Introduction

Formative Assessment Exemplar - ESS.2.3 option

Introduction:

The following formative assessment exemplar was created by a team of Utah educators to be used as a resource in the classroom. It was reviewed for appropriateness by a Bias and Sensitivity/Special Education team and by state science leaders. While no assessment is perfect, it is intended to be used as a formative tool that enables teachers to obtain evidence of student learning, identify gaps in that learning, and adjust instruction for all three dimensions (i.e., Science and Engineering Practices, Crosscutting Concepts, Disciplinary Core Ideas) included in a specific Science and Engineering Education (SEEd) Standard.

In order to fully assess students' understanding of all three dimensions of a SEEd standard, the assessment is written in a format called a cluster. Each cluster starts with a phenomenon, provides a task statement, necessary supporting information, and a sequenced list of questions using the gather, reason, and communicate model (Moulding et al., 2021) as a way to scaffold student sensemaking. The phenomenon used in an assessment exemplar is an analogous phenomenon (one that should not have been taught during instruction) to assess how well students can transfer and apply their learning in a novel situation. The cluster provides an example of the expected rigor of student learning for all three dimensions of a specific standard. In order to serve this purpose, this assessment is NOT INTENDED TO BE USED AS A LESSON FOR STUDENTS.

Because this assessment exemplar is a resource, teachers can choose to use it however they want for formative assessment purposes. It can be adjusted and formatted to fit a teacher's instructional needs. For example, teachers can choose to delete questions, add questions, edit questions, or break the tasks into smaller segments to be given to students over multiple days.

Of note: All formative assessment clusters were revised based on feedback from educators after being utilized in the classroom. During the revision process, each cluster was specifically checked to make sure the phenomena was authentic to the DCI, supporting information was provided for the phenomena, the SEPs, CCCs, and DCIs were appropriate for the learning progressions, the cluster supported student sensemaking through the Gather, Reason, and Communicate instructional model, and the final communication prompt aligned with the cluster phenomena. As inconsistencies were found, revisions were made to support student sensemaking. If other inconsistencies exist that need to be addressed, please email the current Utah State Science Education Specialists with feedback.

General Format:

Each formative assessment exemplar contains the following components:

1. Teacher Facing Information: This provides teachers with the full cluster as well as additional information including the question types, alignment to three dimensions, and answer key. Additionally, an example of a proficient student answer and a proficiency scale for all three dimensions are included to support the evaluation of the last item of the assessment.
2. Students Facing Assessment: This is what the student may see. It is in a form that can be printed or uploaded to a learning platform. (Exception: Questions including simulations will need technology to utilize during assessment.)

Accommodation Considerations:

Teachers should consider possible common ways to provide accommodations for students with disabilities, English language learners, students with diverse needs or students from different cultural backgrounds. For example, these accommodations may include: Providing academic language supports, presenting sentence stems, or reading aloud to students. All students should be allowed access to a dictionary.

References:

Moulding, B., Huff, K., & Van der Veen, W. (2021). *Engaging Students in Science Investigation Using GRC*. Ogden, UT: ELM Tree Publishing.

Teacher Facing Info

Teacher Facing Information

Standard: Standard ESS.2.3
Construct an explanation for how plate tectonics results in patterns on Earth's surface. Emphasize past and current plate motions. Examples could include continental and ocean floor features such as mountain ranges and mid-ocean ridges, magnetic polarity preserved in seafloor rocks, or regional hot spots. (ESS2.B)

Assessment Format: Printable or Online Format (Does not require students to have online access-however, online Figure 5: Mantle Convection is animated. Animation is not required in order to answer questions.)

<table>
<tr><th colspan="2">Phenomenon</th></tr>
<tr><td>Paleomagnetic Patterns</td><td>Proficient Student Explanation of Phenomenon:
Unstable atoms decay over time. By measuring how many unstable atoms are in a rock layer, we can estimate how long ago it formed. By analyzing the rocks near a magnetic reversal we can estimate how long ago it occurred.

Magnetic patterns can be seen in both continental and oceanic crusts. Both types of crust have alternating bands of rock that match (and then oppose) the current magnetic field of the Earth. However, the position of these bands is very different. In continental crust, reversals get older as you move down to deeper layers. This is because the crust in this area formed by stacking over time. In oceanic crust, reversals get older as you move out sideways from the center, and the pattern of stripes is the same on both sides. This is because the crust in this area is formed by magma pushing plates apart and then cooling.

The energy to move these large plates comes from radioactive atoms in the mantle. As they decay they generate a lot of heat. The hot magma rises and pushes its way out through rifts in the ocean floor. This causes the plates to slowly spread apart as new crust forms in between them.</td></tr>
<tr><th colspan="2">Cluster Task Statement</th></tr>
<tr><td colspan="2">In this activity, you will construct an explanation for how magnetic patterns in Earth's crust support our current theory of plate tectonics.</td></tr>
<tr><th colspan="2">Supporting Information</th></tr>
<tr><td colspan="2">Reading 1: Earth's Magnetic Field</td></tr>
</table>

A compass is a useful tool while hiking. But did you know that some rock formations will deflect the compass needle, preventing you from identifying true north? How can this be? The Earth has a magnetic field. When rocks form, the magnetic minerals inside of them align with this field. This turns the new rock formation into a weak magnet. It is possible for a formation to retain this magnetism for millions of years.

The direction of the Earth's field has changed (repeatedly) in the past. This is called geomagnetic reversal. These reversals left magnetic traces in ancient rock formations, which provide useful clues about the Earth's history. By collecting rock samples from multiple depths, scientists can gather magnetic clues and piece together a theory for the past (and future) processes that are shaping our planet.

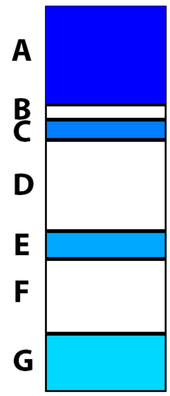
Scenario:
A geologist drills into continental bedrock and obtains vertical rock core samples.

Figure 1: Rock Cores

Rock cores are sections of rock that have been drilled out by a hollow steel tube called a core drill.

After analyzing these cores, the geologist determines the following layer profile. Blue regions (of various shades) represent layers of rock with the same polarity as the current Earth. White regions represent layers with reversed polarity.

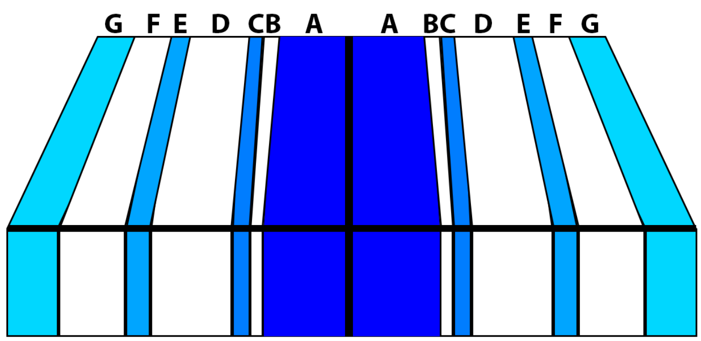
Figure 2: Continental Core Sample



This core sample shows magnetic reversals. Blue indicates rock with the same magnetic alignment(polarity) as Earth. White indicates reversed magnetic alignment (polarity).

Magnetic maps of the seafloor show a similar pattern of magnetic reversals. However, they appear in side-by-side stripes rather than vertical bands.

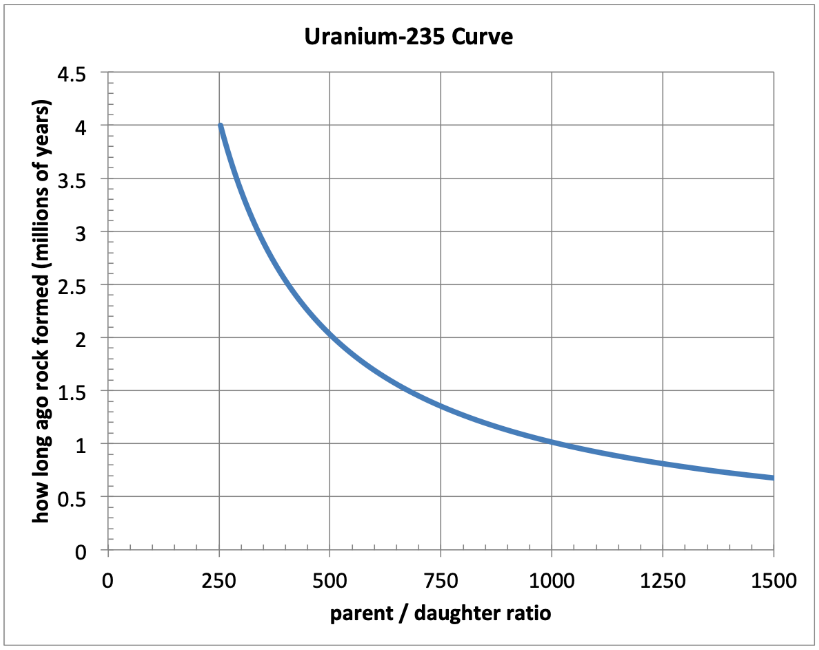
Figure 3: Magnetic Map of Seafloor



Magnetic reversal map of a section of the ocean floor.

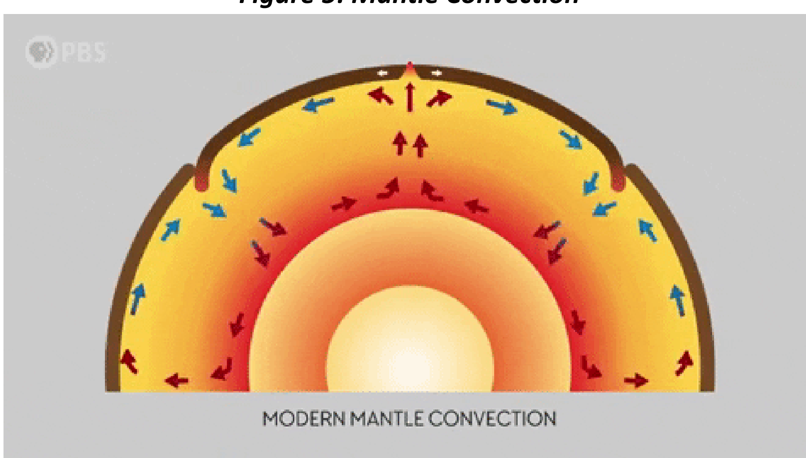
Other Resources:

Figure 4: Uranium-235 Curve



Uranium isotopes (radioactive elements) decay overtime.

Figure 5: Mantle Convection



Motion of mantle within the interior of the Earth.

Cluster Questions

Gather: age of recent reversals
Cluster Question #___1___
Question Type: table grid
Addresses:
__x__ DCI- ESS1.C
__x__ SEP- analyze / interpret
__x__ CCC- scale/prop/quant
Answer:

A to B =
close to 0.8 million

B to C =
close to 1 million

C to D =
close to 1.2 million

D to E =
close to 1.8 million

E to F =
close to 2 million

F to G =
close to 2.5 million

Question 1:
<u>Measuring the Age of Geomagnetic Reversals</u>

Radioactive atoms decay at a predictable rate over time. By comparing the relative amounts of uranium-235 (parent isotope) and lead-207 (daughter isotope), it is possible to estimate how long ago a rock formed.

Figure 4: Uranium-235 curve looks at the isotope ratio over time.

$$\text{isotope ratio} = \frac{\text{number of parent isotopes in sample}}{\text{number of daughter isotopes in sample}}$$

A rock sample near each reversal in ***Figure 2: Continental Core Sample*** was analyzed. This table summarizes the results. Use ***Figure 4: Uranium-235*** to estimate the age of each magnetic reversal.

Boundary	Isotope Ratio	Age of Reversal (millions of years ago)
A to B	1302	
B to C	1128	
C to D	958	
D to E	570	
E to F	507	
F to G	392	

Gather: age distribution of continental crust
Cluster Question #___2___
Question Type: multiple choice
Addresses:
__x__ DCI- ESS1.C
__x__ SEP- analyze / interpret

Question 2:
<u>Geomagnetic Patterns in Continental Crust</u>

Based on ***Figure 2: Continental Core Sample***, how are the rock layers arranged in time?

a) old rocks are found at the top and young rocks are found at

__x__ CCC- patterns Answer: c) young top / old bottom	the bottom b) old rocks are found in the middle and young rocks are found at the top and bottom c) young rocks are found at the top and old rocks are found at the bottom d) young rocks are found in the middle and old rocks are found at the top and bottom
Gather: age distribution of oceanic crust Cluster Question #___3___ Question Type: multiple choice Addresses: __x__ DCI- ESS1.C __x__ SEP- analyze / interpret __x__ CCC- patterns Answer: d) young middle / old edge	Question 3: <u>Geomagnetic Patterns in Oceanic Crust</u> Based on ***Figure 3: Magnetic Map of Seafloor***, how are the magnetic stripes arranged in time? a) old rocks are found at the left and young rocks are found at the right b) old rocks are found in the middle and young rocks are found at the edges c) young rocks are found at the left and old rocks are found at the right d) young rocks are found in the middle and old rocks are found at the edges
Reason: what is causing the seafloor pattern Cluster Question #___4___ Question Type: multiple choice Addresses: __x__ DCI- ESS2.B __x__ SEP- explanation __x__ CCC- patterns Answer: b) magma at ridge	Question 4: <u>Making Sense of Geomagnetic Patterns in Oceanic Crust</u> Which of the following explanations for oceanic crust formation is supported by ***Figure 3: Magnetic Map of Seafloor***? a) Oceanic crust forms from sediments settling to the ocean floor and compacting over time. b) Oceanic crust forms when magma is pushed out (and away from) the mid-oceanic ridge. c) Oceanic crust formed early in the Earth's history when the heat of formation dissipated into space and the surface magma cooled. d) Oceanic crust builds slowly over time as corals spread across the bottom of the ocean.
Reason: what is powering the observed changes Cluster Question #___5___ Question Type: Mult Choice	Question 5: <u>Energy Considerations</u> Radioactive decay is used to date Earth's rocks, but it also serves

Addresses: __X__ DCI- ESS2.B __X__ SEP- models _X___ CCC- energy and matter Answer: a) radioactive decay / moves plates	another function. Science researchers have found that the decay of radioactive isotopes uranium-238 and thorium-232 together contribute 20 trillion watts to the amount of heat Earth radiates into space. Many of these unstable isotopes are found in the mantle, where the heat of decay powers strong convection currents. (See ***Figure 5: Mantle Convection***.) What causes the magma in the mantle to move? And what effect does this motion have on the crust above? a. Energy released from the radioactive decay of isotopes moves the molten mantle which leads to movement of the more rigid lithospheric crustal plates above the mantle. b. Energy from the liquid outer iron and nickel core is responsible for mantle convection and moving the lithospheric plates. c. Radioactive decay generates energy to move the mantle, but the energy from the process is not powerful enough to move the lithospheric plates. d. Energy from isotope radioactive decay moves the molten mantle and most of the energy exits through volcanoes without moving the lithospheric plates.
Communicate: Cluster Question #___6___ Question Type: multiple choice Addresses: __x__ DCI- ESS 1.C / ESS2.B __x__ SEP- explanation __x__ CCC- patterns Answer: Unstable atoms decay over time. By measuring how many unstable atoms are in a rock layer, we can estimate how long ago it formed. By analyzing the rocks near a magnetic reversal we can estimate how long ago it occurred. Magnetic patterns can be seen in both continental and oceanic crust. Both types of crust have alternating bands of rock that	Question 6: <u>Putting It Together</u> Using your previous answers as a guide, **construct an explanation** for the observed <u>patterns</u> in the magnetic reversals of Earth's crust. Your explanation should include: ● a statement describing how the age of reversals is determined ● a statement describing the observed magnetic patterns in both continental and oceanic rocks ● a proposed mechanism for how the patterns came to be ● a proposed mechanism for what is powering the phenomenon

match (and then oppose) the current magnetic field of the Earth. However, the position of these bands is very different. In continental crust, reversals get older as you move down to deeper layers. This is because the crust in this area formed by stacking over time. In oceanic crust, reversals get older as you move out sideways from the center, and the pattern of stripes is the same on both sides. This is because the crust in this area is formed by magma pushing plates apart and then cooling. The energy to move these large plates comes from radioactive atoms in the mantle. As they decay they generate a lot of heat. The hot magma rises and pushes its way out through rifts in the ocean floor. This causes the plates to slowly spread apart as new crust forms in between them.	

Proficiency Scale

Proficient Student Explanation:
Unstable atoms decay over time. By measuring how many unstable atoms are in a rock layer, we can estimate how long ago it formed. By analyzing the rocks near a magnetic reversal we can estimate how long ago it occurred.

Magnetic patterns can be seen in both continental and oceanic crust. Both types of crust have alternating bands of rock that match (and then oppose) the current magnetic field of the Earth. However, the position of these bands is very different. In continental crust, reversals get older as you move down to deeper layers. This is because the crust in this area formed by stacking over time. In oceanic crust, reversals get older as you move out sideways from the center, and the pattern of stripes is the same on both sides. This is because the crust in this area is formed by magma pushing plates apart and then cooling.

The energy to move these large plates comes from radioactive atoms in the mantle. As they decay they generate a lot of heat. The hot magma rises and pushes its way out through rifts in the ocean floor. This causes the plates to slowly spread apart as new crust forms in between them.

Level 1 - Emerging	Level 2 - Partially Proficient	Level 3 - Proficient	Level 4 - Extending
SEP: Does not meet the minimum standard to receive a 2.	SEP: **Construct an explanation** that includes relationships between variables (radioactive decay and crustal movement, radioactive decay and age of rocks, mid-ocean ridge crust creation and magnetic striping) that **predict(s) and/or describe(s)** phenomena. **Construct a scientific explanation** based on valid and reliable evidence obtained from sources 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. **Apply scientific reasoning** to show why the data or evidence is adequate for the explanation or conclusion.	**SEP:** **Construct and revise an explanation** based on valid and reliable evidence obtained from a variety of sources 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. **Apply scientific ideas, principles, and/or evidence** to provide an explanation of phenomena. **Apply scientific reasoning, theory, and/or models** to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.	**SEP:** Extends beyond proficient in any way.
CCC: Does not meet the minimum standard to receive a 2.	**CCC:** Identifies that macroscopic **patterns** are related to the nature of microscopic and atomic-level structure. (Age of a macroscopic rock can	**CCC:** **Recognizes different patterns** that may be observed and provides evidence for causality in explanations of phenomena.	**CCC:** Extends beyond proficient in any way.

	be determined by what is happening in the nucleus of radioactive isotopes.) Uses **patterns** to identify **cause and effect** relationships. Uses graphs, charts, and images to identify **patterns** in data.	**Recognizes empirical evidence** needed to identify patterns.	
DCI: Does not meet the minimum standard to receive a 2.	**DCI:** The **geologic time** scale interpreted from rock strata provides a way to organize Earth's history. Tectonic processes continually generate **new ocean sea floor** at ridges and **destroy old seafloor** at trenches. **Radioactive decay** is a scientific process that looks at how atoms that make up rocks change over time. The changes can be studied to determine the age of continental and oceanic rocks on Earth. Rocks on Earth are continuously in motion due to **movement of lithospheric plates.** The movement is powered by the **movement of materials in the mantle.**	**DCI:** **Radioactive decay** lifetimes and isotopic content in rocks provide a way of **dating rock formations** and thereby fixing the scale of geological time. The **radioactive decay** of unstable isotopes continually **generates new energy** within Earth's crust and mantle, providing the primary source of the heat that **drives mantle convection**. **Plate tectonics** can be viewed as the surface expression of **mantle convection**. **Plate tectonics** is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a	**DCI:** Extends beyond proficient in any way.

		framework for **understanding its geologic history**.	

(Student Facing Format on following page)

Student Assessment

Name: ____ Date: ________

Stimulus

Reading 1: Earth's Magnetic Field

A compass is a useful tool while hiking. But did you know that some rock formations will deflect the compass needle, preventing you from identifying true north? How can this be? The Earth has a magnetic field. When rocks form, the magnetic minerals inside of them align with this field. This turns the new rock formation into a weak magnet. It is possible for a formation to retain this magnetism for millions of years.

The direction of the Earth's field has changed (repeatedly) in the past. This is called geomagnetic reversal. These reversals left magnetic traces in ancient rock formations, which provide useful clues about the Earth's history. By collecting rock samples from multiple depths, scientists can gather magnetic clues and piece together a theory for the past (and future) processes that are shaping our planet.

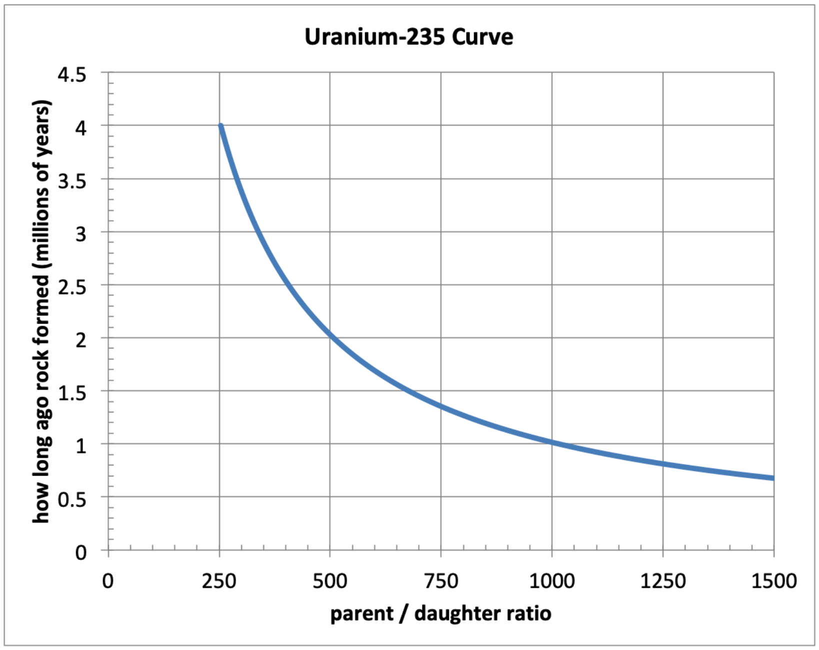
Your Task

In the questions that follow, you will construct an explanation for how magnetic patterns in Earth's crust support our current theory of plate tectonics.

Question 1: Measuring the Age of Geomagnetic Reversals

Radioactive atoms decay at a predictable rate over time. By comparing the relative amounts of uranium-235 (parent isotope) and lead-207 (daughter isotope), it is possible to estimate how long ago a rock formed.

Figure 4: Uranium-235 Curve



Uranium isotopes (radioactive elements) decay overtime.

Figure 4: Uranium-235 curve looks at the isotope ratio over time.

$$\text{isotope ratio} = \frac{\text{number of parent isotopes in sample}}{\text{number of daughter isotopes in sample}}$$

A rock sample near each reversal in ***Figure 2: Continental Core Sample*** was analyzed. This table summarizes the results. Use ***Figure 4: Uranium-235*** to estimate the age of each magnetic reversal.

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Question 2: Geomagnetic Patterns in Continental Crust

<u>Scenario:</u>

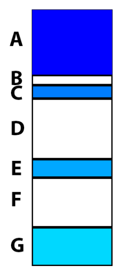
A geologist drills into continental bedrock and obtains vertical rock core samples.

Figure 1: Rock Cores

Rock cores are sections of rock that have been drilled out by a hollow steel tube called a core drill.

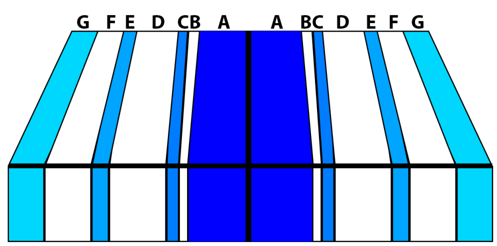
After analyzing these cores, the geologist determines the following layer profile. Blue regions (of various shades) represent layers of rock with the same polarity as the current Earth. White regions represent layers with reversed polarity.

Figure 2: Continental Core Sample



This core sample shows magnetic reversals. Blue indicates rock with the same magnetic alignment(polarity) as Earth. White indicates reversed magnetic alignment (polarity).

Figure 3: Magnetic Map of Seafloor



Magnetic reversal map of a section of the ocean floor.

Magnetic maps of the seafloor show a similar pattern of magnetic reversals. However, they appear in side-by-side stripes rather than vertical bands.

Based on ***Figure 2: Continental Core Sample***, how are the rock layers arranged in time?

a. old rocks are found at the top and young rocks are found at the bottom
b. old rocks are found in the middle and young rocks are found at the top and bottom
c. young rocks are found at the top and old rocks are found at the bottom
d. young rocks are found in the middle and old rocks are found at the top and bottom

Question 3: Geomagnetic Patterns in Oceanic Crust

Based on ***Figure 3: Magnetic Map of Seafloor***, how are the magnetic stripes arranged in time?

a. old rocks are found at the left and young rocks are found at the right
b. old rocks are found in the middle and young rocks are found at the edges
c. young rocks are found at the left and old rocks are found at the right
d. young rocks are found in the middle and old rocks are found at the edges

Question 4: Making Sense of Geomagnetic Patterns in Oceanic Crust

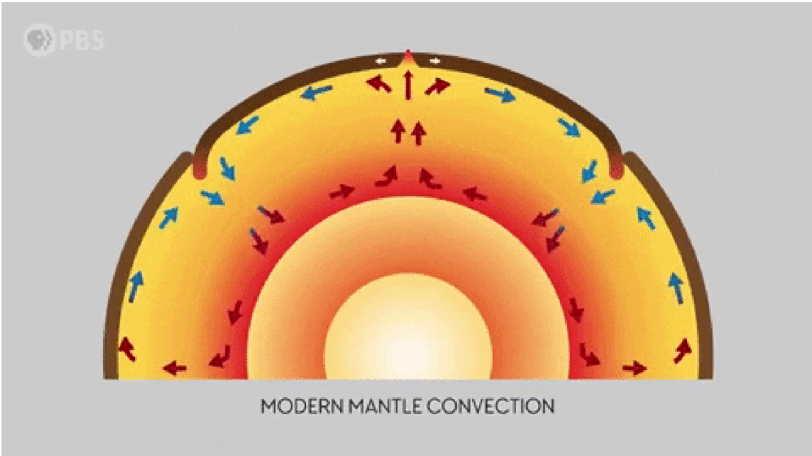
Which of the following explanations for oceanic crust formation is supported by ***Figure 3: Magnetic Map of Seafloor***?

a. Oceanic crust forms from sediments settling to the ocean floor and compacting over time.
b. Oceanic crust forms when magma is pushed out (and away from) the mid-oceanic ridge.
c. Oceanic crust formed early in the Earth's history when the heat of formation dissipated into space and the surface magma cooled.
d. Oceanic crust builds slowly over time as corals spread across the bottom of the ocean.

Question 5: Energy Considerations

Radioactive decay is used to date Earth's rocks, but it also serves another function. Science researchers have found that the decay of radioactive isotopes uranium-238 and thorium-232 together contribute 20 trillion watts to the amount of heat Earth radiates into space. Many of these unstable isotopes are found in the mantle, where the heat of decay powers strong convection currents. (See ***Figure 5: Mantle Convection***.)

Figure 5: Mantle Convection



Motion of mantle within the interior of the Earth.

What causes the magma in the mantle to move? And what effect does this motion have on the crust above?

a. Energy released from the radioactive decay of isotopes moves the molten mantle which leads to movement of the more rigid lithospheric crustal plates above the mantle.
b. Energy from the liquid outer iron and nickel core is responsible for mantle convection and moving the lithospheric plates.
c. Radioactive decay generates energy to move the mantle, but the energy from the process is not powerful enough to move the lithospheric plates.
d. Energy from isotope radioactive decay moves the molten mantle and most of the energy exits through volcanoes without moving the lithospheric plates.

Question 6: Putting It Together

Using your previous answers as a guide, **construct an explanation** for the observed patterns in the magnetic reversals of Earth's crust. Your explanation should include:

- a statement describing how the age of reversals is determined
- a statement describing the observed magnetic patterns in both continental and oceanic rocks
- a proposed mechanism for how the patterns came to be
- a proposed mechanism for what is powering the phenomenon