A Coaches Introduction to the 2017 R & M Event of the Science Olympiad

Presentation B

Minerals Characteristics

- Naturally occurring
- Inorganic
- Solid
- Definite chemical composition
- Orderly internal crystal structure

Physical Properties of Minerals

- Each mineral has a variety of physical and chemical properties which allow it to be identified.
- A few specimens have very unique characteristics: odor, color, magnetic properties, etc.
- Many of the more common properties are addressed in the following slides.

Physical Properties of Minerals

- Color - the color of the mineral as it appears to the eye in reflected light.
- Some minerals may have a range of colors. Example: quartz may be colorless, white, pink, purple, dark brown, green, or blue.

Physical Properties of Minerals

- Streak - the color of a mineral when ground to a powder. Streak color may differ from the mineral's natural color.
- Examples:

  Hematite may be silver or gray, but has a reddish brown streak.

  Pyrite is golden, but has a black streak.

Physical Properties of Minerals

- Luster - the character of light reflected from the mineral.
- A mineral's luster may be metallic or non-metallic.

Physical Properties of Minerals

- Hardness - the resistance of a mineral to scratching.
- Hardness is measured on a scale of 1 - 10 on the Mohs Scale.
- Hardness of minerals can be determined by comparison to several common objects – fingernail, copper object, nail, glass.
- Note: Pennies are no longer made of pure copper. Copper connectors used in plumbing found are available at hardware stores.

Physical Properties of Minerals

- Density - how heavy a mineral is for its size.
- The mass of a mineral divided by its volume is a measure of its density.
- Examples:

  Quartz has a density of 2.65 g/cm3. Gold has a higher density of 19.3 g/ cm_3.

Physical Properties of Minerals

- Crystal form - some minerals have unique crystalline shapes.
- Crystals "grow" through the addition of chemical ions to their surfaces as they crystallize from a magma or lava, mineral-rich waters, or gases.

Physical Properties of Minerals

- Perfect crystals are rare in nature because they typically grow close together in confined spaces, producing a mass of interlocking crystals.
- A crystal growing in a larger space may develop crystal faces.
- Crystal shape is related to the structural arrangement of atoms within the mineral.

Physical Properties of Minerals

- Cleavage - the tendency of a mineral to break along flat surfaces related to planes of weakness in its crystal structure.
- Minerals may be identified by the number of cleavage planes they exhibit and the angles between them.
- Examples:

  Some minerals, including muscovite and biotite, tend to cleave or break into flat sheets. Others, like halite, break into cubes, or calcite and dolomite into rhombs.

Physical Properties of Minerals

- Fracture - irregular breakage not related to planes of weakness.
- Some minerals do not have cleavage. Quartz and olivine, for example, exhibit conchoidal fracture.
- Conchoidal fracture produces curved breakage surfaces, such as seen on arrowheads, chipped glass, or the inside of seashells.

Physical Properties of Minerals

- Magnetism - A few minerals are magnetic. They are attracted to a magnet, or act as a natural magnet, attracting small steel objects such as paperclips.
- Example: Magnetite.
- Caution! Not all magnetite specimens are strong enough to attract metallic objects.

Physical Properties of Minerals

- Flexibility - Some minerals can be bent.
- Examples:

  Muscovite and biotite mica are elastic. When bent they return to their original shape.

  Gypsum is flexible. It bends and stays bent.

Physical Properties of Minerals

- Feel - Some minerals have a distinctive feel.
- Example:

Talc feels “soapy.”

Rock-Forming Minerals

- There are more than 3,000 minerals on the Earth, but comparatively few are common and make up most of the rocks.
- Rock-forming minerals are divided into two groups: silicates and non-silicates.

Rock-Forming Minerals: Silicates

- Earth's crust is dominated by 2 chemical elements:
  1. Oxygen (46.6% by weight)
  2. Silicon (27.7% by weight)
- These elements make up silicates, the dominant group of rock-forming minerals.

Rock-Forming Minerals: Silicates – Feldspar Group

- Feldspar group - Dominant mineral in Earth's crust.
- The feldspars have two directions of cleavage at 90^{o}, with flat, glassy rectangular surfaces.

Rock-Forming Minerals: Silicates – Feldspar Group

- Orthoclase feldspar (or potassium feldspar) group - $KAlSi_3O_8$
- Plagioclase feldspars range in composition from calcium-rich to sodium-rich. Only albite ($NaAlSi_3O_8$) has been included in the NSO list.
- Thin, parallel grooves, called striations, are visible on the plagioclase feldspars.

Rock-Forming Minerals: Silicates – Quartz

- Quartz (SiO_2) - Second-most abundant mineral in Earth's crust.
- Quartz is a major constituent in sand-stone and quartzite.
- Note: Chert is a sedimentary rock composed of microcrystalline quartz.

Rock-Forming Minerals: Silicates – Mica Group

- Mica group - Perfect cleavage in one direction causing it to split into thin sheets.
- Examples:

  Muscovite - Colorless or silvery-colored

  Biotite - Black or dark brown. Its dark color is due to presence of Mg and Fe.

  Lepidolite - lilac or rose-violet

Rock-Forming Minerals: Silicates – Amphibole Group

- Amphibole group - Two directions of cleavage, not at 90^{o}, producing narrow, elongated crystals.
- Example:

  Hornblende. Dark in color due to presence of Mg and Fe.

Rock-Forming Minerals: Silicates – Pyroxene Group

- Pyroxene group - Two directions of cleavage at 90°. Typically dark in color.
- Example:

  Augite. Contains Mg and Fe.

Rock-Forming Minerals: Silicates – Olivine

- Olivine - Olive green color and glassy texture. No cleavage. Conchoidal fracture. Contains Mg and Fe.

Rock-Forming Minerals: Silicates – Clay Minerals

- Clay minerals - A group of minerals formed through the weathering of feldspars and other minerals.
- Typically very fine-grained flakes, dull, earthy luster, soft, smooth feel.
- Example:

  Kaolinite, a white clay with many economic uses.

Rock-Forming Minerals: Non-Silicates

- Non-silicate minerals comprise about 8% of the minerals of the Earth's crust.
- There are many non-silicate minerals, grouped on the basis of their chemical composition into: native elements, oxides, sulfides, sulfates, carbonates, halides, phosphates, etc.

Rock-Forming Minerals: Non-Silicates: Carbonates

- Calcite ($CaCO_3$) - Calcium carbonate.

  Main constituent of limestone and marble.

  Rhombohedral cleavage – "deformed" cube having no right angles

Rock-Forming Minerals: Non-Silicates: Aragonite

- Aragonite ($CaCO_3$) - Calcium carbonate. Same chemical formula as calcite, but with a different crystalline structure.
- In time and with heating, aragonite will alter to form calcite.

Rock-Forming Minerals: Non-Silicates: Dolomite

- Dolomite ($CaMg(CO_3)_2$) - Calcium magnesium carbonate.
- Has rhombohedral cleavage like calcite.
- Main constituent of dolostone, sometimes referred to as dolomite rock.
- Forms from alteration of limestone through the addition of Mg.
- Dolostone is often difficult to distinguish from limestone.

Rock-Forming Minerals: Non-Silicates: Evaporites

- Evaporite minerals are formed through the evaporation of water containing ions in solution or dissolved salts.
- They include several chemical groups such as the halides and sulfates.

Rock-Forming Minerals: Non-Silicates Evaporites: Halite

- Halite (NaCl) - Sodium chloride
- Major constituent of rock salt (and table salt)
- Recognized by its cubic cleavage and salty taste (tasting is not permitted during NSO competitions)

Non-Silicates Evaporites: Gypsum

- Gypsum ($CaSO_4 \cdot 2H_2O$) - Hydrated calcium sulfate. Major constituent of rock gypsum.
- Used in Plaster of Paris and drywall.
- Recognized by its softness. Can be scratched with a fingernail.
- Varieties:
  1. Selenite - clear crystals with rhombohedral cleavage
  2. Alabaster - fine-grained and massive
  3. Satin spar - fibrous

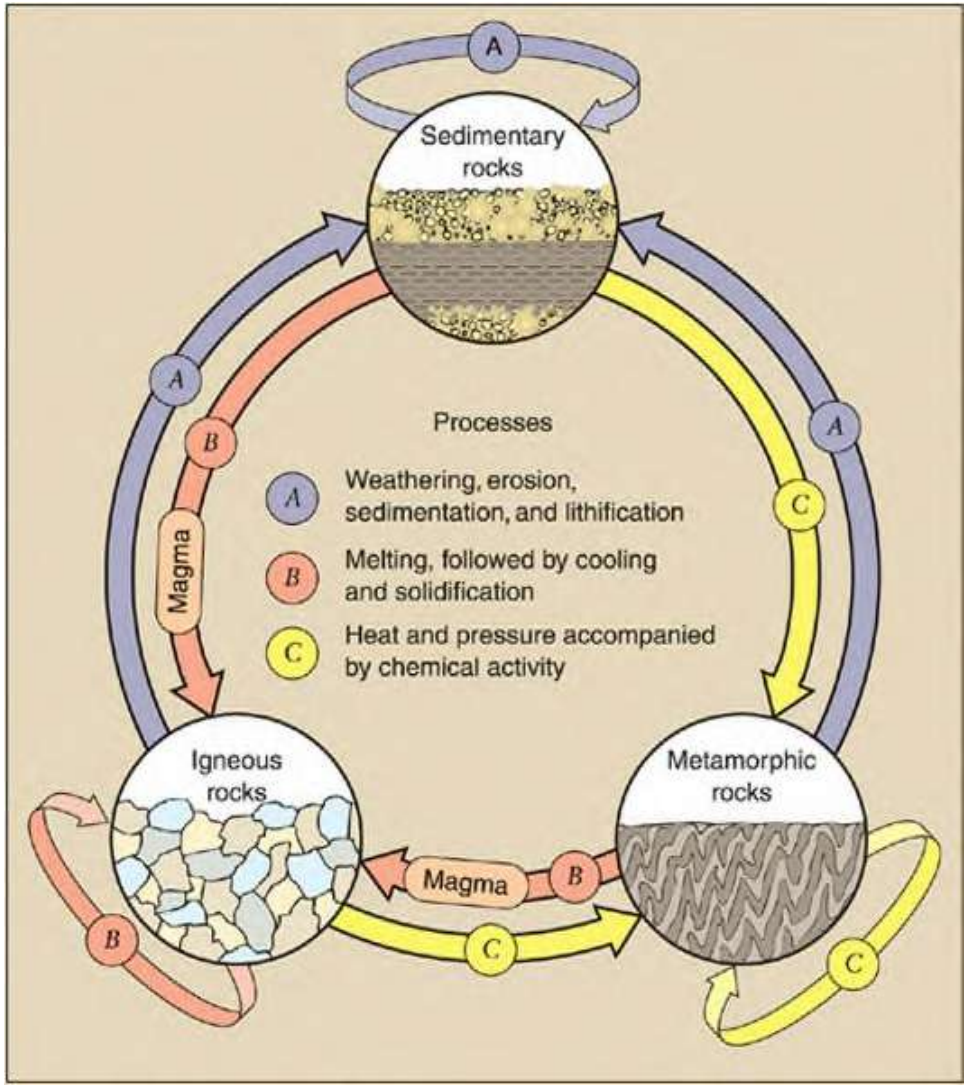
Rocks

- A rock is an aggregate of one or more minerals.
- Rocks are the building blocks of the Earth's crust.

Rocks

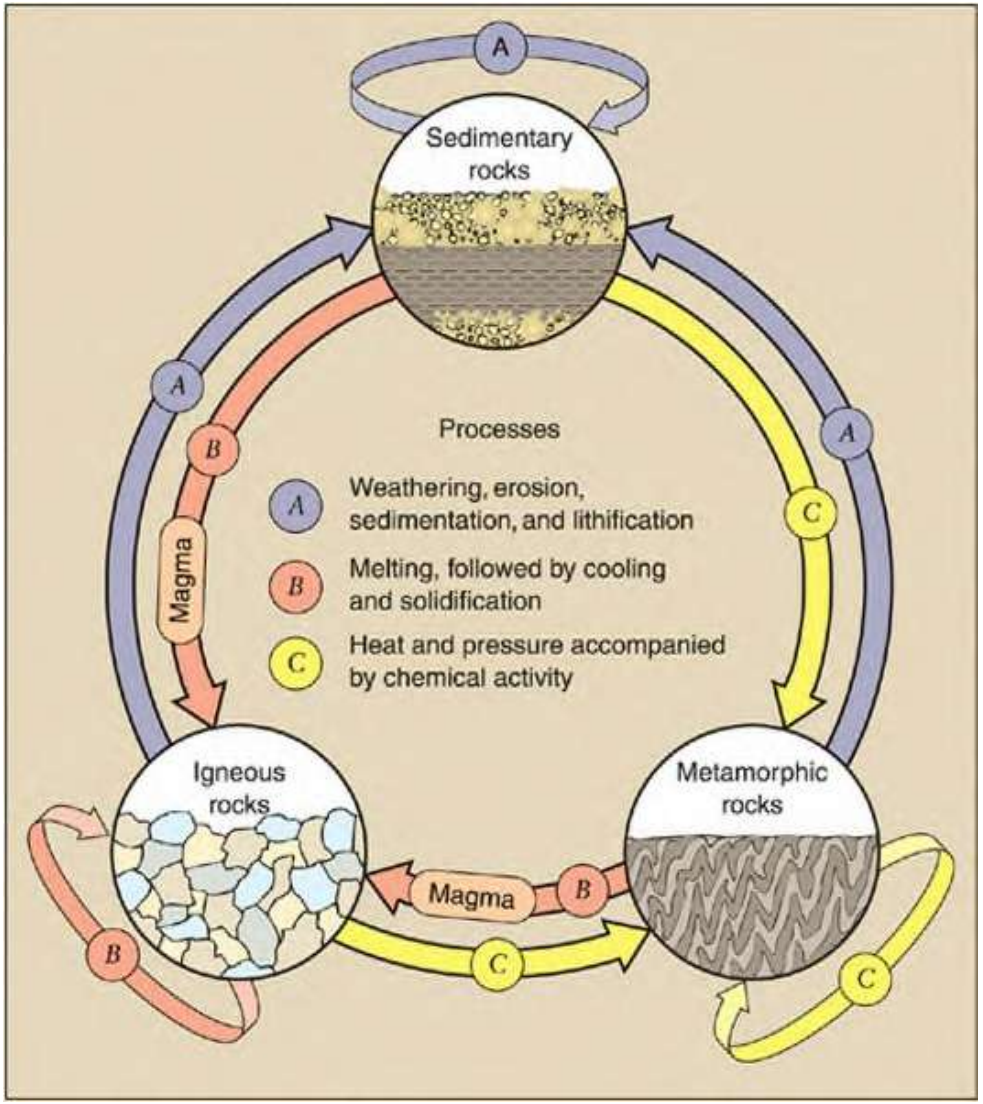
- Igneous - crystallized from hot, molten rock Examples: granite, basalt
- Sedimentary - fragments of sediment laid down by water or wind are compressed or cemented over time Examples: sandstone, shale, limestone
- Metamorphic - rocks changed by heat and or pressure or chemical activity Examples: gneiss, schist, slate, marble

Rock Cycle



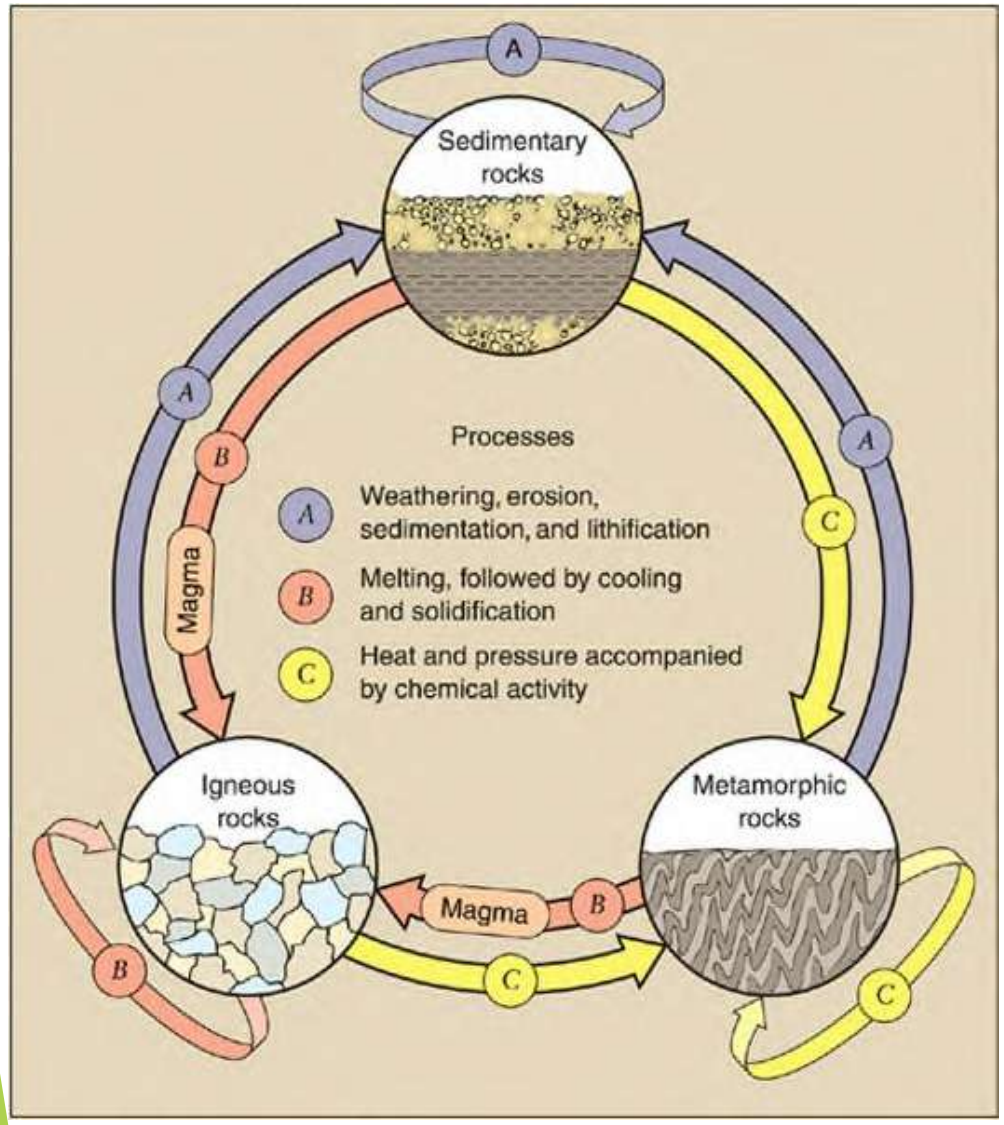
- Igneous rocks can be weathered and eroded to form sediment (gravel, sand, silt, clay).

Rock Cycle



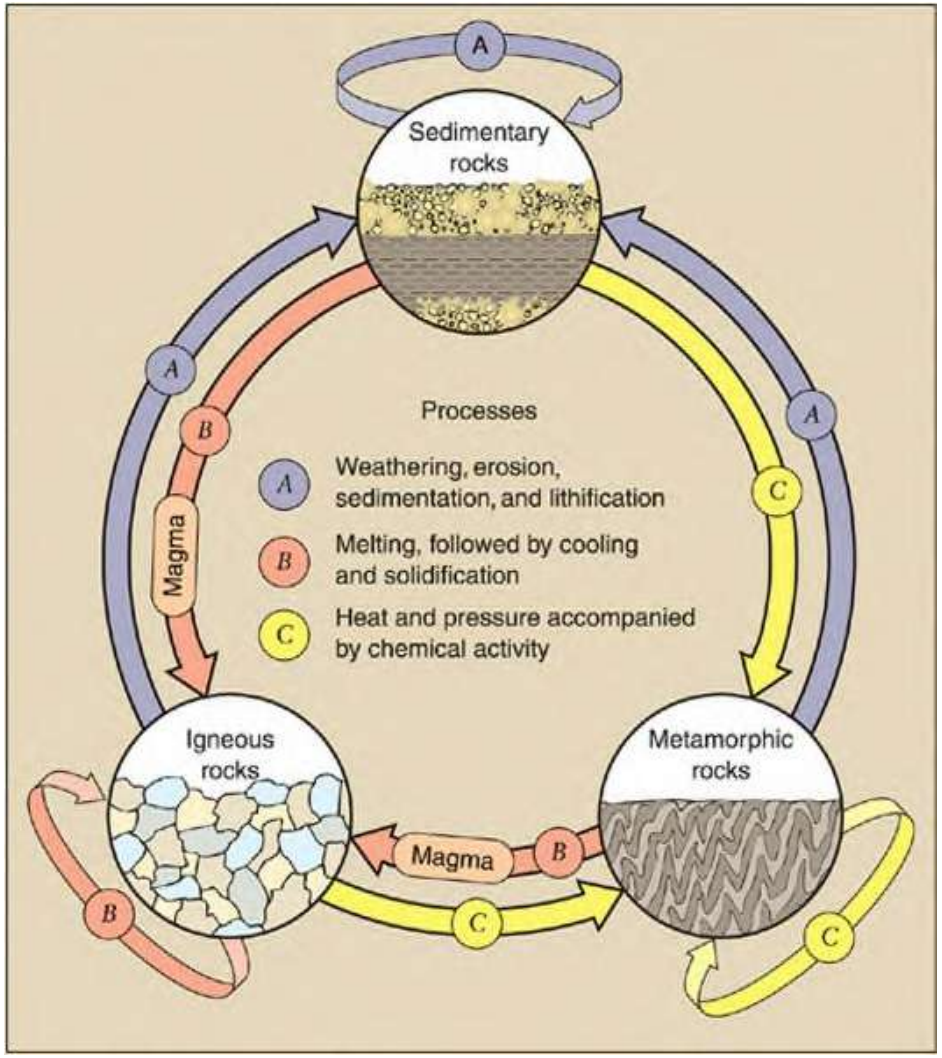
- Sediment is cemented and compacted to form sedimentary rocks.

Rock Cycle



- Sedimentary rocks may be deeply buried and subjected to heat and pressure which convert them to metamorphic rocks.

Rock Cycle

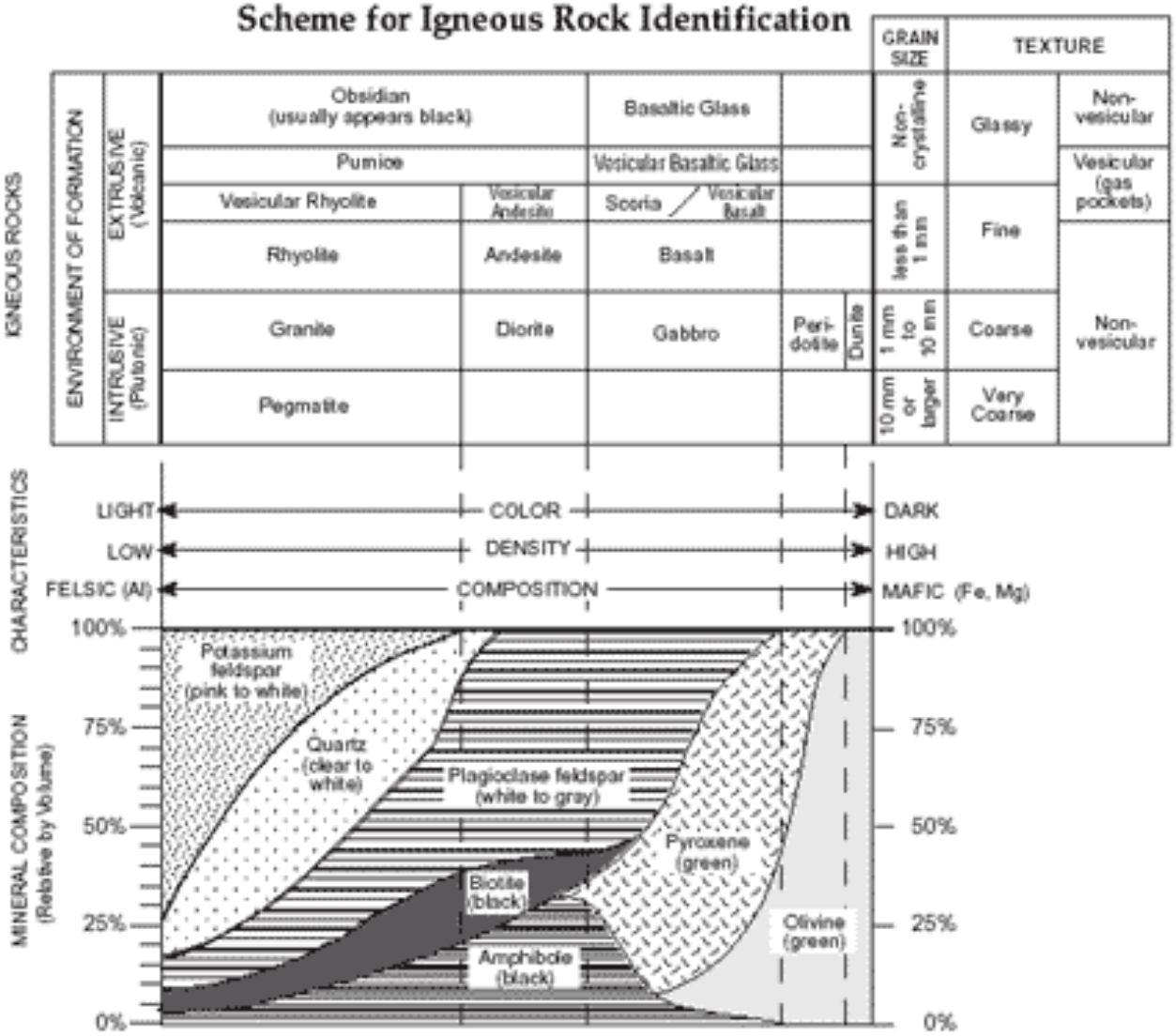


- All three types of rocks may be weathered and eroded.
- Igneous rocks can also be metamorphosed or melted.

Igneous Rocks

- The term igneous means "fire-formed." Igneous rocks crystallized from hot, molten magma or lava, as it cooled.
- Magma is hot, molten rock beneath the surface of the Earth.
- Lava is hot, molten rock that has flowed out and onto the surface of the Earth.
- Igneous rocks make up more than 90% of Earth's crust, by volume.

Igneous Rocks



Igneous Rocks

- Extrusive or volcanic rocks form from lava, which cooled on the Earth's surface.
- Examples: basalt, rhyolite, andesite, obsidian

Igneous Rocks

- Intrusive or plutonic igneous rocks formed from magma which cooled deep beneath the surface of the Earth.
- Examples: granite, gabbro, diorite

Igneous Rocks

- The texture of a rock is a description of its grain size.
- The rate of cooling influences the texture of igneous rocks.

  Extrusive rocks = quick cooling = fine grained

  Intrusive rocks = slow cooling = coarse grained

Igneous Rocks – Composition

- Felsic (or sialic) - Rich in silicon, oxygen, and aluminum. Tends to have light-colored minerals such as quartz and potassium feldspar. Examples: granite, rhyolite.
- Intermediate - Intermediate in composition between felsic and mafic. Mixture of light and dark minerals. Examples: diorite, andesite.
- Mafic - Iron and magnesium rich. Typically dark-colored. Examples: gabbro, basalt.

Igneous Rocks – Basalt

- Earth's continental crust is dominated by granite.
- Granite is coarse-grained and has predominantly light-colored minerals.

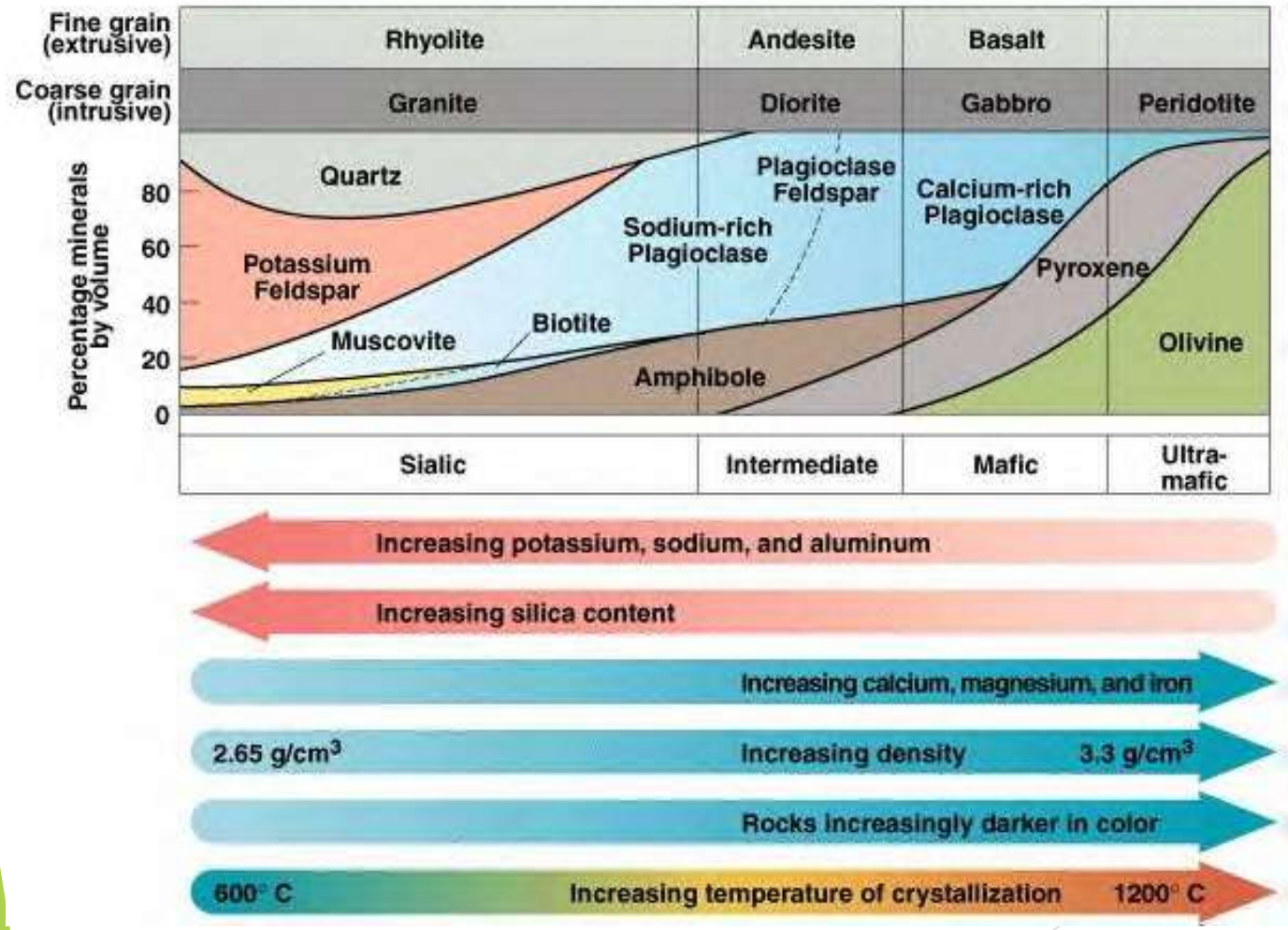
Igneous Rocks – Basalt

- Basalt is fine-grained with a dark color due to its being rich in iron and magnesium.
- Ocean crust is dominated by basalt which covers about 70% of Earth's surface.

Igneous Rocks

Photos courtesy of Pamela Gore.

Igneous Rocks



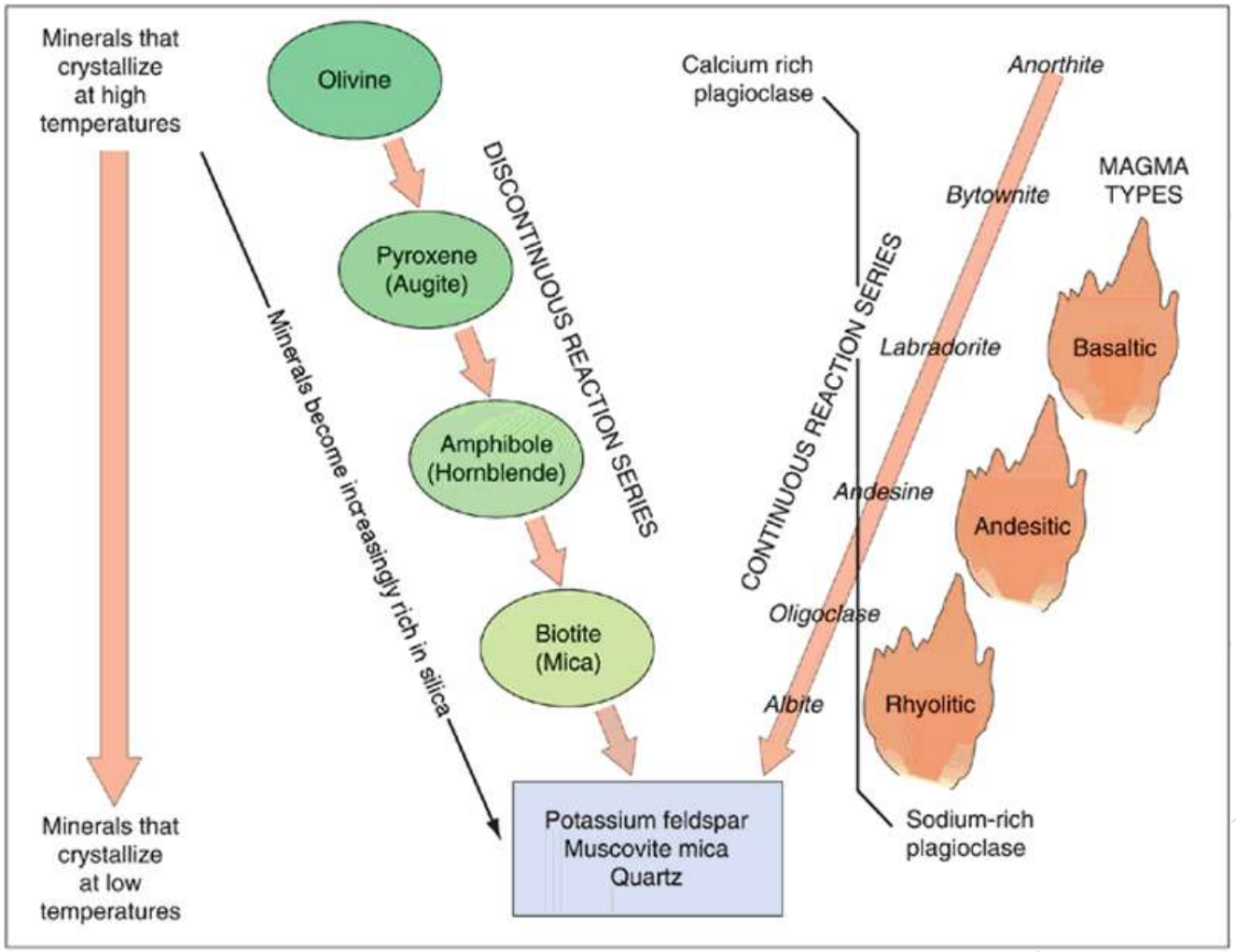
Igneous Rocks

- Volcanic activity has produced enormous volumes of rock.
- Basaltic lavas have a low viscosity and can flow for considerable distances before solidifying.
- Low viscosity means “runny.”

Igneous Rocks

- Felsic to intermediate lavas are more viscous, which causes gases to be trapped producing explosive eruptions.
- Viscous means “thick or pasty.”

Bowen's Reaction Series

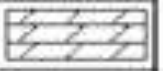
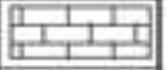


Sedimentary Rocks

- Sedimentary rocks cover about 75% of the world's land area.
- Sedimentary rocks form when loose sediment (gravel, sand, silt, or clay) becomes compacted and/or cemented to form rock.
- The process of converting sediment to sedimentary rock is called lithification.
- Sediment is deposited in horizontal layers called beds or strata.

Sedimentary Rocks

Scheme for Sedimentary Rock Identification

INORGANIC LAND-DERIVED SEDIMENTARY ROCKS					
TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Clastic (fragmental)	Pebbles, cobbles, and/or boulders embedded in sand, silt, and/or clay	Mostly quartz, feldspar, and clay minerals; may contain fragments of other rocks and minerals	Rounded fragments	Conglomerate	
			Angular fragments	Breccia	
	Sand (0.2 to 0.006 cm)		Fine to coarse	Sandstone	
	Silt (0.006 to 0.0004 cm)		Very fine grain	Siltstone	
	Clay (less than 0.0004 cm)		Compact; may split easily	Shale	
CHEMICALLY AND/OR ORGANICALLY FORMED SEDIMENTARY ROCKS					
TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Crystalline	Varied	Halite	Crystals from chemical precipitates and evaporites	Rock Salt	
	Varied	Gypsum		Rock Gypsum	
	Varied	Dolomite		Dolostone	
Bioclastic	Microscopic to coarse	Calcite	Cemented shell fragments or precipitates of biologic origin	Limestone	
	Varied	Carbon	From plant remains	Coal	

Sedimentary Rocks - History

- Sedimentary rocks provide information about ancient history and life on Earth.
- Sedimentary rocks reveal locations of ancient environments such as seas, reefs, deltas, beaches, rivers, lakes deserts, glaciers, and mountains.

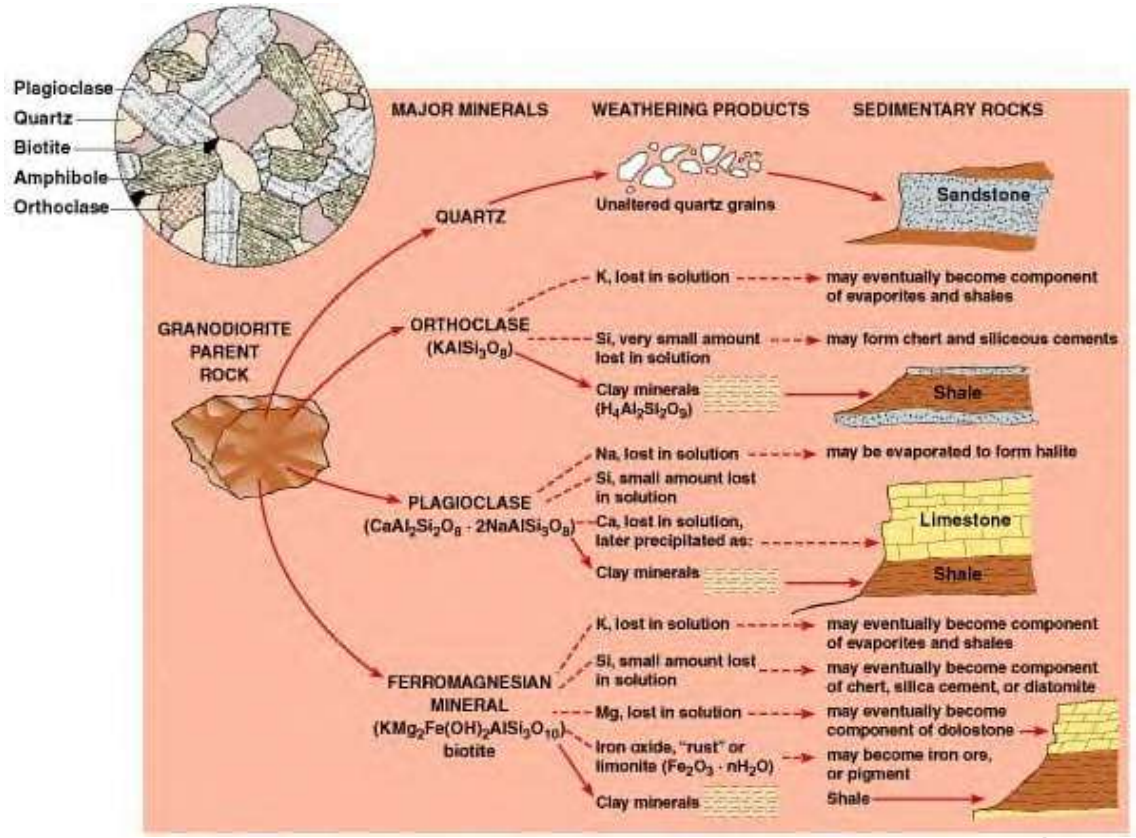
Sedimentary Rocks - History

- Sedimentary rocks provide information about ancient climates:
  1. Times of humid tropical coal swamps
  2. Times of dry wind-swept deserts
  3. Times of glaciers that covered large areas of the continents
  4. Times of high temperatures and high sea levels

Sedimentary Rocks - History

- Sedimentary rocks contain the fossil record, which preserves the evolving story of life on Earth.
- Sedimentary rocks also hold the fossil fuels and energy resources on which our culture depends — coal, oil, natural gas. Careful reading of the rock record allows exploration geologists locate these critical resources.

Conceptual Diagram Showing Weathering Products of Granodiorite



Types of Sedimentary Rocks

- Clastic
- Chemical/Biochemical
- Organic

Clastic Sedimentary Rocks

- Clastic sedimentary rocks are derived from the weathering of pre-existing rocks, which have been transported to the depositional basin.
- They have a clastic (broken or fragmental) texture consisting of:

  1. Clasts (larger pieces, such as sand or gravel)

  2. Matrix (mud or fine-grained sediment surrounding the clasts)

  3. Cement (calcite, iron oxide, or silica)

Clastic Sedimentary Rocks

- Clastic sedimentary rocks are classified according to texture (grain size):
  1. Gravel: Grain size greater than 2 mm.
     If rounded clasts = conglomerate
     If angular clasts = breccia
  2. Sand: Grain size 1/16 to 2 mm.
     Sandstone (various types)
  3. Clay: Grain size less than 1/256 mm
     Shale (if fissile)

Chemical/Biochemical Sedimentary Rocks

- This group includes the evaporites, carbonates, and siliceous rocks.
- These rocks form within the depositional basin from chemical components dissolved in seawater.
- Chemicals may be removed from seawater and made into rocks by chemical processes or with the assistance of biological processes such as shell growth.

Evaporites

- Evaporites form from materials left behind by the evaporation of water (usually seawater).
- Example:

  Travertine - forms in caves and around hot springs

Carbonates

- Carbonate sedimentary rocks are formed through both chemical and biochemical processes.
- They include the limestones and dolostones.
- Minerals in carbonate rocks: calcite, dolomite, aragonite

Carbonates

- Fossiliferous limestone – composed of various types of fossils in a limestone matrix
- Oolitic limestones – sand-sized oolites
- Coquina – fossil hash cemented together

Carbonates

- Chalk - made of microscopic planktonic organisms such as coccolithophores
- Crystalline limestone
- Travertine (see evaporites)

Siliceous Rocks

- Siliceous rocks are dominated by silica (SiO_2).
- Siliceous rocks commonly form from silica-secreting organisms such as diatoms, radiolarians, or some types of sponges.

Siliceous Rocks

- Chert is formed through chemical reactions of silica in solution replacing limestones.
- Silica leaching from beds of volcanic ash also replaces limestone below the ash layers.
- Diatomite - Composed of microscopic planktonic organisms called diatoms.

Organic Sedimentary Rocks (Coals)

- This group consists of rocks composed of organic matter (mainly *plant fragments*) which have accumulated in swamps or marshes.
- They lack minerals which, by definition, must be inorganic.
- These are the various forms of coals.

Organic Sedimentary Rocks (Coals)

- Peat – porous mass of brownish plant fragments resembling peat moss
- Lignite – crumbly and black
- Bituminous coal – dull to shiny and black; sooty; layers may be visible
- Anthracite coal – extremely shiny and black, may have a slight golden shine; low density; not sooty. Some classify it as metamorphic. The Science Olympiad classifies it as sedimentary.

Commercial Use of Coals

- Coal is the source of more than half of all electricity produced in the United States.
- Chemicals derived from coal are used in the manufacture of plastics, tar, synthetic fibers, fertilizers, and medicines.

Metamorphic Rocks

- The word metamorphic means "changed form."
- Metamorphism causes changes in the texture and mineralogy of other rocks.
- Metamorphism results from:

  1. High temperatures,
  2. High pressures, and
  3. Chemical reactions

Metamorphic Rocks

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 increase with depth)	Low-grade metamorphism of shale	Slate	
FOLIATED – MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increase with depth)	Foliation surfaces shiny from microscopic mica crystals	Phyllite	
FOLIATED – MINERAL ALIGNMENT	Fine to medium	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increase with depth)	Platy mica crystals visible from metamorphism of clay or feldspars	Schist	
FOLIATED – BANDING	Medium to coarse	MICA, QUARTZ, FELDSPAR, AMPHIBOLE, GARNET, PYROXENE	Regional (Heat and pressure increase with depth)	High-grade metamorphism; some mica changed to feldspar; segregated by mineral type into bands	Gneiss	
NONFOLIATED	Fine	Variable	Contact (Heat)	Various rocks changed by heat from nearby magma/lava	Hornfels	
NONFOLIATED	Fine to coarse	Quartz	Regional or Contact	Metamorphism of quartz sandstone	Quartzite	
NONFOLIATED	Fine to coarse	Calcite and/or dolomite	Regional or Contact	Metamorphism of limestone or dolostone	Marble	
NONFOLIATED	Coarse	Various minerals in particles and matrix	Regional or Contact	Pebbles may be distorted or stretched	Metaconglomerate	

Types of Metamorphism

- Contact metamorphism - Alteration of rock by heat adjacent to hot molten lava or magma.
- Economically important as setting for metallic ores – gold, silver, copper, lead, zinc, etc.

Types of Metamorphism

- Regional metamorphism - Alteration of rock over a large area by heat and pressure due to deep burial or tectonic processes.

Types of Metamorphic Rock

- Foliated - Laminated structure in a metamorphic rock resulting from the parallel alignment of sheet-like minerals

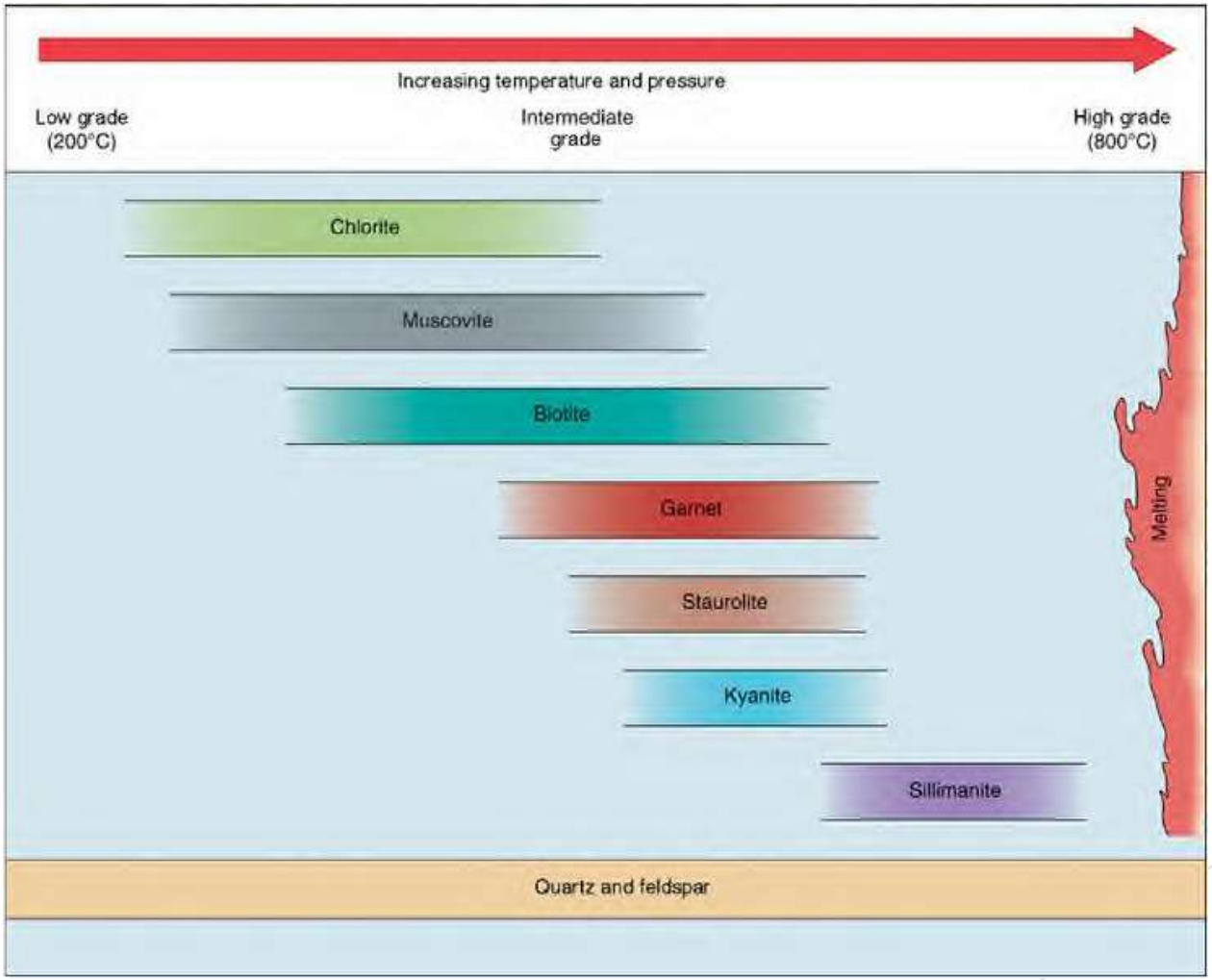
  Examples: slate, phyllite, schist, gneiss
- Non-foliated – no preferred orientation

  Examples: marble, quartzite

Metamorphic Index Minerals

- Certain minerals form during metamorphism, under specific pressure and temperature conditions.
- These metamorphic index minerals can be used as a guide to metamorphic pressures and temperatures.

Metamorphic Index Minerals



Rock Exam

- The following questions and answers are from the New York State Regents Website: http://www.regentsprep.org/Regents/core/questions/topics.cfm?Course=ESCI
- See you well you can do.

Rock Quiz Question # 1

- Compared to felsic igneous rocks, mafic igneous rocks contain greater amounts of

  1. white quartz
  2. aluminum
  3. pink feldspar
  4. iron

Rock Quiz Question # 1

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  1. white quartz
  2. aluminum
  3. pink feldspar
  4. iron

Rock Quiz Question # 2

- What are the two most abundant elements by mass found in Earth's crust?

  1. aluminum and iron
  2. sodium and chlorine
  3. calcium and carbon
  4. oxygen and silicon

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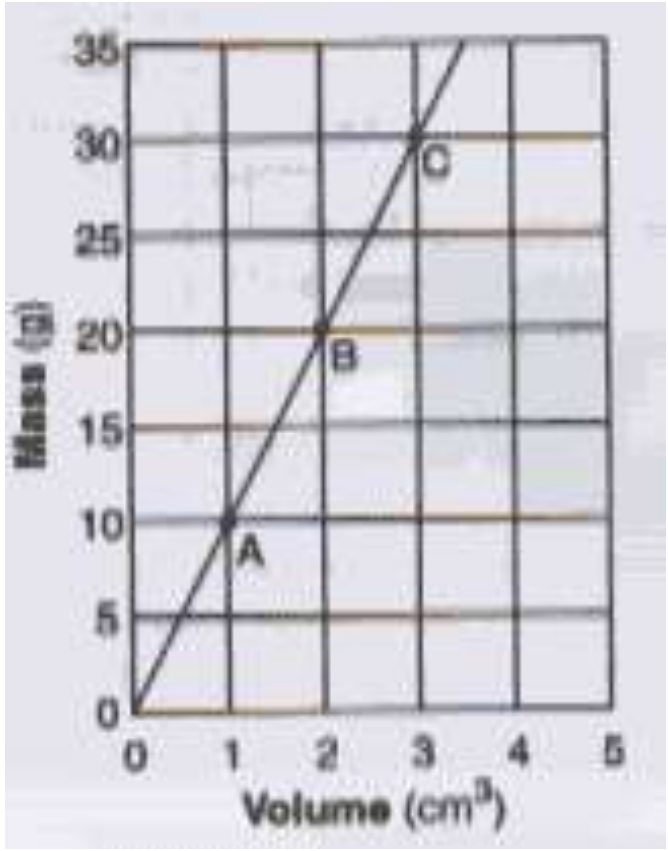
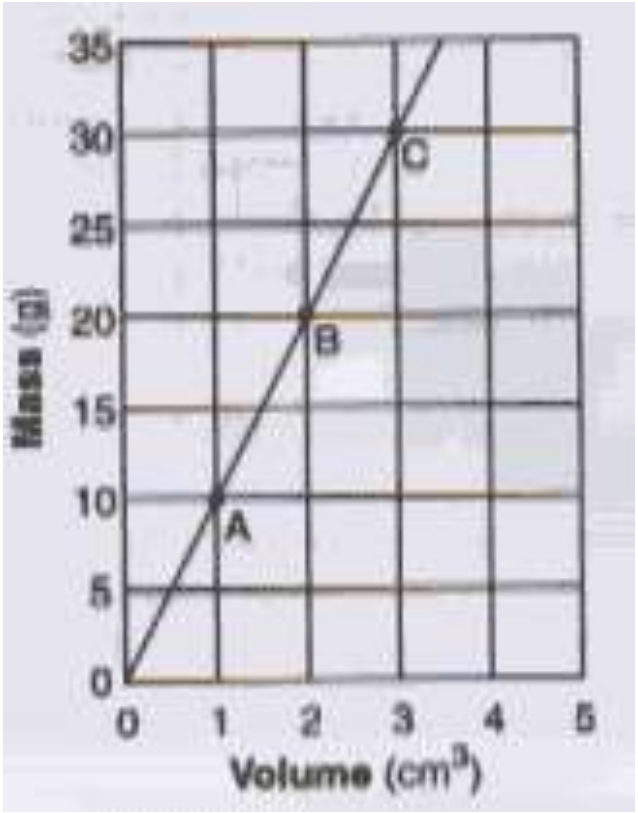
Rock Quiz Question # 3



- The graph below shows the relationship between mass and volume for three samples, A, B, and C, of a given material. What is the density of this material?

  1. 1.0 g/cm³
  2. 5.0 g/cm³
  3. 10.0 g/cm³
  4. 20.0 g/cm³

Rock Quiz Question # 3



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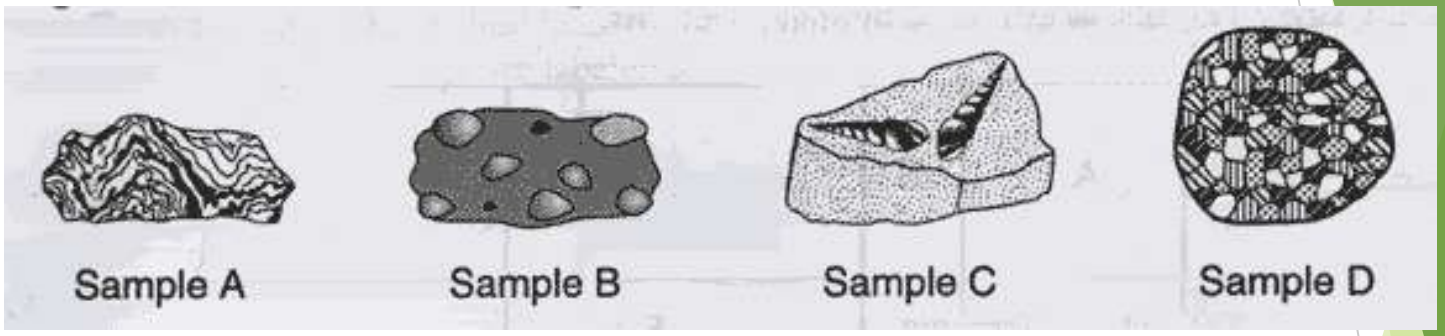
1. 1.0 g/cm³
2. 5.0 g/cm³
3. 10.0 g/cm³
4. 20.0 g/cm³

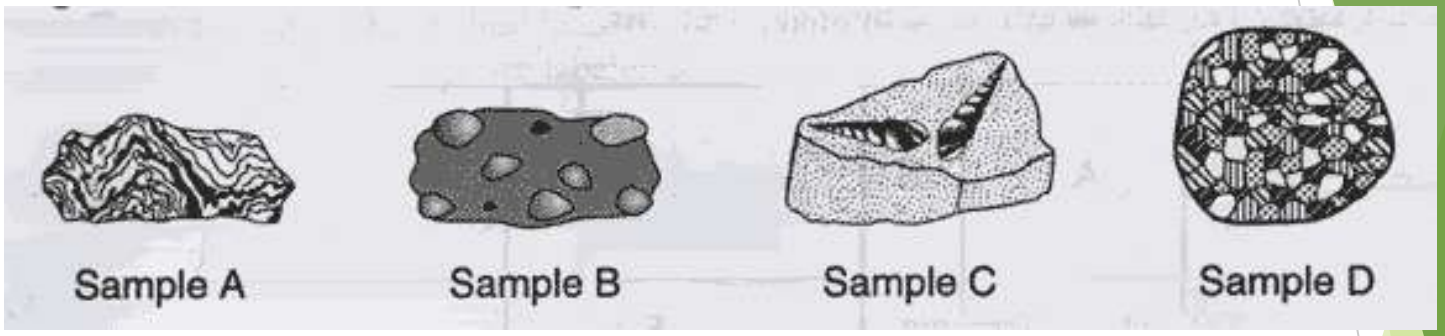
Rock Quiz Question # 4



Which sample best shows the physical properties normally associated with regional metamorphism?

1. *A*
2. *B*
3. *C*
4. *D*

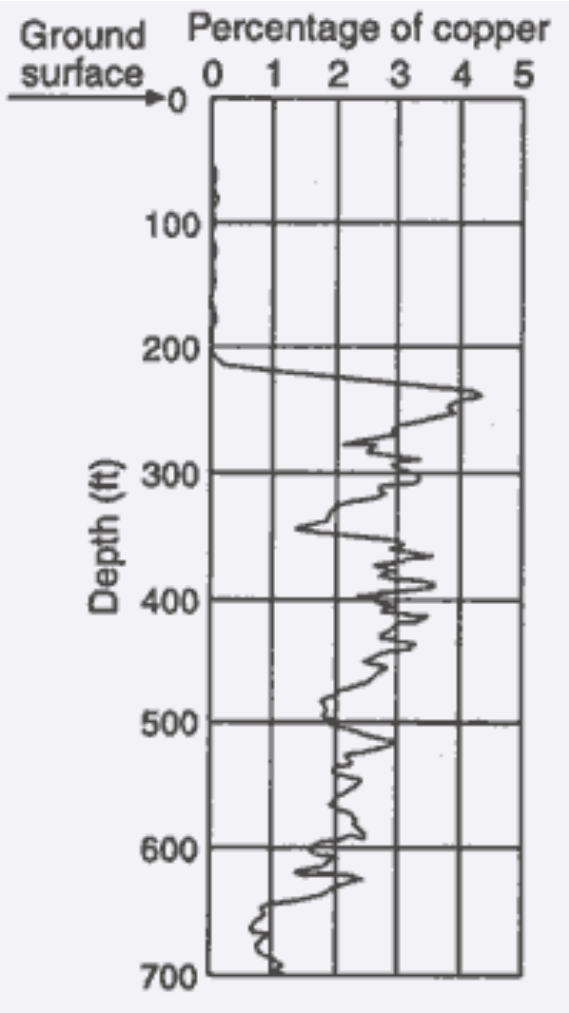
Rock Quiz Question # 4



Which sample best shows the physical properties normally associated with regional metamorphism?

1. *A*
2. *B*
3. *C*
4. *D*

Rock Quiz Question # 5

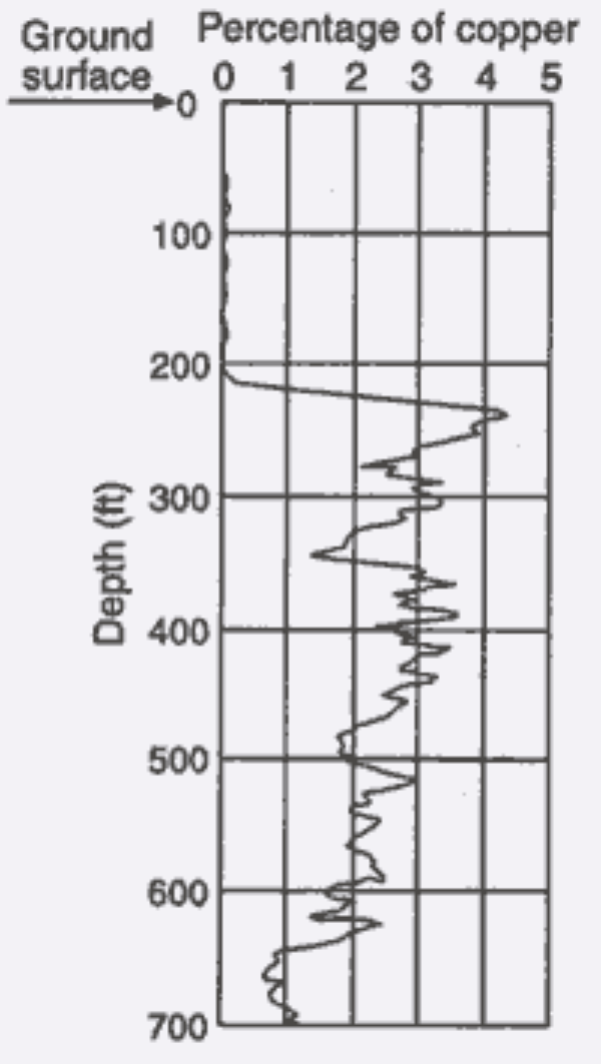


The graph to the left shows the concentration (percentage) of copper at various depths in the bedrock at a mine in Arizona.

Between which depths should the bedrock be mined in order to obtain rock with the highest percentage of copper?

1. 100-130 ft
2. 230-260 ft
3. 330-360 ft
4. 650-680 ft

Rock Quiz Question # 6



The graph to the left shows the concentration (percentage) of copper at various depths in the bedrock at a mine in Arizona.

Between which depths should the bedrock be mined in order to obtain rock with the highest percentage of copper?

1. 100-130 ft
2. 230-260 ft
3. 330-360 ft
4. 650-680 ft

Rock Quiz Question # 6

- Which mineral is white or colorless, has a hardness of 2.5, and splits with cubic cleavage?

1. calcite
2. halite
3. pyrite
4. mica

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Rock Quiz Question # 7

- Compared to dull and rough rock surfaces, shiny and smooth rock surfaces are most likely to cause sunlight to be

1. reflected
2. refracted
3. scattered
4. absorbed

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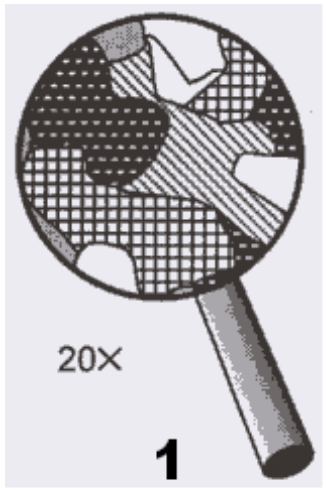
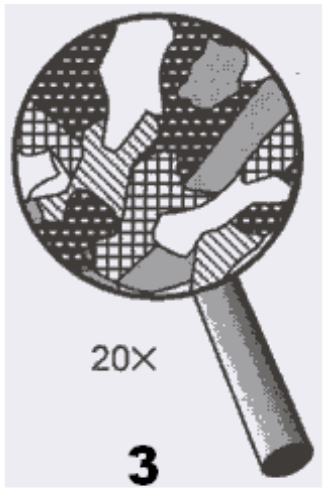
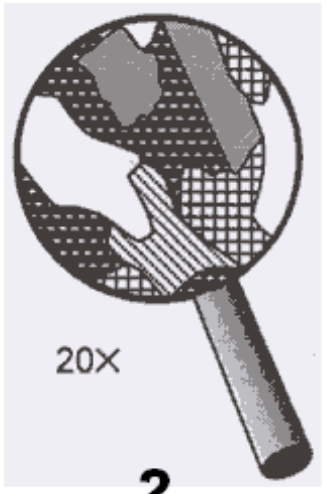
Rock Quiz Question # 8



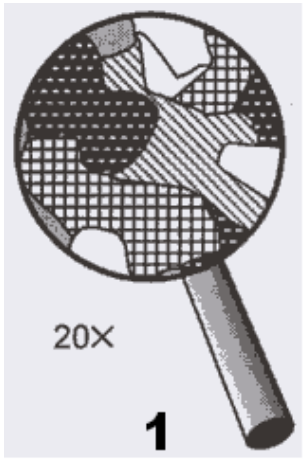


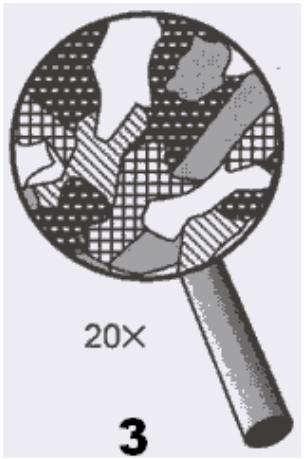


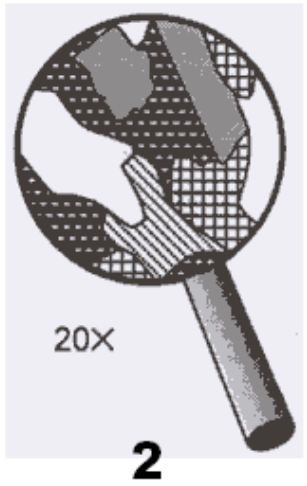
- The diagrams below show the crystals of four different rocks viewed through the same hand lens. Which crystals most likely formed from molten material that cooled and solidified most rapidly?

1 2 3 4

Rock Quiz Question # 8







- The diagrams below show the crystals of four different rocks viewed through the same hand lens. Which crystals most likely formed from molten material that cooled and solidified most rapidly?

1 2 3 4

Rock Quiz Question # 9

- Which sedimentary rock is most likely to be changed to slate during regional metamorphism?

1. breccia
2. conglomerate
3. dolostone
4. shale

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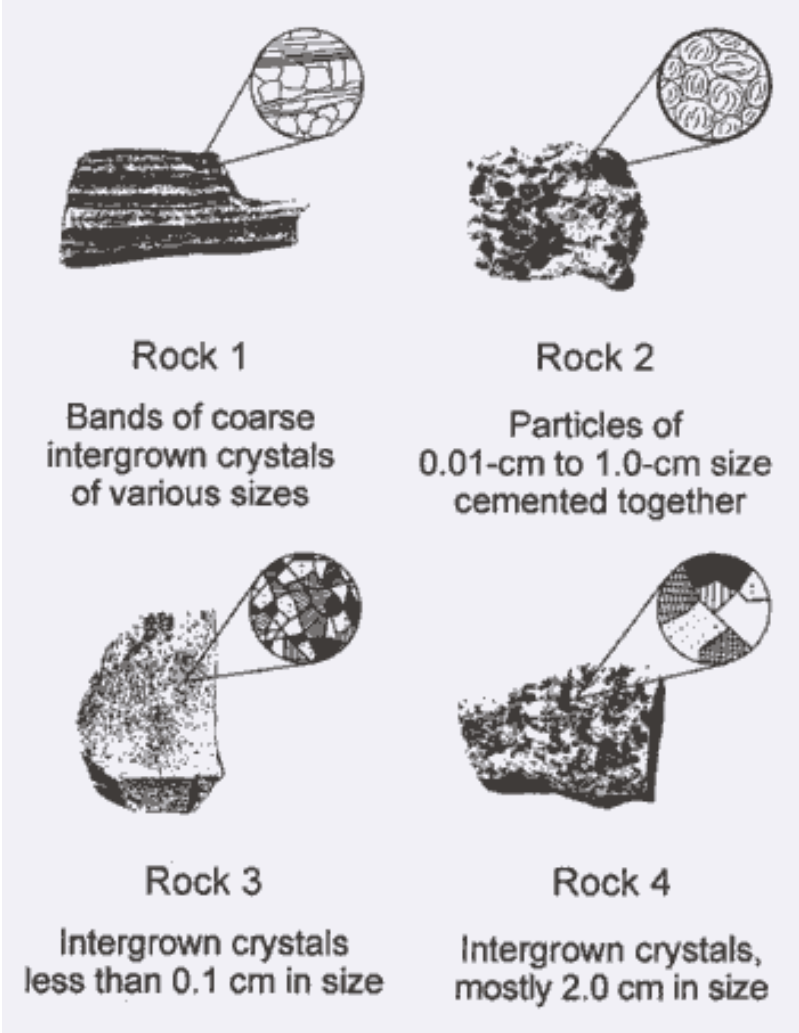
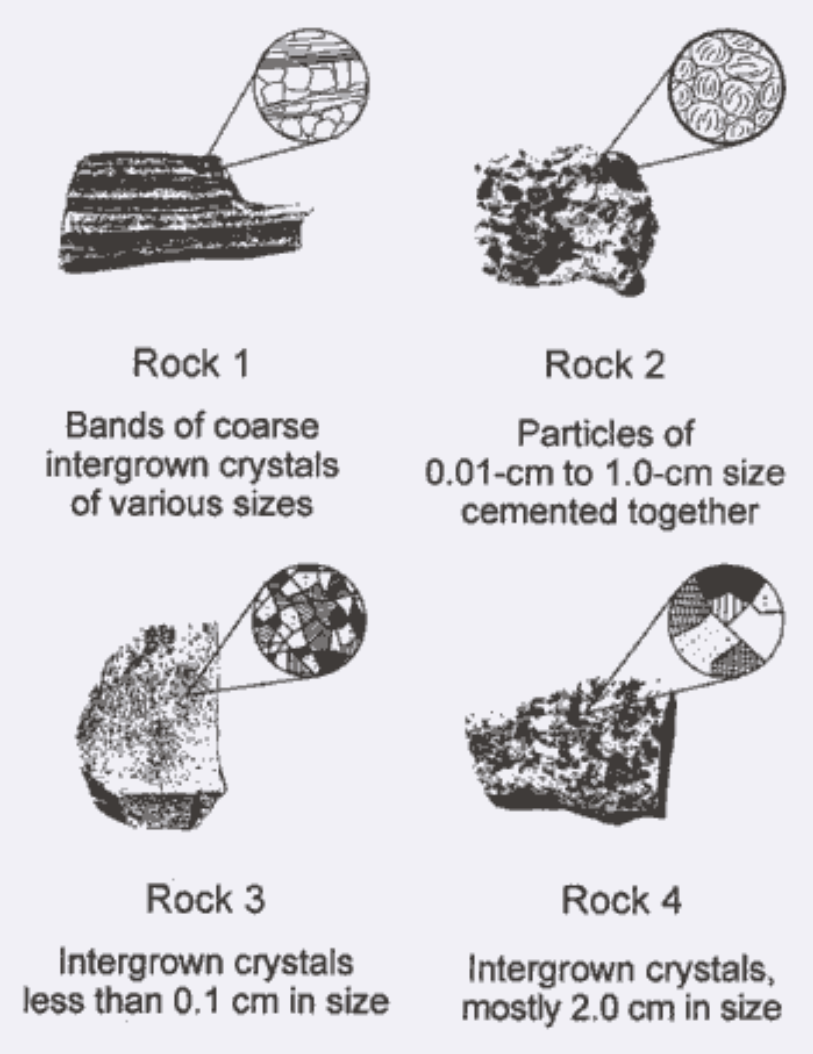
Rock Quiz Question # 10



- Base your answers to this question on the pictures of four rocks shown below. Magnified views of the rocks are shown in the circles.
  Which rock is metamorphic and shows evidence of foliation?

  1 2 3 4

Rock Quiz Question # 10



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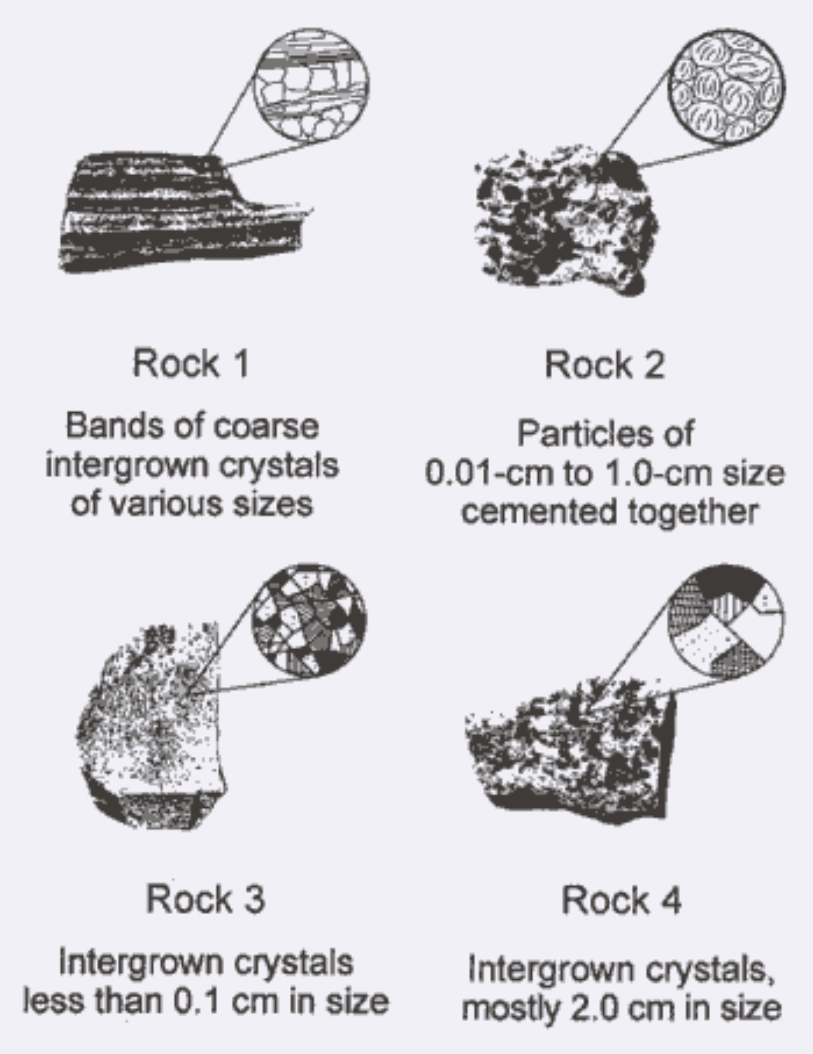
Rock Quiz Question # 11

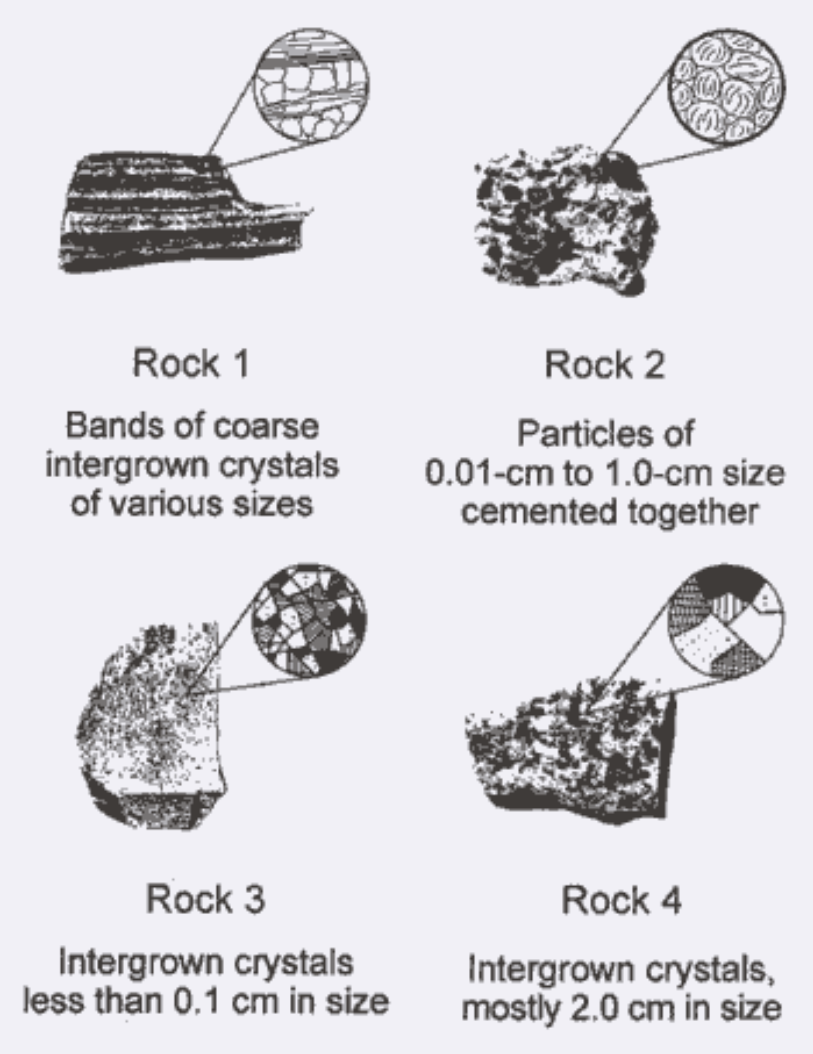


- Base your answers to this question on the pictures of four rocks shown below. Magnified views of the rocks are shown in the circles.

  What do all four rock samples have in common?

  1. They show cleavage.
  2. They contain minerals.
  3. They are organically formed.
  4. They formed on Earth's surface.

Rock Quiz Question # 11



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