6.ESS2.3 Puzzling About the Past

Phenomenon-Based Instructional Task

Performance Expectation (PE) | 6.ESS2.3

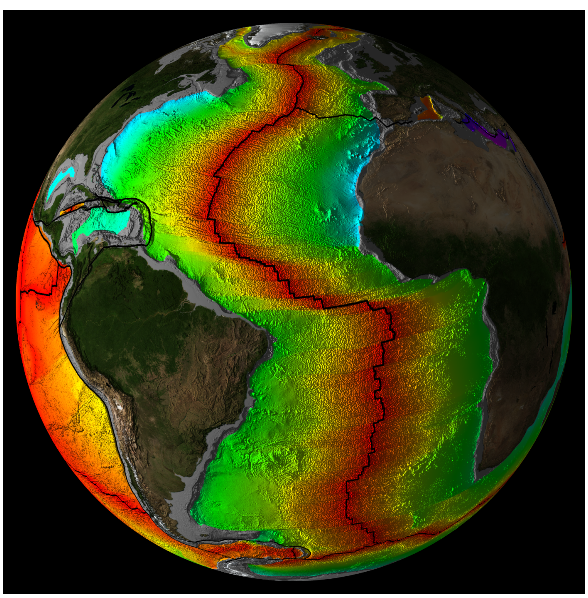
Analyze and interpret data on the distribution of fossils and rocks, continental shapes, and sea floor structures to provide evidence of the past plate motions.

Disciplinary Core Idea (DCI) | The History of Planet Earth + Plate Tectonics and Large-Scale System Interactions

- *History of Planet Earth:* Tectonic processes continually generate new ocean sea floor at ridges and destroy old sea floor at trenches.
- *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.

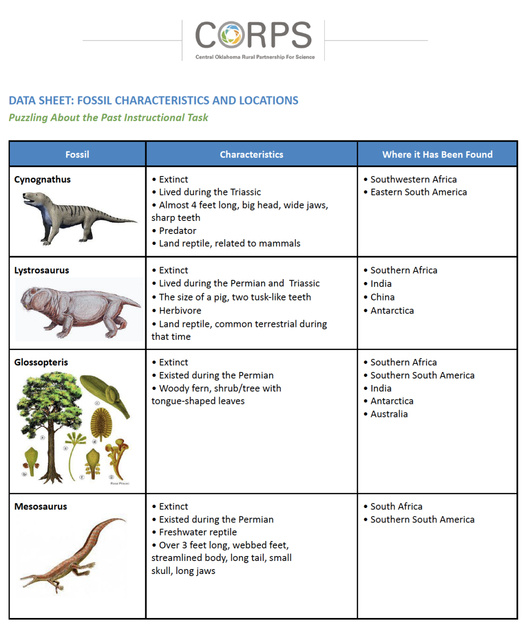
Possible Driving Phenomena

Student Observation or Initial Interaction:
Students are presented with an unlabeled relief map (such as the one below) of a mid-ocean ridge. They are asked what they think the colors could mean. As a class, they generate questions about the map and what it might represent. These questions are used to initiate inquiry into the topography of the ocean floor and how it was created over time.



https://www.ngdc.noaa.gov/mgg/image/crustalimages.html

Student Observation or Initial Interaction:
Students are provided with data about locations where fossilized remains of four organisms from the Permian and Triassic Periods have been found. This information is part of the data used by Alfred Wegener to support his theory of Continental Drift. Students are asked to look for patterns in the data (similarities and differences). They are asked to think about how these patterns might have been used to support a theory proposing that continents move relative to one another over long periods of geologic time.



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DATA SHEET: FOSSIL CHARACTERISTICS AND LOCATIONS

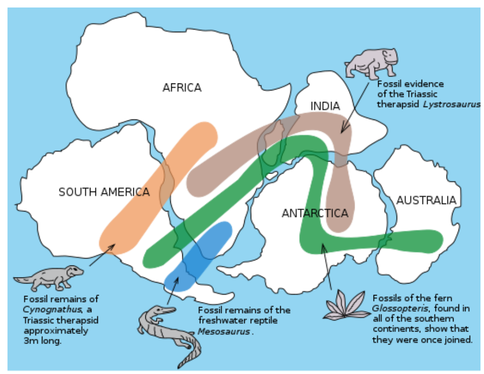
Puzzling About the Past Instructional Task

Fossil	Characteristics	Where it Has Been Found
Cynognathus	• Extinct • Lived during the Triassic • Almost 4 feet long, big head, wide jaws, sharp teeth • Predator • Land reptile, related to mammals	• Southwestern Africa • Eastern South America
Lystrosaurus	• Extinct • Lived during the Permian and Triassic • The size of a pig, two tusk-like teeth • Herbivore • Land reptile, common terrestrial during that time	• Southern Africa • India • China • Antarctica
Glossopteris	• Extinct • Existed during the Permian • Woody fern, shrub/tree with tongue-shaped leaves	• Southern Africa • Southern South America • India • Antarctica • Australia
Mesosaurus	• Extinct • Existed during the Permian • Freshwater reptile • Over 3 feet long, webbed feet, streamlined body, long tail, small skull, long jaws	• South Africa • Southern South America

See Attachment: Fossil Characteristics and Locations

Phenomenon explanation for teachers:
Even without knowing what the colors represent in the unlabeled relief map of the Mid-Atlantic Ridge, it is possible to observe that there is a distinct pattern in this data. The pattern in this representation is that red/yellow colors are found along the middle of the ocean floor and green/blue colors occur closer to the continents, with the continents shown in black/gray. We can also see that the shape of this pattern seems to follow the shape of the continents. We can even imagine that the continents could slide together and might fit nicely like a puzzle. Once we learn that the colors represent the age of the ocean floor rock, we can deduce that the newest rock is colored red, and is found at the mountain range in the middle of the ocean floor. Sea floor spreading results in the older rock, colored green) being farther from the center mountain range (Mid-Ocean Ridge). New ocean floor rocks are formed at these ridges, pushing the plates (and continents) further apart. We can also imagine the plates moving in reverse toward the red region, resulting in the continents fitting together like a puzzle, as they did millions of years ago. Groundbreaking studies in the 1960's by Hess, Vine, Matthews, and McKenzie confirmed these ideas and added to the existing body of evidence supporting Alfred Wegener's theory of Continental Drift and later theories about plate tectonics.

Phenomenon explanation for teachers:
In proposing the Theory of Continental Drift, Alfred Wegener utilized multiple types of evidence to show that the continents have not always been located where they are today. The data suggest that, in the past, the continents were closer to one another and fit together like a puzzle. He utilized the jigsaw-like fit of the continents, matching geological patterns across continents, glacial deposits, and fossil evidence to make his case. This data table summarizes some of the evidence used by Wegener to show that specific fossils are found in linear, continuous patterns of distribution across continents separated by oceans. The only explanation for these patterns is that the currently separated continents must have once been adjoined. The diagram below shows what this distribution might have looked like before the continents drifted apart. Students can match locations of fossil types on a current map of the continents to see where connections would occur if the continents were joined.



https://commons.wikimedia.org/wiki/File:Snider-Pellegrini_Wegener_fossil_map.svg

How Does the Phenomenon Connect to the DCI or PE?

Large plates of Earth's surface have moved and continue to move due to natural forces in the Earth's interior. This process is evident from observations of rock, fossil distributions, the apparent puzzle-like fit of continental shapes, and the ocean floor age. Maps of ancient land (continents) and water locations can provide evidence of changes in the Earth's plates. Data analysis, including maps, charts, the distribution of fossils and rocks, continental shapes, and sea floor spreading provide evidence of past plate motion. This evidence can prompt students to ask questions about why and how this happens. Tectonic plates are large pieces of Earth's crust that move away from, collide into, and slide past other plates at incredibly slow rates and are due in part to stresses caused by convection currents occurring inside the Earth's mantle. These movements generate new ocean sea floor at mid-ocean ridges and destroy old ocean floor at trenches (e.g., subduction zones) as plates overlap or pull away from each other. Analysis of this data also allows students to analyze and forecast possible future events such as volcanoes and earthquakes. Future natural events (earthquakes, volcanic eruptions) can be forecasted by combining an understanding of geological forces, such as tectonic plate motion, and by mapping natural hazards in a region.

Gathering and Reasoning in Order to Construct and Refine Explanations:

Funded by a USDE Math Science Partnership (MSP) grant through the Oklahoma State Department of Education.

How could students gather evidence using SEPs and CCCs that will help them construct/refine a supported explanation of the phenomenon?

1. Initial Engagement with the Phenomenon 1:
The teacher tells students that data from maps such as this one has been used to help scientists learn about the locations of continents millions and even billions of years ago in Earth's history. Without knowing what the colors on the map mean, students discuss in small groups what they think the colors could represent based on the patterns/shapes they observe and their prior knowledge of the Earth's surface and maps. They could create a key/legend for the map based on their initial understanding. In a whole class discussion, they share their ideas, such as elevation, water temperature, types of marine life, etc. If it doesn't come up, the teacher should suggest rock age (which is what this map actually shows). Students should make a claim-evidence-reasoning statement to explain why they chose this characteristic.

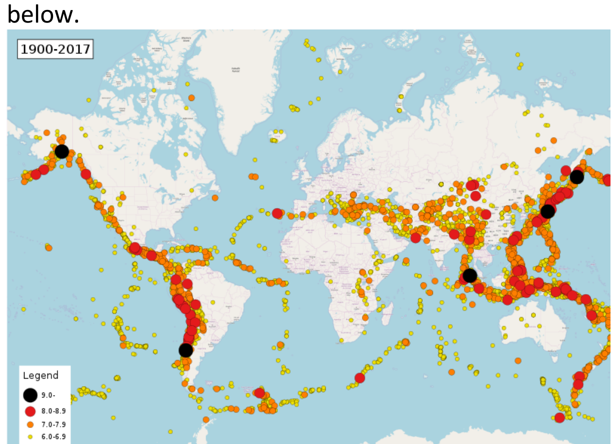
The teacher eventually shares that the colors in this map relate to rock age. Students are then encouraged to ask questions about any of the information that has been generated during the discussion of the map. The teacher records these questions and asks students what kind of information or data they would need to answer their questions. Example questions could be: "What happens in the middle of the ocean that makes rock newer there?"; "Are there mountains in the ocean?"; and "How can this map data tell us about what happened millions of years ago?" This serves as the launching point for students to begin looking at all the types of geological evidence that have led to modern theories about plate tectonics.

2. Continuing Exploration:
Students look for answers to the questions they have generated by examining different types of geological data that have been used as evidence to show that the continents have moved over time. These could include:
• homologous mountain formations on continents that were formerly adjacent but are now separated by oceans
• ancient coral reefs and coal-forming swamps found in areas too cold today to have these types of organisms
• puzzle-like coastal fit between the eastern Americas and western Africa and Europe
• older magnetite rocks pointing to a different magnetic direction than newer rocks on the same continent.
Students can manipulate cut-outs of continents to simulate plate movement. They can also examine various types of plate boundaries (divergent, convergent, transform) to see what types of geologic processes occur there.

3. Initial Engagement with the Phenomenon 2:
Students examine the fossil data to look for patterns that could provide evidence to show how continents may have once been connected. Encourage students to place the data from this table on a world map to ease visualization and analysis. There are different ways to represent this data on a world map (e.g., colors, symbols, etc.). Once students have tried different ways of visualizing the data, the reconstructed map and key in the phenomenon explanation might help them make sense of the movements of plates over time due to large-scale tectonics processes.

[*The last two pages of this instructional task are larger versions of the data table and the reconstructed map for this phenomenon.]

4. Continuing Exploration:
Challenge students to think about both phenomena together to explain what this means for Earth's history. In addition, students might also explore evidence from glacial deposits that show consistency between continents. Further evidence can come from the location of volcanoes and earthquakes in relation to plate boundary types. Many maps showing the location of these features can be found online. An example is shown below.



Phoenix7777. ((2018). Map of earthquakes1900- [Image]. WikiMedia Commons.
https://commons.wikimedia.org/wiki/File:Map_of_earthquakes_1900-.svg

Students' understanding may benefit from looking at the work of scientists who were responsible for the formulation of continental drift and plate tectonic theories in the 20th Century. This includes (but is not limited to) Marie Tharp, Alfred Wegener, Harry Hess, John Tuzo Wilson, and Dan McKenzie. At the time, these theories were highly controversial. Now they are generally accepted in the scientific community.

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GUIDING QUESTIONS	GUIDING QUESTIONS
• What can we learn about the locations of continents in the past by exploring data about the features of the ocean floor? • What do you think Earth looks like without water? • What types of geologic structures are found on the sea floor? • How do they compare to geologic structures on land? • Describe patterns you see in the map data. What do you think the colors in the map might represent? • Could the colors possibly represent something other than rock age? Why do you think this? • What is happening to matter (Earth material) at different types of plate boundaries? • How is "new rock" created? • What happens to "old" rock? • What is the difference between a continent and a plate? • How do these data provide evidence to show that the continents have moved over time? • What other types of data could be examined to find evidence for the movement of continents?	• How is fossil distribution data useful in making sense of the Earth's past? • What patterns in the data could be used to indicate that continents were not always located in their current positions? • How can we organize our data to help us see patterns and make sense of these patterns? • Why is it important to consider the geologic time scale when analyzing the patterns of fossil location? • Why do you think scientists needed multiple types of evidence to show that the continents have moved over time? • How did scientists in the 20th Century put together enough evidence to support theories of continental drift and plate tectonics? • How can an understanding of plate tectonics help us interact with the natural systems on Earth in the present day?

Communicate Final Explanation of the Phenomenon

How might students communicate their understanding of the targeted DCI or PE in an explanation supported by evidence?

Possible formats for constructing explanations of this phenomenon:

• Students can construct a scientific explanation that supports the theory of plate tectonics based on evidence showing rock age at various plate boundaries.

• Students can construct a scientific explanation that supports the theory of plate tectonics based on evidence that demonstrates the idea that fossils of identical species have been found on various plates that used to be connected.

• Students can apply scientific ideas regarding the present shapes of continents and their apparent fit to support an argument that Pangaea once existed.

• Students use mapping and models to explain ideas about the drifting of continents and the existence of continental plates.

• Students present evidence gathered from multiple data sources and explain how these data sets have been used to support modern theories of plate tectonics and Earth's history.

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