Senior High School

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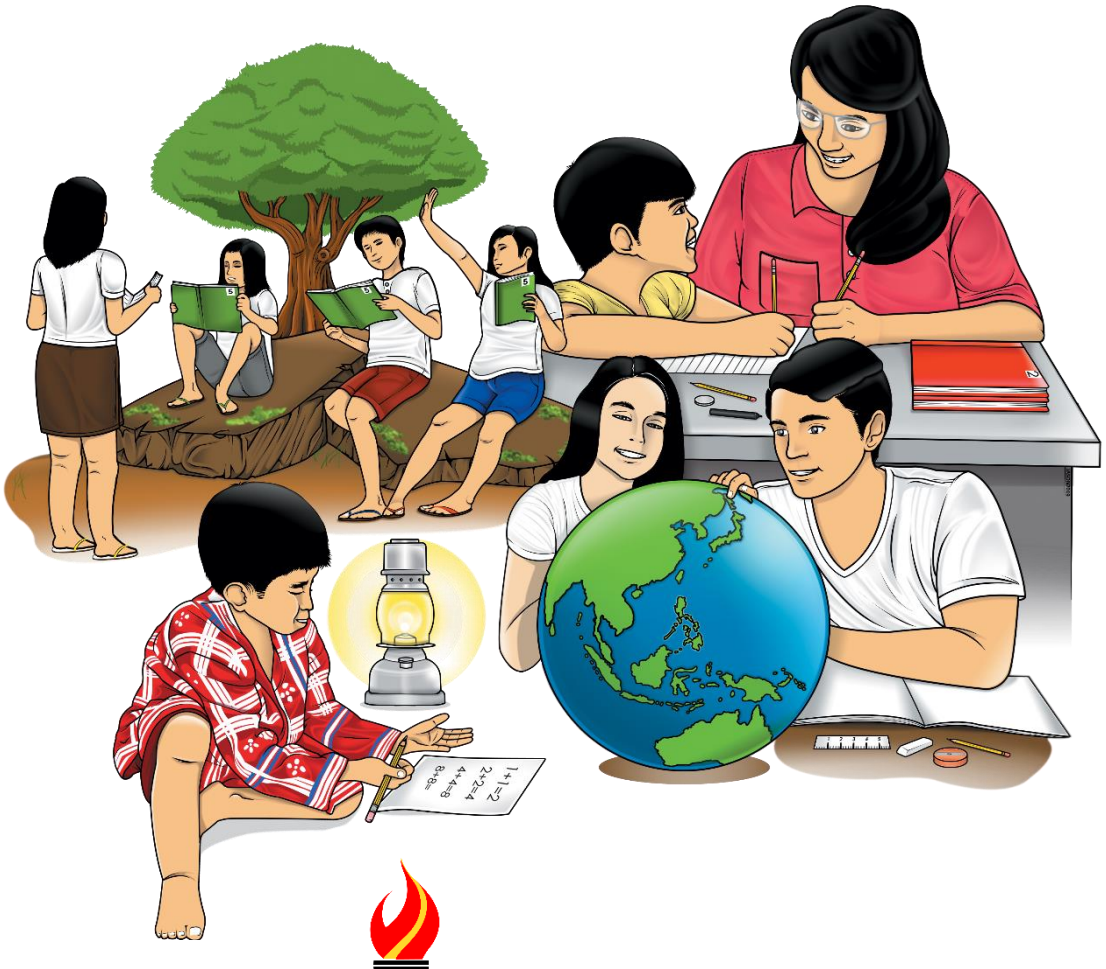
Earth Science for STEM
Quarter 2 – Module 4: Metamorphism



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Introductory Message

This Self-Learning Module (SLM) is prepared so that you, our dear learners, can continue your studies and learn while at home. Activities, questions, directions, exercises, and discussions are carefully stated for you to understand each lesson.

Each SLM is composed of different parts. Each part shall guide you step-by-step as you discover and understand the lesson prepared for you.

Pre-tests are provided to measure your prior knowledge on lessons in each SLM. This will tell you if you need to proceed on completing this module or if you need to ask your facilitator or your teacher's assistance for better understanding of the lesson. At the end of each module, you need to answer the post-test to self-check your learning. Answer keys are provided for each activity and test. We trust that you will be honest in using these.

In addition to the material in the main text, Notes to the Teacher are also provided to our facilitators and parents for strategies and reminders on how they can best help you on your home-based learning.

Please use this module with care. Do not put unnecessary marks on any part of this SLM. Use a separate sheet of paper in answering the exercises and tests. And read the instructions carefully before performing each task.

If you have any questions in using this SLM or any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator.

Thank you.

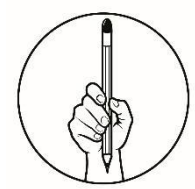
What I Need to Know

This module was designed and written with you in mind. It is here to help you master the concept of the process of metamorphism accompanying the changes in rocks' composition and texture. The scope of 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.

The module discussions are evolving in the different factors affecting the process of metamorphism and its effect on the mineral and texture of the rocks.

After going through this module, you are expected to:

1. identify the factors involved in metamorphism,
2. differentiate the types of metamorphism; and
3. explain the effects of pressure and temperature on the composition and texture of the rocks undergoing metamorphism.



What I Know

Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. What causes changes in the composition of a rock during the process of metamorphism?
    a. increase in pressure
    b. increase in temperature
    c. reaction with hydrothermal fluids
    d. All of these.

2. Which of the following is the process exhibited by parallel alignment of mica in a metamorphic rock?
    a. bedding
    b. foliation
    c. metasomatism
    d. porphyroblasts

3. Which of the following sets of rocks is arranged in order of increasing metamorphic grade?
    a. shale - slate - schist
    b. phyllite - schist - slate
    c. schist - shale – gneiss
    d. phyllite - gneiss - schist

4. Which of the following statements about the metamorphism of limestone is **FALSE**?
    a. With increasing metamorphism, foliation develops.
    b. With increasing metamorphism, the amount of water decreases.
    c. With increasing metamorphism, the calcite minerals form a larger crystal.
    d. With increasing metamorphism, the grain size of the minerals gets smaller.

5. Which of the following is **TRUE** about contact metamorphism?
    a. It occurs within the continental crust.
    b. It takes place when heat and shock waves are formed from meteor or asteroid impact.
    c. Pressure has an important role in the transformation of rocks in contact metamorphism.
    d. It is prominent in areas where surrounding rocks are exposed to heat coming from magma intrusion.

6. Which of the following transformations is directly related to pressure in producing metamorphic rocks?
    a. formation of foliation
    b. change mineralogical in the rock
    c. the increasing size of mineral crystals
    d. change in mineral composition of the rock

7. Which of the following metamorphic rocks would **NOT** come from mudrock?
    a. Gneiss
    b. Marble
    c. Schist
    d. Slate

8. What process contributes to the metamorphism of oceanic crust at the zone of spreading ridge?
    a. Dissolved minerals in the water confined within the rocks react with the heat and trigger a chemical reaction.
    b. Minerals present in the ocean water percolate through the rocks and become deposited within the rocks while replacing other minerals.
    c. The heat coming out from hydrothermal vents under the ocean heats the rock which leads to recrystallization of the original mineral content of the rock.
    d. Interaction of plates below the spreading oceanic crust creates horizontal movements and deforms the rocks within leading to formations of foliations and cracks.

9. Rigel argued with his classmates that the rock that he found in the campsite near the foot of the *Taal* volcano was a metamorphic rock. Others claimed that it was a volcanic rock because it was found near a volcano hence, an igneous rock. What features of the rock would have convinced Rigel that it was a metamorphic rock and not an igneous rock?
    a. The minerals in rocks are almost invisible to be seen.
    b. The rock contains bits of old shells of snails and wood.
    c. The surface of the rock has holes similar to Swiss cheese.
    d. The rock contains interlocking and large crystals of minerals compared to minerals found in igneous rocks.

10. Diamonds are minerals made through a process like metamorphism which results in a very dense arrangement of carbon atoms. What type of metamorphism would create a diamond?
    I. Burial metamorphism
    II. Contact metamorphism
    III. Shock metamorphism
    IV. High-pressure metamorphism
    V. Hydrothermal metamorphism

    a. I and II b. II and V c. III and IV d. IV and V

11. Which of the following metamorphic rocks may have come from a shale?
    a. gneiss
    b. phyllite
    c. schist
    d. All of the above.

12. In which geographic area will there be a metamorphic rock with very distinct foliations?
    a. near magma intrusion
    b. at the core of the Himalayas
    c. in the mid-ocean ridge in the Atlantic Ocean
    d. in convergent boundaries where plates move towards each other

13. Low-grade metamorphism takes place at temperatures between 200 ^{o}C to 320 ^{o}C, and at relatively low pressure. Which metamorphic rock is created in this environmental setting?
    a. Gneiss
    b. Hornfels
    c. Schist
    d. Slate

14. How does the presence of a hot pluton contribute to metasomatism?
    I. The heat coming from the pluton heats up the rock and triggers the recrystallization of its original minerals.
    II. A hot pluton heats the surrounding water, causing groundwater to circulate around the rocks.
    III. Magma within the pluton cooks up the minerals and destroys its original crystal arrangements.

        a. Only I is correct.
        b. Only II is correct.
        c. I and II are correct.
        d. All are correct.

15. How does metasomatism occur?
    a. Minerals recrystallize through contact metamorphism due to heat.
    b. The arrangement of original minerals is destroyed by the impact due to asteroid bombardment.
    c. Minerals recrystallize and realign through regional metamorphism due to heat and pressure.
    d. The dissolved minerals in the fluids react with rocks that the fluids penetrate causing changes in chemical and mineral compositions.

Lesson 4

Metamorphism

This lesson contains activities and readings about one of the geologic activities that take place inside the Earth's crust. You will learn basic concepts and information about metamorphism through a brief discussion of the process, the factors involved during the process, and its connection to tectonic settings and the environment where metamorphism occurs. In the activities, you are expected to use the knowledge and skills that you learned and gained from the previous modules in connection to the new set of skills and information that you will learn from this module.

What's In

In the previous module, you learned about the three processes that take place inside the Earth that influence the shape and structure of the Earth – magmatism, volcanism, and plutonism. In this module, you will learn another important geologic process that also takes place inside the earth – Metamorphism. **Metamorphism** is one of the geologic processes in which rocks change in form, composition, and structure due to intense heat and pressure and sometimes with the introduction of chemically active fluids. While learning through this module, you can make concept connections between major geologic features such as tectonic features of Earth and endogenic processes that you learned previously with the processes that rocks undergo during metamorphism - how those geologic processes influence the changes that rocks undergo and form the so-called metamorphic rocks.

Notes to the Teacher

Hello dear teachers, this module may be used by learners with minimal supervision. The activities included are suitable for their level and capacity. As pre-requisite to this module, make sure that the learners had finished the previous modules on minerals, classification of rocks and endogenic processes such as magmatism, volcanism and plutonism. Thank you.

What's New

Activity 1

Geologic processes that take place underneath the ground are very hard to describe because we cannot directly observe what's going on beneath us. Hence, to visualize the events that are taking place in the Earth's crust, let us do this simulation activity.

For this activity, you may ask the help of your parents or siblings with you at home. You may use materials as alternatives if the ones given are not available at your house. Let's start.

Follow the procedures for each set-up below. Answer the guide questions that follow. Write your answer on a separate sheet of paper.

Set-up 1

Materials:

- Raw egg white
- A shallow pan (you may use a plate as an alternative)
- Boiled water in a glass jar or bottle

Procedures:

1. Separate yolk from the egg white (you will be using only the egg white) and pour it in a shallow pan.
2. Transfer your boiled water to a glass jar or a bottle and place it in the middle of the pan.
3. Observe the changes in the egg white.

Guide Questions:

1. What did you notice on the egg white near the glass jar with hot water? What do you think caused that change?
2. Did you observe any change on the egg white far from the hot glass jar? How can you explain this observation?

Set-up 2

Materials:

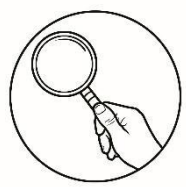
- pieces of sticks taken from *walis ting-ting* with different lengths
- two rulers (you may use any alternative for the purpose)

Procedures:

1. Drop the sticks onto an even surface and let them take a different direction or orientation.
2. Using two rulers, placed on either side of the sticks, pull them toward the center while trapping the sticks in the middle.

Guide Questions:

1. The sticks represent the minerals present in the rocks. What changes did you observe on the sticks when you pulled the rulers together towards the middle?
2. In the activity, the rulers represent the tectonic forces that push rocks. What can you infer from this activity about the minerals in rocks when undergoing the same forces?
3. In this process, can you name the factor responsible for the changes that occurred?



What is It

The activity demonstrates how rocks respond to geologic factors such as heat and pressure in forming ***metamorphic rocks*** through ***metamorphism.*** Metamorphism takes place tens of kilometers below the surface where temperatures and pressures are high enough to transform rock without melting it. The increase in temperature and pressure and change of the chemical environment can change the mineral composition and crystalline textures of the rock while remaining solid all the while. The metamorphic rocks under these change conditions depend on the original rock chemistry, the exact pressures, and temperature to which rocks are subjected, and the amount of water available for chemical reaction.

Factors Involved in Metamorphism

1. Temperature. It plays a crucial role in metamorphism. The heat affects the rock's chemical composition, mineralogy, and texture. For instance, during **burial metamorphism**, at a depth of about 8 to 15 kilometers from the surface of the crust, metamorphic reactions begin. The rocks adjust to the new temperature causing their atoms and ions to recrystallize and form new arrangements thereby creating new mineral assemblages. During recrystallization, new crystals grow larger than the crystals in the original rock.

For example, in figure 1,when sedimentary rock (mudrock) – shale becomes buried deeper and deeper, the clay minerals in the rock will begin to recrystallize and form new minerals, such as micas in slate – a metamorphic rock from shale. With additional burial, at greater depth, where the temperature is higher, mineral micas begin to transform into a new mineral garnet in schist – another metamorphic rock with a higher grade. The rate at which temperature increases

with depth in the Earth's crust is known as ***geothermal gradient*** which varies on plate tectonic settings like the thickness of the crust or whether the area is in the subduction zone between oceanic and continental or under the converging two continental crusts. Subduction zones, for instance, are characterized by low-temperature metamorphism, and the area at which collision takes place between two converging crustal plates is characterized by high-temperature metamorphism. In a nutshell, *the higher the temperature, the higher the metamorphism grade* until such time when the temperature is high enough to melt the rocks resulting in the formation of magma.

Sedimentary rock – Shale with clay minerals

Metamorphic rock – Slate with mica minerals

Metamorphic rock – Schist with garnet minerals

Figure 1. Sedimentary to Metamorphic Rocks

2. Pressure. Like temperature, it changes the composition, mineralogy, and texture of rocks. Pressure is different in various tectonic settings, like temperature. For instance, metamorphism in the subduction zone is characterized by ***high-pressure metamorphism***. In contrast, the collision zone between two continental crusts is marked by ***moderate-pressure metamorphism***.

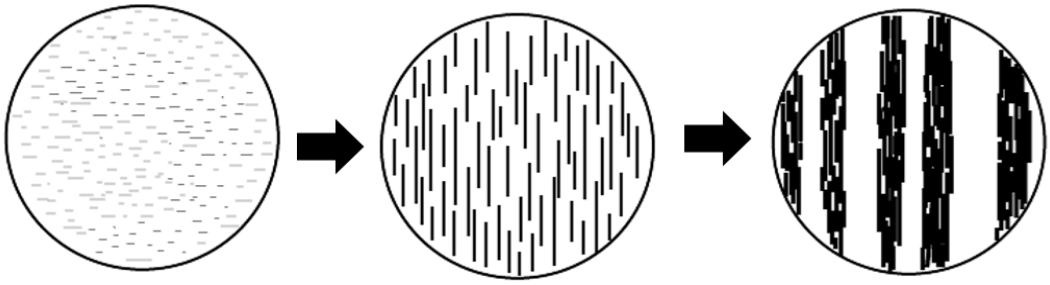
There are two types of pressures known also as stresses that exert force on rocks causing changes.

a. The ***vertical stress*** or ***confining pressure*** is the stress or pressure exerted on the rock by the weight of overlying material such as in *burial metamorphism*. This type of pressure is the same in all directions and makes the rocks to fracture or deform.

b. The ***directed*** or ***differential pressure*** is imposed by a force in a particular direction. Differential pressure is dominant at convergent boundaries where plates move towards each other and collide thus exerting force and cause rocks to deform. *Pressure* causes rocks to form folds in a particular direction as directed by the pressure, thus directed pressure guides the shape and orientation of the new crystals formed as minerals recrystallize under the influence of both heat and pressure. This results in a textural change such that the minerals are elongated in the direction perpendicular to the directed stress and this contributes to the formation of *foliation*.

Foliation is a set of flat or wavy parallel cleavage planes produced by deformation under directed pressures. In the figure below, the effect of compression due to pressure aligns the minerals as they recrystallize during metamorphism. The diagram on the

left represents the minerals in shale, a sedimentary rock with beddings in the direction shown. The diagram in the middle represents minerals in slate, a low-grade metamorphic rock from the original rock shale, with mica crystals orientated perpendicular to the direction of the pressure. The minerals in higher-grade metamorphic rock schist, with very evident foliation, are represented by the diagram in the far right which shows larger bandings of minerals caused by even greater pressure.



Sedimentary rock – Shale with bedding

Metamorphic rock – Slate with foliation

Metamorphic rock – Schist with larger foliation

Figure 2. Foliation during Metamorphism

Hydrothermal fluids also play a role in metamorphism. The dissolved minerals in the fluids react with rocks causing changes in chemical and mineral compositions and sometimes completely replacing one mineral with another without changing the textures of the rocks. This type of metamorphism is known as ***metasomatism*** in which the alteration process is caused by fluids passing through the rock and catalyzing chemical reactions. For example, when the heat of the intrusive igneous body heats up the groundwater containing dissolved minerals, convection of water forms flowing through the surrounding rocks and penetrating through them. Reactions occur among chemicals in the rocks and in the water resulting in significant changes in the mineralogy of the rock. An example is the alteration of feldspars to clays, and deposition of quartz, calcite, and other minerals in fractures or cracks and other open spaces forming veins such as represented by the figure below.

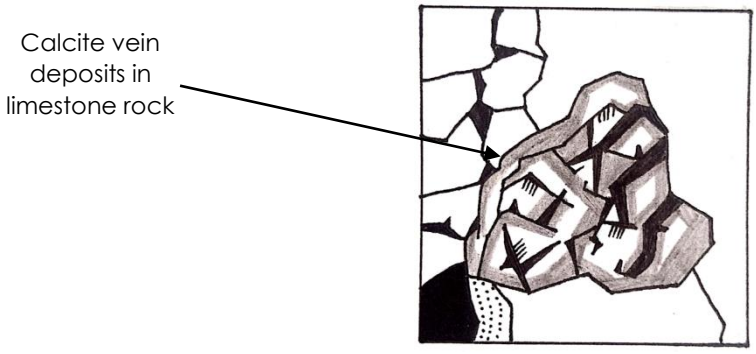


Figure 3. Limestone with Calcite Vein Deposits

Metamorphism caused by hydrothermal fluids also occurs in mid-ocean ridges where hot lava, coming out of the fissures, reacts with mineral-rich ocean water. This causes serpentines to form through oxidation and hydration chemical reaction of peridotites- olivine-rich rocks at the base of the oceanic crust. This is known as ***serpentinization***.

Types of Metamorphism

Metamorphic rocks are categorized based on *geologic origins*.

Regional Metamorphism forms foliated metamorphic rocks such as *Gneiss* and *Schist* due to high temperature and pressure imposed on large parts of the crust. Most regional metamorphism occurs within the continental crust. Although rocks can be metamorphosed at depth in most areas, deep below the mountains produced by the collision of two continental crusts is the area of *greatest regional metamorphism.* In general, the confining and directing pressures exerted by some tectonic forces onto rock formations cause new alignment of minerals (*foliation*) during recrystallization.

Another type of metamorphism is ***contact metamorphism*** which is prominent in areas where surrounding rocks are exposed to heat coming from magma intrusion within the layers of the rocks. *Marble*, *quartzite,* and other ***granoblastic*** rocks with large visible crystals of minerals may be formed through contact metamorphism. For example, when the quartz-rich sedimentary rock encounters enough heat from the presence of igneous intrusions to trigger recrystallization, all sedimentary structures are destroyed and quartz grains in the sandstone recrystallize to form an interlocking mosaic of crystals giving it a granoblastic texture. The resulting rock is white or pale grey known as *metaquartzite*. The size of the crystals is larger near to the contact with the igneous intrusion and smaller when further away from the contact where temperatures are not as high. The same things happen with limestone, the parent rock of marble. The heat coming from igneous intrusion destroys the calcite minerals including the fossils found in the limestone and forms a marble with an interlocking mosaic of crystals. A limestone made of pure calcite minerals would transform into pure white marble.

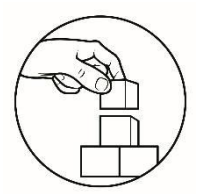
Other types of metamorphism include ***shock metamorphism*** which takes place when the heat and shock waves from meteor or asteroid impact transform rocks immediately around the impact site. Examples of this are the transformation of mineral graphite into ultra-high-pressure *polymorph diamond* and the conversion of quartz minerals into *coesite* under high shock pressures. ***Burial Metamorphism*** occurs at lower temperature and pressure which transforms sedimentary rocks that had undergone *diagenesis* into low-grade metamorphic rocks through relatively low temperature and pressure. Partial alteration of the mineralogy and texture may occur while other sedimentary structures are usually preserved.

In subduction zones, between two converging plates, ***high-pressure metamorphism*** occurs. Metamorphic rocks created through these processes are rarely found on the Earth's surface as they were formed in such a great depth. Some metamorphic rocks formed through these types of metamorphism contain bits of microscopic diamonds, an indication that the rock was formed with great pressure. An example of rock made through this type of metamorphism is the *eglcosite* which has transformed with pressure greater than 28 kbar at a depth of approximately above 80 km.

Based on the discussion presented above. Answer the questions about metamorphism. You may write your answer on a piece of paper.

Questions:

1. At what depths in the Earth do metamorphic rocks form? What happens if temperature and pressure get too high?
2. What texture is formed when mineral crystals are aligned with preferred orientation in a metamorphic rock?
3. How would you relate the grade of metamorphic rocks to the degree of temperature in which it was made?
4. Which metamorphic rock would you associate with a high grade of regional metamorphism (phyllite, slate, schist, or gneiss)? Why?
5. Why is it important to study metamorphism? How would you relate your chosen field (STEM) to this kind of study?



What's More

Activity 1

A. Identify the geologic area and the respective type of metamorphism that occurs in the encircled portion of the illustration below. Please refer to the template table below for your answers. Write your answers on a separate sheet of paper.

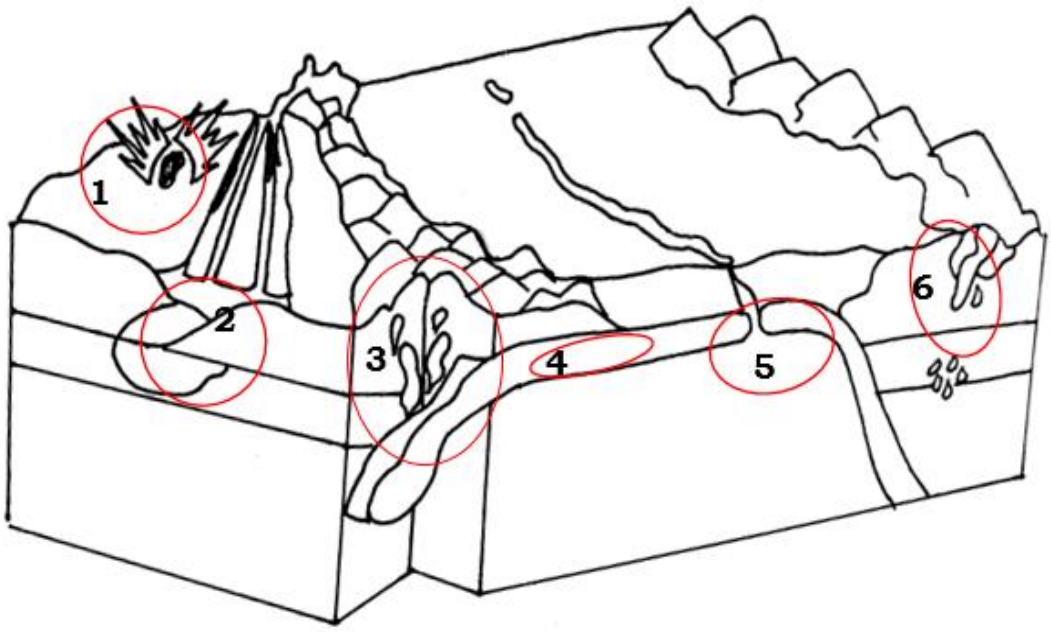


Figure 4. Types of Metamorphism and where they occur

Table 1. Data Table for Activity 1: Metamorphism and Geologic Area

No.	Geologic area	Type of Metamorphism
1		
2		
3		
4		
5		
6		

Activity 2

Fill in the table below with the correct information about metamorphism. Write your answers on a separate sheet of paper.

Table 2. Completion table for Metamorphism

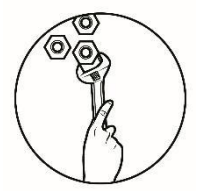
Type of metamorphism	Changes that occur in rocks	Agent/factor responsible for the change	Most strategic geographic location where it occurs	Example of metamorphic rock formed
(1)	alignment of minerals perpendicular to force	(2)	(3)	(4)
(5)	(6)	(7)	(8)	Hornfels
(9)	(10)	the heat from the impact of the asteroid	(11)	(12)
(13)	(14)	(15)	Subduction zone	(16)
Burial metamorphism	(17)	(18)	(19)	(20)
(21)	(22)	Hydrothermal fluids	(23)	(24)

What I Have Learned

Complete the sentences below by writing the correct word/phrase. Write your answer on a separate sheet of paper.

1. Metamorphism is the alteration of rock's _____, _____, and _____.
2. Metamorphic rocks are formed when rocks are subjected to significant changes in _____ and _____.
3. Confining pressure is _____, whereas directed pressure is _____.
4. In the presence of directed pressure, recrystallization may align minerals _____ to the force/stress applied on the rocks.

5. _____ metamorphism takes place where both high pressure and temperature are imposed over large parts of the crust and usually takes place in _____ plate boundaries.
6. _____ is the localized transformation of rocks near to igneous intrusions mainly because of high temperatures.
7. Other types of metamorphism are _____, _____, and _____.
8. _____ is created by alignment of minerals under directed pressure.
9. Granoblastic rocks are _____ rocks composed mainly of crystals that grow in large size and distinct shapes.
10. Metasomatism occurs when the change in rock's composition is due to interactions with _____.



What I Can Do

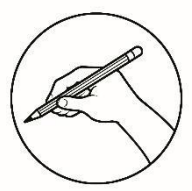
Semi-fieldwork Activity

Go to your backyard, home, or school garden or in any place near and safe for you to collect some metamorphic rocks and bring them home. (Make sure to clean them first and don't forget to wash your hands).

Make a table like the one below and make a log of the information about the rocks that you collected.

Table 3. Data Table for Semi-field Activity

Rock Sample number	Picture/ Drawing	Describe the features of the metamorphic rock sample	Classify the type of the metamorphic rock sample	Write your inference about how the rock samples underwent metamorphism.
1				
2				
3				



Assessment

Multiple Choice. Choose the letter of the best answer. Write the chosen letter on a separate sheet of paper.

1. Which of the following statements about the metamorphism of shale is **FALSE**?
    A. Foliation develops as metamorphism increases.
    B. The amount of water decreases as metamorphism increases.
    C. The clay minerals break down to form micas as metamorphism increases.
    D. The size of the minerals gets smaller as metamorphism increases.

2. Which of the following has the **CORRECT** set of major agents in metamorphism?
    A. temperature and pressure
    B. pressure and tectonic forces
    C. temperature and mineral fluids
    D. hydrothermal fluids and pressure

3. Which of the following **CORRECTLY** describes the major role of pressure in producing metamorphic rocks?
    A. Pressure leads to foliation in the rock.
    B. Pressure decreases the size of mineral crystals.
    C. Pressure leads to a mineralogical change in the rock.
    D. Pressure facilitates change in the mineral composition of the rock.

4. What type of metamorphic rock will form if a mudrock experiences high-grade metamorphism?
    A. Gneiss
    B. Phyllite
    C. Schist
    D. Slate

5. Granite is an igneous rock that is formed through the slow solidification of magma. Accordingly, it does not change very much at lower metamorphic grades. Why is this so?
    A. Granite minerals are still stable at lower temperatures.
    B. Granite, like any other igneous rock, is geologically impossible to become a parent rock of metamorphic rock.
    C. Granite remains largely unchanged at lower metamorphic grades because its surrounding environment is constantly stable.
    D. All of the above.

6. What process contributes to the metamorphism of oceanic crust at a spreading ridge?
    A. Dissolved minerals in the confined water within the rocks react with heat and trigger chemical reactions.
    B. The heat coming out from hydrothermal vents under the ocean heats up the rock and forms recrystallization of the original mineral content of the rock.
    C. Minerals present in the ocean water percolate through the rocks and get deposited within while replacing other minerals.
    D. Interaction of plates below the spreading oceanic crust creates horizontal movements and deforms the rocks within leading to formations of foliations and cracks.

7. While walking, Daniel picked up a rock that had been washed up onto the beach. Noticing that it has wavy bands of light and dark-colored minerals, he claimed that the rock is a metamorphic rock. Which of the following inferences about its formation is the **MOST CORRECT**?
    A. The pressure was the main agent in rock's formation which aligned the minerals into a new orientation.
    B. The rock was formed through high-pressure metamorphism made by the impact of a large body into the Earth's surface.
    C. The minerals in the rocks were altered through recrystallization changing their size into large crystals.
    D. The bands in the rock were formed through the deposition of minerals from the hot fluids that surround it during the formation process.

8. Which of the following is the cause of high temperature and pressure in regional metamorphism?
    A. impact force
    B. greater depth of burial
    C. the local intrusive heat source
    D. increased rate of radioactive decay

9. Which of the following metamorphic rocks **CANNOT** form from a shale?
    A. hornfels
    B. marble
    C. schist
    D. slate

10. On a local field trip, a group of students noticed that they were walking across a path made of rocks that starts from shale into a slate and into a phyllite. What can you infer from the direction taken by the students concerning the grades of metamorphic rocks?
    A. It follows a decreasing metamorphic grade.
    B. It indicates an increasing metamorphic grade.
    C. It indicates an increasing degree of contact metamorphism.
    D. It shows a decreasing degree of regional metamorphism.

11. In which geographic area will there be the **HIGHEST** potential for regional metamorphism?
    A. in the Philippine trench
    B. near an igneous intrusion
    C. at the core of the Himalayas
    D. in the mid-ocean ridge in the Atlantic Ocean

12. Which of the following does **NOT** belong to the group?
    A. Gneiss
    B. Hornfels
    C. Marble
    D. Quartzite

13. Blueschist metamorphism takes place within subduction zones. What are the temperature and pressure characteristics of this geological setting?
    A. low temperature and pressure
    B. high temperature and pressure
    C. low temperature and high pressure
    D. high temperature and low pressure

14. How does the presence of a hot pluton contribute to metasomatism?
    I. A hot pluton heats the surrounding water, causing groundwater to circulate the rocks.
    II. Magma within the pluton is the source of minerals that seeps through the rocks and causes chemical exchange.
    III. The heat coming from the pluton heats up the rock and triggers recrystallization of its original minerals.

    A. Only **I** is correct.
    B. Only **II** is correct.
    C. **I** and **II** are correct.
    D. All are correct.

The figure below shows a microscopic illustration of minerals of certain sedimentary rock (parent rock) which is subjected to high pressure and temperature underground forming a foliated metamorphic rock.

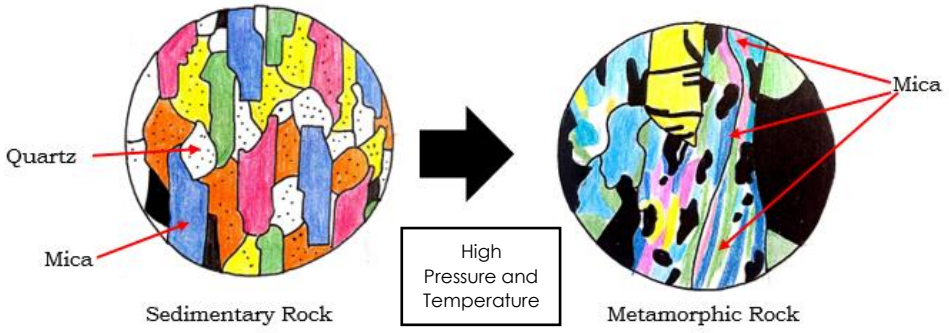
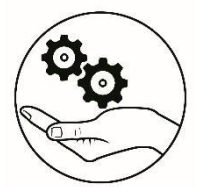


Figure 5. Schematic representation of Metamorphic reaction

15. What type of metamorphism occurs in the given illustration?
    a. Burial metamorphism
    b. Contact metamorphism
    c. Regional metamorphism
    d. Shock metamorphism



Additional Activities

Using the important terms or vocabularies and concepts from this module, create a concept map about metamorphism. You may use a computer in creating your concept map or draw it on a piece of typewriter paper. Once you are done, please submit your work to your teacher. Good luck!

Rubrics

Key Elements	**Very Satisfactory (3pts.)**	**Satisfactory (2 pts.)**	**Needs Improvement (1 pt.)**
Organization	● Terminologies are logically organized. ● Keywords are used/ presented to promote an overview of the unit. ● The organization of the concepts/ terms is easy to follow.	Only two indicators are evident.	Only one indicator is evident.
Content and Concept	● The concept map contains most of the main/important concepts. ● Appropriate terminologies and notations are used/presented. ● No misconceptions and errors are evident in the concept map.	Only two indicators are evident.	Only one indicator is evident.
Relationship among Content/Concept	● All words are accurately connected. ● Arrows easily connect concepts in an informative manner. ● Meaningful and original insights are clearly demonstrated in the concept map.	Only two indicators are evident.	Only one indicator is evident.

Answer Key

What I Know

1. D
2. B
3. A
4. A
5. D
6. A
7. B
8. A
9. D
10. C
11. D
12. D
13. D
14. C
15. D

What is it

Metamorphism begins at about 8 to 15 kilometers below. As the temperature and pressure increase, metamorphism also increases. When temperature is too high, rock melts to form magma.

Foliated texture

The greater the temperature, the higher the metamorphic grade

gneiss

What's More

Part A.

Shock metamorphism; on the Earth's surface around meteor or asteroid impact zone

Burial metamorphism; below sedimentary rock layers

Regional metamorphism; in the convergence zone area, deep below the mountain ranges

High-pressure metamorphism; on the subduction zone area

Hydrothermal metamorphism; on mid-ocean ridges area

Contact metamorphism; Below the Earth's surface along magma/igneous intrusion

What's More

Part B.

1. Regional metamorphism
2. Pressure
3. in convergence zone area
4. Gneiss
5. Contact metamorphism
6. increasing size of crystal
7. Heat
8. along magma intrusion
9. Impact Metamorphism
10. transition of minerals into another mineral
11. Impact zone
12. Diamond
13. High-pressure metamorphism
14. change in mineralogy and texture
15. High pressure
16. Eclogites
17. low temperature and pressure
18. partial alteration in mineralogy and texture
19. below continental crust
20. Slate
21. Hydrothermal metamorphism
22. Change in mineral composition
23. Mid- Ocean ridge
24. Serpentine

Assessment

1. D
2. A
3. A
4. C
5. A
6. D
7. A
8. B
9. B
10. B
11. D
12. C
13. B
14. C
15. C

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