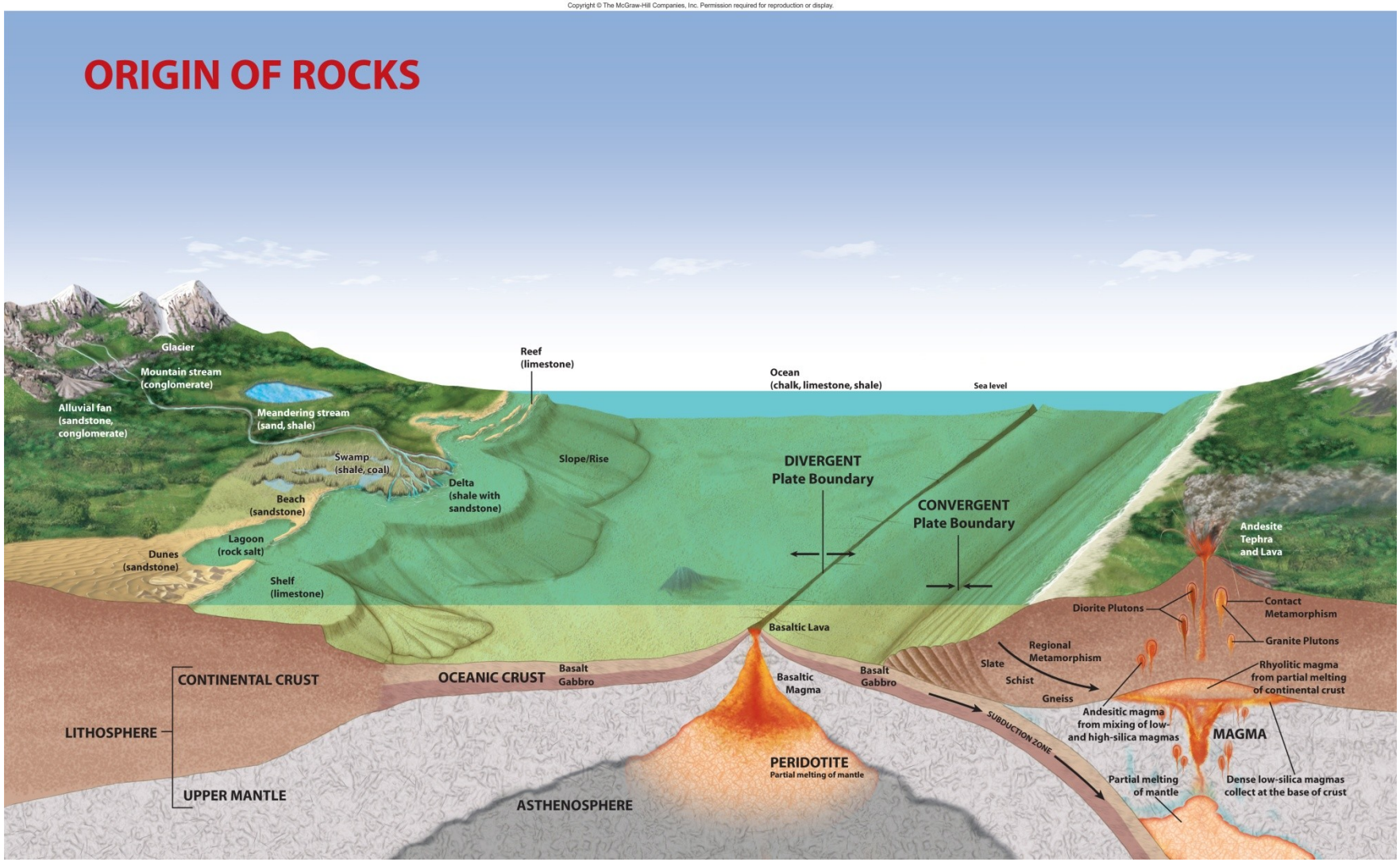
Sedimentary Rocks



Sedimentary Rocks

Sedimentary rocks form as horizontal layers (beds)

- identified based on composition, thickness
- oldest beds at bottom, youngest at top

a.

b.

© USGS Phil Stoffer, USGS

Sedimentary Rocks

Three types of sedimentary rocks

- Clastic, Chemical, Biochemical
  - Identified by materials that make up the rock and/or the process by which they formed

c.

d.

© USGS

Sedimentary Rocks

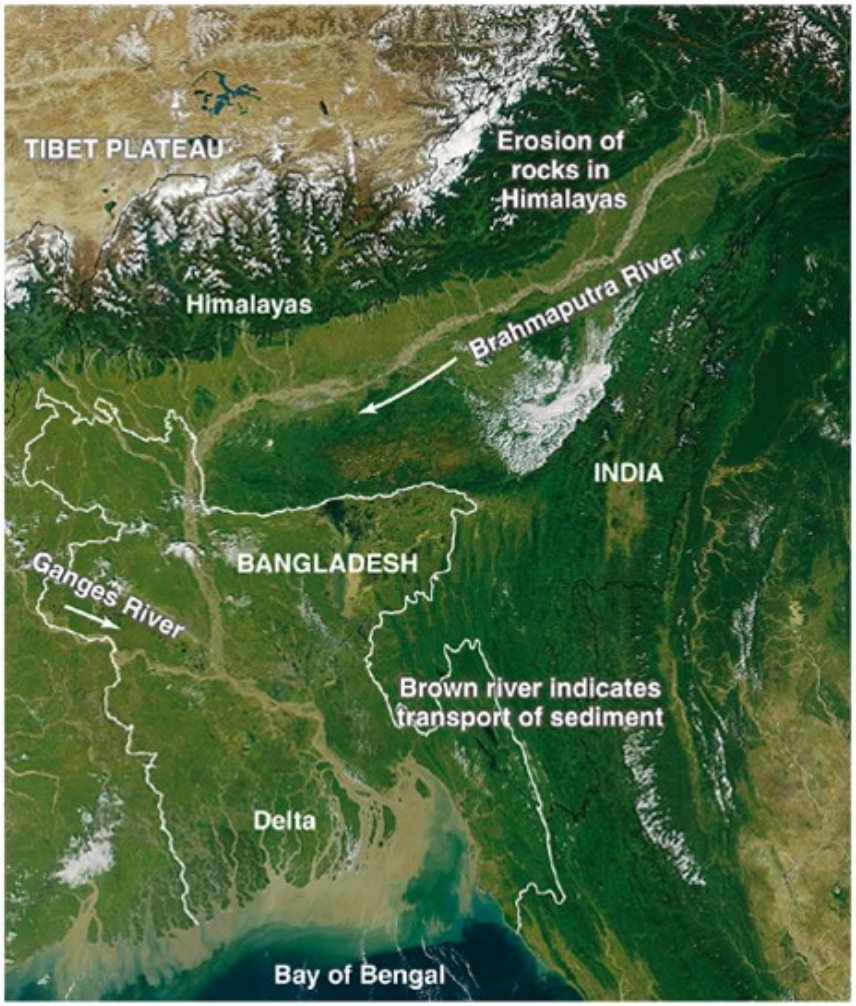
b.

© Phil Stoffer, USGS

Clastic Sedimentary Rocks

- Composed of rock and mineral fragments
  - Most common type of sedimentary rock
- 3 stages of formation
  - Generation
  - Transportation
  - Lithification

Sedimentary Rocks



a. *Sediment generated by weathering of Himalayas and transported in rivers*

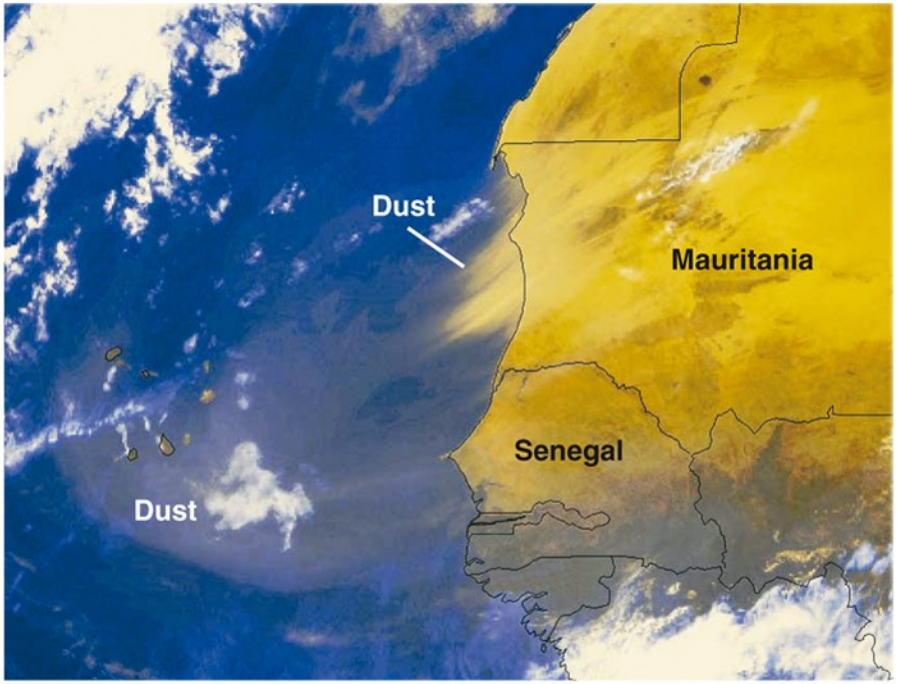
Clastic Sedimentary Rocks

1. Generation
   - Physical and chemical breakdown of any rock at Earth's surface (weathering) to form sediment
   - Sediment = rock and mineral fragments
   - Sediment classified by grain size
     - Clay
     - Silt
     - Sand
     - Gravel

Increasing grain size

Sedimentary Rocks

Clastic Sedimentary Rocks



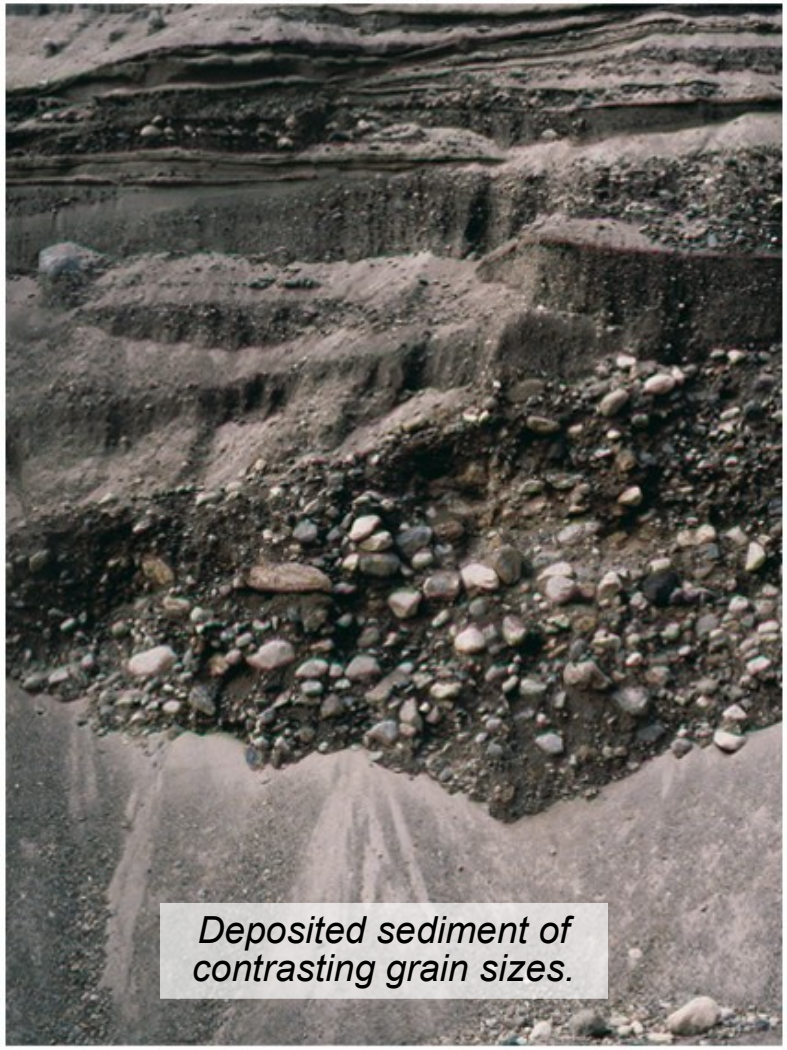
b.

Sediment (dust) transported by prevailing winds from Africa toward the Atlantic Ocean

2. Transportation

- Erosion → Sediment moved from place of origin by streams, wind, glaciers
- Size of transported grains depends on velocity of transport medium
- Erosion produces characteristic landscapes

Sedimentary Rocks



Deposited sediment of contrasting grain sizes.

© U.S. Park Service

Clastic Sedimentary Rocks

3. Lithification
   - Sediment deposited when velocity of transport medium decreases
   - Larger grain sizes deposited first, finest grains remain in suspension and are deposited last
   - Over time, sediment is slowly compacted and grains are cemented together to form a new rock (lithification)

Sedimentary Rocks

Clastic Sediment and Clastic Sedimentary Rocks

- Rock names reflect grain size
  - **Mudstone, Shale** made of clay, silt-sized grains
  - **Sandstone** composed of sand-sized particles
  - **Conglomerate** made of gravel and larger fragments

a. © Scientifica/Visuals Unlimited

Sandstone composed of quartz grains of similar sizes.

b. © Dr. John D. Cunningham/Visuals Unlimited

Conglomerate composed of gravel-sized rock fragments

Sedimentary Rocks

Clastic Sediment and Clastic Sedimentary Rocks

- Rock names reflect grain size (see Table 7.5)
- Transportation process sorts grains so deposits may have characteristic grain size (e.g., sand on a beach)

Table 7.5 Clastic Sediments and Sedimentary Rocks

Sediment	Grain size (diameter)	Rock	Grain size comparisons
Clay	Less than 0.0039 mm (less than 0.00015 in)	Shale, mudstone	Smaller than granulated sugar
Silt	0.0039 to 0.0625 mm (0.00015 to 0.0025 in)	Siltstone	
Sand	0.0625 to 2 mm (0.0025 to 0.079 in)	Sandstone	Ranges from sugar to coarse salt
Gravel	More than 2 mm (more than 0.079 in)	Conglomerate	Ranges from rice grains to oranges

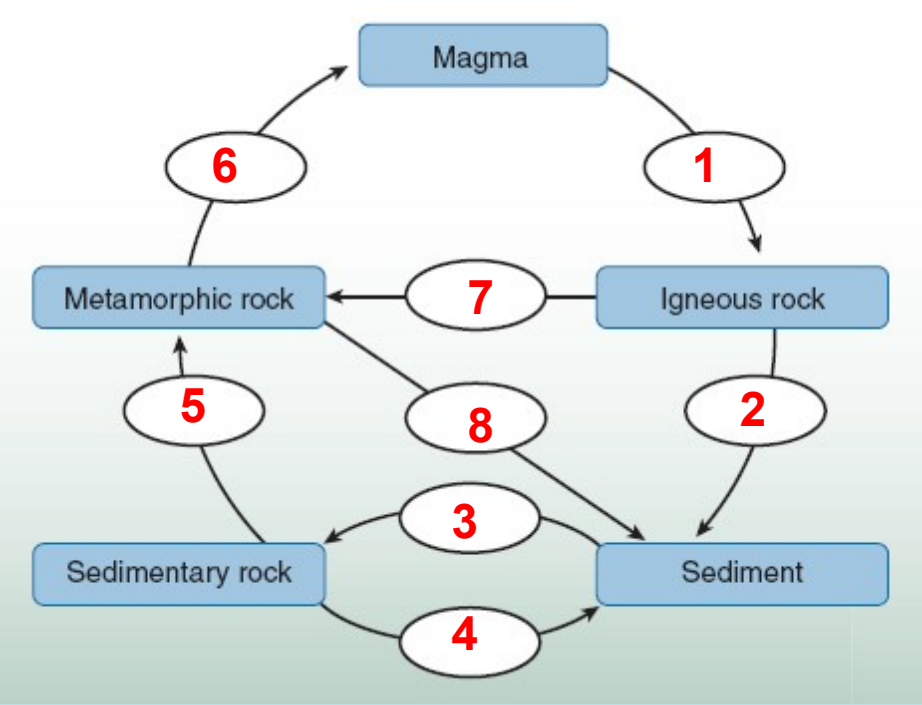
Sedimentary Rocks

Clastic Sediment and Clastic Sedimentary Rocks

- Transportation process sorts grains so deposits may have characteristic grain size (e.g., sand on a beach)
- Sedimentary rocks hold clues to the environment where they were formed:
  - Example: river channels
    - High velocity flow in floods - gravels (conglomerate)
    - Moderate speed flow – sand (sandstone)
    - Slow flow - muds (shale)

Rocks and Minerals Conceptest

Examine the diagram. Weathering, transportation, and deposition can occur during steps:



A. 1, 2, 3

B. 3, 5, 7

C. 2, 4, 8 x

D. 4, 5, 6

6 – melting 5, 7 – heat and pressure 4 – lithification (cementation/compaction)
1 – cooling and solidification=on

Clastic rocks – composed of fragments (clasts) of pre-existing minerals and rock. A fragment is broken off other rocks by physical weathering.

Rocks and Minerals Conceptest

Cooking an egg could be seen as an analog for the formation of :

A. Igneous rock.

B. Sedimentary rock.

C. **Metamorphic rock. (More Later)**

Rocks and Minerals Conceptest

Concrete is formed by adding cement and water to a mixture of sand and gravel. This could be seen as an analog for the formation of what type of sedimentary rock?

A. Clastic rock.

B. Chemical rock.

C. Biochemical rock.

Rocks and Minerals Checkpoint 7.14

What observations can you make about the grain size and arrangement of these clastic sediments that would help determine their origin?

Distinct layers (~5) with different-size materials. Size of the gains would relates to the velocity of the water that deposited them. Suggests a depositional history characterized by “normal” flow (sandy) and flood conditions (pebbles).

Sedimentary Rocks

Chemical Sedimentary Rocks

Salt deposited on floor of ancient Lake Bonneville, Utah

Na and Cl from weathering of minerals in rocks gets left behind when water evaporates

- Form when minerals precipitate (crystallize) from a solution as a result of changing physical conditions
  - Solutions = fresh water in lakes, groundwater or seawater
  - Changing conditions commonly = increased temperatures (evaporation)

Sedimentary Rocks

Chemical Sedimentary Rocks

Salt deposited on floor of ancient Lake Bonneville, Utah

- Can be readily dissolved in water and transported to oceans
- Rocks are typically indicative of shallow, coastal marine conditions in geologic past
  - Termed **evaporites** as most form by precipitation due to evaporation

Sedimentary Rocks

Biochemical Sedimentary Rocks

© Patricia Jordan / Peter Arnold Inc.

a.

© Gerald & Buff Corsi/Visuals Unlimited

- Link the biosphere and geosphere
- Form due to actions of living organisms that cause minerals to be extracted from solution

OR

- From the remains of dead organisms

Sedimentary Rocks

Biochemical Sedimentary Rocks

Coral reef formed in shallow, tropical sea

- Form due to actions of living organisms that cause minerals to be extracted from solution
  - The mineral calcite is present in the rock limestone formed by coral organisms that build tropical reefs

Sedimentary Rocks

Biochemical Sedimentary Rocks

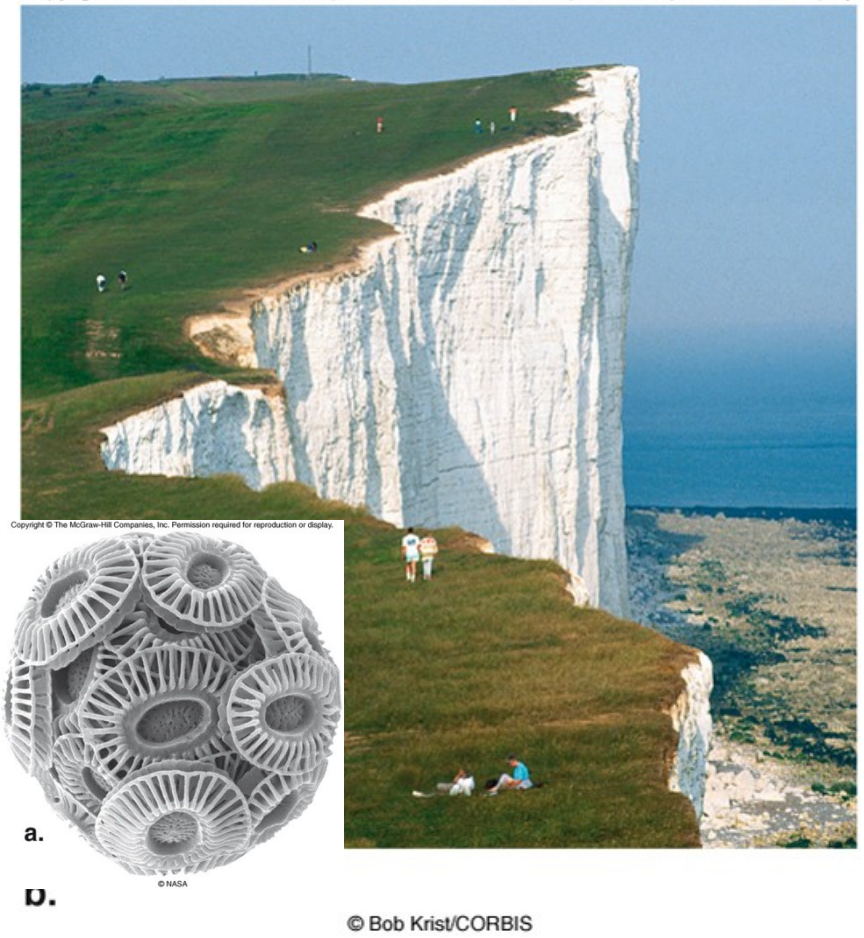
a.

b.

- May form from the remains of dead organisms
  - Coquina → limestone formed from broken shell fragments
  - Coal → carbon-rich rock formed from compacted plant remains

Sedimentary Rocks

Biochemical Sedimentary Rocks

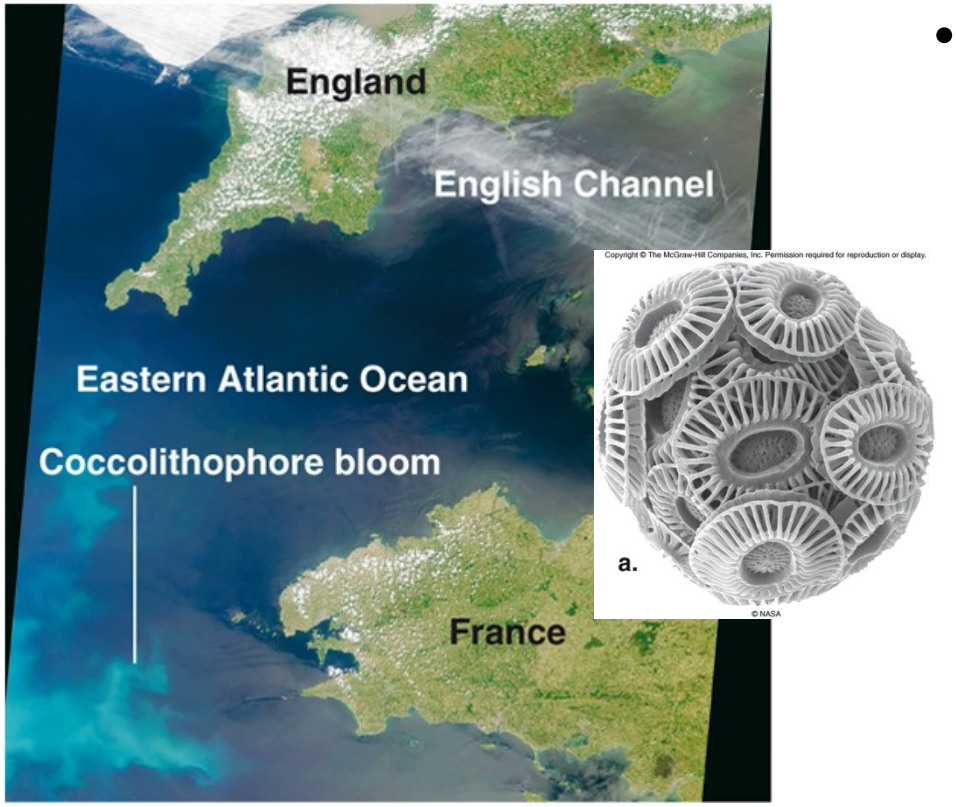


© Bob Krist/CORBIS

- May form from the remains of dead organisms
  - Chalk formed from billions of coccoliths, round plates of calcite from microscopic (clay-sized) coccolithophore organisms
  - Chalk is a type of limestone

Sedimentary Rocks

Biochemical Sedimentary Rocks

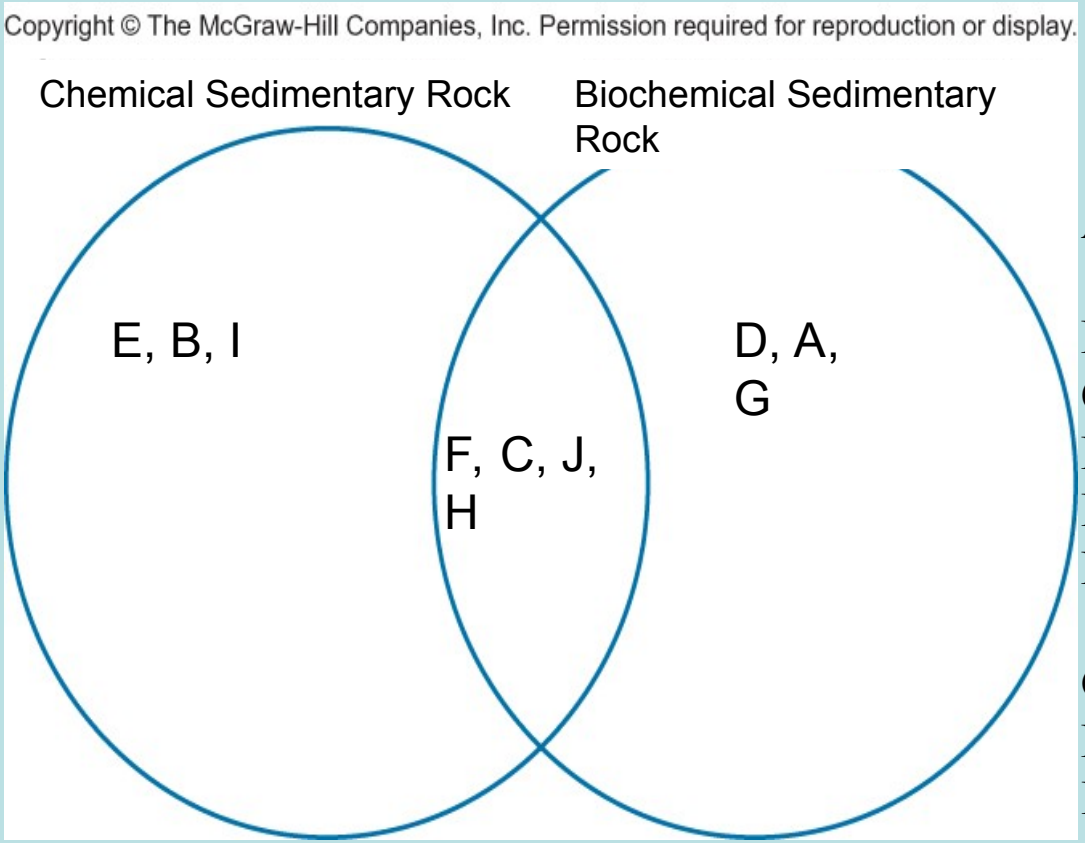


a.

c.

- May form from the remains of dead organisms
  - Coccolithophores live in cold oceans
  - Reflect sunlight to change water color
  - Chalk indicates specific marine conditions in geologic past

Rocks and Minerals Checkpoint 7.15

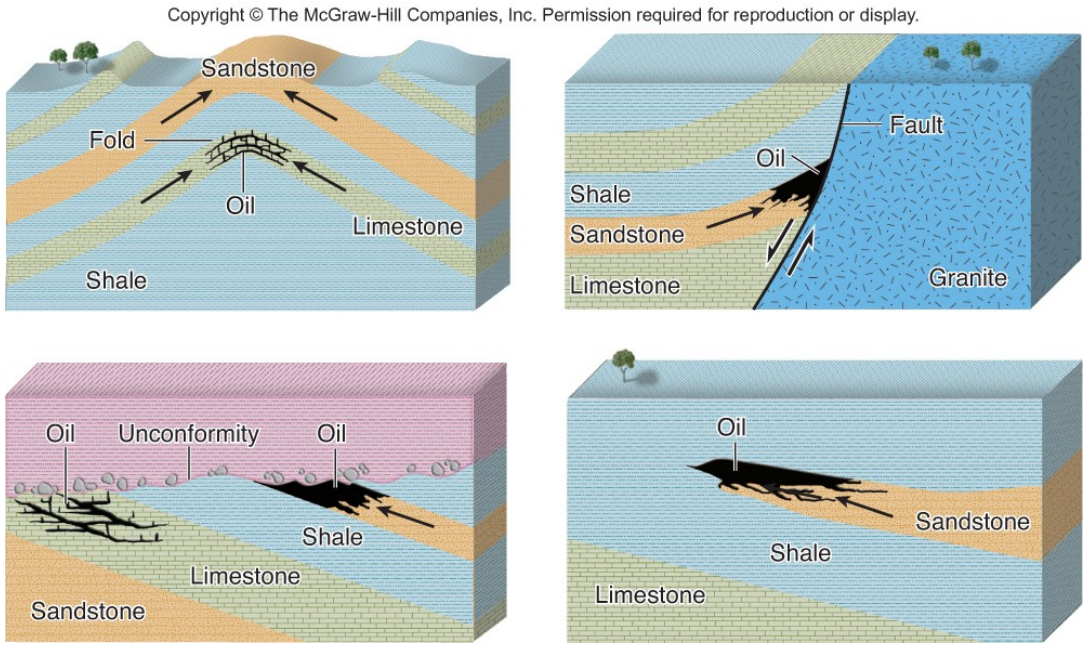


compare and contrast chemical and biochemical sedimentary rocks.

A Chalk and coral form from living organisms
B Evaporatives
C Used to interpret geological past
D Form from organisms (biosphere)
E Examples: gypsum; salt
F Form under shallow marine conditions
G Coal forms from dead plants
H Examples of sedimentary rocks
I Form due to changes in physical conditions
J Form by precipitation from a solution

(seawater)

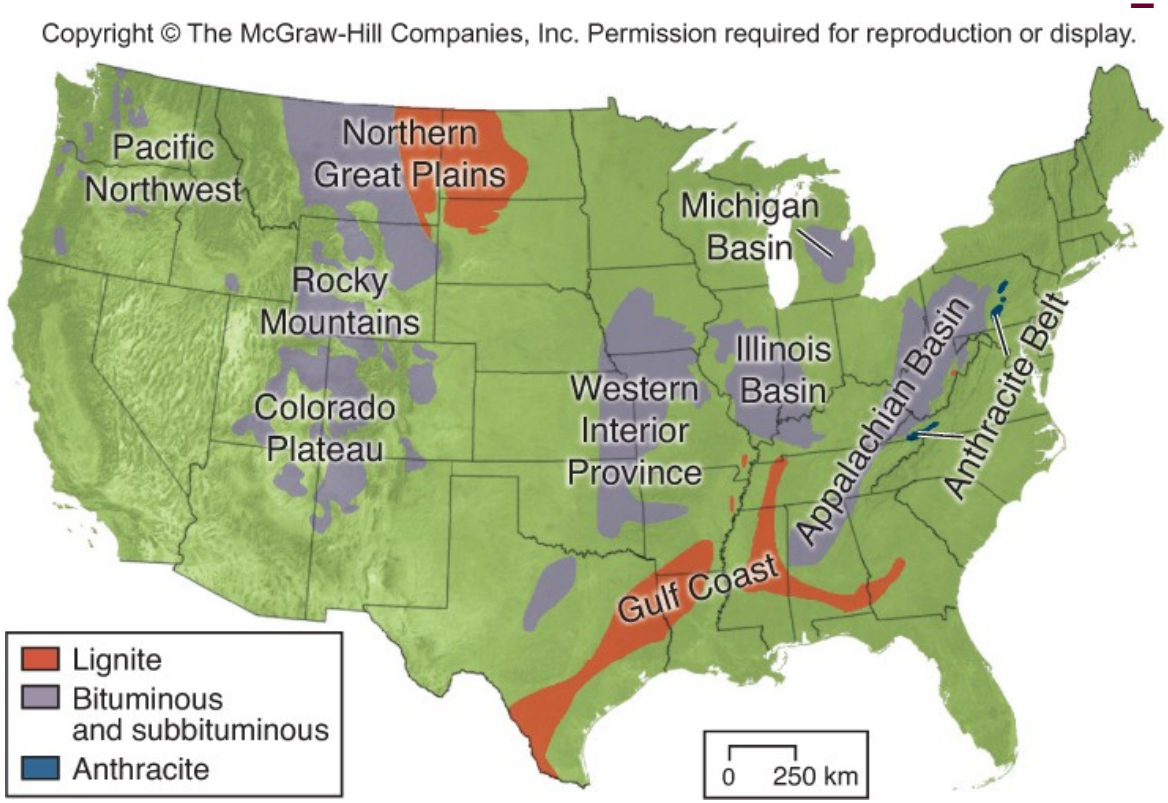
Sedimentary Rocks and Fossil Fuels



- Form from buried organic-rich sediments.
- Chemical reactions convert organics with increased pressures and temperatures of 50-100 ºC.
- Compress for millions years traps oil and gas in specific rock formations (hydrocarbon reservoirs)

Sedimentary Rocks and Coal

US has some of the largest coal reserves in the world.



- Form from buried plants.

Coal type (rank) depends on organic content of parent material, burial depth and heat.

Compress Organic material for many millions years → coal

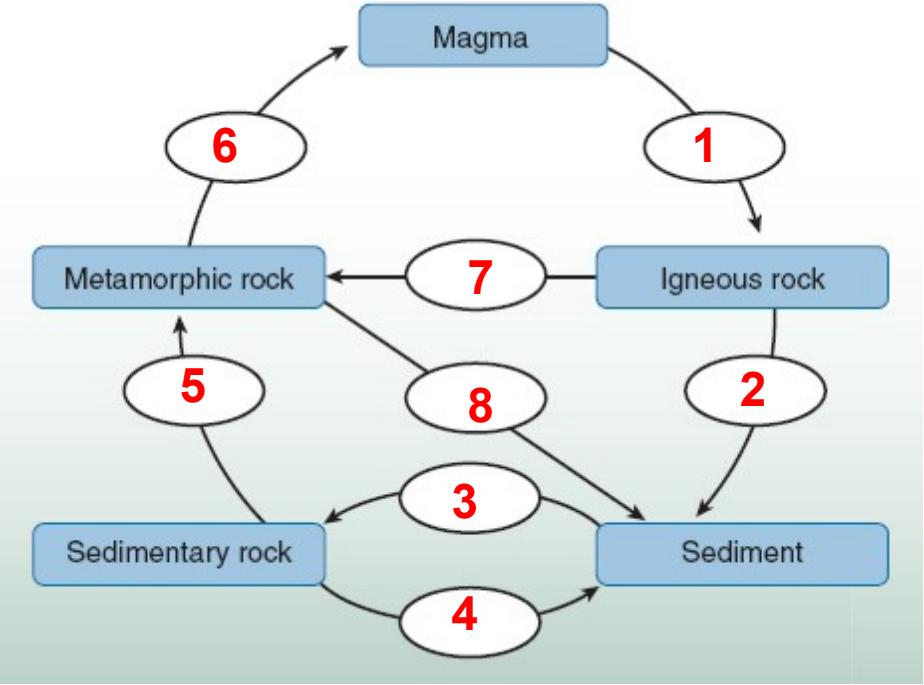
Lignite (low grade); bituminous (medium); anthracite (high).

BUT Coal has more carbon pollution than other fossil fuels (More Later on effects on climate)

Stop here

Rocks and Minerals Conceptest

Examine the diagram. Weathering, transportation, and deposition can occur during steps:



A. 1, 2, 3

B. 3, 5, 7

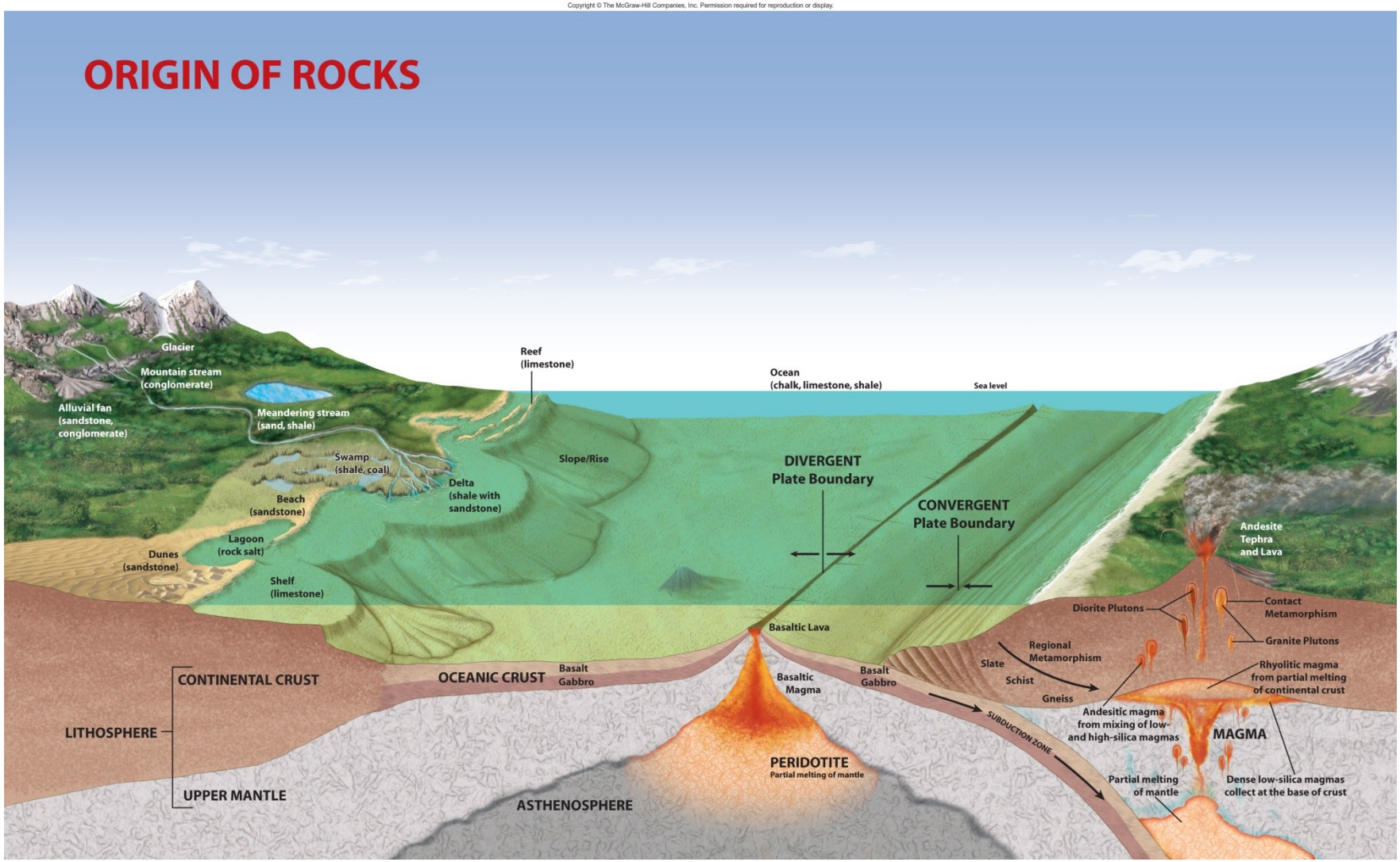
C. 2, 4, 8 x

D. 4, 5, 6

6 – melting 5, 7 – heat and pressure 4 – lithification (cementation/compaction)
1 – cooling and solidification=on

Clastic rocks – composed of fragments (clasts) of pre-existing minerals and rock. A fragment is broken off other rocks by physical weathering.

Metamorphic Rocks



Metamorphic Rocks

Metamorphism

- Changes in mineral composition and texture that can occur in any solid rock
- Changes due to increasing **temperature** and/or **pressure** and/or the **presence of fluids.**
  - Temperatures high enough to promote chemical reactions but not high enough to cause melting
    - Approximately 200°C →1100°C, depending on rock type and conditions
    - Similar temperatures found deep in crust or near magma chambers

Metamorphic Rocks

Two types of **metamorphism**

1. Contact metamorphism

- Changes due to increases in temperature where rocks come in contact with heat source (e.g. magma chamber)
  - Example: limestone around a magma chamber is baked by the heat to form marble

a.

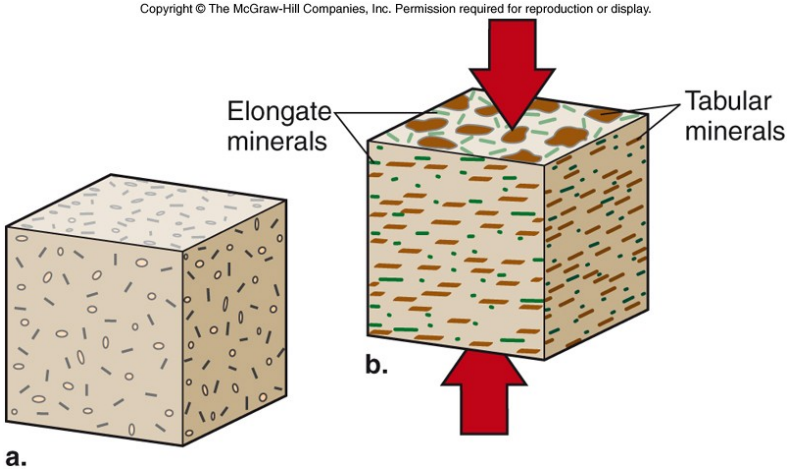
Marble (above) and limestone have similar composition but marble typically has a larger grain size

Metamorphic Rocks

Two types of **metamorphism**

2. Regional metamorphism

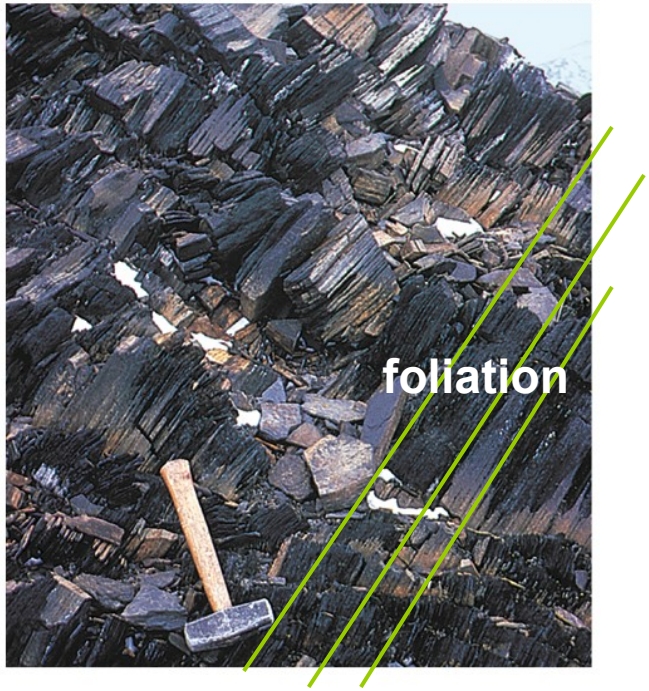
- Increased heat and pressure associated with associated with plate tectonic processes that form mountains
  - Increased pressures and temperatures cause tabular minerals to take on a preferred orientation, **foliation**, perpendicular to direction of pressure



Foliation is produced when tabular minerals grow perpendicular to the direction of pressure.

Metamorphic Rocks

Increased pressures and temperatures cause tabular minerals to take on a preferred orientation, **foliation**, perpendicular to direction of pressure



a.

Unmetamorphosed, non-foliated original rock (granite) with random distribution of minerals

c.

Metamorphic rock (gneiss) with foliation illustrates parallel alignment of minerals

Metamorphic Rocks

Two types of **metamorphism**

2. Regional metamorphism

- Higher temperatures and pressures yield more intense metamorphism

- Grain size increases with degree of metamorphism (metamorphic grade)
- Rock names vary with grain size

Table 7.6 **Metamorphic Rocks Based on Foliation and Texture (Grain Size)**

	Grain size		
Foliation	**Fine (< 0.1 mm)**	**Medium (~0.1–4 mm)***	**Coarse (> 2 mm)***
No	Hornfels	Marble, quartzite	Marble, quartzite
Yes	Slate, phyllite	Schist	Gneiss

* Approximate sizes for comparison purposes only.

Rocks and Minerals Conceptest

The conversion from bread to toast can be seen as an analog for the formation of a metamorphic rock by:

A. **Contact metamorphism**

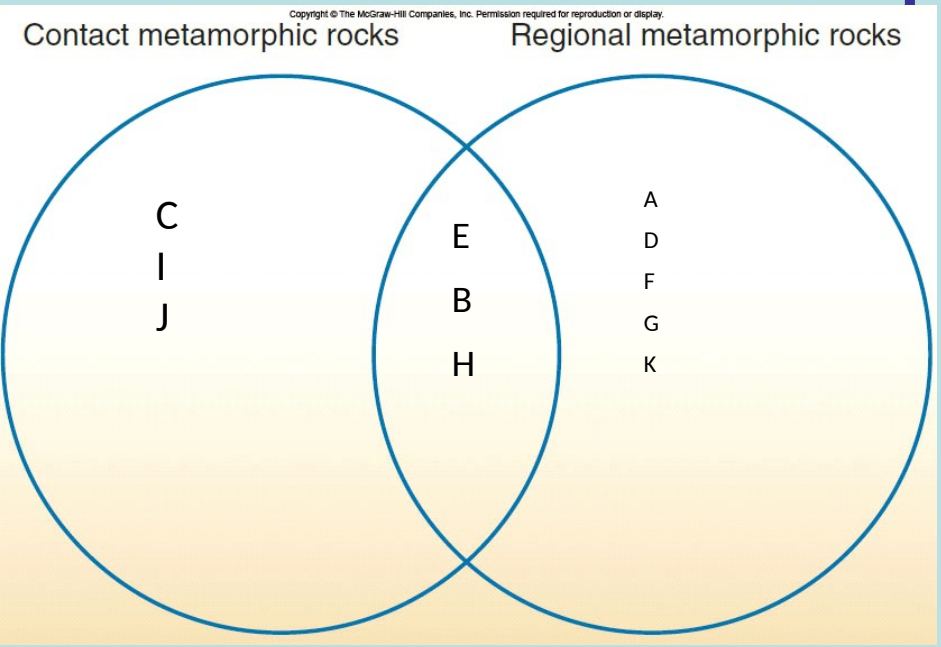
B. Regional metamorphism

Rocks and Minerals Checkpoint 7.18

Characteristic	Rocks formed by	
	Contact metamorphism	Regional metamorphism
Form at temperatures above 200°C	X	X
May originally have been an igneous rock	X	X
Form as a result of increasing pressures		X
May surround plutonic igneous rocks	X	
Slate is an example		X
Form as a result of melting		
May underlie several adjacent states		X
Found in mountain belts	(X)	X
May originally have been a sedimentary rock	X	X
May contain a foliation		X
Marble is a possible example	X	X
Form on Earth's surface	X	
Limestone is an example		
May have originally been a metamorphic rock	X	X

Complete the table by identifying which of the characteristics are present in rocks formed by contact and/or regional metamorphism.

Contact versus Regional Metamorphic Rocks Checkpoint 7.19



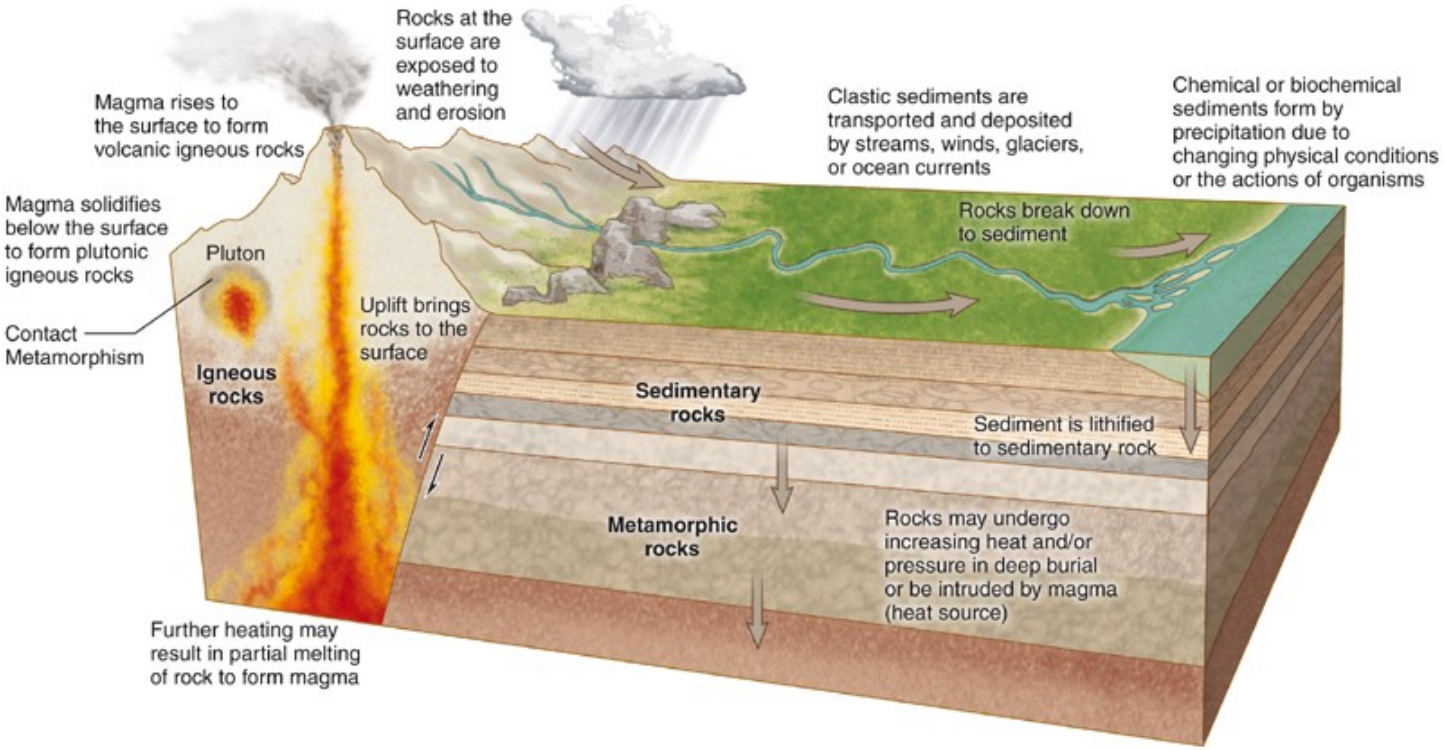
compare and contrast metamorphic rocks formed by contact and regional processes.

A	Rocks usually contain foliations
B	Originally could be any type rock
C	Associated with plutons
D	Due to increased temperature and pressure
E	May include marble and quartzite
F	Associated with mountain building
G	Regional – includes rocks in multiple states
H	Temperature window – 200 to 1100 C
I	Due to increasing temperature only
J	Localized in area
K	Examples: slate, schist, gneiss

Go to the next section: ***Rock Cycle and Mineral Resources***

The Rock Cycle and Mineral Resources

- Rock cycle links igneous, sedimentary, and metamorphic rocks together.
  - Any rock can become any other rock under the appropriate conditions.



Rocks and Minerals Conceptest

Cooking an egg could be seen as an analog for the formation of :

A. Igneous rock.

B. Sedimentary rock.

C. Metamorphic rock.

Rocks and Minerals Conceptest

Concrete is formed by adding cement and water to a mixture of sand and gravel. This could be seen as an analog for the formation of what type of sedimentary rock?

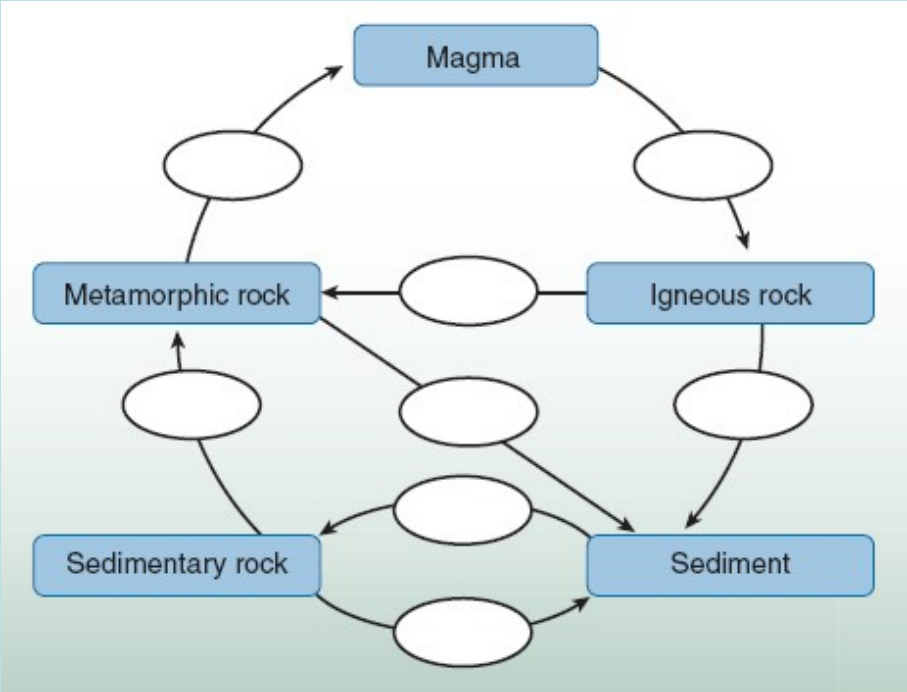
A. Clastic rock.

B. Chemical rock.

C. Biochemical rock.

Rocks and Minerals Checkpoint 7.22

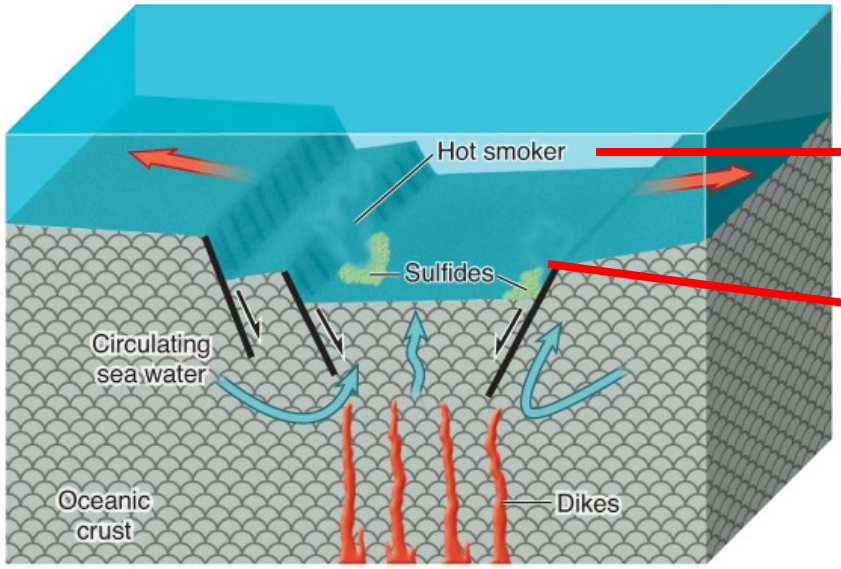
The diagram illustrates the rock cycle. Match the letters below to the blank ovals on the diagram. (Note: some letters are used more than once.)



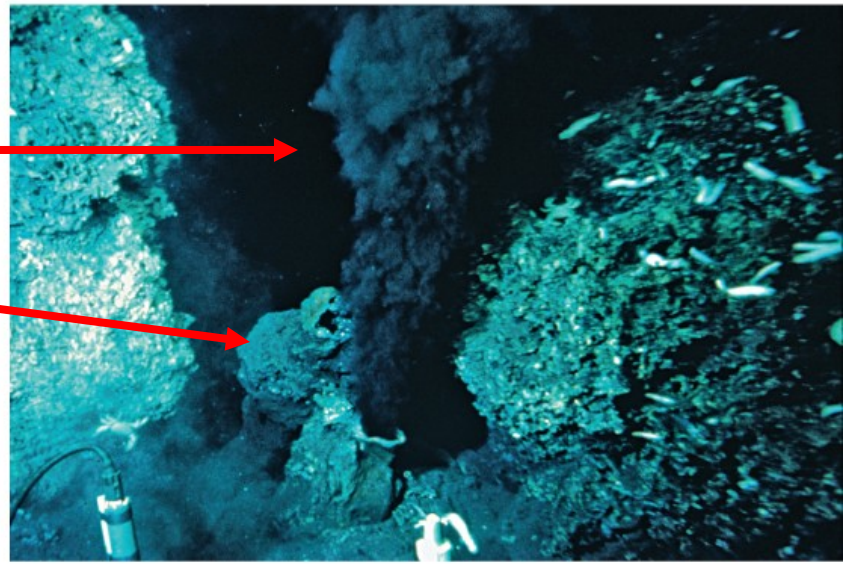
A. Cementation and compaction (lithification)
B. Heat and Pressure
C. Weathering, transportation, deposition
D. Cooling and solidification
E. Melting

Mineral Resources

- Mineral resources result from specific geologic processes associated with formation of rocks.
  - Can result from chemical reactions driven by changing temperatures and movement of fluids through rocks.



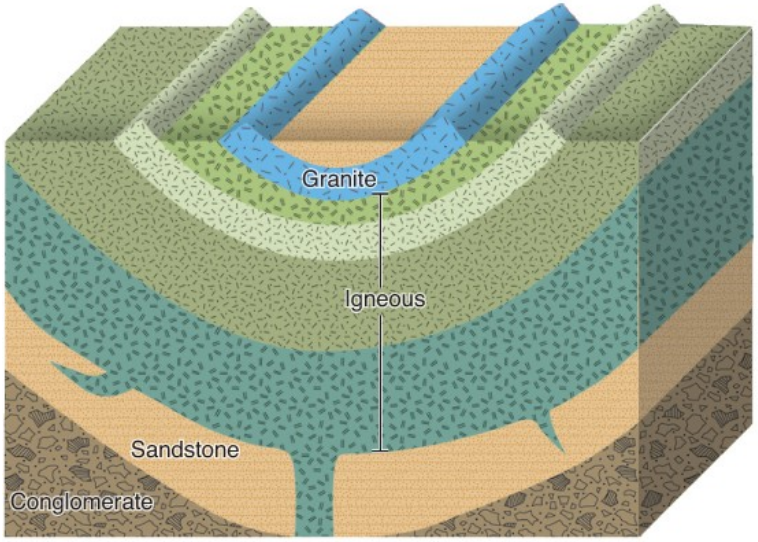
a.



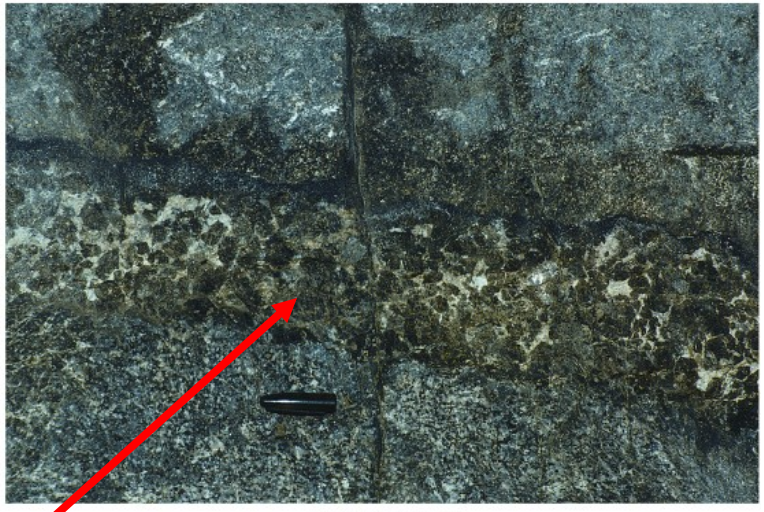
b. © W. R. Normak/USGS

Mineral Resources

- Mineral resources result from specific geologic processes associated with formation of rocks.
  - Can result when minerals crystallize at different temperatures.



a.



b.

platinum

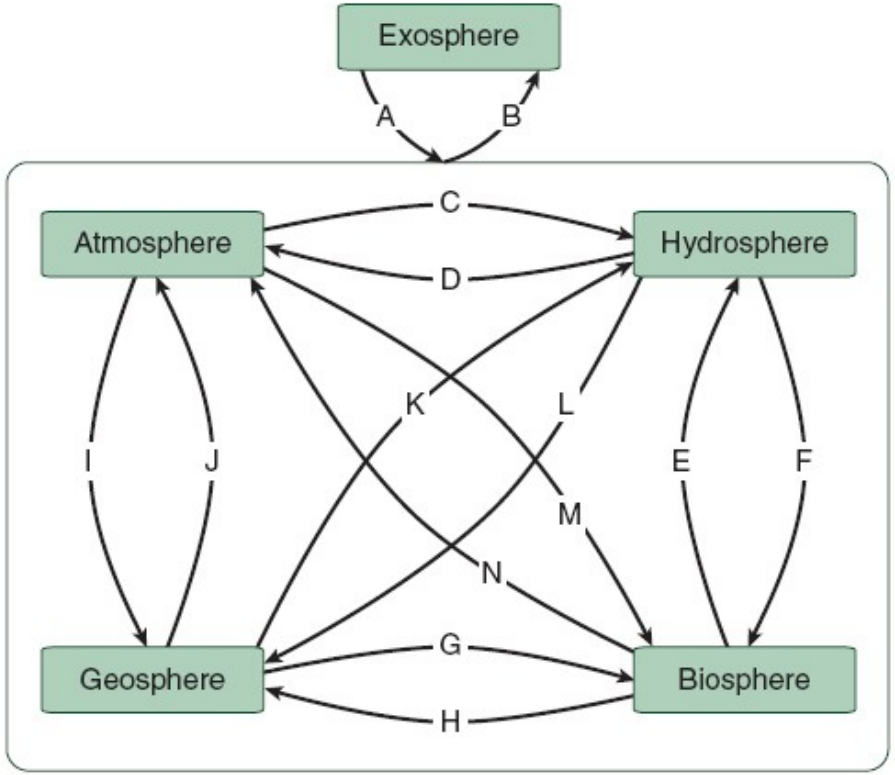
Mineral Resources

- Mineral resources result from specific geologic processes associated with formation of rocks.
  - Can result from concentration of various types of rocks and minerals during erosion, transportation and deposition.

View of the Stullwater Mine, Nye, MT where rocks are collected for making lunar regolith simulant.

Credit: U.S. Geological Survey Department of the Interior/USGS U.S. Geological Survey/photo.

Rocks and Minerals Concept Map



Complete the concept map to evaluate your understanding of the interactions between the earth system and rocks and minerals.

A – Solar energy causes evaporation of seawater to form chemical sedimentary rocks
K – Weathering dissolves some minerals into oceans
L – Formation of sedimentary rocks (weathering, transport)
M – Plants absorb carbon from atmosphere
N – Burning fossil fuels

The End