Formative Assessment Exemplar - [ESS.2.2]

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.

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 Information

Standard: Develop and use a model based on evidence of Earth's interior and describe the cycling of matter by thermal convection. Emphasize the density of Earth's layers and mantle convection driven by radioactive decay and heat from Earth's early formation. Examples of evidence could include maps of Earth's three-dimensional structure obtained from seismic waves or records of the rate of change of Earth's magnetic field. (PS1.C, ESS2.A, ESS2.B)

Assessment Format: Online Only (question 2: Requires students to have online access, all other questions can be printable.

Phenomenon	
Continental Hotspot Supervolcano of Yellowstone	The heat of Earth's interior, produced from the formation of the Earth and through the heat released due to radioactive decay in Earth's core, causes temperature and density changes in Earth's layers. Hot material near the core rises to the surface, releases energy, cools, and sinks back down to the core. This is called thermal convection. The movement of matter in thermal convection has a secondary effect where it moves the plates atop the convecting mantle. Rising hot mantle can produce a column of superheated material in a "plume" which can produce a corresponding volcano in the crust directly above it, called a "hotspot." The plume of molten material never moves, but the crust above it will move due to the cycling of matter associated with thermal convections in the mantle (plate tectonics). In this way a line of volcanoes will be produced as the plate moves over a hot spot due to thermal convection.
Cluster Task Statement	
Students will evaluate and manipulate various models of convection and the Yellowstone hotspot to predict how energy and matter circulate within the Earth and cause motion.	
Supporting Information	
Reading 1: Yellowstone Yellowstone is a continental hot spot. Hot spots occur because of the intense heat of the Earth's outer core. This heat **energy** affects the **matter** of Earth's interior. Energy radiates through the mantle bringing hot molten rock upward to the hot spot at Earth's surface. These areas of rising rock are called mantle plumes. As the North American plate moves over a mantle plume, it affects different areas of the continent. For example, the Yellowstone caldera (a large bowl-shaped crater that is formed by the collapse of a volcano after an eruption) is one of the largest calderas in the world produced from a massive volcanic eruption. It is over 65 miles across! **Figure 1:** Yellowstone Hotspot diagram	

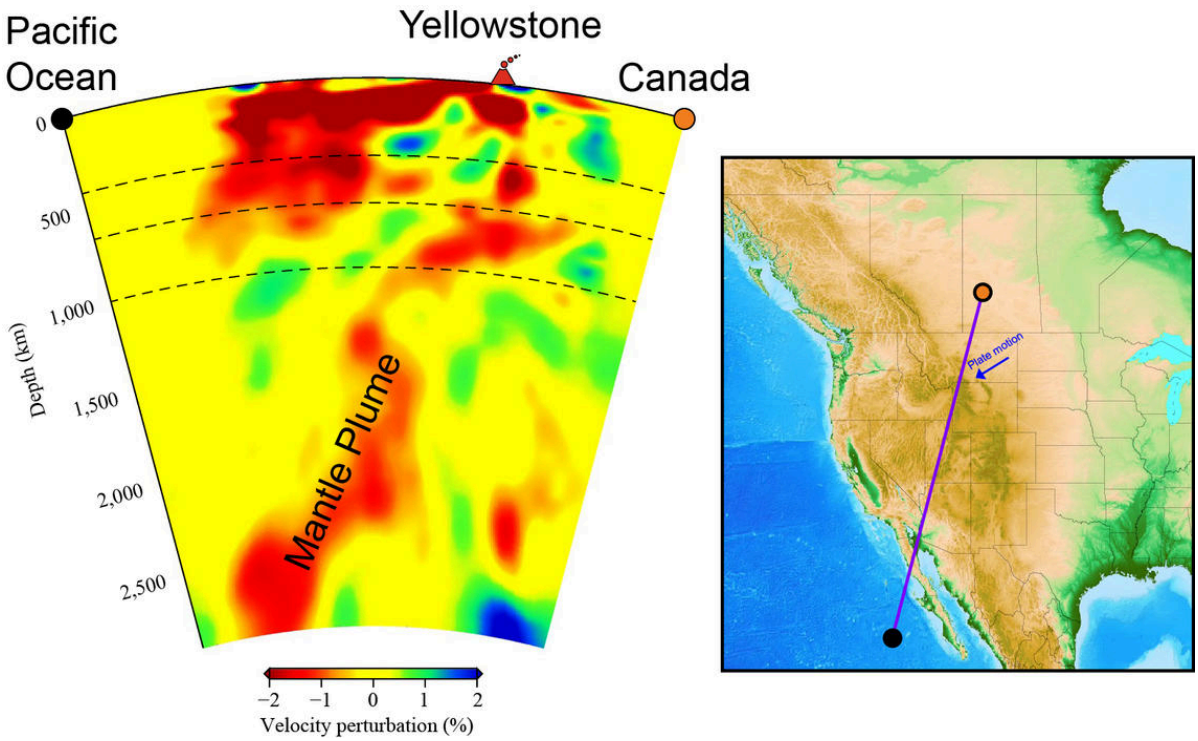


Figure 1: Shows the interior of the Earth directly beneath the Yellowstone hotspot.
Source: Grand, S., Nelson P., (2018) Nature Geoscience. Lower-mantle plume beneath the Yellowstons hotspot revealed by core waves.

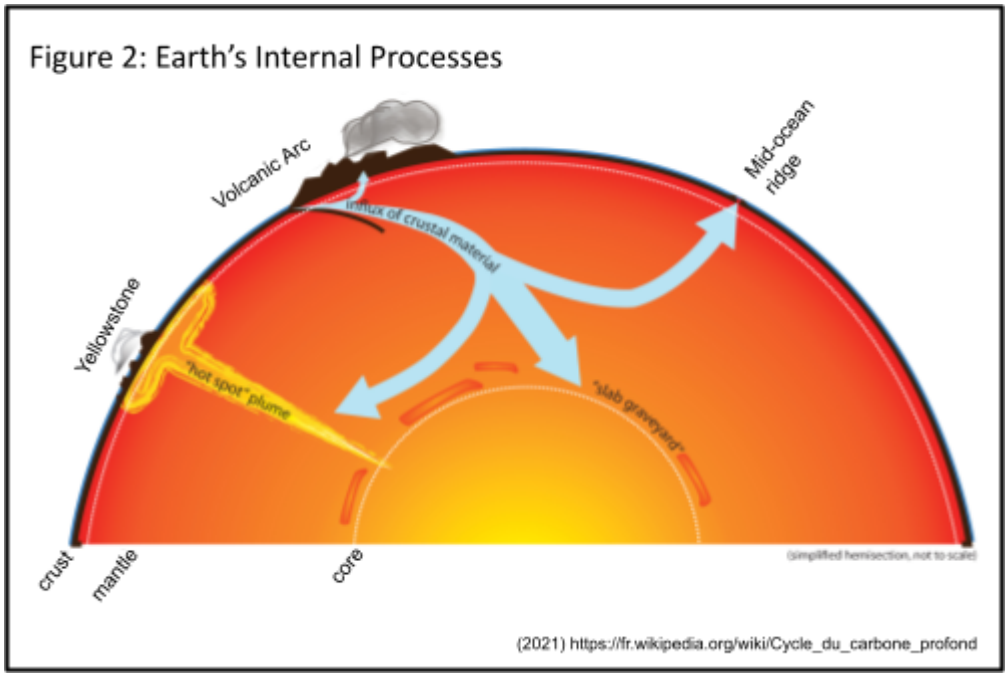


Figure 2 shows the cycling of matter through Earth's interior.

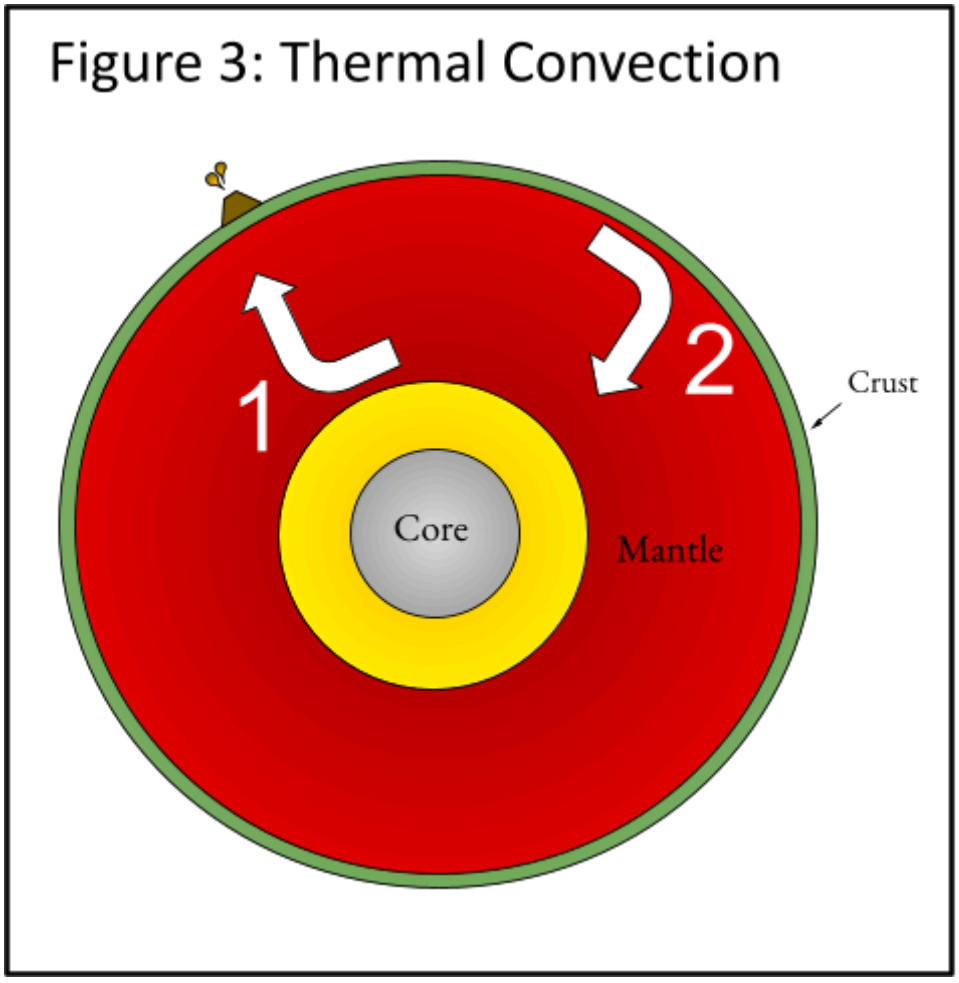


Figure 3: Movement of matter within the Earth's interior.

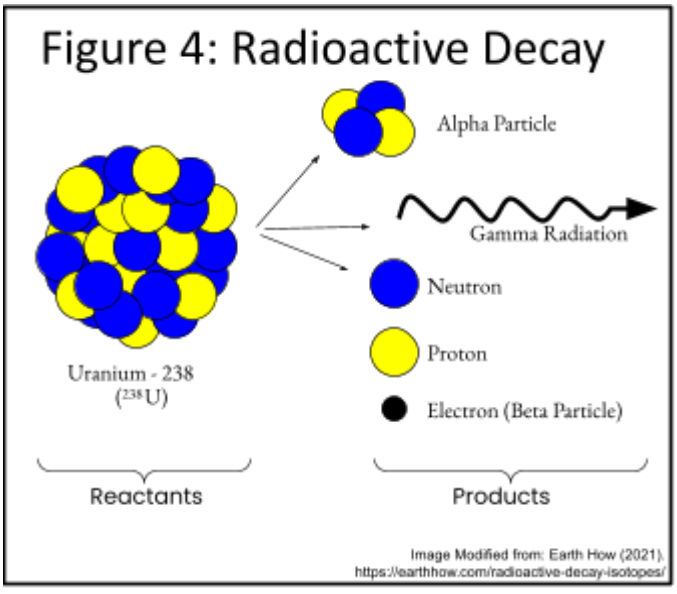


Figure 4 shows radioactive decay of Uranium-238.

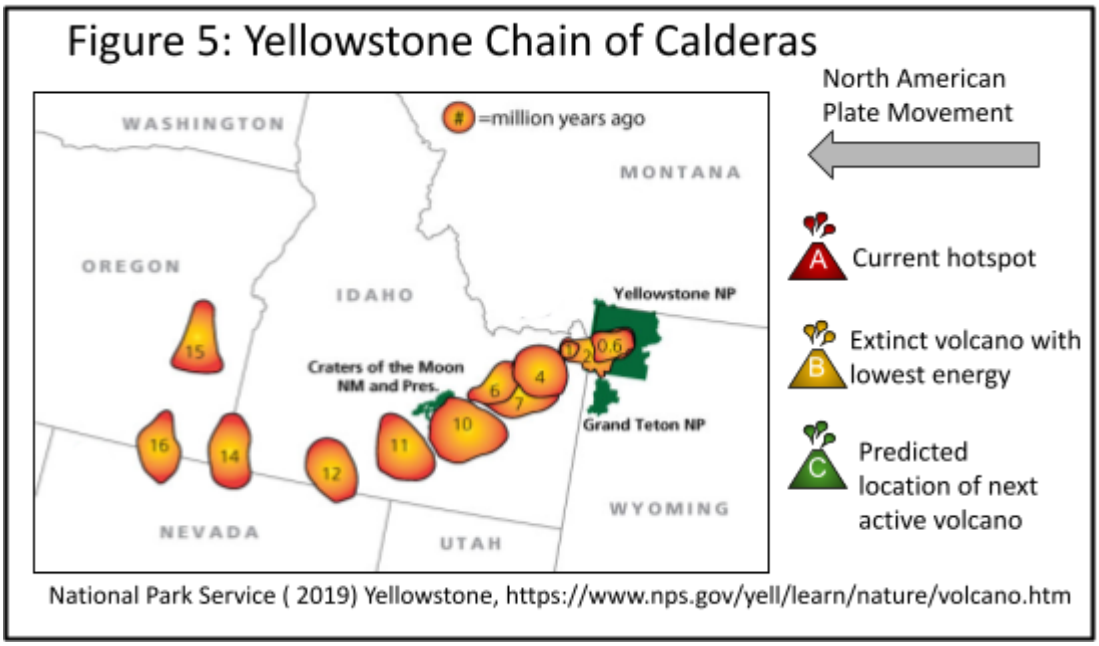
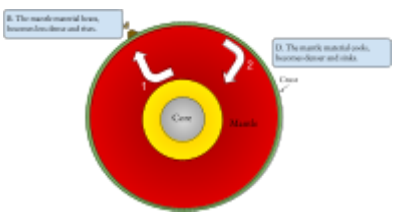


Figure 5 shows the chain of calderas formed by the Yellowstone hotspot.

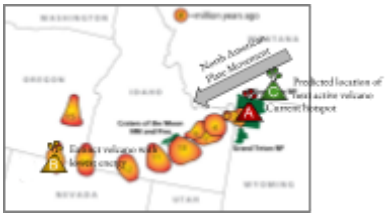
Simulation 1:
https://interactives.ck12.org/simulations/chemistry/density/app/index.html?lang=en&referrer=ck12Launcher&backUrl=https://interactives.ck12.org/simulations/chemistry.html

In the following questions student will **use models** and simulations to determine the role of flowing **energy** and cycling **matter** in the creation of hot spots, mantle plumes, and their associated features.

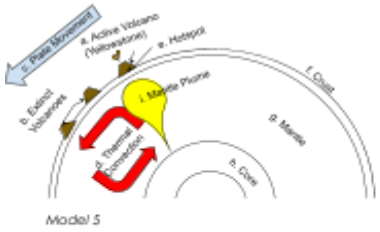
Cluster Questions	
Gather: (use a model to identify Earth's internal processes) Cluster Question #__1____ Question Type: **Multi Select:** 5-8 options, multiple correct Addresses: _x___ DCI: ESS2.A _x___ SEP: **Use** a model _x___ CCC: Energy and Matter Answer: A, B, and D.	Question 1: ***Use Figure 2: Earth's Internal Processes*** to describe the flow of ***energy*** and the cycling of ***matter*** through Earth's interior. Select all correct answers. a. Matter (crust) can be pushed by the flow of energy down into the mantle all the way to the top of the core. b. Matter (crust) can be pushed by the flow of energy down into the mantle and rise again in other areas. c. Matter (crust) always stays just beneath the surface of the Earth. d. The energy to move matter and create a hotspot comes from the hot core. e. The energy to move matter and create a hotspot comes from the subduction of the Earth's crust.

	f. The energy to move matter and create a hotspot comes from the volcano.
Gather: (use a simulation to identify the factors affecting density) Cluster Question #__2____ Question Type: **Simulation:** Provides inputs to manipulate, runs an animation, and/or creates an output table. **Multi Select:** 5-8 options, multiple correct Addresses: __X__ DCI: ESS2.A _x___ SEP: **Use** a Model _x___ CCC: Energy and Matter Answer: A and C	Question 2: Density is used to describe how compact the molecules of an object are. Your Task: In the following question you will determine how the density of ***matter*** increases or decreases as a result of a change. ***Use simulation 1*** to manipulate the mass and density of an object to affect density. As you complete the simulation, identify the trends in the attached graph. Which of the following statements are correct? Select all that apply. a. If the mass is increased and the volume decreases the object will sink. b. If the mass is decreased and the volume increases the object will sink faster. c. If the volume increases and the mass decreases the object will float. d. All of the above. e. None of the above.
Reason: (correlate the cycling of matter and flow of energy with changes in density and temperature) Cluster Question #__3____ Question Type: **Multi Select:** 5-8 options, multiple correct [drop down] Addresses: __x__ DCI: ESS2.A, __x__ SEP: **Use** a Model __x__ CCC: Energy and Matter Answer: 	Question 3: Thermal convection is the process by which ***matter*** moves due to temperature and density differences. Model 2 shows thermal convection. Your Task: ***Use figure 3 Thermal Convection***, to determine the correct descriptions for what is happening to ***matter*** as a result of the flow of ***energy*** at points 1 and 2 shown on the model. a. The mantle material cools, becomes less dense and sinks. b. The mantle material heats becomes less dense and rises. c. The mantle material cools, becomes denser and rises. d. The mantle material cools, becomes denser and sinks. e. The mantle is cooled as it loses energy at Earths' surface. f. The mantle is heated as it gains energy at Earth's surface.

1. B. The mantle material heats becomes less dense and rises. 2. D. The mantle material cools, becomes denser and sinks.	
Reason: (construct an explanation for the relationship between the heat energy provided by radioactive decay and the cycling of matter and the flow of energy in Earth's interior) Cluster Question #__4____ Question Type: **Long Answer:** Explanation, Model, Argument Addresses: _x___ DCI: ESS2.A, ESS2.B _x___ SEP: **Use** a Model _x___ CCC: Energy and Matter Answer: The radioactive decay of unstable isotopes in Earth's interior continually generates new energy. This energy heats mantle material, making it less dense as it expands. The less dense material floats toward the surface where it releases heat at the surface, cools, contracts, and sinks. The movement of crust can be viewed as the surface expression of mantle convection.	Question 4: ***Use the information from Figure 4: Radioactive Decay*** to *construct an explanation* for the *relationship* between radioactive decay and the cycling of ***matter*** and the flow of ***energy*** within Earth's interior and at the surface.
Reason: (develop a model that illustrates that features of the crust around a hotspot is the surface expression of mantle convection) Cluster Question #___5___ Question Type: **Modeling:** Student develops/uses a model	Question 5: ***Further develop Figure 5: Yellowstone Chain of Calderas*** using your understanding of the flow of ***energy*** and cycling of ***matter*** associated with the Yellowstone hotspot: ● Add an arrow to model 4 to indicate the direction of crust movement. ● Add labels to model 4 to show ○ A) the location of the current hotspot, ○ B) the extinct volcano with the lowest amount of energy, and ○ C) a prediction for the location of the next active volcano.

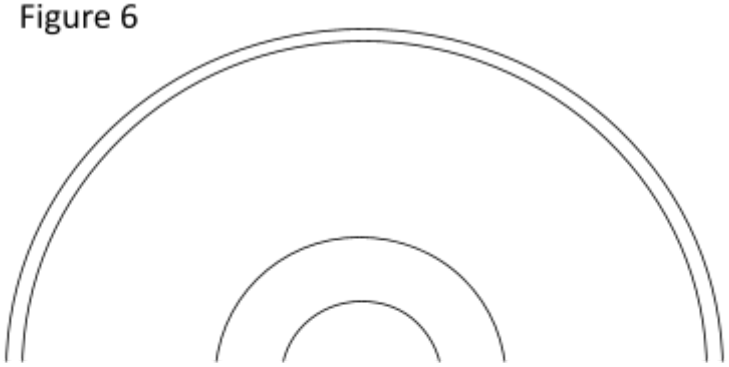
Addresses: _x___ DCI: ESS2.A _x___ SEP: **Develop** a Model _x___ CCC: Energy and Matter Answer: 	
Communicate: (students use models to construct an explanation of the Yellowstone chain of calderas) Cluster Question #___6___ Question Type: **Long Answer:** Explanation, Model, Argument Addresses: _x___ DCI: ESS2.A, ESS2.B _x___ SEP: Develop a Model _x___ CCC: Energy and Matter Radioactive decay produces heat in Earth's interior and causes temperature and density changes in Earth's layers. Hot, low density material near the core rises through the mantle to the crust at the surface, releases heat, cools, becomes dense, and sinks back down to the core; this is thermal convection within the mantle. When rising hot mantle produces a column of superheated material in a "mantle plume," it will produce a corresponding volcano in the crust directly above it, called a "hotspot."	Question 6: Your task: ***Using the information gathered from figures 1-5*** to construct an explanation for thermal convection and how it produces the chain of active and extinct volcanoes in and around Yellowstone National Park. Your explanation should **include:** ● The flow of energy and the cycling of matter in Earth's interior. ● Active and extinct volcano(es) ● Plate movement ● Thermal convection ● Hotspot ● Mantle plume ● Crust, mantle, and core

As the plate moves, a result of the flow of energy and cycling of matter, a line of extinct volcanoes will be produced trailing away from the hotspot area in the direction of plate movement.



Model 5

Figure 6



Label the following:

a. Active Volcano (Yellowstone)
b. Extinct Volcano(es)
c. Plate Movement
d. Thermal Convection
e. Hotspot
f. Crust
g. Mantle
h. Core
i. Mantle Plume

Figure 6 is not provided on the student template, it is only provided here as a resource for scaffolding students.

Proficiency Scale

Proficient Student Explanation:
Radioactive decay produces heat in Earth's interior and causes temperature and density changes in Earth's layers. Hot, low density material near the core rises through the mantle to the crust at the surface, releases heat, cools, becomes dense, and sinks back down to the core; this is thermal convection within the mantle.

When rising hot mantle produces a column of superheated material in a "mantle plume," it will produce a corresponding volcano in the crust directly above it, called a "hotspot."

As the plate moves, a result of the flow of energy and cycling of matter, a line of extinct volcanoes will be produced trailing away from the hotspot area in the direction of plate movement.

Level 1 - Emerging	Level 2 - Partially Proficient	Level 3 - Proficient	Level 4 - Extending
SEP:	**SEP:** Develop a model to predict and/or	**SEP:** Develop, revise, and/or use a model	**SEP:** Extends beyond proficient in any way.

Does not meet the minimum standard to receive a 2.	describe phenomena. Develop a model to describe unobservable mechanisms.	based on evidence to illustrate and/or predict the relationships between systems or between components of a system.	
CCC: Does not meet the minimum standard to receive a 2.	**CCC:** Can track the transfer of energy drives the motion and/or cycling of matter, within a natural or designed system. Understands that the transfer of energy can be tracked as energy flows through a designed or natural system.	**CCC:** Describes changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. Understands that energy drives the cycling of matter within and between systems.	**CCC:** Extends beyond proficient in any way.
DCI: Does not meet the minimum standard to receive a 2.	**DCI:** All Earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from Earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials.	**DCI:** 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. Motions of the mantle and its plates occur primarily through thermal convection, which involves the cycling of matter due to the outward flow of	**DCI:** Extends beyond proficient in any way.

		energy from Earth's interior and the gravitational movement of denser materials toward the interior.	

(Student Facing Format on following page)

Name: _____ Date: _____

Stimulus

Reading 1: Yellowstone

Yellowstone is a continental hot spot. Hot spots occur because of the intense heat of the Earth's outer core. This heat **energy** affects the **matter** of Earth's interior. Energy radiates through the mantle bringing hot molten rock upward to the hot spot at Earth's surface. These areas of rising rock are called mantle plumes.

As the North American plate moves over a mantle plume, it affects different areas of the continent. For example, the Yellowstone caldera (a large bowl-shaped crater that is formed by the collapse of a volcano after an eruption) is one of the largest calderas in the world produced from a massive volcanic eruption. It is over 65 miles across!

Figure 1: Yellowstone Hotspot diagram

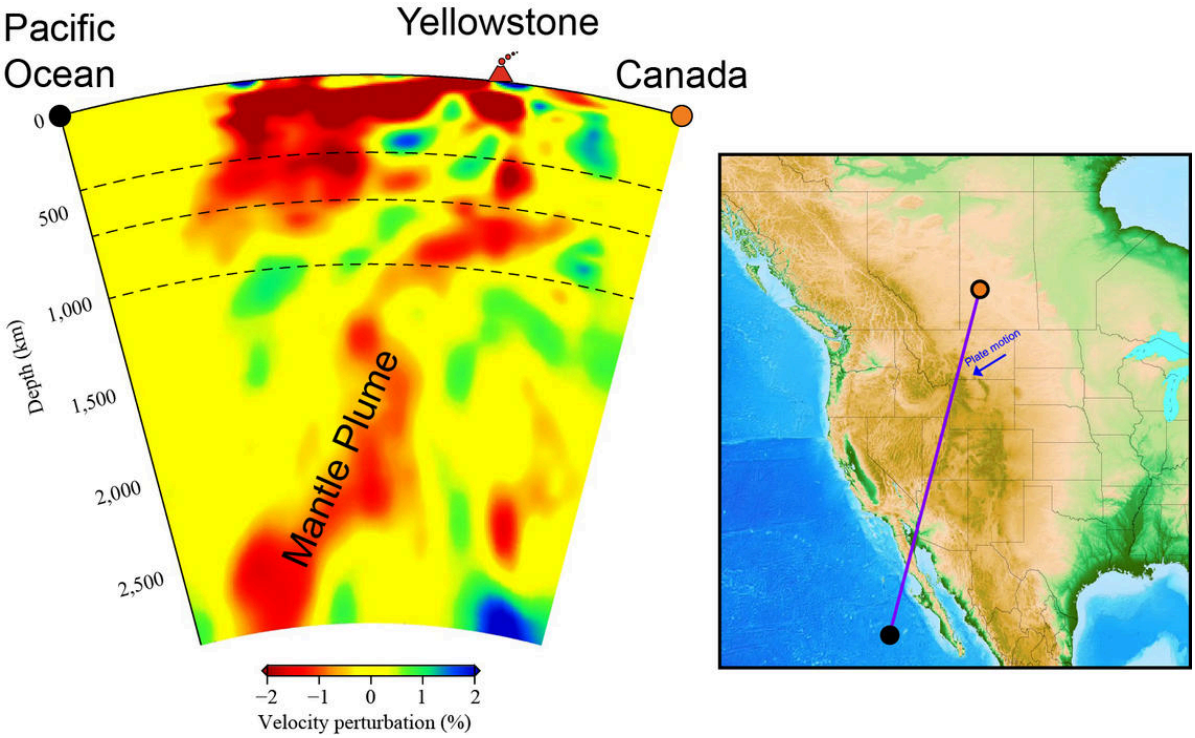


Figure 1: Shows the projected Earth's interior mantle plume directly beneath the Yellowstone hotspot and the effected part of the Earth's crust.

Source: Grand, S., Nelson P., (2018) Nature Geoscience. Lower-mantle plume beneath the Yellowstons hotspot revealed by core waves.

Your Task

In the questions that follow, you will **use models** and simulations to determine the role of flowing **energy** and cycling **matter** in the creation of hot spots, mantle plumes, and their associated features.

Question 1

Use Figure 2: Earth's Internal Processes to describe the flow of ***energy*** and the cycling of ***matter*** through Earth's interior.

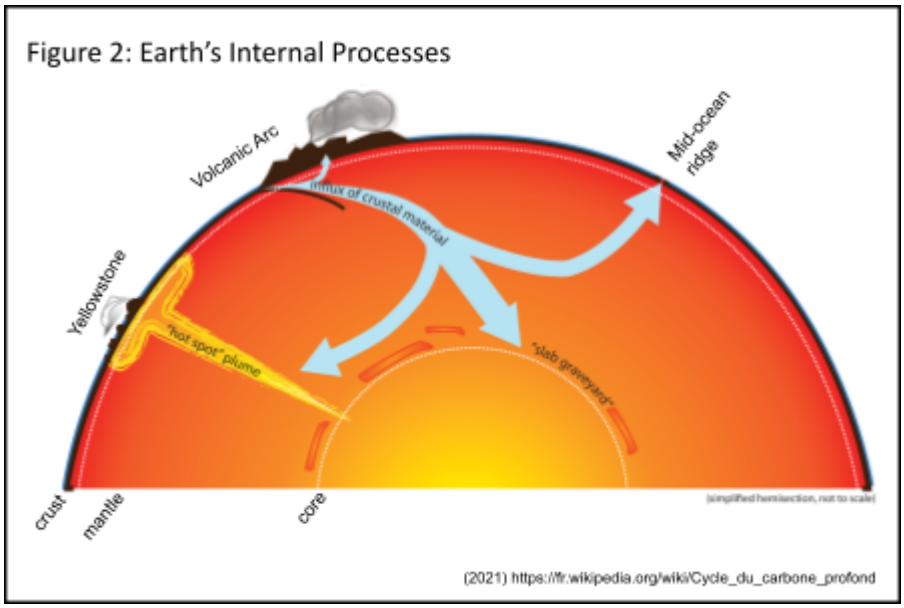


Figure 2 shows the cycling of matter through Earth's interior.

Select all correct answers.

a. Matter (crust) can be pushed by the flow of energy down into the mantle all the way to the top of the core.
b. Matter (crust) can be pushed by the flow of energy down into the mantle and rise again in other areas.
c. Matter (crust) always stays just beneath the surface of the Earth.
d. The energy to move matter and create a hotspot comes from the hot core.
e. The energy to move matter and create a hotspot comes from the subduction of the Earth's crust.
f. The energy to move matter and create a hotspot comes from the volcano.

Question 2

Density is used to describe how compact the molecules of an object are. In the following question you will determine how the density of ***matter*** increases or decreases as a result of a change.

Use simulation 1 to manipulate the mass and density of an object to affect density. As you complete the simulation, identify the trends in the attached graph.

Simulation 1:
https://interactives.ck12.org/simulations/chemistry/density/app/index.html?lang=en&referrer=ck12Launcher&backUrl=https://interactives.ck12.org/simulations/chemistry.html

Which of the following statements are correct? Select all that apply.

a. If the mass is increased and the volume decreases the object will sink.
b. If the mass is decreased and the volume increases the object will sink faster.
c. If the volume increases and the mass decreases the object will float.
d. All of the above.
e. None of the above.

Question 3

Thermal convection is the process by which ***matter*** moves due to temperature and density differences.

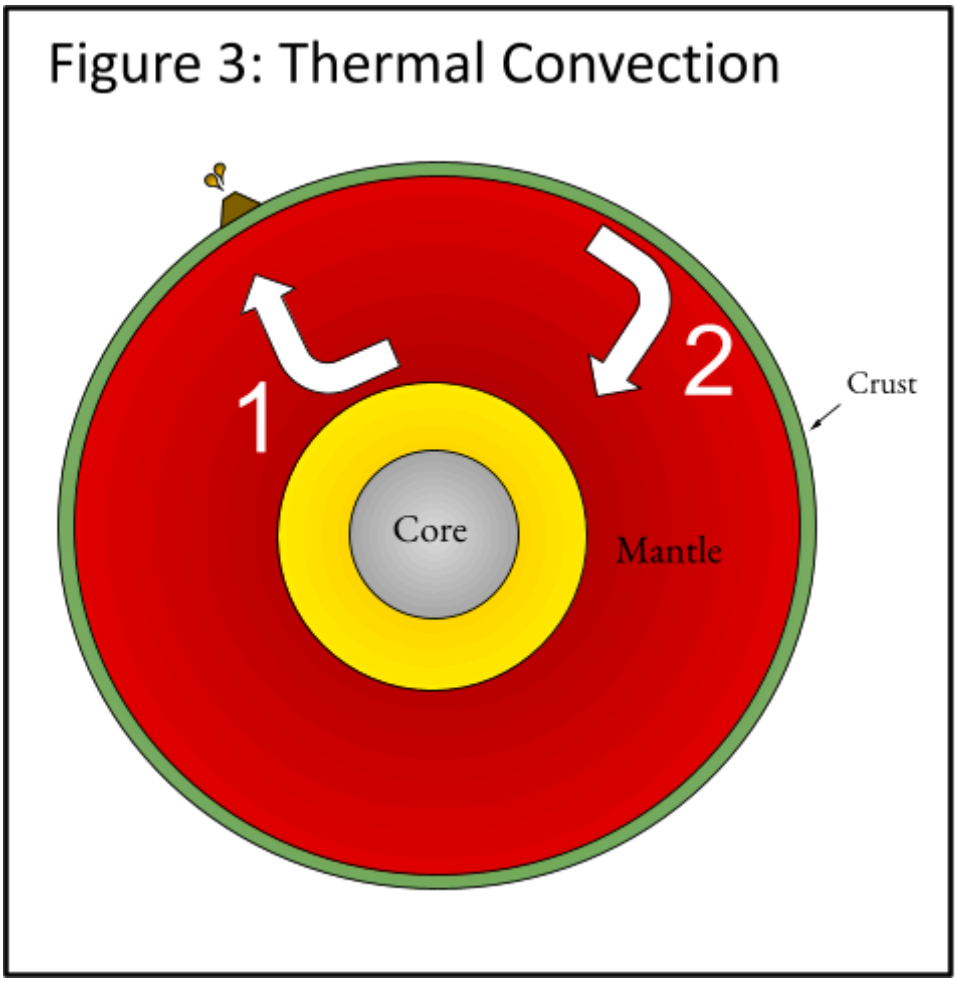


Figure 3: Movement of matter within the Earth's interior.

Using Figure 3: Thermal Convection, determine the correct descriptions for what is happening to ***matter*** as a result of the flow of ***energy*** at points 1 and 2 shown on the model.

a. The mantle material cools, becomes less dense and sinks.
b. The mantle material heats becomes less dense and rises.
c. The mantle material cools, becomes denser and rises.
d. The mantle material cools, becomes denser and sinks.
e. The mantle is cooled as it loses energy at Earths' surface.
f. The mantle is heated as it gains energy at Earth's surface.

Question 4

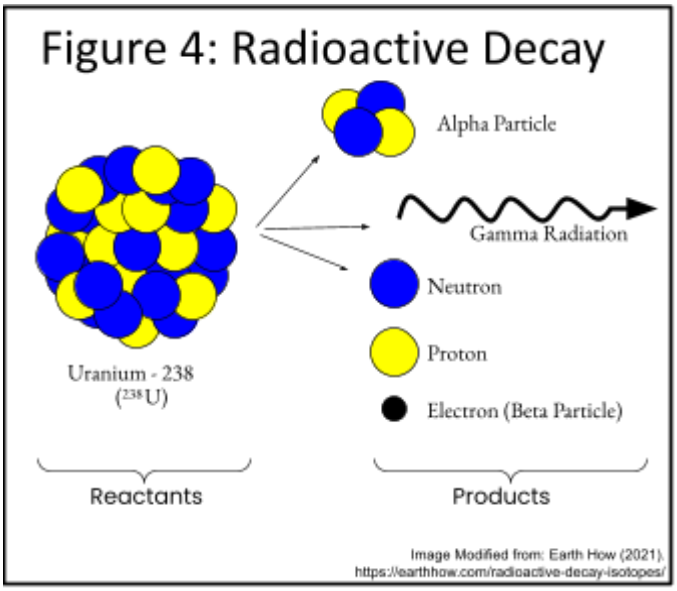


Figure 4 shows radioactive decay of Uranium-238.

Use the information from Figure 4: Radioactive Decay to *construct an explanation* for the *relationship* between radioactive decay and the cycling of ***matter*** and the flow of ***energy*** within Earth's interior and at the surface.

Question 5

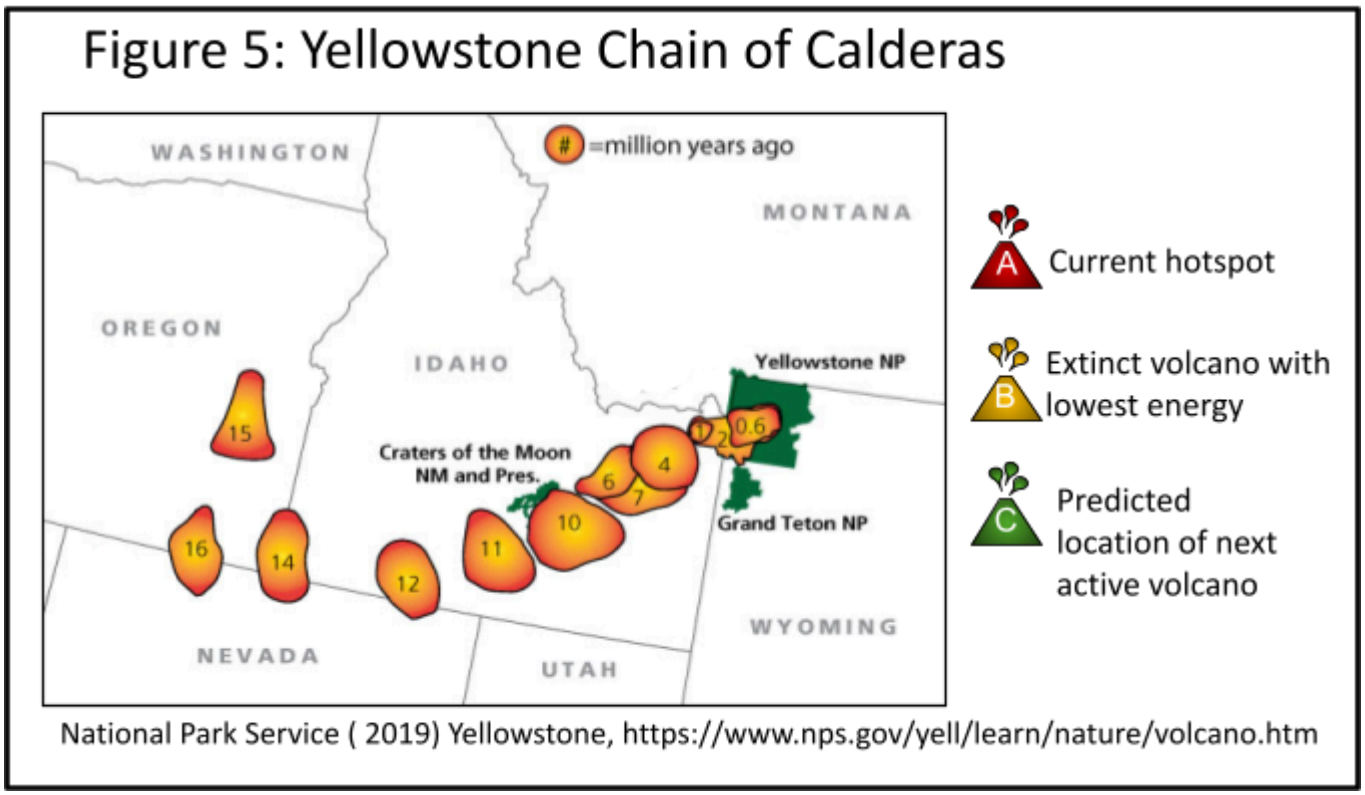


Figure 4 shows the chain of calderas formed by the Yellowstone hotspot.

Further develop Figure 4: Yellowstone Chain of Calderas using your understanding of the flow of ***energy*** and cycling of ***matter*** associated with the Yellowstone hotspot:

- Add an arrow to Figure 5: Yellowstone Chain of Calderas to indicate the direction of crust movement.
- Add labels to Figure 5: Yellowstone Chain of Calderas to show:
    - A) the location of the current hotspot,
    - B) the extinct volcano with the lowest amount of energy, and
    - C) a prediction for the location of the next active volcano.

Question 6

Your task:

Use the information gathered from figures 1-5 to construct an explanation for thermal convection and how it produces the chain of active and extinct volcanoes in and around Yellowstone National Park. Your explanation should **include:**

- The flow of energy and the cycling of matter in Earth's interior.
- Active and extinct volcano(es)
- Plate movement
- Thermal convection
- Hotspot
- Mantle plume
- Crust, mantle, and core