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UNIT EIGHT

Metamorphism and Metamorphic Rocks

*Dedicated to: _____

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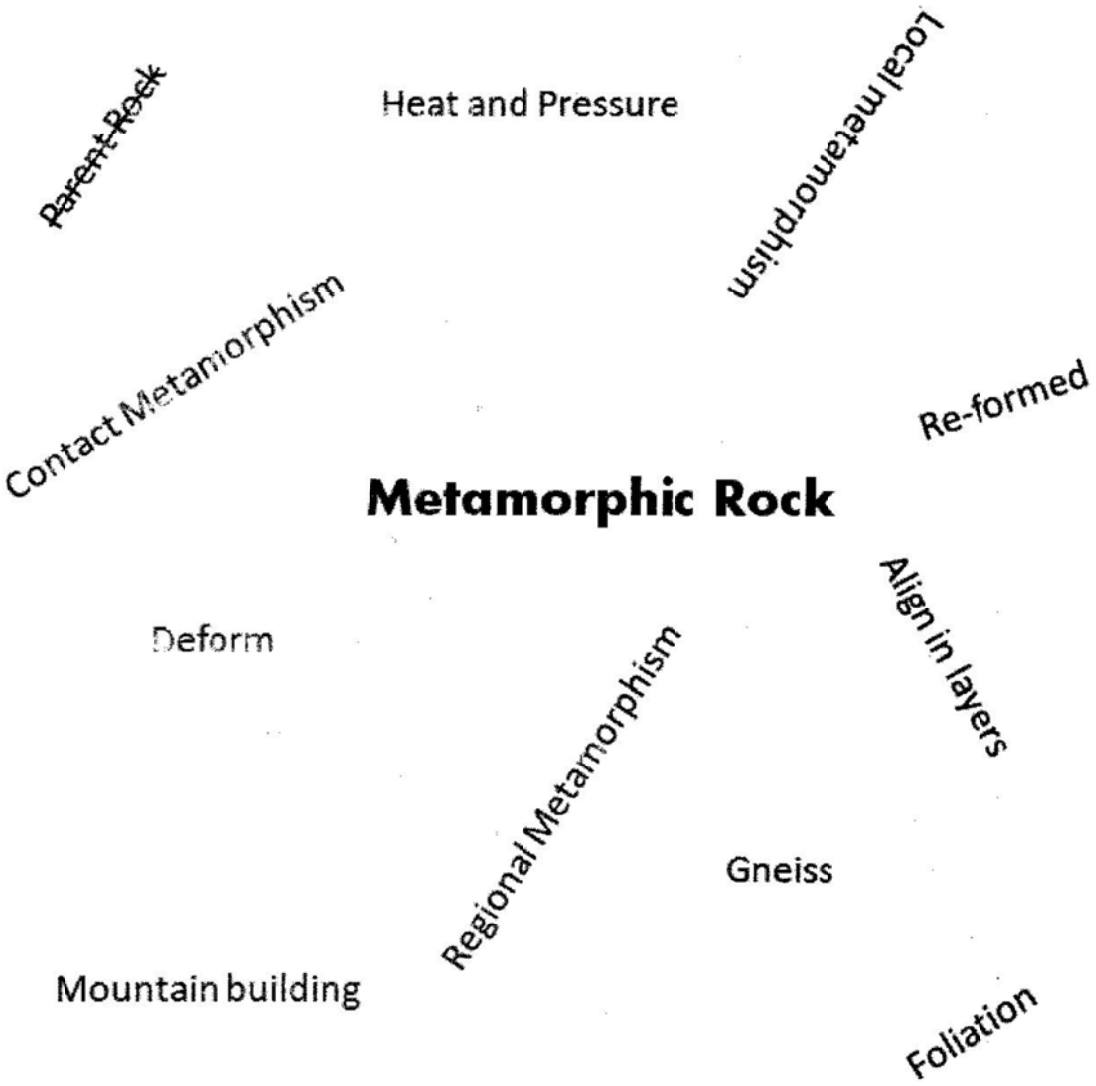
Metamorphic Rock Reading Word Splash

Below are some key words that explain the formation of metamorphic rock. Read page 133-137, put these key words into a sentence on a separate sheet of paper. See examples below



Example: ***Metamorphic rock are formed from pre-existing rocks called parent rock***

Learn about Meta***morphic*** Rocks - USING your ESRT

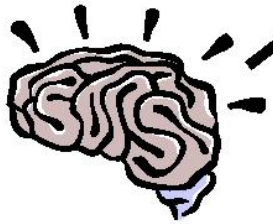
Intro: Metamorphic Rocks form wherever enough heat and/or pressure exist to *morph* (change) available rock types into another type of rock. The heat and/or pressure compresses and recrystallizes other rock types and changes their characteristics. They form in the depths of the Earth at great pressure from compression generated by tectonic plate motion. This pressure can also be generated by the weight of overlying rock. The heat often comes from the Earth's internal heat - the geothermal gradient states that heat increases with depth (see ESRT pg. 10) OR the heat can come from nearby magma or lava. Sometimes metamorphic rocks formed over very large areas by the process called regional metamorphism. Other times metamorphic rocks are formed over smaller areas by the process called contact metamorphism. Texture in metamorphic rocks falls into 2 main categories foliated or non foliated. Foliation is best described as layering, striping or bands of minerals that result from a parallel alignment of minerals in the rock giving it a striped appearance.

Procedure:

First gather what you need:

Your ESRT and a pencil or pen

And your



Then:

1. Read the explorations carefully.
2. Use your ESRT (especially page 7) to help explore for the answer.
3. Hand in completed lab for grading.

Explorations:

1. Determine the name of a metamorphic rock that is foliated, HAD some mica which has changed into feldspar, and has medium to coarse grain size_____.

2. There is one metamorphic rock with variable composition, it is nonfoliated and forms from contact metamorphism, it is _____.

3. Part of its name comes from a sedimentary rock formed from glacier deposits, it is formed by regional or contact metamorphism. This rock is _____.

4. Another metamorphic rock with composition similar to a mineral AND a bioclastic sedimentary rock, also bubbles with acid, and is non foliated. Name it _____.

5. This silicate based metamorphic rock is non foliated with fine to coarse grain size. It is known by the name _____.

6. A foliated rock showing mineral alignment and formed from regional metamorphism. It can contain mica, feldspar, quartz, garnet and amphibole. The ESRT names it _____

7. With a fine grain size, it has undergone regional metamorphism, it can split easily into flat surfaces partly due to its mica content. You should call it _____.

8. All metamorphic rocks are formed by one of two general types of metamorphism, these are _____ and _____ metamorphism

9. This rock shows a kind of foliation described as 'mineral alignment' and does not contain pyroxene. _____.

10. How does contact metamorphism change rocks? _____ _____

11. This metamorphic rock can have various mineral particles in it, and does have a coarse grain size with particles in a matrix.. It is also called _____

12. . One particular specimen starts as a clastic sedimentary rock with a grain size of 0.04 cm called _____. It undergoes metamorphosis to become _____

13. Name 5 minerals that can be found in schist

a. _____ d. _____

b. _____ e. _____

c. _____

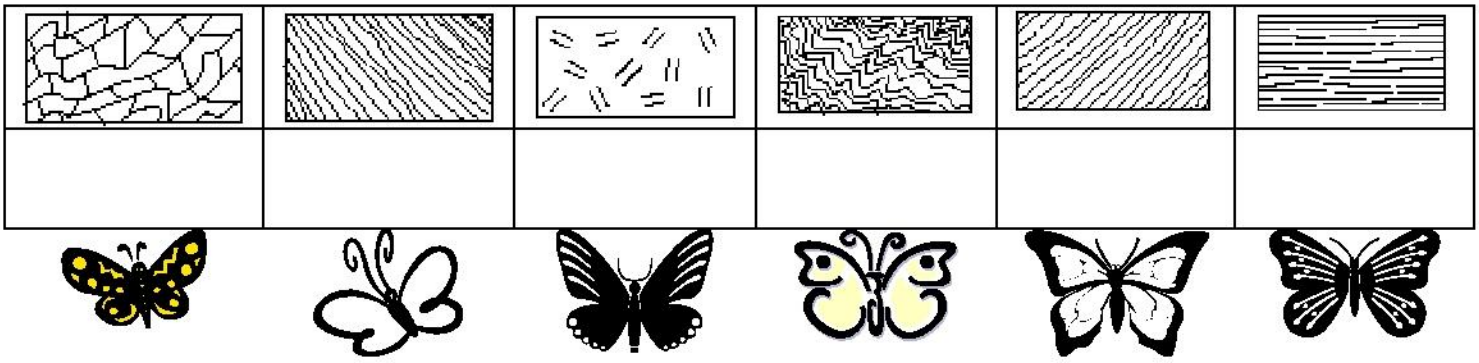
15. What other metamorphic rock also has the above 5 minerals in it? _____

16. Is there a metamorphic rock, that is foliated, has a fine texture, composed mainly of mica and is formed from contact metamorphism? Yes or No (circle answer)

17. Metamorphic rock texture is described by two major characteristics. Metamorphic rocks are either _____ or _____.

18. Provide the latitude and longitude of one location in New York state where you can find metamorphic rocks. Give your answer to the closest minute (remember there are 60' in 1°). Don't forget to put directions (N, S, E, or W) on your answer. _____ latitude _____ longitude

19. Write the name of each metamorphic rock type below its map symbol.



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Metamorphic Rock Notes

Metamorphism (Metamorphic Rock): _____

Environment of Formation#1 : _____

Environment of Formation #2: _____

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What factors influence the formation of metamorphic rock?

Process	Physical Characteristics	Type of Metamorphism

Answer the following questions based on the **Scheme for Metamorphic Rock Identification** on Page 7 of your Earth Science Reference Tables…

1) What is the parent rock of slate? _____

2) If metamorphism were to continue, list the next 3 rocks that would form after slate:

_____ → _____ → _____

3) How are foliated rocks classified?

_____

4) How are non-foliated rocks classified? _____

5) You find a metamorphic rock that has visible mica crystals and it is medium-grained. What is the name of this rock?

_____

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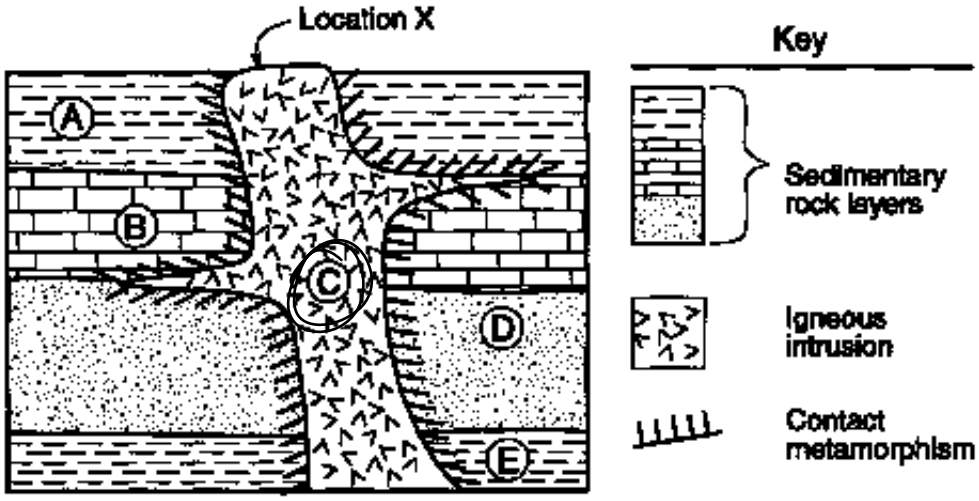
Base your answer to the following question on the geologic cross section below. The cross section shows an outcrop in which the layers have not been overturned. Rock units are labeled *A* through *E*.



Review Questions:

1a) State the name of the sediment that was compacted to form rock unit A _____

1b) List the rock unit in order from oldest to youngest_____

1c) State one observation about the crystals at location X that would provide evidence that igneous rock unit C was formed by very slow cooling of magma _____

1d) What would layer A change into after igneous intrusion? _____

1e) What would layer B change into? _____

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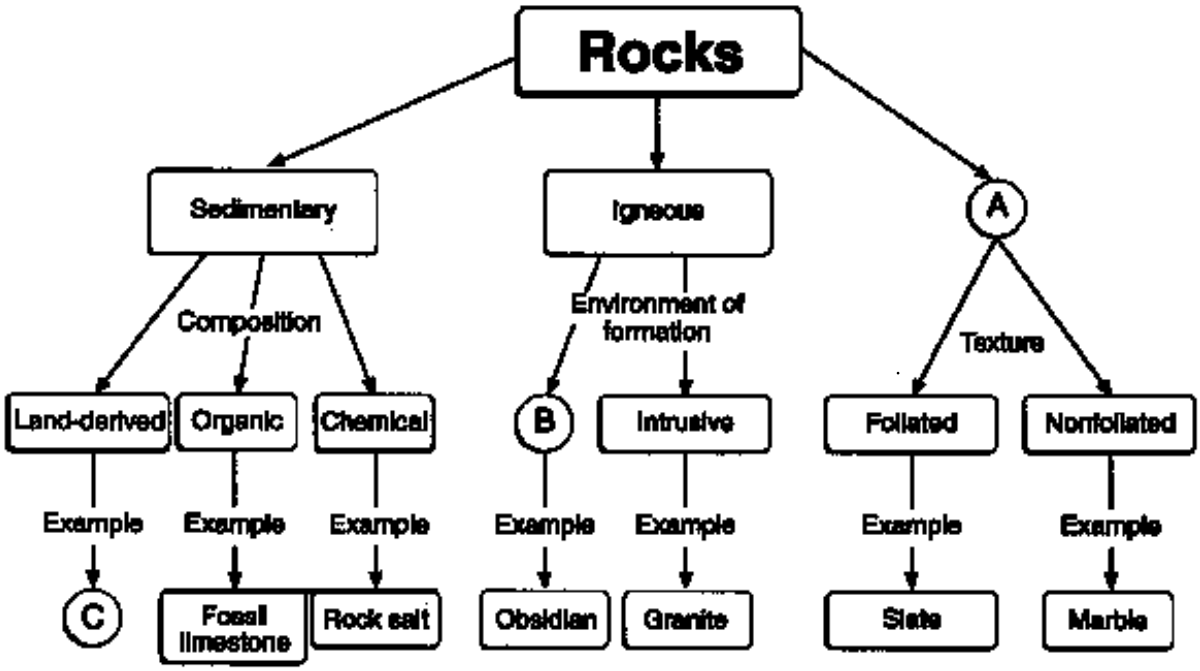
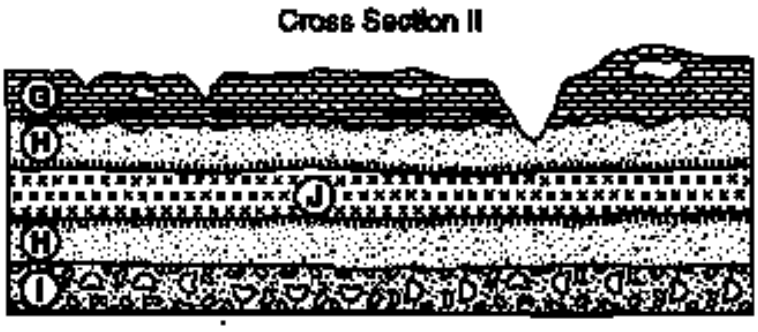
The chart below shows the different rock families and their subdivisions. The circled letters, *A*, *B*, and *C*, indicate parts of chart that have not been completed.



2a) Complete the chart by writing the missing terms in the spaces labeled A, B and C

<u>Using the reference table as a key for the rock type H, then answer question 3a</u>

*Letter J shows lava intruding and contacting rock layer H.



_____

3a) State the name of a metamorphic rock that would be found in the zone of contact metamorphism surrounding rock H

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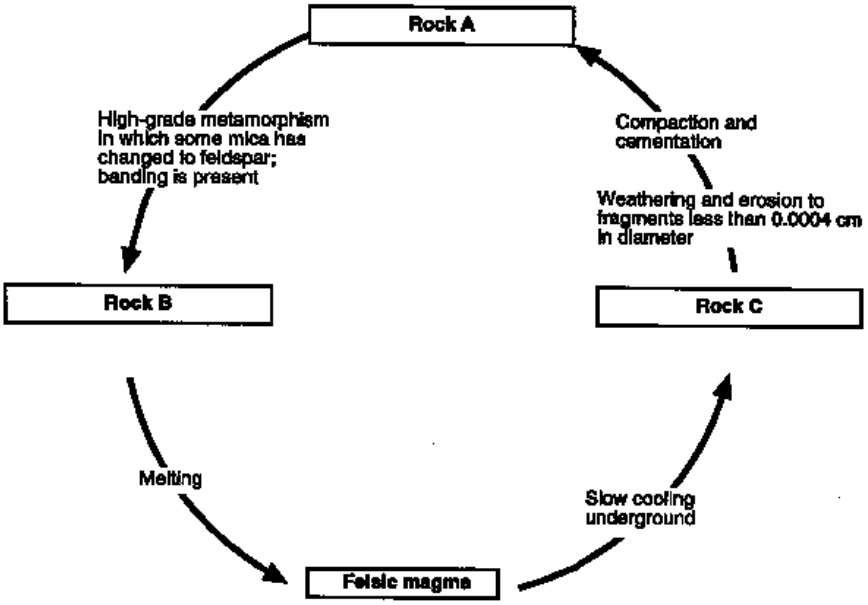
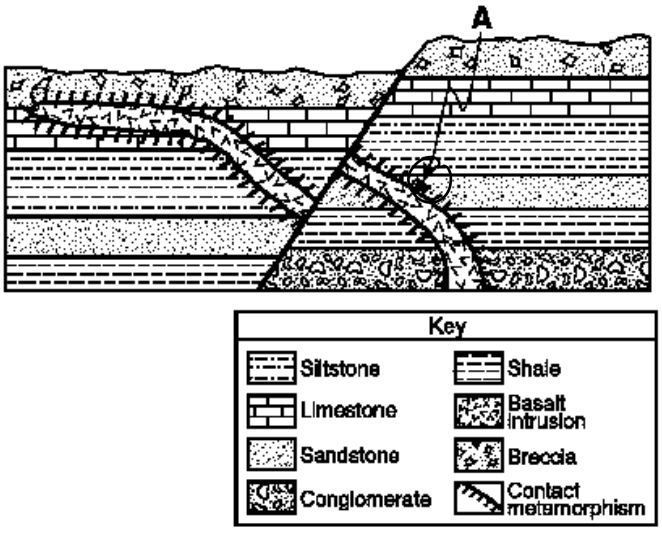
Base your answer to the following question on the rock cycle diagram below.



4a).State the <u>specific names</u> of rocks A, B and C in the diagram. **Do not write the rock type** _____

The diagram below shows an igneous intrusion cutting through all layers of the rocks. Analyze the picture and think about what caused the igneous intrusion to be shifted.



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5a) What do we call the phenomenon at A? _____

5b) Which metamorphic rock most likely formed at point A? _____

5c) What do we call the line that splits the magma at A? _____

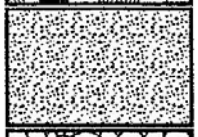
___ 1) Most metamorphic rocks are formed when
1) flows of lava cool rapidly
2) rocks are subjected to heat and pressure
3) sediments are cemented and compacted
4) magma cools slowly, deep underground

___ 2) Metamorphic rocks result from the
1) recrystallization of rocks
2) compression and cementation of soil particles
3) cooling and solidification of molten magma
4) erosion of rocks

___ 3) Which characteristics are most useful for identifying the conditions under which a metamorphic rock was formed?
1) shape and mass
2) composition and structure
3) color and luster
4) hardness and size

___ 4) What is the main difference between metamorphic rocks and most other rocks?
1) Many metamorphic rocks exhibit banding and distortion of structure.
2) Many metamorphic rocks have an organic composition.
3) Many metamorphic rocks contain only one mineral.
4) Many metamorphic rocks contain a high amount of oxygen- silicon tetraheda.

___ 5) Which diagram *best* represents a sample of the metamorphic rock gneiss?

1) 
2) 
3) 
4) 

___ 6) The diagram below represents a rock with a distorted layer structure.

The distorted structure of this rock is most likely the result of
1) wind erosion
2) extreme pressure
3) a long period of weathering
4) glacial activity

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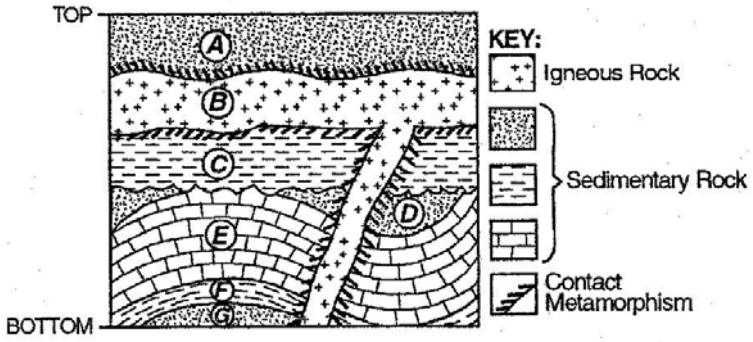
___ 7) The diagram below represents a geologic cross section of a portion of the Earth's crust. Letters identify individual rock units.



The contact metamorphism zone in rock layer *C* represents

1) loose sediments resulting from weathering
2) rock changed by heat and pressure
3) a carbon-rich layer
4) a less dense sedimentary rock

___ 8) The diagrams below represent five different rock samples.

Bands of alternating light and dark intergrown minerals	Easily split layers of 0.0001-cm-diameter particles cemented together	Glassy black rock that breaks with a shell-shape fracture	Intergrown 0.5-cm-diameter crystals of various colors	Sand and pebbles cemented together
A	***B***	***C***	***D***	***E***

If sample *E* were metamorphosed, it would most likely become

1) marble
2) metaconglomerate
3) slate
4) anthracite coal

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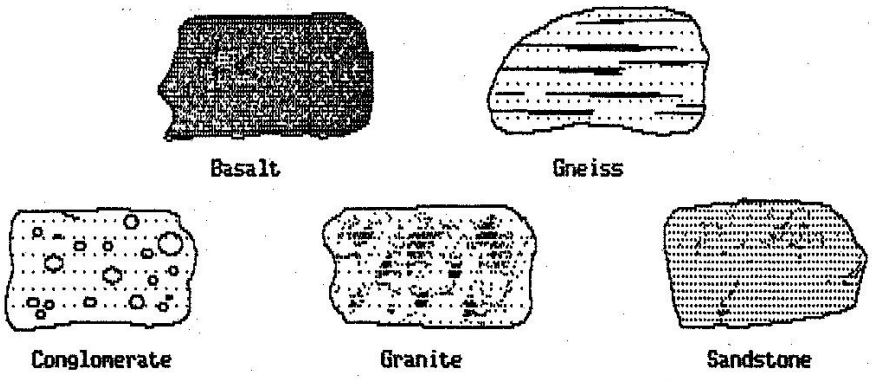
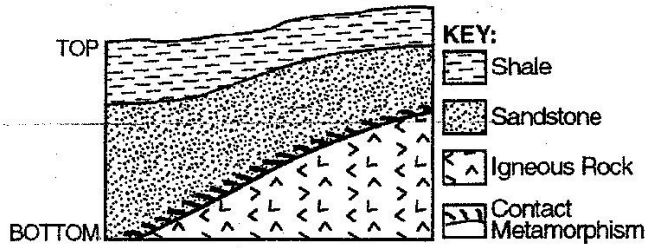
___ 9) The diagrams below illustrate five rock samples (including metamorphic gneiss). [Refer to the *Earth Science Reference Tables*.]



Which rock shows banding that formed as a result of recrystallization of unmelted material under high temperature and pressure?

1) sandstone
2) gneiss
3) conglomerate
4) granite

___ 10) The diagram below represents a geologic cross section.



Which inference is *best* supported by the evidence shown in the diagram?

1) Shale formed from the melting and solidification of the sandstone layer.
2) Sandstone formed after sand was deposited on top of the metamorphic rock.
3) Igneous rock was changed to sedimentary rock.
4) Contact metamorphism occurred when the igneous rock was in its molten state.

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Questions 11 and 12 refer to the following:

METAMORPHIC ROCKS

Rock	Composition	Formed From	Characteristics	Use
Gneiss	Quartz, feldspar, mica	Various rocks	Minerals are arranged in parallel bands (foliated)	Monuments, buildings
Quartzite	Chiefly quartz	Sandstone	Grains of sand are fused (not porous)	Buildings
Marble	Calcite	Limestone	*A*	Buildings, statues, monuments
B	Mud and clay	Shale	Splits into thin sheets	Roofs, sidewalks
Anthracite Coal	Chiefly carbon	Bituminous coal	Harder and shinier than bituminous coal	Fuel
Schists	Variable, quartz plus other minerals	Igneous or sedimentary rock	Parallel bands of minerals; flakes of mica, talc, and chlorite may be visible	Various uses

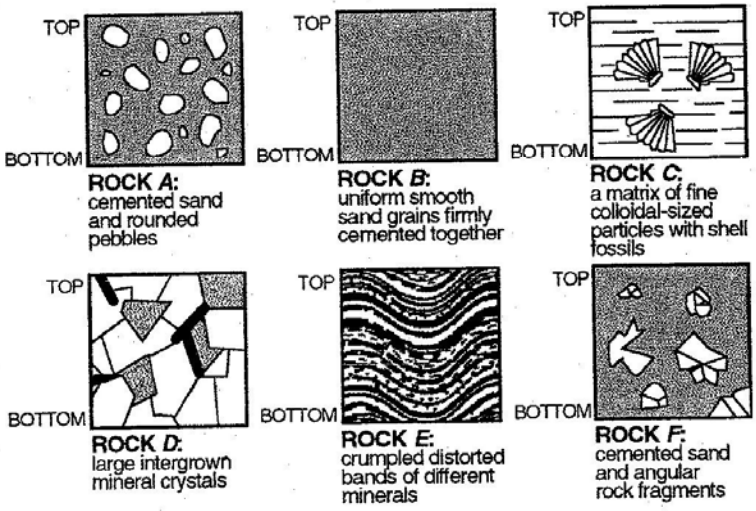
___ 11) Which rock is represented by letter *B* in the "Metamorphic Rocks" table?

1) rhyolite
2) diorite
3) slate
4) hornfels

___ 12) Which characteristic is represented by letter *A* in the "Metamorphic Rocks" table?

1) nonfoliated
2) clastic
3) porous and permeable
4) particles rounded and cemented together

___ 13) The diagrams below represent six different rock types.



Which rock was probably formed from a pre-existing rock that was changed by heat and pressure, but r melted?

1) *B*
2) *A*
3) *E*
4) *F*

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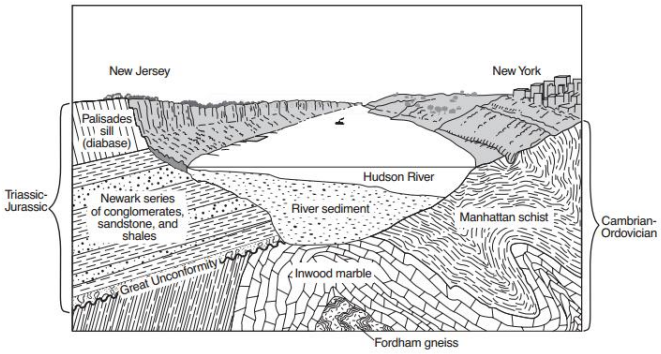
Part II Homework Practice

Base your answers to questions 1 through 3 on the cross section below showing the underlying bedrock of New York and New Jersey along the Hudson River

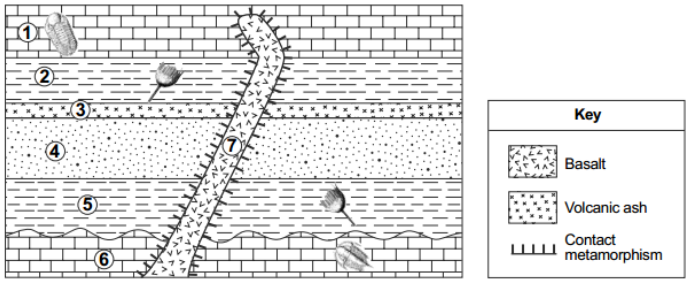


1. Identify the oldest bedrock shown in the diagram. _____

2. Describe one piece of evidence shown in the cross section that indicates that the Inwood marble was formed by regional metamorphism.

3. Identify two processes that led directly to the development of the Great Unconformity beneath the Newark series.

Base your answers to questions 4 through 7 on the geologic cross section below, which shows rock units 1 through 7 that have not been overturned. Some of the rock units contain New York State index fossils. An unconformity exists between rock units 5 and 6.



4. State the grain size of the sediment that was deposited to form rock unit 2. _____
5. Identify two processes that produced the basalt. _____
6. What evidence shown in the cross section indicates that the basalt rock unit is the youngest rock unit?

7. Identify one metamorphic rock that could've been formed by the contact metamorphism within rock unit 1.

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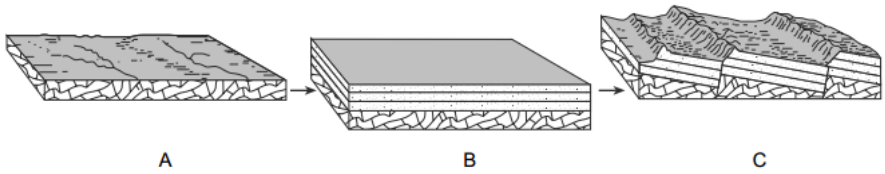
The sequence of block diagrams below shows stages of development of a landscape. The stages are labeled A, B, and C.



8. Which sequence of geologic processes best describes the events that created each stage shown?
   (1) erosion → subsidence and deposition → uplift and faulting
   (2) uplift and deposition → flooding → folding and erosion
   (3) metamorphism → erosion and deposition → volcanic eruptions
   (4) uplift and erosion → subsidence and erosion → folding

Meteorite Composition

Meteors that strike Earth's surface are called meteorites. Analysis of meteorite composition has provided scientists with information regarding the formation of Earth and our solar system, and possibly the development and evolution of life on Earth. Two types of meteorites are iron meteorites and chondrites. Iron meteorites consist mostly of iron and nickel, and are inferred to be from core materials of early planetary bodies in our solar system. More than 60% of meteorites studied have been identified as chondrites. Chondrites are made of millimeter-sized spheres of olivine and pyroxene crystals embedded in a mass of mineral and metal grains. The chondrites are thought to represent fragments of the earliest solid materials in our solar system. One type of chondrite, the carbonaceous chondrite, contains water, organic compounds, and minerals that represent the chemical composition necessary for life to form.

9. Identify the type of meteorite that is inferred to have a composition similar to the composition of Earth's core.

10. Identify two elements that can be found in both olivine and pyroxene.

11. Explain why there is little evidence of meteorite impact craters on Earth.

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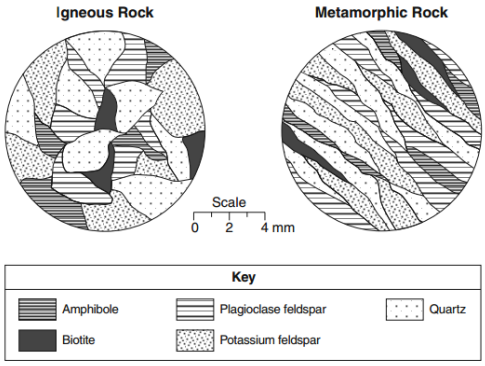
Base your answers to questions 12 through 14 on the magnified views shown below of the minerals found in an igneous rock and in a metamorphic rock. The millimeter scale indicates the size of the crystals shown in the magnified views.



12. Identify the environment of formation of this igneous rock based on the size of its intergrown crystals.

13. Based on the minerals present, identify the relative color and density of this igneous rock compared to mafic igneous rocks with the same crystal size.

14. Describe the texture shown by this metamorphic rock that indicates it could be schist.

The weathering of four different rock samples with different masses was studied. Each rock sample was placed in a separate beaker containing 500 milliliters of a dilute acid for 10 minutes. Bubbling was observed in some of the beakers. The data table below shows the mass of each sample, in grams, before placement in the acid and after removal from the acid.

Data Table

Rock	Mass Before (g)	Mass After (g)
limestone	19.72	19.64
granite	20.77	20.77
gneiss	26.83	26.83
marble	20.81	20.73

15. Which Earth process is being modeled in this experiment?
(1) physical weathering in the hydrosphere
(2) physical weathering in the mesosphere
(3) chemical weathering in the hydrosphere
(4) chemical weathering in the mesosphere

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16 Which table correctly shows the classification of the rock samples based on the amount of weathering during this experiment?

Group A	Group B
limestone marble	granite gneiss

(1)

Group A	Group B
limestone	granite marble gneiss

(3)

Group A	Group B
limestone granite gneiss	marble

(2)

Group A	Group B
limestone granite	gneiss marble

(4)

17. Approximately what percentage of the marble sample remained after the experiment?
(1) 0.4% (2) 20.7% (3) 8.0% (4) 99.6%

18.Which property of the gneiss sample prevented it from weathering?
(1) crystalline texture (3) density
(2) mineral composition (4) cleavage

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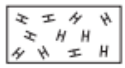
Scheme for Metamorphic Rock Identification

TEXTURE	GRAIN SIZE	COMPOSITION	TYPE OF METAMORPHISM	COMMENTS	ROCK NAME	MAP SYMBOL
FOLIATED – MINERAL ALIGNMENT	Fine	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increases)	Low-grade metamorphism of shale	**Slate**	
	Fine to medium			Foliation surfaces shiny from microscopic mica crystals	**Phyllite**	
				Platy mica crystals visible from metamorphism of clay or feldspars	**Schist**	
FOLIATED – BAND-ING	Medium to coarse			High-grade metamorphism; mineral types segregated into bands	**Gneiss**	
NONFOLIATED	Fine	Carbon	Regional	Metamorphism of bituminous coal	**Anthracite coal**	
	Fine	Various minerals	Contact (heat)	Various rocks changed by heat from nearby magma/lava	**Hornfels**	
	Fine to coarse	Quartz	Regional or contact	Metamorphism of quartz sandstone	**Quartzite**	
		Calcite and/or dolomite		Metamorphism of limestone or dolostone	**Marble**	
	Coarse	Various minerals		Pebbles may be distorted or stretched	**Metaconglomerate**	

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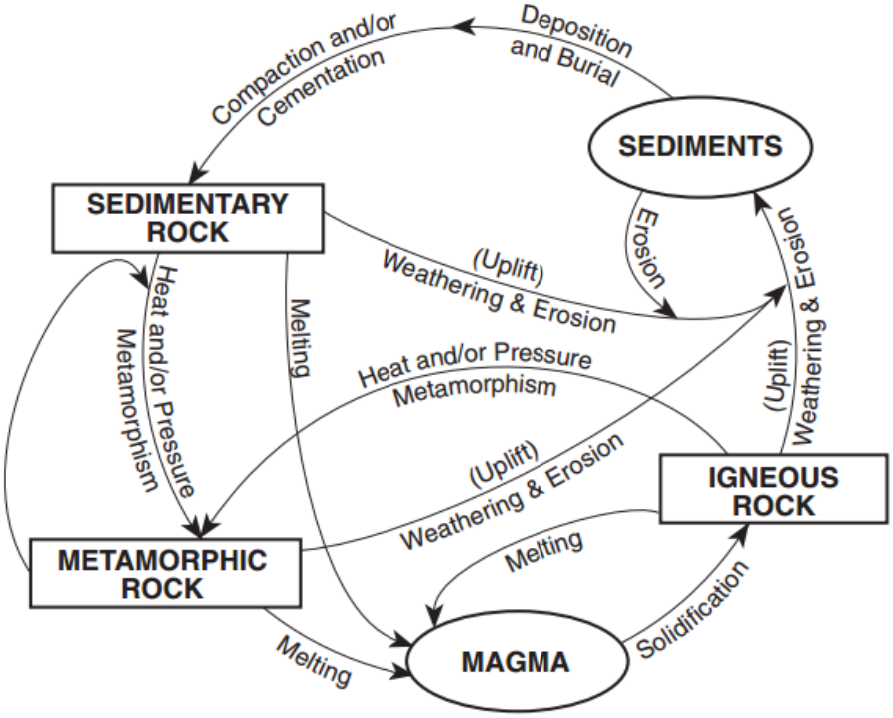
Rock Cycle in Earth's Crust



What do all rocks do? _____

Textures from various environment of formation

Igneous Rock		Sedimentary Rock		Metamorphic Rock	

Rubric for Rock Cycle unit/Learning objectives

INDICATORS	JUST STARTING Novice	GETTING THERE Apprentice	YOU'VE MADE IT Practitioner	ABOVE AND BEYOND Expert
Formation and classification of igneous rocks	Describe and compare igneous rocks by observing petrographic slides	Identify the environment of formation and how igneous rocks are classified Graph and explain the relationship between magma or lava cooling time and crystal size	☐ Identify the observable characteristics and textures of igneous rocks ☐ Explain how igneous rocks are formed ☐ Explain the connection between the textures of igneous rock and the environment of formation ☐ Explain the difference between intrusive and extrusive igneous rocks ☐ Contrast the different types of plutons that form as a result of intrusive igneous activity ☐ Identify different igneous rocks using the identification chart ☐ Identify 1-2 observable mineral(s) in an igneous rock ☐ Explain the formation of palisades sill	*Practitioner Plus* Using Bowen Reaction Series to explain the variation in the composition of igneous rocks Use the concept of Bowen Reaction Series to explain why certain igneous rocks are formed at certain tectonic settings. Explain how plate tectonic theory accounts for the distribution of various types of rocks and for the different kinds of intrusive phenomena and volcanic activity
Formation and classification of sedimentary rocks	Compare and contrast the characteristics of igneous and sedimentary rocks by observing petrographic slides Explain the process of formation of clastic sedimentary rocks	Identify the environment of formation and how sedimentary rocks are classified Identify and explain the types of sedimentary rock that would be susceptible to fossilization	☐ Distinguish among the three types of sedimentary rocks and how they form ☐ Discuss different features of sedimentary rocks ☐ Explain how sedimentary rocks can be formed chemically ☐ Describe fossilization ☐ Define terminologies such as precipitate, evaporites, crystalline, bioclastic, and land derived ☐ Identify the observable characteristics and sedimentary rocks ☐ Identify different sedimentary rocks using the identification chart ☐ Identify 1-2 observable minerals in an sedimentary rock	*Practitioner Plus* Identify 7 different depositional environments in which sedimentary rocks can form Identify the different types of fossils Explain how the shape, sequence of rock layer, sediment grains and the sedimentary structures such as fossils, cross-beds, ripple marks, and mud cracks in the rock indicate about the environment and the origin
Formation and classification of metamorphic rocks	Compare and contrast the characteristics of igneous and sedimentary rocks and metamorphic rock by observing petrographic slides	Identify the environment of formation and how metamorphic rocks are classified	☐ Identify the observable characteristics and textures of metamorphic rocks ☐ Explain how meta. rocks are formed ☐ Explain the connection between the textures of meta. rock and the environment of formation ☐ Explain the difference between regional metamorphism and local metamorphism ☐ Identify different metamorphic rocks using the identification chart ☐ Identify 1-2 observable mineral(s) in an metamorphic rock	*Practitioner Plus* Understand the types of rocks that exist in Westchester and NYC and how the rocks indicate about the geologic history of the region.

Rubric for Rock Cycle unit/Learning objectives

INDICATORS	JUST STARTING Novice	GETTING THERE Apprentice	YOU'VE MADE IT Practitioner	ABOVE AND BEYOND Expert
Rock cycle	Identify key features of each rock type. Identify the main formation process of each rock type Understand the sequence of rock formation and the concept behind daughter rock and parent rock	Understand how to read the rock cycle chart on the Earth Science Reference Table Understand that all rock types can go through weathering and erosion and share common formation processes	☐ Draw and formulate the rock cycle diagram using concept maps ☐ Identify rock samples by using the Earth Science Reference table charts ☐ Understand the major differences in the rock samples and how they can be used in the real world ☐ Understand the difference between commercial rock name and actual rock type and composition	*Practitioner Plus* Students not only show proficient and mastery of the content material, student also collects and enthusiastically bring samples to the classroom for discussion
Writing component (Task statement)	The letter describes the types of rocks and the accurate characteristics	The letter accurately describes the types of rocks and the accurate characteristics with evidences Clearly explains the reason behind the type of tombstone you choose.	☐ Sufficiently describes the rock characteristics and the minerals in the rocks ☐ Clearly explains the reason behind the type of tombstone you choose with connections to mineral composition, regional climate and rock formation process ☐ Completed all components of the task statement with quality and sufficient scientific connections ☐ The conclusion is persuasive and connects to the scientific knowledge learned in class ☐ Uses terminology from the unit accurately	*Practitioner Plus* Completed all components of the task statement with quality. The content in the letter includes thorough scientific connections and terminologies learned during prior topics. Not only the science is accurate, the writing shows superb quality.

Igneous Rock Vocabularies	Sedimentary Rock Vocabularies	Metamorphic Rock Vocabularies

1. **Felsic**
2. **Mafic**
3. **Intermediate**
4. **Ultramafic**
5. **Intrusive**
6. **Extrusive**
7. **Porphyritic**
8. **Equigranular**
  a. **Aphanitic**
  b. **Phaneritic**
9. **Vesicular**
10. **Amorphous**
11. **Volcanic**
12. **Plutonic**
13. **Batholith**
14. **Pluton**
15. **Dike**
16. **Sill**
	1. **Disintegration**
	2. **Decomposition**
	3. **Mechanical weathering**
	4. **Erosion**
	5. **Oxidation**
	6. **Clastic**
	7. **Stratification**
	8. **Bioclastic**
	9. **Crystalline**
	10. **Weathering rate**
	11. **Abrasion**
	12. **Cementation**
	13. **Deposition**
	14. **Erosional agent**
	15. **Land derived**
	16. **Precipitate**
	17. **Evaporite**
	18. **Layers**
		1. **Deformation**
		2. **Foliation**
		3. **Crystalline**
		4. **Regional metamorphism**
		5. **Contact metamorphism**
		6. **Parent rock**
		7. **Daughter rock**
		8. **Metaclastic**
		9. **Recrystallization**
		10. **Schistocity**
		11. **Fluid migration**