

Senior High School

Department of Education
National Capital Region

**SCHOOLS DIVISION OFFICE
MARIKINA CITY**

Earth & Life Science

First Quarter-Module 5

Endogenic Processes

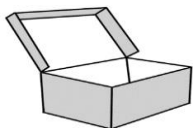


Evangeline C. Agtarap



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What I Need to Know

This module was designed and written with you in mind. It is here to help you understand geologic processes that occur within the Earth. This module permits it to be used in many different learning situations. The language used recognizes the diverse vocabulary level of students. The lessons are arranged to follow the standard sequence of the course.

Learning Competencies

1. Describe where Earth's internal heat comes from (S11/12ES-Ib-14)
2. Describe how magma is formed (magmatism) (S11/12ES-Ic-15) and
3. Describe the changes in mineral components and texture of rocks due to changes in pressure and temperature (metamorphism) (S11/12ES-Ic-17)

The module has three lessons which are:

- Lesson 1 – Earth's Internal Heat
- Lesson 2 – Magmatism
- Lesson 3 – Metamorphism

After going through this module, you are expected to

1. identify the sources of Earth's internal heat;
2. describe magma;
3. describe the different conditions under which magma forms; and
4. describe the changes in rocks due to changing pressure, temperature, and chemical conditions.



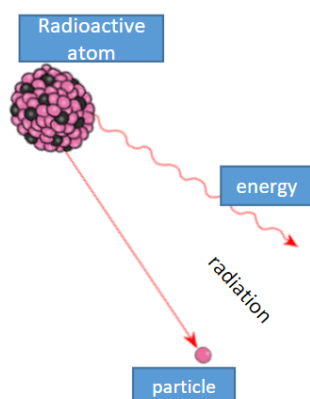
What I Know

Read each question carefully and encircle the letter of the correct answer.

1. Why is the internal heat of Earth important to life?
 - A. It drives the movement of plates.
 - B. It protects the planet from solar flares.
 - C. It provides the energy for photosynthesis.
 - D. It shields the planet from harmful radiation from the sun.
2. How did Earth acquire heat according to the Planetesimals Theory?
 - I. Radioactive atoms undergo radioactive decay.
 - II. Particles of dust origin collided and accumulated.
 - III. Materials in the earth moved and separated into layers.
 - IV. To become more stable, radioactive atoms emit high energy particles and waves.

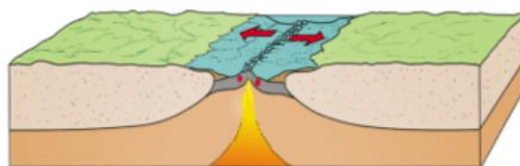
A. I and II	C. II and III
B. III and IV	D. III and IV

3. See the picture below. How does radioactive decay contribute to Earth's internal heat?

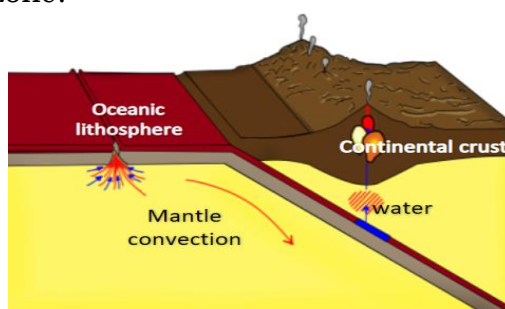


- A. As planetesimals collide and accrete, energy is released.
 B. As atoms change to a more stable state, energy is released.
 C. Materials in the earth separated into layers producing friction that is converted to heat.
 D. Denser materials settle at the center of Earth while less dense materials rise to the surface.
4. Which of the following are sources of Earth's internal heat?
- solar energy
 - radioactive decay
 - accretional energy
 - differentiation energy
- A. I and II
 B. III and IV
 C. I, II, and III
 D. II, III, and IV
5. Suppose someone asks you how Earth's internal heat allows life forms to thrive, how will you answer?
- It makes Earth like the other planets.
 - It helps maintain Earth's surface temperature.
 - It supplies energy for the formation of landforms.
 - It adds to the number of years of Earth's existence.
- A. I and II
 B. III and IV
 C. II and III
 D. I and IV
6. How does magma usually form in divergent plate boundaries?
- A. By flux melting
 B. By heat transfer
 C. By compression
 D. By decompression melting
7. How does flux melting happen?
- A. By the addition of water and carbon dioxide
 B. By the transfer of heat to surrounding rocks
 C. By the lowering of melting point due to decrease in pressure
 D. By the lowering of melting point due to increase in temperature

8. The figure below shows divergent plate boundaries. What usually causes the melting of rocks along divergent plate boundaries?

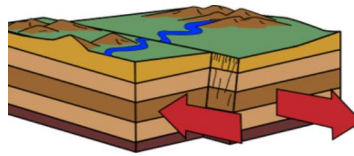


- A. Rising hot water
 B. Increase in pressure at high temperature
 C. Decrease in pressure at high temperature
 D. Hotter rocks transfer heat to cooler surrounding rocks
9. Why is the study of magma important?
- I. So we can better understand volcanoes
 - II. To have clues on how long Earth's life is
 - III. To understand better the structure of the core
 - IV. So we can gain insights on the structure of the mantle
- A. I and II
 B. I and IV
 C. II and III
 D. II and IV
10. The figure below shows a subduction zone. How does magma usually form in a subduction zone?

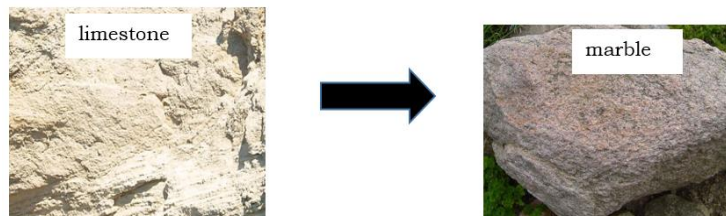


- A. Increase in pressure causes mantle rocks to melt faster.
 B. Hot rocks from the mantle rise to an area of lower pressure.
 C. Water in the subducting sea floor would lower the melting temperature of the mantle.
 D. Hotter rocks from the plate below rise into the cooler plate above, transferring heat.
 E.
11. Why do rocks undergo metamorphism?
- I. Changing pressure
 - II. Changing temperature
 - III. Changing chemical conditions
 - IV. Changing atmospheric conditions
- A. I and II
 B. III and IV
 C. I, II, and III
 D. I, II, and IV

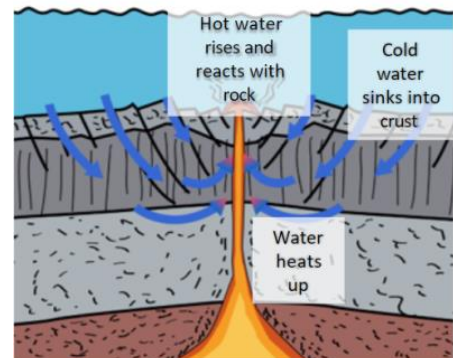
12. Examine the illustration below. How does metamorphism usually occur along Earth's fault lines? Choose the correct sequence below.



1. Rocks are pulverized due to high pressure.
 2. Original minerals are completely broken down.
 3. Rocks are scraped together along the Earth's fault lines.
 4. Minerals recrystallize as smaller, tightly intergrown grains making the rock denser.
- A. 1, 2, 3, 4
 B. 3, 1, 2, 4
 C. 2, 1, 3, 4
 D. 3, 4, 1, 2
13. Marble is formed when hot magma meets rocks like limestone at shallow depths. What changes will be seen in marble?



- A. Foliation
 - B. Growth in crystal size
 - C. Change in mineral composition
 - D. Bands of light and dark colored minerals
14. Slate is a metamorphic rock characterized by foliation or alignment of minerals. It is usually formed when plates move towards each other. What causes foliation?
- A. Reaction with hot water
 - B. High temperature, low pressure
 - C. High pressure, low temperature
 - D. High temperature, high pressure
15. The figure below shows hot water rising and reacting with rocks. When this happens, what changes will be observed?



Lesson 1

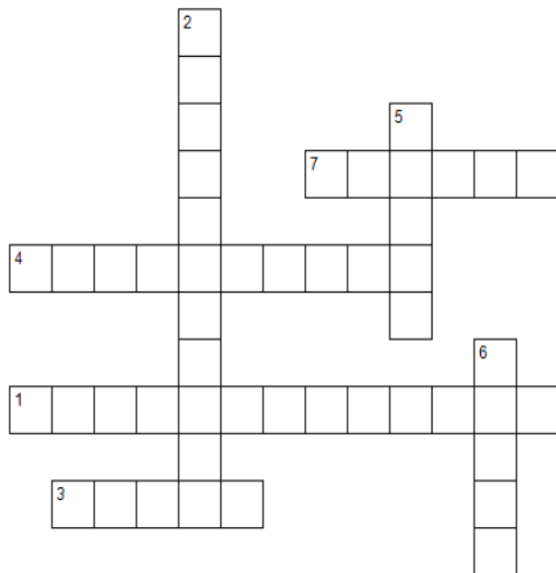
Earth's Internal Heat



What's In

Activity 1.1 Layers of the Earth Crossword Puzzle

In your previous science classes, you have studied the layers of the earth. You learned that temperature and pressure go up as we go down to the center of the earth. The crossword puzzle below contains important terms about the layers of the earth.



Across:

1. a layer within the mantle composed of hot, weak material that is capable of gradual flow
3. _____ core, molten layer of the earth
4. the envelope of gases surrounding the earth
7. layer of rock beneath the crust

Down:

2. rigid and relatively cool outer layer of the earth, composed of both crust and a portion of the upper mantle
5. _____ core, solid and dense layer at the center of the earth
6. thin, relatively light outer skin of the earth



What's New

In the previous lessons, you learned that Earth is unique because of its characteristics, one of which is plate tectonics. Plate tectonics is important in maintaining Earth's surface temperature. It is also responsible for the formation of landforms like mountains and volcanoes and the birth of new bodies of water where organisms live. Plate tectonics is one characteristic of Earth that allows it harbor life.

Have you ever wondered what causes plate tectonics? Scientists believe that it is the **internal heat** of the earth that fuels the movement of lithospheric plates.



Without Earth's internal heat, we would not be able to enjoy scenic views like our very own Mayon Volcano. Life, as we know it would change.



Figure 1.1. Mayon Volcano

Source: "Mayon Volcano". Wikimedia Commons. Accessed August 7, 2020.

https://commons.wikimedia.org/wiki/File:Paranoma_of_Maout_Mayon_Volcano,_Philippines.jpg



What Is It

When we say, "**internal heat**", this refers to heat emitted from Earth's layers. There is evidence that suggests that Earth's internal heat comes from two sources: one is the heat from when Earth started to form, and the other is from radioactive decay. The diagram below summarizes the sources of Earth's internal heat.

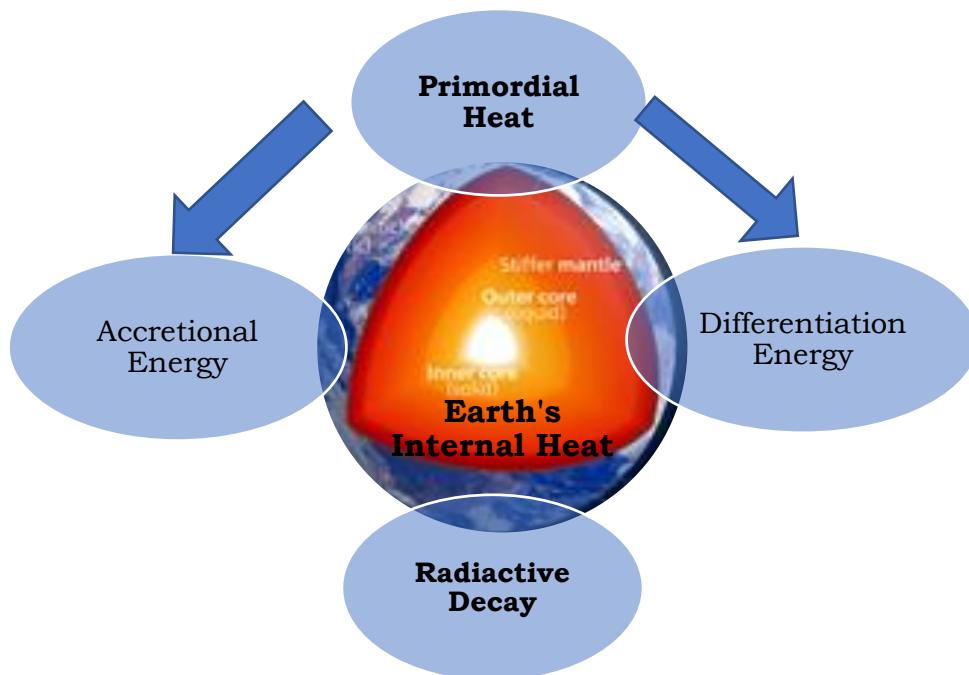


Figure 1.2. Sources of Earth's Internal Heat

Source: "Earth Poster". Wikimedia Commons. Accessed August 7, 2020.

https://commons.wikimedia.org/wiki/File:Earth_poster.svg

"**Primordial Heat**" is the term used to refer to the heat accumulated by Earth when it was formed. According to one theory called "Planetesimals Theory", terrestrial planets like Earth formed because of collision and accumulation of objects of dust origin called planetesimals. When they collided and accumulated, they produced heat.

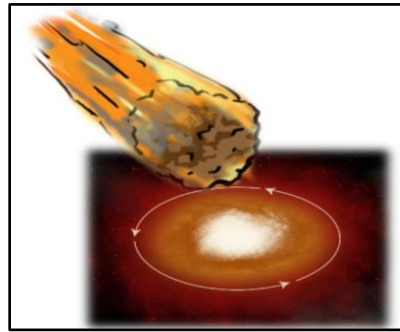


Figure 1.3. Primordial Heat

Source: Primordial Heat. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

Earth, according to the theory, started as a homogenous whole. The energy that it acquired while it grew is called **accretional energy**. Later, materials in Earth moved and separated from each other. The denser materials settled in the center and the lighter materials rose to the surface of Earth. This process called **differentiation**, formed Earth's layers: core, mantle, and crust. Movement of materials produced friction, which later was converted to heat.

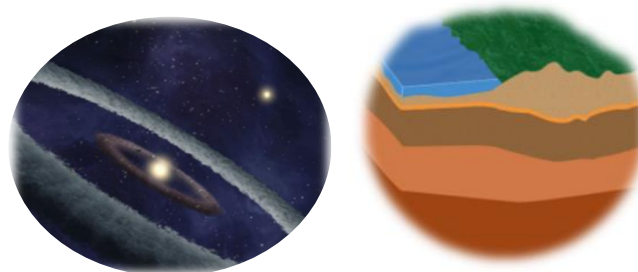


Figure 1.4. Accretional Energy and Differentiation Energy

Source: Accretional Energy and Differentiation Energy. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

The second source of Earth's internal heat is **radioactive decay**. Inside Earth are some unstable atoms. Because they are unstable, they do not live very long in that form. They tend to naturally turn themselves into more stable atoms. In the process of doing so, they release high energy particles and waves. This process is called radioactive decay. Current researches show that almost 50% of Earth's internal heat comes from radioactive decay. The elements identified to have the most abundant unstable isotopes are Uranium, Thorium and Potassium. Uranium is also used in nuclear power plants to produce electricity.

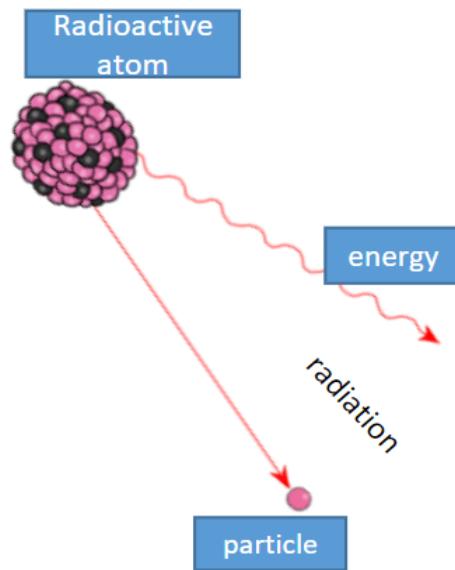


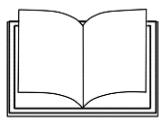
Figure 1.5. Radioactive Decay

Source: Radioactive Decay. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com



Figure 1.6. Nuclear Power Plant

Source: "Urumqi, China, Nuclear Power Plant". Pikist.com. Accessed August 7, 2020. <https://www.pikist.com/free-photo-iobtl>



What's More

Activity 1. 2 Sources of Earth's Internal Heat

Based on what you have learned, fill in the gaps with the word that will best complete the sentence. Copy and answer on a separate sheet of paper.

The 1. _____ (internal, external) heat of the earth comes from its layers. This heat is important because it is what drives the movement of lithospheric

2. _____ (plates, layers).

Scientists identify two sources of this heat. One is from when the Earth started to form. This is called 3. _____ (evolution, primordial) heat. This heat came from accretional energy and differentiation energy. 4. _____ (Accretional, Differentiation) energy is from the accumulation of objects of dust origin called 5. _____ (infinitesimals, planetesimals.) 6. _____ (Accretional, Differentiation) energy comes from the separation of Earth into layers with different properties. The denser materials settled in the center and form the 7. _____ (core, crust). The lighter materials rose to the surface forming the 8. _____ (crust, core).

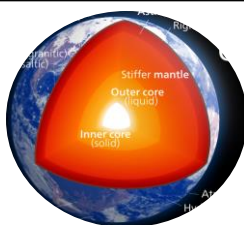
Another source of this heat are 9. _____ (stable, unstable) atoms. These atoms undergo a process where in they change into a more 10. _____ (stable, unstable) form. The byproduct of this process is the release of



What I Have Learned

Activity 1.3 Earth's Internal Heat Lesson Summary

Complete the sentences below.



1. Earth's internal heat is important because _____.

2. The sources of Earth's internal heat are _____.



Suppose you are a writer for a children's book. You want to write a story about our planet. Part of the story is where the internal heat of Earth comes from. How will you write that part of the story? Write your answer on a clean sheet of paper. Include illustrations that will make the story more interesting.

	3 points	2 points	1 point	0 point
Content	The story explains accurately accretional energy, differentiation energy and radioactive decay.	The story explains accurately two of the required contents.	The story explains accurately one of the required contents.	The story does not contain any explanation of the sources of Earth's internal heat.
Use of Illustrations	The illustrations add to the story's appeal to readers all the time	The illustration adds to the story's appeal to readers most of the time.	The illustration adds to the story's appeal to readers sometimes.	The illustration does not add to the story's appeal to readers.
Neatness	Incredibly neat, with no tears or smudges	Neat, with a few smudges or tears	With several smudges or tears	With many smudges or tears



- I. It fuels photosynthesis.
- II. It causes plates to move.
- III. It makes Earth like other planets.
- IV. It causes the formation of landforms.

- C. I and III
D. II and IV

2. How does radioactive decay contribute to Earth's internal heat?
 - A. Radioactive atoms tend to have a less stable form.
 - B. Particles of dust origin collided and accumulated.
 - C. Materials in the earth moved and separated into layers.
 - D. To become more stable, radioactive atoms emit high energy particles and waves.

3. How does differentiation energy add to Earth's internal heat?
 - A. Planetesimals collided and grew into a terrestrial planet.
 - B. Radioactive isotopes emit high energy waves and particles.
 - C. Movement of materials produce friction that is converted to heat.
 - D. Denser materials rise to the surface and lighter ones sink to the center.

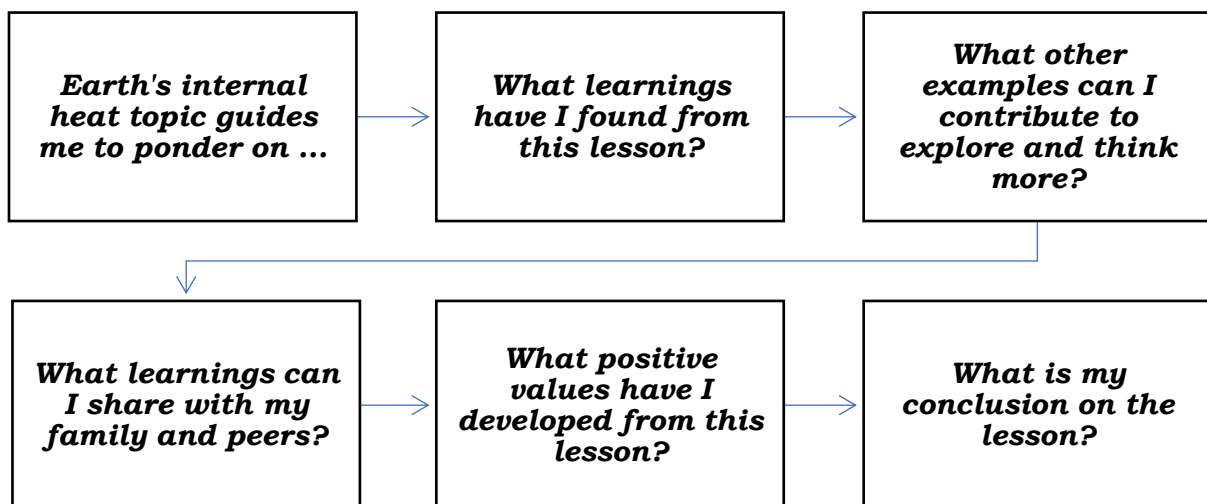
4. How does accretional energy add to Earth's internal heat?
 - A. Planetesimals collided and grew into a terrestrial planet.
 - B. Radioactive isotopes emit high energy waves and particles.
 - C. Movement of materials produce friction that is converted to heat.
 - D. Denser materials rise to the surface and lighter ones sink to the center.

5. Which of the following is **NOT TRUE** about Earth's internal heat?
 - A. It comes from the sun.
 - B. It comes from Earth's layers.
 - C. It is acquired during the early years of Earth's life.
 - D. Radioactive atoms contribute to around 50% of this heat.



Additional Activities

Write your reflection on Earth's internal heat by answering the questions inside the box. Express your critical and creative thinking skills in your answers. Have fun and enjoy!



Lesson 2

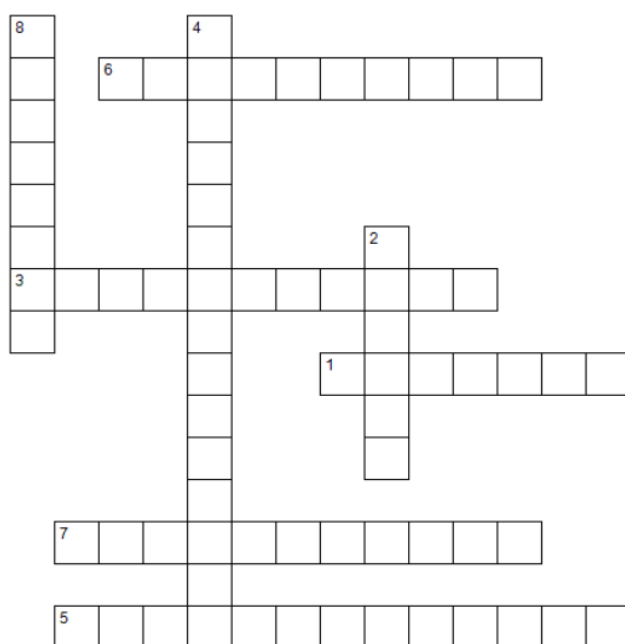
Magmatism



What's In

Activity 2.1 Earth's Internal Heat Crossword Puzzle

In the previous lesson, you studied the sources of Earth's internal heat. Do you still remember them? As a review, answer the crossword puzzle below.



Across:

1. an example of a radioactive element
3. energy from the accumulation of planetesimals
5. objects of dust origin
6. means "from the beginning of time"
7. an atom that is unstable

Down

2. emitted during radioactive decay
4. energy from the separation of Earth into layers
8. heat from Earth's layers



What's New

Have you ever tried hiking? Many people want to climb up mountains to experience nature in a new and exciting way. The Philippines is blessed with several mountains and volcanoes, one of which is Mount Hibok Hibok in Camiguin Island.



Figure 2.1. Mount Hibok Hibok

Source: "Hibok Hibok Volcano Crater". Wikimedia Commons. Accessed August 7, 2020. https://commons.wikimedia.org/wiki/File:Hibok_Hibok_Volcano_Crater.jpg

Volcanic activities have both benefits and hazards. Volcanic activities create fertile soil for agriculture. On the other hand, volcanic eruptions emit poisonous gases and lahars. Scientists study volcanoes to understand them better in the hope of minimizing hazards and maximizing benefits. Inside a volcano is magma. What is magma? Read on and find out.



What Is It

Magma refers to hot, molten material found below the earth's surface. When magma flows onto Earth's surface, it is called lava. Most of what we know about magma comes from studying lava and igneous rocks.



Figure 2.2. Lava

Source: "Magma, Lava, Volcanic Eruption". Pixabay.com. <https://pixabay.com/photos/lava-magma-volcanic-eruption-glow-67574/>

We know that magma is composed of the following: hot liquid base called melt, minerals, solid rocks, and dissolved gases.

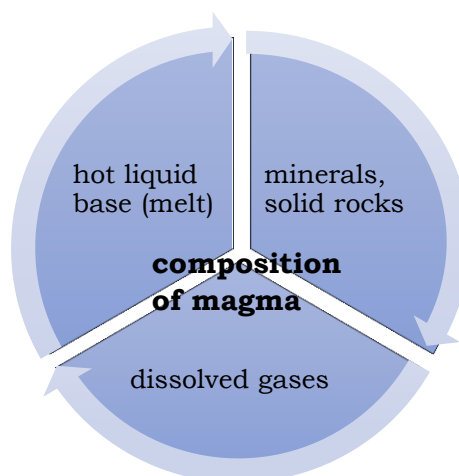


Figure 2.3. Composition of Magma

We also know that magma can be found in the lower portion of the Earth's crust and the upper part of the mantle. Because of its unique characteristics, scientists are studying magma closely to be able to find more clues about the structure of the mantle. In 2009, researches from Iceland, also found proof that magma can be utilized as a source of geothermal energy to produce electricity.

How does magma form? There are three different ways by which magma forms depending on temperature, pressure, and the properties of Earth's crust and mantle. We discuss them one by one here.

Examine the picture below. What type of plate boundary is shown in the picture? If your answer is divergent boundary, you are correct. When plates move away from each other just like what is shown here, there is an opening formed. The rocks of Earth's mantle move upward through this opening. The hot mantle rocks move to an area of less pressure and areas with less pressure have lower melting temperature. Because of this, rocks melt. We call this process of magma formation due to decrease in pressure, "**decompression melting**".

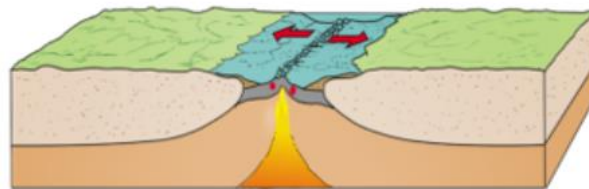


Figure 2.5. Decompression Melting

Source: Decompression Melting. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

Quick Review 1: Choose the correct word: **Decompression melting** happens when hot mantle rocks rise to an area of 1. _____ (increased, decreased) pressure. This normally occurs in 2. _____ (convergent, divergent) plate boundaries like mid-ocean ridges.

Magma also forms along hotspots. A hotspot is a particularly hot part of the mantle. When hot liquid rocks from the hotspot rise to Earth's surface, they cool and solidify. When they solidify, heat is transferred to the crust layer, causing the neighboring rocks to melt. This process of magma formation is called "**heat transfer**".

The illustration below demonstrates how heat transfer happens.

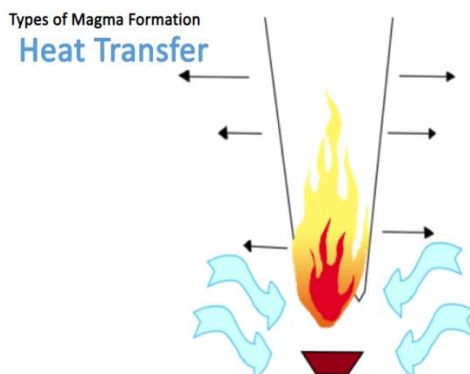


Figure 2.6. Magma Formation by Heat Transfer

Source: Magma Formation by Heat Transfer. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

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The Hawaiian Islands are believed to have formed from a hotspot. The picture below shows a simplified cross-section of the Hawaiian hotspot.

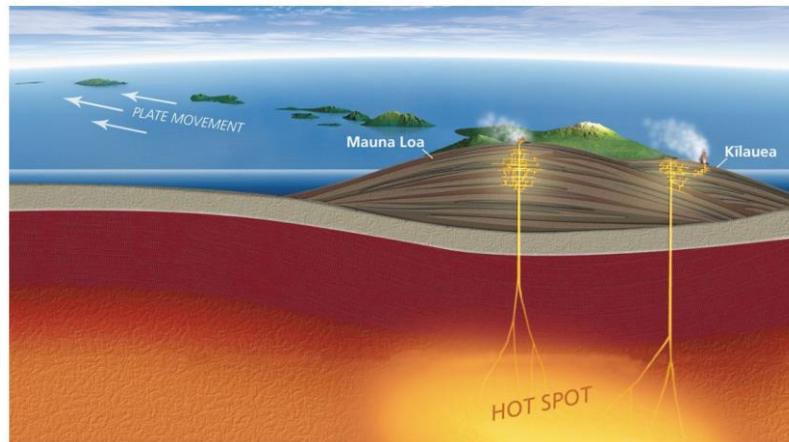


Figure 2.7 The Hawaiian Hotspot

Source: "Hawaiian Volcanoes". National Park Service. Accessed August 8, 2020.
<https://www.nps.gov/havo/learn/nature/volcanoes.htm>

Quick Review 2: Choose the correct word: **Heat transfer** usually occurs along
 1. _____ (hotspots, mid-ocean ridges). 2. _____ (Heat, Pressure) is
 transferred to cooler rocks causing them to melt.

The third type of magma formation occurs along convergent plate boundaries when a continental plate and an oceanic plate meet. Examine the illustration below showing a subduction zone.

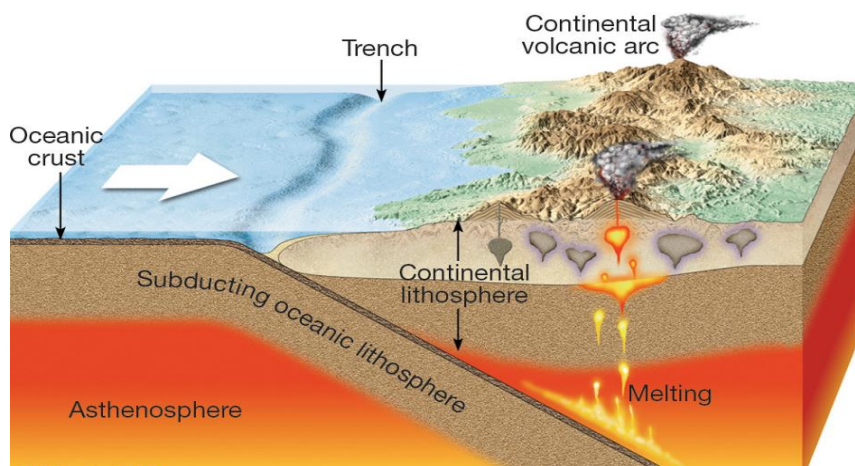


Figure 2.8. Subduction Zone

Source: PML Convergent Boundary. Flickr. Accessed August 7, 2020.
<https://www.flickr.com/photos/64320116@N08/15828380529>

The addition of substances that easily evaporate at normal temperature (called volatile substances) like water and carbon dioxide would disrupt the bond between the minerals of the mantle rock. As a result, the mantle rocks melt at lower temperature and form magma. This type of magma formation by the addition of water and carbon dioxide is called **flux melting**. It usually happens at subduction zones.

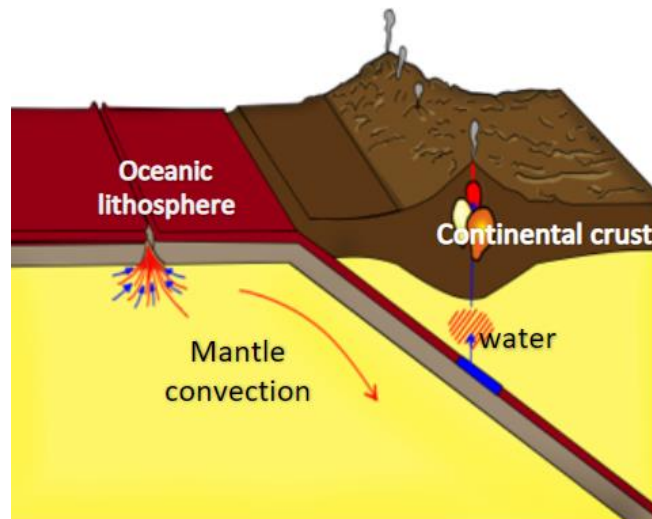
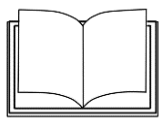


Figure 2.9. Magma Formation by Flux Melting

Source: Magma Formation by Flux Melting. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

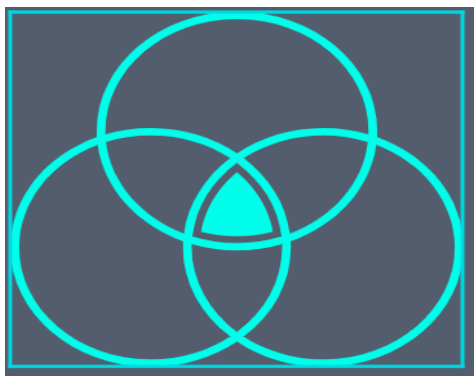
Quick Review 3: Choose the correct word: **Flux melting** usually happens in 1. _____ (mid-ocean ridges, subduction zones). The addition of water and carbon dioxide to mantle rocks _____ 2. (decrease, increase) the temperature at which they melt, forming magma.



What's More

Activity 2.2 Comparing the Different Ways Magma Form

Use a Venn Diagram to compare decompression melting, heat transfer and flux melting. Write your answer on a clean sheet of paper.



What I Have Learned

Activity 2.3 Magma Formation Lesson Summary

Summarize what you have learned today by answering the questions below.



Source: Magma. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

1. What is magma? What is it made of?
2. What are the three ways by which magma is formed? Describe each.

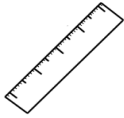


What I Can Do

Activity 2.4 Magma Infographic

Make an infographic about what magma is and the three ways by which magma is formed. Your work will be evaluated based on the rubrics below:

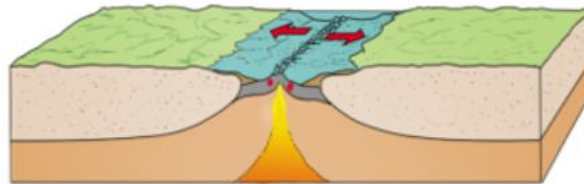
Criterion	3 points	2 points	1 point	0 point
Content	Accurate explanation on what magma is and the three ways magma can be formed is presented.	Most of the information presented is accurate.	Half of the information presented is accurate.	Less than half of the information presented is accurate.
Visual Appeal	Has all these elements: 1. originality, 2. creativity. 3. pleasantness achieved with the use of color, design, and space	Has two of the required elements.	Has one of the required elements.	Does not have any of the required elements.
Neatness	Incredibly neat, with no tears or smudges	Neat, with a few smudges or tears	With several smudges or tears	With many smudges or tears



Assessment

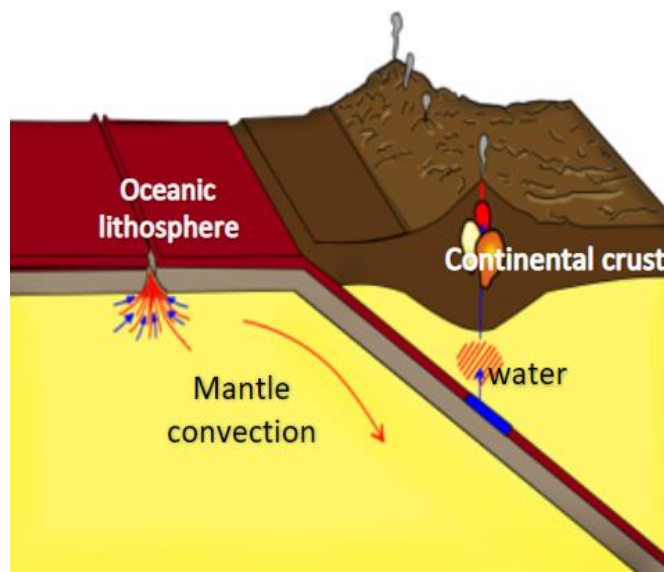
Read each question carefully and encircle the letter of the correct answer.

1. How does magma usually form in mid-ocean ridges?
 - A. Flux melting
 - B. Heat transfer
 - C. Compression melting
 - D. Decompression melting
2. Which of the following describes flux melting?
 - A. Rocks melt more easily because of decrease in pressure.
 - B. Rocks melt more easily because of increase in temperature.
 - C. Heat is transferred to surrounding rocks causing them to melt.
 - D. Adding water and carbon dioxide to mantle rocks make them melt easier.
3. The figure below shows decompression melting at divergent plate boundaries. Which of the following describes decompression melting?



- A. Hotter rocks transfer heat to cooler surrounding rocks.
 - B. Rising hot water reacts with rock causing them to melt.
 - C. Increase in pressure at high temperature causes rocks to melt.
 - D. Decrease in pressure at high temperature causes rocks to melt.
4. Which of the following is **TRUE** about magma?
 - I. It contains a liquid base.
 - II. It can be found in Earth's core.
 - III. It has minerals, rocks, and dissolved gases.
 - IV. It can be found in the lower part of the crust and upper mantle.
 - A. I and II
 - B. III and IV
 - C. I, III and IV
 - D. I, II and III

5. The figure below shows an oceanic plate and a continental plate in a convergent plate boundary. How does magma form in this type of plate boundary?



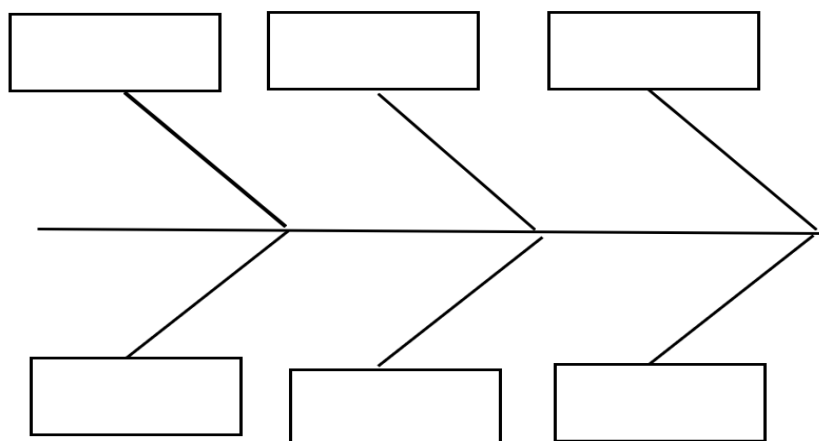
- A. Hot rocks from the mantle rise to an area of lower pressure.
- B. Adding water or carbon dioxide lowers the rocks' melting point.
- C. Water in the subducting sea floor would lower the melting temperature of the mantle.
- D. Hotter rocks from the plate below rise into the cooler plate above, transferring heat.



Additional Activities

How will you organize your learning about magma formation? Fill in the graphic organizer below. Copy and answer on a clean sheet of paper.

Types of Magma Formation



Lesson 3

Metamorphism



What's In

Activity 3.1 Types of Rocks

In your previous lessons, you classified rocks into igneous, sedimentary, and metamorphic rocks. Can you still differentiate the three? Identify which type of rock is described below. Write your answers on a separate sheet of paper.

Questions

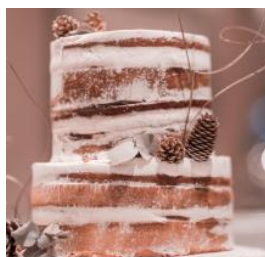
1. Which rock type is formed through the cooling and solidification of magma or lava like the process of making ice cubes with fruits inside them?

Answer: _____



2. Which rock type is formed by the accumulation and deposition of small particles like in the process of making a layered cake?

Answer: _____



3. Which rock type started out as some other type of rock, but have been substantially changed from their original form much like making omelets?

Answer: _____



Photo Credit

Source: "Blueberry and Cherry Baby Food Cubes". Wikimedia Commons. Accessed August 8, 2020.
https://commons.wikimedia.org/wiki/File:Blueberry_and_Cherry_Baby_Food_Cubes.JPG

Source: "Layered Cake". Pexels.com. Accessed August 8, 2020.
<https://www.pexels.com/photo/close-up-photo-of-two-layered-cake-1869342/>

Source: "Omelet". Pikrepo.com. Accessed August 8, 2020.
<https://www.pikrepo.com/fuqop/omelette-on-top-of-frying-pan>

? What's New

Do you like to cook or bake? If you have a knack for cooking, you can have a worthwhile hobby plus additional income. You can be an entrepreneur. Cooking involves taking raw ingredients and subjecting them to higher pressure and temperature so that something flavorful comes out.



Figure 3.1. Food

Sources: (from left to right) Food.

- (1) Pxhere. Accessed August 8, 2020. <https://pxhere.com/en/photo/1048398>
- (2) Pixabay.com Accessed August 8, 2020 <https://pixabay.com/photos/pancake-honey-nuts-fruits-3099315/>
- (3) Needpix.com. Accessed August 8, 2020. <https://www.needpix.com/photo/1777956/muffins-cake-bake-cupcake-delicious-schokoladenmuffins-free-pictures-free-photos-free-images>
- (4) Pickpix.com. Accessed August 8, 2020. <https://www.pickpik.com/small-cake-baking-delicious-strawberry-cake-food-and-drink-dessert-152853>

Rocks undergo similar process like cooking food. Rocks beneath the Earth's surface undergo changes because of the different conditions there. As a result, stronger, more dense rocks are formed.



What Is It

Metamorphism comes from two Greek words: "*meta*" meaning change and "*morphe*" meaning form. When rocks are exposed to different temperature, pressure, and chemical conditions, they undergo changes in texture and mineral composition. New minerals that can withstand these different conditions are formed.

The new rocks are called metamorphic rocks. Metamorphic rocks are denser and stronger rocks than the original parent rocks. Because of these properties, they are widely used as building materials. Some are also used as gemstones. Aside from economic values, scientists also study metamorphic rocks because of the insights they get about the changes that take place deep within Earth.

What are the changes that metamorphic rocks undergo? As rocks are exposed to increasing temperature or pressure, they experience more and more intense metamorphism. We call this intensity of metamorphism, **metamorphic grade**. As metamorphic grade increases, rocks undergo the following changes: increase in the size of crystals, foliation or alignment of minerals, and formation of

band of light and dark colored minerals. Other changes that happen to these rocks are changes in mineral composition and recrystallization of minerals into smaller, tightly intergrown grains. See the figure below:

Changes in Rocks with Increasing Metamorphic Grade

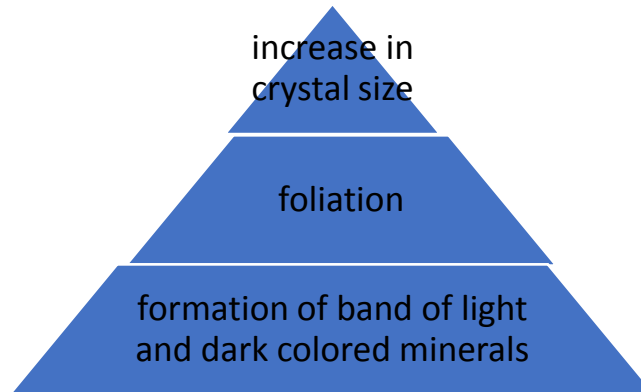


Figure 3.1. Changes in Rocks with Increasing Metamorphic Grade

Increase in size of crystals. This normally happens where there is temperature difference in shallow depths. At shallow depths, pressure is relatively low. This kind of metamorphism is called contact metamorphism. The picture below shows hot magma coming in contact with developed rocks causing them to transform.

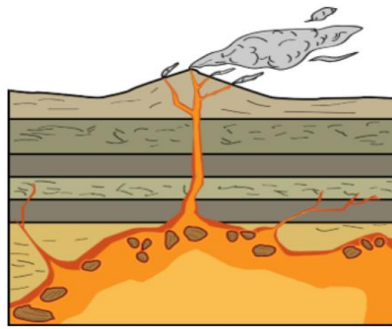




Figure 3.2. Contact Metamorphism

Source: Contact Metamorphism. Digital image. FrontLearners. Accessed August 7, 2020.
www.frontlearners.com

The metamorphic rocks formed would normally have the same mineral composition as the parent rock. However, the crystals would grow bigger. Quartzite and marble are examples of rocks that undergo this kind of metamorphism. Contact metamorphism is also called high temperature, low pressure metamorphism.

Table 3.1. Contact Metamorphism

Parent Rock	Metamorphic Rock	Change	Type of metamorphism
limestone  <i>Fig. 3.3 limestone</i> Source: Limestone Rock Free. Needpix.com. Accessed 8, 2020. https://www.needpix.com/photo/427472/limestone-rock-sea	marble  <i>Fig. 3.4 marble</i> Source: Stone marble rock. Wikimedia Commons. Accessed 8, 2020. https://commons.wikimedia.org/wiki/File:Stone_marble_rock.jpg	Increase in crystal size	Contact Metamorphism (high temperature, low pressure metamorphism.)

In the Philippines, the province of Romblon prides itself with its marble industry. The picture below shows some marble products from Romblon.



Figure 3.5. Marble Products from Romblon

Source: Romblon. Wikipedia. Accessed 8, 2020.

https://en.wikipedia.org/wiki/File:Romblon_island_089col.jpg

Foliation or alignment of minerals. Foliation refers to minerals aligning themselves due to pressure exerted on them. Foliation can either appear in visible band or microscopically. See the illustration below. If we have pens that are unaligned and we apply pressure (represented by the arrows) from the top and the bottom, we will notice that the pencils will move and align themselves.

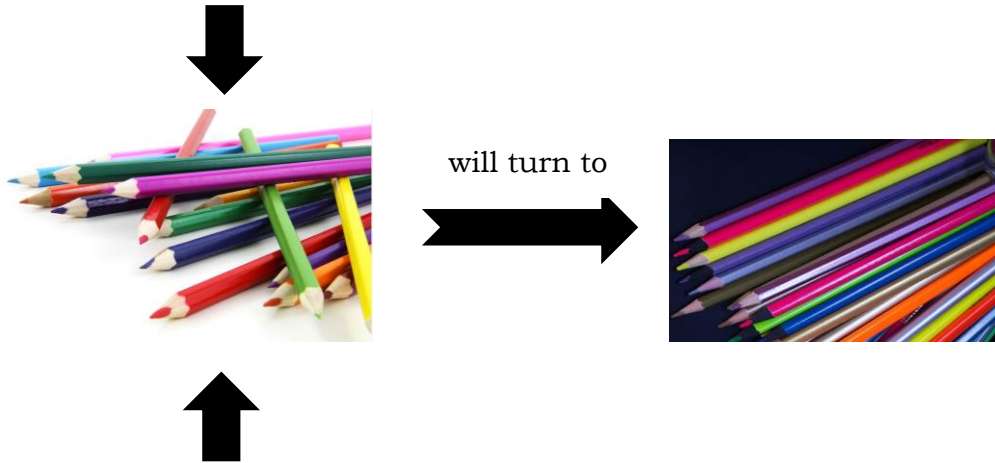


Figure 3.6. Foliation

Source: Pencils.Publicdomainpictures.net. Accessed August 8, 2020.

<https://www.publicdomainpictures.net/en/view-image.php?image=1786&picture=colored-pencils>

<https://www.publicdomainpictures.net/en/view-image.php?image=346136&picture=collection-of-colorful-pencils>

Foliation commonly occurs in settings with high pressure but relatively low temperature. An example of this setting is along convergent plate boundaries. See image below.

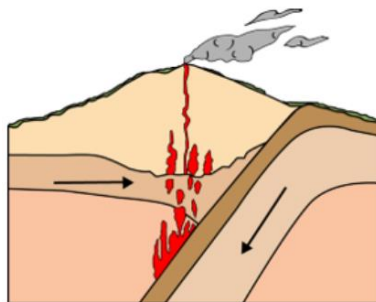


Figure. 3.7. Magma Formation in Convergent Plate Boundary

Source: Magma Formation in Convergent Plate Boundary. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

Like what we have mentioned before, plates moving toward each other create high pressure between them. This type of metamorphism is called regional metamorphism, also called high pressure, low temperature metamorphism. Slates and schists are examples of rocks formed this way. Slate is commonly used in roofing and flooring.

Table 3.2. Regional Metamorphism



Parent Rock	Metamorphic Rock	Change	Type of Metamorphism
shale  <p>Figure 3.8. shale</p> <p>Source: Shale stone broken. Needpix.com. Accessed 8, 2020.</p> <p>https://www.needpix.com/photo/923842/shale-stone-broken-texture-rocky</p>	slate  <p>Figure 3.9. slate</p> <p>Source: Red Slate. Flickr. Accessed 8, 2020.</p> <p>https://www.flickr.com/photos/jsjgeology/16896763826</p>	Alignment of minerals or foliation	Regional Metamorphism (low temperature, high pressure metamorphism)



Figure 3.10. Slate Used in Roofing

Source: Slates and Valley. Flickr. Accessed 8, 2020.
<https://www.flickr.com/photos/12394349@N06/3241240574>

Formation of alternating bands of light and dark colored minerals. See the picture below. It shows rocks buried in layers in sedimentary basins. The layers of sediment would have an increased pressure due to its weight, and an increase in temperature as it sinks into the deeper layer of the earth. As a result, rocks undergo what is called burial metamorphism, also called high temperature, high pressure metamorphism.

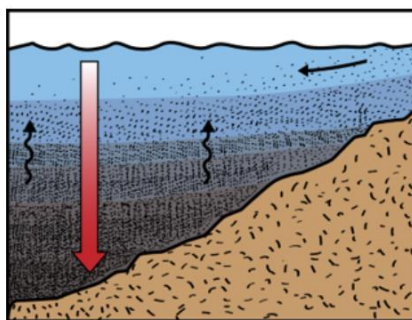




Figure 3.11. Burial Metamorphism

Source: Burial Metamorphism. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

Gneiss is an example of a rock that has undergone this type of metamorphism. See the table below. Do you notice that gneiss has alternate bands of light and dark colored minerals?

Table 3.3 Burial metamorphism

Parent rock	Metamorphic rock	Change	Type of Metamorphism
granite  <p>Figure 3.12. granite</p> <p>Source: Granite 20. Flickr. Accessed 8, 2020. https://www.flickr.com/photos/jsjgeology/49200364626</p>	gneiss  <p>Figure 3.13. gneiss</p> <p>Source: Gneiss. Flickr. Accessed 8, 2020. https://www.flickr.com/photos/jsjgeology/26196405084</p>	alternate bands of light and dark colored minerals	Burial Metamorphism (high temperature, high pressure metamorphism)

Gneiss has many uses as a building material such as flooring, gravestones, and ornamental stones.

Change in mineral composition. When hot water rises from the Earth's core, it dissolves and accumulates minerals as it moves towards the surface. Once it reaches the surface, it reacts with another rock and transforms that rock and the accumulated minerals. This type of metamorphism is called Hydrothermal Metamorphism. Hydrothermal comes from “hydro” which means water and “thermal” which refers to heat. The figure below demonstrates how this happens.

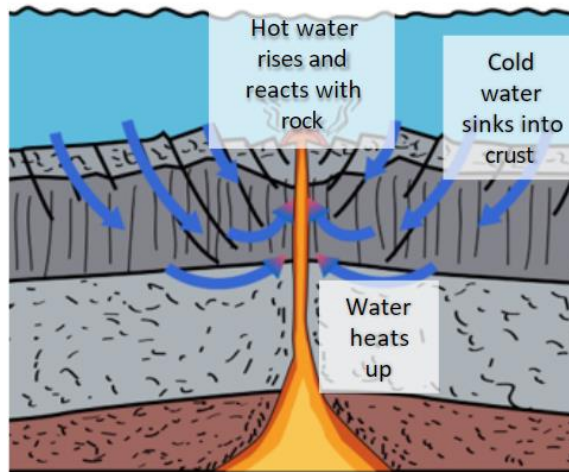


Figure 3.14 Hydrothermal Metamorphism

Source: Hydrothermal Metamorphism. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

This type of metamorphism results in rocks like Serpentinite. Serpentinite is formed when olivine and pyroxene minerals are transformed into serpentine minerals with the action of hot water. Serpentinite has uses in construction, ceramics, and agriculture.



Figure 3.15. Serpentinite Used as Ornament

Source: Serpentinite. Wikimedia Commons. Accessed August 7, 2020. https://commons.wikimedia.org/wiki/File:Kula_serpentynit.jpg

Recrystallization of minerals into smaller, tightly intergrown grains. This normally happens along Earth's fault lines. See the figure below:

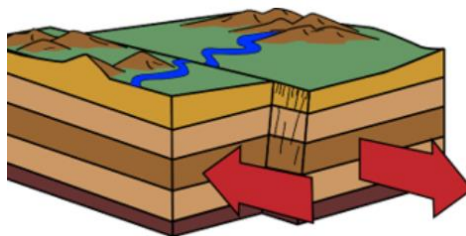


Figure 3.15. Fault Line

Source: Fault Line. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

In this setting, rocks are scraped together and pulverized due to high pressure and low temperature. Because of this, original minerals are almost completely broken down. They recrystallize as smaller, tightly intergrown grains.

The result is a denser metamorphic rock. This type of metamorphism is called Dynamic or Cataclastic Metamorphism. Example of rocks formed by this process is mylonites. Mylonites are used as aggregate in construction and roading industries as well as in medical industry.

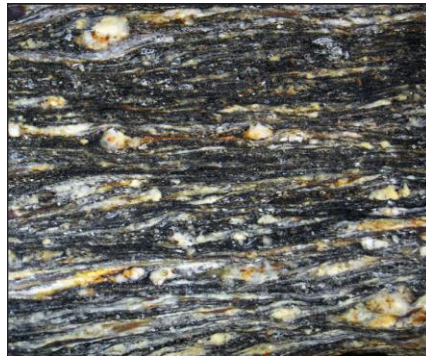
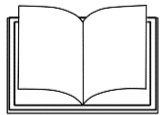


Figure 3.16. Mylonite

Source: Mylonite. Flickr. Accessed August 7, 2020.

<https://www.flickr.com/photos/jsjeology/30851255647>

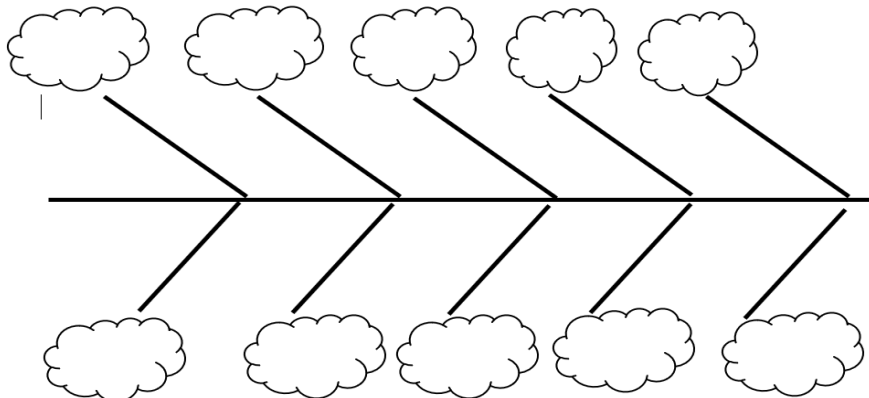


What's More

Activity 3.2 Types of Metamorphism

Use the graphic organizer below to organize your knowledge about the changes that rocks undergo in the different types of metamorphism. Copy and answer on a clean sheet of paper.

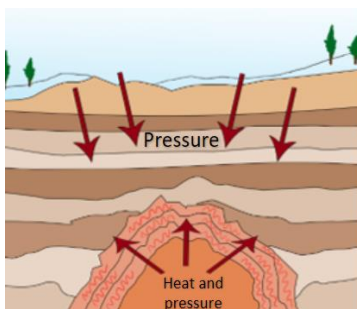
Types of Metamorphism and Changes in Rocks



What I Have Learned

Activity 3.3 Changes in rocks lesson summary

Summarize what you have learned in this lesson by filling in the blanks.



Source: Metamorphism. Digital image. FrontLearners. Accessed August 7, 2020. www.frontlearners.com

1. Metamorphism is the process wherein rocks and minerals _____.
2. Agents of metamorphism are _____, _____, and _____.
3. Some changes that rocks undergo during metamorphism are _____, _____, _____, _____ and _____.



What I Can Do

Activity 3.4 Development of Educational Material

As a geologist, you have been tasked to create an educational material that will serve as a visual aid about metamorphism of rocks. This material will be used by schools in your community to teach learners about the types of metamorphism and the changes that rocks undergo. You want them to appreciate the many uses of metamorphic rocks and to be good stewards of our environment and natural resources. You may choose to do **ANY** of the following:

- A. an educational poster
- B. an educational infographic
- C. an educational chart
- D. a big book
- E. a comic strip

For A, B, and C, your work will be evaluated based on the rubrics below:

Criterion	3 points	2 points	1 point	0 point
Content	Accurately describes three changes in mineral components and texture of rocks due to changes in pressure	Accurately describes two changes in mineral components and texture of rocks due to changes in pressure and	accurately describes one change in mineral components and texture of rocks due to changes in pressure and	does not describe any change in rocks due to changes in pressure and temperature and chemical

	temperature and chemical conditions	temperature and chemical conditions	temperature and chemical conditions	conditions
Visual Appeal	Has all these elements: 1. originality, 2. creativity. 3. pleasantness achieved with the use of color, design, and space.	Has two of the required elements.	Has one of the required elements.	Does not have any of the required elements.
Neatness	Incredibly neat, with no tears or smudges	Neat, with a few smudges or tears	With several smudges or tears	With many smudges or tears

For D and E, your work will be evaluated based on the rubrics below:

Criterion	3 points	2 points	1 point	0 point
Content	Accurately describes three changes in mineral components and texture of rocks due to changes in pressure and temperature	Accurately describes two changes in mineral components and texture of rocks due to changes in pressure and temperature	accurately describes one changes in mineral components and texture of rocks due to changes in pressure and temperature	does not describe changes in rocks due to changes in pressure and temperature
Appeal to Readers	The story is made interesting by appropriate word choice, illustration, and play of story elements.	One required element is missing.	Two required elements are missing.	The story does not have any of the required elements.
Neatness	Incredibly neat, with no tears or smudges	Neat, with a few smudges or tears	With several smudges or tears	With many smudges or tears



Assessment

Read each question carefully and encircle the letter of the correct answer.

1. Which of the following are considered agents of metamorphism?

- I. changing pressure
- II. changing temperature
- III. changing chemical conditions
- IV. changing atmospheric conditions

A. I and II

B. III and IV

C. I, II, and III

D. I, II, and IV

2. The illustration below shows gneiss. What change is noticeable in gneiss?

- A. Foliation
- B. Increase in crystal size
- C. Development of bands of light and dark minerals
- D. Recrystallization of minerals as smaller, tightly intergrown grains



3. Quartzite is formed in high temperature, low pressure settings. What changes can be observed in quartzite?



quartz sandstone



quartzite

Source:

Quartz Sandstone. Wikimedia Commons.
Accessed August 8, 2020.
https://commons.wikimedia.org/wiki/File:Quartz_Sandstone_Geopark.jpg

Source:

Quartzite. Wikimedia Commons. Accessed August 8, 2020.
https://commons.wikimedia.org/wiki/File:Sample_of_Quartzite.JPG

- A. Foliation
- B. Increase in crystal size
- C. Change in mineral composition
- D. Bands of light and dark colored minerals

4. Slate is a metamorphic rock characterized by foliation. Under what setting does foliation normally develop?
 - A. Hot water reacts with rocks.
 - B. High temperature, low pressure
 - C. High pressure, low temperature
 - D. High temperature, high pressure

5. What changes in rocks can be expected when hot water rises and reacts with them?
 - A. Foliation
 - B. Increase in crystal size
 - C. Change in mineral composition
 - D. Development of bands of light and dark colored minerals



Additional Activities

What is your favorite recipe? Just like what we have shared at the beginning of this lesson, metamorphism is like cooking. Can you make a model of a metamorphic rock using something edible like gelatin, bread, or cake? Cook the food then add some design to it (also edible) so that it looks like one of the metamorphic rocks that we have discussed. Explain in writing what changes your model underwent.

Example:



Explanation: The dough was subjected to high temperature. The finished product is harder and denser. The pepperoni toppings represent crystal growth. This model represents marble rock.

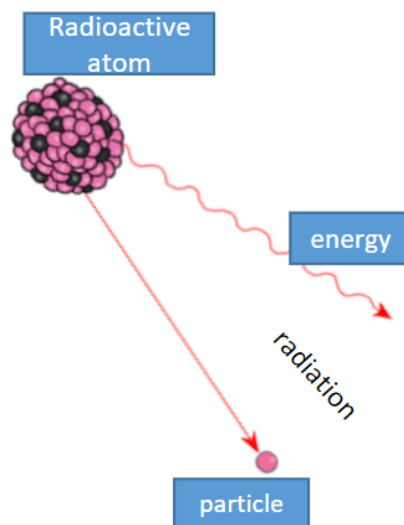


Posttest

Read each question carefully and encircle the letter of the correct answer.

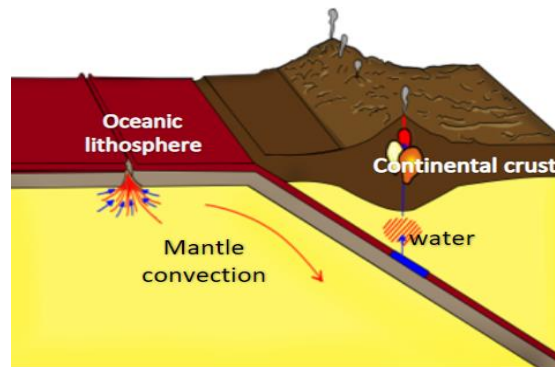
1. Suppose someone asks you how Earth's internal heat allows life forms to thrive, how will you answer?
 - I. It makes Earth like the other planets.
 - II. It helps maintain Earth's surface temperature.
 - III. It supplies energy for the formation of landforms.
 - IV. It adds to the number of years of Earth's existence.
 - A. I and II
 - B. III and IV
 - C. II and III
 - D. I and IV

2. Which of the following are sources of Earth's internal heat?
- I. solar energy
 - II. radioactive decay
 - III. accretional energy
 - IV. differentiation energy
- A. I and II
B. III and IV
C. I, II, and III
D. II, III, and IV
3. See the picture below. How does radioactive decay contribute to Earth's internal heat?

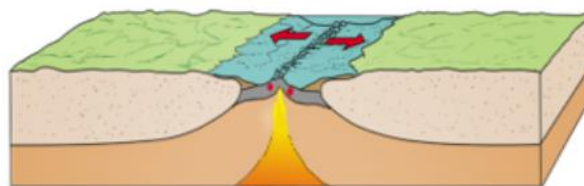


- A. As planetesimals collide and accrete, energy is released.
B. As atoms change to a more stable state, energy is released.
C. Materials in the earth separate into layers producing friction that is converted to heat.
D. Denser materials settle at the center of Earth while less dense materials rise to the surface.
4. How did Earth acquire heat according to the Planetesimals Theory?
- I. Radioactive atoms undergo radioactive decay.
 - II. Particles of dust origin collided and accumulated.
 - III. Materials in the earth moved and separated into layers.
 - IV. To become more stable, radioactive atoms emit high energy particles and waves.
- A. I and II
B. III and IV
C. II and III
D. III and IV
5. Why is the internal heat of the Earth important to life?
- A. It drives the movement of plates.
 - B. It protects the planet from solar flares.
 - C. It provides the energy for photosynthesis.
 - D. It shields the planet from harmful radiation from the sun.

6. The figure below shows a subduction zone. How does magma usually form in a subduction zone?



- A. Increase in pressure causes mantle rocks to melt faster.
 B. Hot rocks from the mantle rise to an area of lower pressure.
 C. Water in the subducting sea floor would lower the melting temperature of the mantle.
 D. Hotter rocks from the plate below rise into the cooler plate above, transferring heat.
7. Why is the study of magma important?
- so we can better understand volcanoes
 - to have clues on how long Earth's life is
 - to understand better the structure of the core
 - so we can gain insights on the structure of the mantle
- A. I and II
 B. I and IV
 C. II and III
 D. II and IV
8. The figure below shows divergent plate boundaries. What usually causes the melting of rocks along divergent plate boundaries?



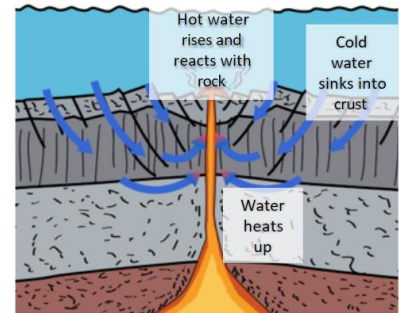
- A. Rising hot water
 B. Increase in pressure at high temperature
 C. Decrease in pressure at high temperature
 D. Hotter rocks transfer heat to cooler surrounding rocks
9. How does flux melting happen?
- By the addition of water and carbon dioxide
 - By the transfer of heat to surrounding rocks
 - By the lowering of melting point due to decrease in pressure
 - By the lowering of melting point due to increase in temperature

10. How does magma usually form in divergent plate boundaries?

- A. By flux melting
- B. By compression
- C. By heat transfer
- D. By decompression melting

11. The figure below shows hot water rising and reacting with rocks. When this happens, what changes in rocks is to be expected?

- A. Foliation
- B. Increase in crystal size
- C. Change in mineral composition
- D. Development of bands of light and dark colored minerals and dark colored minerals



12. Slate is a metamorphic rock characterized by foliation or alignment of minerals. It is usually formed when plates move towards each other. What causes foliation?

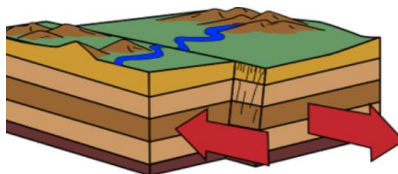
- A. Reaction with hot water
- B. High temperature, low pressure
- C. High pressure, low temperature
- D. High temperature, high pressure

13. Marble is formed when hot magma meets rocks like limestone at shallow depths. What changes can be observed in marble?

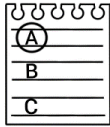


- A. Foliation
- B. Growth in crystal size
- C. Change in mineral composition
- D. Bands of light and dark colored minerals

14. Examine the illustration below. How does metamorphism usually occur along Earth's fault lines? Choose the correct sequence below.



1. Rocks are pulverized due to high pressure.
 2. Original minerals are completely broken down.
 3. Rocks are scraped together along the Earth's fault lines.
 4. Minerals recrystallize as smaller, tightly intergrown grains making the rock denser.
- A. 1, 2, 3, 4
B. 3, 1, 2, 4
C. 2, 1, 3, 4
D. 3, 4, 1, 2
15. Why do rocks undergo metamorphism?
- I. changing pressure
 - II. changing temperature
 - III. changing chemical conditions
 - IV. changing atmospheric condition
- A. I and II
B. III and IV
C. I, II, and III
D. I, II, and IV



Answer Key

Lesson 1

What's In

Activity 1.1

Across:

1. asthenosphere

3. outer

4. atmosphere

7. mantle

Down:

2. lithosphere

5. inner

6. crust

What's More

Activity 1.2

1. internal

2. plates

3. primordial

4. accretional

5. planetesimals

6. Differentiation

7. core

8. crust

9. unstable

10. stable

11. radioactive

Lesson 1

Assessment

1. D

2. D

3. C

4. A

5. A

What I Have Learned Activity 1.3

1. Earth's internal heat is important because it is what drives plate tectonics or the movement of plates.

2. The sources of Earth's internal heat are primordial heat and radioactive decay. Primordial heat consists of accretional energy from the accumulation of planetesimals and differentiation energy from the separation of Earth into layers.

Lesson 2

What's In

Activity 2.1

Across:

1. Uranium

3. accretional

5. planetesimals

6. primordial

7. radioactive

Down

2. energy

4. differentiation

8. internal

What's More

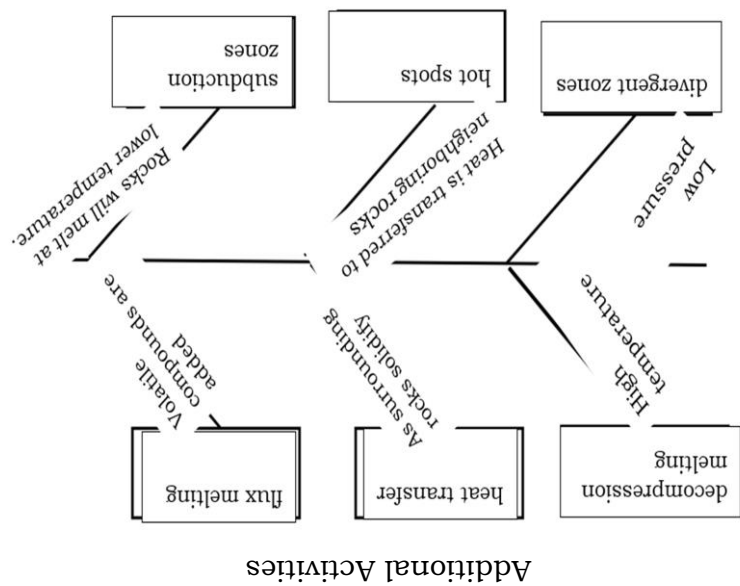
Activity 2.2

What I Have Learned

Activity 2.3

1. Magma is hot, molten material found below the earth's surface. Magma is composed of the following: hot liquid base called melt, minerals, solid rocks, and dissolved gases.

2. There are three different ways by which magma forms. Decompression melting happens when hot mantle rocks rise to an area of decreased pressure. This normally occurs in divergent plate boundaries like mid-ocean ridges. Heat transfer usually occurs along hotspots. Heat is transferred to cooler rocks causing them to melt. Flux melting usually happens in subduction zones. The addition of water and carbon dioxide to mantle rocks decrease the temperature at which they melt, forming magma



Quick Review 1

1. decreased

2. divergent

Quick Review 2

1. hotspots

2. heat

Quick Review 3

1. subduction zones

2. decrease

Lesson 2 Assessment

1. D

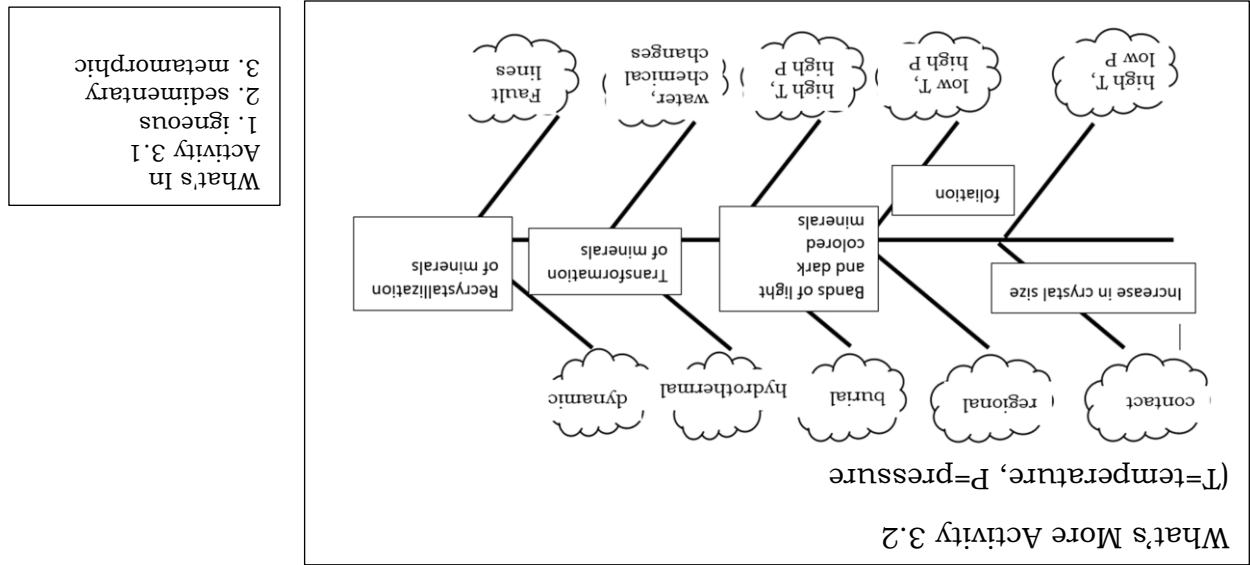
2. D

3. D

4. C

5. B

Lesson 3



What I Have Learned Activity 3.3

1. Metamorphism is the process wherein rocks and minerals undergo transformation due to change in chemical and environmental conditions.
2. Agents of metamorphism are temperature, pressure, and volatile compounds like water.
3. Some changes that rocks undergo during metamorphism are increase in crystal size, foliation, alternating bands of light and dark-colored minerals, transformation of minerals and recrystallization of minerals into smaller, tightly intergrown grains making the rock denser.

Lesson 3 Assessment

1. C
2. C
3. B
4. C
5. C



References

- (1) "Dynamic Metamorphism." Chemeketa Community College Faculty Web Server. Accessed July 16, 2020.
<https://faculty.chemeketa.edu/afrank1/rocks/metamorphic/dynamic.htm>
- (2) "Earth Rocks!" CCSF. Accessed July 16, 2020.
<https://www.ccsf.edu/en/educational-programs/school-and-departments/school-of-science-and-mathematics/earth-sciences/Courses/EarthRocks.html>.
- (3) "Geological Society - Gneiss Uses." The Geological Society. Accessed August 8, 2020.
<https://www.geolsoc.org.uk/ks3/gsl/education/resources/rockcycle/page3486.html>.
- (4) "Geology - Rocks and Minerals." Access Restricted. Accessed August 8, 2020.
https://flexiblelearning.auckland.ac.nz/rocks_minerals/rocks/mylonite.html.
- (5) "Hazards and Benefits of Volcanic Activity | Physical Geography." Lumen Learning – Simple Book Production. Accessed August 8, 2020.
<https://courses.lumenlearning.com/suny-geophysical/chapter/hazards-and-benefits-of-volcanic-activity>.
- (6) "How Volcanoes Work - Earth's Internal Heat, Energy, and Interior Structure." Accessed August 8, 2020.
https://sci.sdsu.edu/how_volcanoes_work/Heat.html.
- (7) "Mineral Identification Key Mineral Properties & Luster." Mineralogical Society of America - Mineralogy, Petrology and Crystallography. Accessed July 16, 2020.
https://www.minsocam.org/msa/collectors_corner/id/mineral_id_keyi3.htm.
- (8) "Primordial." Oxford Learner's Dictionaries | Find Definitions, Translations, and Grammar Explanations at Oxford Learner's Dictionaries. Accessed July 16, 2020.
<https://www.oxfordlearnersdictionaries.com/us/definition/english/primordial?q=primordial>.
- (9) "Serpentinities: Mineral Structure, Properties and Technological Applications." SciELO - Scientific Electronic Library Online. Accessed August 8, 2020. https://www.scielo.br/scielo.php?pid=S0103-50532020000100002&script=sci_arttext.
- (10) "Slate." Geology and Earth Science News, Articles, Photos, Maps and More. Accessed August 8, 2020.
<https://geology.com/rocks/slate.shtml>.

- (11) "Volcanoes: Magma Rising | AMNH." American Museum of Natural History. Accessed August 8, 2020.
<https://www.amnh.org/explore/ology/earth/volcanoes-magma-rising>.
- (12) FOG. Accessed August 8, 2020.
<https://fog.ccsf.edu/~kwiese/content/Classes/MetamorphismScript.pdf>.
- (13) Institute of Physics. "Radioactivity." Institute of Physics - For Physics • For Physicists • For All: Institute of Physics. Accessed July 16, 2020.
<https://www.iop.org/resources/topic/archive/radioactivity/#gref>.
- (14) National Geographic Society. "Magma." National Geographic Society. Last modified April 4, 2019.
<https://www.nationalgeographic.org/encyclopedia/magma/>.
- (15) National Geographic Society. "Magma's Role in the Rock Cycle." National Geographic Society. Last modified October 31, 2014.
<https://www.nationalgeographic.org/article/magma-role-rock-cycle/>.
- (16) Science and Technology Academic and Research-Based Openly Operated KioskS. Accessed August 11, 2020.
<https://www.starbooks.ph>.
- (17) Schwartz, Ariel. "Volcanic Magma Could Provide Geothermal Energy." Fast Company. Last modified July 30, 2012.
<https://www.fastcompany.com/1728785/volcanic-magma-could-provide-geothermal-energy>.
- (18) YouTube. Last modified August 11, 2019.
https://www.youtube.com/watch?v=QO2OO1r_tFg.

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