METAMORPHIC ROCKS

Teacher Guide
including
Lesson Plans, Student Readers, and More Information

Lesson 1 - Formation of Metamorphic Rocks

Lesson 2 - Metamorphic Rock Classification Chart

Lesson 3 - Metamorphic Rocks - Lab

Lesson 4 - The Many Facies of Metamorphic Rocks

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designed to be used as an Electronic Textbook
in class or at home

materials can be obtained from the Math/Science Nucleus

EARTH SCIENCES - METAMORPHIC ROCKS

Lesson 1 - Formation of Metamorphic Rocks

MATERIALS:

reader

Objective: To learn where metamorphic rocks are formed.

Teacher note

Metamorphic rocks are the most difficult to understand and to identify. Show a picture of the rock cycle before beginning this unit. Illustrate how the three different types of rocks can change into another type of rock. Although metamorphic rocks are forming today, it is difficult to see. Increasing temperature and pressure occurs inside the crust of the Earth, which is impossible for humans to observe.

Hold up a sedimentary or igneous rock. Ask the students to imagine what the rock would look like if it was squished. Accept any reasonable answers. Explain that metamorphism uses heat and pressure to change rocks. There is no net gain of elements in the system, just a changing of the chemistry. You can use the analogy of a square dance, when you “change” partners to make a different pair dancing. This creates new metamorphic rocks. Remind students that if pre-existing rocks are broken and recemented they are sedimentary, and if they are remelted and cooled, they are igneous.

You may want to have several samples of metamorphic rocks and the rocks they changed from. A gneiss could have come from a granite (igneous). Shale (sedimentary) could have become slate. Slate (metamorphic) if put under more pressure could change into a schist. A basalt (igneous) could also become a schist. Limestone (sedimentary) can become marble.

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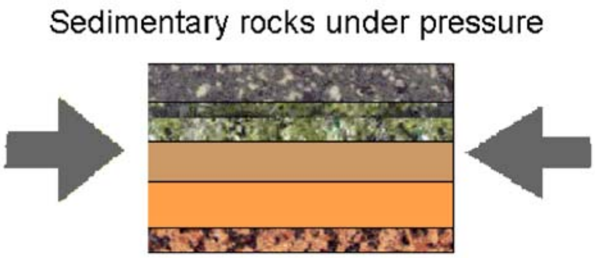
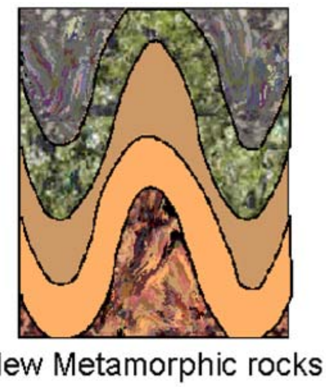
Metamorphic rocks in nature

Metamorphic rocks record how **temperature** and **pressure** affected an area when it was forming. The rocks provide clues to their transformation into a metamorphic rocks. Metamorphic rocks are best identified when looking at the rock as you see them in nature. You can clearly see the **deformation** and features that are characteristic of an entire area.

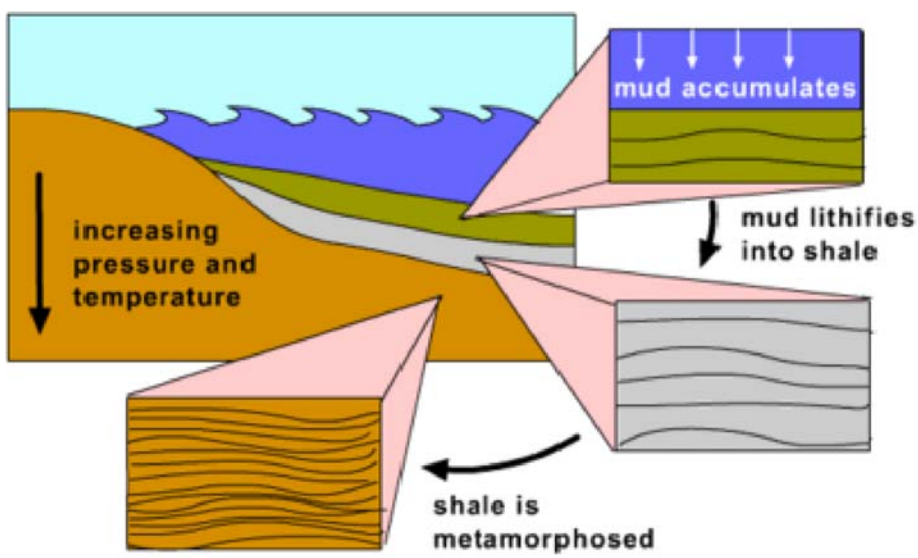
Metamorphic rocks were once sedimentary, igneous, or another metamorphic rock. These rocks are physically deformed and chemically changed due to different temperatures and pressures. The elements in the minerals can actually "move" to form new minerals. The rock does not melt, or else it would be considered an igneous rock. A rock looks different after it has been **metamorphosed**. The rocks texture and overall appearance changes also. It now has a squished look!



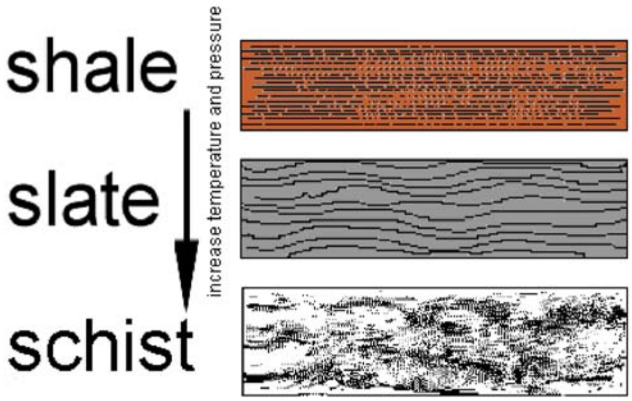


Deformation of sedimentary rocks

Metamorphism is difficult to understand because there are many combinations of temperature and pressure that can create rocks. For example, mud and clay quietly settle on the ocean floor. As more mud and clay settle on top of it, the weight of the sediments "squeezes" the water from the mud and clay on the bottom. It becomes cemented together by chemical interactions and it becomes a sedimentary rock called **shale**. The shale is put under moderate pressure and low temperature due to burial or plate movements. The new pressure and temperatures changed the chemical make up of the shale into the metamorphic rock called **slate**.



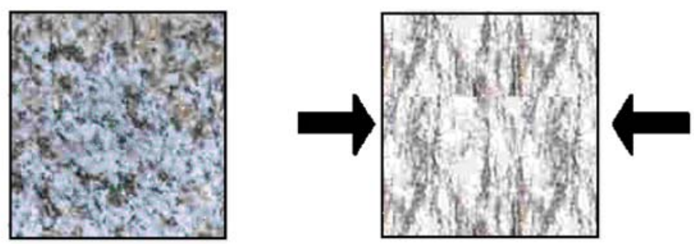
Shale to slate metamorphism

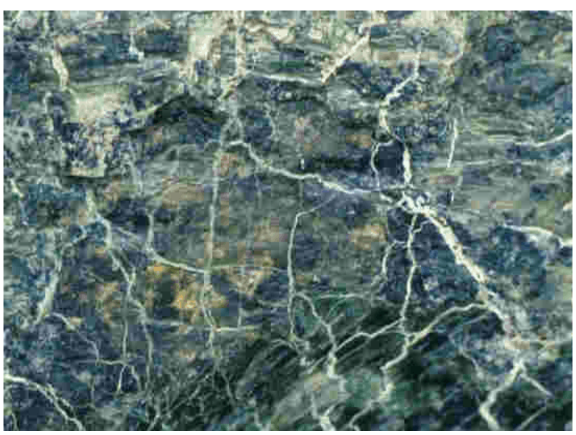


If not enough heat and temperature were applied another metamorphic rock could have been formed called **phyllite,** which is not as hard as slate.

However, if the shale was in an area that was exposed to higher pressures and moderate temperatures, it might have been transformed into **schist**. The clay in the shale could have been converted to **mica**, which gives schist its shiny look.

Granite is a light-colored rock made of quartz, feldspars, mica, and small amounts of hornblende. The crystals of all these minerals are randomly arranged. Granite can be metamorphosed into a rock called **gneiss** (pronounced like "nice"). Gneiss has about the same mineral composition as granite, but the pressure of metamorphism causes the minerals to line up, giving gneiss a distinct **banded** appearance. Schist may also be converted into gneiss, if increased pressure and temperature is added. Metamorphic rocks are a mixed up group that have been under a lot of **stress**!

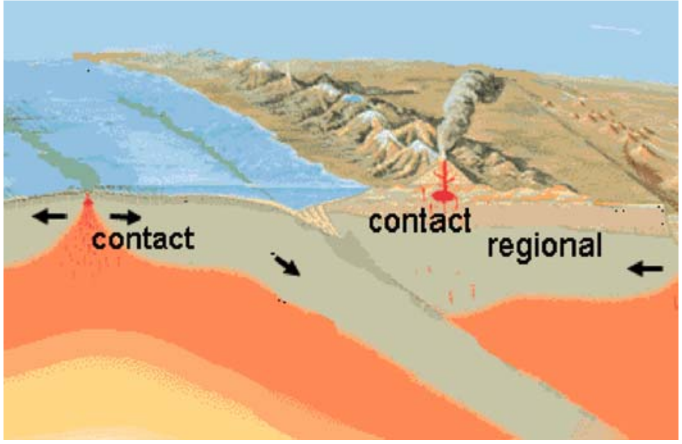



Serpentinite with quartz veins

The metamorphic system can also react differently if fluids are part of the system. Serpentinite, a mottled green rock, is usually formed with high pressure and low temperature. The original rock could contain a large amount of olivine (i.e., basalt). The **olivine** (Mg_2SiO_4) reacts with water (H_2O) to form the mineral serpentine ($Mg_3Si_2O_5(OH)_4$)plus magnesium oxide (MgO).

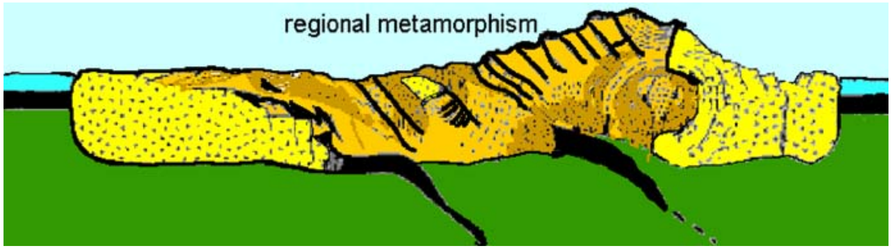
Serpentinite is found in areas where faulting occurs. Along the San Andreas fault zone in California, serpentinite is so abundant it is recognized as the California state rock. The pressure of **shearing** seems to be ideal for the serpentinite to form a fibrous pattern. This form of serpentinite is a variety of asbestos, which is used as a fire retardant.

There are several ways that metamorphic rocks form at or near plate boundaries. There is localized metamorphism called **contact metamorphism**. Usually this occurs near molten magma or lava, under high temperature and low pressure. Metamorphism affecting a large area or **regional metamorphism** involves large increases of temperature and pressure. Contact metamorphism is common at both **convergent** and **divergent** plate boundaries, in areas where molten rock is produced. Regional metamorphism largely occurs at convergent plate boundaries.

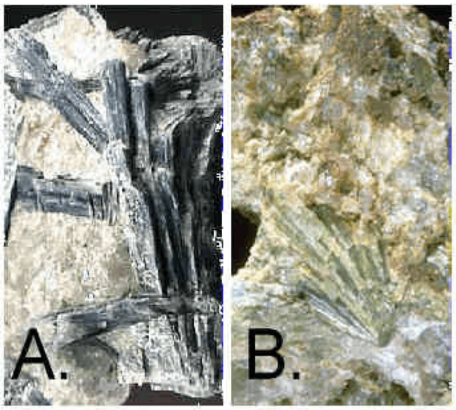


Each of these types of metamorphism produces typical metamorphic rocks, but they may occur in different sequences. For example, both regional and contact metamorphism produce schists and shales. However, gneiss would be common in regional metamorphism.

In regional metamorphism conditions can range from low to high pressures and temperatures that occur over a large area. This will produce different zones or rocks that have characteristic minerals. The minerals are like a pressure gauge and thermometer and record the history of the conditions under which the rocks formed.



Finding these minerals in metamorphic rocks are clues to the temperature and pressure. For example, **chlorite**, **muscovite**, and **biotite** (all micas) are common in low grade metamorphism which is low temperatures (200°C) and pressure. (Remember water boils at 100°C). Intermediate grade metamorphisms usually contains the minerals **garnet** and **staurolite**. High grade metamorphism (800°C) usually produces **kyanite** and **sillimanite**.

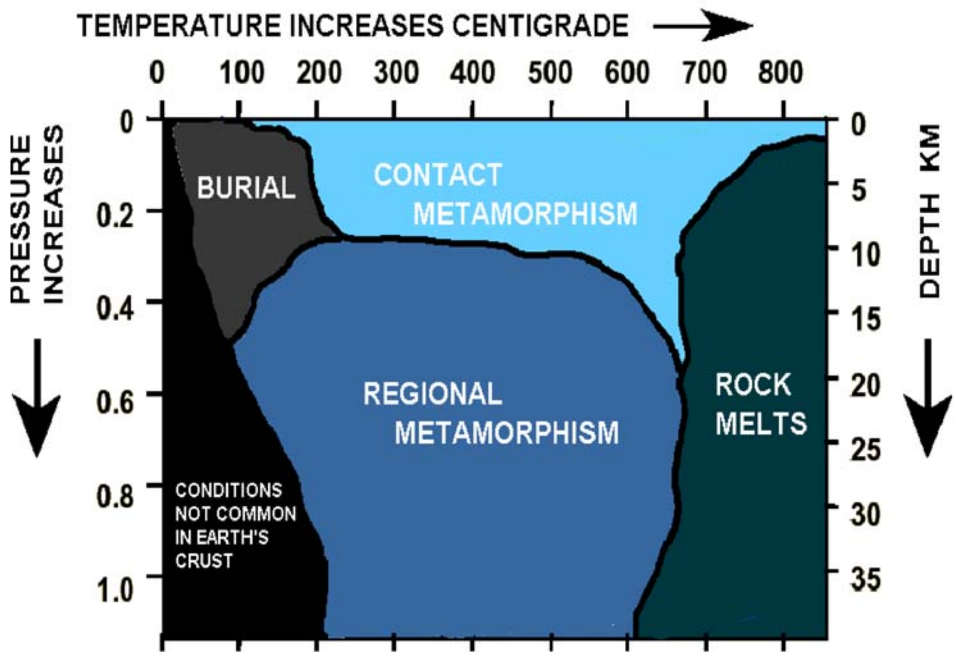


A. Kyanite, B. Sillimanite

Contact metamorphism does not affect as large an area as regional metamorphism. It is associated with areas around a magma chamber as well as other smaller igneous structures like dikes or sills. Contact metamorphism zones can be a few centimeters to several kilometers, especially around large plutons. The rocks that are formed will depend on the country rock that the intrusion invades.

There are other conditions that form metamorphic rocks. **Burial metamorphism** is a special type of low grade metamorphism with low temperatures and pressures. **Cataclastic** metamorphism only occurs along fault zones, usually associated with subduction or transform zones. Conditions include high pressures under lower temperatures.

The formation of many metamorphic rocks is still debated. Observation of extreme pressure and temperature inside the crust and upper mantle and how they affect rocks is difficult. Some rocks are only slightly metamorphosed and given the term meta-igneous or meta-sedimentary.



EARTH SCIENCES - METAMORPHIC ROCKS

Lesson 2 - Metamorphic Rock Classification Chart

MATERIALS:

reader

Objective: To learn characteristics of metamorphic rocks.

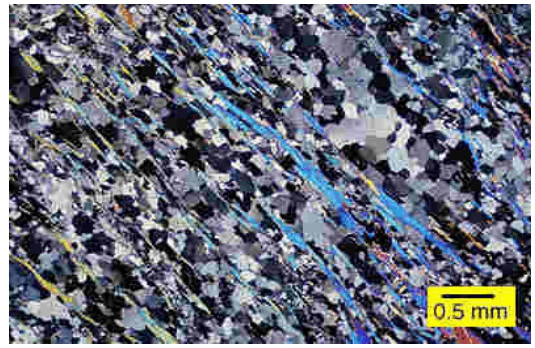
Teacher note

Identification of metamorphic rocks is difficult because there are so many varieties created by just a wide range of conditions. Students are asked to distinguish foliated and nonfoliated textures to help identification of metamorphic rocks. We only emphasize eight rocks, but there are many more varieties (and names) from these few basic forms.

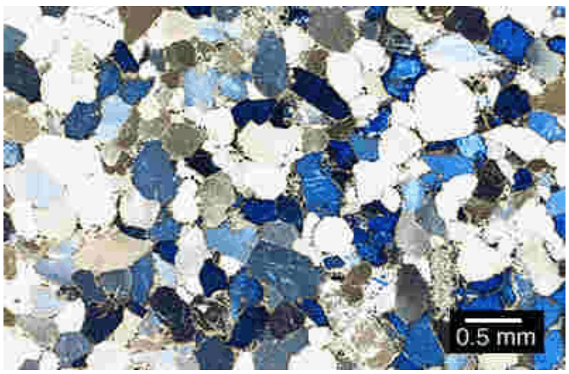
ANSWERS:

1. Slate, phyllite, schist, gneiss
2. Hornfels, quartz, quartz, marble, serpentinite
3. Slate: clay family, mica family, quartz
   Phyllite: mica family, quartz
   Schist: mica family, augite/hornblende family, feldspar family, quartz
   Gneiss: mica family, augite/hornblende family, feldspar family, quartz
   Hornfels: mica family, augite/hornblende family, feldspar family, quartz
   Quartzite: quartz
   Marble: calcite, little quartz
   Serpentinite: serpentine

Metamorphic rocks are either easy to identify or very difficult. Some textures or appearances, like **foliation**, are unique to metamorphic rocks. Foliation comes from the Latin meaning leafy. The texture is platy because it contains minerals like mica. However some nonfoliated textures like **granoblastic** or minerals that are large grained are difficult to distinguish from chemical sedimentary or plutonic igneous rocks. These rocks do not have a squished look.

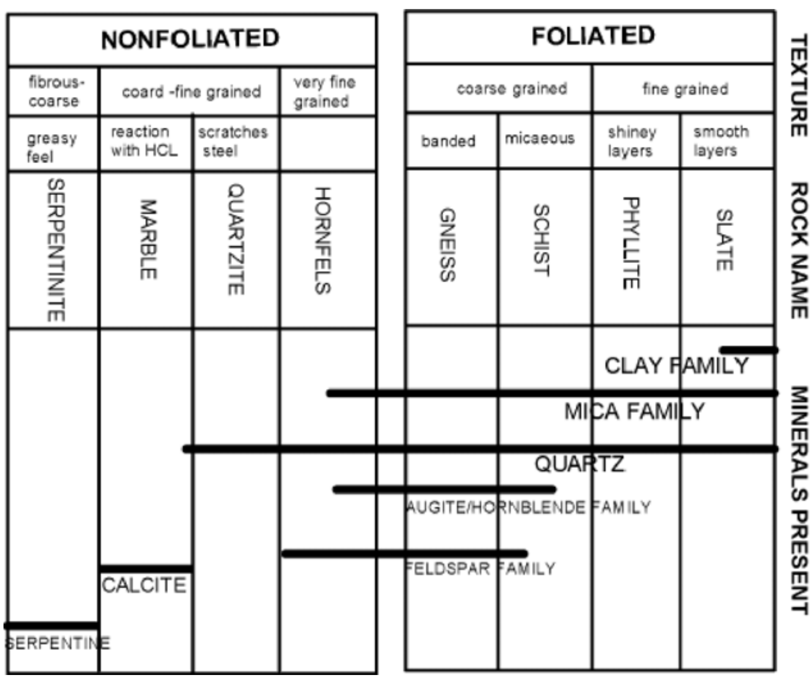


Mica (bluish) is aligned in a foliated texture in this mica schist (thin section)



Granoblastic texture of quartzite (thin section)

On the identification chart we separate the rocks by texture and refer to them as foliated or nonfoliated. Both groups are further subdivided by coarse and fine grained, depending on the size of the minerals. Mineral groups that are found within each rock can also help to identify the type of metamorphic rock.

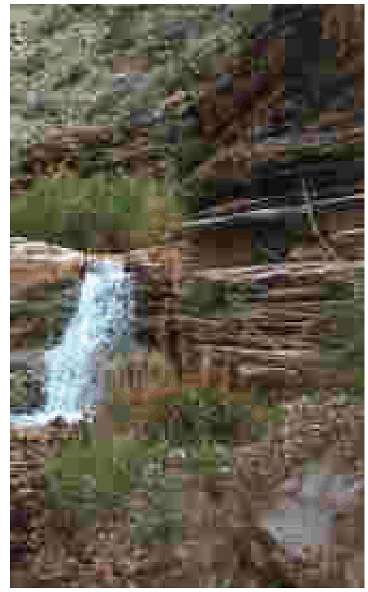


There are many types of metamorphic classifications that geologists use. The one we use in this unit is simplified into foliated and nonfoliated. We also group the minerals into "families." "Clay Family" can include several specific minerals, like kaolinite. For example, "Mica Family" includes chlorite, mica, and biotite. "Feldspar Family" includes orthoclase and plagioclase.

Metamorphic rocks use the minerals that are found to help identify it to distinguish one from another. For example, "schist" is a general term. A geologist would see which minerals are dominate then name it depending on the most abundant minerals.

Slate roof

Slate is heavy, often dark colored and smooth when it breaks in sheets. It does not contain visible minerals, but with a microscope, you would see that all its minerals are lined up. The properties of slate make it ideal to use on the top of pool tables, shingles on roofs, walking stones, and the original blackboards, which teachers write on.



Slate outcrops in Grand Canyon

Phyllite resembles slate but has a somewhat coarser texture. The flat surfaces have a lustrous sheen due to mica and chlorite. However, it is not as hard or flat as slate, and not used in construction like slate.

Phyllite

Gneiss is coarsely foliated in bands. The bands can be straight, pancake-like, or wavy. The bands differ in composition and are coarse grained making them easy to identify. Many of the light-colored bands are composed of either quartz or feldspar. The dark bands belong to the augite/hornblende groups.

Schist

Schist is finely foliated forming thin parallel bands. The individual minerals are visible but are usually platy or rod-like. Some minerals are larger within the foliated minerals, and these can include garnet, pyroxene or feldspars. Schist looks like it is composed of "glitter."

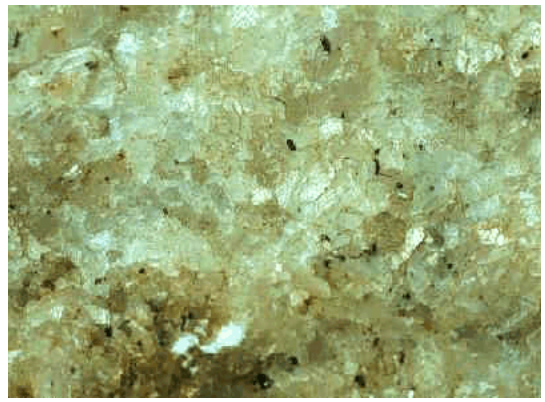
Gneiss

Thin section of hornfel

Nonfoliated metamorphic rocks are more difficult to identify because of their large, undeformed minerals. **Hornfels** are nonfoliated rocks composed of equal sized minerals in a random orientation. It is usually formed in low pressure, high temperature, during contact metamorphism.

Quartzite is usually nonfoliated and composed of recrystallized quartz. Sandstone and chert are the common parent rock.

Marble is composed of either calcite or dolomite, and usually derived from limestone. The purity of the marble will depend on the purity of the limestone.

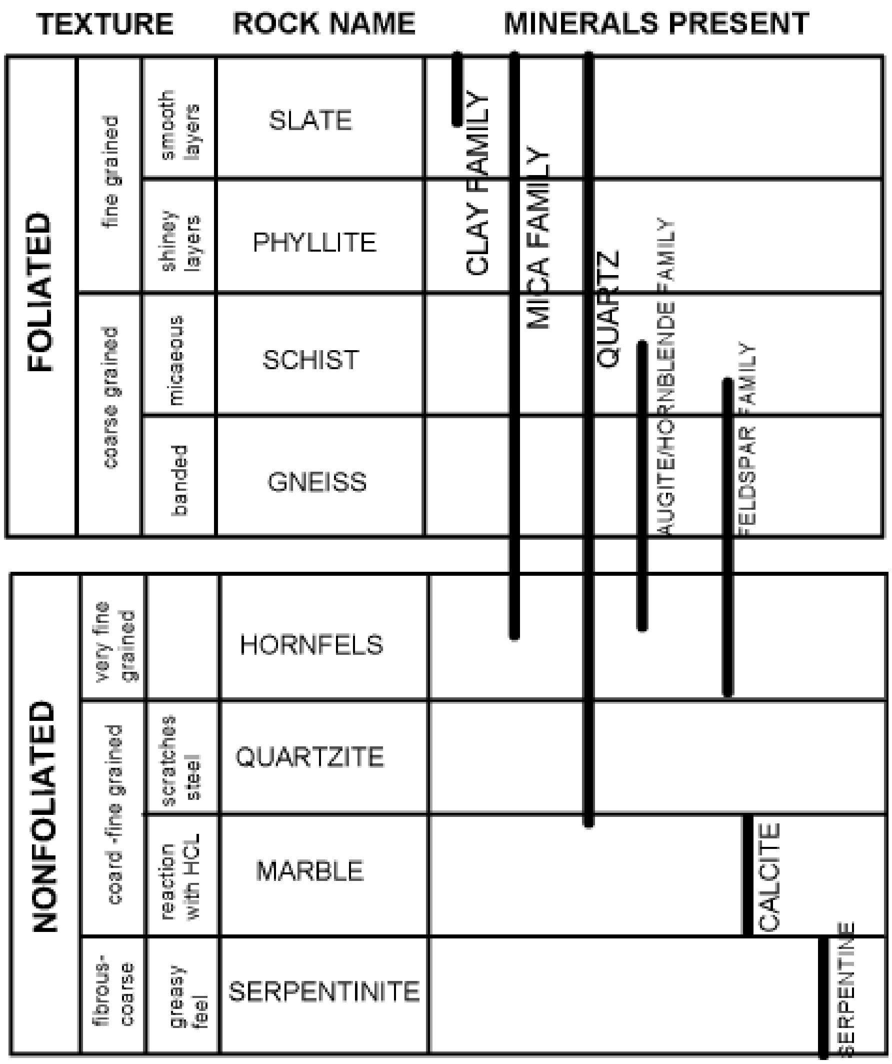

Marble

Serpentinite is nonfoliated, and composed mainly of the mineral serpentine. Serpentinite also occurs as a fibrous variety, especially found near fault zones.


Quartzite

Metamorphic Rock Classification Chart

Answer the questions below using the following chart:



1. List the metamorphic rocks that have a foliated texture:

2. List the metamorphic rocks that have a nonfoliated texture.

3. List what minerals can be found in the following rocks:

Rock	Minerals
SLATE	
PHYLLITE	
SCHIST	
GNEISS	
HORNFELS	
QUARTZITE	
MARBLE	
SERPENTINITE	

EARTH SCIENCES - METAMORPHIC ROCKS

Lesson 3 - Metamorphic Rock Lab

MATERIALS:

reader
Metamorphic Rock Kit
HCl acid
steel nail

Objective: To identify metamorphic rocks.

Teacher note

Metamorphic rocks are easily identified in nature. Usually you can see an association of rocks that have a "squished" look. Foliated metamorphic rocks are easier to identify in hand sample than non-foliated rocks. However, sometimes gneiss is difficult to identify if the bands are large, and the sample a student has is just one band. The non-foliated rocks are more difficult, but after learning the key characteristics of each, they become a little easier. However, some, like marble, are sometimes difficult to distinguish from some types of limestones. Hornfels are difficult, even for geologists because they resemble basalts.

ANSWERS:

Part I. 1. No there is not enough temperature and pressure. However, close to the surface, along fault zones, metamorphic rocks can form

2. Along different types of plutons from sills, dikes, to large batholiths

3. Convergent zones

Part II. 1 A. flat, squished look; B. White - muscovite; black-biotite; C. The flat shiny one

2. A. 12 sides (answer depends on specimens); B. On Mohs hardness scale it ranges from 6.5 - 7.5 so it is harder than a steel nail

3. A. It is flat and they lay on top of each other, like leaves; B. Yes, depends on specimen; C. Mica

4. A. Depends on sample; B. It fizzes, releases carbon dioxide from calcium carbonate; C. Calcite, depends on sample

5. A. Quartz, B. No you would have to scratch it with a steel nail; C. Steel nail because you can tell if it is quartz; D. Quartz; E. Quartz sandstone

6. A. Flat; B. Yes unlike phyllite; C. Pool tables, blackboards; stepping stones; D. Shale or mudstone

7. A. Depends on sample; B. It is banded. Term layered refers to sedimentary C. depends on sample

8. A. Green mottled color, like a serpent; B. Greasy; C. Decorative, carving (soft varieties), asbestos (some varieties)

9. A. Basalt; B. Depends on sample

10. Depends on sample, B. Thud

Metamorphic rocks are all around us. We use them from everything from old fashion chalk boards to decorative rocks around our homes. These rocks were formed inside the Earth's crust or near the surface along fault zones. Metamorphic rocks are easy to identify in nature, when you see squished, deformed rocks. Hand samples are more difficult.

In this exercise you need to compare and contrast the different metamorphic textures. Learning to identify foliated texture in a hand sample is important. Recognition of nonfoliated metamorphic rocks is difficult, because they look similar to igneous and chemical sedimentary.

Use a hand lens to look closely at the textures.

The squished look in the field

EARTH SCIENCES - METAMORPHIC ROCKS LAB

PROBLEM: How can you identify metamorphic rocks?

HYPOTHESIS:
Part I: General Questions Answer each of the following questions.

1. Can metamorphic rocks form on the Earth's surface? Explain your answer.

2. In what areas of the Earth is contact metamorphism likely to occur?

3. Where might regional metamorphism take place?

Part II Examining Metamorphic Rocks and Minerals Look at each of the metamorphic rock specimens. Carefully answer the questions for each.

1. MUSCOVITE AND BIOTITE MICA
Muscovite and biotite are both flat silicate minerals. This is because the silica compounds they contain are joined together to make sheets, like the pages of a book. Mica commonly forms under metamorphic conditions. However, you find mica in igneous and sedimentary rocks.

A. What properties does mica have that could associate it with metamorphic rocks?

B. What is the difference between the two micas?

C. How can you recognize mica in rocks?

2. GARNET
Garnets are most common in metamorphic rocks formed under moderate temperature and pressure. It comes in various colors ranging from red to green. It forms a characteristic 12 sided crystal.

A. Describe your crystal.

B. Can a steel nail scratch your specimen?

3. MICA SCHIST
Mica schist is a common metamorphic rock that is produced by regional metamorphism. The shiny look of schist is one of its key characteristics. The schist also has a nicely developed foliation. The word foliation comes from the Latin "folia" meaning leaves.

A. In what way does schist have a ”leaf-like” appearance?

B. Are the minerals present in this schist visible with the naked eye?

C. What is the sparkly mineral visible in this schist?

4. MARBLE is metamorphosed limestone. Limestone is a sedimentary rock that is mainly composed of calcite, derived from the shells of living organisms like clams and snails. Marble can be produced by contact or regional metamorphism. Marble does not develop foliation like schist, because the calcite crystals are all about the same size. There is no way for them to line up. Marbles often contain other minerals, such as quartz, mica, and hematite.

A. Is this sample of marble fine (small) or coarse (large) grained?

B. What happens when dilute HCl is dropped on marble? Why?

C. How many types of minerals are in this specimen of marble?

5. QUARTZITE
Quartzite is a very hard metamorphic rock. It can be made by contact or regional metamorphism. Like marble, it is made of crystals that are all about the same size, so it does not have foliation. Primitive people often used quartzite to make bladed weapons like knives and arrowheads.

A. From its name, what mineral makes up quartzite?

B. Can you tell this just by looking at the rock? Explain your answer.

C. Which would be more useful in identifying quartzite, a bottle of HCL or a steel knife? Explain your answer

D. What was the likely mineral composition of the rock from which quartzite was made?

E. You saw a rock in the sedimentary lab that could be this original rock. Can you guess which one it is?

6. SLATE

Slate is formed by regional metamorphism. It is a low-grade metamorphic rock, meaning that it was created by relatively low temperature and pressure. Schist, which you have already examined, is a medium-grade metamorphic rock.

A. Describe your piece of slate.

B. Slate is formed under low to moderate pressure and temperature conditions. Does slate ring when lightly dropped?

C. Can you think of any uses for a large piece of slate? (Hint: think about buildings.)

D. Which sedimentary rock was slate most likely made from?

7. GNEISS

Gneiss is a high-grade metamorphic rock. It is common only in areas of regional metamorphism. Several different rocks, such as granite, schist, and diorite can be metamorphosed to make gneiss. This is one of the most difficult things to understand about metamorphic rocks. Different preexisting rocks can produce the same kind of metamorphic rock.

A. Describe your piece of gneiss. Make sure you look at the arrangement of the minerals.

B. Is gneiss banded or layered?

C. What makes up the different bands?

8. SERPENTINITE
Serpentinite is a metamorphic rock produced largely by metamorphism along fault zones. The original rock is often an igneous rock like gabbro or basalt. Serpentinite is composed mainly of the mineral serpentine. Serpentinite is the state rock of California. However, the state legislators didn't know the difference between serpentinite (the rock) and serpentine (the mineral), and voted to make "serpentine" the state rock.

A. Where do you think serpentinite got its name?

B. How does serpentinite "feel?"

C. Can you think of any uses for serpentinite?

9. HORNFEL
Hornfel is a fine grained metamorphic rock that is nonfoliated. It usually forms under low pressure and varying ranges of temperature. It is difficult to distinguish.

A. What igneous rock could you confuse hornfels with?

B. Describe your sample.

10. PHYLLITE
Phyllite is a metamorphic rock that has not been under as much pressure as slate. It is usually derived from mudstone or shale.

1. Describe your specimen?

2. What is the difference of dropping phyllite about 6 cm from a hard surface and a piece of slate?

EARTH SCIENCES - METAMORPHIC ROCKS

Lesson 4 - The Many Facies of Metamorphic Rocks

Objective: Students learn to interpret a metamorphic facies chart.

MATERIALS:

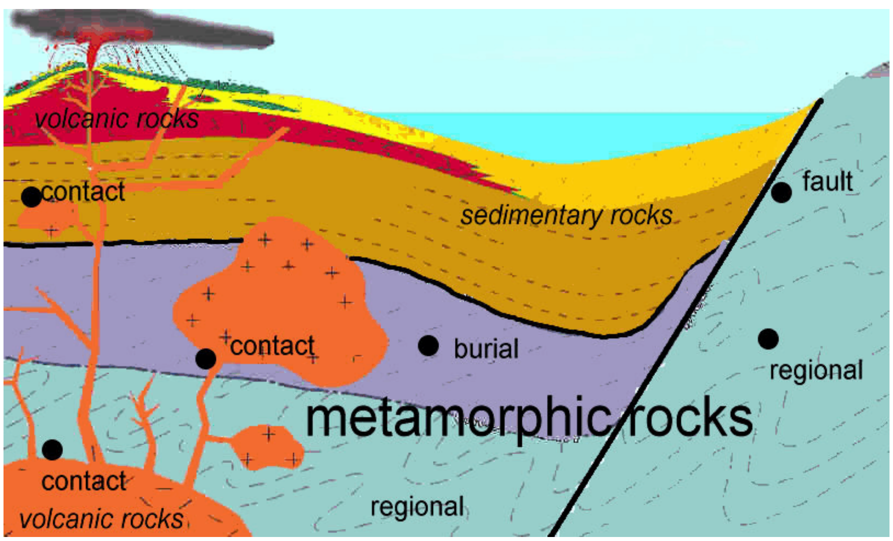
reader

Teacher note

Metamorphic facies refers to zones of rock that have similar metamorphic minerals. These facies help to determine under what temperature and pressure the rock was created.

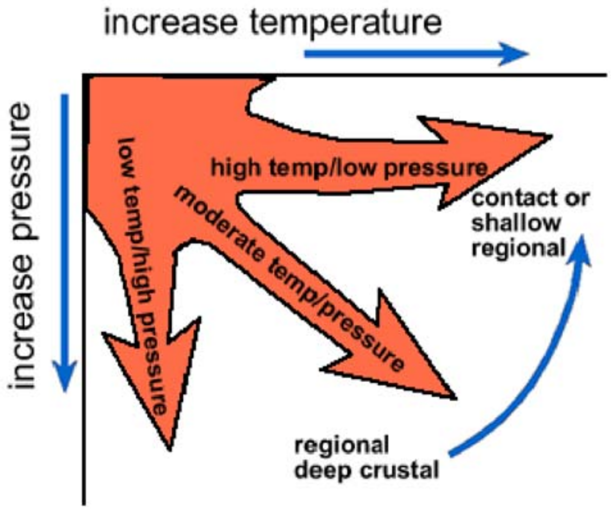
This lesson can help students learn how to read graphs and gather information. This is not meant for students to memorize the different facies. More information on facies can be found on the following website.

http://www.science.ubc.ca/~geol202/meta/metacon.html
Illustrates the different rocks of the different facies.



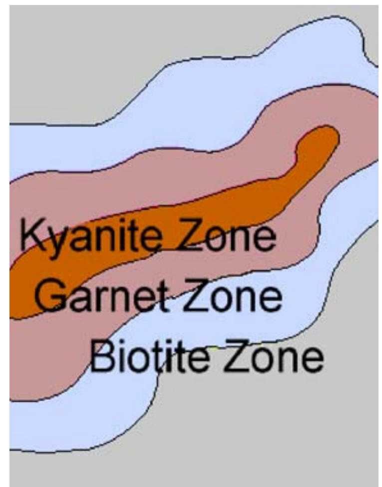
A rock is made of minerals that are stable in a given environment. If the physical conditions of a rock change, especially temperature and pressure, the minerals will not be stable. A new group of minerals will begin forming under metamorphism until the environment becomes stable again. These mineral assemblages will appear depending on conditions.

The initial composition of a rock is very important. This will decide what it will become with changing metamorphic conditions. A rock with the same composition can turn into a different metamorphic rock, depending on the pressure and temperature. If the pressure and temperature are the same, the initial rock control the path metamorphism takes.



Ranges on temperature and pressure

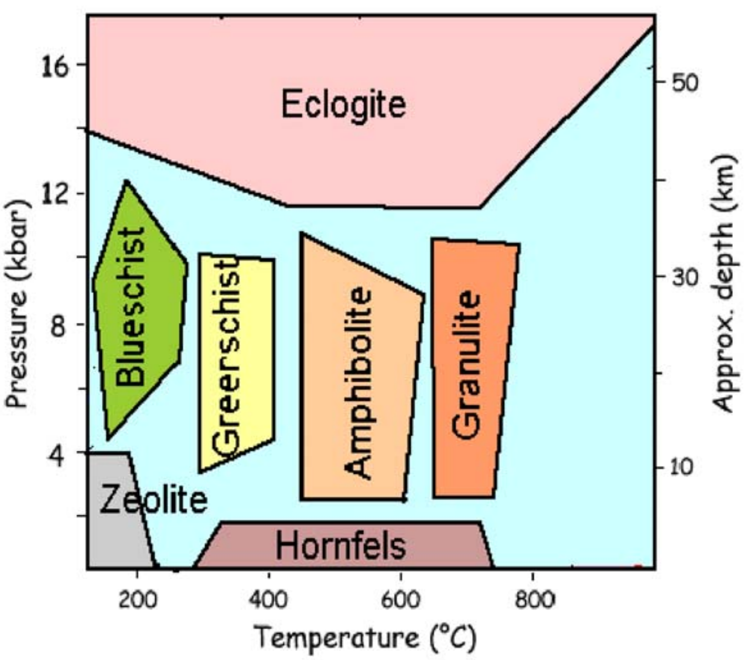
The amount of heat and pressure is the main factor that control mineral development. The length of time of metamorphism is also a major factor on the eventual rock. The varying temperature and pressures are found in different regions of the Earth, depending on its position according to the plate tectonic model.



Simplified geologic map

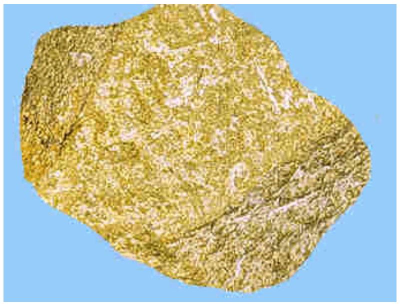
How do we know this? It took geologists a long time to understand metamorphic rocks. They mapped the different area and found that minerals were clues to the temperature and pressure an area experienced.

George Barrow, in the late 1900's was the first to map zones in Scotland. He recognized six zones on the first appearance of six minerals including chlorite, biotite, garnet, staurolite, kyanite, and sillimanite. He did not know for sure if the zones had anything to do with the physical conditions of metamorphism, because he could not confirm his observations in a lab.



Eventually the idea of metamorphic facies developed that included contact and regional metamorphism. These facies were defined by geologists in the field, but also experimental data helped to define the minerals more precisely. A facies is a metamorphic mineral assemblage that provides a geologist with a predictable relation between mineral composition and chemical composition with respect to the pressure and temperature of its formation.

These metamorphic facies are defined by the minerals and corresponding rocks that they produce. Some of the minerals and rocks we have not discussed, but this facies concept is an important way of relating rocks in time and space. In the exercise you are read the graphs to try and derive information.

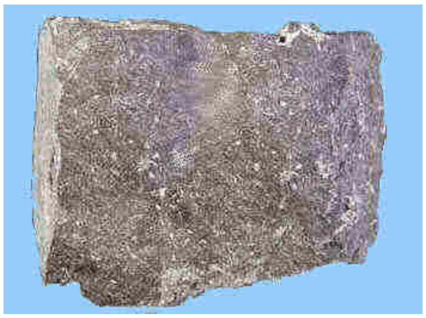


Zeolite

Zeolite facies is the lowest grade of burial metamorphism. It main minerals are quartz, muscovite and chlorite. Recrystallization is usually incomplete so these rocks don't look as squished.

Blueschist

Hornfels facies is confined to high temperature with lower pressured and associated with contact metamorphisms. The minerals present include plagioclase, orthoclase, and quartz. Lower temperatures to higher temperatures produce other types of minerals.



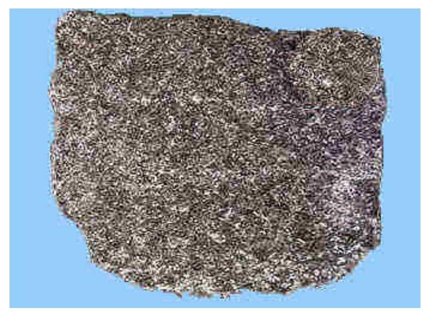
Hornfel

Blueschist facies is a low grade type of regional metamorphism specially in mountain building areas. Blue minerals like glaucophane are common, with quartz, chlorite, muscovite and garnet.

Greenschist

Greenschist facies is a common low grade metamorphism that produces rocks that are greenish because of the chlorite and biotite present.

Amphibolite facies is a medium to high grade type of regional metamorphism, which is very common. The minerals include members from the amphibolite (hornblende) family.



Amphibolite

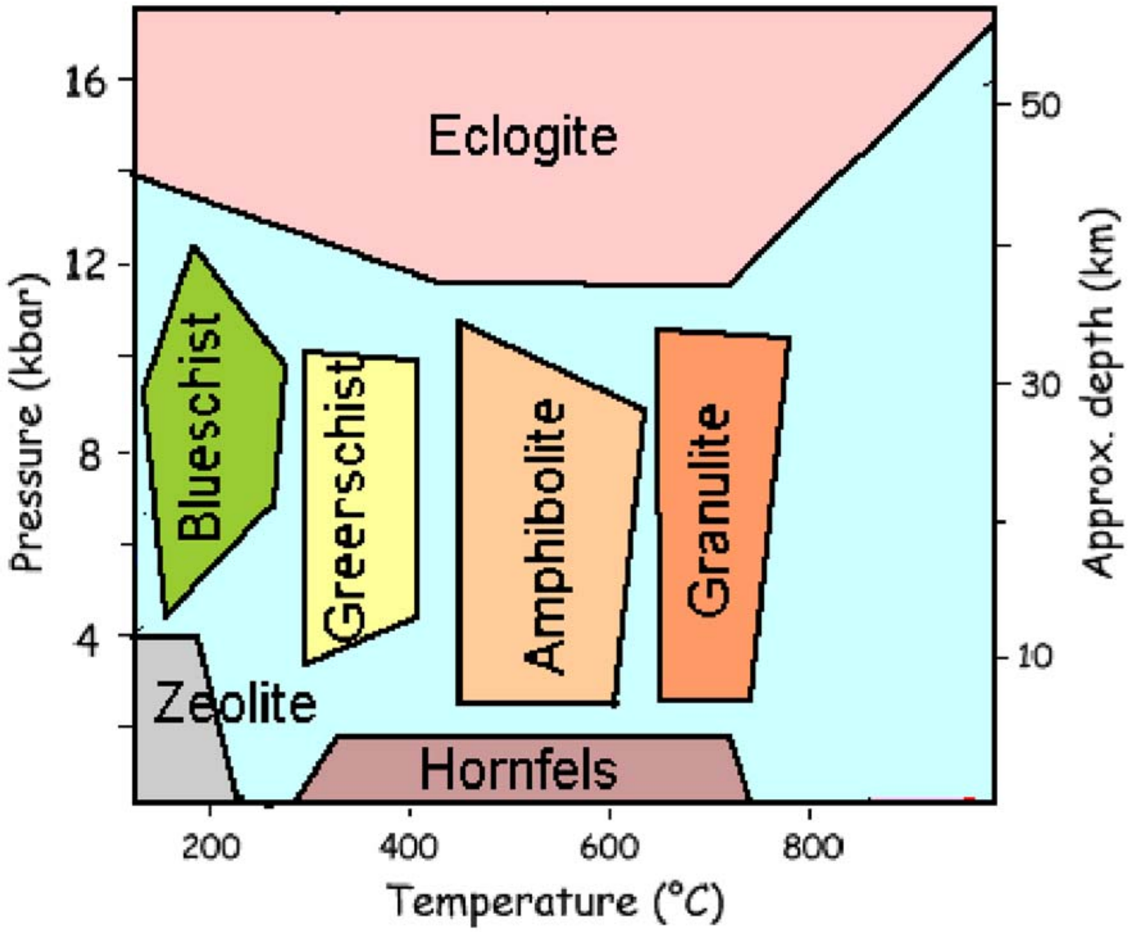
Granulite facies is the maximum grade of region metamorphism found in older metamorphic rock formation.

Eclogite

Eclogite facies represents a very deep, high grade form of metamorphisms found with high pressures and temperatures.

Granulite

Interpreting a Metamorphic Facies Graph



facies	pressure range	temperature range	depth range

EARTH SCIENCES - METAMORPHIC ROCKS

Lesson 5 - Michelangelo and Marble

MATERIALS:

reader

Objective: To learn how marble was used by Michelangelo..

Teacher note

Michelangelo was one of the most productive and famous artists in the world. His genius was not only in paintings but also in sculpturing. His ability was discovered early through his persistence of knowing what he wanted to do. Michelangelo's life can help students realize that some of them should follow their dreams and skills. The following web sites can help your students gather more information on his life.

http://www.michelangelo.com/buonarroti.html
a detailed biography and history of Michelangelo.
http://www.anselm.edu/homepage/dbanach/mich.htm
good links to images
http://www.cavemichelangelo.com
link to a Carrara marble quarry in Italy. A detailed site with many good pictures


Michelangelo

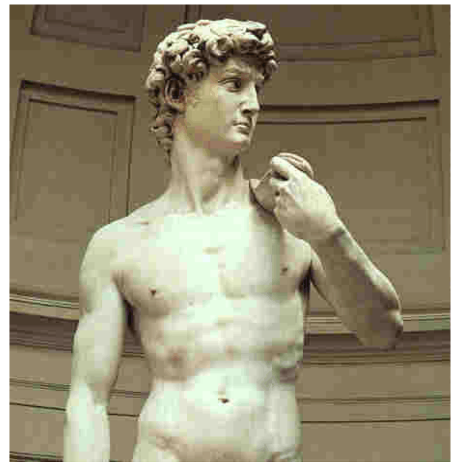
Michelangelo was an Italian artist who lived from 1475-1564. He was the second of five brothers, born in Tuscany. He was a sculptor, painter, architect, and poet. He is considered to be one of the greatest Western artists of all time. He was especially gifted at using art to express human emotions and meaning. Michelangelo lived and worked during the Renaissance, a period of European history when many discoveries and innovations in art, science, and technology were made.

When Michelangelo turned 13 years old, he shocked his father when he told him that he had agreed to apprentice to the painter Domenico Ghirlandaio. He studied the technique of **fresco** painting. Michelangelo then went on to study at the sculpture school in the Medici gardens and then apprenticed in the household of Lorenzo de Medici, the Magnificent.

Michelangelo carved sculpture throughout his lifetime. *The Pieta* shows the biblical figure Mary holding the body of Jesus in her lap. Her face expresses sorrow and sadness. This is the only sculpture Michelangelo ever signed. The Pieta was a great success, so one night he snuck into the display hall and carved MICHEL ANGELUS BONAROTUS FLORENT FACIBAT on the front of the statue. This means "Michelangelo Buonarroti of Florence made this! (Note: Michelangelo is his first name, Buonarroti is his family name.)

The Pieta

The David is Michelangelo's image of an ideal man, based on the biblical story of King David and Goliath. The "David" is a huge statue, standing 14 feet, 3 inches high. It took Michelangelo almost three years, and several models, to carve the final David which now stands in Florence, Italy.



David

Michelangelo was commissioned by Julius II to produce his tomb, which was planned to be the most magnificent of Christian times. Michelangelo was asked to include 40 statutes to depict the glory of the pope. So, he had to spend months in the quarries to obtain the necessary Carrara marble. Due to a mounting shortage of money, however, the pope ordered him to put aside the tomb project in favor of painting the Sistine ceiling.

When Michelangelo went back to work on the tomb, money forced the project to not be as grand. Michelangelo still made some of his finest sculpture for the Julius Tomb, including *the Moses* around 1515.

Statute of Moses

Michelangelo carved his statues from the metamorphic rock, marble. Almost all of this material came from quarries near the town of Carrara, Italy, so this rock is referred to as the "Carrara marble." He would inspect the marble before he would work with it, to insure that the rock would express his artistic genius.

Marble is composed of carbonate minerals, mainly of calcite ($CaCO_3$). The original rock is limestone, usually derived from fossil shells. During metamorphism, the original fossils and cement dissolve, and reform in place as new calcite crystals. Since the crystals all form at about the same time, they are pretty close to the same size. This gives marble a "sugary" appearance.

Colors of Carrara Marble

Marbles often contain small amounts of quartz, mica, pyrite, or hematite. These often give a color to the marble. For example, small amounts of hematite make the marble yellow-orange in color.


Carrara quarries, Italy

Michelangelo used Carrara marble for three reasons. First, calcite is a soft mineral, which makes it easy to carve. Second, the calcite crystals in the Carrara marbles are very small. This also makes carving easier. More important, it makes the finished statue look more lifelike. Finally, the Carrara marbles are pure in color, which makes the statues more beautiful.

The Carrara limestone quarries are still open. Modern sculptors still use the same marble as Michelangelo.


Outcrop of Carrara Marble

Earth Science - Metamorphic Rocks - Unit Test

Part I. Definitions-Match the term or concept in column 1 with the definition in Column 2.

Column 1	Column 2
1. Preexisting rock	A. Metamorphism caused along a fault
2. Contact metamorphism	B. Country rock
3. Pressure	C. A metamorphic rock composed largely of calcite
4. Foliation	D. The alignment of minerals in a metamorphic rock
5. Cataclastic	E. A metamorphic rock containing lots of mica
6. Marble	F. Metamorphism caused by the weight of overlying rocks
7. Burial metamorphism	G. A metamorphic rock showing mineral banding
8. Regional metamorphism	H. Metamorphism caused by high temperature
9. Gneiss	I. Moderate temperature and pressure over a large area
10. Schist	J. One of the main causes of metamorphism

Part II. Multiple choice. Choose the best answer to complete each statement.

1. Quartzite is composed largely of
    a. calcite
    b. mica
    c. quartz
    d. clay

2. Granite can be metamorphosed into
    a. gneiss
    b. schist
    c. slate
    d. serpentinite

3. Which is not a cause of metamorphism?
    a. temperature
    b. Pressure
    c. faulting
    d. hydrochloric acid

4. Contact metamorphism is found near
    a. water
    b. magma
    c. pyroclastic ejections
    d. trees

5. Regional metamorphism is found mainly in
    a. volcanoes
    b. magma
    c. convergent zones
    d. divergent zones

6. Slate is a metamorphic rock. It may have formed from
    a. granite
    b. gneiss
    c. shale
    d. sandstone

7. Schist is easy to identify because it
    a. has foliation
    b. reacts with HCl
    c. has mineral bands
    d. is harder than a steel nail

8. Michelangelo carved statues with Carrara marble because
    a. the marble was soft
    b. the marble was fine grained
    c. the marble was pure in color
    d. all of the above

9. Which characteristics describe serpentinite?
    a. green, with a greasy feel
    b. red with fibrous texture
    c. harder than a steel nail
    d. None of the above

10. Which metamorphic rocks are easy to identify?
    a. nonfoliated rocks
    b. foliated rocks
    c. green rocks
    d. greasy rocks

Answers:

1. B
2. H
3. J
4. D
5. A
6. C
7. F
8. I
9. G
10. E

Part 2.

1. C
2. B
3. D
4. B
5. C
6. C
7. A
8. D
9. A
10. B