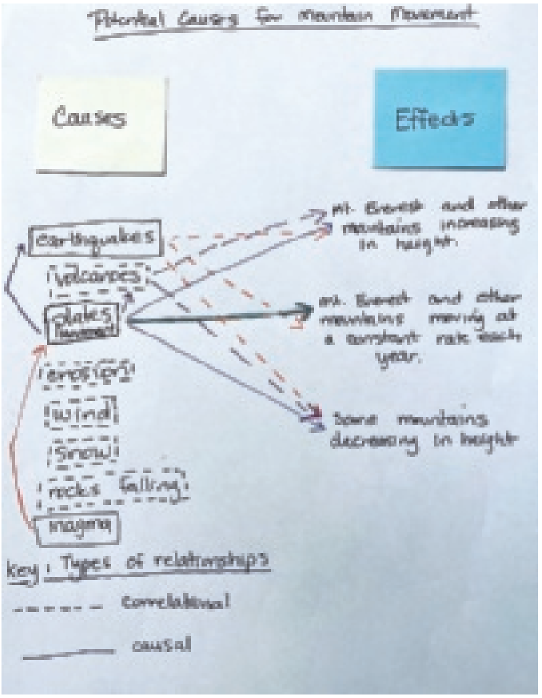
Say, *Right, we figured out that as the ground heats up, it also heats up the air above it but this doesn't happen at the same rate for all ground materials in different places at the same time, which is part of what produces less dense air masses and more dense air masses. Now let's think about how we could use these ideas to think about what might be happening under the ground.*

Suggested prompts	Sample student responses
Do you think something similar could be happening underground with different materials being heated differently in different locations around the world?	*maybe* *Yeah… we saw there are volcanoes or hot vents in different places, but not everywhere.*
So if it gets hotter the further down we go, then where will the melted rock be the hottest?	*far down below the surface*
And if the liquid, melty rock is hotter further down compared to the melted rock above it, how would the density of the rock change as it gets hotter?	*Oh… the melted rock that is hotter will be less dense than rock that surrounds it that is less hot.*
If the melted rock that is a hotter temperature is less dense than the melted rock that is not as hot of a temperature, what might happen when these interact with each other? Or are they next to each other like the air masses in the air that were of different density?	*The less dense, hotter sections of rock would rise and the denser sections would sink.*
Where did we say the hotter melted rock would be under the surface?	*far down below the surface*
Okay, so if this less dense section of melted rock is farther from the surface and rises towards the surface because it is less dense, then what might we see happening at the surface?	*We might see the melted rock coming up out of the surface!*
What are some locations on Earth where we think we have evidence of this happening?	*Mid-Atlantic Ridge* *anywhere there are volcanoes*
So if we were to look at another place where two plates were moving away from each other, like another oceanic ridge, do you think we would see the same thing?	*Yeah, we would see the melted rock coming up there too.* *Yeah the pushing of the magma moves the plates, so that would come up out of the surface if there was a crack or a break there.*
How might this movement of the less dense and more dense sections of rock affect the overall movement of the plates?	*As the less dense sections rise towards the surface, if they don't come up to the surface, then they would push on the plates.* *All that moving around is probably causing the plates to move lots of different ways.*

Additional Guidance

If students need extra support to understand that mantle material is pushing on the plates, revisit the demo from Lesson 6 where two plates are coming apart. Physically move two plates (foam pieces) apart and ask students to observe if the material under the plates (the water) comes up on it's own. Students should make the observation that it does not come up on it's own, meaning that it has to be pushed up. You could continue by asking students what differences they might see if they were to heat the water to represent the heated magma. This should help them think about how the heated water (water vapor or steam) would eventually rise and push up to the surface if heating the water.

Update the Potential Causes for Mountain Movement chart with magma from the mantle. Allow students to restate that the movement of magma within the mantle is causing plates to move and mountains to change location and elevation. Add magma to the bottom of the list of causes. Draw a line linking magma to plates on the cause side of the board.



11. Update Progress Tracker and navigate to next lesson. 3 MIN

Materials: science notebook

Update Progress Trackers. Project **slide O.** Allow students to return to their seats.

Say, *Over the last two class periods we have learned a lot about volcanoes, ridges, and magma and updated our* Potential Causes for Mountain Movement *chart. Let's take a moment to update our Progress Trackers to show what we now think is happening at the locations where two plates are moving away from each other.*

Give students time to update their Progress Trackers. Have students add *Evidence Tracker* to their notebooks.

The Rocking Rock Cycle

1 **What's That Rock?**
2 **Fossils**
3 **Building on Bedrock**
4 **Volcano Lessons**
5 **The Laws of Layers**

Literacy Objectives

✓ Summarize key points related to rocks, fossils, and tectonic plates.

✓ Distinguish cause(s) and effect(s) related to rocks, fossils, and tectonic plates.

✓ Translate text to visual/graphic representation of ideas.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 6–8.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare an If/Then graphic organizer in response to the reading.

Instructional Resources

Student Reader

Collection 3

Science Literacy Student Reader, Collection 3
"The Rocking Rock Cycle"

Exercise Page

EP 3

Science Literacy Exercise Page
EP 3

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 6: How could plate movement help us explain how Mt. Everest and other locations are changing in elevation?
- Lesson 7: What happens at mountains where we see volcanic activity?
- Lesson 8: What is occurring at locations where two plates are moving away from each other?

Standards and Dimensions

NGSS

Disciplinary Core Idea
ESS1.C: The History of Planet Earth The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4)

Science and Engineering Practices: Constructing Explanations and Designing Solutions; Obtaining, Evaluating, and Communicating Information

Crosscutting Concept: Cause and Effect

CCSS

English Language Arts
RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts.

RST.6-8.5: Analyze the structure an author uses to organize a text, including how the major sections contribute to the whole and to an understanding of the topic.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

rock cycle

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

absolute dating **igneous rock**

hot spot **relative dating**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations.

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Plate Tectonics and Rock Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *First, you will explore a field guide to some common types of rock, with close-up photos and information on how these rocks form.*
  - *Next, you'll read a science fair report about identifying fossils from a fictitious team of 10th graders.*
  - *Then, you'll read a brief technical guide to building foundations on soil or bedrock.*
  - *You'll also read the amazing explanation for how the Hawaiian Islands formed, or should I say ARE forming.*
  - *Finally, you'll read about the scientific laws that apply when interpreting layers of rock.*
- Distribute Exercise Page 3. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate an If/Then graphic organizer that summarizes key ideas from all five readings.*

Exercise Page

EP 3

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What are two kinds of igneous rock?	*basalt and granite*
Which Hawaiian island is the youngest?	*the Big Island, called Hawaii*
When you see layers in bedrock, what can you assume about the ages of the rocks in each layer?	*The oldest are the bottom layers, and the youngest are the top layers.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
Which kind of rock could have also formed from cooling lava? How?	*Since lava is magma that flows on Earth's surface, it could be basalt, which was described as a rock formed from cooling magma.*
On what kind of Earth material should the foundations for very heavy buildings and bridges be built?	*on bedrock*
What can you assume about the layers of rock on two sides of a canyon, such as in Canyonlands National Park?	*that the two sides are actually the same layers and the same ages, although geologists always check very carefully to see if this is the case because it's not uncommon for faults to run through canyons*

Exercise Page

EP 3

- Refer students to the Exercise Page 3. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to complete an If/Then graphic organizer that summarizes a key cause-and-effect relationship from each of the five reading selections.*
  - *For some readings, the "if" statements are missing, and for others the "then" statements are missing.*
  - *You may want to work on the organizer as you finish reading each selection. Or you can wait until the end and complete the task all at once.*
  - *Keep in mind that the organizer should summarize big ideas rather than small details.*
  - *The important criteria for your work are that you can distinguish between causes and effects and state the relationships accurately.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion.

(Friday)

Facilitate class discussion about the reading collection and writing exercise. Back in Lesson 3, students discussed generally how different types of rock make up bedrock. In the first reading in this collection, they will take a close-up look at six specific rock types and also see how each type looks when bedrock is exposed at the surface.

Student Reader

Collection 3

Pages 24–33 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "What's That Rock?"	*It names six kinds of rocks and describes their properties and how they were formed.*
What are some reliable ways to confirm the kinds of rocks you think you see where you live?	*Ask a local Earth science teacher or other expert.*
	Search online for a college or state website that shows rocks of my state.
	Think of a local rock formation that is well known and find online information about it written by scientists.
What do marble and limestone have in common that makes them both susceptible to acid rain?	*They must be made of the same substances because marble comes from limestone that was heated and crushed.*
What is the general purpose of the second selection, Fossils	*It is a science fair report, written by a team of high school students, about how they found the age and name of a mystery fossil.*
What is the purpose of the Discussion subheading in this selection?	*This is the subsection of the report where the students reflect on the hypothesis they made at the beginning. It also summarizes their work and makes a conclusion.*
What can you infer about the age of fossils found in the same rock layer?	*that they are about the same age as the rock and the same ages as one another*
What does "relative dating" of fossils mean?	*It means that you may not know the exact number of years old a fossil is, but you know about how old it is by comparing it to fossils with known ages.*
What is the general purpose of the third article, "Building on Bedrock"?	*It discusses building and bridge foundations and where engineers decide to set them.*
What are the advantages of building foundations on bedrock?	*Bedrock can hold a big weight without moving, giving the building stability.*
Think about what you have learned about bedrock in our investigations. Is it possible to build on bedrock anywhere on Earth? Explain.	*Yes, bedrock is the solid rock that plates are made of, so it is everywhere, even underwater.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—The term *rock cycle* is not fully explained in this unit but is referred to in the first reading. Support English learners by eliciting students' understanding of the meaning of *cycle* from other usages, such as *water cycle*, *motorcycle*, and *bicycle*. Guide application of the definition related to a repeating series of events to rocks, and have students develop operational (explaining what the rock cycle does) definitions.

EXTEND—Show students a NASA video that reinforces the information on igneous, metamorphic, and sedimentary rocks developed in the first selection and then explains how the rock cycle on Earth is similar to the rock cycle on the moon.

Pages 24–33 **Suggested prompts**	**Sample student responses**
What is the general purpose of the fourth article, "Volcano Lessons"?	*It describes how the Hawaiian Islands formed and how this relates to plate movement.*
What is a hot spot?	*a place where magma breaks through the crust*
Based on your reading and our class discussions, what do you infer the rock cycle is?	*We know that a cycle is something that happens again and again. And we read in the first reading that rocks can change. We also know that rocks on Earth wear away and produce sediments and that magma produces new rock. So the rock cycle must be all those changes repeated over long periods of time.*
What is the general purpose of the fifth article, "The Laws of Layers"?	*It describes four rules that scientists use to compare the ages of rock layers.*
What was one idea that was hard to understand in this reading? Why?	*It was hard to understand the law of cross-cutting relationships because it was hard to think of magma as a "layer."*
Recall the three types of rocks from the first selection: igneous, metamorphic, and sedimentary. Which one or ones are pictured in the diagrams, and how do you know?	*The layers of rock are sedimentary because we learned in class that sedimentary rock forms when sediments are compressed by heavy layers above them. The magma that cuts across layers will be igneous rock when it hardens, as the text box for the law of cross-cutting relationships explains.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 3, students should complete a partially filled in If/Then graphic organizer that addresses key concepts presented in each of the five reading selections in Collection 3. Look for evidence that they focused on main ideas from the readings appropriately, that they followed the style provided by writing in complete sentences, and that they were able to distinguish causes from effects. A sample completed graphic organizer is shown below with student's text in color, but other student responses may also be appropriate.

If	Then
If, over millions of years, dead organisms sink to the bottom of a body of water, the water dissolves some of the parts of the shells and pressure breaks down other parts, and there is pressure on the sediments,	then, limestone, a kind of sedimentary rock, may form.
If you can compare a fossil you find to ones that are identified in field guides,	then you can figure out the age of an unknown fossil.
If a building foundation is built in soil,	then the building foundation may shift and crack.
If there is a hot spot in the middle of a plate where magma breaks through,	then a chain of volcanic islands will form in the middle of a plate.
If rock layers appear level or flat,	then you should suspect that no uplift or folding has occurred

What causes mountains to change?

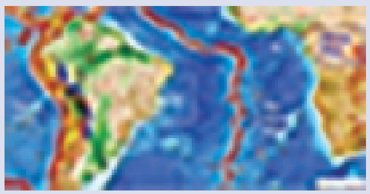
Previous Lesson

We established claims about what occurs where two plates are moving away from each other and analyzed evidence to support or refute our claims. We figured out that magma from the mantle is slowly creating new plate material at the Mid-Atlantic Ridge and updated our Potential Causes for Mountain Movement chart to show that pressure from the mantle causes the observed mountain changes.

This Lesson

Putting Pieces Together

1 DAY



Seismic Explorer by Concord Consortium is licensed under CC BY 4.0.

We revisit our Potential Causes for Mountain Movement chart to take stock of what we have figured out. We revise this chart to capture the causal chain of events that need to occur for a mountain to move or grow. We revisit the DQB to see what questions we can answer and make predictions about what we think the Andes Mountains and the Mid-Atlantic Ridge will look like in the future and what it looked like in the past.

Next Lesson

We will use mathematical reasoning to determine that Africa and South America could have been together 146 million years ago and reason out that this older rock and fossils will be found deeper underground compared to younger rock and fossils. We will look for patterns in data across the continents from this period. We will complete an exit ticket to make a claim about the two plates touching.

Building Toward NGSS

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

What Students Will Do

9.A Construct an explanation using representations on the Causal Chain of Events poster to explain how the causal (not correlational) events lead to a mountain changing in elevation or location.

What Students Will Figure Out

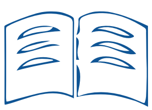
- Plate movement causes changes to mountains.
- There are a sequence of events that occur to cause changes to a mountain.
- This sequence involves magma moving and pressing on the crust, which makes the plates move. This plate movement results in changes to the surface of Earth, including changes to mountain height and location.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Return to our *Data Cards for Other Mountains and Mount Everest* to remind ourselves of the changes happening at each location and reflect on which changes we can explain.	A	
2	20 min	**REVISE POTENTIAL CAUSES FOR MOUNTAIN MOVEMENT CHART** Revisit the *Potential Causes for Mountain Movement* chart. Reorganize the causes into a chain of cause and effect events that lead to changes to Earth's surface.	B-C	Potential Causes for Mountain Movement chart, another piece of poster paper titled Causal Chain of Events for Changes in Mountains
3	15 min	**REVISIT THE DQB** We go back to our DQB and see what questions we can answer.	D	poster paper titled "Questions We Have Answered" or a space in the room for this on a white board or bulletin board, Related Phenomena poster
4	7 min	**EXIT TICKET** We think about what the ocean where the Mid-Atlantic Ridge is will look like in the future and what it looked like in the past.	E	*Making Predictions*

End of day 1

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Making Predictions*		• Potential Causes for Mountain Movement chart • another piece of poster paper titled Causal Chain of Events for Changes in Mountains • poster paper titled "Questions We Have Answered" or a space in the room for this on a white board or bulletin board • Related Phenomena poster

Materials preparation (15 minutes)

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

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

Either have a poster with the title "Questions We Have Answered" ready prior to the lesson, or have a space in the room near the DQB where students can post the questions that can be answered. This space could be on a section of whiteboard or on a bulletin board instead of a poster paper.

Online Resources

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

Up until this lesson, students have been investigating and analyzing data to figure out what causes changes to mountains and Earth's surface. In this lesson, the class works together using what they have figured out about the potential causes to develop a causal chain of events. This causal chain has students beginning with the final outcome: the mountains growing in elevation and the mountains changing location, before they work through the events that happen which cause these effects. This causal chain will begin with magma under the surface moving, causing the plates to move, which in turn results in changes to Earth's surface. As this causal chain is developed, students also include other effects that happen that are correlated with, but not causes for, mountains changing (i.e., volcanic activity and earthquakes).

Where We Are NOT Going

This lesson, and the grade band, binds us to a causal chain that begins with the fact that magma, a liquidy rock, moves. We do not go further into why this magma moves, which is due to thermal convection.

LEARNING PLAN FOR LESSON 9

1. Navigation — 3 MIN

Materials: None

Revisit mountain case cards to see which changes we can explain. Say, *Up to this point in our unit, we have figured out a lot about what could be causing changes to mountains, and to the land at and above the surface. All of these causes had to do with things happening at or below the surface of Earth. Take a moment and look back at our mountain cards. Do you feel like you could explain what we have figured out so far for the observed changes in each mountain (growing, or moving, or shrinking)? Turn and talk with a partner about which mountain changes you can explain.* Give students a minute or two to share with a partner. Later in this lesson they will write a short explanation about this, so no need to have anyone share their ideas at this point. This conversation supports students in synthesizing what they have figured out about Earth's underground processes that cause land change.

Project slide A. Ask students to consider the following questions and share their ideas with a partner:

- Which of these changes can you explain using what you have figured out so far about what is happening at and below Earth's surface?

Say, *Keep thinking about this as we work to revise our* Potential Causes for Mountain Movement *chart as a class. We will revisit this question at the end of the lesson.*

2. Revise Potential Causes for Mountain Movement chart. — 20 MIN

Materials: science notebook, Potential Causes for Mountain Movement chart, another piece of poster paper titled Causal Chain of Events for Changes in Mountains

Revise the Potential Causes for Mountain Movement chart. Show **slide B.** Ask the students to convene in a Scientist's Circle and make sure the *Potential Causes for Mountain Movement* chart is in a prominent location where everyone can see it. Say, *Let's begin by looking back at our* Potential Causes for Mountain Movement *chart. We have figured out quite a bit about what we initially thought could cause a mountain to change in elevation and location. All of the causes we have figured out are about things happening under the surface of Earth, and we have a lot of arrows and edits on our chart. Let's use what we have here to reorganize what we have figured out about these processes below the surface. We have plates moving, earthquakes, magma moving, and volcanoes listed as causes. Let's start a fresh poster to capture the chain of events leading to the mountain changes we have seen happening at the different mountain locations on our data cards. We will begin with what we know is happening to the different mountains.*

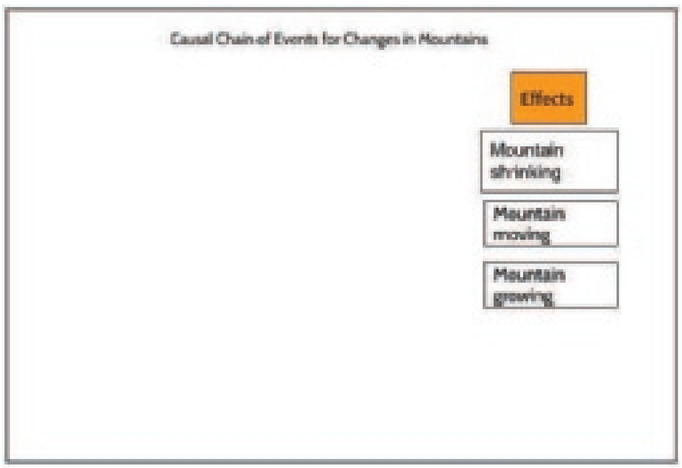
Key Ideas

Purpose: Now that the class has figured out and collected evidence for the different causes brainstormed in Lesson 1 that could be causing mountains to change, use this Building Understandings Discussion to reorganize these causes into a causal chain that reflects the order that the causes occur before a mountain is affected. The prompts and responses below are included to help facilitate this discussion to support students in making sense of how some of the causes included on the poster from Lesson 1, are really correlated events that also happen when a mountain is changed, but are not the cause of the mountain change. In addition, there are images as examples of how the *Causal Chain of Events for Changes in Mountains* may be developed, but use what your students suggest, and argue for the development of this representation as long as the causal and correlational events are clearly represented.

Say, *Let's begin by recording on the right hand side of our poster the effects, or changes, that we know are occurring to mountains*. With students' help, begin to develop a representation on the poster paper to represent the changes to the mountains that we have evidence of. This representation will be developed incrementally with students. A suggested plan for developing this representation, along with example images showing its incremental co-construction, is provided below. Ensure that the representation you develop with your students represents their shared thinking. Different classes may develop this representation in a different order or way.

Suggested prompt	Sample student responses
What if we begin by recording what we are trying to explain, or the effects that occur—what would that be?	*the mountain moving* *the mountain getting taller* *the mountains shrinking*

Say, *Okay, let's add these three effects or changes to mountains, to the poster on the right hand side.*



Additional Guidance

When constructing the chart, place "mountains shrinking" above the other two effects or changes to mountains. In this lesson we will focus on explaining the relationship between our previously investigated potential causes for mountain movement and the effects on the right of our original poster. In later lessons we figure out more about how erosion affects the elevation of mountains and add to this poster. It is important to include this shrinking label above the increasing and moving labels, as we will later classify these interactions as occurring above and below the surface.

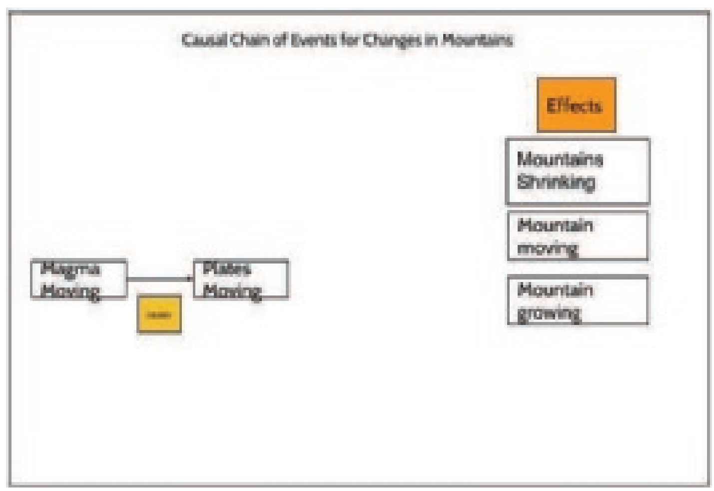
If mountain shrinking is placed below the other two effects, then this "above the surface" process will end up in the "below the surface" space of the causal chain poster. This will happen in Lesson 13.

Suggested prompts	Sample student responses
Based on what we have figured out so far about causes that affect Earth's surface, what "effects" have we made progress explaining the causal mechanisms?	*mountains that are moving* *mountains that are growing*
We know that we've brainstormed lots of potential causes over the past few lessons for mountains that are growing and mountains that are moving—some of which are events that happen to occur at the same time these changes are happening, and some that are the ultimate causes for these events. Which of the ideas on our Potential Causes for Mountain Movement chart is a cause of a mountain moving or growing?	*plates moving* *magma moving*
Which of the ideas on our Potential Causes for Mountain Movement chart are events that also occur when a mountain is changing, but is NOT a cause for mountains changing in elevation and/or location?	*earthquakes* *volcanic activity - volcanoes erupting*
So if we were to begin on the left side of our poster representing the one cause on our Potential Causes for Mountain Movement chart that is always happening when a mountain is changed, what would be that one cause?	*We should start with the magma, or hot liquidy rock, moving around.*
Is everyone in agreement that we should begin with the magma moving? Some of you mentioned plate movement is another cause of mountains changing.	*Yeah, we should begin with the magma because that is what causes the plates to move.*

Say, *Okay let's capture this on our Causal Chain of Events for Changes in Mountains poster. On the far left, let's add magma moving. What if we connect it with an arrow to represent what you all are saying about how the magma movement causes the plates to move?*

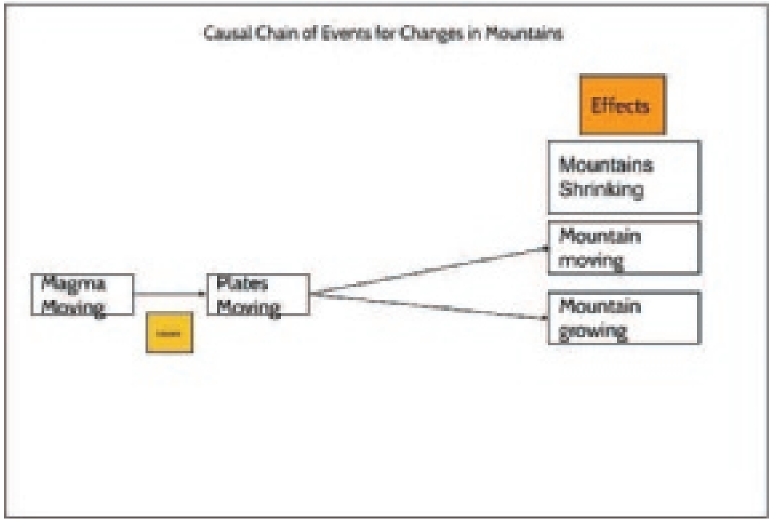
Students should agree that this helps show the relationship between magma and plates moving.

Add these two causes to the poster in a way to capture this idea that one cause happens before the other cause. It is suggested to include notation in between these two causes with some wording about the causal relationship between these two events, such as what is shown in the image to the right. Use the prompts and responses below as an example of this addition to the poster.



Suggested prompt	Sample student responses
So if we look at our poster, can we connect plates moving to mountains changing location and/or elevation?	*Yes we can.* *We can because when the magma far under the surface moves, everything above it moves as well, including the plates. When plates collide, mountains can get taller.* *Plates colliding can also cause a mountain to move if the plate the mountain is on moves.*

Say, *Okay, let's add this to our poster.*

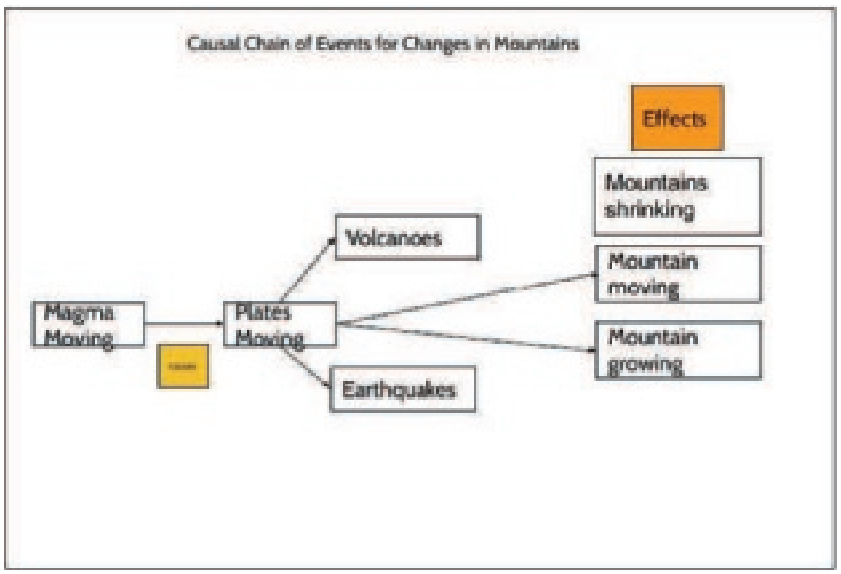


Additional Guidance

Students may argue that they want to add an arrow from magma moving directly to the effects (mountains moving, mountains growing). If they do argue for this, ask them to think back to Lesson 7 where we investigated the locations most volcanoes occur—at plate boundaries—to help them synthesize what they have figured out in a causal relationship. Through the next part of this discussion that is supported through the prompts and responses below, students should come to agree that volcanoes are correlated with these events, but not the causes of these events.

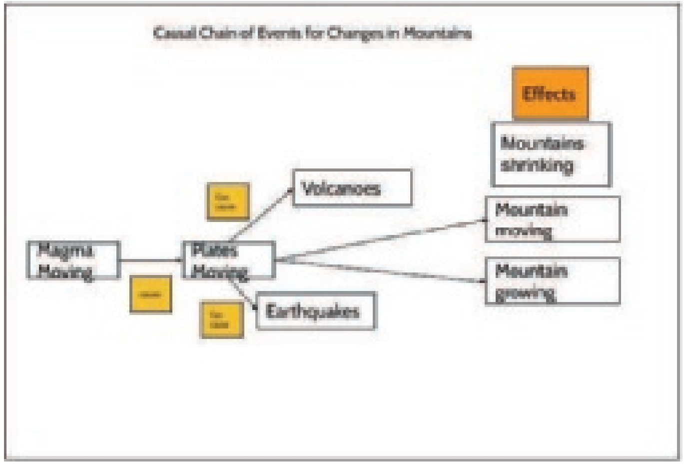
Suggested prompts	Sample student responses	Follow-up questions
Okay, so now we have two things we figured out that are happening and are definite causes of mountains changing in elevation and location. What else is there from our Potential Causes chart that we want to include here as well?	*We should also include earthquakes and volcanoes.* *We noticed that earthquakes happen where plates are colliding.* *And lines of earthquakes occur at all the plate edges.* *We saw volcanoes where plates collide and move apart.*	*Do others agree with this?*
If we add earthquakes and volcanoes to our poster, where should they go? How are they related or linked to mountains changing in elevation or location?	*When plates collide and run against each other, earthquakes happen, so maybe they should be linked to plates moving.* *Volcanoes are also linked to plates moving because we saw that when the plates move apart, there can be volcanoes and sometimes when they collide, one goes under the other.*	*Are we all in agreement with this?*

Say, *Okay, let's add earthquakes and volcanoes to our poster.*



Suggested prompts	Sample student responses
I hear us arguing that both earthquakes and volcanoes happen when plates move, so how should we represent this?	*We should do the same thing we did for magma moving and plates moving—put an arrow between them to show plate movement causes earthquakes and volcanoes.*
Does plate movement always cause earthquakes and volcanoes?	*No. I don't think so.* *qMaybe, I am not sure it happens everytime, but we did see there are smaller earthquakes and larger earthquakes so maybe?*
Okay, so if we know that earthquakes and/or volcanoes can occur when plates move, but we aren't sure these happen every time, how could we include this on our poster?	*We could say something like, plates moving can cause earthquakes and/or volcanoes.* *We could say something like, plates moving sometimes causes earthquakes and/or volcanoes.*

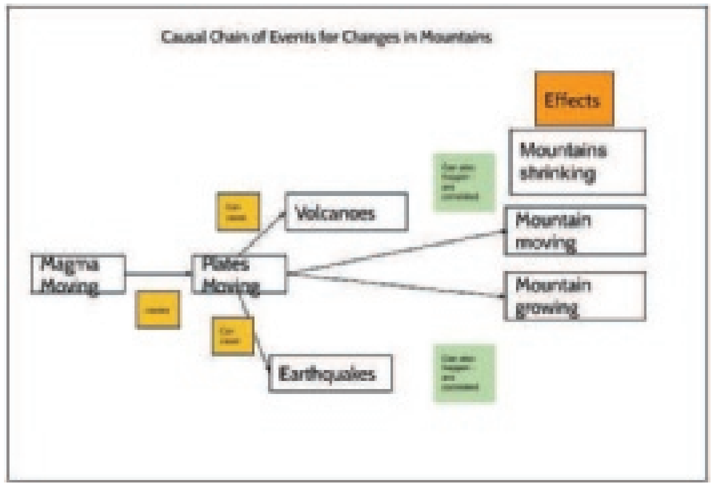
Say, *Okay, let's add this to earthquakes and volcanoes on our poster.*



Suggested prompt	Sample student responses
So now that we have added to our causal chain of events the relationship between magma moving and plates moving, and the relationship between plates moving and mountains moving or growing, and the relationship between plates moving and earthquakes and/or volcanoes, what can we include between earthquakes and/or volcanoes and mountains moving or growing? Do earthquakes CAUSE a mountain to grow or move location? Do volcanoes CAUSE a mountain to grow or move location? Do volcanoes or earthquakes CAUSE a mountain to shrink?	*No. . . earthquakes happen when the plates move as they collide or bump into each other.* *No. . . volcanoes happen when plates move and collide or move apart.* *Sometimes volcanoes can cause mountains to shrink if they explode violently.* *Not all mountains shrink because of volcanoes. Our mountain cases that are shrinking don't have volcanoes.*

Suggested prompts	Sample student responses
Okay, so if earthquakes and volcanoes don't cause mountains to change location or increase in elevation but sometimes happen at the same time, how could we represent that on our poster?	*We could include something between earthquakes and the mountain changes that says: sometimes happens with or sometimes happens at the same time.* *Yeah, we could include the same thing between volcanoes and the mountain changes.*
How would we represent that volcanoes can sometimes cause mountains to shrink? Would we say that volcanoes are causing or are correlated to mountains shrinking?	*We can say that it's correlated, but since it doesn't happen at every mountain in our cases, we can't say that it causes all mountains to shrink.*
We talked about this before, what did we call something that wasn't a cause of mountains moving and growing but could happen at the same time as those changes?	*We said it was correlated.*

Say, *So let's add this to our causal chain since we now know that earthquakes and volcanoes can happen when plates move at the same time that mountains are being changed, but they don't cause mountains to change.* Add whatever wording or representation your class agrees on to capture this idea that earthquakes and volcanoes are correlated with but not causes of mountains changing.



Suggested prompt	Sample student response
Take a moment and reflect on what we have represented on our poster. We have been trying to figure out up to this point in our unit what the causes are of mountain changes and what the correlated events are that happen at the same time but are not causes of mountains changing. Looking at our representation, what are the causes that we have figured out that lead to mountains changing?	*plates moving*

Suggested prompts	Sample student responses
And what causes plates to move?	*The melty rock in the magma that moves around pushes on the plates and makes them move.*
Okay and what else is plate movement a cause of?	*earthquakes and volcanoes*

Make a claim. Ask students to return to their seats. Display **slide C.** Make sure they can see both the *Potential Causes for Mountain Movement* chart and the new *Causal Chain of Events* poster. Say, *Now, let's think back to what you talked about with your partner at the beginning of class. Look back at our* Potential Causes for Mountain Movement *chart and our new* Causal Chain of Events *poster and answer this question in your notebook: What causes a mountain to change in height or location? State your claim and use evidence to support your answer.* Tell students to open up to a new page in their notebook to record their answer to these questions.

- What causes a mountain to change in height or location?

Assessment Opportunity

9.A Construct an explanation using the representation on the causal chain of events poster to explain the causal events, not the correlations events, that need to occur in order for a mountain to change in elevation or location.

What to look for/listen for:

Students explaining that:

- Magma is far below the surface and is liquidy rock that moves
- When magma moves, everything above it moves
- Magma movings makes the plates on the surface of Earth move
- Plate movement changes the surface of Earth when they interact or spread apart

What to do: Some students may include correlational events as part of their causal explanation, such as earthquakes or volcanoes. If they do, encourage them to look back at the *Causal Chain of Events for Changes to Mountains* poster to remind themselves what we figured out about earthquakes and volcanoes in relation to mountains changing. Have them think about the causes for volcanoes forming, earthquakes happening, or mountains changing. In each of these cases, they should say that it's due to magma moving and plate movement. Thus, they all have a common event that occurs, so volcanoes and earthquakes can't be the ultimate cause for mountains changing.

3. Revisit the DQB. 15 MIN

Materials: science notebook, poster paper titled "Questions We Have Answered" or a space in the room for this on a white board or bulletin board, Related Phenomena poster

Convene in a Scientist's Circle around the Driving Question Board. Display **slide D.** Say, *Let's see what new questions we can answer from our DQB. You are going to get a sticky note off of our DQB and will have a couple of minutes to read it to yourself. Think about whether it can be answered with evidence we have collected so far in our unit.* Distribute one sticky note from the DQB to each student. Give students a minute or two to read their question and think about whether there is evidence the class has that can be used to answer it. If any student says they are not sure, encourage them to look back through their notebook if needed. After a minute or two, say, *We will go around so that everyone has a chance to share the question they have and whether or not we can answer it. If you share your question and we can answer it with evidence, then put it up on our poster, Questions We Have Answered. If you share your question and we can't yet answer it, or we can only partially answer it, tell us and why, then put it back up on our DQB.*

Begin at one point in your Scientist's Circle either by choosing someone to start or asking a volunteer to start. After the first student has shared their question and placed it either on the poster, *Questions We Can Answer* or back on the DQB, continue around the circle until everyone has shared.

Once everyone has had a chance to share, take a minute as a class to reflect on the overarching question for the unit from Lesson 1, What causes mountains to move, grow, or shrink? Ask, *Now that we have figured out so much about what is going on below the surface to cause changes to the mountains we have been investigating from Lesson 1, do you think these same processes could be affecting the events we have on our Related Phenomena poster?* Bring the Related Phenomena poster to a place in the room so everyone can see it and/or point it out.

Sample student response:

- Yes! I think the hills I see in my neighborhood might be caused by things shifting underground.
- Yes! Maybe the large crack in the road I see in my neighborhood is from plates moving.
- Accept all responses in which students can link the processes we have figured out to their related phenomena, even if it is just conjecture and not accurate. The purpose here to help support students in beginning to think about how not only mountains are affected by earthquakes, volcanoes and plates moving.

Say, *So it sounds like the processes that we have been investigating and figuring out not only happen at mountains, but may also happen around us. Could we revise our Driving Question Board unit question to capture this idea? What are some of your ideas for how to revise it?*

Allow students to respond. Guide students to add in a portion about the land around them. Consider revising the question to this format, or use the format suggested by the class:

What causes mountains and the land beyond them to move, grow, or shrink?

Say, *Okay, now that we have revised our Driving Question to include not only causes of changes to mountains but to the land beyond the mountains, let's keep this broader question in mind and we continue to investigate other landforms to see if what we figured out for mountains applies to explaining what is happening in other places. Let's think not only about these changes to mountains, but also consider what changes might be happening to land as these mountains change, and if changes have been occurring to our land as well.*

4. Exit Ticket

7 MIN

Materials: *Making Predictions*, science notebook

Make predictions. Display **slide E.** Say, *Now that we have taken stock of what we have figured out about some of the processes that cause mountains to change, let's use what we have figured out to make some predictions about what one part of Earth will look like in the future and what it might have looked like in the past. Use Making Predictions to record your predictions.* Pass out *Making Predictions* to each student and give them the rest of the class to complete it. They should turn it in before leaving class.

ADDITIONAL TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.6.1

Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 6 topics, texts, and issues, building on others' ideas and expressing their own clearly.

Students will engage with peers in a Scientist's Circle to come to consensus on a causal chain of events representation for mountains changing. In order for the class to come to a consensus on this, they will need to share what they have figured out over the course of the unit so far and build on each other's ideas.

LESSON 10

Where were Africa and South America in the past?

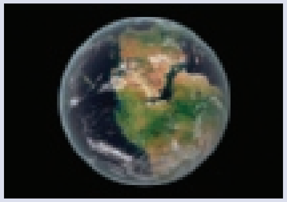
Previous Lesson

We revised our Potential Causes for Mountain Movement chart to develop a causal chain of events that lead to a mountain moving or growing. We revisited the DQB to see what questions we can answer. We made predictions about what we think the Andes Mountains and the Mid-Atlantic Ridge will look like in the future and what it looked like in the past.

This Lesson

Investigation

1 DAYS



We consider what evidence we would need to determine if Africa and South America were once touching. We determine that we need to use data from both continents, and the data needs to be from the time period when they were possibly together. We use mathematical reasoning to determine they could have been together 146 million years ago. Older rock and fossils are found deeper underground compared to younger rock and fossils. We examine patterns in data across the continents. We complete an exit ticket to make a claim that the two plates used to be touching and support the claim with evidence from our maps.

Next Lesson

We will use multiple types of data and models to examine how the continents moved and relocated on Earth over millions of years. We will identify the strengths and weaknesses of our models, then construct an explanation for the position of continents millions of years ago.

Building Toward NGSS

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

What Students Will Do

10.A Analyze maps displaying patterns of large sets of data to determine that Africa and South America could have been touching at the Mid-Atlantic Ridge (spatial relationship) between roughly 125 and 146 million years ago.

What Students Will Figure Out

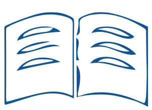
- Oceanic plates that were created over time were not always in existence.
- Average rates of plate movement and plate direction can be used to determine where plates were once located.
- Small changes to the distance between continents can add up to larger visible changes seen from a larger scale.
- Older rock and associated fossils can be found under younger rock and fossils.
- To support that two land masses were once together, patterns in data across the two land masses need to be similar or the same.
- Data from rock strata, fossils, and other changes in land supports that the African and South American continents were once together at the Mid-Atlantic Ridge.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	6 min	**NAVIGATION** Discuss if Africa and South America could have been touching in the distant past, and determine what evidence we would need to prove they used to be touching.	A-B	
2	14 min	**USE RATES OF PLATE MOVEMENT TO DETERMINE WHEN AFRICA AND SOUTH AMERICA WOULD HAVE TOUCHED** Use the constant rate of the movement of the South American plate and the African plate to determine when continents might have been touching.	C	*Calculating Plate Movement*, calculator
3	5 min	**REASON OUT THE LOCATION OF OLDER DATA ON CONTINENTAL PLATES** Consider where material from long ago would be found on both continental plate pieces. Reason out that the older material (rocks, fossils, etc.) would be found layered below younger material.	D-G	
4	12 min	**ANALYZE MAPS TO DETERMINE PAST PLATE LOCATIONS** Analyze maps with varying data to determine if the African and South American plates have corresponding evidence that could show they were once touching.	H-I	dry erase marker, *South America and Africa Evidence Maps* with different maps placed in individual sheet protectors, *Talking Sticks Protocol for Our Continental Data Sets*
5	8 min	**EXIT TICKET** Revisit the idea that Africa and South America were once touching. Write a claim about their past positions and provide evidence to support the claim on an exit ticket.	J	*Lesson 10 Exit Ticket*

End of day 1

Lesson 10 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• *Calculating Plate Movement* • calculator • dry erase marker • *Lesson 10 Exit Ticket*	• *South America and Africa Evidence Maps* with different maps placed in individual sheet protectors • *Talking Sticks Protocol for Our Continental Data Sets*	

Materials preparation (20 minutes)

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

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

Print 5 color copies of each map on *South America and Africa Evidence Maps*. Cut apart each half page map and place each one in a separate sheet protector. The only map that will be a full page map will be the rock layers map, since it includes a rock layers key. All other maps will be a half page.

Print extra copies of *South America and Africa Evidence Maps* in case students would like to physically cut out Africa and South America and move them together. Consider pre-cutting a few continents from each data set to distribute to students who would benefit from physically manipulating the data sets.

Cut out one African continent and one South American continent to use for the movement of continents on meter sticks. The data set used to cut out the continents for this activity does not matter.

Online Resources

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

In the previous lesson, students considered whether the oceanic plate material has always existed in between Africa and South America. In this lesson, students will determine that the plate material may not have always existed, and consider what data they might need to show evidence of the two continents touching at some point in the past. To understand where the plates might have been in the past, students use constant rate data to figure out that the two plates may have been touching somewhere between 146 and 125 million years ago. Knowing that the plates may have started to separate as far back as 146 million years ago, students bound their needed data to a time period before 146 million years ago when the plates might have been touching. They recognize that the plates themselves may have evidence of being together, but things from that long ago must be found very deep underground. Students use data from this time period to look for similar patterns across the two continents. These patterns in data serve as evidence to support in their exit ticket that the two continents were once together.

Where We Are NOT Going

Students use an average yearly rate of 48-56 mm of movement from the ridge to estimate the time at which Africa and South America were touching. This average rate does not account for differences in the actual movement, such as periods of deceleration in the past 35 million years nor the exact angular velocity of the plates or the changes in plate direction seen in the geomagnetic data from the past 130 million years. Current plate movement rates are believed to be historically slower than past rates. We calculate the average movement in this lesson using the general magnetic data seen when mapping seafloor age of various parts of the ridge. Analyzing angular velocity and the accompanying magnetic data are associated with high school mathematical standards. For this lesson, students are utilizing the average growth rate from the continental shelf off the coast of the State of Rio Grande Do Norte of Brazil to the corresponding section of the Mid-Atlantic Ridge, then to the continental shelf located off the Gulf of Guinea. This area was chosen because of it’s visual correspondence of the continental plates with the Mid-Atlantic Ridge and alignment with projected scientific averages, along with connections to the Mid-Atlantic Ridge from prior lessons. While not in this lesson, it is worth noting that the Northern part of the plates and Southern part of the plates have experienced different rates of movement and angular shifts over time.

LEARNING PLAN FOR LESSON 10

1. Navigation

6 MIN

Materials: None

Consider the final question from *Making Predictions* from last class. Say, *We ended last class by thinking about the Mid-Atlantic Ridge. As I was reading through your handouts, I saw similar ideas across the class converging towards a common argument. Let's revisit the last question from the handout and take some time to share our ideas with the class.*

Project **slide A**. Display the last handout question on the slide. Read the last question from the exit ticket aloud to the class:

- If the Mid-Atlantic Ridge is spreading apart one inch per year, does that mean that oceanic plate material has always existed in the Atlantic Ocean?
- Would there be any changes to the two continents on either side of the Mid-Atlantic Ridge?

Allow students to share their ideas with the class. Guide students to determine that the oceanic plate is created or destroyed over time. Example prompts and responses are below.

Suggested prompts	Sample student responses
If the Mid-Atlantic Ridge is spreading apart between 1.9-2.2 inches per year, does that mean that oceanic plate material has always existed in the Atlantic Ocean?	*If the ridge is spreading apart, then the material has to be coming up and filling some space that is newly open. Like the crack or the plate material hasn't always been there if it is just created.* *Maybe the plate material hasn't always been there.*
Where would this plate material come from?	*We learned that the new plate material is coming up at the ridge from underground and filling in the space.* *We saw the new plate material in Iceland and on the ridge coming up from the mantle as the plates spread apart.*
So if there are new oceanic plates being created on both sides of the ridge, then has that oceanic plate always been there?	*Since the plates are created, it means they weren't always there.* *The oceanic plate must not have been there long ago, if it is being created now.*
What do you think it could have looked like long ago?	*The ridge would have been much closer to the continents of Africa and South America.* *Maybe the distance between the continents was less, but the ridge was still there.*

Suggested prompt	Sample student responses
Do you think that the ridge has always been there?	*maybe not* *The plate boundary might have been there, but maybe the continental plates were the only pieces you could see.* *Maybe the two continents were touching.*

Discuss what the Atlantic Ocean looked like in the distant past. Project **slide B**. Say, *Okay so if we are thinking that in the past the Atlantic Ocean may have been smaller and the distance between the two continents may have been shorter, do you think it is possible if we go far enough back in history these two continents could have been touching? Talk with a partner for a moment about this idea.* Ask students to turn and talk with a partner about the following questions:

- Do you think it is possible that the African and South American continents could have once been together?
- If they were closer together or touching, what might other areas, like the Atlantic Ocean, look like?

Additional Guidance

During this step, students are considering if the two continents could have been together. This may require students to think more spatially than in prior lessons. If needed, reference the class map and/or the image on *Making Predictions* to point out the South American and African continents and the Mid-Atlantic Ridge before having students turn and talk.

Allow students to share their ideas with the class. Example prompts and responses are below.

Suggested prompts	Sample student responses
Do you think it is possible that the African and South American continents were once together?	*Possibly. They look like they could have been.* *Maybe. They both fit the line of the Mid-Atlantic Ridge.* *No, they are so far apart!*
So if we think the two continents were touching, do we have any evidence that this could have happened? Do the continents look like they could have actually fit together?	*I think so. There's a curved piece that sticks out on the tip of South America that could fit into Africa.* *Yeah, they kinda look like puzzle pieces.* *Definitely. The edges of the continent match the shape of the Mid-Atlantic Ridge, so maybe we could slide them back to that spot and match.*
If they were together, how might that change the Atlantic Ocean?	*The Atlantic Ocean couldn't have been between the two continents.* *The entire ocean and all that water would have to be out of the way.* *All that oceanic crust would have to disappear.*

Suggested prompt	Sample student responses
We know the plates are moving apart from each other from earlier lessons. So if we were to think about reversing the plate movement to go back in time to see if they would come together, what changes would this have on the Mid-Atlantic Ridge or the Atlantic Ocean?	*The Mid-Atlantic Ridge would still be in the middle, but the plates might meet where it's at.* *The ocean would be gone, and the Mid-Atlantic Ridge might be gone too.*

Say, *It sounds like we are thinking that if we were to go backwards in time, or reverse time, that the continents might have been together, and we are thinking that it even looks like they could fit together. What data do we already have about how the continents are moving that we can use to do this "reverse" time and see where these continents would have been in the past so we can figure out if they might have been together?*

Allow students to respond. Students should suggest that we have plate movement data and we know the rate the Ridge is spreading apart, so we can use this number to reverse the plate movement back in time and figure out where they would have been in the past.

2. Use rates of plate movement to determine when Africa and South America would have touched. 14 MIN

Materials: *Calculating Plate Movement*, calculator

Say, *It sounds like we can use plate movement rates to calculate when the plates were together. Using that rate will help us "reverse" plate movement from the Mid-Atlantic Ridge back in time. Let's look at some of that data together and try to figure out when the plates might have been touching.*

Introduce *Calculating Plate Movement*. Project **slide C.** Distribute *Calculating Plate Movement* to students. Read the section titled *Scientific Data* with students. After reading *Scientific Data*, ask students how far 48mm and 56mm would be (1.9-2.2in) using the distance between their thumb and index finger.*

Say, *That seems pretty small, but millimeters or just an inch or two can sometimes be hard to estimate or show. Let's try to get more accurate. The continents are way too big to manipulate and move back ourselves, but I do have these cut out versions. How can we use these to visualize how far the continents actually move each year? And how could we know we are more accurate?*

Allow students to respond. Students should suggest that we can move the representative continents the distance by the yearly rate the scientists have estimated using rulers or other measurement tools.

Additional Guidance

For the next portion of the lesson the class will be using representations of the two continents and the distance between them. These items will not represent a scale model. The purpose of this next section is not to recreate the true scale at which these occur, but to understand that the timescales and distances associated with these interactions occur over a much greater timescale than discussed in previous lessons. This next task focuses on shifting from spatial understanding to a temporal understanding that will lead us into the ideas of geologic time and larger changes that add up over larger timescales associated with plate movement and plate interactions.

***Supporting Students in Engaging in Planning and Carrying Out Investigations**

As students are comparing rates of change, ask students to consider if the changes over 10 years, 100 years, or 1,000 years would be noticeable on the larger world map on **slide C**. Students should note and make the connection that while these changes are observable in the classroom on our meter sticks with small paper representations of the continents this would not be observable at a global scale. Since the data for the movement of these plates is small enough to represent on meter sticks in close proximity, we can see a change in our classroom. Students should note that the small changes have occurred over

Introduce plate movement rate manipulative. Hold up the cut out representation of Africa and South America that were prepared before the beginning of the lesson.

Suggested prompts	Sample student responses
How do these compare to the actual continents?	*These representations of the continents are much smaller than the actual continents.*
How far apart are these continents?	*Our reading said they are about 7,000km apart.*

Say, *We can't spread them 7,000km apart in our classroom, and like you all said, the representations of the continents are much smaller than the actual continent. To begin to figure out how the yearly movement of these continents might affect their location in relation to each other, what if we use a few meter sticks to think about how movements of mm/year could affect a change in location of the land and represent that distance on a much smaller scale, like we did with our paper continent representations?*

Suggested prompt	Sample student responses
We know the paper representations of the continents are much smaller than the actual continents. We also are using meter sticks to represent the distance between them that is at a scale much smaller than the actual distance. What are some of your ideas for how we could use these representations to help us figure out where these continents might have been in the past?	*We could move the paper continents back in time using the meter sticks to see where they would be in the past.* *The distance between the continents could represent a time period much earlier when the continents might have been closer together.* *We can use the meter sticks to see how much they move over time and help us represent the rate they move apart from the Ridge yearly.*

Use meter sticks to represent past plate distances. Ask 4 students to hold the 4 meter sticks end to end in front of the class. Using tape, place a continent on each end. Ask students what the distance in between the continents represents. Students should identify that the distance is representative of the Atlantic Ocean. Ask students what would be at the middle of this distance between the two plates. Students should respond that the Mid-Atlantic Ridge would be in the middle of the Atlantic Ocean.

Determine how far to move each continent back in time. Engage in a discussion with students about how the continents are moving apart a total of 48mm to 56mm a year from the ridge, which represents the movement of both continents from the center of the ridge, not just one continent. Work together to decide how far to move each continent on the meter sticks. Example prompts and responses are below.

Suggested prompt	Sample student response
We have placed our continents on each end of the meter sticks. If we were to turn back the clock one year, how far towards the center, or the Mid-Atlantic Ridge in the Atlantic Ocean, would we move the continents? Or where would these two continents be one year ago?	*We would move them either 48mm or 56mm.*

a short period of time and are very close together, so they would not be observable on this larger global scale on slide C for many centuries.

***Supporting Students in Engaging in Using Mathematics and Computational Thinking**

Students will use basic operations to help them answer the question of when the African and South American plates might have been touching. During this process, students will convert from millimeters to kilometers, and kilometers to millimeters. Although this understanding of using base ten math and the metric scale is built into elementary school common core mathematics, utilizing this math in a real world context by multiplying or dividing by 1,000,000 to get scaled measurements may be new to some students. To support students in understanding the scale difference between kilometers to millimeters, consider revisiting the scale of metric measurements from millimeters to kilometers, including how many millimeters are in centimeters, meters, and so on to explain why 1,000,000 is being used to convert between the two measurements.

Suggested prompt	Sample student response
Would each continent move towards the center 48 or 56mm, or would that be the total distance moved between each continent?	*It would be the total distance between each continent.*
OK. We only have one representation of the continents on our meter sticks. We can't move one representation both 48mm towards the center AND 56mm towards the center. What measurement do we want to use?	*Accept the general class response.*
OK. Let's move them in. But wait, do we just move one continent in (amount decided on by the class), or do we move both continents in?	*No, we need to move both continents.* *We should move one continent in and then move the other continent in.* *Both continents are moving away from the ridge, so we need to move both back towards the ridge.*
But if we are moving each continent, how much do we move each one?	*We need to move them about the same distance in, so maybe half of (either 48 or 56mm) is how much we should move each continent towards the middle.*
As a class, decide on a distance to move each plate in, that adds up to the rate of movement estimate picked by the class.	*Some plates move faster than others. Maybe we could move South America more than Africa since it looked like it moved more on Seismic Explorer.*

Say, *OK. Let's begin to move in our continents!*

Move continents back in time one year. Direct 2 additional students to move in each continent the distance specified by the class. After they have been moved, step back and ask the class if the distance moved is noticeable. Students should respond that the distance is not very noticeable, they still look pretty far apart.

Say, *OK, so we don't really notice a big difference in the distance between the continents after a year, even at this small scale. But what about 10 years?*

Move continents back in time 10 and 100 years. Reason out how far the continents would have moved over 10 and 100 years with students while moving the continents to represent the changing distances between Africa and South America as time is turned back. Determine if those distances would then be noticeable on a global scale.* Example prompts and responses are below.

Suggested prompt	Sample student response
So the distance between the continents was not noticeable in 1 year. How far would the continents have moved back if we reverse the clock 10 years?	*It would have moved 10 times as far.*

*Supporting Students in Developing and Using Patterns

Movements that are perceived in the scale of millimeters that add up over time to thousands of kilometers may be hard for students to comprehend. If after the discussion students are still questioning this spread rate of the continents, consider demonstrating this pattern in the rates of change. Begin by asking students to make marks that are 4cm and 6cm apart (or 40mm and 60mm if students have the ability to attend to precision of this scale). Ask students to make 20 marks in succession at these rates, and then compare the difference. Continue to scale up the measurements using multiplication over 100 years, 1,000 years, 10,000 years, and 100,000 years as a class to show how these temporal and spatial relationships can become more dramatic in differences over larger scales of time.

Suggested prompts	Sample student responses
How can we figure out how far the continents have moved back in time 10 years without moving our continents 10 separate times? *Guide students in multiplying the rate of movement by 10. Have students move the continents.*	*We could use multiplication.* *We could multiply the movement rate by 10.*
Alright, can we see a difference now?	*A little bit, but the difference still isn't that big.* *Not really. They didn't move a lot.*
So what if we move them back in time even more. What about 100 years? How could we figure that out?	*We may be able to see a difference in 100 years. We would just multiply the number by 100.*
Guide students in multiplying the rate of movement by 100. Have students move the continents.	*Yeah, 100 is a lot. We could see a difference then.*
So do we see a difference now?	*Yeah, we can begin to see the difference!*
Do you think we could see the difference on a globe or a map?	*Not if you're looking from space. We can't see that like we see continents from space.* *No it wouldn't be noticeable.* *It's too small to see.*

Say, *Okay, it seems like we are beginning to make progress in thinking about how moving the continents towards each other at a small scale could help us figure out what is happening on Earth between these two continents since we are finally starting to see the distance between the continents shrinking as we moved 100 years back in time. But, we know that these continents are much larger. This change in the distance over 100 years probably isn't enough to see the continents coming together from space and the gap between them getting smaller on our current day globes. What might we need to do in order to become more sure about whether these continents could have been together?* Students should suggest that we should figure out where the continents would have been further back in time, like longer than 100 years ago.

Use mathematical reasoning to reverse continent movement for greater periods of time. Direct students to look at Part 1 of *Calculating Plate Movement*. Explain that we can use the plate rates and the multiplication like what we just used as a class in this section to help us see if our estimates are close to the actual kilometer distance between the two plates. Remind students that we were able to easily turn our estimates that we made in intervals of 10 into distances moved between plates over time. Ask students to make estimates about how many years we need to turn back the clock using numbers that are multiples of 10 to make our math more accessible as we estimate and convert measurements.

Elicit a couple of estimates from the class, and decide on one estimate to use class-wide. Explain that since we have two different rates of movement, we can start doing the math to see how the rates would vary if we use the two

***Supporting Students in Developing and Using Stability and Change**

As students use the small movement (measured in mm) that the land is spreading at the Mid-Atlantic Ridge to determine if Africa and South America could have once been touching or connected, they will begin developing a conceptual model of comparative time scales—mm/year to km/millions of years. At this moment students are making a pronounced shift in considering temporal and spatial relationships and thinking about how these changes add up over these larger temporal scales. Using this data and grappling with whether such a small yearly movement could have such a large result in the position of the continents will support students in gaining a more intuitive understanding about stability and change that can only be "seen" over very long time periods. In addition, students will begin thinking about how a system can appear stable in one time scale but realize that at a different time scale the system is changing.

different plate movement rate numbers. Write the estimate down in a space visible to all students. Most students will estimate smaller ranges of time, ranging from thousands to a few million years.

Say, *We can see how close some of our estimates are by using math to determine how far the plates would have traveled in these time periods. Let's try to see how close we get with the estimate we have.*

Test out estimates for plate movement. Pick one estimate that the class feels more certain about and have students add this estimate to the table in Part 1. Work as a class to do the math associated with plate movement.* Below is an example is for an estimate of 10,000 years:

10,000 years x 48mm/year = 480,000mm ÷ 1,000,000 (to convert to km) = 0.48 km

10,000 years x 56mm/year = 560,000mm ÷ 1,000,000 (to convert to km) = 0.56 km

After finishing the math, restate the results for students. An example is below.

10,000 years ago, at a rate of 48mm/year, the plates would have been 0.48 km closer together.

10,000 years ago, at a rate of 56mm/year, the plates would have been 0.56 km closer together.

Revise estimates. Allow students to pick one more estimate (for example 1,000,000 years), or revise their estimate from above as a class. Work through the associated math to determine how far the plates would have traveled in that time period.* Restate the results to the class again.

Begin Part 2 of the handout. Say, *It seems like we are getting closer to the distance between the plates, but we aren't exactly sure yet of when they might have been together. Let's rearrange our data using the estimate from Calculating Plate Movement that scientists estimate the continents have moved apart and start with the two things we know-distance and the rate the continents are spreading apart-to determine how long ago it would have been that they were together.*

Go over the rest of the handout with students. Point out to students that it is OK to round to the nearest million years. Divide students into partner pairs, assigning half the class to work with that rate of spread of 48 mm/year (labeled in the table with an A in front of the number) and the other half of the class working with the rate of 56 mm/year (labeled with a B in front of the number). Give students time to work through Parts 1 and 2 of the handout. As students are working, circulate to ensure that students are processing the information and calculating distances and times correctly. Students should calculate the following data for Part 2:

- Plate movement at a rate of 48 mm/year = 125,000,000 years ago
- Plate movement at a rate of 56 mm/year = 146,000,000 years ago

Additional Guidance

As students work on *Calculating Plate Movement*, students may believe that the age calculated is an exact time, not the average. Remind students that since the plates are moving at different rates from the ridge, and parts of the different plates experience conditions and resistance that might slow the movement of certain parts of the plate or speed up the movement, and there were periods of greater movement or stagnation while they were moving, these numbers aren't exact. You can encourage them to think back to Lesson 6 when they developed the model of the different plate motions to help remind them of how plates don't move smoothly at a constant movement. Explain that with movements this small and timescales this large, that this is an approximation that scientists have understood to vary by thousands of years.

Report out results. Once students have completed their calculations, bring the class back together to discuss the results, having volunteers share what they found. Tell students that they should fill in the number of years in Part 2 for the rate that they didn't work with so that they have both parts filled in. Tell students that we all seem to have large numbers, so when we are talking about these time spans we will start referring to them in terms of millions of years. Ask students to look at their calculations and any number that has 6 zeros after it will be shortened to exclude the zeros. We will instead write "million" after the numbers that are in front of the 6 zeros. On a whiteboard or another space visible to the class, demonstrate this with the class. Ask one student to share their first calculation from Part 2 using the smaller (48 mm/year) of the two average plate movements. Write the full number on the board. After the full number has been written, cross out the last 6 zeros and under it, write "million years."

The numbers should look like this:

125,000,000 = 125 million years

146,000,000 = 146 million years

Ask students to do the same and re-write both numbers on their handouts in Part 2.

Discuss the results of the handout. Point out that there is a large span of time between the first scientific estimate in Part 2 and the second scientific estimate in Part 2. Lead a discussion with students to understand this data variation, and prompt the need to use more data to be more certain of the plates touching, since we know that plates can twist and turn as they move. Example prompts and responses are below.

Key Ideas

Purpose of this discussion: Determine that the time period estimates varied because of the smaller movements of the plate adding up over a large period of time. Even though we have this data that points to a time period, we still cannot say with certainty that they were touching. The data that we will need to look at also needs to come from the continental plates and may be data such as fossils and rocks.

Listen for these ideas:

- Small changes, such as millimeter differences in data, can add up over a long period of time.
- We have data to track back the continents in time to the Mid-Atlantic Ridge, but this does not constitute proof that they were once touching.
- We need more data to be more certain that the continents were once together.
- We may want to look at rock or fossil data from this time period.
- The data that we would need would have to come from a period before our calculated timeframe.
- Since the oceanic plates are created or destroyed over time, we would need to look at the continental plates for our new data.

Say, *We have two different results for the number of years ago that these two continents may have been together.*

Suggested prompts	Sample student responses
If we look at the difference in the amount of years this may have taken, what is the difference between these numbers?	*21 million years!*
That's a big difference, but the difference in the estimated plate movement rate was so small. Why would those times range so dramatically?	*There isn't much difference between the estimates in millimeters, but when I multiply that out over time the small differences add up.*
If we were to look at images of where the two continents were located this year and then again next year at the same time, do you think we would be able to see any difference in their location?	*No… 48mm or 55mm is so small!*
Right! So do you think these movements this small, measured in millimeters, really have any effect on changing the surface of Earth, like the mountains we have been looking at?	*It looks like it… but it takes a long time.* *Yeah… for our mountains they are moving small amounts too, but there are still changes that can be measured and seen.*
So far we have used evidence we are familiar with, plate movement, but if we just use this one piece of data, does that mean that they were once together? Do all plates move the same?	*No… we saw that the plates are moving in different directions and different speeds.* *Some plates twist and turn, so they might not have been together. The math helps us figure out it would have been a long time ago, but we aren't certain.* *No, some plates slide and collide in different ways, like we saw with the foam investigation.*

Say, *So from using the data we are familiar with, we have two different results for how many years ago Africa and South America may have been together. And we noticed that the difference between these two results is very large—21 million years. In order to help us become more sure of when these two continents may have been touching, what additional data could we use?*

Suggested prompts	Sample student responses
What type of data might we want to look at?	*If Africa and South America were together in the past, then we could look at the land and see if the land is the same... like do they have the same type of land.*
Okay, if we looked to see if the type of land was the same today, would that mean the same type of land would have been there hundreds of millions of years ago? What do we know is happening to the land under the ocean between these two continents?	*Oh… the land today may not be the same as millions of years ago.* *The land under the ocean at the Mid-Atlantic Ridge is making more and more new land each year, so if these two continents were together in the past, it might have been different types of land.*

Suggested prompts	Sample student responses
Right… if new land is being made today at the Ridge, then millions of years ago the land we see on the continents today wouldn't have been there. So if we want to see if the land was the same on both continents millions of years ago, where might we look for this data?	*We could dig down underground and look at land or materials that are millions of years old for both continents.* *We need to look at older data.*
Okay, cool! How would we know how far to dig to reach material that is millions of years old?	*We might look at fossil or rock data, since we can find those things from millions of years ago. The animals that live in certain places can change over time.* *There used to be dinosaurs. Maybe they were touching when dinosaurs were around, but not when people and the animals we now know were around. If we look for evidence of matching current animals and plants, then we may not see a connection.*
Would we want to look at evidence from on the continents, or look at evidence from the ocean?	*If we want to know if the continents were touching, we should look at evidence from on the continents.*
So if the oceanic plates are being created or destroyed, should we also look at data from the oceanic plates from long ago?	*The new oceanic plate won't help us know what it was like way back then when they might have been together, because the animals would have lived on the continent or continental plates.* *The oceanic material is made as the two plates are moving apart, so that data wouldn't show us what it was like if they were together. The oceanic parts of the plates might not have existed then.* *If we get oceanic data, it can't be from between the two continents because those oceanic plate areas may not have existed millions of years ago.*
So we need older data, and that data needs to be from the continents, not the oceanic crust in between. But if we are looking for old continent data, how old would it need to be?	*We definitely want to look at when they might have been together.* *The data needs to be from when the continents were touching.*
So do we want to look at data from before 125 million years ago, or data from 146 million years ago?	*We need to go back in time before they were moving apart, so before the 146 million year mark.* *We don't know if they had started moving at or before the 125 million mark. We have to use the later mark.*

Say, *It sounds like we need to analyze continental data from before they started to move apart, so the data would have to be from before 146 million years ago. But where would we even begin to find this data on our continents?*

3. Reason out the location of older data on continental plates.

5 MIN

Materials: None

Turn and Talk about available data. Project **slide D**. Allow students 2 minutes to turn and talk to a partner about the following question: We identified that we might want to look at data like rocks and fossils.

- If we were to look at the African and South American plates for this type of data, where would we find it?

Ask students to share their ideas with the class. Guide students to determine that most of this information would be located underground. An example prompt and responses are below.

Suggested prompt	Sample student responses
Where would we find evidence, like (whatever students have identified) on the plates?	*We would find fossils underground. We would have to dig them up to get the data.* *Old rocks are underground too. Most really old stuff is underground.*

Say, *It seems like we think any data we need to collect would be found underground. Why do you think that old stuff is further underground?*

Allow students to respond. Students will have varied ideas, including that the older material is buried over time.

Consider the placement of older versus younger items. Project **slide E**. Ask students, *Do you have evidence from your life that shows things that are older getting buried under things that are younger or that younger things have been there less time? Do you have any experiences where you have had to "dig" to find what you are looking for? If so, why did you have to dig?*

Allow students to share examples of places where items that are older are under younger or newer items. Students may share examples such as:

- Dirty dishes in the sink, where the older dishes are buried in the sink
- Toys in a toy chest or pile, where older unused toys are under the newer, more used toys
- Laundry in a hamper or in a pile on the floor, where older laundry is under the newer laundry
- Last season's sports equipment is found under this season's sports equipment

Analyze placement of items in a trash can. Say, *We do have a place where we have been adding material over time here at school, which sounds like we think is happening to cause things from millions of years ago to be underground. Let's look at a trash can to see if we see the same trend of older items being below younger items.*

Display **slide F**. Allow students a moment to look at the image on the slide and consider the placement of the trash. Ask students where the older trash versus younger trash would be located. Students will gather that the younger trash will be on top of the older trash.

Ask students about where they might find trash from yesterday. Students should identify that the trash would be towards the top, but not on the top. Ask students if trash from yesterday is towards the top, and where they think trash from last week would be. Students should identify that it might be closer to the bottom.

Compare trash layers to rock layers. Project **slide G**. Explain that scientists use this same idea to find and date different data that they find in the layers of Earth. Explain that the layer of coal seen from the Appalachian Mountains is older than the sedimentary rock above it.

Additional Guidance

Prior to middle school, students have determined that the presence and location of certain fossil types indicate the order in which the layers have formed (4.ESS1.1). The emphasis of this section is to explain that older layers are found under younger layers (the emerging idea of stratigraphy) and their order can be used to relatively date those layers. In addition, 4.ESS1.1 provided students background knowledge in landscapes changing over time, such as areas that were once underwater are now above water. As students progress in this lesson, students are expected to have the understanding that areas that were able to support certain dinosaurs or glacier deposits may have landscapes that are very different now than they were when those items were present on the land from 4.ESS1.1.

4. Analyze maps to determine past plate locations.

12 MIN

Materials: dry erase marker, *South America and Africa Evidence Maps* with different maps placed in individual sheet protectors, *Talking Sticks Protocol for Our Continental Data Sets*

Introduce data sets. Say, *The data we will be analyzing is from a time period before 146 million years ago. If we just figured out that the time these two continents were last touching was 146 million years ago, then what does that mean about what was happening between these two continents after this time?*

Students should say they would have begun to move apart, slowly, but they wouldn't be fully touching.

Say, *Why would we want to look at data older than 146 million years ago?*

Students should say because we are looking for evidence that shows the two continents were once together, or one piece of land.

Go over each data set. Project **slide H**. Divide students into groups of five. Distribute *South America and Africa Evidence Maps* and give each student in the group a different data set, so that all members of the group have a different data set. Color copies of these maps are also located in the Student Procedures. Take a moment to orient students to what each data set shows.

- **Evidence of Past Mountains** - This card shows similar mountain ranges, hills, valleys, etc. from this time period.
- **Evidence of Past Glaciers** - This shows where glaciers were located during this time period.
- **Location of Fossils -** This shows specific types of fossils found that are from this time period.
- **Similar Rock and Mineral Types -** This shows rocks that are of the same kind and age from this time period.
- **Evidence of Past Coral Reefs -** This card shows data from where coral and marine fossils were found in oceans from this time period.
- **Similar Rock Layers and Formations -** This shows rock layers from the two continents.

Pause at the rock layers data set and ask students if this layer would need to match completely, or if there might be data younger or older than the rock layers. Students should identify that the rock layers should look similar for the time period in which we think they were together, but may not look similar before or after that time period since they may or may not have been together.

***Attending to Equity**

The difficulty level of the maps vary based upon the type of data. For students who would like or could benefit from a greater cognitive challenge, consider giving them one of the following maps:

- **Evidence of Past Coral Reefs-** Since there is no data on the actual continents, students will have to deduce that the evidence of past coral reefs indicates where water might have been at that time, meaning that there was no water between the two continents at this time.
- **Similar Rock Layers and Formations-** This rock strata will be harder to analyze than other data sets, since rock layers across these continents are similar, not the same. Students will have to apply the trash can analogy from above to dissect the similarities between these plates.

Additional Guidance

If students are struggling to develop the idea that there would be similar, if not the same, rock layers for part of the layers shown, take time to revisit the garbage analogy. Ask students if trash from two different areas of the school (try to pick very different locations, such as outside a gym and outside the school) would be the same. Students should respond that they could be very different from each other. Ask students if the trash would become very similar if not the same when the two trash cans were placed together. Students should identify that they would then be the same for the time period they were together. Ask students if the trash were then moved apart, if the trash would continue to be similar. Students should identify that the trash that is from the time period when they were together should be about the same, but the new, younger trash might be different. Have students also consider if each trash can would accumulate the same amount of trash in each layer, or if the depth of each layer would be variable. Students should identify that the layers can be of variable depths and thicknesses, but the order of the similar layers would still be the same.

These differences in the rock layers could be due to erosion and pressure that was happening at the time, or volcanic eruptions, or another reason. This is not the purpose of this investigation, but students may need support in analyzing the data if the layers aren't a one to one match. Some of these ideas, such as pressure, are above grade band, and are not the purpose why we are analyzing this data. We are not trying to make sense of the differences between the data at this point, we are instead looking for similarities that could help us figure out if these two large pieces of land could have been touching in the past.

Individually analyze data. Say, *We have multiple types of data so each of you will be responsible for analyzing one type of data.* Explain that students will get 4 minutes to look over their data set on their own to try and make connections.* Direct students to mark up the card with any patterns they see while they are inside the protective sleeves using a dry erase marker.*

Share data sets in student groups. Project **slide I**. Distribute *Talking Sticks Protocol for Our Continental Data Sets* to each group. After the 4 minutes is up, go over the talking sticks protocol on the group handout. Ask students to share their data with their mixed data set groups. Students should share one by one using the talking sticks protocol. As students share, ask them to mark any areas of similarities or differences between the data set being presented and their data sets. Give students 1-2 minutes after they have shared to discuss the evidence as a group.

***Attending to Equity**
Universal Design for Learning
Some students may benefit from extra support in the *perception* of their data and need to physically move the continents back together. By providing pre-cut versions of the continents containing their data sets, we can support students in finding patterns between the two plates. This will allow students to move two static images together to determine if patterns of data hold between the two continents.

5. Exit Ticket

8 MIN

Materials: *Lesson 10 Exit Ticket*

Bring students back together as a class. Ask students to place their maps where others in their group can easily see them.

Conduct exit ticket. Project **slide J**. Distribute *Lesson 10 Exit Ticket* to students. Go over the exit ticket with students. Give students time to complete the exit ticket. As students are working, circulate to make sure that students are citing data sets and explaining how the data supports their claims. Ask students to turn in their exit ticket at the end of class.

Assessment Opportunity

Building towards: 10.A Analyze maps displaying patterns of large sets of data to determine that Africa and South America could have been touching at the Mid-Atlantic Ridge (spatial relationship) between roughly 125 and 146 million years ago.

What to look/listen for:

- Look for students to state in their claim that the two continents were once touching at the Mid-Atlantic Ridge.
- Students should cite all data sets to show that the plates were touching.
- Students should include the following reasons when justifying how the data supports their claim:
  - Similar rock types, rock strata, and land formations: some areas that show similarities can be traced directly across from one continent to another, specifically at the top and middle of the two continents.
  - Evidence of past glaciers: glacier data fits like a puzzle piece if the continents were moved together.
  - Location of fossils: fossils of the same type are found at the middle and bottom sections of both continents.
  - Rocks of similar types and ages: the top-middle of each rock layer are very similar across the two continents.
  - Areas where coral fossils have been found: coral fossils were found on the outside of the two continents, meaning that when they were formed there was no ocean in between the continents.

What to do:

- Students should be able to make multiple connections between data sets and the continents touching. If students do not provide evidence from more than their original data set, guide students to individually look at the data set from another partner.
- Use the pre-cut pieces of continents with the data on them to move the continents back together so that they touch. Ask students if the data shown on the cards presents any patterns that span the two continents.
- After students have identified that the data shows a pattern across the two continents, allow students to revise their work.

ADDITIONAL LESSON 10 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.6.NS.C.5

Understand that positive and negative numbers are used together to describe quantities having opposite directions or values (e.g., temperature above/below zero, elevation above/below sea level, credits/debits, positive/negative electric charge); use positive and negative numbers to represent quantities in real-world contexts, explaining the meaning of 0 in each situation.

As students are creating a model of where continents would have been located millions of years ago, they are working with positive and negative rates of motion. Initially, students use four meter sticks to represent the space between two continents, Africa and South America—this space representing the Atlantic Ocean and Mid-Atlantic Ridge—would represent the starting point, or location “0.” Using manipulative representations (cut outs) of the two continents, they discuss what it would look like in a year from now, and 10 years from now, etc., as they continue to move apart the two continent representations—this represents positive movement. In an effort to figure out if these two continents were together in the past, students work backwards in time, moving the manipulatives back towards each other, or in a negative movement.

CCSS.MATH.CONTENT.6.EE.B.7

Solve real-world and mathematical problems by writing and solving equations of the form $x + p = q$ and $px = q$ for cases in which p, q and x are all nonnegative rational numbers.

Students use approximated numeric data for yearly movement from the Mid-Atlantic Ridge between Africa and South America to determine if these two continents could have been touching in the past. On *Calculating Plate Movement*, students use this data to solve equations that result in how long ago these two continents may have been together.

LESSON 11

Where were the other plates located in the distant past?

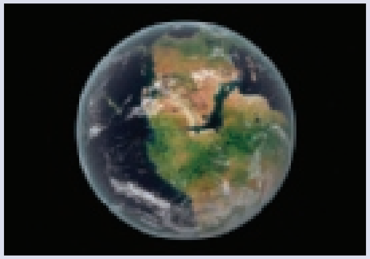
Previous Lesson

We used mathematical reasoning to determine that Africa and South America could have been together 146 million years ago. We completed an exit ticket to make a claim about the two plates touching and supported the claim with evidence from our maps.

This Lesson

Investigation, Putting Pieces Together

2 DAYS



We use multiple types of data as evidence to develop a flat map model that predicts where the continents used to be located relative to one another millions of years ago. We identify the strengths and weaknesses of the evidence used to support our model. We use models and data to justify our predictions for the positions of the continents millions of years ago.

Next Lesson

Since the Appalachians and the Urals are different from other mountains that we are studying, we will use an online simulation to help us figure out how these mountain ranges were formed. Then we will brainstorm other possible causes for the decreasing elevation of the Appalachians and the unchanged elevation of the Urals.

Building Toward NGSS

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

What Students Will Do

11.A Construct an explanation of changes in the global position of land masses over time including reasoning that shows how rock strata and fossil evidence adequately supports a map of where Earth's land masses (parts of plates that were not created or destroyed as plates were moving) were located millions of years ago.

What Students Will Figure Out

- All major continents were once touching and formed a large single landmass that existed hundreds of millions of years ago.
- Multiple sources of data are needed to determine where plates were located in the past.

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**NAVIGATION** Consider how to figure out where plates were in the distant past, and what evidence they would need to confirm their ideas.	A	
2	8 min	**ORIENT TO THE FLAT MAP AND GLOBE** Consider the differences between a flat map and a globe and how different representations might affect data and models.	B-D	landmass data set baggie, one world map with arrows, Earth squish ball globes (1 per pair in each group), inflatable globe
3	8 min	**USE EVIDENCE TO INVESTIGATE PAST LAND MASS LOCATIONS** Make predictions using plate movement, shape of land masses, and expert group data about where these land masses could have been in the past.	E-F	
4	22 min	**ANALYZING MULTIPLE TYPES OF DATA TO DETERMINE PAST LAND MASS LOCATIONS** Compare models based on different types of data and come to a consensus about past land mass locations based on evidence.	H-J	Land Mass Data sets, Plate Movement Map
				End of day 1
5	5 min	**RECONSTRUCT MODELS FROM LAST CLASS PERIOD** Place land masses in the agreed upon arrangement from the last class period.	K-L	Land Mass Data sets, Plate Movement Map
6	12 min	**EXPLAIN OUR MODEL** Annotate model of the land masses location millions of years ago with the data supporting this location. Then explain the reason why the data supports the model.	M	*Evaluating Two Models*, Assembled group consensus model of arrangement of all land masses
7	18 min	**DESCRIBE THE REASONING THAT SUPPORTS THE CLAIM DIAGRAM** Students answer reflection questions to articulate their reasoning for positioning the land masses in the model.	N	*Evaluating Two Models*
8	5 min	**REFLECT ON USE OF CLASSROOM NORMS IN JIGSAW GROUPS**	O	
9	5 min	**NAVIGATION** Students consider how mountains that were already on the land masses millions of years ago might have formed.	P	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 11, students are ready to read Student Reader Collection 4 and then respond to the writing exercise.		Student Reader Collection 4: *The Mysteries of Earth*

Lesson 11 • Materials List

	per student	**per group**	**per class**
Lesson materials **Student Procedure Guide** **Student Work Pages**	• landmass data set baggie • one world map with arrows • science notebook • Land Mass Data sets • *Evaluating Two Models*	• Earth squish ball globes (1 per pair in each group) • Plate Movement Map • Assembled group consensus model of arrangement of all land masses	• inflatable globe

Online Resources

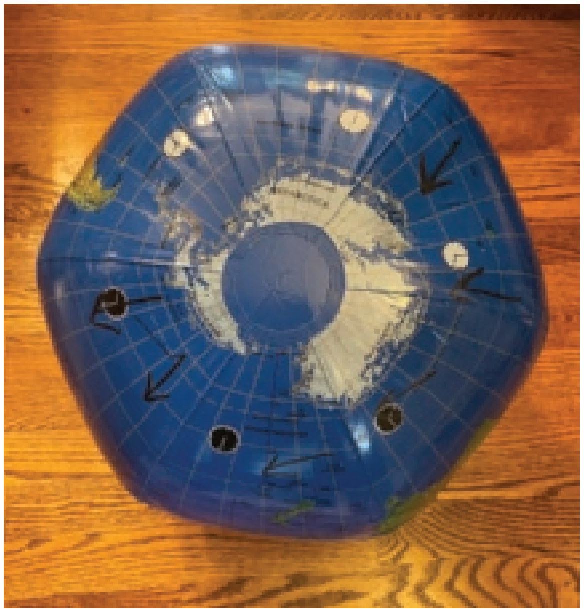
Materials preparation (30 minutes)

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

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

Prior to Day 1:

- Inflate the 16" globe. Use a large black marker to draw arrows on the globe as described in *Teacher Prep for Labeling Arrows on the Inflatable Globe*.
- There are 6 sets of map data cards to be used in a jigsaw. Pieces of these data sets will need to be cut apart prior to class to save time and streamline the activity. This will only need to be done once, as these data sets will be reused between classes and even year to year. Cut out the continents on the 6 different pre-printed 11x17 inch cardstock sheets and sort them into ziplock bags as described in *Teacher Prep for Assembling Landmass Data Set Baggies*.
- Test the projection of the video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).
- Do not staple pages of *Evaluating Two Models* together. Each page of the assessment will be handed out separately.
- Review the slides and work through the activity so that you can help students with the complex task of relocating continental plate pieces.



Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will rearrange continental land masses by moving them through time to predict their positions approximately 240 million years ago, when Earth's land was virtually all contiguous (referred to as Pangaea). They will determine the positions of the continental plates in this arrangement based on synthesizing multiple data sources. They will assess the sufficiency of evidence to justify their explanations for how the continents were positioned approximately 240 million years ago.

Where We Are NOT Going

Students will not be identifying or memorizing the types of plate boundaries that currently exist on Earth, nor those that existed in the distant past. They will not seek to prove whether the positions they have predicted are correct using mathematical calculations of distance based on speed, or using any other specific methods; rather, they will assess the strength of the evidence that exists in the available data to support their predictions. They will not examine changes in intracontinental characteristics over time or in the distant past, but will focus on the historical movements of the continental portions of currently existing plates.

While we have geological evidence that these continents were once together in a single solid landmass, students will not have had the science ideas needed to explain the physical mechanisms underlying the separation of a solid plate into distinct sections, and why plates fracture in the locations that they do. Because of this, this lesson utilizes terms such as "continents touching" or "continents together," and does not refer to Pangaea as one solid landmass. We also do not name this landmass Pangaea, as the focus is more on the ability of plates to move instead of the naming of the plates and their associated land masses over time and how this movement and how the movement of these plates can be used to predict what the Earth looked like in the distant past. Plate names and continent names were only used for students to refer to these regions or areas as they are manipulating the change that occurred over the 250 million year timespan.

Because students do not have the mechanisms to explain how a plate can break or be separated into smaller or different plates, we have also decided to include the Arabian plate within the African plate in this representation, since over the last 250 million years this Arabian plate has become a new plate in the region. Students do not have the science ideas to explain the mechanisms behind this plate separation, as the ideas are above grade band. The physical mechanisms behind continental plates forming and new boundaries like this being created are above grade band.

1. Navigation

7 MIN

Materials: None

Turn and talk about other plates. Display **slide A**. Have students turn and talk with a partner and consider the questions on the slide: We have evidence that the South American and African plates were together and are now moving apart.

- What has been happening to the other continental plates for millions of years?
- Where were the other plates located millions of years ago?
- How could we figure out where they were?
- What evidence would we need to look at to help us?

After a couple of minutes of partner talk, have several students share their answers to the questions.

Suggested prompts	Sample student responses
We figured out the South American and African plates have been moving for millions of years. We know the other plates on Earth are moving right now. Do you think they have also been moving for millions of years?	*They probably have also been moving for millions of years, but in different directions according to the plate directions on the maps we looked at in other lessons.*
Where do you think the other plates were located millions of years ago?	*We don't know. We'd have to figure it out using some plate movement data like we did in the last lesson.* *They could have been anywhere on Earth.* *I've heard the land all used to be together.*
Do you think any others might have been together like we think South America and Africa were?	*It's possible. It depends on how they moved in the past.*
How could we figure out where they were?	*We could move the different plates by following the movement arrows backwards like we did when we were thinking about South America and Africa moving over time.* *We'd need to look at the arrows showing how they're moving, and move them backwards from those directions.*

Suggested prompt	Sample student responses
What evidence would we need to look at to help us figure out where they were and whether any other continents were together?	*We need to know what direction each plate is moving so we can move them backwards.* *We should look at how/whether any of the shapes fit together.* *We could look at the data/evidence that we looked at in Lesson 10 (Evidence of Past Mountains, Evidence of Past Glaciers, Location of Fossils, Similar Rock and Mineral Types, Evidence of Past Coral Reefs, Similar Rock Layers and Formations).*

Divide students into groups for the investigation. Say, *These are some great ideas. Let's use some of them to try to figure out where the continents could have been in the past.* Organize students into six groups of no more than five students per group. This first group students will work with will all have the same type of data to analyze. Tell them they will work with this group to become experts on one type of data and how they might use this data to figure out where the continents used to be millions of years ago. Then, later, they will share their ideas about the placement of continents based upon their data from others who used different types of data and compare their predictions with others about where the continents used to be.

Say, *Today we will be starting in groups where we all are working with the same type of data as the other members of your group. You will work in that group to really understand the potential relationships between your group's type of data for the continents and try to figure out, using that data set, where the continents used to be. After you and your expert group have determined where the continents might have been located based upon your group's data, you will share your findings with people from other groups who used different data sets. As you share with people from other groups we will get a chance to see if their data sets help to compliment or clarify some of your continental movement ideas, and revise based upon all of our data sets where we think the continents might have been located in the past.*

2. Orient to the flat map and globe.

8 MIN

Materials: landmass data set baggie, one world map with arrows, Earth squish ball globes (1 per pair in each group)

Start to organize models. Display **slide B**. Distribute a copy of the *Plate Movement Map* to each student. Distribute a set of baggies with the same type of data for each student in each expert group, and one Earth squish ball globe per pair of students. Direct students to take out their pieces and think about how we can describe these pieces. Point out that the pieces are of many continents, but some pieces are sections of continents, so we cannot refer to these pieces as continents. Work with students to determine that we can refer to these as continental crust pieces, land masses, or another agreed upon term such as plate sections that accurately reflects the parts of the globe that are being manipulated. Example prompts and responses are below.

Suggested prompt	Sample student responses
Let's look at these pieces. What are these pieces we are seeing? What do they represent?	*They look like pieces of continents.* *They are just the continents without the ocean.*

***Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Due to the distortion necessitated by using a flat map, the arrows indicating plate movement on the Plate Movement Map are not positioned exactly like the arrows showing plate movements on previous maps or in Seismic Explorer. This is especially true for the Australian land mass by

Suggested prompt	Sample student responses
Are they all continents?	*No, we have India separate and a couple of these, like Asia and Europe, aren't separated.*
So can we call them continents?	*No, they aren't all continents?*
What can we call all of these pieces? Is there anything that they have in common that we can use to describe them?	*Well, they are all continental land masses. They are all sections of land.* *They are all sections of plates above water.* *They all seem to be made of continental crust.*
OK. So what do we want to call them?	*plate sections*
(Work with students to determine a word or phrase that accurately describes what these pieces represent. From this point on in the teacher guide, we will use continental land masses and continental crust to reflect the potential word choices of students.)	*land masses* *sections of continental crust*

virtue of its location closer to the south pole. The arrows do show representations of the general direction, and rate of movement (by length of arrows) that has occurred over the last couple of hundred million years. The arrows are designed and positioned on the map to help students move and twist the continents backward into their approximate relative positions they were in about 240 million years ago.

Align pieces of the flat map to the Plate Movement Map. Ask students to remove all of the continental land masses from their baggies and place them on the corresponding locations on their Plate Movement Map. As they are placing the pieces, students will notice that Antarctica pieces from their baggies do not have a space reserved for it on the map, and do not fit where Antarctica is traditionally located on the map. As students try to place this piece, use this controversy to navigate into the next slide.

Investigate the inaccuracies of a flat map. Display **slide C**. Show students the 16" inflatable globe. Ask students to turn and talk about the differences between a flat map and a globe by considering the question on the slide.

- Why do continents look different on a flat map versus your Earth squish ball globes?

After students have talked for a moment, gather them together and show them the short video of the teacher trying to flatten out a globe. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Have them share what they saw. They should understand that while a flat map is easier for us to work with in this activity, it distorts the shape and size of the continents. Say, *What are some things you noticed happening to the globe as the person "cut" it apart and tried to flatten it out?* Students should notice that it was difficult for the person in the video to lay the cut globe down flat and when they did get it flattened out, the different land pieces looked different than when they were on the inflatable globe.

Additional Guidance

Students should agree that using a flat map instead of a globe affects how things look and where they are relative to each other in the model. To bring home the point that the positions of continents are different on a flat map versus a globe, you might ask them to trace the path an airplane would take when flying from New York City to London on a flat map and on the Earth squish ball globe they have. On a flat map, the shortest straight route goes entirely over the ocean, but on a globe, the shortest straight route goes over much of Canada and only a little bit over the ocean.

Introduce students to the plate movement arrows on the globe. Display **slide D**. Explain to students that because Antarctica is the hardest land mass to represent on a flat map, the slide shows them how to position Antarctica.*

Show them the globe you've prepared with the arrows showing how the Antarctic land mass is moving today. The image to the right has the arrows placed appropriately around Antarctica. Help students situate Antarctica on their *Plate Movement Map* as shown in the figure on the slide and orient them to how the Antarctic land mass is moving currently. They will use the arrows drawn on the globe to direct their movement of the Antarctic land mass as they individually develop their initial models.

3. Use evidence to investigate past land mass locations.

8 MIN

Materials: None

Engage with data sets in expertise groups. Display **slide E.** Say, *Let's get ready to use the data from our data sets and the arrows located on our* Plate Movement Map *to try and determine the past locations of our land masses, like we did with Africa and South America in Lesson 10. Let's start by tracing back those two land masses to where we figured out they could have been located millions of years ago. Then let's work pieces in your baggie representing the different land masses to determine based on our data if the other land masses could have also been in different locations millions of years ago.*

Work with groups to analyze plate movement based upon group data. As students work, circulate among the groups and prompt them to consider their positioning of the land masses based on the data type they are analyzing using questions like the ones listed below:

- Did you move each of the landmass backwards in the opposite direction of the arrows on the *Plate Movement Map*?
- Do the edges of the continents look like they might fit together based on their shapes? Did you have to twist any of them a little bit to get them to fit?
- Were any of the continental land masses particularly hard to find a position for?
- **Evidence of Past Mountains**: What do you notice about how mountain ranges are arranged? Why would you expect mountain ranges to be in a sort of line?
- **Evidence of Past Glaciers**: Why did you fit the land masses together that way? Do glaciers just appear in many places, or do glaciers spread out to cover the land from a central location? Does this data help you position all the land masses?

- **Location of Fossils**: Are there the same kind of fossils on each of the land masses that you have right next to each other? How would the same organisms have gotten to both those places? Do you think the fossil data is important to support your positioning of those land masses?
- **Similar Rock and Mineral Types**: Would land masses that are connected be likely to have the same rock and mineral types? Why?
- **Evidence of Past Coral Reefs**: What does it mean if coral fossils were found near that piece of land? Where do corals live? If you know that side of the land mass was a coastline based on the coral data, can it be positioned that way?
- **Similar Rock Layers and Formations**: Would land masses that are connected be likely to have the exact same rock formations and the same layers? Why or why not? Why don't all the layers match up?

Additional Guidance

Reassure students that this is an initial prediction of the past locations of land masses and they will work with their group to revise it. It is not expected that any group will definitively be able to position all the land masses in their placement in the distant past, but they should make a preliminary prediction on where they think every continental land mass would be, based on the direction the land masses move, how well the shapes of their edges fit together, and the inferences they can make from the the data set they have. For some data, there may be no information at all that either supports or refutes their positioning of some of the continental land masses. In the next step of the investigation, students will work with other groups to look for patterns between sets of data to help guide the placement of these land masses that have less data within their personal data set.

Articulate the strengths and weaknesses of their model. Display **slide F**. Have students create a T-chart to record the strengths and weaknesses of the evidence supporting their particular model. If students struggle to identify what support is stronger, have them consider which land masses have the most data supporting them, and therefore were easier to move and place. The more data they have that supports their positions, the stronger that support is. They should carefully record strengths and weaknesses since they will use this information when they join a jigsaw group to compare models. There may be some positions they have no data for other than the shape and the movement of the continental crust pieces.

Record the positions of the land masses in their model. Display **slide G**. Have students individually diagram their group's arrangement of the land masses in their science notebook using the directions on the slide. This diagram will help them communicate with their jigsaw group, and, importantly, will serve as the basis for some of the reasoning that students will articulate in the assessment at the end of the lesson.

4. Analyzing Multiple Types of Data to Determine Past Land Mass Locations

22 MIN

Materials: science notebook, Land Mass Data sets, Plate Movement Map

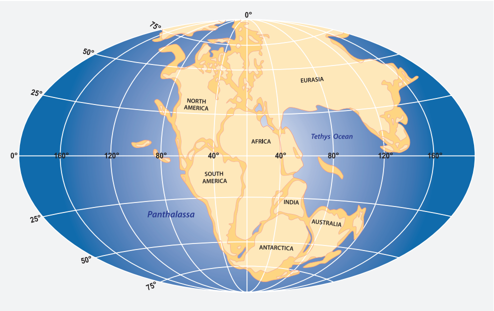
Arrange students in jigsaw groups. Display **slide H**. Say, *Now that you all have had a chance to analyze the data set you were assigned, you will join a new group. With this new group, you will each take turns sharing what you discovered about where the continental land masses could have been in the past supported by what you figured out with your data set.*

***Supporting Students in Engaging in Constructing Explanations and Designing Solutions**
Each student may come into the jigsaw group with a somewhat

Have students join a group of 6 consisting of one person who has been working with each of the 6 different types of data. Tell students to begin by assembling their data set in the arrangement that their prior group agreed upon based upon their individual data set. Have students place this on a desktop or other space where it will be easy for other members of their jigsaw group to see the arrangement and the data. Once all group members have assembled and displayed their land masses arranged by their data sets, have students create another T-chart in their science notebook to record the similarities and differences of other students' models regarding the positions of land masses. Give students 5 minutes to individually look at the other five models in their jigsaw group.

Resolve differences between models. Display **slide I**. After several minutes of recording individual observations, ask students to share the similarities and differences they noticed with students in their group. Ask students to begin with the Evidence of Past Glaciers data and discuss similarities and differences. After that data set has been discussed, move to the next data set on the right. Students should work to resolve any differences between the various models in their group by discussing the strength of the evidence that supports each arrangement of the land masses using the sentence stems on the slide. Each group should come to a consensus based on evaluating the information from all the different types of data and assessing which data is most convincing for their arguments for the positions of land masses.

Articulate the strengths and weaknesses of their model. Display **slide J.** Have students create a T-chart in their science notebook to record the strengths and weaknesses of the evidence supporting their particular model. They should work together with their group to articulate the strengths and weaknesses of their consensus model with the multiple pieces of data. Encourage students to discuss in their groups which pieces of data support the position of the land masses in their consensus model more and which data pieces are weaker for supporting the location of the land masses in the past. If students struggle to identify what support is stronger, have them consider which decisions about positions of land masses have the most data supporting them. They should carefully record strengths and weaknesses which they may want to refer to during the assessment at the end of Day 2.*



A scientific representation of what the jigsaw group's land mass arrangement might look like is shown here. However, if their positioning of the land masses is substantially different than this, that is OK. They will be looking at models at the end of this lesson and in the next lesson that represent scientists' predictions of where the land masses were millions of years ago. The important work they are doing here is identifying evidence and developing reasoning that supports their positioning of each land mass based on all the different types of data they have examined.*

Make any necessary adjustments to arrangements. Display **slide K**. After they have come to agreement of potential placement based upon their shared data sets, have each group create a consensus model of the positions of all the land masses. Tell students to work with their jigsaw groups to reorganize their personal data sets. Have at least one person in the group create a record by taking a picture or making a sketch of where they agreed the land masses were located. They will use this record to recreate their models with their group at the beginning of the next class period.

Collect all the model pieces. Have students clean up by placing all of their land mass pieces back into their specific *Land Mass Data* set baggies and close them up. Collect all the baggies from students.

End of day 1

different arrangement of the land masses. In order to resolve differences between the models in the jigsaw groups, students will need to articulate reasons for why they think one arrangement is more likely than another. Listen for students to articulate reasons based on weighing which evidence (data) is most convincing, or which positions they have the most data to support or refute. They should rely on reasoning that takes into account evidence from multiple data sources and be able to articulate that having data from multiple sources supporting the same positioning claim, makes that claim more convincing.

***Supporting Students in Three-Dimensional Learning**

Note that the Indian land mass is likely to be the most difficult to position because there is not much data that supports its positioning, and it travels further away from its present-day position than the other land masses do, making the position of this land mass less predictable than the other land masses. In order to place this land mass, students will have to use *data from multiple data sets* and *identify patterns that are found* on data sets across multiple maps to make connections between multiple land masses.

5. Reconstruct models from last class period. 5 MIN

Materials: Land Mass Data sets, Plate Movement Map

Reassemble the consensus model. Display **slide L**. Redistribute the baggies of the *Land Mass Data* sets from last class period to each student. Have students reconvene in their jigsaw groups from the previous class period. Distribute the *Plate Movement Map* to each group. They should quickly rearrange their land mass pieces to recreate the consensus model that they had agreed on at the end of the previous class period in their jigsaw groups. Remind each group that one of the members recorded an image or drawing of this representation.

6. Explain our model. 12 MIN

Materials: *Evaluating Two Models*, Assembled group consensus model of arrangement of all land masses

Construct an individual explanation. Say, *You have figured out so much about how land masses move throughout time, and you've analyzed data in the last two lessons to figure out where the land masses were likely located millions of years ago. Let's capture all you've figured out by explaining how you decided on where the land masses were located in the distant past. First you will record the shape of your consensus model of where the land masses were in the past. Include in your model the evidence you used. Then, using this model, and the data included on the model, you will explain your model—where the land masses were in the past, how confident you are of this model and why. This will be a chance for you to individually explain what you have figured out about how Earth's surface has changed over time, millions of years ago until now.*

Record the group model that represents the claim about where land masses were in the past. Display **slide M**. Distribute the first page only of *Evaluating Two Models* to each student. Have them follow the directions on the slide to replicate their group's model of the arrangement of the land masses and tell them to be sure to add all the evidence onto the model that supports this arrangement. This record of the group consensus model will serve as part of the assessment and the basis for the reasoning that students will articulate in the reflection questions in the assessment. It is critical that students complete this carefully and thoroughly. They will be comparing it to the individual model they made in their notebook using only one piece of data.

Additional Guidance

This copy of the group consensus model serves as the claim for the explanation that students are incrementally constructing through multiple questions for this assessment. They should be encouraged to do work that makes their thinking clear, e.g. showing all the outlines of the land masses and placing a depiction of any and all data that serves as evidence for positioning two land masses next to each other across the boundary between the plate boundary by the land masses. Accurate labeling of land masses and data types is very important. It is not important that their depictions are precise as to shape or size of the various land masses, or data sets, and allowances should be made for those students who "can't draw." Some students may ask to have the land mass shapes back so they can use them to trace.

7. Describe the reasoning that supports the claim diagram. 18 MIN

Materials: *Evaluating Two Models*, science notebook

Articulate reasoning about individual models. Display **slide N**. Distribute the second page of *Evaluating Two Models* to each student. Students should have one model drawn in their science notebook (from their work with their first group), and one model drawn on the first page of *Evaluating Two Models* (from their work with their jigsaw group). Have students work individually to compare their first model from their notebook with their copy of the group consensus model they recorded on the first page of the assessment as they answer the assessment questions on *Evaluating Two Models*. They may refer to the various T-charts they created in their notebooks as well. **Collect student work.** When students have finished their work on *Evaluating Two Models*, collect the completed model and the completed assessment questions from each student. Stop students and gather the attention of the whole class with sufficient time left in the class period to participate in the navigation step that follows.

Assessment Opportunity

11.A Construct an explanation of changes in the global position of land masses over time including reasoning that shows how rock strata and fossil evidence adequately supports a map of where Earth's land masses (parts of plates that were not created or destroyed as plates were moving) were located millions of years ago.

What to look for/listen for: The model that students draw on the first page of *Evaluating Two Models* is likely to represent a single large landmass, though that is not absolutely necessary. They should represent that at least most of the landmass are touching or adjacent to each other in a way that matches according to shape. Their diagram should include labeled regions representing each of the 7 land masses, and at least 3 or 4 different kinds of data represented graphically or with labeling. Look for data to be located near and across boundaries where land masses are next to each other. For responses to the written assessment questions, see *Teacher Key for Evaluating Two Models* for details.

What to do: There are multiple elements in the written answers to the assessment questions that would provide an adequate answer. Not every element must be present in a student answer for a question to be answered sufficiently. See *Teacher Key for Evaluating Two Models* for scoring guidance. If students have not included any of the listed elements in their answer, list possible elements for them to consider. Also, provide feedback to students on their written work and models that calls out any missing elements in order to bring these to students' attention.

8. Reflect on use of classroom norms in jigsaw groups. 5 MIN

Materials: None

Reflect on use of norms. Display **slide O**. Say, *Over the last two days, as we all have been working to make sense of the different data pieces of where the land masses were millions of years ago, there were many points where you had to share your ideas with your group members and then work to come to an agreement based on all your data sets. This took some negotiation in some groups. We have been doing such an amazing job working together as scientists and peers to figure things out and the use of the norms we developed and continually revisit has supported us in our work. Turn to the next blank page in your notebook. Title it "Reflection on Norms". Then take a couple minutes to individually reflect on:*

- Which of the norms did you feel you personally used when putting together the model with your expert, same-data set group?
- Which of our norms most helped your mixed-data, jigsaw group be able to work together to come to a consensus on where the land masses should be placed to represent the data?

9. Navigation

5 MIN

Materials: None

Orient to what is shown on a new model. Display **slide P**. Introduce the model as one that scientists have put together using data similar to what we have worked with in this lesson. Help students orient to the model by pointing out parts of the globe that they will recognize like the poles, the equator, and familiar continents. Give students a moment to turn and talk with a partner or with a group about how this model compares to the consensus model they just constructed.

Additional Guidance

It is important that students understand what type of geography they are looking at on the map. If necessary, review with students the common topographical conventions used in this map.

- ice is shown as white
- land that is mostly flat is shown as green: the darker green it is, the lower the elevation
- mountains are depicted as brown: higher mountains are darker brown, while very tall mountains are white because they are covered with ice
- deep water is dark blue while shallower water is light blue

Consider the origin of mountains. Ask students to recall what they know about how mountains are formed. They should say mountain ranges form when moving plates collide with each other and crumple up into mountains. Then, point out the Appalachian Mountains on the model. Say, *So if mountains form when plates collide with each other and we just figured out that all the land masses look like they were joined together at one point, how are there mountains on this land millions of years ago?*

Suggested prompts	Sample student responses
What do you remember about the Appalachian Mountains from the mountain cards?	*They're really old.* *They used to be really tall.* *Mt. Mitchell is getting shorter.*
How do you think the Appalachian Mountains formed?	*Accept all answers.*
What evidence from what you're seeing here makes you think that's what happened?	*Accept all answers that draw on evidence students can identify in the data and prior ideas the class has developed.*

Suggested prompts	Sample student response
What evidence from what we've figured out about plate movement and mountains makes you think that's what happened? *What evidence would you want to see to help you decide whether that's what happened?* *When do you think that happened?* *Why do you think that's when it happened?*	*Accept all answers that draw on evidence students can identify in the data and prior ideas the class has developed.*

If students do not suggest that the Appalachian Mountains must have formed by different plates moving around in the deeper past, raise that possibility. Suggest that we should investigate that in our next class period.

SCIENCE LITERACY: READING COLLECTION 4

The Mysteries of Earth

1. **How Did They Get There?**
2. **Unsolved Mystery: The Marianas Trench**
3. **Visit the Natural Wonders!**
4. **Is Yellowstone About to Explode?**
5. **Induced Earthquakes**

Literacy Objectives

- ✓ Summarize key points related to plate tectonics.
- ✓ Distinguish cause(s) and effect(s) related to continental drift and fossils.
- ✓ Argue a position on the issue of whether human activity can cause mountains to sink.
- ✓ Distinguish between credible and non-credible sources.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 9–11.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a well-reasoned paragraph in response to the reading.

Instructional Resources

Student Reader

Collection 4

Science Literacy Student Reader, Collection 4
"The Mysteries of Earth"

Exercise Page

EP 4

Science Literacy Exercise Page
EP 4

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 9: What causes mountains to change?
- Lesson 10: Where were Africa and South America in the past?
- Lesson 11: Where were the other plates located in the distant past?

Standards and Dimensions

NGSS

Disciplinary Core Ideas

ESS1.C: The History of Planet Earth The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4)

ESS2.A: Earth Materials and Systems The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future. (MS-ESS2-2)

ESS2.C: The Roles of Water in Earth's Surface Processes Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations. (MS-ESS2-2)

Science and Engineering Practice(s): Analyzing and Interpreting Data; Obtaining, Evaluating, and Communicating Information

Crosscutting Concept(s): Cause and Effect; Stability and Change

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

LITERACY.W.6.1: Write arguments to support claims with clear reasons and relevant evidence.

Math

CONTENT.6.NS.C.7.C: Understand the absolute value of a rational number as its distance from 0 on the number line; interpret absolute value as magnitude for a positive or negative quantity in a real-world situation. *For example, for an account balance of –30 dollars, write* $|-30| = 30$ *to describe the size of the debt in dollars.*

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

paleontologist

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

correlated **cumulative**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations.

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Plate Tectonics and Rock Cycling unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will examine a map showing fossil evidence supporting the idea that the continents were once joined.*
    - *Next, you'll read a mock online encyclopedia entry about exploration of the Marianas Trench.*
    - *Then you'll also read a simulated travel agency brochure, advertising a trip to visit Earth's most spectacular natural wonders.*
    - *You'll also read a facsimile of a scientific research report about the Yellowstone volcano and the likelihood that it will erupt in the near future.*
    - *Finally, you'll read an article about human-caused earthquakes.*
- Distribute Exercise Page 4. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
    - *For this assignment you will be expected to generate a well-reasoned paragraph to support one of two claims—that humans can or cannot cause mountains to sink.*

Exercise Page

EP 4

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
    - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
    - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
    - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
    - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
    - *Revisit the reading selections to complete the writing exercise.*
    - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (WEDNESDAY)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What's the answer to the question, "How did fossils of the same species end up on continents separated by oceans?"	*The continents used to be connected.*
What methods have scientists used to measure the depth of the Marianas Trench?	*dropping a weighted rope off a boat, making echo soundings, and using submersibles*
What does it mean to say that data are collected "cumulatively"?	*It means that the data are added up over time.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
In addition to comparing fossils, what else do scientists looking for evidence of continental drift compare about fossils?	*They compare the rock layers in which the fossils are found.*
A trench is a place where two tectonic plates meet. What would scientists want to know about this type of plate boundary?	*if one plate is slipping under the other or if the two plates are colliding and making a mountain range*
Which of the natural wonders in the travel brochure are caused by moving magma?	*nearly all of them* *Any plate movement, such as when the Himalayas are lifted, involves magma.* *Any change involving a volcano also involves magma.* *The only one that might not be caused by magma is the formation of the harbor at Rio de Janeiro.*

- Refer students to the Exercise Page 4. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
    - *The writing expectation for this assignment is to choose one of two claims to support in a well-structured paragraph.*
    - *You'll want to reread the Preface to this unit and think back on our classroom discussions before writing your paragraph.*

Exercise Page

EP 4

- *The paragraph should be formal in style, as if you are writing for a scientific publication.*
- *The important criteria for your work are that you develop a clear argument in support of your claim and use knowledge gained from this unit.*

- Answer any questions students may have relative to the reading content or the exercise expectations.

4. Facilitate discussion. (Friday)

Facilitate class discussion about the reading collection and writing exercise. The first selection consists nearly entirely of maps showing where fossils of the same ancient species are found in certain areas of present-day continents and what inferences can be made about the locations of continents hundreds of millions of years ago. The second reading is about human exploration of the deepest part of the ocean. In all the remaining selections, students should pay close attention to "reading" data in images, graphs, and maps.

Student Reader

Collection 4

Pages 34–43 **Suggested prompts**	**Sample student responses**
What is the general purpose of the first selection, "How Did They Get There?"	*It presents fossil evidence that the continents were once one big continent.*
How does this selection help you build knowledge on top of what you learned in the Collection 2 reading about Alfred Wegener?	*The article in Collection 2 explains who Wegener was and that he looked at fossils to come up with the idea of continental drift. This article details which species of plant and animal fossils are used as evidence of continental drift.*
What assumption do paleontologists make about the ability of the plants and animals they study as fossils to live in or cross the ocean?	*that these are all land creatures and could neither live in the ocean nor cross it*
Think about what the climate of Antarctica is like now. How is the discovery of reptile fossils evidence that this continent was once quite far from Earth's South Pole?	*Antarctica has an extremely cold climate, and no reptiles are likely to survive there now. But, if reptiles once lived there, this is evidence that Antarctica was once where the climate was much warmer.*
What is the general purpose of the second selection, "Unsolved Mystery: The Marianas Trench"?	*It describes the history of people's attempts to measure the deepest part of the Marianas Trench.*
The peak of Mt. Everest is about 8,849 meters above sea level. The bottom of the Marianas Trench is about 10,927 meters below sea level. If, on a number line, sea level is 0, what is the distance between the lowest and highest points on Earth? Show your work.	*8,849 meters + 10,927 meters = 19,77 meters*
If this trench is along a plate boundary, what kinds of changes might be occurring there?	*One plate has to be slipping below another plate, causing earthquakes and magma to escape.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—The noun *paleontologist* is likely unfamiliar to many students. However, students should be able to infer from context that it might have something to do with fossils. Explain that the root *pale* comes from a Latin/Greek word meaning "old" or "ancient." *Ontology* is from a Latin word for "the science or study of." Adding the suffix *ist*, meaning "one who performs or specializes in," results in a word meaning a scientist who investigates ancient life using fossils.

Pages 38–43 **Suggested prompts**	**Sample student responses**
What is the general purpose of the third article, "Visit the Natural Wonders!"?	*It tries to persuade the reader to purchase a tour of natural sights from a travel agency.*
Which of the natural wonders on the tour were caused by weathering and erosion?	*the Grand Canyon and Guanabara Bay*
How credible is the science information in this selection? Explain your thinking.	*Since it is a travel brochure, we cannot be sure how accurate or up to date the science is. On the other hand, these natural features are known to be spectacular, so there is no reason to exaggerate the facts to convince people to buy the tour.*
Think back to the Collection 3 selection "The Laws of Layers." Which law is illustrated by the Grand Canyon rock?	*the law of superposition as well as the law of cross-cutting relationships down in the bottom near the Colorado River*
What is the general purpose of the fourth article, "Is Yellowstone About to Explode?"	*It is a scientific report explaining why it is not likely that the Yellowstone volcano will explode any time soon.*
Check out the "Dig into Data" box. What kinds of earthquake data trends do you notice from Figure 1?	*From 1994 to 2002, there seem to be more earthquakes per quarter than in previous 18-year periods.*
Looking again at the Figure 1 graph, how would you describe the earthquakes per quarter during the five-year period from 1984 to 1989?	*The number of earthquakes was very low except for one quarter in 1985, when the number was almost 1,000.*
Look at the "Dig into Data" box again. Which city on the map would most likely have the thickest amount of ashfall after a volcanic eruption?	*Billings*
What is the general purpose of the fifth article, "Induced Earthquakes"?	*It describes the changes in the number of earthquakes in the central United States, and explains three ways humans cause earthquakes.*
What information would you need to decide if the increase in earthquakes shown on the graphic is correlated to fracking?	*I'd need to compare the map of earthquake locations to a map showing fracking locations in the same years.*
What information in this article is related to the issue introduced in the unit preface, whether fracking is dangerous or not?	*the third example in the diagram, which shows fluid injection into the ground to get at oil and gas*

Online Resources

CHALLENGE—Point out to students that the Yellowstone volcano is over a hot spot, similar to the hot spot that forms the Hawaiian Islands—which they read about in Collection 3. Challenge interested students to learn more about the source of heat for the hot spot that is below the Yellowstone volcano and how the hot spot has left a "track" showing that the North American Plate is moving in a northeast direction.

EXTEND—The U.S. Geological Survey (USGS) issues monthly online video updates from the Yellowstone Volcano Observatory, accompanied by detailed text descriptions and transcripts. The videos are also posted on YouTube. Students can also watch annual updates to compare earthquake frequency to the previous year.

Pages 42–43 **Suggested prompts**	**Sample student responses**
Check out the "Consider the Source" box. What sources of information about earthquakes in oil and gas country might be less credible than this one?	*The oil and gas companies themselves might be but also could be accurate.* *Organizations that are opposed to fracking might present skewed information, but they also might present accurate data.* *In both cases, one has to be careful about analyzing the data.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 4, students should choose one of two provided topic sentences and write a well-constructed paragraph to support their claim with reasoning and evidence.

- If students claim that humans activities *cannot* cause mountains to sink, they may refer to differences in scale, comparing the masses of tectonic plates that uplift mountains to the masses that human can move, and infer that human changes are not large enough to sink a mountain. They may also explain that mountains can "sink" at plate boundaries as the edge of one plate slips under the edge of the adjoining plate (subduction).
- If students claim that humans activities *can* cause mountains to sink, they may refer to the earthquakes caused by fracking as evidence and infer that the cumulative small earthquakes people cause can change bedrock enough to cause a mountain to sink. They may also have heard of sinkholes caused by the removal of groundwater by humans and explain that the land above a sinkhole will fall into the void. Finally, they might explain that mountains become shorter due to erosion and that erosion is often increased by human activities.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 12

Where did mountains that aren't at plate boundaries today, like the Applachians and Urals, come from?

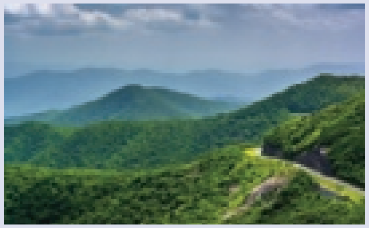
Previous Lesson

We used multiple types of data and models to examine how the continents moved and relocated on Earth over millions of years. We identified the strengths and weaknesses of our models. We used data to develop an explanation for the positions of continents millions of years ago.

This Lesson

Putting Pieces Together, Problematizing

1 DAY



We use map images and the Data Cards for Other Mountains and Mt. Everest to compare the mountain sites we are studying. We remember that the Appalachians are decreasing in elevation, while the Urals are neither increasing nor decreasing. We know that colliding plates cause mountains to form and increase in elevation, but the Appalachians and the Urals are not located near plate boundaries. We use evidence from an online simulation to construct an explanation for how and when the Applachians and the Urals were formed. We are left wondering about other processes causing the Appalachians to decrease in elevation and the Urals to neither increase or decrease.

Next Lesson

After recalling what we already know about erosion and weathering, we read about erosion rates and how scientists use these rates to determine how erosion is changing the surface. Then, using both the erosion rates and uplift rates for Mt. Everest and Mt. Mitchell, we develop a representation of each model and how these two processes are affecting them. We determine that when erosion rates are higher than uplift rates, like at Mt. Mitchell, a mountain will shrink in elevation.

Building Toward NGSS

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

What Students Will Do

12.A Construct a scientific explanation based on evidence from a model that colliding tectonic plates caused the formation of the Appalachian Mountains and the Ural Mountains at time and spatial scales that are not observable.

What Students Will Figure Out

- The Appalachian Mountains, formed 470 million years ago, and the Ural Mountains, formed more than 300 million years ago, were both created in the same way that other mountains were formed—through plate collisions.
- Plate interactions cannot explain why the Appalachians are decreasing in elevation or why the Ural Mountains are neither increasing or decreasing in elevation.

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	4 min	**NAVIGATION** Consider whether we can use our model for how mountains form to explain what is happening with all our mountain sites, and determine that we cannot explain why some mountains are not increasing in elevation.	A	Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, markers
2	11 min	**GATHER ADDITIONAL INFORMATION ABOUT THE APPALACHIANS AND THE URALS** Use the *Data Cards for Other Mountains and Mt. Everest* to gather and document additional information about the Appalachian and the Ural Mountains.	B	Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, markers, What We Know About the Appalachians and the Urals chart
3		**ANALYZE PLATE BOUNDARY MAPS** Analyze maps to determine that the Appalachian Mountains and the Ural Mountains do not have active plate boundaries under them.	C-D	optional: *Satellite and Relief Maps*
4	8 min	**OBSERVE A VIRTUAL SIMULATION** Explore a virtual simulation of continental plate movement over time and make observations about relative plate movements and land masses.	E-F	Ancient Earth simulation: Dinosaur Pictures and Facts (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Alternate: Formation of the Appalachians slide deck
5	18 min	**INVESTIGATE THE FORMATION OF THE APPALACHIANS AND THE URALS** Use a virtual simulation to observe and describe the formation of the Appalachians and the Urals. Use observations as evidence to construct a scientific explanation for the formation of mountains.	G-M	chart paper, markers, What we know about the Appalachians and the Urals chart, Ancient Earth simulation: Dinosaur Pictures and Facts (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
6	4 min	**NAVIGATION** Brainstorm possible processes that are causing the Appalachians to shrink and the Urals to neither grow or shrink.	N	

End of day 1

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebooks • optional: *Satellite and Relief Maps*	• Data Cards for Other Mountains and Mt. Everest from Lesson 1	• chart paper • markers • What We Know About the Appalachians and the Urals chart • Ancient Earth simulation: Dinosaur Pictures and Facts (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Alternate: Formation of the Appalachians slide deck • What we know about the Appalachians and the Urals chart • Ancient Earth simulation: Dinosaur Pictures and Facts (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (20 minutes)

Online Resources

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

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

This lesson requires the use of the *Ancient Earth Globe* virtual simulation. Access the simulation prior to using it to ensure you can project it and are familiar with the features. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

As an alternate option to using the simulation, there is a slide deck titled *Formation of the Appalachians* that captures screenshots from the simulation to be used with students to support them in making sense of how land around Mt. Mitchell has changed over hundreds of millions of years.

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students use map images to determine that the four mountain sites they are studying are increasing in elevation and located along plate boundaries, but the Appalachian Mountains and the Ural Mountains are not. Students know that collisions between plates create mountain ranges and cause mountains to continue to grow and move. Students use the virtual simulation to observe the changes that have occurred on Earth across millions of years, which helps them figure out that the Appalachians were formed about 400 million years ago and the Urals were formed 280 million years ago by the same processes that are at work today—interactions between plates. Students use information and data gathered in this lesson to construct a scientific explanation for how the Appalachians and the Urals formed.

Where We Are NOT Going

Students can use plate interactions to explain how the Appalachian Mountains and the Ural Mountains were initially formed and continued to grow and move over millions of years ago. However, students cannot explain why the Appalachians and the Urals are no longer increasing in elevation. Processes, such as weathering and erosion, that cause mountains and other landforms to shrink will be investigated during the next lesson. In this lesson we will not go into the mechanisms that can cause a tectonically inactive, or dormant plate boundary, like what is seen at the Appalachian Mountains.

In this lesson, mountain ranges are discussed; however, not all parts of a mountain range move and grow or shrink in elevation consistently. Due to the materials, location, erosional factors, and uplift that is occurring across the large plate edges, certain parts of a mountain range can be increasing in height while others are decreasing. This is true of the Appalachians and the Urals as well. The Appalachian data focuses on the processes and data that comes from the Southern part of the mountain range, around our mountain peak, Mt. Mitchell. Scientists believe that due to isostasy and slight tectonic shifts, the Northern part of the Appalachian mountains could be experiencing slight uplift. This also applies to the Urals. We have chosen to focus on range data from around the location of the mountain peak for that range. Overall, when looking at all the location data for both ranges, the Appalachians are decreasing in elevation and the Urals are remaining relatively constant.

1. Navigation

4 MIN

Materials: science notebooks, Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, markers

Revist information about other mountains. Distribute a copy of the *Data Cards for Other Mountains and Mt. Everest* from Lesson 1 to each group. Show **slide A**, and say, *Let's revisit what we have figured out about what causes mountains, like Mt. Everest, to continue to grow and move. As you look back at these cards, look to see what we still need to figure out, if anything. Feel free to use the* Data Cards for Other Mountains and Mt. Everest *and look in your science notebooks to review your work from previous lessons.*

Give students a few minutes to talk with a partner. Use the questions on the slide to guide a quick review of what we have figured out about mountains that are growing and moving, then navigate to what we need to figure out next.

Suggested prompts	Sample student responses
What is one process we now know causes mountains, like Mt. Everest, to change in elevation and location?	*Mt. Everest, like many of the mountain sites we are studying, was formed by colliding plates.* *The colliding plates caused bedrock and sedimentary layers to crumple and move upward, forming the Himalayas.* *We also know that mountains that are increasing in elevation and moving every year, are still changing because two or more plates are colliding and moving over time.* *We know that the plates are always moving, so that means that the mountains are moving on them too.*
Which changes have we not figured out?	*We haven't figured out why some mountains are not growing—the Appalachians are shrinking and the Urals are neither growing or shrinking. We have only figured out what is causing mountains to increase in elevation.* *The Appalachians are the only mountains on the Mountain Cards that are decreasing in elevation, and we don't know why.*

If students do not notice that we have not explained mountains decreasing or staying the same in elevation from our *Data Cards from Other Mountains*, direct them to look back at our *Potential Causes for Mountain Movement* chart. Guide students to determine that we have not explained how a mountain could decrease in elevation. Prompt students to give examples of this happening from our *Data Cards from Other Mountains* and support students in being able to identify the Appalachian and Ural Mountains.

Remind ourselves what we already know about these mountains. Say, *Okay, so we still want to figure out what causes a mountain to decrease in elevation and we think investigating more about the Appalachian Mountains and the Ural Mountains can possibly help us figure this out. Let's begin by looking back at some of our data cards that might help us explain why these mountains are not growing.*

2. Gather additional information about the Appalachians and the Urals. 11 MIN

Materials: science notebooks, Data Cards for Other Mountains and Mt. Everest from Lesson 1, chart paper, markers, What We Know About the Appalachians and the Urals chart

Gather additional information about the Appalachians and the Urals from the Data Cards. Show **slide B** and ask students to take a few moments to look back over the information about the Appalachians and the Urals on the *Data Cards for Other Mountains and Mt. Everest* from Lesson 1. Tell them to compare the kinds of changes happening to the Appalachians and the Urals to the other mountains we have been studying. Ask, *In what ways are the Appalachians and the Urals different from the other mountain sites that we are studying?*

Give small groups a few minutes to talk, then ask them to share what they found. Listen for the following ideas to surface that will help guide the learning in this lesson:

- Both are much older than the Himalayas.
- Both have very few earthquakes, and those that do occur are very small.
- Both the Appalachian Mountains and the Urals aren't increasing in elevation.

Probe into the observation of an absence of earthquakes. Ask students what we can recall from prior lessons about mountain growth, and what signs exist of mountain growth. Determine that earthquakes are a sign of this growth and they are evidence of colliding and moving plates. Ask students what it might mean if we do not see any earthquakes at our mountains that are not growing, and how that relates to plate movement. Example prompts and responses are below.

Suggested prompts	Sample student responses
Thinking about the differences between these mountain ranges and what we have figured out about the Potential Causes of Mountain Movement since Lesson 1, what do we already know about signs or causes of mountain growth?	*We know that earthquakes are a sign of mountains growing.* *Earthquakes were happening at each place and the land was growing and changing.* *Volcanoes were happening at some locations too, but not all of them.*
So we noticed earthquake activity at those mountains growing. How does the earthquake activity compare for the mountains that are growing vs. the mountains that are not?	*There are more earthquakes and stronger earthquakes at the mountains that are growing.* *Some mountains even have really strong earthquakes as they grow.* *The earthquakes are also in lines, and there are a lot of them!* *We saw on Seismic Explorer that the mountains that aren't growing don't have a lot of earthquakes, and when they have them, they aren't very strong.*

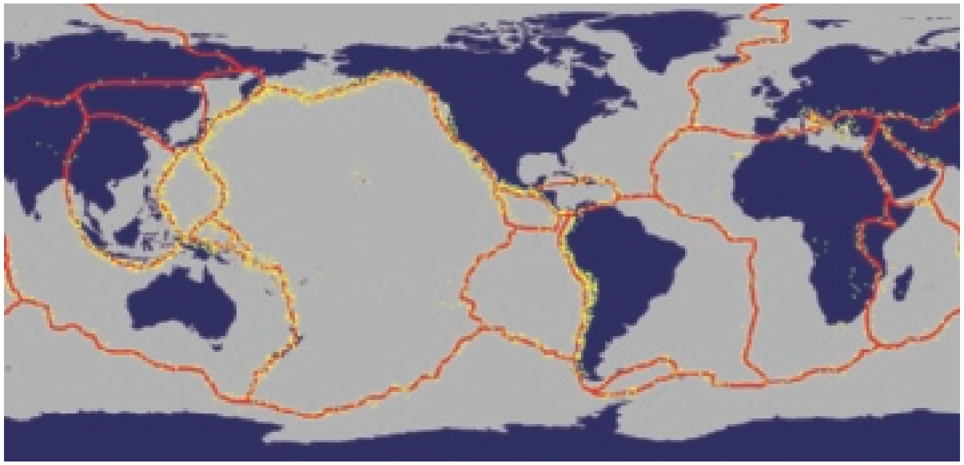
Suggested prompt	Sample student responses
So if we are noticing that there are very few earthquakes happening in these two mountain ranges that are not growing, what are some of your ideas for why this could be the case?	*Maybe the plates are not moving very fast?* *Maybe the plates in these locations are moving in the same direction and at the same speed?*

Say, *It seems like we have a lot of questions about what is happening to these plates at these mountains. Let's look back at these locations on the maps we looked at from Seismic Explorer to see what we can find out about the plates where the Applachians and Urals are found.*

3. Analyze plate boundary maps.

Materials: optional: *Satellite and Relief Maps*

Show **slide C**. Prompt students to look at the locations of the Ural and Appalachian Mountains on the map that is projected. Tell students to look at the map on the slide and make observations about what they see for the two locations we are trying to figure out. Tell them we will look at one more map and then they will share with a partner what they notice.*



Project **slide D.** Repeat the process of allowing students to turn and talk to a partner about what they notice in regards to our mountain ranges. Ask students to turn and talk to an elbow partner briefly to:

- Summarize what they already know about the relationship between earthquakes and where plates are located.
- Share anything they notice about these two locations in relation to earthquakes and plates that might help us explain why the two mountain ranges may not be growing like our other mountain cases.

***Attending to Equity**
Universal Design for Learning: The maps from **slides C-D** can also be found in *Satellite and Relief Maps*. If students are having difficulty seeing the images being projected, or need assistance visually, consider increasing the *accessibility* of the images by printing these materials for students who could benefit from them. These maps can also be scaled up to be presented on 11x17 paper, or the maps as all maps in the unit could be uploaded to a web-based learning management system and shared with students who would like to increase the size as needed. Alternatively, consider sharing a student friendly version of the lesson presentation with students who can increase the size of the image digitally.

Discuss observations. Bring the class back together after viewing the maps. Ask students to share their observations regarding the potential relationship between plate boundaries and our mountain cases that are growing versus mountain cases that are not growing or shrinking in elevation. Example prompts and responses are below.

Suggested prompts	Sample student responses
What do you notice about where the mountain sites are located in relation to plate boundaries?	*All those mountain sites that are growing are actually very close to the boundaries between colliding plates.* *We noticed that the Appalachians and the Urals are not located anywhere near a boundary between plates.*
What do we know or what have we figured out about the four mountain sites that are close to a boundary between colliding plates?	*We know that these mountains are growing and moving every year.* *We also know that the plates are actively colliding in these areas.* *We have figured out that the mountains are growing in elevation and moving because of the collision of the plates.*
What do we know about the two mountain sites that are not located near a boundary between plates?	*We know that these two mountains are not growing:* • *Mt. Narodnaya and the Urals are not growing or shrinking.* • *Mt. Mitchell and the Appalachians are shrinking.*

Summarize the discussion and motivate the need to investigate further. Say, *So if these mountains aren't near plate boundaries, how did they form? What do we know about the formation of mountains?* Students should respond that the mountains are formed by plates colliding.

Say, *So if we know mountains form when plates collide and we don't see plate boundaries where the Appalachians and Urals are currently, then do you think they also formed by plates colliding? How could we figure this out?* Ask students what kind of data they might need in order to determine if there was once a plate boundary. Students should mention the following:

- We need to see what happened in the distant past.
- We need to figure out how the plates moved over time.
- We need data that goes back further than what we used in Lessons 10-11 with Africa and South America and the World Data sets.

Say, *We may have a simulation that could give us this look at a larger timescale and help us see what scientists think may have occurred in the distant past.*

4. Observe a virtual simulation.

8 MIN

Materials: science notebooks, Ancient Earth simulation Alternate: Formation of the Appalachians slide deck Lesson 12 Dinosaur Pictures and Facts (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Propose using a model of continental plate movement that looks more like Earth. Say, *During the last lesson, we spent time looking at six sets of data that we used as evidence to place the plates into a single landmass that showed what Earth looked like millions of years ago. We also explored 2- and 3-dimensional maps of Earth, which helped us understand that flattening a three-dimensional globe onto a flat surface isn't possible without some distortion of the continents. So, let's take some time to explore an online simulation that uses a virtual, 3-dimensional model of Earth.*

Show **slide E** and ask students to draw a Notice and Wonder chart on the next available left-hand page in their notebooks. Tell them to label the page as shown on the slide. Give students a few moments to get ready, then click on the link to open the virtual simulation.

Orient students to the features of the simulation. Say, *In the last two lessons, we have figured out, using multiple data sources, that many millions of years ago the continents were all together. Scientists have collected and compiled data to develop a simulation to represent how Earth looked even further back in history. Let's take a moment to make sense of what is represented in the simulation.* Give students a few moments to examine the simulation as you project it. As the model of Earth slowly rotates, orient students to the model by first pointing out that it is showing Earth as it looks today. Then move it around to show parts of the globe that students will recognize—the poles, the equator, and familiar continents. Be sure to point out the following landmarks:

- The continent of North America
- The Mid-Atlantic Ridge
- The continents of South America and Africa that were identified in Lesson 10
- The continent of Asia, where Mt. Everest is located, and how the Himalayan mountain range is positioned between India and the rest of Eurasia

Additional Guidance

It is important that students understand what type of geography they are looking at on the maps. If necessary, review with students the common topographical conventions used in this map:

- ice is shown as white
- land that is mostly flat is shown as green: the darker green it is, the lower the elevation
- mountains are depicted as brown: higher mountains are darker brown, while very tall mountains are white because they are covered with ice
- deep water is dark blue while shallower water is light blue

Observe the movement of the North American plate through time. Explain that you are going to select display options that will help us more easily observe changes on the surface of Earth, which will help us explore the formation of mountain ranges.

Click on "Display Options" in the upper right corner of the simulation. (If you do not see "Display Options" on the screen, widen the browser window across your computer screen, and the "Display Options" will be visible.)

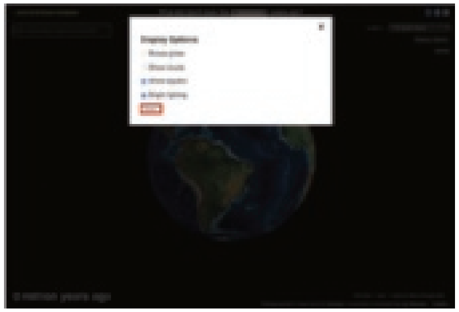

Ian Webster/DinosaurPictures.org.

*Strategies for This Building Understandings Discussion

The purpose of this type of discussion is to give students the opportunity to share and build on one another's claims, evidence, and explanations of a phenomenon. To accomplish this, you can:

- Set and maintain focus around the key ideas at each stage of the discussion.
- Invite students to share their claims and explanations.
- Push for the use of evidence to support claims.
- Encourage students to come to tentative conclusions.

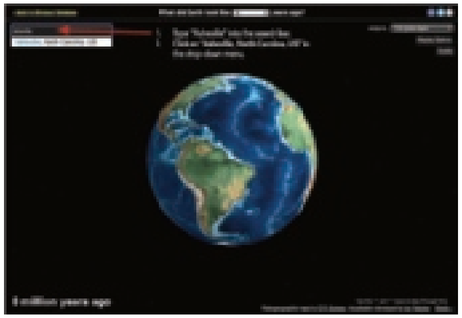
When the display options window opens, turn off the "Rotate globe" and "Show clouds" features, and turn on the "Show equator" and "Bright lighting" features. Then click "done" to close the display options.



Ian Webster/DinosaurPictures.org.

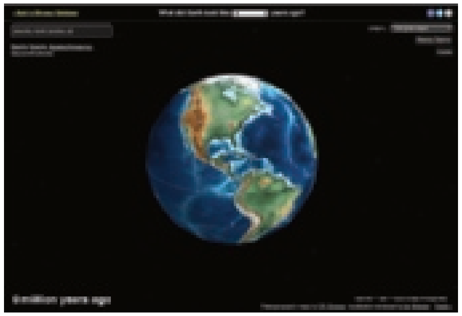
Next, tell students that we will begin by first exploring the formation of the Appalachians. Explain that Asheville, NC is a city located very close to Mt. Mitchell in the Appalachian Mountains.

Type "Asheville, NC" into the search bar located in the upper left corner of the simulation.



Ian Webster/DinosaurPictures.org.

When you click on the city's name in the drop-down menu below the search bar, the simulation will rotate to North America and students will see a red pin showing where Asheville, NC is located.



Ian Webster/DinosaurPictures.org.

Before starting the simulation, ask students, *What do you notice about the Appalachians in comparison to the Andes Mountains in South America?* Point out both mountain ranges, if needed, then have students document what they see in their science notebooks.

Tell students the simulation will allow us to go back in time to observe the changes that have occurred at and around Asheville, NC. Tell them we will go as far back as 240 million years ago, and as we do so, they should document what they notice and wonder in their notebooks.

Use the back button on the computer keyboard to show what the area looked like at various times in the past until you reach 240 million years ago. Be very careful **NOT** to go farther back than 240 million years ago at this point in the lesson. Every time you click back, call out the number of years in the past the model represents. Have students focus their attention on changes they notice around Asheville, NC, the North American Continent, other continents, and bodies of water that are visible on the globe.

Return to the present day and repeat this process of moving slowly back in time to 240 million years ago, and have students document what they notice and wonder. Use the prompts below to facilitate a Building Understandings Discussion. As students share what they noticed or wondered while watching the simulation, encourage them to reference the time frame when discussing what they observed and, If needed, revisit the simulation so that students can point out what they observed at different points in time.

Additional Guidance

During this conversation, it will be important to discuss why we are using a simulation that models the movement of the continents into a large landmass, similar to the model students created in the last lesson. Some students might feel frustrated that they spent time building a model that they could have observed using the simulation. Therefore, the following ideas need to be developed before returning to the simulation:

- Students' models were created using reliable scientific data.
- The similarities between students' models and the simulation validate the data students used and the reliability of their model.
- The simulation, which validates students' work, will allow us to see farther back in time without having to access and apply complex data.

If students struggle to make these connections, use questions like following to guide this part of the discussion:

- As you developed your models using the continents, what helped you make decisions about where to place the continents?
- Does the simulation support or refute the decisions you made as you placed the continents near one another? How do you know?

Key Ideas

Purpose of this discussion: Students share the changes they notice in the Appalachians as they observe the virtual simulation from present day to 240 million years ago.

Listen for these ideas:

As the simulation moved back in time from present day to 240 million years ago, we observe:

- South America and Africa moved closer together and collided between 120 and 150 million years ago.
- North America moved toward South America and Africa.
- The Atlantic Ocean was decreasing in size as the continents moved closer to one another.

- The continents kept moving together until they looked like one big landmass around 240 million years ago.
- The Appalachian Mountains were a much longer and larger mountain range between 200 and 240 million years ago, but they were still not located near the boundary between plates.

As students watch the simulation, it will be important to remind them that we are observing changes as we move backwards in time. Therefore, the changes we are observing are actually in reverse. It might help students if they watch the simulation the first time by moving backwards in time, then observe the changes as they move forward in time from 240 million years ago to the present day. This will give students the opportunity to watch and discuss the changes as they actually occurred over time.

Suggested prompts	Sample student responses
When the simulation showed present day Earth, what did you notice about Mt. Mitchell, Asheville, NC and the oceans?	*We could see North America, and Asheville was pinned right on the Appalachian Mountains.* *We could also see South America and the Andes Mountains. The Andes are a much taller and longer mountain range than the Appalachians. We could tell the Andes were taller by the darker colors of the Andes when compared with the Appalachians.* *We saw the Atlantic and Pacific Oceans, and Central America, too.*
What did you observe as we went back in time using the simulation?	*The Atlantic Ocean got smaller and smaller over time.* *Parts of North America were under water.*
When did that happen?	*Florida, Louisiana, parts of Texas, and some of the states along the east coast went under water around 50 million years ago.* *Then we saw water covering the whole middle section of the U.S. and Canada! That was about 90 million years ago.*
What other changes did you notice?	*It looked like parts of South America were also going underwater, too.* *South America and Africa were moving closer together. They actually collided between 120 and 150 million years ago.* *While that was happening, North America was moving toward South America and Africa.* *The Atlantic Ocean was closing up.*
As we continued to go back in time to about 240 million years ago, what did you observe?	*We noticed that the continents kept moving together until they looked like a big landmass.* *It reminded me of the model we created with the continent pieces.*

Suggested prompts	Sample student responses
Does this large landmass that formed 240 million years ago look something like the arrangement of continents that you came up with?	*It's mostly the same, but the shapes of the continents are a little different from those in the model we made.* *We are looking at a round globe and not flat map pieces—that could be why the shapes of the continents look a little different.*
What else did you notice?	*I also noticed that you could see mountains that formed where the continents had come together. It's easy to see on the simulation at 200 million years ago.* *The Appalachian Mountain range looked taller and longer between 200 and 240 million years ago than it does today.*
What were some of the things you wondered as you watched the simulation?	*As the Atlantic got smaller, I wondered if the Pacific was getting bigger.* *I wanted to know if there was any land on the other side of Earth because it looked like all the land was moving together on the side of Earth that we were observing.* *I was wondering how far back in time we could go using the simulation.*

Reflect on what we have observed and how we have used the virtual simulation. Show **slide F** and say, *Scientists often have their data and conclusions validated when other scientists test their claims, collect evidence, and come up with very similar or the same conclusions. How is this similar to the models we developed using data sets about rock types, fossils types, and glacier patterns and the virtual simulation?*

Have students talk with a partner and then share ideas with the class. Look for students to make connections between the model they developed in Lesson 11 and the virtual simulation in this lesson. Summarize by saying, *We have used the simulation to observe what Earth looked like at various points in time dating all the way back to 240 million years ago. We noticed that the continents were actually a giant landmass about 240 million years ago, similar to the giant landmass that we created when we matched up the continents using three different sets of data. What do you think we will see if we go further back in time?*

Have students again turn and talk with a partner and then share a few responses. Look for students to predict similar changes to what they have already observed—continued plate movement.

5. Investigate the formation of the Appalachians and the Urals. 18 MIN

Materials: science notebooks, chart paper, markers, What we know about the Appalachians and the Urals chart, Ancient Earth simulation Lesson 12 Dinosaur Pictures and Facts (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Revisit the simulation and document additional observations. Show **slide G** and have students draw a second Notice and Wonder chart on the right side of their science notebooks and label it as shown on slide. Say, *One of the things we noticed as we observed changes to Earth while moving back in time was that the Appalachian Mountain range looked taller and longer between 200 and 240 million years ago than it does today. Let's revisit the simulation and go even farther back in time to see what we can learn about the Appalachian Mountains.*

Start the simulation at present day, and then have students focus on the changes to the Appalachians as you click back to 240 million years ago. Ask, *What other changes do you notice happening between the continents at the same time that the Appalachians were taller and longer?* Have students add their observations to the Notice and Wonder chart in their notebooks.

Slowly click farther back in time using the simulation. Have students document what they notice and wonder. If needed, repeat the process from 240 million years ago to 500 million years ago, and give students time to document their observations and questions. After a few minutes, show **slide H** and use the questions on the slide to continue the Building Understandings Discussion. As students share, encourage them to include the time frame for each of the changes they observed. If needed, revisit the simulation so that students can point out what they observed at different points in time. Add student ideas to the *What we know about the Appalachians and the Urals* chart.

Key Ideas

Purpose of this discussion: Students share the changes they notice in the Appalachians as they observe the virtual simulation from 240 million years ago to 500 million years ago.

Listen for these ideas: As the simulation moved back in time from 240 million years ago to 500 million years ago, we observed:

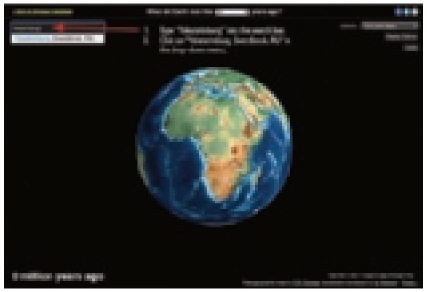
- There was a point in time that the Appalachians were not yet formed—about 500 million years ago.
- There were collisions between smaller land masses as long ago as 470 million years ago.
- Larger land masses moved towards North America about 400 million years ago.
- Between 260 and 400 million years ago, the Appalachians were a huge mountain range—very long and tall—they went well beyond North America.
- The Appalachians were created by the same processes that created the Himalayas—colliding plates.
- The Appalachians were first formed approximately 470 million years ago, and they continued to grow and move until about 280 million years ago.
- 240 million years ago, the Appalachians were no longer as tall as they once were, so the mountain range was no longer growing at that point in time.

Remind students we are observing changes moving backwards in time, so we are observing changes in reverse. It might be helpful for students to watch the simulation moving forward in time from 500 million years ago to 240 million years ago to watch and discuss the changes as they actually occurred over time.

Suggested prompts	Sample student responses
What changes did you observe in the Appalachians as the simulation went back in time?	*About 500 million years ago, the Appalachians were not formed.* *Around 470 million years ago, it looked like a collision with a smaller landmass caused the Appalachians to begin to form.* *A larger landmass collided with North America about 400 million years ago, which caused the Appalachians to grow much taller.* *If we look carefully, we see Florida move towards North America and become part of this continent between 370-400 million years ago.* *Between 260 and 400 million years ago, the Appalachians were a huge mountain range—very long and tall. They must have been very tall—there was snow covering a large portion of the mountain range.* *We noticed the mountain range went beyond just North America.* *By the time we get to 240 million years ago, the Appalachians are no longer as tall as they once were.* • *The Appalachians were created by the same processes that created the Himalayas—colliding plates.* • *The Appalachians were first formed approximately 470 million years ago, and they continued to grow and move until about 280 million years ago.* • *240 million years ago, the Appalachians were no longer as tall as they once were, so the mountain range was no longer growing at that point in time.*
What did you figure out about the Appalachian Mountains?	*The Appalachians first formed about 470 million years ago. They are a very old mountain range.* *They were formed as land masses collided—first a small landmass collision about 470 million years ago, then a larger landmass collision about 400 million years ago.* *For a long time—From 470 until 280 million years ago—the Appalachians were a growing mountain range.* *Plate collisions caused the Appalachians to form, grow, and move, just like the Himalayas.*

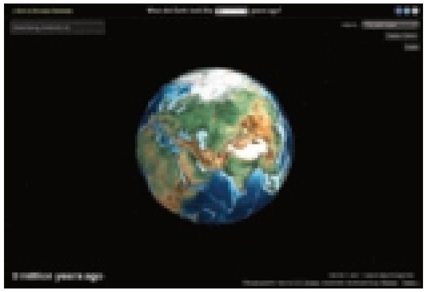
Reconfigure the simulation and observe the formation of the Ural Mountains. Return the simulation to the present day (0 million years ago) and explain that we will follow the same procedure with the simulation so that we can explore the formation of the Ural Mountains. Tell students that Yekaterinburg is a city in Russia located in the Ural Mountains.

Type “Yekaterinburg” into the search bar located in the upper left corner of the simulation. When you click on the city’s name in the drop-down menu below the search bar, the simulation will rotate to show Europe and Asia.



Ian Webster/DinosaurPictures.org.

Students will see a red pin showing where Yekaterinburg is located.



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Show **slide I** and ask students to draw a Notice and Wonder chart on the next available left-hand page in their notebooks. Tell them to label the page as shown on the slide. Give students a few moments to get ready, then remind them that the simulation will allow us to go back in time to observe the changes that have occurred at and around Yekaterinburg and the Ural Mountains.

When students are ready, use the back button on the computer keyboard to show what the area looked like at various times in the past until you reach 400 million years ago. Every time you click back, call out the number of years in the past the model represents. Have students focus their attention on changes they notice around Yekaterinburg and the visible landmasses and water. Then, return to the present and repeat the process. Have students document what they notice and wonder.

Show **slide J** and use the prompts on the slide to continue the Building Understandings Discussion. As students share what they noticed or wondered while watching the simulation, encourage them to reference the time frame when discussing what they observed.

Key Ideas

Purpose of this discussion: Students share the changes they notice in the Urals as they observe the virtual simulation from present day to 400 million years ago (mya).

Listen for these ideas:

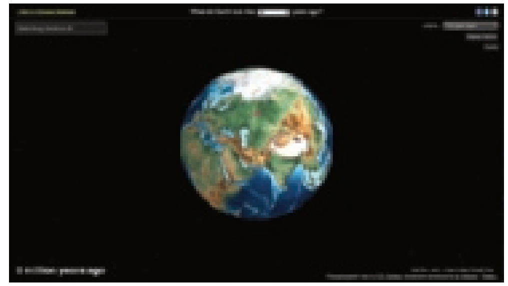
As the simulation moved back in time, we observed:

- The Ural Mountains seem to remain almost unchanged as we move back from present day to 240 mya. The Urals appear to be about the same length and height through that time period.
- The landmass that the Urals are on changed drastically around 50 mya, and continued to change, with large portions under water at various points in time; however, the Urals look relatively unchanged from present day to 240 mya.
- 260 mya: water covered a large portion of the landmass.
- 280 mya: the Urals were much taller and larger.
- In the simulation, the Urals first appeared as a mountain range 300 mya, so they must be more than 300 million years old.
- We can see the plates that formed the Ural Mountains moving toward one another as early as 370 mya.

Suggested prompts	Sample student responses
What changes did you observe in the Urals as the simulation went back in time?	*The Ural Mountains don't seem to change much as we moved back from the present day to 240 million years ago.* *During that time, the Urals were about the same length and height, and they stayed in the middle of a large landmass, even though the landmass changed from the way Europe and Asia look today.* *Parts of the landmass were under water at various times throughout that time period—from present day to 240 million years ago.* *260 million years ago, water covered the middle of the landmass.* *280 million years ago, the Urals were much taller and longer—they were much darker and covered more area of the landmass.* *In the simulation, the Urals first appeared as a mountain range about 300 million years ago, and they were not visible 340 million years ago. They must be more than 300 million years old.* *We can see the plates that formed the Ural Mountains moving toward one another as early as 370 million years ago.*
What did you figure out about the Ural Mountains?	*The Ural Mountains are a very old mountain range that formed more than 300 million years ago.* *The Urals were formed by the collision of plates.* *They continued to form and grow, and were a very tall mountain range about 280 million years ago.*
How could we compare the formation of the Appalachians and the Urals with Mt. Everest and the Himalayas?	*We should use the simulation to see when Mt. Everest and the Himalayas were formed.*

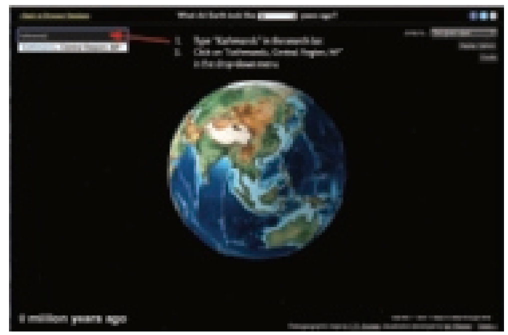
Reconfigure the simulation and observe the formation of the Himalayan Mountains. Show **slide K** and tell students to draw another Notice and Wonder chart on the right-hand page in their notebooks and label it as shown on the slide.

Return the simulation to the present day (0 million years ago) and tell students that Kathmandu is the capital city of Nepal and located in the Himalayan Mountains near Mt. Everest. Type "Kathmandu" into the search bar located in the upper left corner of the simulation, then click on the city's name in the drop-down menu below the search bar. The simulation will rotate to Asia and students will see a red pin showing where Kathmandu, Nepal is located.



Ian Webster/DinosaurPictures.org.

Once the simulation is ready, tell students that we are going to use the simulation to go back in time to observe the changes that have occurred at and around the Himalayan Mountains. Remind them to document what they notice and wonder in their science notebooks as they watch the simulation, and to keep in mind that our goal is to compare the formation of the Himalayan Mountains to the formation of the Appalachian and Ural Mountains.



Ian Webster/DinosaurPictures.org.

Starting at the present day, slowly click back to 66 million years ago. Repeat the process, giving students time to observe the changes. Ask students, *What changes do you notice as the simulation moves back in time?* Have students add their observations to the Notice and Wonder chart in their notebooks.

Compare the formation of the Himalayas to the Appalachians and the Urals. Show **slide L** and use the prompts on the slide to continue the Building Understandings discussion. As students share what they noticed or wondered while watching the simulation, encourage them to tell you the time frame for each of the changes they observed. If needed, revisit the simulation so that students can point out what they observed at different points in time.

Key Ideas

Purpose of this discussion: Students share the changes they notice in the Himalayas as they observe the virtual simulation from present day to 66 million years ago.

Listen for these ideas: As the simulation moved back in time from present day to 66 million years ago, we observe:

- 66 million years ago, the Himalayas were not yet formed, and the Indian plate was not part of Asia.
- Sometime between 35 and 50 million years ago, the Indian plate collided with the Asian plate and the Himalayan Mountains were formed.
- The Himalayan Mountains are somewhere between 35 and 50 million years old.

- Between 35 million years ago to the present day, the Himalayas continue to grow and change as the two plates continue to collide.
- The Appalachians, which were first formed about 470 million years ago, are approximately 420 million years older than the Himalayas.
- The Urals, which were formed more than 300 million years ago, are more than 250 million years older than the Himalayas.

Suggested prompts	Sample student responses
What changes did you observe in the Himalayas as the simulation went back in time?	*66 million years ago, there were no mountains near where Kathmandu is located.* *The Indian plate is not part of Asia, yet, either.* *Sometime between 35 and 50 million years ago, the Indian plate collided with the Asian plate and the Himalayan Mountains were formed.* *Between 35 million years ago and present day, the Himalayas continue to grow and change as the two plates continue to collide.*
What did you figure out about the Himalayan Mountains?	*The Himalayan Mountains are somewhere between 35 and 50 million years old.* *They are still growing and changing as the plates continue to collide.*
How does this compare with the formation of the Appalachian Mountains and the Ural Mountains?	*The Appalachian Mountains were formed about 470 million years ago and the Urals were formed more than 300 million years ago.* *The Himalayan Mountains were formed around 50 million years ago.* *The Appalachians are about 420 million years older and the Urals are more than 250 million years older than the Himalayas!*

Construct a scientific explanation. Show **slide M**, and tell students that we need to construct a scientific explanation of how the Appalachian and Ural Mountains were formed and how their formation compares to that of the Himalayan Mountains. Remind them that constructing a scientific explanation includes: making a claim; supporting the claim with evidence; and using reasoning to explain how the claim is supported by the evidence.

Use the questions on the slide to guide students to construct a scientific explanation. Encourage students to work collaboratively as you document their responses on chart paper. Remind them that they can use the sentence starters on the *Communicating in Scientific Ways* chart in their science notebooks, if they need to.

Assessment Opportunity

Building towards 12.A Construct a scientific explanation based on evidence from models that Earth's tectonic plates interact to change the surface of Earth at time and spatial scales that are not directly observable.

What to look for/listen for: Now that students have observed the formation of the Appalachian Mountains, the Ural Mountains, and the Himalayan Mountains using the virtual simulation, students can use the evidence they have collected to collaboratively construct a scientific explanation of the formation of the Appalachians and the Urals and make comparisons to the formation of the Himalayas. Students' scientific explanation should include the following key ideas:

- The Appalachian Mountains were formed approximately 470 million years ago and the Ural Mountains were formed more than 300 million years ago by the same processes that continue to cause the formation and growth of mountains today—the collision of plates.
- The Appalachian and Ural Mountains are much, much older than the Himalayan Mountains, which were formed between 35 and 50 million years ago.
- The Appalachians and the Urals were once growing mountain ranges, even though they are no longer growing.

What to do: If students' scientific explanation does not include the key ideas listed above, you can:

- Revisit the simulation, stopping at strategic points and ask students to describe what they observe and how it can be used as evidence to explain how and when the Appalachians and the Urals were formed.
- Guide students to look for similarities between the formation of the Himalayan Mountains and the formation of the Appalachians and the Urals, which can be observed using the virtual simulation.
- Let students work in small groups to revisit the simulation and write a claim supported by evidence about the formation of the Appalachian and the Ural Mountains. After small groups share their claims and evidence, the class can work together to collaboratively develop a scientific explanation that describes the formation of these two mountain ranges.

Suggested prompts	Sample student responses
What claim can we make about the formation of the Appalachians and the Urals, and how does their formation compare to the formation of the Himalayas?	*The Appalachian Mountains, which were formed about 470 million years ago, and the Ural Mountains, which were formed more than 300 million years ago, are much older than the Himalayan Mountains, which were formed sometime between 35 and 50 million years ago.* *The Appalachian Mountains, the Ural Mountains, and the Himalayan Mountains were formed by plate collisions.* *The Appalachians and the Urals were both growing mountain ranges for a period of time, even though they are no longer growing.*
What evidence do we have to support our claim?	*We made observations and collected data from the Ancient Earth simulation.*
How does the evidence support our claim?	*From our observations and the data we collected, we know about how long ago the Appalachians, the Urals, and the Himalayas were formed.* *The simulation allowed us to observe the changes that have occurred at each mountain range over millions of years up to the present day.*

6. Navigation

4 MIN

Materials: None

Determine next steps. Show **slide N** and say, *We have figured out a lot about the changes both below and above the surface of Earth caused by the interaction of plates. We have also figured out that the Appalachians and the Urals are very old mountain ranges formed by the collision of plates many millions of years ago. What we cannot explain is why the Appalachians are shrinking or why the Urals are neither shrinking or growing if they aren't at a current plate boundary. So, let's think about other processes that occur at the surface of Earth that might help us explain what is happening. Turn and talk to your partner:*

- *What processes might be at work to cause the Appalachians to decrease in elevation?*
- *Do you think these processes might also explain why the Urals aren't increasing or decreasing in elevation?*

Give students time to talk, then ask a few to share their ideas with the class. Look for the following to surface:

- Rain, snow, and ice can cause erosion.
- Plants can break down rock and compacted soils, which can then be washed away by water.
- These processes might help us explain why the Appalachians are shrinking and why the Urals are not shrinking or growing.

Say, *These are ideas that we need to investigate further to see if they can help us explain the changes we have not yet been able to explain.*

Additional Guidance

If rain, snow, and ice, or processes such as weathering and erosion do not surface, you can:

- Revisit the *Possible Causes for Mountain Growth* chart, which may include one or more of these ideas.
- Take a walk around the school to find examples of weathering and erosion. Then ask students to describe what they think might be causing the land around the school to change.
- Use images to show examples of weathering and erosion, and ask students to describe the changes they see and what might be causing those changes.

LESSON 13

What causes mountains to shrink in elevation?

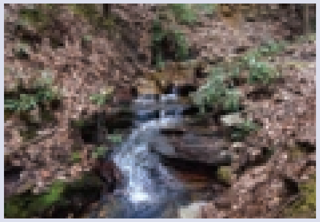
Previous Lesson

We determined that the Appalachians and the Urals are different from the other mountains that we have studied because they are not located near plate boundaries and are not increasing in elevation. We used an online simulation to help us figure out how both mountain ranges were formed. This led us to think that other processes are causing the decreasing elevation of the Appalachians and the unchanged elevation of the Urals.

This Lesson

Problematizing

1 DAY



After recalling what we already know about erosion and weathering, we read about erosion rates and how scientists use these rates to determine how erosion is changing the surface. Then, using both the erosion rates and uplift rates for Mt. Everest and Mt. Mitchell, we develop a representation of each model and how these two processes are affecting them. We determine that when erosion rates are higher than uplift rates, like at Mt. Mitchell, a mountain will shrink in elevation.

Next Lesson

We will revisit our Driving Question Board and explain our related phenomena using our science ideas. We will gather relevant evidence and take an assessment to explain the presence of marine fossils on mountains. We then revisit our Driving Question Board and answer our unit question.

Building Toward NGSS

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

What Students Will Do

13.A Apply mathematical concepts (proportional relationships and unit rates) from the unobservable processes of erosion and plate movement over time to figure out how much Mt. Everest and Mt. Mitchell are changing now and use these to predict how much they would change in the future.

What Students Will Figure Out

- Erosion rates are a representation of how much an area of land is worn down by all the erosive processes together.
- Uplift rates are a representation of how much the land is being pushed up from below by plate movements.
- The relationship between the erosion rates above the surface and the uplift rates below the surface determine the elevation above sea level.
  - *Erosion rates that are higher than uplift rates result in land decreasing in elevation.*
  - *Erosion rates that are less than uplift rates result in land increasing in elevation.*
  - *Erosion rates that are equal to uplift rates results in no change in elevation.*

Lesson 13 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	2 min	**NAVIGATION** Recall what we still want to figure out about Mt. Mitchell and the Appalachians.	A	
2	5 min	**ABOVE THE SURFACE PROCESSES** Recall from earlier grades what we already know about erosion and weathering events.	B	poster paper, markers
3	10 min	**WHAT ARE EROSION RATES?** Make sense of erosion rates and how the processes above the surface affect how the surface looks.	C-D	*Erosion Rates*, 6.4 Lesson 13 Erosion Timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	20 min	**EROSION RATES VS. UPLIFT RATES** We analyze ratio data to compare how plate collision versus the rate of erosion is related to whether an area is increasing in elevation, decreasing in elevation or not changing in elevation.	E- I	*Erosion Rates vs. Uplift Rates*
5	4 min	**ADD TO CAUSAL CHAIN OF EVENTS** Revisit the Causal Chain of Events poster from Lesson 9 to add what we have figured out about above the surface processes and mountains shrinking.	J	Causal Chain of Events poster, markers
6	6 min	**PREDICT FUTURE CHANGES USING EROSION AND UPLIFT RATES** Individually calculate the changes to Mt. Everest and Mt. Mitchell in the future using the rates of erosion and uplift we have figured out in this lesson.	K	*Erosion Rates vs. Uplift Rates*

End of day 1

Lesson 13 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• *Erosion Rates* • *Erosion Rates vs. Uplift Rates*		• poster paper • markers • 6.4 Lesson 13 Erosion Timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Causal Chain of Events poster

Materials preparation (15 minutes)

Online Resources

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

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

Be sure you have materials ready to add the following words to the Word Wall: erosion rate and uplift rate. Do not post these words on the wall until after your class has developed a shared understanding of their meanings.

A sample definition is included below:

- erosion rate (the rate an area is worn down over time)
- uplift rate (how much an area of land is pushed up over time)

Prior to class, ensure the link is working properly (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Though it is only a little over two minutes long, it is recommended to double the playing speed to make the erosion happening over time more visible. This can be controlled using the gear icon at the bottom right of the menu bar under the video. After opening the gear menu, choose playback speed and click on "2" to double the speed.

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

Students are using what we know about erosion and weathering from elementary grades to figure out how erosion affects land on Earth, specifically mountains, over time. In particular, this lesson leverages these pieces of these previously developed disciplinary core ideas:

ESS1.A: Rainfall helps shape the land and affects the types of living things found in a region. Water, ice, wind, living organisms, and gravity break rocks, soils, and sediments into smaller particles and move them around.

ESS1.C: Understanding how landforms develop, are weathered (broken down into smaller pieces), and erode (get transported elsewhere) can help infer the history of the current landscape.

In this lesson students work with two rates, erosion rates and uplift rates. The rates represented here are approximated. Working with unit rates is a key idea targeting the CCMS standards for math. Students engage with using computational and mathematical thinking as they compare rates of change due to erosion processes (above the surface) to rates of change due to plate processes (from below the surface) over time to figure out why Mt. Everest is still growing (erosion rates lower than plate processes) and why Mt. Mitchell is shrinking (erosion rates higher than plate processes). They further engage with this SEP as they considered the combined (net) effect of erosion and plate motion on a mountain, which is an extension opportunity to use mathematical models related to moving up and down a number line. Students use the crosscutting concepts that proportional relationships (e.g., speed as the ratio of distance traveled to time taken) among different types of quantities to provide information about the magnitude of properties and processes. This occurs when students use change in mm/year or rates change in mm/1,000 years, to proportionally scale up these rates to and predict how these two rates will affect the scale of change one would expect to see on mountains over different magnitudes of time (of change one would see over 1 year, 100 years, 100,000 years and 1 million years into the future).

Where We Are NOT Going

In the middle school grade band, we are not figuring out many of the mechanisms that affect the rates of both erosion and uplift, as they are above grade band. The uplift rates represented in this lesson are bound to orogenic uplift and not surface plasticity or buoyancy which will be investigated in higher grade bands. These characteristics are described here for teacher reference only:

- Orogenic uplift - the result of tectonic-plate collisions that results in mountain ranges or a more modest uplift over a large region.
- Surface plasticity - the land has elastic characteristics and stretches and rebounds over time, this rebound can cause plates to change densities and thicknesses over time as they are compressed or stretched as they move in relation to other plates and are affected by the flow of the mantle.
- Buoyancy of the plates/Isostasy - plate buoyancy depends on the density and thickness. The tectonic plates (part of the lithosphere or top layer of Earth's crust) float on the asthenosphere (the layer directly below the crust) which is made up of molten rock. This physical property of the plates affects the ways continents change in stability. As the land is eroded, the plate's buoyancy will be affected, as it will become less dense and will allow the plate to rebound.

In addition, for every meter that an area of land erodes, it rebounds (due to plate buoyancy/plasticity) roughly $\frac{5}{6}$ back up. For this lesson we are focused on the $\frac{1}{6}$ that erodes or wears down the land. We don't investigate rebound or isostasy because they are above grade band, and have simplified the erosion and uplift rates to inherently include these ideas based upon the current data.

Just as rates vary over many years, the uplift is approximated in this lesson. As with all scientific geologic measurements over time, the rates we use in the lesson are indicative of the more recent day uplift rates. The uplift for Mt. Mitchell was extrapolated from various data points across the Appalachian region based upon current plate processes at and around the continental US.

References used in determining the approximations for erosion and uplift rate can be found online. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

LEARNING PLAN FOR LESSON 13

1. Navigation 2 MIN

Materials: None

Recall we still don't know why Mt. Mitchell is decreasing in elevation. Display **slide A.** Say, *Okay, in our last lesson we figured out the Appalachian Mountains that are currently shrinking, are not located on an active plate boundary. Let's take a moment to remind ourselves what we have already figured out so we can zero in on what we still need to investigate.*

Suggested prompts	Sample student responses
What have we figured out about the relationship between mountains and plate boundaries? What effect do they have on mountains?	*When the plates move, they can cause the mountains to move to a different spot and if they collide, they can cause mountains to get taller in elevation.* *When they spread apart new land can be made.*
Okay, so if there isn't plate movement near the Appalachians causing the mountains to grow or shrink, what were some of our ideas for what could be causing a mountain to shrink over time?	*Maybe erosion, rain, and wind can make a mountain get smaller?* *We had ideas on our Possible Causes chart, like wind, rain, erosion, rocks on the surface moving or breaking apart.*

Say, *Let's investigate some of these ideas about water, wind, and other things that may be causing erosion today to see how they might be interacting with the surface of the land.*

2. Above the Surface Processes 5 MIN

Materials: poster paper, markers

Recall what we already know about erosion and weathering from earlier grades. Display **slide B.** Say, *Let's begin by sharing what we already know about erosion from earlier grades. As you share, I will record these ideas on a poster. Many of you have talked about erosion as processes you think can change the surface of Earth. Some of you also had this listed or drawn as well in your initial model.*

Suggested prompt	Sample student response
What about weathering? What do you already know about weathering, or things that can cause the rocks and material on the surface of Earth to break down?	*This happens where wind or rain breaks down the surface.*

Suggested prompts	Sample student responses
What are some examples of weathering?	*big rocks being broken down into smaller rocks near a shoreline* *like when ice cracks the sidewalks in the winter* *wind wears down large hills into smaller hills*
Weathering describes the processes that break down rock. Erosion describes processes that move that broken rock away from the place where it is broken down. What do you already know about erosion from earlier grades?	*It is when materials, like dirt or sand, are moved from one place to another.* *Wind and precipitation or water moving over the surface can carry things like rocks, sand, gravel and dirt away from one place to somewhere else.*
What are some examples of erosion happening?	*like when a river moves rocks or sand or gravel from one part and deposits it somewhere else* *when strong wind blows sand or dirt from one place to another place further away* *waves on a shore washing away big parts of a cliff*
So it sounds like erosion and weathering are closely related. How are they different?	*The difference is that weathering wears down the land in one area and erosion is when these worn down pieces get moved to other places on Earth through wind or water moving.* *Erosion moves the worn off pieces to a different location by wind or moving water. Sometimes these pieces collide with other land and wear it down as well.*
Okay so now that we have reminded ourselves what these two processes are, let's think about their effects on the land. If weathering wears down the land and erosion moves material from one place to another, let's talk about one other process—deposition. Deposition is when that material is carried away and is deposited somewhere new. What are some examples of this?	*dirt, sand, or rocks falling out of a water current* *wind that dies down and dust or sand that falls out of it*
What are some ways that weathering, erosion, or deposition could change the height of the surface of the land?	*Since weathering breaks down rocks, it would decrease the height of the surface of the land.* *Since erosion carries materials away from one place to somewhere else, it would decrease the height of the surface of the land where it carries those materials away from.* *Since deposition deposits new material from somewhere else in a new place, the height of the land at that new place would increase.*

Additional Guidance

This brief discussion is designed to elicit from students what they already know about erosion and weathering, based on prior knowledge or DCIs related to ESS1.A and ESS1.C, from engaging with the related PEs around weathering and erosion from 4th grade.

According to **4ESS2-1: Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation**, students will have investigated different erosional and weathering events and their effects on the land including thinking about these processes as a rate or effect. Students will have figured out that water, wind and biological factors all play a role in eroding and breaking down the land.

3. What are erosion rates?

10 MIN

Materials: *Erosion Rates*, 6.4 Lesson 13 Erosion Timelapse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Read an article about erosion and how scientists measure the effect it has on land. Display **slide C.** Show a short clip of computer simulation that a scientist created to try to visualize what is happening to a mountain over time as water flows over it. Tell students this clip is a timelapse that has been sped up so we can make observations of what we notice about interactions that might be happening. Show the clip (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). It is suggested to speed up the timelapse to twice the speed so that students will see the changes more readily. This can be done by clicking on the gear button at the bottom right corner of the video and choosing playback speed. Then choose "2" as the playback speed to increase the speed to 2.

Ask students to share what they saw happening and how this might be causing the land to increase in height in some areas and decrease in height in others.

Suggested prompts	Sample student responses
Does the flow of water over this surface seem to affect the height of the surface?	*Yes!*
Is it possible that erosion and weathering make a mountain decrease in height or shrink based on what we see here?	*I think so.* *It looked like it definitely changed how wide the mountains were.* *It looked like some changed in height a little bit.*
The material that was eroded away must eventually be deposited somewhere else. What would happen to the height of the surface at the locations where that material was deposited?	*It would start to pile up.* *Its height would increase.*

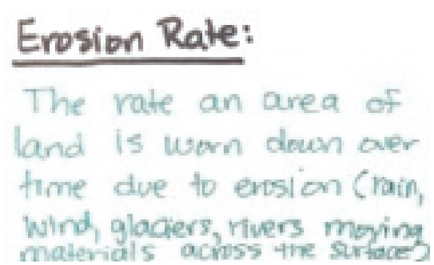
Making sense of rates of erosion. Display **slide D.** Say, *When scientists research how different areas on Earth are changing due to erosion, one rate they use in their research is called an erosion rate. What do you think this might refer to based on what you already know about erosion?* Students should say something like, how fast erosion happens, or what types of erosion happen.

Continue by saying, *Let's read a short article on how scientists collect this data and how they determine this rate*. Distribute *Erosion Rates* to each student. Say, *Let's record at the top what question we are trying to answer by reading an article. What are we trying to figure out?* Guide the class to record a question such as "What are erosion rates?" or "How are erosion rates found?" Give students 8 minutes to read. Then hold a brief discussion to share what we determined erosion rates are, how they are determined, and the types of erosion that have the biggest effect on land.

Suggested prompts	Sample student responses
What did you figure out from the reading about erosion rates?	*They are how fast or slow erosion is affecting the land.* *They are a number that tells how fast an area is being eroded or worn down over a certain time.* *Erosion rates are different rates for different locations.* *Erosion rates are measured over different timescales. Mt. Everest has a yearly measurement, but Mt. Mitchell has a 1,000 year measurement.*
What are the types of erosion that the scientists measure to figure out the erosion rate for an area?	*They measure how a river moves—like how deep and fast it is.* *They measure glaciers too! Like how much they are melting and how much they move—I didn't know glaciers move!* *They also measure winds in different areas—how often and how fast they are.*
So when researchers determine the rate of erosion, how do they do that when there are different types of erosion?	*They mainly focus on the effects of rivers and glaciers.* *By taking a lot of measurements over time, they can come up with a rate based on how an area of land changes in size.*

Add **erosion rate** to the Word Wall.

Ask, *So it seems like these processes that are happening above and just under the surface have a regular effect on the land like the processes below the surface (plate movement). What relationship might all these processes have to how Earth's surface changes?* Accept all responses.



4. Erosion Rates vs. Uplift Rates

20 MIN

Materials: *Erosion Rates vs. Uplift Rates*

Briefly reflect on erosion rates of Mt. Mitchell and Mt. Everest we read about. Say, *In our reading we read about the erosion rates between Mt. Mitchell and Mt. Everest. What did you notice and wonder about the erosion rates and the two mountains?*

Students might respond that the erosion rate for Mt. Everest is much higher than Mt. Mitchell, but Mt. Mitchell is decreasing in height, while Mt. Everest is increasing in height.

Ask students, *I found that interesting too. If there is a higher rate of erosion happening at Mt. Everest than Mt. Mitchell, but Mt. Everest is growing in height, then what else do we have to figure out about what is happening at Mt. Everest that could be causing it to keep growing in elevation?*

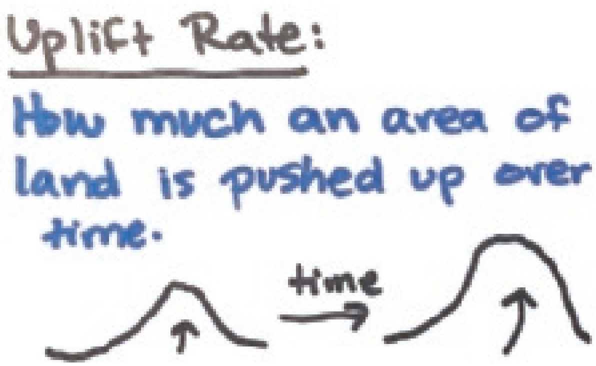
Students should respond that we have figured out that the plates moving under the surface are causing Mt. Everest to keep growing.

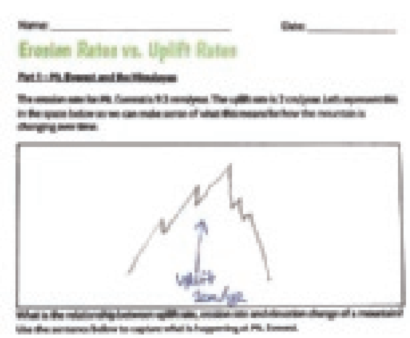
Problematize the idea about the relationship between erosion rates and uplift rates. Display **slide E.** Say, *So if we know that there are processes that are affecting the land above the surface, like erosion and weathering, and there are processes occurring below the surface, like plates colliding causing uplift, then let's think about how these affect Earth's surface when they are occurring at the same time.*

Distribute *Erosion Rates vs. Uplift Rates*. Read through the first part together. Then do part one together. Say, *Let's do Mt. Everest and the Himalayas together.*

Suggested prompt	Sample student response
First let's think about the uplift rate. What would this be referring to?	*I think this would be how much taller the mountain is getting. We figured out that when plates collide the land gets pushed or lifted up, and this is where mountains are forming, so this number is how much the land is being pushed up. Uplift must be how much it's lifted up.*

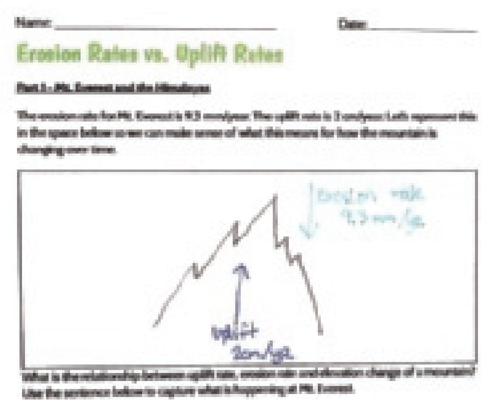
Add **uplift rate** to the Word Wall. Say, *Great. So in the first box, let's capture this idea by drawing Mt. Everest and an arrow pointing up, labeled uplift = 2 cm/year.* As students are doing this on their handout, do this along with them either on a whiteboard, or on a piece of paper under a document camera or on a poster paper. An example is included here:





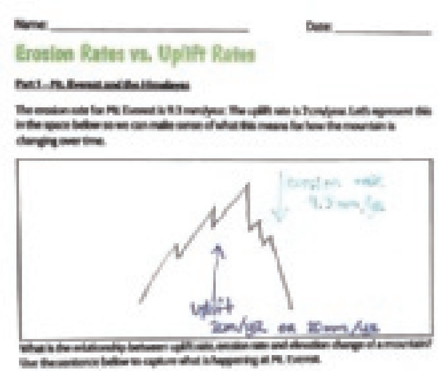
Suggested prompts	Sample student responses
The erosion rate for Mt. Everest is also included here. What do you think the main forms of erosion are for Everest?	*I would think glaciers or ice since we read there are glaciers on Everest and we see ice.* *Yeah, and I think rivers too because lower on the mountain there isn't snow or ice, but there would be rivers.* *Maybe wind too. It looked really windy in some of the videos or photos.*
What is the erosion rate for Everest?	*9.3 mm/year*

Say, *So if we want to add this to our handout for the image of Mt. Everest we drew, and we used an up arrow to represent the uplift, how might we represent the erosion rate?* Guide the class to argue that we need to draw an arrow pointing down for erosion since it wears down the land.



Say, *Okay, let's add a down arrow for the erosion rate, and label it "erosion rate = 9.3 mm/year".* An example is included here.

Compare unit and rate representations. Make sense of these two numbers with the class by asking, *Let's make sense of what these two numbers are representing. I noticed they are not represented in the same units so in order for us to be able to more accurately compare them, let's put them both in the same units. Can anyone do that for us?* Ask for a volunteer to share; they should say that 2 cm is the same as 20 mm, so we could change the 2 cm/year for uplift to 20 mm/year. Model this class example you have been developing.



Compare the two rates and make sense of what they represent. Ask, *What is happening to the elevation of Mt. Everest?* Students should say we know it is getting taller. Tell students to turn and talk with a partner about any connections they see between the rates they have represented on their handout and what is happening to the elevation of Mt. Everest. Then bring the class back together and discuss.

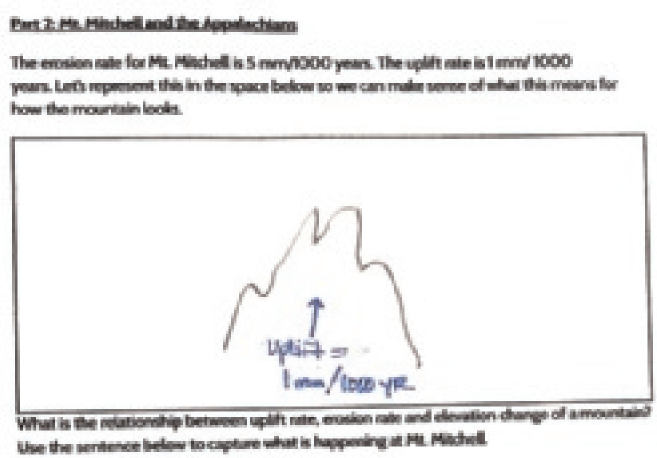
Suggested prompt	Sample student responses
If we look at the model we just developed with the rate of erosion and the rate of uplift recorded, what is the relationship between these two rates and whether a mountain is getting taller or not?	*The amount of uplift is higher than the amount of erosion so the mountain is getting taller.* *The uplift is 20 mm each year and the erosion is 9.3 mm each year. That is a difference of almost 11 mm/year.*

Ask, *So if we were to write a statement about the relationship between uplift rates and erosion rates for a mountain that is increasing in elevation, what would we write? Use the space on your handout to formulate your statement*. Give students a minute or two to write this then ask for a volunteer or two to share. Make sure the class is in agreement before moving on to analyzing the data for Mt. Mitchell and the Appalachians. They should say that when uplift is greater than erosion, the mountain will increase in elevation.

Continue making sense of erosion rates versus uplift rates for Appalachians and Urals. Display **slide F.** Say, *Now that we have a better idea about how processes above the surface and below the surface affect Mt. Everest, let's go back to Mt. Mitchell and the Appalachians. We were trying to figure out more about why they are shrinking in elevation. Let's look at the same rates for Mt. Mitchell. Look at part two of your handout.*

Suggested prompts	Sample student responses
What is the uplift for Mt. Mitchell?	*Very little uplift! It is measured over 1,000 years!*
What does this mean?	*This means the land is barely being lifted upwards.*
Does this make sense with what we now know about uplift?	*Yes! We just figured out there isn't a plate boundary today where Mt. Mitchell is, so there isn't anything colliding directly underground that would cause it to lift up.*

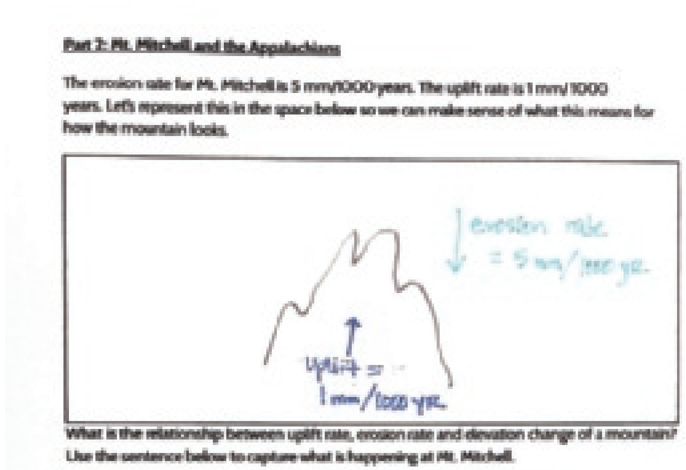
Tell students to represent Mt. Mitchell in the space on part 2 of *Erosion Rates vs. Uplift Rates*. Then they should add notation to represent there is very little uplift currently at Mt. Mitchell. Continue with your class example as well, either on the whiteboard, or under the document camera or on poster paper.



Suggested prompts	Sample student responses
What is the erosion rate at Mt. Mitchell?	*5 mm/1,000 yr*
What does this mean? It looks different than the erosion rate for Mt. Everest that was per year.	*This means that every 1,000 years, Mt. Mitchell erodes away by 5 mm.*

Say, *Okay, great! Let's add this to our representation of Mt. Mitchell too. Should we represent the erosion rate with a downward arrow as well?* Students should say yes since it is how much the mountain wears down. Be sure to add to the model you are making as well.

Display **slide G.** Tell students to turn and talk with their partner: what do they notice about the relationship between the rate of uplift and the rate of erosion at Mt. Mitchell and how the mountain is changing?



Suggested prompt	Sample student responses
What did you and your partner notice about the erosion rate and the uplift rate in relation to what is happening to the elevation of Mt. Mitchell?	*Since the rate of uplift is zero and there is some erosion, we think that is why the mountain is shrinking.* *Since there is some erosion happening at Mt. Mitchell but there aren't plates pushing the mountain up, that is why the mountain is shrinking.*

Ask, *So if we were to write a statement about the relationship between uplift rates and erosion rates for a mountain that is shrinking in elevation, what would we write? Use the space on your handout to formulate your statement.* Give students a minute or two to write this, then ask for a volunteer or two to share. Make sure the class is in agreement. They should argue that when uplift is less than erosion, the mountain will shrink in elevation. Say, *Now let's take stock of what we have just figured out. It seems like a big idea!*

Suggested prompts	Sample student responses
So if erosion rates represent how much the land is worn down, does erosion happen everywhere? Just some places?	*Erosion happens everywhere on Earth because there is wind and water moving everywhere.*
And the larger the rate of erosion means what?	*The more the land is worn down in that area.*

Suggested prompts	Sample student responses
How do the erosion rates of Mt. Everest and Mt. Mitchell compare?	*Mt. Everest has a much higher rate of erosion than Mt. Mitchell.* *Yeah… and Mt. Everest changes in elevation every year but Mt. Mitchell only changes every 1,000 years.*
How do we know this—that the changes to Mt. Everest occur more often than Mt. Mitchell?	*Because the measurements, or rates for Mt. Mitchell are per 1,000 years and for Mt. Everest the rates are per 1 year.*
I noticed that too, so why isn't Mt. Everest shrinking even more than Mt. Mitchell, if the erosion rate is higher?	*Because Mt. Mitchell also has almost no uplift.* *Because there are plates colliding under Mt. Everest, pushing it up, and this is happening at a rate that's higher than the erosion is happening.*
So now we have some ideas for what causes a mountain to grow or shrink in elevation. We should be able to return to our mountain cards and explain why they are changing. What about the one mountain we have been investigating as part of the Urals, Mt. Narodnaya? What could be causing them to not be changing in elevation (they are not shrinking or growing)?	*The rate of erosion must be the same as the rate of uplift.*
If we could get data for this mountain, what would we expect to see with the relationship between the rates of erosion and uplift?	*They would be the same.*

Add to models in *Erosion Rates vs. Uplift Rates* how energy is involved. Display **slide H.** Say, *Okay, so now that we have figured out how the processes that are occurring above and below the surface affect how the surface looks, let's continue to add onto our two mountain drawings on our handout to include what is causing these processes to happen to explain what is causing THOSE causes, erosion and uplift, to occur.*

Additional Guidance

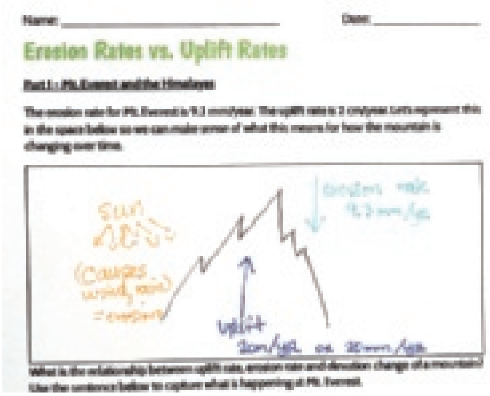
One of the DCIs that is part of this unit is **ESS2.C: The Roles of Water in Earth's Surface Processes**: Water's movements—both on the land and underground—cause weathering and erosion, which change the land's surface features and create underground formations.

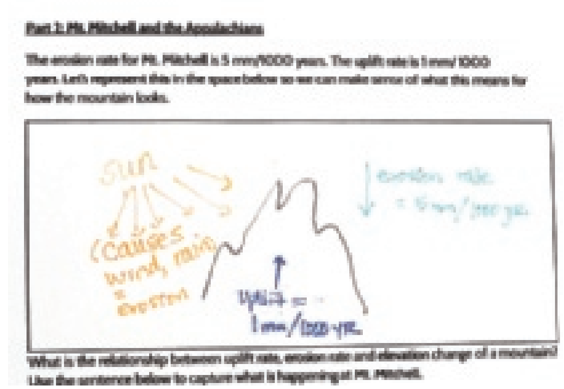
Students are at a point in the unit that they are ready to put pieces together thinking about the source of the energy that causes erosion processes and plate movement. This next section contains a couple brief discussions with students to encourage them to think about the causes of the processes that are affecting mountain elevation changes, such as the cause of the wind and rain that leads to erosion and the cause of the movement of the magma. In *Storms Unit* students have already figured out that the cause of the wind and rain is ultimately the sun's interaction with the ground which leads to the ground heating up and transferring energy to everything above it. The uneven heating of different parts of the ground lead to different densities of air rising and sinking which results in wind and rain occuring. Here we want students to draw on this prior understanding to reason out that the energy source for erosion is the sun.

In the same *Storms Unit*, students figured out that materials that are less dense than the surrounding area will rise, and materials that are denser than the surrounding area will sink. They figured this out in terms of air masses. In the brief discussion we have about why rock gets hotter deeper underground, we want students to begin thinking about the possibility this could have to do with density of material under the surface as it heats up differently underground. Going further than this to explain convection of the mantle is above grade band.

Suggested prompts	Sample student responses
If we think our big drivers of erosion are wind and rain, we probably need to explain how those are occurring as well. When did we figure out how wind and rain move?	*We figured that out in Storms Unit.*
Back in our Storms Unit unit, what did we figure out causes precipitation to happen?	*Clouds form when water evaporates from the ground and becomes water vapor that condenses when it is cooled down as it gets higher in the air.* *Precipitation happens when the water vapor in the clouds gets too heavy and falls to the ground.*
We also figured out how energy from the sun can cause convection. How does that contribute to causing winds at the surface?	*Convection causes warm air to rise. Cooler (or denser air) fills in the space left behind by that rising air, which contributes to surface winds moving toward the place where that rising air left.*
And what did we figure out causes water to evaporate?	*Water evaporates when it gets heated up by the sun.*
Right… we figured out that the ground heats up when the sunlight is absorbed by it, which leads to this evaporation process and it also contributes to convection, which causes some of the winds we experience.	
If we think about the wind and rain that cause erosion, how could we revise our mountain model to represent the primary source of where the energy comes from? What causes the air and water to move, so that it ultimately ends up moving over the land to cause things like weathering and erosion?	*I think we could add the sun since it is what causes wind and rain.* *Without the sun the water and wind wouldn't move to the top of the mountains.*

Say, *Great! Add that to both of your mountains on your handout*. Add this to the examples you have been creating too.





Suggested prompt	Sample student responses
And so if mountains are eroding and getting weathered down today by wind and water, do you think these processes will keep going into the future? Will mountains keep eroding many years from now?	*As long as the sun is heating the land.* *Yes!*

Make the connection between magma moving and mountain growth. Say, *In addition to erosion we also have figured out that there are plates below the surface and that uplift affects mountains.*

Suggested prompts	Sample student responses
Now let's think about what is going on below the surface. We have uplift labeled on our drawings. What causes a mountain to be uplifted?	*When there are plates colliding underneath it.*
Right and what causes the plates to move?	*The movement of the magma below the plates.*
Why does the magma move?	*It gets hot and cold, and the hot magma pushes things around more.* *It is hot liquidy rock that moves and creeps.*

Make a connection between processes above and below the surface. Say, *So if the magma is hot and liquidy and moves, then something must be causing it to heat up and move.*

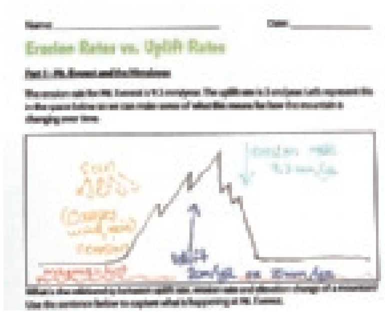
Suggested prompts	Sample student responses
When we explained erosion and the movement of water and wind, we identified an energy source that drives the movement of those two materials. We said above the surface, the sun is what heats things up. Could the sun be causing it to get hotter and hotter further and further under Earth's surface?	*I don't think so.* *No… when I dig a little bit down into the ground, it isn't hot near the surface, it actually feels cold.* *No, because we read that it begins to get much hotter after people dig far below the surface so that wouldn't make sense for the sun to cause that.* *We know something is making it hot underground because we read about how it was hotter the further down we go. The machinery started to melt and stuff.*
So if the temperature is getting higher the further we go underground, then what could be causing this increase in temperature if not the sun?	*Maybe there is something like a sun in the middle of Earth too?* *There has to be something hot underneath the mantle.* *There must be something really hot in the middle of Earth.*

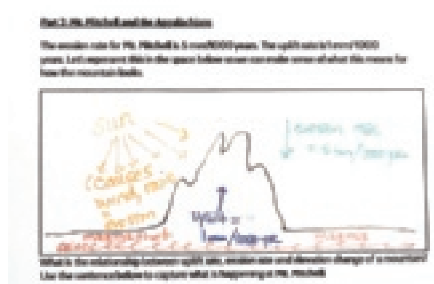
Brainstorm source of energy for magma movement. Display **slide I.** Say, *This is what scientists thought too, that there must be something in the middle of Earth or towards the middle of Earth that is really hot. The image on the slide represents what they found through collecting data.*

Suggested prompts	Sample student responses
What do you notice is happening to the temperature the further into Earth one goes?	*It is really hot in the middle of Earth!*
So if it is really hot in the middle of Earth, how could this be related to what we have figured out about magma and plates moving?	*This could be what is causing the magma to be liquidy and move.* *It seems like this could be transferring energy to the magma which then moves the plates.*
If there is stuff that is hotter more towards the middle of Earth, then how does this affect the material that is above?	*It would transfer energy to it and make it hotter.*
So could this really hot stuff in the middle of Earth be the source of energy that is causing the underground processes to happen that affect the surface of Earth?	*Yeah!* *Maybe. It seems like it could be since we know energy can be transferred between particles of hotter materials to cooler materials.* *Maybe, but I wonder what is causing it to be so hot in Earth's center?*

Suggested prompts	Sample student responses
So I hear us thinking the really hot stuff deep in Earth could be transferring energy to the magma and plates above it to cause them to move, separate, and lift in different places?	*Yes! That makes sense.*
But we are still wondering what is going on deep inside Earth that is the ultimate source for all of this energy?	*Yes.*
Okay, so would it make sense to add to our model that there is an energy source causing the magma to move that comes from deep in Earth, but we aren't sure what?	*Yes.*

Tell students to capture this on their handout and add it to the class example. Make sure to include students' questions about why this is.





Additional Guidance

MS-ESS2-1 (**Develop a model to describe the cycling of Earth's materials and the flow of energy that drives this process**), includes making sense of multiple sources of energy that affect the different processes forming and changing the surface of Earth. In *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)* students have already figured out that the sun is the main cause of weather processes. In this lesson, we use what we have already figured out about the sun as a source of energy and connect it to erosion processes. This helps us to expand our understanding of how the interaction of the sunlight with Earth helps to form the different features we see on the surface. And in *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*, students have figured out that when particles interact they transfer energy between them. We also figure out that particles of materials that are at a higher temperature are moving faster and transfer energy faster than particles of a material at a lower temperature. We use this conceptualization as we reason out where the energy source must be that is causing the magma in the mantle to move which in turn moves the plates and results in changes to the surface. If your students have not participated in these two units, this connection and discussion may need extra support or you may choose to skip this discussion.

5. Add to causal chain of events.

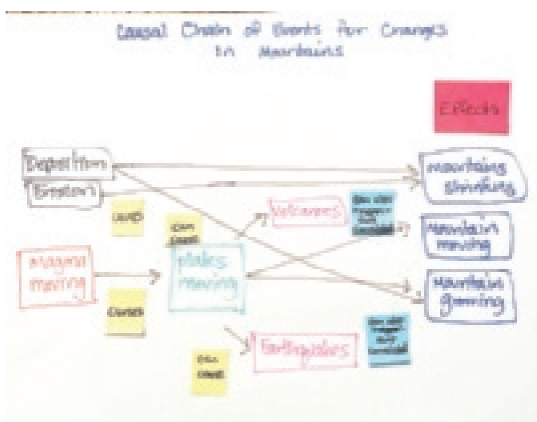
Materials: Causal Chain of Events poster, markers

Add to the *Causal Chain of Events* poster. Display **slide J.** Say, *We know Mt. Mitchell is shrinking and we wanted to figure out what is causing that. Now that we know more about erosion and how it affects Earth's surface over time, let's return to our Causal Chain of Events poster to update it with what we have figured out.*

Suggested prompts	Sample student responses
What causes of change to Earth's surface have we been investigating today?	*erosion* *uplift*
Right. So if we look at our Causal Chain of Events poster, do we have these causes on our poster?	*We have plates moving which is what causes uplift, so kind of.* *We don't have erosion.*
So do we want to add uplift next to plates moving then?	*Yes!*
And what about erosion, where should that go on our poster?	*not sure*
Does erosion cause mountains to move or grow—the two effects we have on our poster?	*No! It causes land to wear down or erode, so it would be a cause of a mountain shrinking.*
So it sounds like we need to add another effect, mountains shrinking to our poster?	*Yes!*
How about deposition, how can that cause the height of any surface to change?	*It can cause it to increase.*

Say, *Okay, let's add uplift and erosion to our poster.*

Say, *Wow! We have figured out a lot about how things happening below and above the surface can lead to changes to Earth's surface.*



6. Predict future changes using erosion and uplift rates.

6 MIN

Materials: *Erosion Rates vs. Uplift Rates*

Display **slide K.** Distribute *Erosion Rates vs. Uplift Rates* to each student. Say, *Now that we have a better idea about how processes above and below the surface affect changes we see on the surface, let's use this to think about the future. Erosion Rates vs. Uplift Rates has a few questions based on what we have just figured out for you to work through to help you think about how Mt. Everest and Mt. Mitchell will look in the future. Take the last few minutes to work on this and turn it in before the end of class. And then next time, let's see if we can explain all the changes we saw on all of our mountain sites.*

Assessment Opportunity

13.A Apply mathematical concepts (proportional relationships and unit rates) from the unobservable processes of erosion and plate movement over time to figure out how much Mt. Everest and Mt. Mitchell are changing now and use these to predict how much they would change in the future.

What to look for/listen for: See *Erosion Rates vs. Uplift Rates* for guidance.

What to do: Depending on when in the year you teach this unit, your students may need more or less scaffolding with the mathematics used in this assessment. Unit rate and ratios are part of the Common Core State Standards for Mathematics in 6th grade (CCSS.MATH.CONTENT.6.RP.A.3). Because the rates of change for Mt. Mitchell are per 1,000 years, students will need to do some conversions to figure out how much this mountain will be affected per year in order to be able to successfully make comparisons between Mt. Everest and Mt. Mitchell. Some students may need some scaffolding in these conversions. See *Erosion Rates vs. Uplift Rates* for more guidance.

Additional Guidance

The constant unit rates we have been using in the lesson for the erosion rate and uplift rate for both Mt. Mitchell and Mt. Everest are used again in the assessment. The purpose of the assessment is to continue to support students in beginning to develop a conceptual model of the competing mechanisms occurring above and below the surface to Earth's surface that result in the changes we see happening. As explained in the *Where we are not going* section of this lesson, we acknowledge that the processes that are measured and used to calculate these rates are much more complicated than they are represented here. In addition, we acknowledge that over time, as plates collide, the uplift rates change. We simplified both the uplift and erosion rates for this lesson and unit due to grade level boundaries and to allow students to begin seeing that erosion wears down the land, and plate movement can push up the land, and the elevation we see and can measure is due in part to these two processes. In later years, they will continue to add to this model as they figure out more about the mechanisms that affect Earth and the changes we see at the surface.

ADDITIONAL LESSON 13 TEACHER GUIDANCE

Supporting Students in Making Connections in MATH

CCSS.MATH.CONTENT.6.RP.A.3: Use ratio and rate reasoning to solve real-world and mathematical problems, e.g., by reasoning about tables of equivalent ratios, tape diagrams, double number line diagrams, or equations.

Students work with constant unit rates of change for erosion and uplift to determine how both Mt. Mitchell and Mt. Everest will change over different time periods (1,000 years and 1,000,000 years). Using the unit rates for both erosion and uplift, students will determine how the elevation of each of the two mountains will be affected over time.

CCSS.MATH.CONTENT.6.RP.A.3.D: Use ratio reasoning to convert measurement units; manipulate and transform units appropriately when multiplying or dividing quantities.

The unit rate for Mt. Mitchell is represented as a change in mm per 1,000 years. This mountain is changing very slowly. Because the unit rates for this mountain are represented this way, in order for students to successfully calculate these rates for different times in the future, they will need to convert the 1,000 years to per year by dividing by how many years into the future they are calculating the change for.

LESSON 14

How is there an exposed marine fossil on Mt. Everest? And, what other remaining questions from our Driving Question Board can we now answer?

Previous Lesson

After recalling what we already know about erosion and weathering, we read about erosion rates and how scientists use these rates to determine how erosion is changing the surface. Then, using both the erosion rates and uplift rates for Mt. Everest and Mt. Mitchell, we develop a representation of each model and how these two processes are affecting them. We determine that when erosion rates are higher than uplift rates, like at Mt. Mitchell, a mountain will shrink in elevation.

This Lesson

Putting Pieces Together

2 DAYS

In this lesson, we revisit our Driving Question Board to determine what questions we have made progress on and explain our related phenomena using our science ideas. We revisit our mountain cards to determine that we still need to explain the presence of marine fossils on mountains. We gather evidence to help support what is occurring for marine fossils to end up on mountains and take an assessment. We then revisit our Driving Question Board and answer our unit question.

Next Lesson

There is no next lesson.

Building Toward NGSS

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

What Students Will Do

14.A Develop and use a model to show the tectonic process of uplift can create mountains at a time scale too large to see.

14.B Construct an explanation based upon prior investigations and evidence that gradual changes have caused marine fossils to become exposed on mountains due to erosion (accumulating) over time, and those gradual changes will lead to the destruction of the marine fossils due to erosional processes over time.

What Students Will Figure Out

- Tectonic plate movement has caused uplift to occur at mountains, pushing up rocks that used to exist on ancient seafloors.
- Over time, marine fossils from the ancient seafloor are exposed due to erosional processes.
- Erosional processes will always be occurring and will continue to erode the landscape into the distant future.

- We can now better explain our related phenomena using our science ideas.
- We can now explain more questions from our Driving Question Board using our science ideas.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Celebrate all we have accomplished.	A	
2	15 min	**REVISIT OUR DRIVING QUESTION BOARD** Students revisit the DQB to take stock of all the questions we can now answer.	B-C	5 sticky dots, Driving Question Board, markers
3	15 min	**EXPLAIN RELATED PHENOMENA** Revisit the Related Phenomena poster and compare them to mountain creation and destruction processes. Use those processes to explain what might cause the related phenomena to occur.	D-G	2 sticky notes, Related Phenomena poster from Lesson 1, Potential Causes for Mountain Movement, markers, sticky notes (or index cards or scratch paper)
4	12 min	**TAKE STOCK OF WHAT WE CAN AND STILL NEED TO EXPLAIN** Revisit the *Data Cards for Other Mountains and Mt. Everest* to take stock of what we can explain and we still need to figure out.	H-I	Data Cards for Other Mountains and Mt. Everest from Lesson 1
				End of day 1
5	3 min	**NAVIGATION** Get ready to share with the class the pages in our notebook that have evidence to help explain how a fossil was found on the top of Mt. Everest.		
6	15 min	**DEVELOP A LIST OF RELEVANT EVIDENCE** Share the pieces of data and evidence we have identified as important in explaining the fossil found on Mt. Everest and record these ideas as a list.	J	poster paper titled, Supporting Evidence
7	20 min	**TAKE THE LESSON 14 ASSESSMENT** Use the *Fossil Assessment* to explain how the marine fossil is at the top of Mt. Everest, how it is exposed, and if it will always be on Mt. Everest.	K	*Fossil Assessment*
8	8 min	**TAKE ONE LAST PASS AT THE DQB AND UNIT QUESTION** Return to the remaining questions on the DQB to see if we can answer them after working through the assessment. Revisit and answer the unit question.	L	Driving Question Board, Potential Cause for Mountain Movement chart, Chain of Events poster
				End of day 2

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide** **Student Work Pages**	• science notebook • Data Cards for Other Mountains and Mt. Everest from Lesson 1 • *Fossil Assessment*	• 5 sticky dots • 2 sticky notes	• Driving Question Board • markers • Related Phenomena poster from Lesson 1 • Potential Causes for Mountain Movement • sticky notes (or index cards or scratch paper) • poster paper titled • Supporting Evidence • Potential Cause for Mountain Movement chart • Chain of Events poster

Materials preparation (15 minutes)

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

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

Online Resources

Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students begin by revisiting our DQB and Related Phenomena poster to take stock of what questions we can answer. At this point in the unit, students should be able to explain most of the questions on the DQB. The lingering questions will most likely be around the information on the mountain cards that there are fossils found on these tall mountains.

In Lessons 10 and 11, students have worked with fossil data to develop a model of where the continents would have been in the distant past and how the placement of fossils indicates the order in geologic time that they were formed. Once students have determined we still need to explain how it is that fossils can be found **and** seen on mountain tops, they will spend the second day of the lesson on a summative, near transfer task. During the assessment they will explain how and why marine fossils are exposed on many of the mountain ranges. The models they make of the large-scale tectonic processes over large periods of time, that led to the creation of Mt. Everest and the Himalayan Mountains, will utilize ideas from Lessons 10-12. They also use science ideas from Lesson 13 to explain how the marine fossils are exposed, and that over time the marine fossils will no longer be on the mountains due to erosional processes.

Students ultimately wrap up the unit in this lesson by revisiting the Driving Question Board to answer questions related to the discovery of fossils on mountains as they revisit and answer the unit question, “What causes Earth’s surface to change?”

Where We Are NOT Going

While students may use ideas from Lesson 13 to explain why a marine fossil is exposed on Mt. Everest and determine that such exposed fossils will also eventually erode, students will not be calculating an estimate of time in which the marine fossils will take to erode from the mountain. Erosion rates that occur with mineral replacement, as seen in many of the marine fossils, are slightly different than the surrounding material they are embedded in (e.g. limestone). But, this difference is not an important focus for their work and therefore is not raised in this unit.

1. Navigation

3 MIN

Materials: None

Reflect on all we have figured out. Project **slide A**. Say, *Wow! We have figured out a lot about what causes changes to Earth's surface, not only mountains! We have a causal chain of events for processes that happen to cause mountains to move, grow, and shrink. We have really figured out a lot! Let's look back at our DQB and see what questions we have made progress on and what questions we can now answer.*

2. Revisit our Driving Question Board.

15 MIN

Materials: 5 sticky dots, Driving Question Board, markers

Gather at the DQB and mark questions that students think we have answered. Present **slide B.** Ask students to turn to a partner. Distribute 5 sticky dots to each partner pair and have partners discuss and place sticky dots on the class DQB next to the questions that they think we have made progress on. You may want to have students do something similar for the *Ideas for Investigations and Sources of Data* poster they started in Lesson 1 and added to across the unit. Using this list you could ask them to identify and tag any of the ideas where we ended up exploring a very similar source of data or idea for an investigation.*

Alternate Activity

Another option for evaluating DQB questions is to have students work either individually or in pairs to answer the questions they posed. This can be done by asking them to write their questions on a sheet of paper and answer the questions in words and/or pictures. To help students feel like they made progress answering their own questions, create a focus on the questions that we have not answered, but now feel we could (or partially could) using the ideas we have developed.

As another option, some teachers may start a Wonder board to house questions that have not yet been answered, but students are still interested in pursuing. These questions are available for students to pursue independently or as time allows.

Look for patterns using the sticky dots. In the Scientists Circle, ask the class to focus on the questions that have the most newly added sticky dots.

Discuss as a class the questions the class can now answer. Present **slide C** if desired. Have the class discuss the answers to these questions as a group. If you have space, you might make a Take-Aways poster to record the class's answers.

Prompts on the slide:

- Which questions have we made the most progress on?
- What have we figured out?

***Supporting Students in Engaging in Asking Questions and Defining Problems**

Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering the questions that were important to them at the onset of the unit. At that time, students have asked a wide series of questions "that required sufficient and appropriate evidence to answer." Through investigations and individual and whole-group sensemaking around the lines of evidence they have developed, they can now answer many of their initial questions. This final visit to the DQB also allows students to see how their work toward a shared learning goal can help them figure out the anchoring phenomenon and can also explain other phenomena in the world.

3. Explain related phenomena.

15 MIN

Materials: science notebook, 2 sticky notes, Related Phenomena poster from Lesson 1, Potential Causes for Mountain Movement, markers, sticky notes (or index cards or scratch paper)

Say, *Now that we have had a chance to answer many of our questions, let's work together to see if we can explain any more phenomena. That is one of the exciting things about developing a set of general model ideas about how the world works—we can continue to test the applicability of those ideas to a larger and larger set of phenomena to better understand what other things in our world they might help explain. Let's look back at our Related Phenomena poster from Lesson 1 to see if we can explain any of our related phenomena.*

Recap development of ideas in the unit thus far. Direct students to look at the Related Phenomena board and quickly verbally list the related phenomena identified by the class, along with their accompanying potential causes.

Group potential causes with related phenomena. Project **slide D.** Be sure the *Potential Cause for Mountain Movement* chart is visible along with the *Related Phenomena* poster. Also have sticky notes, or notecards, or scratch paper available with markers. Say, *Let's use what we have figured out about the different causes we have on our* Potential Cause for Mountain Movement *chart to look back at our related phenomena and see if any of these causes could help explain any of our related phenomena. Any that we agree on as a class, let's take the sticky note with that related phenomenon and place it on our* Potential Cause for Mountain Movement *chart next to the cause.* Tell students they also might want to look back at the causal chain of events posters for processes that cause mountains to grow, shrink, and move. Decide as a class if we believe that the causes are accurate or if they need updating. Move any related phenomena next to the cause we believe to be accurate. Add any new causes to the board.

Remind students that when we started our unit, we began by figuring out how a mountain can increase in elevation over time and move due to plate movement and plate interactions. After that, we determined how a mountain can decrease in elevation over time through surface processes such as erosion. We used the constructive process of tectonic uplift and destructive erosional processes to describe how these mountains have changed over time.

Additional Guidance

Should students struggle to connect these processes to their related phenomena, you may wish to remind students of two terms added to our Word Wall in Lesson 7, constructive and destructive, when we discovered different ways volcanoes affect the land. You may wish to remind students of these two words on the Word Wall if they struggle to connect these processes to their related phenomena.

Ask students, *If we were to start to group our related phenomena to better explain what is occurring, how could we group these processes? What have we done so far in our unit that we can utilize here?*

Students should consider that we could group the list by phenomena that seem constructive and phenomena that seem destructive or wear away the land. Students also might suggest processes that happen to the surface of mountains versus processes that occur under mountains, such as uplift.

Remind students that when we started our unit, we first started to determine how a mountain can increase in elevation over time. After that, we then determined how a mountain can decrease in elevation over time. We used the constructive process of tectonic uplift and destructive erosional processes to describe how these mountains have changed over time.

Organize phenomena into ones that are occuring due to either primarily constructive vs. destructive processes. Work with the class to organize the cards into two groups—constructive and destructive. At the end of the sorting process, reflect on the sorting.

Say, *We have now sorted our related phenomena into two groups. When we looked at mountains, we also thought of them in two groups. Mountains that are growing and mountains that are shrinking or staying the same. Let's look at these that are now grouped into mostly constructive vs. mostly destructive processes, and compare them to our mountains to see if what is occurring on our mountains also applies to our related phenomena.*

Begin *Comparing Related Phenomena*. Project **slide E**. Distribute *Comparing Related Phenomena* to partner pairs. Explain that students will pick one related phenomena and try to explain what is causing that change to occur. After that, we will then reflect on whether the same processes that create and destroy mountains are influencing the changes we see in the related phenomena.

Conduct a related phenomena gallery walk. Project **slide F.** After students have had time to complete *Comparing Related Phenomena*, have students place the handouts in a highly visible place, such as on a wall or on the top of desks. Give partner pairs a moment to walk around the room with 2 sticky notes. Ask each partner pair to analyze other students *Comparing Related Phenomena* and think about the related phenomena being explained and how the processes are similar or different from the processes of the related phenomenon that they themselves explained on their *Comparing Related Phenomena*. Have the partner pairs discuss and write how this related phenomenon is similar or different to their related phenomena on their sticky notes, and leave the sticky note by the related phenomenon they are comparing it to.

Asks partners to return to their seats. Give partners a moment to read over any sticky notes that were left by their chosen related phenomenon.

Discuss similarities and differences as a class. Project **slide G**. Take a moment to debrief similarities and differences as a class. Ask students to explain any patterns that they noticed over the related phenomena or sticky notes, and any similarities or differences that stood out to them.

Students may mention the following:

- Most of the classroom destructive related phenomena were a result of erosional processes.
- Even though we had some constructive processes, most were not related to plate movement directly.
- Most of the constructive processes that we observe around us had to do mostly with deposition of sediment or other materials that were moved away (eroded) from other places.
- The natural processes we tend to see above the surface are a result of weathering, erosion, and deposition.
- The process of uplift happens on a much larger scale than what we see in just our backyards or communities.
- Some processes occur relatively quickly, while others are much slower or more gradual.

4. Take stock of what we can and still need to explain. 12 MIN

Materials: Data Cards for Other Mountains and Mt. Everest from Lesson 1

Take stock of what we have been able to explain about the different mountains. Display **slide H.** Say, *If we look back at our Data Cards for Other Mountains and Mt. Everest, we can explain a lot of the data on the cards. For example, if we look at Mt. Everest card and remind ourselves that it moves 4 cm/year to the NE and grows 2 cm/year, we now know the processes that are happening to cause Mt. Everest to move and grow. What is causing this?* Students should say plate movement.

Continue the discussion with, *And, I bet using some of what we figured out in Storms Unit, we might even be able to explain some of the weather Mt. Everest has. But what about the image of the marine fossil that was found on Mt. Everest? How is it that a fossil of a marine organism that lives in the sea could be found on the top of the tallest and very cold mountain? We may have some initial ideas for why this is possible, but we know that in our class we need to support our explanations with evidence.*

Explain to students that before anyone shares their explanation, we need to consider what evidence we have that would help us develop an explanation for the marine fossil. Tell students that they will work with a partner to go back through their notebooks, and mark any page or data that can be used as evidence to explain how the marine fossil is found at the top of a mountain.

Work in partner pairs to identify potential evidence. Pair up students and project **slide I.** Tell students they can dog-ear, or attach a sticky note to any pages that has evidence they and their partner want to include in their explanation. Give groups until the end of this class to go back through their notebook. In the last minute of class, tell students that at the beginning of the next day, we will share out as a class the different pieces of data and evidence we think will be important to include in this explanation through developing a Gotta-Have-It Checklist.

End of day 1

5. Navigation 3 MIN

Materials: science notebook

Get ready to share the data and evidence marked in our science notebook. Say, *Last class you worked with a partner to find the evidence in your notebook that will be needed to explain how a fossil of an organism from the ocean could end up on top of Mt. Everest and be seen by people. Let's get together in our Scientists Circle and be ready to share with the class what you and your partner found.* Gather the class into a Scientists Circle and have a poster paper ready to record the data or evidence students share.

6. Develop a list of relevant evidence. 15 MIN

Materials: science notebook, poster paper titled, Supporting Evidence

Convene in a Scientists Circle. Display **slide J.** Say, *What are some of the pages you flagged in your notebook as having data and evidence that would be needed to explain how a tropical fossil could be seen at the top of Mt. Everest?* Ask volunteers to share. As students share their ideas, press them to explain why they chose that piece of data or evidence. Then ask the rest of the class if anyone else also had the suggested data or evidence flagged in their notebook. Press for consensus on what should and shouldn't be included on the *Supporting Evidence* poster. Below are suggested prompts to use as probing questions.

Suggested prompts	Sample student responses	Follow-up questions
What data or evidence did you flag in your notebook?	*Plate movement images from Lesson 5 because we know there are plates colliding to form Mt. Everest.*	*Did others have this too?*
What other data or evidence should we add that you have flagged in your notebook?	*The way the continents looked in the past from Lesson 11 because we should move the plates that are forming Mt. Everest back in time to see where they would be.*	*What do others think of adding this?*

Continue with the discussion until the class has narrowed in on what they think is important to include on the *Supporting Evidence* poster. Below is an example of what students might argue as evidence that should be included on the poster:

- From Lesson 5 - these plates move at different speeds and in different directions - everything on top of the plate moves with it.
- From Lesson 6 - when plates collide, mountains can form and move and grow. When plates move apart from each other, the creepy, hot rock, or magma might come to the surface.
- From Lesson 8 - where the plates spread apart, magma rises to the surface and makes new land and new mountains.
- From Lesson 8- when plates move away from each other, new oceanic plate is created. When plates move towards each other, oceanic plate between them is destroyed.
- From Lesson 10 - back in time, South America and Africa used to be together in a different configuration and we know this based on multiple pieces of data.
- From Lesson 10 - the arrows of current plate movement can be reversed to infer where the plates probably used to be located.
- From Lesson 11 - all the land masses were together at one point in history and we know this from multiple pieces of data.
- From Lesson 11 - coral reef data shows that there was once an ocean between China and Nepal.
- From Lesson 12 - now we have a good idea how mountains are formed and how they move and grow - plate collisions. We figure out that all mountains at one time were formed at plate boundaries, but over hundreds of millions of years plate boundaries can become inactive based on our data.
- From Lesson 13 - erosion rates and plate movement rates both affect land changes. When one is more than the other, mountains grow or shrink. When these are the same, mountains don't change based on our erosional and uplift comparison data.

7. Take the Lesson 14 assessment. 20 MIN

Materials: *Fossil Assessment*

Additional Guidance

Prior to middle school, students will have had some experiences with fossils and begun to figure out some things about fossils. According to **3LS4-1**, **Analyze and interpret data from fossils to provide evidence of the organisms and the environments in which they lived long ago**, students will figure out fossils are of organisms from the past and can help to determine the environment that the organism lived in, specifically marine fossils found where there is not water anymore and fossils of tropical organism in areas that are not currently tropical. In fourth grade, according to **4ESS1-1, Identify evidence from patterns in rock formations and fossils in rock layers to support an explanation for changes in a landscape over time**, students will build on their understanding about fossils to figure out that looking at patterns of where fossils are found can be used to determine what the land was like in the past. For example, if fossils of marine organisms are found below fossils of non-aquatic plants, then what once might have been an ocean later became dry land.

In addition, according to **4ESS2-1, Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation**, students will have investigated different erosional and weathering events and their effects on the land, including thinking about these processes as a rate or effect. Students will have figured out that water, wind and biological factors all play a role in eroding and breaking down the land.

This lesson assumes students have engaged with these performance expectations (PEs) prior to middle school and therefore will begin with a short discussion to support students in recalling what they have figured out from elementary school. If your students have not experienced these PEs in elementary school, you will need to build in time to support them in making sense of:

1. What fossils are and why they are found where they are found.
2. What erosion and weathering are and the effects they have on the land.

Say, *We saw a lot of marine fossils on most of our mountain cards. We even saw a picture of a sea lily fossil like the ones found on Mt. Everest. Using our list of supporting evidence, let's try to explain how this marine fossil got in the Himalayan Mountains and what we think will happen to it over time.*

Go over the lesson assessment. Project **slide K.** Distribute *Fossil Assessment*. Go over each question with students. On question 1, make sure to point out that there is an area to draw and label what is happening with the mountain, and an area added for students to explain what they are representing in their models.

Conduct the Lesson 14 assessment. Allow students time to complete *Fossil Assessment*.

Assessment Opportunity

Building towards: 14.A Develop and use a model to show the tectonic process of uplift can create mountains at a time scale too large to see.

What to look for: Look for students to show an ancient ocean between the Indian and Eurasian plate. Students should model the tectonic plate movement of the Indian plate from the Southern region of a world map to the Northern region over millions of years. Look for students to show that during this process, the oceanic plate material is broken up and some of that material is pushed up during the collision of the Indian plate and Eurasia over a scale that spans millions of years. This slow process of plate material folding should be modeled and explained, condensing millions of years into three distinct models. See *Key for the Fossil Assessment* for further guidance.

What to do:

- Revisit the puzzle pieces from Lesson 11 and consider the placement of the Indian and Eurasian plates. Determine what had to occur over time for the two plates to have merged together.
- Look back at data (specifically coral reef data) to determine that there was once an ocean between India and Eurasia.
- Discuss what must have happened to the oceanic plate material that used to exist between the two plates based upon the plate movement arrows on the basemap and GPS data, and what life would have once existed in that space.
- Revisit the slow plate folding processes from Lessons 6-9 to determine what occurred when the two plates collided to create the mountains we now see today.

Assessment Opportunity

Building towards: 14.B Construct an explanation based upon prior investigations and evidence that gradual changes have caused fish fossils to become exposed on mountains due to erosion (accumulating) over time and those gradual changes will lead to the destruction of the marine fossils due to erosional processes over time.

What to look for: Look for students to identify that the slow process of erosion on the mountain sides has caused the marine fossils to become exposed over time, and over time the currently exposed marine fossils will be eroded away, exposing matter from underneath the marine fossils. See *Key for the Fossil Assessment* for further guidance.

What to do:

- Revisit science ideas listed by the class as evidence that can help to explain the sea lily fossil on Mt. Everest. Go over each piece of evidence independently and ask the students to explain how the data helps to answer the question.
- Look back at erosional data from Lesson 13 and have the students consider the changes to the fossil over time with the proposed erosional rate.
- Ask students to consider if the mountain range will always be as tall as it is, and if it will ever look like Mt. Mitchell. Determine that eventually it will erode away once uplift ceases, and along with it, the marine fossil will also erode away.

8. Take one last pass at the DQB and unit question.

8 MIN

Materials: Driving Question Board, Potential Cause for Mountain Movement chart, Chain of Events poster

Convene in a standing Scientists Circle around the DQB. Say, *We still have a few questions left on our DQB about fossils found on the mountains. Let's see if we feel we can answer any of these now after the assessment.*

Gather at the DQB and mark questions that students think we have answered. Read over the remaining questions about fossils with students and determine if the class has made progress on these questions. Mark any new questions the class has made progress on. Say, *Now that we have looked at our individual questions, let's revisit our unit question and see if we have made progress on it.*

Revisit the unit question. Project **slide L.** To begin to close out the discussion, pose the current driving question,*"What is causing mountains and the land beyond them to grow, shrink, and move?"* Reflect on how well the learning fits the current driving question, and realize that the processes of mountain change are not the only things we have learned about. Collaboratively with the class, update this question to be reflective of the broader changes in which we have been studying in Lessons 10-13 to something similar to: "*What causes changes to Earth's surface?"*

Suggested prompts	Sample student responses
At the beginning of our unit we started with the question, "What causes mountains to move?" As we learned more over time, we came back to this question and modified it. What did we change it to as we learned more information?	*We changed it to, "What is causing mountains and the land beyond them to grow, shrink and move?"*
Does this question really reflect what we were wondering over the past few lessons, or have we broadened what changes we are studying?	*We've definitely studied some bigger changes.* *Yeah, like we not only learned about how mountains change, but about how landscapes are changed by erosion.*
So does this process only happen on mountains?	*No, it definitely happens everywhere else.* *We saw it happen a lot in our related phenomenon.*
So would we say that we were studying, in the end, how mountains are changing, or how something broader is changing?	*Definitely something more than just mountains.* *We were looking at the areas around us and also at the mountains. It was like how the land around us is changing, not just mountains.*
So should we update our question to focus less on mountains, and more on what we were looking at, Earth's surface around us?	*Yeah, it should focus on Earth's surface.*
How about, What causes Earth's surface to change? *Modify and update this question to be reflective of changes on Earth's surface, and in the language used by students if they desire.*	*Yes. That sounds right.*

Answer the new unit question as a class. Elicit students' new ideas and answers to this question. As students mention factors such as plates and erosional processes, press students to explain how those forces interact with Earth to cause broader changes.

Suggested prompts	Sample student responses
Now that we have considered our questions we had during our unit, let's think back on our bigger unit question we just developed. In light of what we have learned, what do we think causes Earth's surface to change?	*Plate movement definitely causes Earth's surface to change.* *Yeah, when plates move they can cause mountains to form and oceans to get created or destroyed.* *Plates moving also cause earthquakes and volcanoes, which change the surface.*
Tell me more about the plates. What do they do? What changes do they cause to Earth's surface?	*The plates move over time. When they collide they can create ridges or mountains. Sometimes they go under one another too and create mountains that way.* *Yeah the interactions where one plate goes under another generally have volcanoes that form too.* *When they move away from each other they make ridges, and that can make some volcanoes too, but it also can create ridges and more oceanic plate material.* *Plate movement also causes earthquakes, which can really affect what we see on the surface. The plates moving change the location of the ground, like at Ridgecrest, and can also destroy things above ground when it shakes.*
So it seems like plates moving causes changes to Earth's surface. Is there anything else that causes Earth's surface to change?	*Weathering and erosion do too.*
What changes do those things cause?	*Weathering causes things to break down. We see that happening on our mountains over time, and we also see that happening with a lot of our related phenomena.* *Erosion carries some of that material away from where it originally was. That means that the landscape changes in a couple of locations because that material has to end up somewhere. Wherever it ends up is changed too.* *Water and wind can break up landscapes and then pick it up and move that material around, eventually depositing it in new locations.* *They also cause changes around us. Like we saw with some of our related phenomena.*

Celebrate the progress made on answering the unit question. Take a moment with the class to look back at what they have learned over the course of the unit. Reflect on how our unit question has evolved as we have learned more, and how our understanding of changes have shifted from a simple Potential Cause for Mountain Movement chart to a causal chain of events that we can use to explain processes all over and under Earth's surface. As class is ending, ask students if they have any larger takeaways about the processes of Earth and the changing landscape. Allow students to share any reflections they have with the class.

Teacher Resources

Table of Contents

ASSESSMENT SYSTEM OVERVIEW

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the “Assessment Icon” in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	Initial models in science notebooks Driving Question Board	**Pre-Assessment** The student work in Lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Revealing these ideas early on can help you be more strategic in how to build from and leverage student ideas across the unit. The initial models developed on the first and third days of Lesson 1 are a good opportunity to pre-assess student understanding of Earth’s systems, including how land can move and change. At the end of day 1, after students compare their initial models, and during day 2, the class develops an initial consensus model for a mountain growing. On day 3, after students compare their second initial model for a mountain shrinking, the class develops an initial consensus model. The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as how and why questions and to post to the board. However, any questions students share, even if they are close-ended questions, can be valuable. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these questions into open-ended questions when they relate to the investigations underway.
Lesson 11	Student Assessment L11 Assessment Scoring Guidance	**Summative** This is a summative assessment at a point in the unit where students can synthesize what they have figured out. Using models they have co-developed of where the continents might have been in the past based on multiple data sets, students explain why the evidence they have from the data sets supports the model they created and where the continents will be in the future. This is an opportunity for midpoint grading, if needed.
Lesson 13	Student Assessment L13 Assessment Scoring Guidance	**Formative and Summative** This is an assessment that could be used either formatively or summatively or both. Students use erosion rate data and uplift rate data to predict how Mt. Everest and Mt. Mitchell will potentially be changed over time into the future. This could be used formatively informing whether students are ready for the assessment in the following lesson where students will need to apply this idea that there are opposing processes affecting changes to the surface of Earth.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 14	Student Assessment L14 Assessment Scoring Guidance	**Summative** This lesson includes a transfer task to give students an opportunity to use the 3 dimensions to make sense of a different phenomenon. This is meant to be a summative assessment task for the unit and it gives you a grading opportunity. In this task it is presented to students that fossil fragments of crinoid organisms ended up towards the top of mountains like Mt. Everest. Scientists were able to see and identify these exposed fossils on mountains without having to dig them up. Using what students know about plate tectonics and the processes of weathering and erosion, they develop a model and explain how this fossil can be at the top of Mt. Everest and how it can be seen at the top of Mt. Everest without having to dig to find it.
After each lesson	Lesson Performance Expectation Assessment Guidance	**Formative Assessment** Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.
Occurs in several lessons	Progress Tracker	**Formative and Student Self-Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figures out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress Tracker can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative "grade" other than for completion.
Anytime after a discussion	Student Self-Assessment Discussion Rubric	**Student Self-Assessment** The student self-assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try to improve for the next time, such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive.
After Students Complete Substantial, Meaningful Work	Peer Feedback Facilitation: A Guide	**Peer Feedback** There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their three-dimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes student-facing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving peer feedback. It should be a formative, not summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback. For this unit, Peer Feedback works best for Lessons 8, 10, 13, and 14 during the consensus moments where students are sharing their consensus models, or after an investigation where students share what they figured out with peers.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	**1.A** Develop a model showing what is happening at a scale larger than we can see (patterns) to help explain what happened to the different mountains to (cause) them to change (in elevation and/or location). **1.B** Ask questions that arise from our analysis of information showing that Mt. Everest and four other mountain peaks are changing to seek additional information about what caused the changes (effects) we read about.	**1.A Developing and Using Models; Patterns, Cause and Effects** **When to check for understanding:** Collect students' initial models on *Explain How Mt. Everest Moves and Grows* and *Explaining Other Mountains That Shrink* at the end of day 1 and day 3. **What to look for/listen for:** Look for students to include causes for a large mountain moving and changing in height using mechanisms they are familiar with, such as weathering (rain, ice, snow) and erosion (wind, moving water). See the related Assessment callout box for additional guidance. **1.B Asking Questions; Cause and Effects** **When to check for understanding:** When students generate questions on sticky notes with their initials on back. You may also want to look through student notebooks to see their individual ideas for future investigations to pursue. **What to look for/listen for:** Listen for questions that are open (how/why) and testable versus closed (yes/no) in the classroom. Also listen for questions that are specific to Mt. Everest, the mountain case sites, and related phenomena involving land and landforms changing over time. See the related Assessment callout box for additional guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 2	**2.A** Present an oral and written argument that earthquakes either caused or are correlated to the elevation and location changes of the mountain cases and Ridgecrest, California. **2.B** Use digital tools to examine a large data set at different spatial and temporal scales to compare global earthquake activity to local activity.	**2.A Engaging in Argument from Evidence; Cause and Effect** **When to check for understanding:** At the beginning of day 2, students argue if earthquakes cause or are correlated to mountain changes in elevation and location, and support their argument with evidence. **What to look/listen for:** • Look and listen for students to write and orally argue that data and observations support a correlation, not a causal relationship, between earthquakes and mountain growth and movement. • Students should cite changes to the surface after an earthquake as evidence of a correlational relationship, and evidence from the videos as not showing direct changes occurring during the earthquakes to make a causal relationship. **2.B Using Mathematics and Computational Thinking; Scale, Proportion, and Quantity** **When to check for understanding:** During day 2, as students work with larger data sets in Seismic Explorer to make sense of the depth and breadth of earthquake depth and magnitude data. **What to look/listen for:** • Look for students to locate mountain regions identified in case site information and narrow focus to earthquake data that applies to those areas that would not be discernible at a larger scale. • Students should filter through earthquake data and analyze the large sets of earthquake data for any patterns in depth, location, frequency, or magnitude at the regional scale for evidence of earthquakes being causal or correlational to mountain movement and growth.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance

Lesson 3	**3.A** Develop and use models to describe the structure, composition, and temperature of materials below the surface of Earth, and some of the processes (pressure and heat) that cause changes to those earth materials.
	
	3.B Construct a scientific explanation based on evidence from text, media, and investigations to explain changes that occur to materials below the surface of Earth that are not directly observable.
		3.A Developing and Using Models; Stability and Change
		When to check for understanding:
		• At the end of day 1, students revisit their models and make changes using data as evidence to support their thinking.
		• At the end of day 2, students again revisit their models and use pictures, words, and symbols to represent their current understandings in their Progress Trackers.
		What to look for/listen for:
		• At the end of day 1, look for students to adjust their models to include bedrock at or just below the surface of Mt.Everest. They might include a thin layer of loose sediment (soil, dirt, broken rocks) at the surface, if at all. They should also indicate that the temperature of the rock below the surface increases with depth.
		• At the end of day 2, look for students to revise their model in their Progress Trackers and cite sources of evidence for their ideas related to the structures found on and below the surface of Earth, the composition of those structures, and the changes that occur due to pressure and heat deep in Earth's bedrock. Students' Progress Trackers should include the following ideas:
		  ◦ There may be sediment at the surface of Mt.Everest. This sediment is most likely made up of soil, sand, and/or broken rock.
		  ◦ The layers of bedrock found below the surface are made up of sedimentary (limestone and shale) and volcanic (granite) rock.
		  ◦ Some of the rock deep beneath the surface of Mt. Everest has changed due to heat and pressure, which caused the rock to become soft and pliable.
		3.B Constructing Explanations and Designing Solutions; Scale, Proportion, and Quantity
		When to check for understanding: At the end of day 2, students revisit their models and document their current understandings in their Progress Trackers. They cite evidence to support their thinking from storymap, images, readings, and the rock investigations.
		What to look for/listen for: As students revise their models in their Progress Trackers to reflect their current thinking, look for the following ideas in their models and supporting evidence from their observations of storymap and images, readings, and their investigations.
		• Possible composition of the layers of bedrock (sedimentary rock, including shale and limestone, and volcanic rock, including granite).
		• Increases in the temperature of the rock as the depth increases.
		• Changes in the rock due to high temperature and pressure. For example, students should indicate that the rock becomes soft and pliable and tends to shift and move.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	**4.A** Develop a profile model across the North American plate to explain the changes seen in bedrock after an earthquake by showing what is found at and below the observable surface. **4.B** Construct an explanation using qualitative evidence from class investigations to explain what is happening to the bedrock below the observable surface when an earthquake causes a shift or break in the land.	**4.A Developing and Using Models; Scale, Proportion, and Quantity** **When to check for understanding:** On day 2 on *Constructing Profile Model West and East of Ridgecrest.* **What to look for/listen for:** Students to include • differences in elevation across the North American plate • some type of sediment at the surface in the lower elevation areas • bedrock exposed on some of the higher elevations • bedrock underneath everything going down deep • additionally, they may represent rock beginning to shift or move far under the surface due to temperature **4.B Construct Explanations and Design Solutions; Scale, Proportion, and Quantity** **When to check for understanding: 1.** On day 1, when students work with their small group to explain what must happen to the bedrock below the surface when there is an earthquake that results in breaking the surface. **2.** On day 2, when students fill in their Progress Tracker. **What to look for/listen for: 1.** Listen for students to explain that the surface of the land cracks and shifts in elevation and location during an earthquake. **2.** Listen for students to explain that where there are long lines of fault lines from earthquakes, these cracks must go all the way through the bedrock, otherwise the land couldn't change in elevation or shift. In addition, students should argue that if these long lines of fault line cracks in the bedrock happen at the edges of the different plates on Earth, then maybe the whole plate moves too.
Lesson 5	**5.A** Analyze a graphical display of a large data set of plate movement in order to determine whether a causal or correlational relationship exists between plate movement and mountain movement.	**5.A Analyzing and Interpreting Data; Cause and Effect: Mechanism and Prediction** **When to check for understanding:** Students have two opportunities to demonstrate their ability to find patterns in data to establish the existence of a causal relationship. (1) First, with a partner, students will use GPS data regarding the North American plate (after **slide F)** to say that the movement of Mt. Mitchell **may** be caused by the movement of the North American plate. (2) Later, students will revisit Seismic Explorer to explore a larger set of data **(slides K-L)** in order to uncover patterns **establishing a causal link** between plate movement and mountain movement. **What to look for/listen for:** (1) Using *North American Plate Manipulative,* students place the North American plate slightly to the west of its original location, and rotate it slightly counterclockwise. Students should be able to support this prediction by referring to the arrows shown on the Seismic Explorer map of the North American plate. (2) Students use Seismic Explorer data to make the claim that all plates are moving, and conclude that each case of mountain movement is due to plate movement. On the *Potential Causes for Mountain Movement* chart, students will change the link between plate movement and mountain movement from a dashed line (representing correlation) to a solid line (representing causation).

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	**6.A** Develop and use models showing what is happening at varying spatial and time scales to describe how plates interact at plate boundaries. **6.B** Construct an argument supporting a model of how plate interactions could cause mountains and earthquakes.	**6.A Developing and Using Models; Scale, Proportion, and Quantity** **When to check for understanding:** As students develop representational models of plate interactions on day 2. **What to look/listen for:** Students make connections between the components and relationships in students' models and the real-world phenomena they represent, such as the following: • Referring to the foam pieces as "plates" as they work with them. • Describing a change in height of a foam piece as a "change in elevation." • Proposing surface phenomena that might be explained by the observations they are making as they manipulate their models. • Wondering about how the model interactions they are observing would look (or feel) at an Earth-sized scale. • Labeling and describing components of their models with the real-world phenomena they represent (e.g. plate rather than foam piece; liquidy rock layer rather than water; arrows labeled as plate movement). **6.B Engaging in Argument from Evidence; Cause and Effect** **When to check for understanding:** On Day 3, students construct two explanations. (1) After students have written their arguments supporting the model they think best explains what is happening at Mt. Everest and (2) how earthquakes happen. **What to look/listen for:** For both explanations, students should include similar pieces of evidence in supporting two different claims. (1) These pieces of evidence will have been discussed or referenced in the lesson before students are called to use them in their writing. (2) The evidence that plate movement causes specific surface changes should come from what they see in their models, and what they know about surface phenomena involving mountains and earthquakes. Through constructing their written arguments, they identify pieces of evidence and articulate why the evidence supports the claim for both explanations.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 7	**7.A** Apply scientific ideas and evidence to construct an explanation for the processes that cause some of the large scale interactions of Earth's plates that result in the effects (volcanoes) of those interactions.	**7.A Construct Explanations and Design Solutions; Scale, Proportion, and Quantity** **When to check for understanding:** At the end of the lesson. **What to look for/listen for:** Look for students to use evidence from the Seismic Explorer map images, the *Data Cards for Other Mountains and Mt. Everest* from Lesson 1, and *How are Volcanoes Formed and What Kinds of Changes Do They Cause?* to describe the processes that play a role in the development of volcanoes and the changes that volcanoes cause to the surface of Earth. (See the key ideas listed above.) Some examples of what students might argue: • We know that volcanoes do not cause mountains to move, so we can claim that none of the changes in location were caused by volcanoes at or near any of the mountain sites. • We also know that volcanoes can create new landforms or build up existing land when lava flows out and over the top of a volcano. • But a volcano can only add to its own height, not the height of surrounding mountains. • So, the only mountain that might possibly be increasing in elevation because of volcanic eruptions is Mt. Hotaka because it is the only active volcano in our list of 6 mountain sites.
Lesson 8	**8.A.1** Support or refute a claim orally and in writing, based on evidence from multiple locations over a large distance along the ridge to explain what is happening where two plates are moving apart. **8.B** Compare data and evidence from the case cards and the Mid-Atlantic Ridge to determine that volcanoes are correlated with some cases of mountain change, but not the cause of all mountains changing.	**8.A Constructing Explanations and Designing Solutions; Scale, Proportion, and Quantity** **When it happens:** (1) At the end of day 1 when students complete the final question on *Evidence Tracker* and (2) at the beginning of day 2 as students share their claims and evidence, and explain whether the evidence supported or refuted their claims. **What to look/listen for:** (1) On day 1, look for students to cite evidence that is relevant to their claim and use the evidence to evaluate whether their claims are supported or refuted. (2) On day 2, listen for students to explain whether the evidence supports or refutes their claims, and give feedback to their partners on whether their evidence is sufficient for supporting or refuting their claims. **8.B Analyzing and Interpreting Data; Cause and Effect** **When it happens:** On day 2 as students update the Potential Causes for Mountain Movement chart to consider the relationship between volcanoes, changes to elevation, and location of mountains. **What to look/listen for:** Students should state that while there is evidence of volcanoes at some of our mountain cases, this evidence does not exist at all of the class mountain locations. While volcanoes can cause changes to mountain elevation, this is not seen at all of our mountain cases. Students should reason out that volcanoes are correlated, but not causing changes in location and elevation to all mountain cases.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 9	**9.A** Construct an explanation using representations on the Causal Chain of Events poster to explain how the causal (not correlational) events lead to a mountain changing in elevation or location.	**9.A Constructing Explanations and Designing Solutions; Cause and Effect** **When it happens:** After the class has developed the causal chain of events for a mountain to change. **What to look for/listen for:** Students explaining that: • Magma is moving liquidy rock that is found far below the surface. • Magma moving makes the plates on the surface of Earth move. • Plate movement changes the surface of Earth when they interact or spread apart.
Lesson 10	**10.A** Analyze maps displaying patterns of large sets of data to determine that Africa and South America could have been touching at the Mid-Atlantic Ridge (spatial relationship) between roughly 125 and 146 million years ago.	**10.A Analyzing and Interpreting Data; Patterns** **When to check for understanding:** During the exit ticket on *Lesson 10 Exit Ticket,* students construct an evidence-based argument for whether the plates were or were not touching. Students use evidence from maps to support their claim. **What to look for/listen for:** • Students state in their claim that the two continents were once touching at the Mid-Atlantic Ridge. • Students should cite all data sets to show that the plates were touching. • Students should include the following reasons when justifying how the data supports their claim: ◦ Similar rock types, rock strata, and land formations: some areas that show similarities can be traced directly across from one continent to another, specifically at the top and middle of the two continents. • Evidence of past glaciers: ◦ Glacier data fits like a puzzle piece if the continents were moved together. • Location of fossils: ◦ Fossils of the same type are found at the middle and bottom sections of both continents. • Rocks of similar types and ages: ◦ The top-middle of each rock layer are very similar across the two continents. • Areas where coral fossils have been found: ◦ Coral fossils were found on the outside of the two continents, meaning that when they were formed there was no ocean in between the continents.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	**11.A** Construct an explanation of changes in the global position of land masses over time including reasoning that shows how rock strata and fossil evidence adequately supports a map of where Earth's land masses (parts of plates that were not created or destroyed as plates were moving) were located millions of years ago.	**11.A Constructing Explanations and Designing Solutions; Stability and Change** **When to check for understanding:** On day 2 of the lesson, collect students' diagrams from the *Create a Map that Represents a Claim* activity along with their written answers from the *Describe the Reasoning that Supports the Claim Diagram* activity as recorded on *Evaluating Two Models.* **What to look for/listen for:** See Assessment Callout and *Teacher Key for Evaluating Two Models* for details. **What to do:** If students are struggling, direct their attention to the T-charts they constructed in their science notebooks that describe similarities and differences as well as strengths and weaknesses of their models.
Lesson 12	**12.A** Construct a scientific explanation based on evidence from a model that colliding tectonic plates caused the formation of the Appalachian Mountains and the Ural Mountains at time and spatial scales that are not observable.	**12.A Constructing Explanations and Designing Solutions; Scale, Proportion, and Quantity** **When to check for understanding:** After students have used the virtual simulation to observe the formation of the Appalachian Mountains, the Ural Mountains, and the Himalayan Mountains, and have documented their observations in a series of Notice and Wonder charts in their science notebooks. **What to look for/listen for:** After using the virtual simulation to observe the formation of the Appalachian Mountains, the Ural Mountains, and the Himalayan Mountains, students work collaboratively to construct a scientific explanation that describes how the Appalachians and the Urals were formed in the same way as the Himalayas—through plate collisions. Students also figure out that the Appalachian Mountains, which were formed about 400 million years ago, and the Urals, which were formed about 280 million years ago, are much older than the Himalayan Mountains, which were formed 35 to 50 million years ago, and that the Appalachians increased in elevation for a long time, but are now decreasing in elevation.
Lesson 13	**13.A** Apply mathematical concepts (proportional relationships and unit rates) from the unobservable processes of erosion and plate movement over time to figure out how much Mt. Everest and Mt. Mitchell are changing now and use these to predict how much they would change in the future.	**13.A Using Mathematics and Computational Thinking; Scale, Proportion, and Quantity** **When to check for understanding:** At the end of the lesson. **What to look for/listen for:** See *Erosion Rates vs. Uplift Rates* for guidance.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 14	14.A Develop and use a model to show the tectonic process of uplift can create mountains at a time scale too large to see. 14.B Construct an explanation based upon prior investigations and evidence that gradual changes have caused marine fossils to become exposed on mountains due to erosion (accumulating) over time, and those gradual changes will lead to the destruction of the marine fossils due to erosional processes over time.	**14.A Developing and Using Models; Scale, Proportion, and Quantity** **When to check for understanding:** On day 2 during Question 1 of *Fossil Assessment*. **What to look for:** Look for students to show an ancient ocean between the Indian and Eurasian plate. Students should model the tectonic plate movement of the Indian plate from the Southern region of a world map to the Northern region over millions of years. Look for students to show that during this process, the oceanic plate material is broken up and some of that material is pushed up during the collision of the Indian plate and Eurasia over a scale that spans millions of years. This slow orogenic process folding of the plate material) should be modeled and explained, condensing millions of years into three distinct models. See *Key for the Fossil Assessment* for further guidance. **14.B Constructing Explanations; Stability and Change** **When to check for understanding:** On day 2 during Questions 2-3 of *Fossil Assessment*. **What to look for:** Look for students to identify that the relatively slow process of erosion on the mountain sides has caused the marine fossils to become exposed over time, and that over time the currently exposed marine fossils will be eroded away in the future, exposing additional matter from underneath the marine fossils. See *Key for the Fossil Assessment* for further guidance.

Student Mountain Observations Key

Mountain	Change	Magnitude(s)	Depth(s)	Other observations
Mt. Mitchell, Appalachian Mountains, North Carolina	Decreasing in elevation	Most are a magnitude of 3 or below	All earthquakes are at a depth of 30km or above Most earthquakes are very shallow	Appalachia doesn't have very many earthquakes in general. Earthquakes are shallow and weak.
Mt. Aconcagua, Andes Mountains, Argentina	Increasing in elevation	Most near the mountain have a magnitude of 3-6; other earthquakes north of the mountain have been as large as a magnitude 9	Depth of 100-200km under Mt. Mitchell; other earthquakes on the range can be deeper than 500km	The larger earthquakes on the map tend to be deeper in the earth in this region.
Mt. Narodnaya, Ural Mountains, Russia	Not changing in elevation	Only 1 earthquake has occurred near the mountain, magnitude of 4.4	Only earthquake by the mountain was at a depth of 13.64km	Almost all earthquakes on the range are under a magnitude of 5. All but 1 is at a depth 30km or above.
Mt. Everest, Himalayan Mountains, between China and Nepal	Increasing in elevation	Mostly magnitude 2-5 earthquakes on the mountain Some larger earthquakes 7-8 magnitude around mountain	Many earthquakes between 0-100km deep	Most earthquakes on the range are between 2-5 magnitude. Some larger earthquakes exist, vary in depth from 0-100km deep. Larger earthquakes tend to be between 0-30km.
Mt. Hotoka, Japanese Alps, Japan	Increasing in elevation	Most around the mountain have a magnitude of 3, but some can be as large as a 6	The east of the mountain has earthquakes with an average depth of 0-30km; to the west some can be between 300-500km deep	Most earthquakes at the mountain are around a magnitude of 3, and 0-30km in depth. A lot of earthquakes occur to the east of the mountain, with magnitudes as high as 9. Some earthquakes in the region are over 500km deep.

Mountain	Change	Magnitude(s)	Depth(s)	Other observations
Mt. Cook, Southern Alps, New Zealand	Increasing in elevation	Majority of earthquakes around the peak are magnitude 3-5, with some larger earthquakes in the 6-7 range	Around Mt. Cook the earthquakes are mostly above 30km Very few earthquakes are between 30-100km in depth North of the peak earthquakes can become much deeper Some earthquakes to the north can reach over 500km deep	Larger earthquakes around Mt. Cook (6-7 in magnitude) occur mostly above 30km. Larger earthquakes happen around New Zealand, and to the north, very large and deep earthquakes can occur.

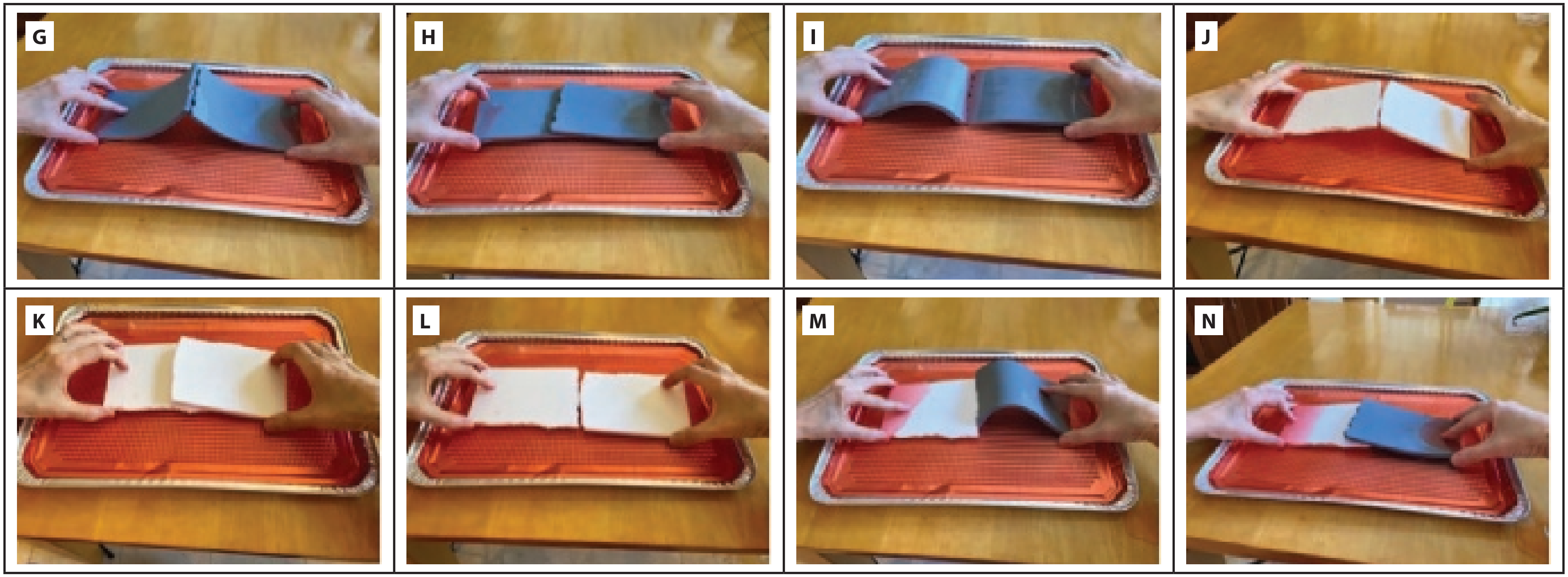
Guidance for Physical Modeling Activity

This video will illustrate how to hold and move the models of plates, as well as some of the types of interactions that students may observe as they use the physical model. The water in the video and the images that follow has some red food coloring added to make it easier to see. Note that it is important for students to hold and move the plate models from the back, and keep them as flat as possible on the surface of the water as they move them. Slow sustained movement is the most useful for making observations. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Students should be encouraged to move slowly, splash as little as possible, and make very detailed observations about what is happening. It will be helpful to have them try out the "moving apart" motion first since that has the fewest details to observe and record. Students are likely to see models that look like these:

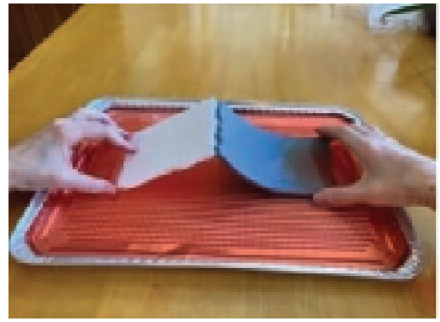
Next, have them try out the "sliding past each other" motion. Here they should observe and record how the rough edges of the plates catch on each other, and then snap past each other as they continue to try to move the plates past each other laterally. They may also observe the continental plate model bending. Students are likely to see models that look like these:

Lastly, have them try out the “moving together” motion. This motion has the widest variety of interaction types, and students are likely to make and record several different types of interactions. In each interaction, the relative position of the two plate rock models to each other, and where the liquid layer is in relation to the plate rock models will be important for students to notice. Students may see models that look like any of these, or possibly others:



Or, as they continue to move the plates together, they may see that **J** resolves into **K**, or that **M** resolves into **N**. All of these models represent plate interactions that may actually occur on Earth.

They may also observe some of the interactions shown below, which do not represent plate interactions that happen in the real world. In reality, denser (basalt, oceanic) plates will always move underneath plates that are less dense (granite, continental), leading to the denser plates eventually going down into the mantle. The model they are working with, like every other model, is not perfect. However, if students observe and record these “impossible” interactions, that is fine. They should be encouraged to record what they actually observe happening as they manipulate their models.



Different groups may record different interactions, even if they have the same plate rock types. ***Those interactions that are outlined in blue above are critical for at least one group in the class to observe and record.*** These represent models that will be necessary to have for subsequent lessons. Students should repeat their observations multiple times and may see different results even when they are modeling the same plate movement. They should take careful notes to record their observations, using the questions on *Plate Movement Maps* to guide their observations. Sketches or drawings of the shapes they see should also be recorded.

Questions listed in the description of this activity in the *Teacher Guide* may help students to arrive at useful models of plate interactions that they can observe and record.

LESSON 8: TEACHER REFERENCE 1

Mid-Atlantic Ridge Artifact Evidence

Artifact	Observations/ Evidence Collected by Students
1	Divide between two plates • Two distinct plates are present. • It is very rocky. • There is a gap between the two plates filled in with rock and living things. • This appears to have been active in the past, but the presence of living things and a road make it appear as if it is a somewhat stable area.
2	Divide between plates in Silfra - underwater • There appears to be a larger, deeper gap in the plates than between the first artifact. • It is very rocky, like the first artifact. • If divers are there, it must not be too active of an area at the moment.
3	Divide between two plates - near the Bridge between Continents • There are still two distinct plates. • The sediment between the rocks is mainly volcanic rock. • There are no volcanoes in the picture. • The gap is still very large. • Something happened to the volcanic rock to turn it into dirt.
4	Reykjanes Peninsula Fissure • There isn’t as much of a gap between where the two plates may be in this picture. • There are hot gasses coming out of the ground. • It is very rocky and made of basalt (like the ocean bedrock). • The ground looks similar in color to artifact #3. • The area seems a lot more active than artifact #1.

Artifact	Observations/ Evidence Collected by Students
5	Fissure with magma • We can see a split in the ground in artifact #5, but the plates aren't as distinct. • The opening is filled with lava/magma. • The lava may or may not be flowing. • There is hot gas coming out of the ground. • It is near a volcano, but is not a volcano, rather it's an opening in the ground.
6	Mid-Atlantic Ridge seafloor vent • The water coming out of the vents is over 400 degrees. • The drills melt, like in the really deep mines. • The water comes into contact with something hot to heat it up. • The hot stuff is inside the vent, which kind of looks like a mini volcano.
7	Video of black smoker • Minerals are coming out of the ground with the water. • The minerals come out hot and cool down. • The minerals form deposits and new land. • The water is being heated somewhere and coming out very hot, just like artifact #6.
8	Bathymetric map • The seafloor of the ridge is higher in elevation than the ocean around it. • The Mid-Atlantic Ridge looks like a mountain range under the ocean.
9	Iceland map • Magma is located under a large portion of iceland. • It follows the line of the Mid-Atlantic Ridge. • Volcanoes can be found on Iceland on the Ridge, but there isn't a line of volcanoes forming.

Potential Ridge Claims and Evidence

Potential claims made by students	Example evidence that may be used by students	Potential questions to ask students about the evidence
Claim: Volcanoes are forming all along the ridge. **Conclusion:** Some volcanoes are forming at the ridge, but not in a constant line. We also do not have complete evidence to show that there are volcanoes all along the ridge.	**To support:** • Iceland has volcanoes. • There are lava flows on the surface. **To refute:** • We only saw volcanoes on Iceland. • There were places along the ridge where magma was coming out, but not from a volcano cone.	• Are volcanoes forming at all locations along the ridge? • Do we see volcanoes in places other than Iceland? • Are there areas where we did not see volcanoes forming? • Would we say that this claim is still supported by evidence?
Claim: Volcanoes are filling in the space in the ridge and forming new mountains. **Conclusion:** While some volcanoes are present, volcanoes are not filling the space between the plates. Instead, magma appears to be filling this space.	**To support:** • Iceland has volcanoes present on the ridge. • Magma can be found under the country where the plate boundaries are. • Some areas where there were fissures had volcanoes nearby. **To refute:** • We did not see volcanoes in all the spaces along the ridge. • In places where the ridge had seemingly moved less recently, we saw a crack not a volcano. • We did see evidence of some magma filling in the space between the plates, but did not see a volcano.	• Did we see places along the ridge where there weren’t volcanoes? • Can there be locations where magma exists under the plates, and not have volcanoes in those locations? • Were the fissures active volcano sites? • What did we see in those other places? Did we see something other than volcanoes? • Do we see evidence of anything else other than tall volcanoes filling the spaces between the plates?

Claim: A big gap is appearing at the ridge. OR A canyon is forming at the ridge. **Conclusion:** A gap has formed in each case, but something is filling in that gap as the plates are moving.	**To support:** • There is a space seen in between the plates in artifacts 1, 2, and 3.	• Was the gap empty? Or did it have a bottom? • What did we see at the bottom of the gap? Was it the same in each picture? • Were there places where we didn't see gaps? What was going on there? Does this support or refute our cairns?
	To refute: • The space between the plates was always filled or filling in with something. • The space between some plates had lava or magma. • Some cracks in the ground had gases or magma coming out. • In the ridge, where the plates are coming apart, we see that there are a lot of minerals coming out of the ground.	• What was the something that it was filled in with or is filling up with? Was this the same thing in each case? • Why do you think that the space was being filled in some places like artifacts 4, 5, 6, and 7? • Does the rock or magma just naturally fill that space, or is it acting like it is being pushed up? • In the vents, do we see gaps?
Claim: Lava is flowing in the ridge. **Conclusion:** Lava is flowing at some places of active movement, and evidence of lava/magma under the surface is present. But, not all areas have active lava flows.	**To support:** • We saw lava or magma coming up and out of the ground in artifact 5. • The ocean seafloor vents all had superheated water coming out of them, and the water had to be heated that hot by something. • There is magma under Iceland, and volcanoes are present.	• Do all areas have active lava flows, or just some? • Is lava the same as magma?
	To refute: • There are areas, like in artifacts 1-3, where something has filled in the plate gap in the past, but it is not currently being filled. • The areas that have been filled in are rocky, so it may have been magmatic in the past, but not now.	• Do we see anything other than magma coming out of the ridge? • Are there any locations where we don't see magma, but there is evidence of it potentially being in that location?

LESSON 8: ANSWER KEY

Individual Potential Claims and Evidence

Use the table below to assess the individual student claims on the bottom of *Evidence Tracker that* you have collected at the end of Day 1. Use this to gauge where your students are at in connecting evidence with claims, specifically using data as evidence to support or refute their initially developed claim and to prepare for the discussion around the *Class Claims for What is Happening at the Ridge* chart on Day 2. The purpose of collecting this and providing you this scoring guidance is formative, not summative and therefore we recommend you collect the handout and record your own data. In addition, you may choose to use this to help you organize partnerships depending on the claims students have written to pair up students that will lead to rich arguments and discussions as they share evidence in Day 2.

Potential claims made by students	Example evidence that may be used by students
Volcanoes are forming all along the ridge. **Conclusion:** • Some volcanoes are forming at the ridge, but not in a constant line. • We do not have complete evidence to show that there are volcanoes all along the ridge.	**To support:** • Iceland has volcanoes. • There are lava flows on the surface. **To refute:** • We only saw volcanoes on Iceland. • There were places along the ridge where magma was coming out, but not from a volcano cone.
Volcanoes are filling in the space in the ridge and forming new mountains. **Conclusion:** • While some volcanoes are present, volcanoes are not filling the space between the plates. • Instead, magma appears to be filling this space.	**To support:** • Iceland has volcanoes present on the ridge. • Magma can be found under the country where the plate boundaries are. • Some areas where there were fissures had volcanoes nearby. **To refute:** • We did not see volcanoes in all the spaces along the ridge. • In places where the ridge had seemingly moved less recently, we saw a crack not a volcano. • We did see evidence of some magma filling in the space between the plates, but did not see a volcano.

A big gap is appearing at the ridge. OR A canyon is forming at the ridge. **Conclusion:** • A gap has formed in each case, but something is filling in that gap as the plates are moving.	**To support:** • There is a space seen in between the plates in artifacts 1, 2, and 3. **To refute:** • The space between the plates was always filled or filling with something. • The space between some plates had lava or magma. • Some cracks in the ground had gases or magma coming out. • In the ridge, where the plates are coming apart, we see that there are a lot of minerals coming out of the ground.
Lava is flowing in the ridge. **Conclusion:** • Lava is flowing at some places of active movement, and evidence of lava/magma under the surface is present. • Not all areas have active lava flows.	**To support:** • We saw lava or magma coming up and out of the ground in artifact 5. • The ocean seafloor vents all had superheated water, and the water had to be heated that hot by something. • There is magma under Iceland, and volcanoes are present. **To refute:** • There are areas, like in artifacts 1-3, where something has filled in the gap in the past, but it is not currently being filled. • The areas that have been filled in are rocky, so it may have been magmatic in the past, but not now.

Teacher Prep for Assembling Landmass Data Set Baggies

The materials needed to prepare the manipulatives for the investigation

Make sure you start with the following:

- 30 - 11×17 Plate Movement maps
- 5 - 11×17 Evidence of Past Coral Reefs maps
- 5 - 11×17 Evidence of Past Mountains maps
- 5 - 11×17 Evidence of Past Glaciers maps
- 5 - 11×17 Location of Fossils maps
- 5 - 11×17 Similar Rock and Mineral Types maps
- 5 - 11×17 Similar Rock Layers and Formations maps
- 5 - 11×17 Antarctic pieces for each map
- 5 - 8.5×11 Evidence of Past Coral Reefs maps
- 5 - 8.5×11 Evidence of Past Mountains maps
- 5 - 8.5×11 Evidence of Past Glaciers maps
- 5 - 8.5×11 Location of Fossils maps
- 5 - 8.5×11 Similar Rock and Mineral Types maps
- 5 - 8.5×11 Similar Rock Layers and Formations maps

Note: The 11×17 are to be used for cutting out the manipulative pieces for students to use. The 8.5×11 are to be used as reference maps for the students as they manipulate the different landmass pieces. If you have not chosen to order the kit for this unit you will need to print out a class set of these different data sets. You can reuse them between classes. Ideally these would be printed in color on cardstock for durability.

Land Mass Data Set Preparation and Baggie Assembly Instructions

Prior to this lesson you will need to prepare the following 6 landmass data map types. There are 6 different data sets.

- 5 sets - 11×17 Evidence of Past Coral Reefs maps
- 5 sets - 11×17 Evidence of Past Mountains maps
- 5 sets - 11×17 Evidence of Past Glaciers maps
- 5 sets - 11×17 Location of Fossils maps
- 5 sets - 11×17 Similar Rock and Mineral Types maps
- 5 sets - 11×17 Similar Rock Layers and Formations maps
- 5 sets - 11×17 Antarctic pieces for each map—these will be added to the related data set.

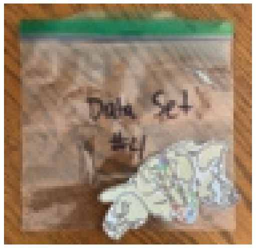
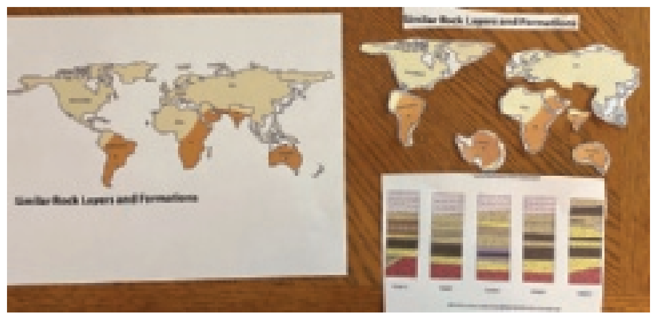
For a class of 30 students, 6 students will be analyzing the same data set, so you will want 5 sets of each data set. Each student should receive a set of cut apart landmass data for the group they are assigned and a 8.5×11 map reference that includes the key for the cut apart pieces.

<u>For each map data set:</u>

1. Cut up each map on the 11×17 paper to make a set of manipulatives for each student. Every map should be cut up along the **<u>same dotted lines overlain in the example below</u>** so that the continent pieces are the same shape for every set. Your maps will **not** have a dotted line to follow. It is not important to follow all the details of the coastlines as you cut. To simplify the activity for students, a number of adjustments have been made to what landmass pieces students will manipulate.
    - The following locations are not included on the landmass pieces: Mexico, the Caribbean, some of the Indonesian islands, New Zealand, the northeasternmost area of Asia, and the Bering Islands of Alaska.
    - The Saudi Arabian Peninsula is attached as part of the African landmass and will be moved together in the activities.

2. Cut out each of the 6 Antarctica pieces (30 total) and place them with their corresponding map data.
3. Number 30 baggies - 5 each with Data Set #1, Data Set #2, Data Set #3, Data Set #4, Data Set #5 and Data Set #6. These will be used to collect the map data pieces for each of the 30 sets of data.
4. See the images below for representations of what each map set of data will look like before cutting, after cutting and paperclipped together on a baggy with a Data Set # on it. After cutting out each map piece for a data set, number each piece on the back with the number that matches the baggy they will be included in. This will help students replace the correct map pieces into the correct baggy.
5. Assemble one baggy per data set. For 30 students, you will have 30 baggies - 5 each of the 6 different data sets.

Data set	*How it looks cut apart*
 #1 - Past Coral Reefs	
 #2 - Past Mountains	
 #3 - Past Glaciers	

 #4 - Location of Fossils	
 #5 - Rock and Mineral Types	
 #6 - Rock Layers and Formations	

Completing your Baggie Assembly

After all the data set pieces have been added to the baggies, insert a 8.5x11 map with the corresponding data set in each baggie. This will allow students to have access to the original arrangement of the land masses and their associated key - the cut out pieces will not have a key associated with them if the 8.5x11 map is not added.

Name: ______________________ Date: ______________

Evaluating Two Models

To do this assessment, you will need two models for where the continents might have been in the distant past.

1. You developed a first model with your first group based on one type of data and recorded it in your notebook.
2. You will carefully diagram the second model that you developed with your jigsaw group here.

You can also use any resources in your notebook as you do this assessment.

Second model of the location of the continents in the past based on combining all the data sets

As you compare the two models, answer the questions below.

Reflection Questions

1. How do your two models compare? What changes did you make in the second model?

2. What continents did you keep in the same location? Why? Explain using evidence from the data sets.

3. What continents did you change the position or location of? Why? Explain using evidence from the data sets.

4. Which model is a better representation of where the continents were millions of years ago? Why?

5. What kind of data do you wish you had to be more confident about the location of the continents millions of years ago? How would this data make you more confident?

Teacher Key for Evaluating Two Models

To do this assessment, you will need two models for where the continents might have been in the distant past.

1. You developed a first model with your first group based on one type of data and recorded it in your notebook.
2. You will carefully diagram the second model that you developed with your jigsaw group here.

You can also use any resources in your notebook as you do this assessment.

Second model of the location of the continents in the past based on combining all the data sets

As you compare the two models, answer the questions below.

Reflection Questions

1. How do your two models compare? What changes did you make in the second model?

Accept all answers.

Students will most likely say they made some changes in positions of continents relative to one another (they may or may not describe spedfic changes), or that they twisted or adjusted the orientation of individual continents (they may or may not describe which continents they adjusted).

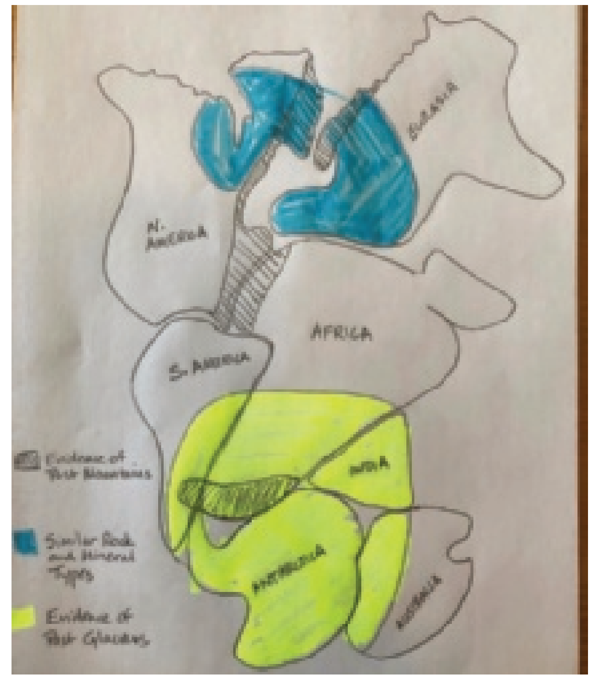
It is possible that some students may not have made any changes in the second model. This is OK as long as they have clearly articulated reasons for why they did not change anything in their answer to question 2.

2. What continents did you keep in the same location? Why? Explain using evidence from the data sets.

Students should explain why they left particular continents in the same location using references to one or more types of data from the map continent pieces that support the position in both models. Some examples of what students might say are included below, but this list is not necessarily exhaustive.

If your students can refer to *specific types* of data, or *multiple types* of data and articulate some reasons why

- the data that refutes the continent's position is weak or absent, or
- the data that supports the continent's position is strong, or
- there are multiple types of data that support the continent's position, then they have successfully responded to this question.



An example of what a model will look like.

- I did not change any of the locations of the continents between the two models. The data set I had to analyze was the coral reef data which had data on almost all the continent pieces. Using the data, shapes of the continents and the movement of the plates, I was able to figure out where all the continents would have been in the past. When I worked with my jigsaw group, the other data types didn't have data on all their continent pieces, but the data they did have matched the positions from my first model, so it just helped me be more sure of where the continents would have been in the past.

3. What continents did you change the position or location of? Why? Explain using evidence from the data sets.

Students should explain why they changed any of the positions of the continents using references to one or more types of data from the map continent pieces that support the position in the second model. An example of what students might say is included below, but this answer is not necessarily exhaustive.

If your students can refer to *specific types* of data, or *multiple types* of data and articulate some reasons why

- the data that provided weak, or no support in their original data set was refuted by a different kind of data that showed stronger support, or
- the data that supported the continent's position in their original data set could also support (did not refute) the changed position in the second model, or
- there are multiple types of data that support the continent's position in the second model, then they have successfully responded to this question. Some examples:
- The type of data I analyzed was glacial data. Based on the glacial data, it was difficult to know where the North American continent would be in the past because there wasn't any glacial data for it. But when I joined my jigsaw group and could see all the different types of data for the continents, then it was easier to figure out where North America would have been in the past.
- The type of data I analyzed was mountain data. The mountain data made it seem like the edge of the European continent would have been in line above the edge of the North American continent. But when I joined my jigsaw group and could see all the different types of data, most of that data supported Europe being lower down, and the mountain ranges could still fit together when we moved it down lower.

4. Which model is a better representation of where the continents were millions of years ago? Why?

Students may say either their first model, their second model, or that both looked the same, so they are both a good representation of where the continents were millions of years ago. Which model is better relies on which model has more data, or stronger data, or data of multiple types that support the positions of the continents.

If your students can refer to the *amount* or *quality* of data and articulate that

- more data is more convindng, or
- having data of multiple different types is more convincing, then they have successfully responded to this question. Some example student responses:
  - When I met with my small group and was able to use all the types of data, I felt more confident in the model I had for where the continents would have been in the past, so the second model I have is the best one to predict where the continents were millions of years ago.
  - My model looked the same as the model my small group put together, so both models are good predictions of where the continents were millions of years ago. But maybe the second model is even better because more than one type of data supported the location of the continents.

5. What kind of data do you wish you had that would make you even more sure of the location of the continents millions of years ago? How would this data make you more sure of the locations?

Accept all answers regarding what kind or type of data.

Regarding why data would make them more sure of the locations, students should refer to there being

- *more* of one (or several) of the types of data they worked with, or
- *a different type of data that would support* their locations, i.e. exist across continents that are adjacent, or not exist on two continents that are not adjacent, or
- data *from a time millions of years ago*.

Erosion Rates vs. Uplift Rates

<u>Part 3: What will Mt. Mitchell and Mt. Everest look like in the future?</u>

Mt. Everest

If erosion rates stay at 9.3 mm/year and uplift rates stay at 20 mm/year, how much will the elevation of Mt. Everest potentially change in:	
1,000 years	
1,000,000 years (1 million years)	

Mt. Mitchell

If erosion rates stay at 5 mm/1,000 years and uplift rates stay at 1 mm/1,000 years, how much will the elevation of Mt. Mitchell potentially change in:	
1,000 years	
1,000,000 years (1 million years)	

Using your predictions above, which mountain do you predict will change the most over the next 10,000 years? Why? (use the calculations above as evidence in your explanation)

Erosion Rates vs. Uplift Rates

Part 3: What will Mt. Mitchell and Mt. Everest look like in the future?

Mt. Everest

If erosion rates stay at 9.3 mm/year and uplift rates stay at 20 mm/year, how much will the elevation of Mt. Everest potentially change in:	
1,000 years	Erosion = 9.3 mm x 1,000 = 9,300 mm of erosion Uplift = 20 mm x 1,000 = 20,000 mm of uplift If uplift is 20,000 mm and erosion is 9,300 mm, then Mt. Everest will get (20,000–9,300) 10,700 mm taller over 1,000 years. Students may go further with their conversions to represent the 10,700 mm as cm (1,070 cm) or m (1.07 m), but this is not expected as part of the task. The goal is for students to be thinking about the two mechanisms at work that are leading to changes to the mountain.
1,000,000 years (1 million years)	Erosion = 9.3 mm x 1,000,000 = 9,300,000 mm of erosion Uplift = 20 mm x 1,000,000 = 20,000,000 mm of uplift If uplift is 20,000,000 mm and erosion is 9,300,000 mm, then Mt. Everest will get (20,000-9,300) 10,700,000 mm taller over 1,000 years. Students may go further with their conversions to represent the 10,700,000 mm as cm (1,070,000 cm) or m (10,700 m), but this is not expected as part of the task. The goal is for students to be thinking about the two mechanisms at work that are leading to changes to the mountain.

Mt. Mitchell

NOTE: The mathematics for this mountain includes one more step students will need to do in order to compare the rate of erosion to the rate of uplift. Since these rates are measured per 1,000 years, when students are figuring out how much the mountain will change over other time periods, they will need to divide the time period by 1,000 in order to make a one to one comparison between the effects of erosion to the effects of uplift. If your students are struggling with this extra step, you may want to pause and talk through this with the class so that students will be able to do the calculations successfully and be able to make sense of the results.

If erosion rates stay at 5 mm/1,000 years and uplift rates stay at 1 mm/1,000 years, how much will the elevation of Mt. Mitchell potentially change in: (Hint: Remember the rate here is per 1,000 years.)	
1,000 years	Erosion = 5 mm x 1 = 5 mm of erosion Uplift = 1 mm x 1,000 = 1 mm of uplift The erosion rate and uplift rate at Mt. Mitchell are slow, so over 1,000 years there wouldn't be much change. Since the uplift is 1 mm compared to the erosion rate of 5 mm, Mt. Mitchell will continue to shrink by erosion, but at a very slow rate of 4 mm. OR Mt. Mitchell will continue to shrink, but very slowly over time. The amount of erosion is higher than the amount of uplift by 4 mm, so it will continue to shrink.
1,000,000 years (1 million years)	Erosion = 5 mm x (1,000,000/1,000) = 5 mm x 1,000 = 5,000 mm of erosion Uplift = 1 mm x (1,000,000/1,000) = 1 mm x 1,000 = 1,000 mm or uplift The amount of erosion is higher than the amount of uplift for Mt. Mitchell so it will continue to shrink.

Using your predictions above, which mountain do you predict will change the most over the next 10,000 years? Why? (use the calculations above as evidence in your explanation)

Mt. Everest will continue to get taller over the next 10,000 years by 107,000 mm since the amount of uplift is more than the amount of erosion.

Erosion = 9.3 mm x 10,000 = 93,000 mm

Uplift = 20 mm x 10,000 = 200,000 mm

200,000 - 93,000 = 107,000 mm

Mt. Mitchell will continue to shrink over the next 10,000 years by 40 mm since the amount of erosion is more than the amount of uplift.

Erosion = 5 mm x (10,000/1,000) = 5 mm x 10 = 50 mm

Uplift = 1 mm x (10,000/1,000) = 1 mm x 10 = 10 mm

Mt. Everest will continue to grow and Mt. Mitchell will continue to shrink. The changes to Mt. Mitchell are happening slower than the changes to Mt. Everest. So over 10,000 years, Mt. Everest will have more changes than Mt. Mitchell.

Name: ______________________ Date: ______________

Fossil Assessment

Scientists and others who have trekked on Mt. Everest have reported seeing many marine organism fossils. This includes fossils like sea lilies, small shrimp-like organisms, and other small shelled organisms, which date back to 500 million years ago. Marine fossils have not only been found in the Himalayas, they have been found on many other mountain ranges as well, including the Appalachian Mountains.

The images of the fossil shown here are part of a type of tropical organism called a crinoid, or feather star. These sea creatures would attach to the sea bottom with their very long stalk, or stem, and then use the feathery type limbs to capture food. Some of the stalks of these ancient organisms were several feet tall.

Somehow, fossil fragments of crinoid organisms ended up towards the top of mountains like Mt. Everest. Scientists were able to see and identify these exposed fossils on mountains without having to dig them up. Using what we know about plate tectonics and the processes of weathering and erosion, answer the following questions about ***how*** this fossil can be at the top of Mt. Everest ***and*** how it can be seen at the top of Mt. Everest without having to dig to find it.

1) From what we figured out in our unit, we now know that Mt. Everest did not always exist. So it seems odd and surprising that a fossil of a sea organism is at the top of the tallest mountain above sea level. Using the space below and all that you have figured out about the different causes and processes that affect changes to Earth's surface, you will develop three models to show:

- what the area that created the mountain might have looked like as far back as 500 million years ago;
- what happened to the area over time to create the Himalayan Mountains and Mt. Everest; and
- what happened to cause a fossil to end up towards the top of Mt. Everest.

As you develop your models, use evidence from your notebook as you think about how this fossil, which is much older than the mountain itself, ended up towards the top of Mt. Everest. Make sure to label the different components in your model. Use your model to explain what processes led to this fossil being at the top of Mt. Everest and led to it being visible to be found by scientists without them having to dig to find it.

	Develop your models in this column:	Explain what is happening in this model:
Show what the area that created the mountain might have looked like as far back as 500 million years ago. Include in your model how this could account for there being a sea organism found here.		
What happened to the area over time to create the Himalayan Mountains and Mt. Everest?		
What happened to cause a fossil to end up towards the top of Mt. Everest?		

2) Every year, people on Mt. Everest find new fossils that were not visible the year before. Some fossil fragments from other sea creatures are now visible that were not visible 100 years ago. What is causing new fossils to be exposed on Mt. Everest?

3) Do you think that these newly exposed fossils will be visible on the mountain range thousands or millions of years from now?

Name: ______________________ Date: ______________________

LESSON 14: ANSWER KEY 1

Key for the Fossil Assessment

Scientists and others who have trekked on Mt. Everest have reported seeing many marine organism fossils. This includes fossils like sea lilies, small shrimp-like organisms, and other small shelled organisms, which date back to 500 million years ago. Marine fossils have not only been found in the Himalayas, they have been found on many other mountain ranges as well, including the Appalachian Mountains.

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1) From what we figured out in our unit, we now know that Mt. Everest did not always exist. It seems odd and surprising that a fossil of a sea organism is at the top of the tallest mountain above sea level Using the space below and all that you have figured out about the different causes and processes that affect changes to Earth's surface, you will develop three models to show:
   - what the area that created the mountain might have looked like as far back as 500 million years ago;
   - what happened to the area over time to create the Himalayan Mountains and Mt. Everest: and
   - what happened to cause a fossil to end up towards the top of Mt. Everest.

As you develop your models, use evidence from your notebook as you think about how this fossil which is much older than the mountain itself, ended up towards the top of Mt. Everest. Make sure to label the different components in your model Use your model to explain what processes led to this fossil being at the top of Mt. Everest and led to it being visible to be found by scientists without them having to dig to find it.

	Develop your models in this column:	Explain what is happening in this model:
Show what the area that created the mountain might have looked like as far back as 500 million years ago. Include in your model how this could account for there being a sea organism found here.	Model should show: • Nepal and China separated. • An ocean or other large body of water, such as a sea between Nepal and China.	Explanation should include: • In the past, the two sides of the mountain (Nepal and China or the Indian and Eurasian plate) were once separated by an ocean. • The presence of an ocean indicates that there would have been marine life there at one point. Potential supporting evidence could include: • From Lesson 5 - plates move at different speeds and directions, indicating that they have been in different locations according to GPS and other data. • From Lesson 6 - mountains form when plates collide, so prior to a collision, the mountains could have been flatter land based upon our investigations. • From Lesson 11 - one source of data indicated a coral reef used to exist between Nepal and China. • From Lesson 11 - all of the continents used to be in different locations according to multiple sources of data.
What happened to the area over time to create the Himalayan Mountains and Mt. Everest?	Model should show: • Land mass containing Nepal (the Indian plate) moving towards the land mass containing China (the Eurasian plate). ++ Nepal moving North at a much faster rate than the land mass with China moving. • Arrows or other indicators of movement showing the two plates colliding. • The two plates pushing up on each other to create a mountain.	Explanation should include: • The two land masses (that Nepal and China are on) moved together over time. • While the two plates met, the continental land masses collided and pushed up on each other, creating mountains. Potential supporting evidence could include: • From Lesson 5 - the plates move over time to new locations based on plate movement and GPS data. • From Lesson 6 - mountains form when plates collide, so prior to a collision, the mountains could have been flatter land based upon our investigations. • From Lesson 11 - all continents used to be in different locations, meaning that there had to have been collisions and movement occuring in the Nepal/China region. • From Lesson 12 - evidence shows that these plate interactions to create mountains occur over millions of years, meaning that this interaction occurred over millions of years to create the mountains in the Himalayas.

What happened to cause a fossil to end up towards the top of Mt. Everest?	Model should show: • Oceanic plate material getting destroyed as the two plates merge. • In the collision, part of the oceanic material getting pushed up as the land masses are material colliding. • A marine fossil rising towards the top of the mountain during the collision.	Explanation should include: • As the two plates are moving, the two plates (mainly the Indian plate) destroy oceanic plate material between the two plates. • During the collision of the two plates, some of the oceanic material is lifted up towards the top of the mountain. • As the oceanic material, matter that is on the material also rises, such as marine fossils. Potential supporting evidence could include: • From Lesson 6 - mountains form when plates collide, so prior to a collision, the mountains could have been flatter land based upon our investigations. • From Lesson 8 - oceanic plate material is created or destroyed as continental plates move towards and away from each other. • From Lesson 11 - one source of data indicated a coral reef used to exist between Nepal and China.

2) Every year, people on Mt. Everest find new fossils that were not visible the year before. Some fossil fragments from other sea creatures are now visible that were not visible 100 years ago. What is causing new fossils to be exposed on Mt. Everest?

Explanation should include:

- Over time, forces such as rain, wind, and ice break down the landscape.
- After the materials are broken down, they are moved to a new location through erosion.
- This will expose material that was not previously seen from under the eroded material.
- Fossils that were once layered under rock have had the rock eroded away from above it, exposing these new fossils.

Potential supporting evidence could include:

- From Lesson 10 - older material is layered under newer material.
- From Lesson 13 - erosion is always occurring.
- From Lesson 13 - (recalled from elementary school) the process of erosion exposes material under the material that is being eroded.

3) Do you think that these newly exposed fossils will be visible on the mountain range thousands or millions of years from now?

Potential supporting evidence could include:

- From Lesson 10 - older material is layered under newer material.
- From Lesson 13 - erosion is always occurring.
- From Lesson 13 - (recalled from elementary school) the process of erosion exposes material under the material that is eroded away over time.
- From Lesson 13 - the process of erosion is acting on all of our mountains, even if the mountains are experiencing uplift.
- From Lesson 13 - erosion happens over a long period of time.
- From Lesson 13 - (recalled from elementary school) erosion is always occurring.
- From Lesson 13 - erosion will continue to happen in the future as it is happening today and has happened in the past.

- PEs
  - **MS-ESS-2.2 Construct an explanation based on evidence for how geoscience processes have changed Earth's surface at varying time and spatial scales.** [Clarification Statement: Emphasis is on how processes change Earth's surface at time and spatial scales that can be large (such as slow plate motions or the uplift of large mountain ranges) or small (such as rapid landslides or microscopic geochemical reactions), and how many geoscience processes (such as earthquakes, volcanoes, and meteor impacts) usually behave gradually but are punctuated by catastrophic events. Examples of geoscience processes include surface weathering and deposition by the movements of water, ice, and wind. Emphasis is on geoscience processes that shape local geographic features, where appropriate.]
- SEPs
  - SEP6.3 Construct a scientific explanation based on valid and reliable evidence obtained from sources (including the students' own experiments) 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.
  - SEP2.5 Develop and/or use a model to predict and/or describe phenomena.
- DCIs
  - ESS2.A The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.
- CCCs
  - CCC7.3 Stability might be disturbed either by sudden events or gradual changes that accumulate over time.
  - CCC3.1 Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

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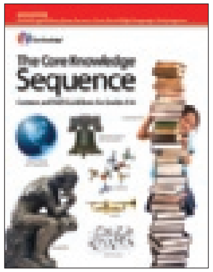

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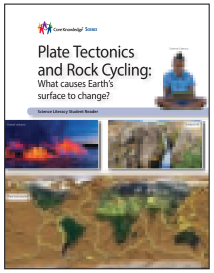

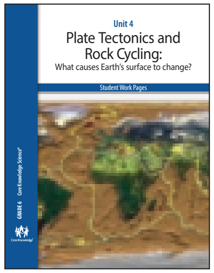

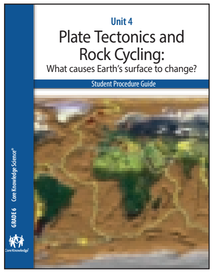

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