EARTH SCIENCE

KEY

UNIT 3-H

YOUR PLANET

YOUR INHERITANCE

YOUR LEGACY

UPDATED AND ADAPTED FROM DAVID J. MILLS 2001

UNIT 3
ROCKS AND MINERALS

I. MINERALS:

A. DEFINITION: A mineral is:

1. NATURALLY OCCURRING - FOUND IN NATURE, NOT MAN MADE
   - Minerals: QUARTZ, PYRITE
   - Not minerals: CEMENT, STEEL

2. INORGANIC
   - NOT FORMED FROM LIVING THINGS OR THE REMAINS OF LIVING THINGS

   - COAL is NOT a mineral because it comes from PLANTS
   - AMBER is NOT a mineral because it comes from TREE SAP
   - PEARLS are NOT minerals because they come from OYSTERS

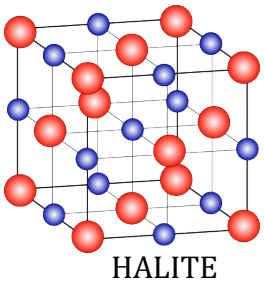
3. SOLID: Have a definite SIZE / VOLUME and a definite SHAPE

   - OIL is not a mineral because it is a LIQUID

4. DEFINITE CHEMICAL COMPOSITION (SAME COMPOSITION ALL OVER)

Name of Mineral	Chemical Formula	Chemical Name	Elements and number of Atoms/Molecules
HALITE	NaCl	SODIUM CHLORIDE	1 SODIUM
			1 CHLORINE
QUARTZ	SiO_2	SILICON DIOXIDE	1 SILICON
			2 OXYGEN
PYRITE	FeS_2	IRON SULFIDE	1 IRON
			2 SULFUR

5. **DEFINITE CRYSTAL STRUCTURE** –
   - **Atoms Arranged In Repeating Patterns**.
   - **Characteristic Geometry Of Its Internal Structure Of Atoms**.


HALITE

B. **FORMATION OF MINERALS**- Minerals form:
1. **From Cooling Magma / Lava**
2. **When Water Evaporates And Dissolved Minerals Are Left Behind. (EVAPORITES)**

3. **When A Solution (Water) Is Saturated With Minerals, The Minerals Will Settle Out Of The Solution – "PRECIPITATES"**

II. **IDENTIFYING MINERALS**: Minerals can be identified based on their **PHYSICAL** and / or **CHEMICAL** properties.

A. **PHYSICAL PROPERTIES**:

1. **COLOR**: **Least reliable property for identification**.


Malachite

a. Some minerals have only one color
   1. Malachite - **GREEN**


Sulfur

   2. Sulfur – **YELLOW**

b. Other minerals can have many colors
   1. Quartz – **CLEAR, PINK,(ROSE), PURPLE AMETHYST), WHITE (MILKY), GRAY-BROWN SMOKY), ETC.**


Quartz

   2. Hematite: **BLACK, GRAY, REDDISH-BROWN, DARK RED**


Hematite

c. Colors can vary as the result of:

1. **NATURAL COLORING AGENTS (IMPURITIES)**
2. **WEATHERING – EXPOSURE TO THE ENVIRONMENT; AIR, TEMP. CHANGES, POLLUTION**

2. **STREAK: THE COLOR OF THE POWDER LEFT BEHIND WHEN A MINERAL IS RUBBED ON A STREAK PLATE**

a. Hematite- Colors: Dark red
Reddish brown
Gray
Black
} Streak: **REDDISH-BROWN**

b. Quartz – Colors: Colorless (clear)
Variable
} Streak: **WHITE / COLORLESS**


Hematite

3. **LUSTER**: **THE WAY THE MINERAL SHINES OR REFLECTS LIGHT FROM ITS SURFACE**.

a. a. **METALLIC** – **Shines / reflects light like the surface of polished metal**.
Exaples: **galena**, **pyrite**, **graphite**, **magnetite**

b. **NON-METALLIC** – **Do not look like metals**:

(1)	**Pearly**	**Mica**
(2)	**Glassy**	**Quartz, halite**
(3)	**Dull, earthy**	**Bauxite**
(4)	**Waxy**	**Talc**
(5)	**Brilliant**	**Diamond**

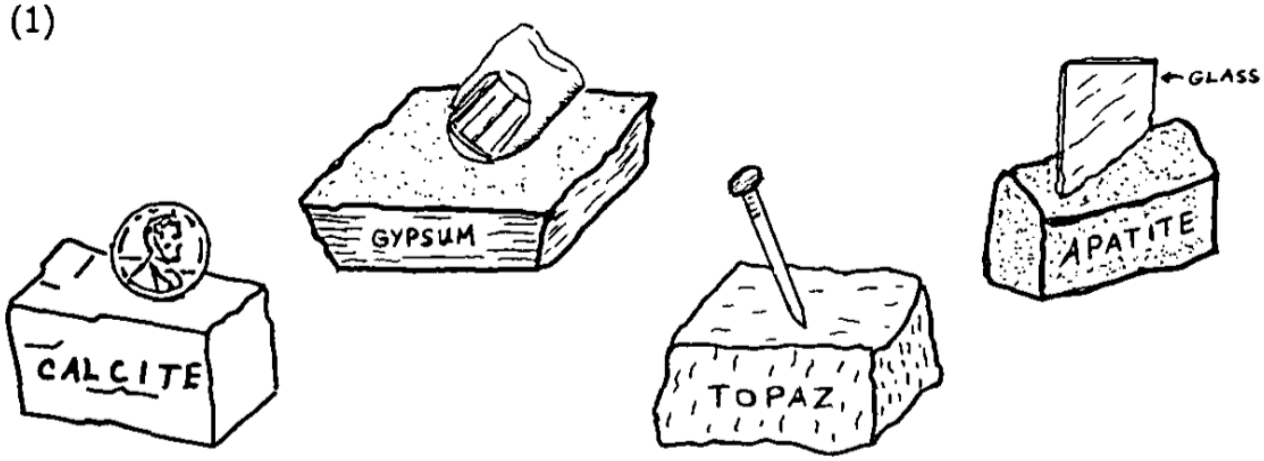
4. **HARDNESS**- A measure of how easily the mineral can be scratched.
   a. Softest Mineral – **TALC**
   b. Hardest Mineral – **DIAMOND**

NUMBER	MINERAL
1	Talc
2	Gypsum
3	Calcite
4	Fluorite
5	Apatite
6	Feldspar
7	Quartz
8	Topaz
9	Corundum
10	Diamond

HARDNESS OF COMMON OBJECTS		
2.5	Fingernail	
3.5	Copper (Penny)	
4.5	Iron Nail	
5.5	Glass (slide)	
6.5	Steel File	
7	Streak Plate	

d. **TESTING HARDNESS**: Under each picture, write **YES** if the object will scratch the mineral, or **NO** if it won't scratch it.

(1)



YES **YES** **NO** **YES**

(2) (a) Will the mineral FLUORITE, hardness **4,** be scratched by:

A piece of glass? **YES**
Your fingernail? **NO**
An iron nail? **YES**

(b) Will the mineral QUARTZ, hardness **7**, be scratched by:

A piece of glass? **NO**
A copper penny? **NO**
A steel file? **NO**

e. **WHAT DETERMINES A MINERAL'S HARDNESS**?

THE INTERNAL ARRANGEMENT OF THE MINERAL'S ATOMS. THE STRENGTH OF THE BONDS HOLDING THE ATOMS TOGETHER.

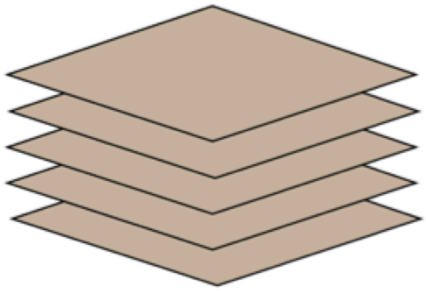
5. **CLEAVAGE AND FRACTURE**:

a. **CLEAVAGE**:

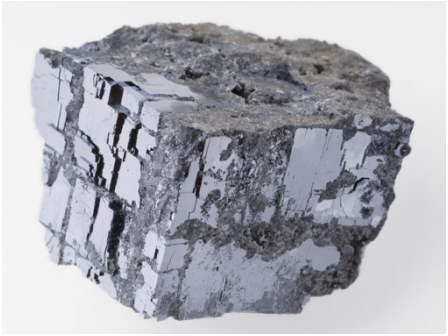
A MINERAL IS SAID TO HAVE CLEAVAGE WHEN IT SPLITS ALONG SMOOTH, FLAT SURFACES.

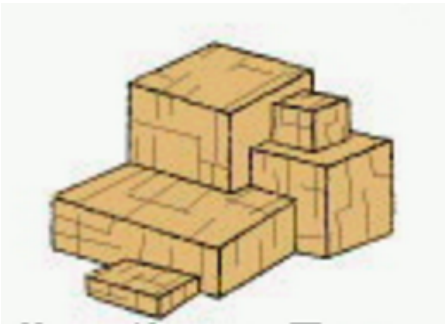
(1) Examples of cleavage:

a. The mineral MICA cleaves in **ONE** direction(s).



b. The mineral GALENA cleaves in THREE direction(s).





(2) What determines cleavage?

THE INTERNAL ARRANGEMENT OF THE MINERAL'S ATOMS. THE TYPES OF BONDS HOLDING THE ATOMS TOGETHER.

(3) Cleavage should not be confused with crystal shape. Cleavage is a property of the way a mineral **BREAKS**, while crystal shape is a property of the way a mineral **GROWS**. When minerals have plenty of space to "grow" they form **CRYSTALS**.

b. **FRACTURE**:

A MINERAL IS SAID TO HAVE FRACTURE WHEN IT BREAKS UNEVENLY INTO CURVED OR IRREGULAR PIECES WITH ROUGH AND JAGGED SURFACES.

(1) Examples of minerals that show fracture:

SULFUR, BAUXITE, HEMATITE, QUARTZ

6. **DENSITY OR HEFT**: Due to the kinds of atoms a mineral contains, and how closely packed the atoms are, different mineral samples of the same size have different densities and feel heavier or lighter when lifted (or measured). A piece of gold has **8** times as much mass as a piece of halite that is the same size.

B. CHEMICAL PROPERTIES:

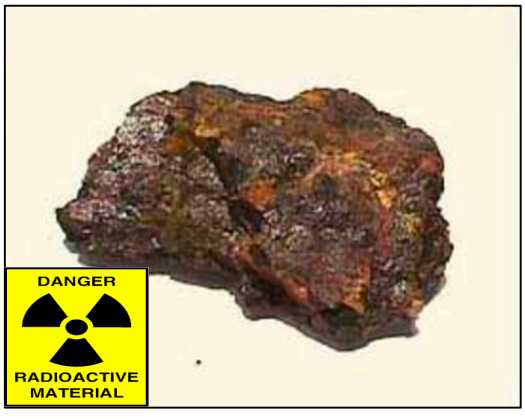
CALCITE reacts with hydrochloric acid. It forms bubbles of carbon dioxide gas.

$CaCO_3 + 2HI \rightarrow CaCL_2 + H_2O + CO_2$

C. SPECIAL PROPERTIES

Lodestone, a form of the mineral **MAGNETITE**, is naturally **MAGNETIC**.

Iceland Spar, a form of the mineral **CALCITE**, produces **DOUBLE REFRACTION**.



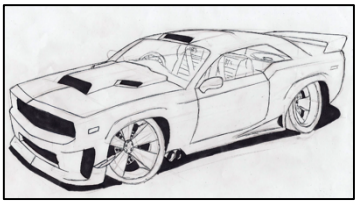
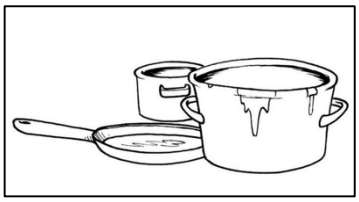
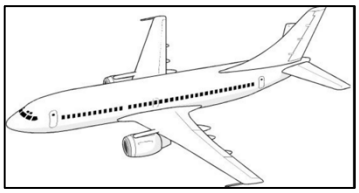
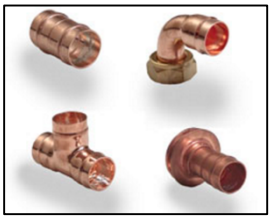
PITCHBLEND is an example of a mineral that is **RADIOACTIVE**.

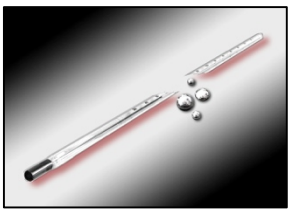
III. USES OF MINERALS

A. Ore – A mineral that contains **METALS AND NON-METALS A CAN BE MINED AND REMOVED IN USABLE AMOUNTS FOR A PROFIT.**

1. Metals – Elements that have shiny surfaces and are able to conduct **HEAT** and **ELECTRICITY**.

a. Examples:

METAL	MINERAL(S)	USE
1. IRON	Hematite Fe_2O_3 Magnetite Fe_3O_4	 
2. ALUMINUM	Bauxite $Al(OH)_3$ $AlO(OH)$ $HAlO_2$	 
3. COPPER	chalcopyrite $CuFeS_2$ Malachite $Cu_2CO_3(OH)_2$	  
4. LEAD	GALENA PbS	

METAL	MINERAL(S)	USE
5. SILVER	ARGENITE Ag_2S	
6. GOLD	GOLD Au	
7. MERCURY	CINNABAR HgS	 

b. **ALLOY** – a mixture of two or more metals or a mixture of metals and non-metals.

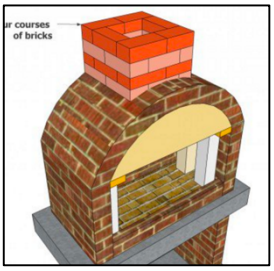
1. Tin + Copper = **BRONZE**

2. Copper + Zinc = **BRASS**

3. Iron + Chromium + Limestone = **STEEL**

4. Lead + Tin = **PEWTER**

2. Non-Metals – elements that have dull surfaces an are poor conductors of **HEAT** and **ELECTRICITY**.

MINERALS		USE
a. HALITE		**TABLE SALT**
b. **GYPSUM**		**SHEETROCK / WALLBOARD**
c. **SULFUR**		**MATCHES**
d. **TALC**		**"BABY" POWDER**
e. **GRAPHITE**		**PENCIL "LEAD"**
f. **KAOLINITE**		**BRICKS**
g. **CALCITE**		**CEMENT**

B. **GEMS** – Minerals that have the following durable (Lasting) qualities:

HARDNESS , COLOR, LUSTER, CLARITY, DURABILITY, RARITY

1. Precious stones: **DIAMONDS, RUBIES, SAPPHIRES, EMERALDS**

2. Semiprecious stones- **AMETHYST, GARNET, TOPAZ**

3. Gems that are NOT minerals – **PEARLS, AMBER**

PETROLOGY – The branch of science that studies rocks.

I. CLASSIFICATION OF ROCKS

A. Rocks are **CLASSIFIED** on the basis of their **FORMATION AND ORIGIN**

B. The three groups of rocks are:

1. **SEDIMENTARY**
2. **IGNEOUS**
3. **METAMORPHIC**

II. ROCKS IN RELATION TO MINERALS

A. Many kinds of rocks are composed of **MINERALS**.

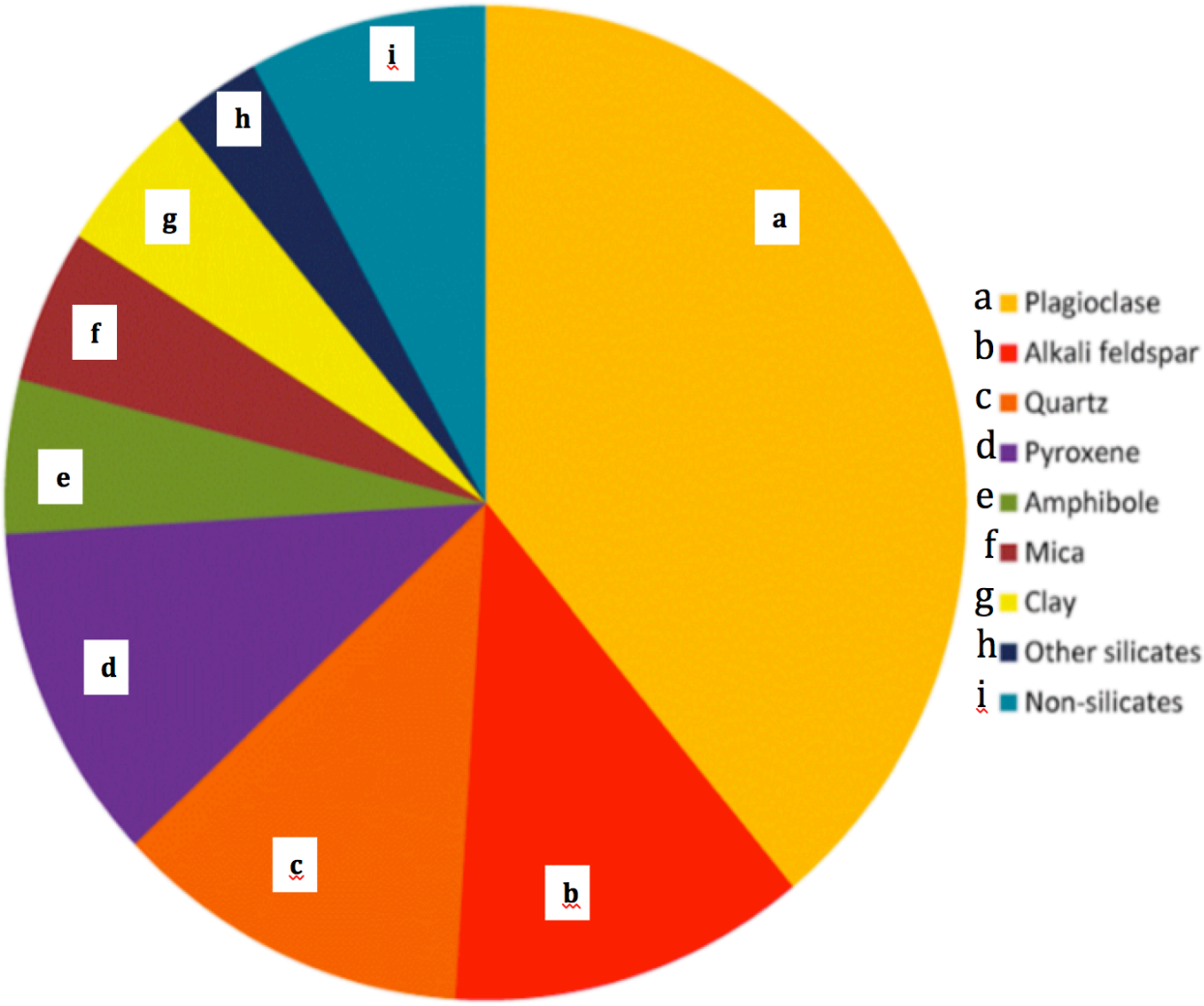
B. Some rocks are **MONOMINERALLIC** – Composed of **ONLY ONE MINERAL. (LIMESTONE IS MADE FROM CALCITE)**

C. Most rocks are **POLYMINERALLIC**- **COMPOSED OF TWO OR MORE MINERALS**

D. LETTERS: WORDS = MINERALS: ROCKS

E. There are almost **3000** types of minerals, but only **8** of these minerals make up **90 %** of the rocks of Earth's crust.

F. Common Rock-forming Minerals:

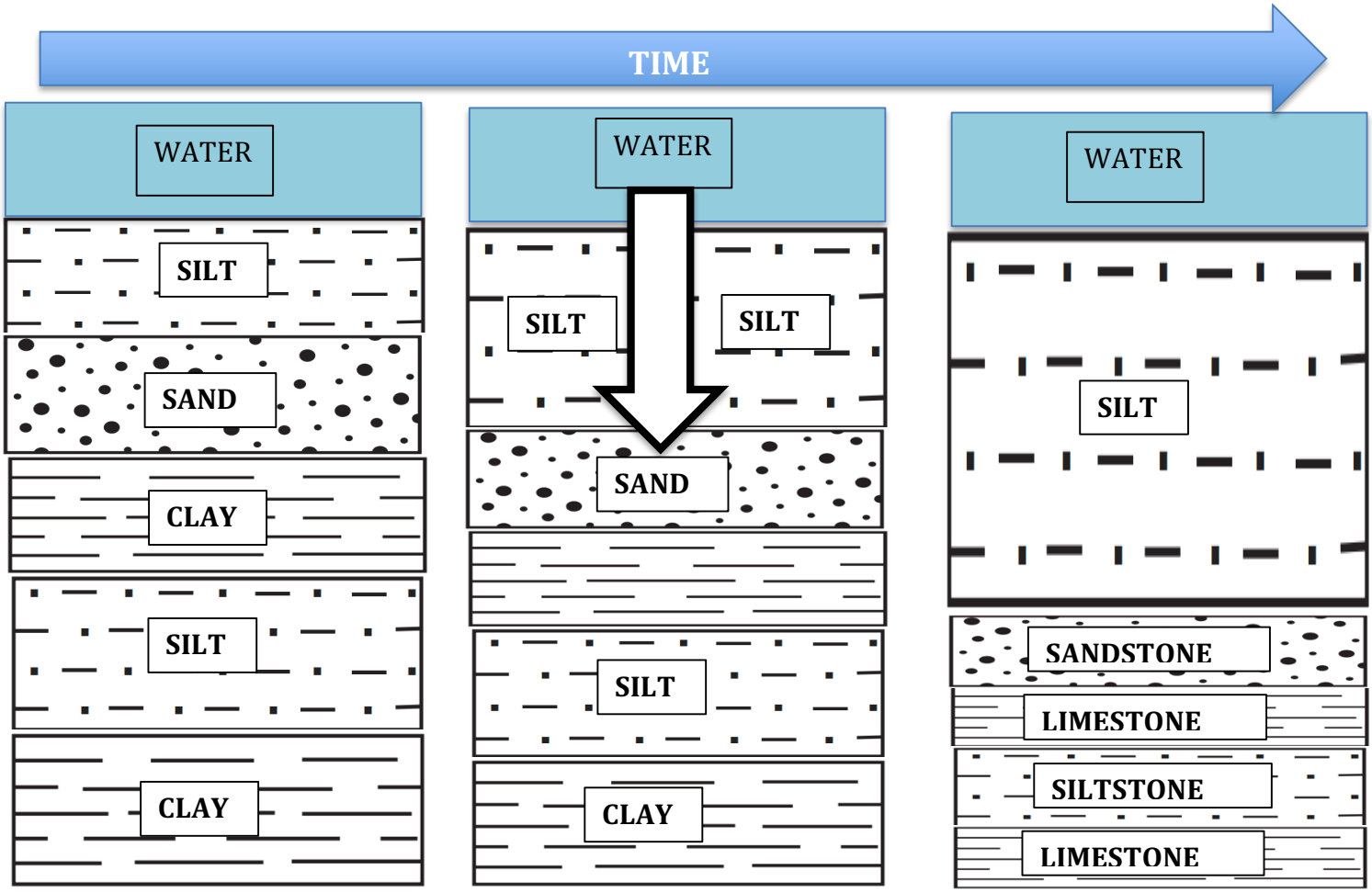


III. SEDIMENTARY ROCKS

A. **ROCKS THAT USUALLY FORM IN LAYERS FROM THE ACCUMULATION (BUILD-UP) OF SEDIMENTS, ORGANIC MATTER, OR CHEMICAL PRECIPITATES**.

1. Most sedimentary rocks are made up of slid sediments that have been weathered from other rocks. The weathered sediments are then eroded (transported) by water, wind, and/or moving ice. Eventually, the eroded sediments r deposited I a new location either in water or on land. Most sedimentary rocks form in layers underwater in lakes, seas, or oceans.

2. From Sediments to rocks:



LAYERS OF SEDIMENTS DEPOSITED AND ACCUMULATE

PRESSURE / WEIGHT SQUEEZES LOWER LAYERS

SEDIMENTS COMPACTED INTO ROCK

B. Types of sedimentary Rocks:

1. **CLASTIC – Form from rock particles / sediments that are compacted and cemented together**.
   a. **Compaction** – **Pressed by weight from overlying rock**
   b. **Cementation** – **Glued by natural cements in water (calcite)**

Individual particles of rock

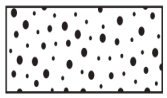
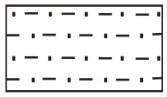
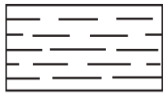
AFTER DEPOSITION

PRESSURE

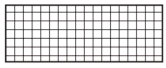
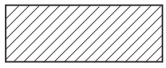
COMPACTION

Natural sediments dissolved in water

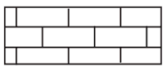
CEMENTATION

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 (0.006 to 0.2 cm)		Fine to coarse	**Sandstone**	
	Silt (0.0004 to 0.006 cm)		Very fine grain	**Siltstone**	
	Clay (less than 0.0004 cm)		Compact; may split easily	**Shale**	

2. CHEMICAL: FORM FROM DISSOLVED MINERALS IN WATER THAT SETTLE OUT / PRECIPITATE. DISSOLVED MINERALS ARE LEFT BEHIND WHEN WATER EVAPORATES

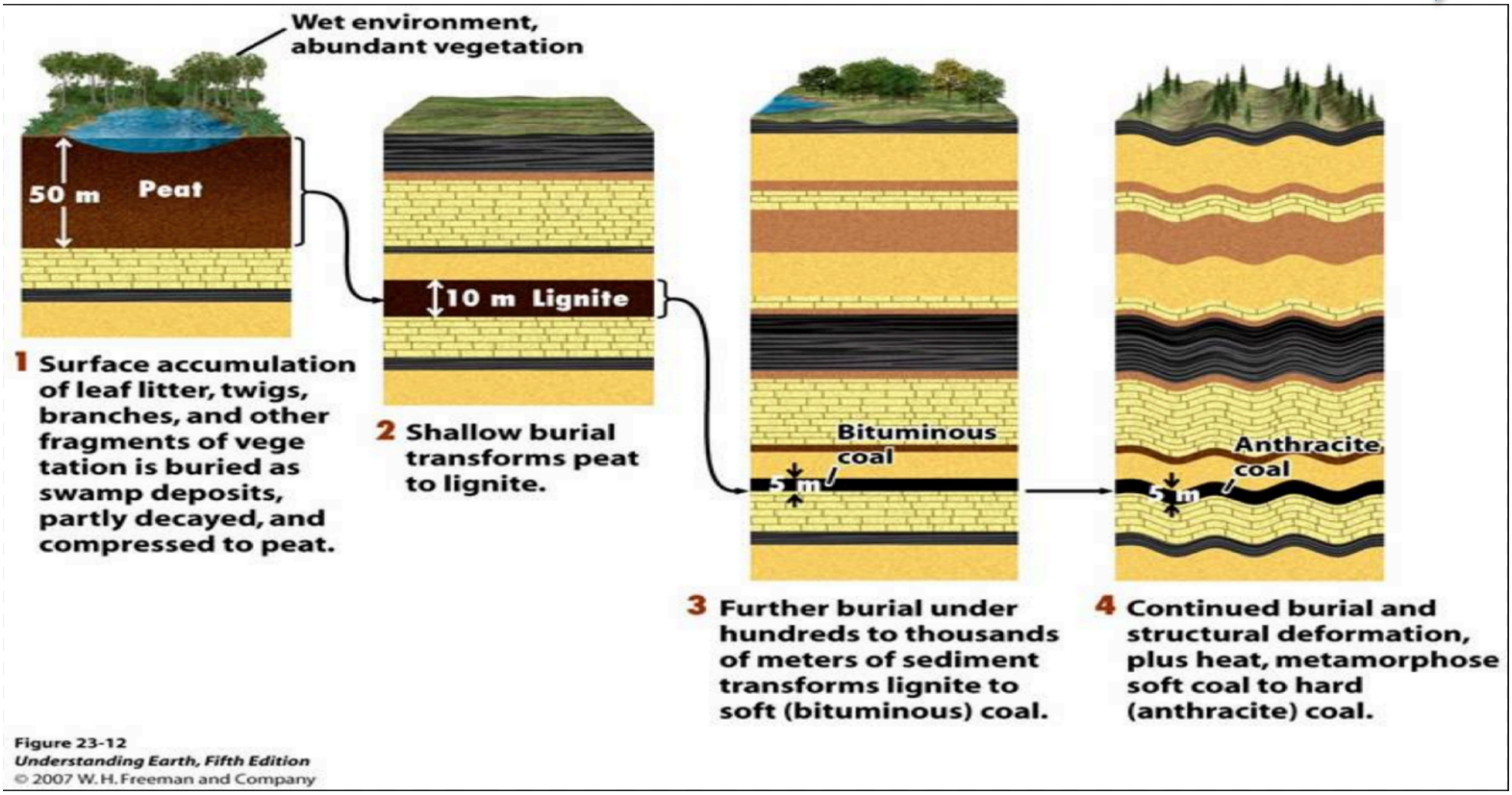
TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Crystalline	Fine to coarse crystals	Halite	Crystals from chemical precipitates and evaporites	**Rock salt**	
		Gypsum		**Rock gypsum**	
		Dolomite		**Dolostone**	

3. ORGANIC: FORM FROM THE ACCUMULATION OF PLANT / ANIMAL MATTER THAT UNDERGOES A TRANSFORMATION INTO ROCK.

TEXTURE	GRAIN SIZE	COMPOSITION	COMMENTS	ROCK NAME	MAP SYMBOL
Crystalline or bioclastic	Microscopic to very coarse	Calcite	Precipitates of biologic origin or cemented shell fragments	**Limestone**	
Bioclastic		Carbon	Compacted plant remains	**Bituminous coal**	

FORMATION OF COAL

TIME



C. Important characteristic of sedimentary rocks:

1. They are composed of rock fragments or organic particles

a. Some have a range of particle of sediment sizes.

CONGLOMERATE

b. Others consist mainly of one size of sediment - due to sorting during deposition

SANDSTONE

2. Some are organic – they form from plant and animal remains - **FOSSILS**

FOSSIL LIMESTONE

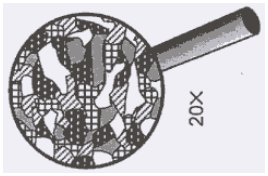
3. **Sedimentary Rocks form in layers called strata or beds**

SHALE

IV. IGNEOUS ROCKS

A. **FORMS FROM THE COOLING AND SOLIDIFICATION / CRYSTALLIZATION OF MOLTEN LAVA AND MAGMA**.

1. When molten (liquid) lava or magma **COOLS** and **SOLIDIFIES**, crystals of different minerals form the rock.
   a. The rock contains a crystalline structure and intergrown crystals of different **SIZES**, **SHAPES**, and **COMPOSITION**.
   b. –



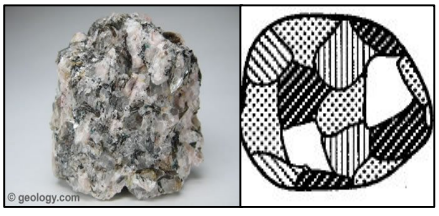
B. Types of igneous rocks:

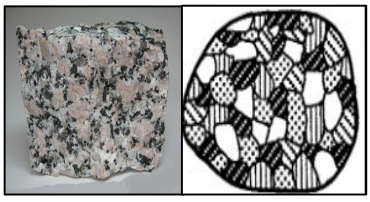
1. EXTRUSIVE / VOLCANIC:

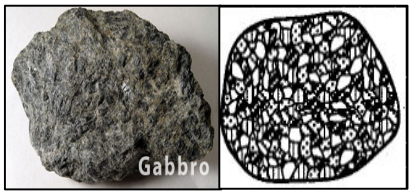
a. FORMS FROM THE FAST COOLING OF LAVA AT OR NEAR EARTH'S SURFACE.
b. FAST COOLING DOES NOT ALLOW TIME FOR CRYSTALS TO FORM.
c. ROCKS HAVE SMALL OR NO CRYSTALS – THEREFORE A SMOOTH / FINE TEXTURE.

2. INTRUSIVE / PLUTONIC:

a. FORMS FROM SLOW COOLING OF MAGMA WITHIN THE EARTH.
b. SLOW COOLING ALLOWS LARGE CRYSTALS TO FORM.
c. ROCKS HAVE LARGE CRYSTALS - THEREFORE A COARSE, ROUGH TEXTURE.







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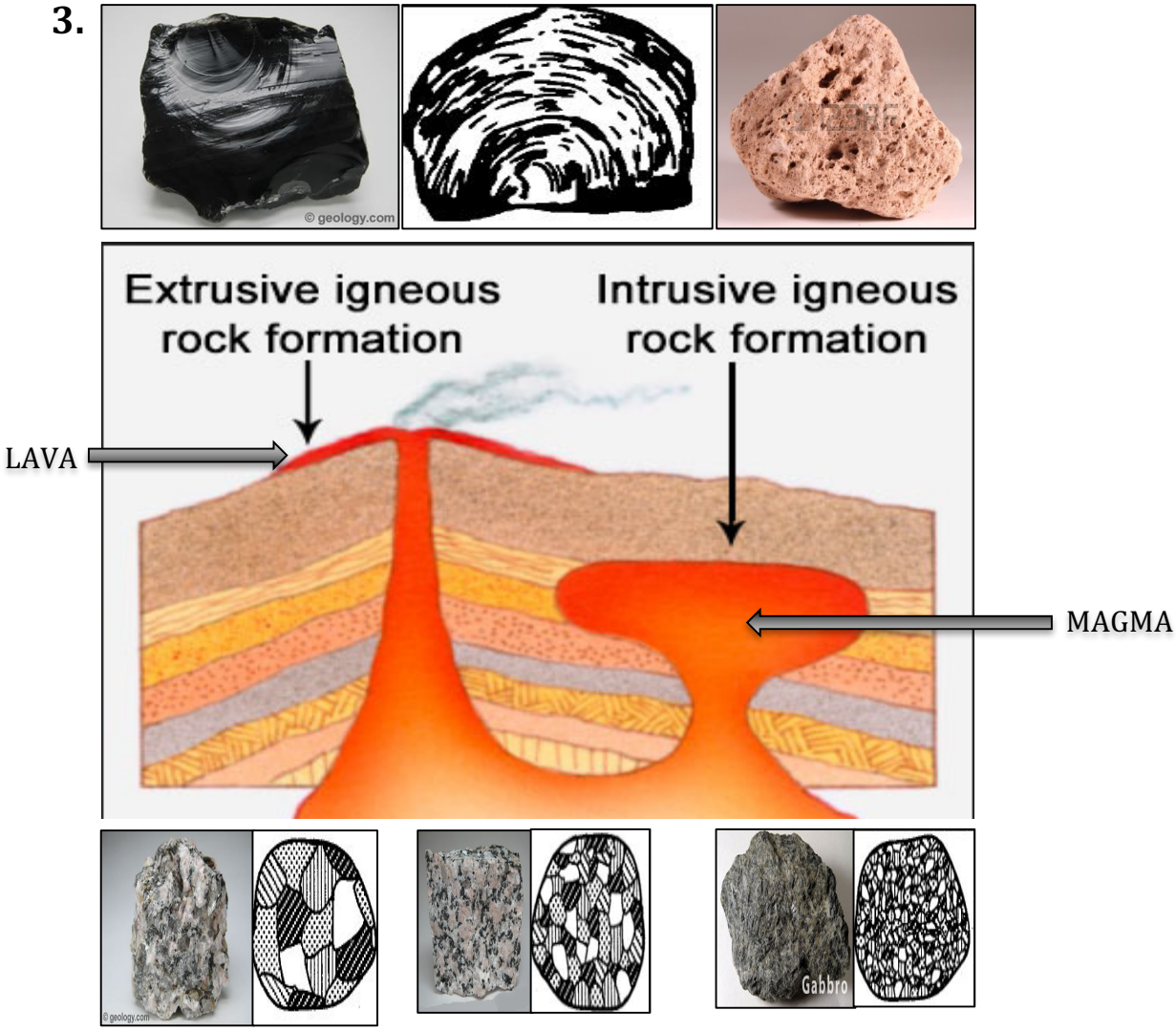
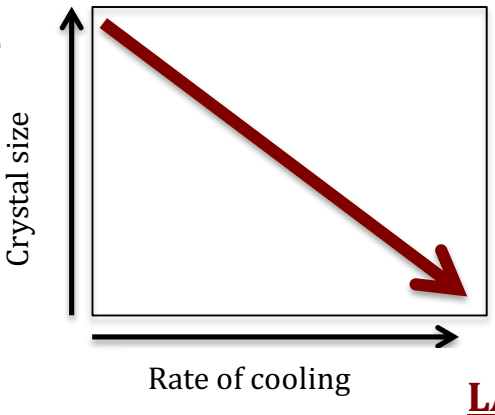


4. Environment of Formation:

	ENVIRONMENT OF FORMATION		
	EXTRUSIVE (VOLCANIC)		INTRUSIVE (PLUTONIC
Rate of cooling	VERY FAST	FAST	SLOW
Grain Size	NON-CRYSTALLINE	LESS THAN 1 MM	1MM OR LARGER
Texture	GLASSY	FINE	COARSE
Examples	OBSIDIAN	BASALT/RHYOLITE	GRANITE / GABBRO

5. Relationship between **CRYSTAL SIZE** and **RATE OF COOLING** (the environment effects the cooling rate)

b.

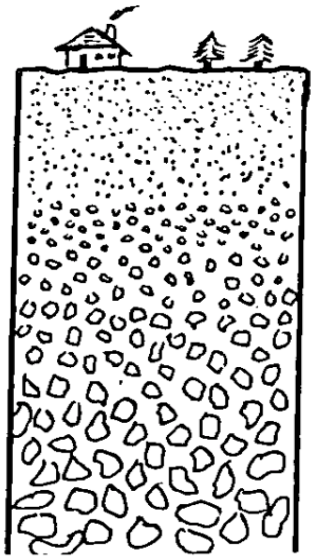


c.

NONE crystals — **VERY FAST** cooling

SMALL / FINE crystals — **FAST** cooling

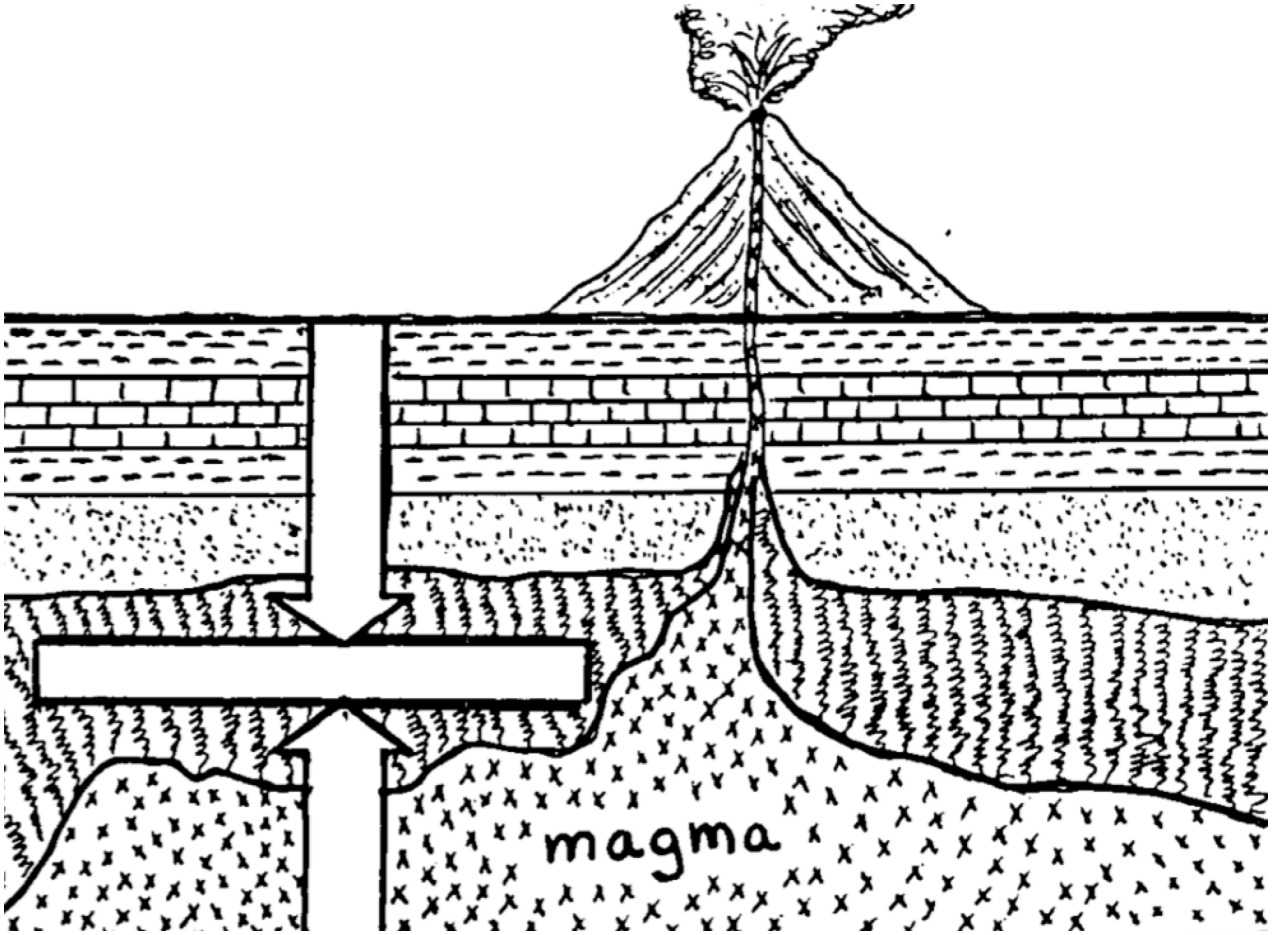
LARGE / COARSE crystals — **SLOW** cooling



V. METAMORPHIC ROCKS

A. **Form from other, preexisting, rock (sedimentary, igneous, and/or other metamorphic), that have been changed.**

B.



C. **CONDITIONS THAT CAUSE ROCKS TO UNDERGO METAMORPHISM**:

1. **HEAT**
2. **PRESSURE**
3. **CHEMICAL ACTIVITY**

Such conditions are often associated with deep burial and pressure that result from mountain formation (orogeny). Therefore, metamorphic rocks are often found in mountainous regions where weathering and erosion have exposed this rock that was once deeply buried.

Under conditions of high temperature and high pressure, many metamorphic rocks form by the process of **RECRYSTALLIZATION**. This is the growth of **NEW** crystals from the sediments of a **SEDIMENTARY** rock or the NEW mineral growth from the crystals of an **IGNEOUS** or **METAMORPHIC** rock. Recrystallization occurs without true melting.

D. **CHANGES IN A ROCK CAUSED BY METAMORPHISM**:

1. **INCREASED DENSITY**
2. **CHEMICAL CHANGE / NEW MINERALS**
3. **BANDING** – is a layered arrangement of firmly joined crystals of minerals; the minerals are aligned in bands. These bands are formed when rock is subjected to extreme pressure and temperature. Usually, the greater the pressure and temperature, the thicker the bands.
4. **Distorted structure** – is the curving and folding of the bands. These distortions of once horizontal bands are caused by great environmental pressure exerted on the rock from different directions.

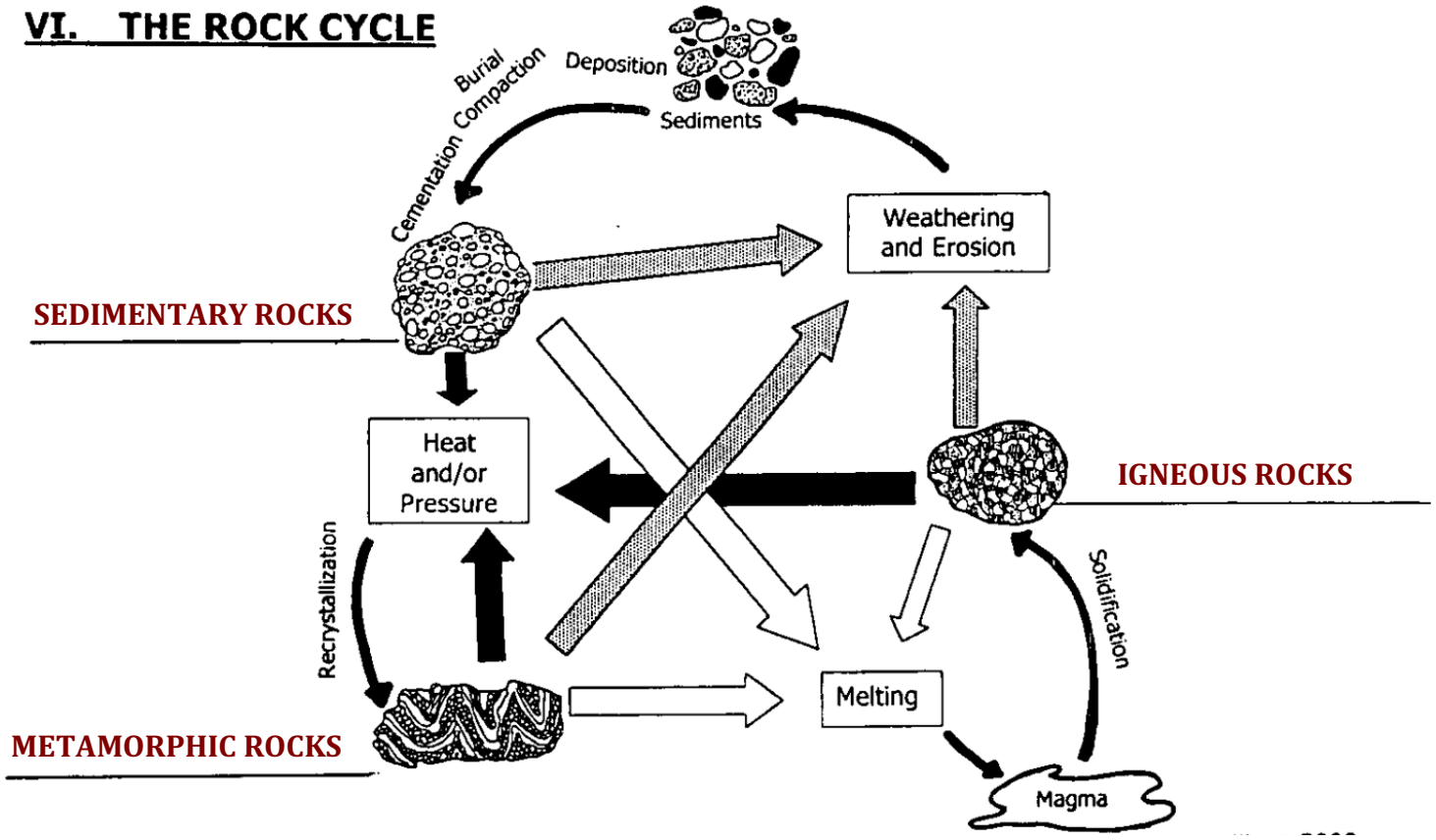
E. **TYPES OF METAMORPHIC ROCKS**:

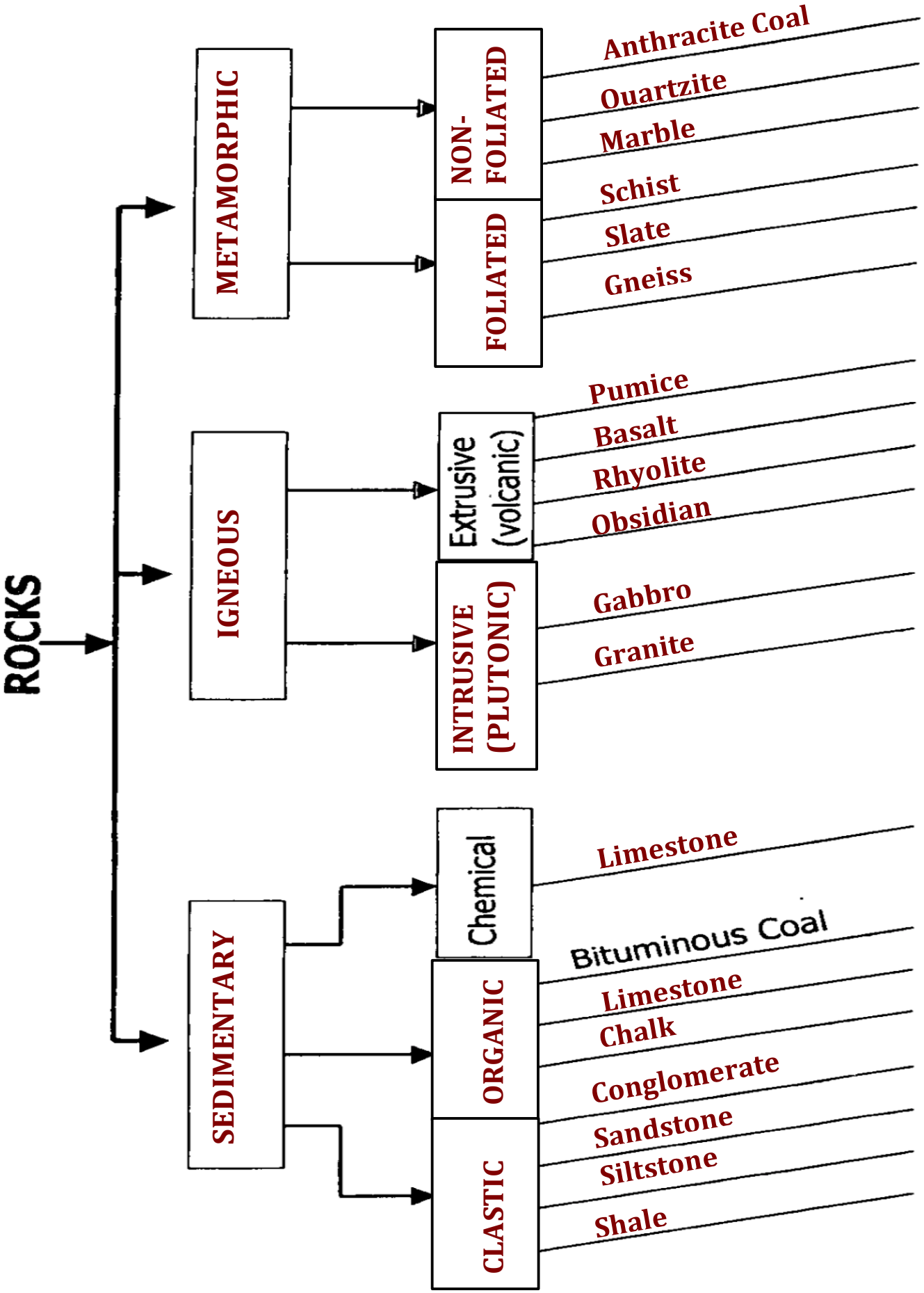
1. **FOLIATED** – **HAVE MINERAL CRYSTALS ARRANGED IN PARALLEL LAYERS OR "BANDS".**
2. **NONFOLIATED** – **DO NOT HAVE MINERAL CRYSTALS IN BANDS. DO NOT BREAK IN LAYERS OR SHEETS**.

F.

	METAMORPHIC ROCK	ORIGINAL ROCK	ORIGINAL TYPE
FOLIATED	SLATE	SHALE	SEDIMENTARY
	SCHIST	SLATE	METAMORPHIC
	GNEISS	GRANITE	IGNEOUS
NONFOLIATED	MARBLE	LIMESTONE	SEDIMENTARY
	QUARTZITE	SANDSTONE	SEDIMENTARY
	ANTHRACITE COAL	BITUMINOUS COAL	SEDIMENTARY

VI. THE ROCK CYCLE




ROCKS
METAMORPHIC
NON-FOLIATED
FOLIATED
Anthracite Coal
Quartzite
Marble
Schist
Slate
Gneiss
IGNEOUS
Extrusive (volcanic)
INTRUSIVE (PLUTONIC)
Pumice
Basalt
Rhyolite
Obsidian
Gabbro
Granite
SEDIMENTARY
Chemical
ORGANIC
CLASTIC
Limestone
Bituminous Coal
Limestone
Chalk
Conglomerate
Sandstone
Siltstone
Shale

FAMOUS ROCKS

STONEHENGE

(Wiltshire, England)

GRAND CANYON

(Arizona, USA)
Layers of sedimentary rocks

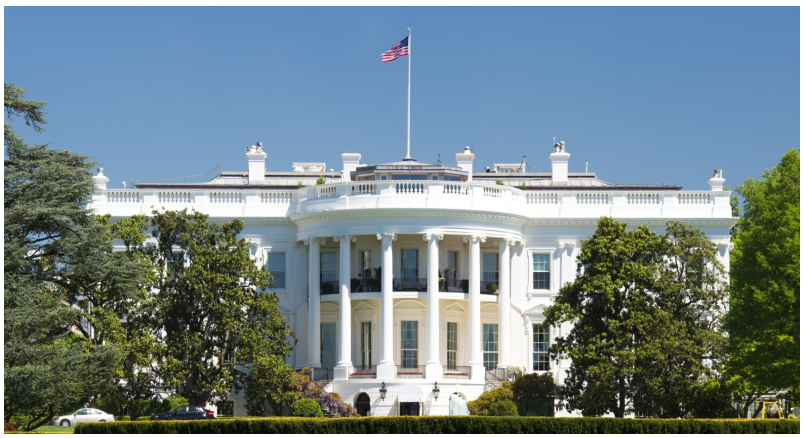
PYRAMIDS

(Cairo, Egypt)
Limestone

WHITE HOUSE

(Washington, D.C.)
Sandstone

(Note- painted white after war of 1812)



Michelangelo's Statue of **DAVID**

(Florence, Italy)
Marble

VIETNAM VETERAN'S WALL

(Washington, D.C.)
Gabbro / "black granite"

CLEOPATRA'S NEEDLE

Central park, NYC (also London & Paris)
Granite

LINCOLN MEMORIAL

(Washington, D.C.)
Marble

UNIT TOPICS FOR STUDY

MINERALS

- 5 physical properties (streak, luster, hardness, cleavage/fracture, color)
- **ESRT p. 16**
- IAOA (Internal Arrangement of Atoms)

SEDIMENTARY ROCKS

- 3 categories (Clastic, Organic, Chemical)
- How they form (Rock Cycle Diagram ESRT p.6)
- Sedimentary Rock ID chart, **ESRT p. 7**

METAMORPHIC ROCKS

-2 categories (Foliated & nonfoliated)
- How they form (Rock Cycle Diagram ESRT p.6)
- Metamorphic Rock ID chart, **ESRT p. 7**

IGNEOUS ROCKS

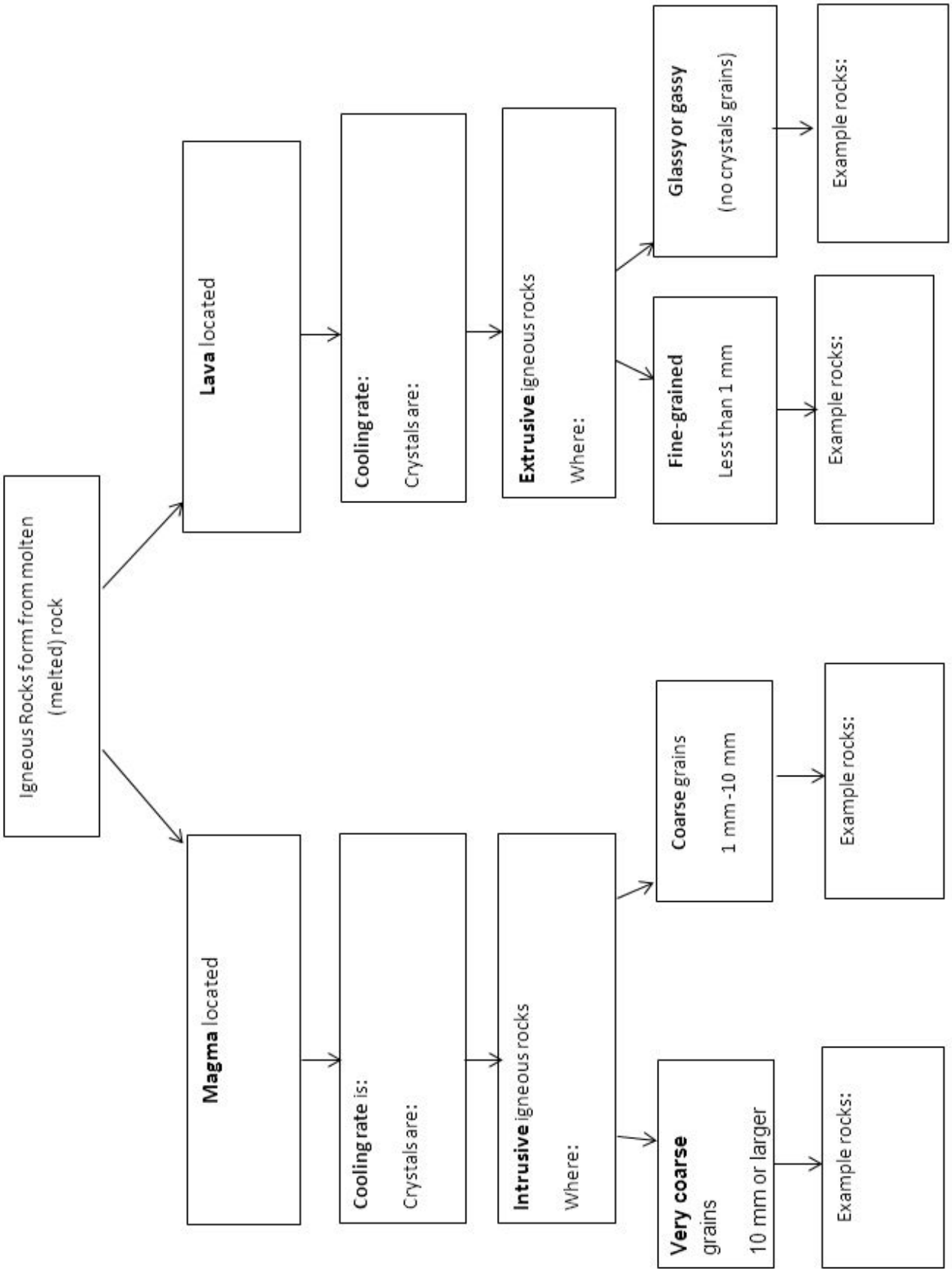
- 2 categories (Intrusive / Extrusive)
- How they form (Rock Cycle Diagram ESRT p.6)
- Igneous Rock ID chart, **ESRT p. 6**
- Cooling time vs. crystal size

Rock Cycle
- ALL rocks can turn into ANY other kind of rock!
- How each rock type forms
- **ESRT p. 6!**

UNIT VOCABULARY

1) **Bioclastic Sedimentary Rock**
2) **Chemical Sedimentary Rock**
3) **Clastic Sedimentary Rock**
4) **Cleavage**
5) **Contact Metamorphism**
6) **Extrusive Igneous Rocks**
7) **Foliation**
8) **Fossil**
9) **Fracture**
10) **Hardness**
11) **Igneous Rock**
12) **Inorganic**
13) **Intrusive Igneous Rock**
14) **Luster**
15) **Magma**
16) **Metamorphic Rock**
17) **Metamorphism**
18) **Mineral**
19) **Mineral Resources**
20) **Organic**
21) **Precipitation (Of Minerals)**
22) **Regional Metamorphism**
23) **Rock Cycle**
24) **Sedimentary Rocks**
25) **Streak**
26) **Texture**

REVIEW


Igneous Rocks form from molten (melted) rock
Lava located
Cooling rate:
Crystals are:
Extrusive igneous rocks
Where:
Glassy or gassy
(no crystals grains)
Example rocks:
Fine-grained
Less than 1 mm
Example rocks:
Magma located
Cooling rate is:
Crystals are:
Intrusive igneous rocks
Where:
Coarse grains
1 mm-10 mm
Example rocks:
Very coarse
grains
10 mm or larger
Example rocks:

UNIT 3 SAMPLE QUESTIONS

1 Which rock is composed of the mineral halite that formed when seawater evaporated?

A) limestone B) dolostone C) rock gypsum **D) rock salt**

2 Which is an accurate statement about rocks?

A) Rocks are located only in continental areas of the Earth.
B) Rocks seldom undergo change.
C) Most rocks contain fossils.
D) Most rocks have several minerals in common.

3 The internal atomic structure of a mineral most likely determines the mineral's

A) color, streak, and age
B) origin, exposure, and fracture
C) size, location, and luster
D) hardness, cleavage, and crystal shape

4 What is the best way to determine if a mineral sample is calcite or quartz?

A) Observe the color of the mineral.
B) Place the mineral near a magnet.
C) Place a drop of acid on the mineral.
D) Measure the mass of the mineral.

5 Minerals are identified on the basis of

A) the method by which they were formed
B) the type of rock in which they are found
C) the size of their crystals
D) their physical and chemical properties

6 Most rocks that form from fragmental rock particles are classified as

A) extrusive igneous
B) intrusive igneous
C) clastic sedimentary
D) chemical sedimentary

7 Which processes lead directly to the formation of igneous rock?

A) weathering and erosion
B) compaction and cementation
C) heat and pressure
D) melting and solidification

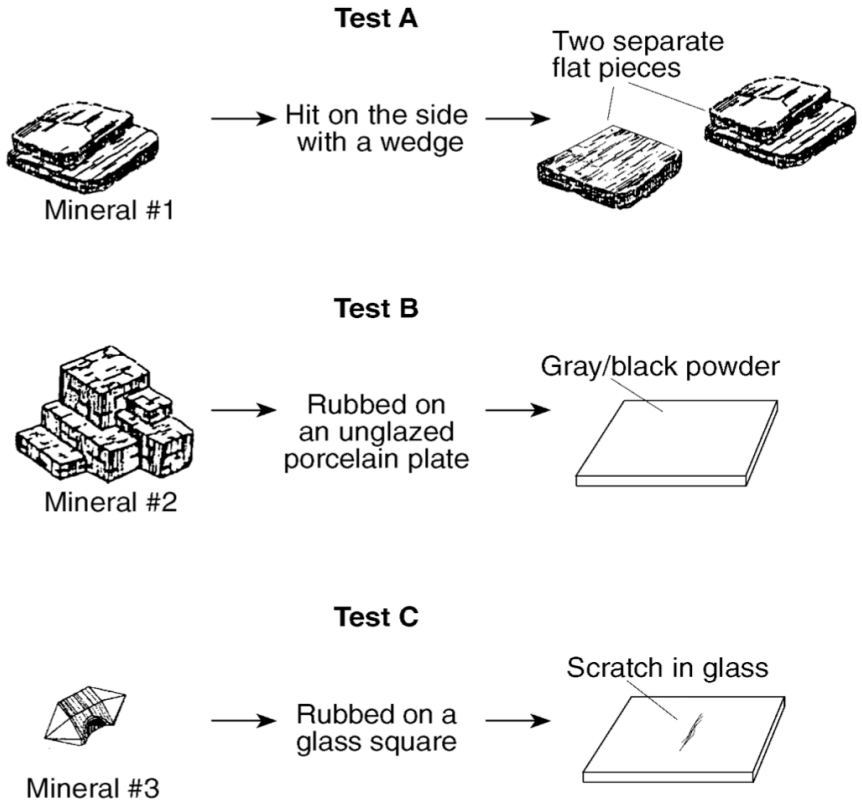
8 Which texture best describes an igneous rock that formed deep underground?

A) glassy B) vesicular
C) fine grained **D) coarse grained**

9 Obsidian's glassy texture indicates that it formed

A) slowly, deep below Earth's surface
B) slowly, on Earth's surface
C) quickly, deep below Earth's surface
D) quickly, on Earth's surface

Base your answers to questions **10** and **11** on the diagram below, which shows three minerals with three different physical tests, *A, B,* and *C,* being performed on them.



10 The results of all three physical tests shown are most useful for determining the

A) rate of weathering of the minerals
B) identity of the minerals
C) environment where the minerals formed
D) geologic period when the minerals formed

11 Which sequence correctly matches each test, *A, B,* and *C,* with the mineral property tested?

A) *A*—cleavage; *B*—streak; *C*—hardness
B) *A*—cleavage; *B*—hardness; *C*—streak
C) *A*—streak; *B*—cleavage; *C*—hardness
D) *A*—streak; *B*—hardness; *C*—cleavage

12 Base your answer to the following question on the two tables below and on your knowledge of Earth science. Table 1 shows the composition, hardness, and average density of four minerals often used as gemstones. Table 2 lists the minerals in Moh's Scale of Hardness from 1 (softest) to 10 (hardest).

Table 1

Gemstone Mineral	Composition	Hardness	Average Density (g/cm^3)
emerald	$Be_3Al_2(Si_6O_{18})$	7.5–8	2.7
sapphire	Al_2O_3	9	4.0
spinel	$MgAl_2O_4$	8	3.8
zircon	$ZrSiO_4$	7.5	4.7

KEY	
Al = aluminum	O = oxygen
Be = beryllium	Si = silicon
Mg = magnesium	Zr = zirconium

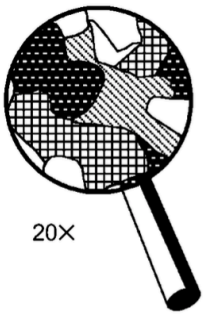
Table 2

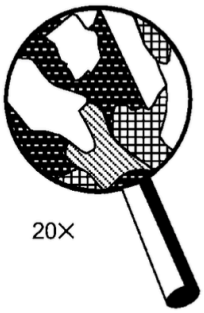
Moh's Scale of Hardness
1 talc
2 gypsum
3 calcite
4 fluorite
5 apatite
6 feldspar
7 quartz
8 topaz
9 corundum
10 diamond

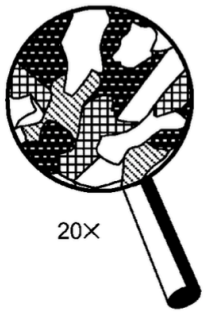
The hardness and density of each gemstone is based primarily on the gemstone's

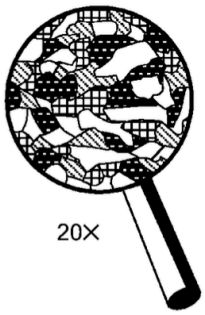
A) internal arrangement of atoms B) geologic time of formation
C) oxygen content D) natural abundance

13 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?

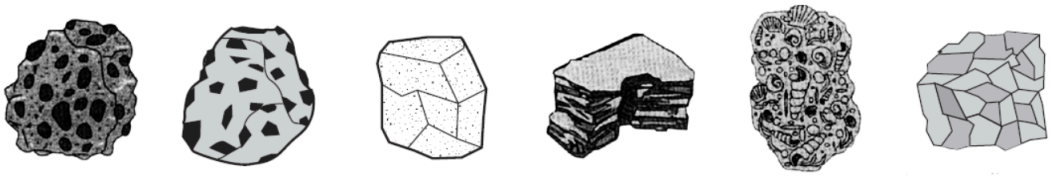
A) 

B) 

C) 

D) 

Base your answers to questions **14** and **15** on the drawings of six sedimentary rocks labeled *A* through *F*.



A Conglomerate **B** Breccia **C** Sandstone **D** Shale **E** Limestone **F** Rock salt

14 Which table shows the rocks correctly classified by texture?

A)

Texture	clastic	bioclastic	crystalline
Rock	A, B, C, D	E	F

B)

Texture	clastic	bioclastic	crystalline
Rock	A, B, C	D	E, F

C)

Texture	clastic	bioclastic	crystalline
Rock	A, C	B, E	D, F

D)

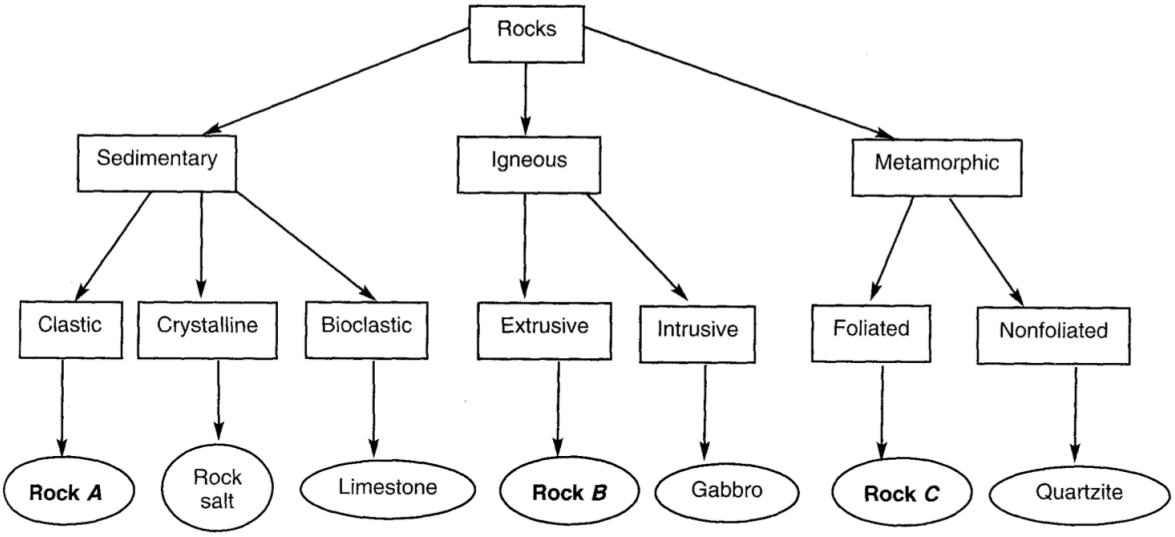
Texture	clastic	bioclastic	crystalline
Rock	A, B, F	E	C, D

15 Most of the rocks shown were formed by

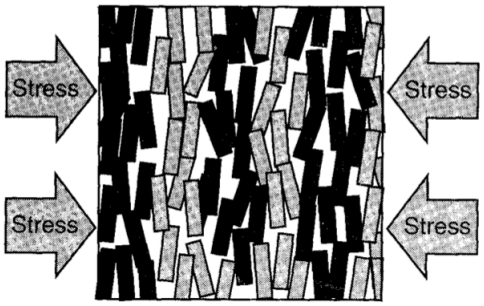
A) volcanic eruptions and crystallization
B) compaction and/or cementation
C) heat and pressure
D) melting and/or solidification

Base your answers to questions **16** through **18** on the Rock Classification Flowchart shown below. Letters *A*, *B*, and *C* represent specific rocks in this classification scheme.

Rock Classification Flowchart



Mineral Arrangement
Before Metamorphism



Rock C Showing Banding
After Metamorphism

16 Rock *B* has a glassy, vesicular texture and is composed mainly of potassium feldspar and quartz. State the name of rock *B*.

17 Rock *A* is composed of very fine-grained quartz and feldspar particles 0.005 centimeter in diameter. State the name of rock *A*.

18 The diagram above represents two magnified views showing the arrangement of minerals before and after metamorphism of rock *C*. State the name of rock *C*.