Fundamentals of Earth Sciences (ESO 213A)

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Sedimentary Rocks

Previous Class: Volcanoes

Important Announcements

- Quiz 1 will be conducted during normal class hours (11:00 -11:40 AM)
- Date: 2nd September 2022
- Venue: L-16
- Syllabus: Material covered up to 29th August
- Type: MCQ (30 questions/1 mark each/0.25 marks negative marking, you can open notes, books and internet but no discussion)

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What Is a Sedimentary Rock?

- Sedimentary rocks are products of mechanical and chemical weathering.
- They comprise about 5% (by volume) of Earth's outer and are concentrated at or near the surface
- Contain evidence of past environments:
    - Provide information about sediment transport
    - Often contain fossils
    - Hydrocarbon, grounwater reservoirs

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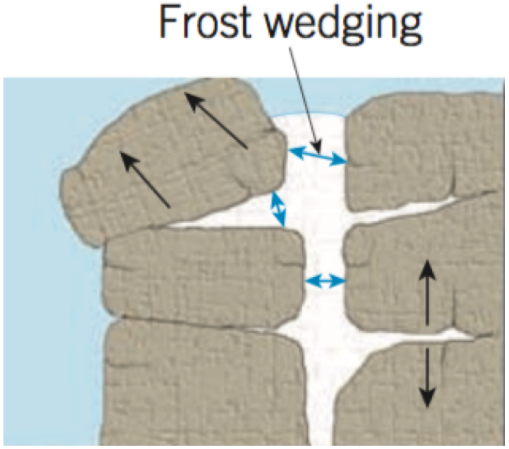
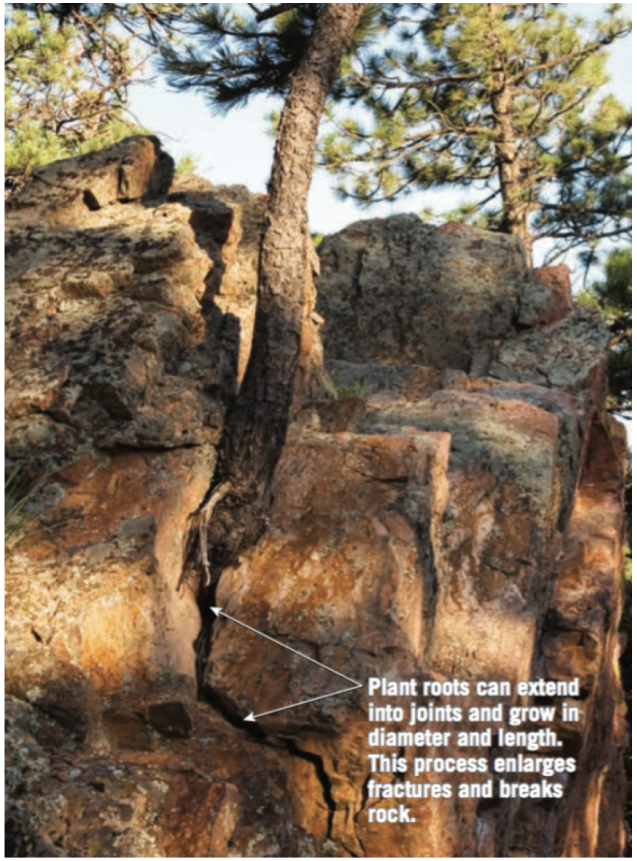
Physical Weathering

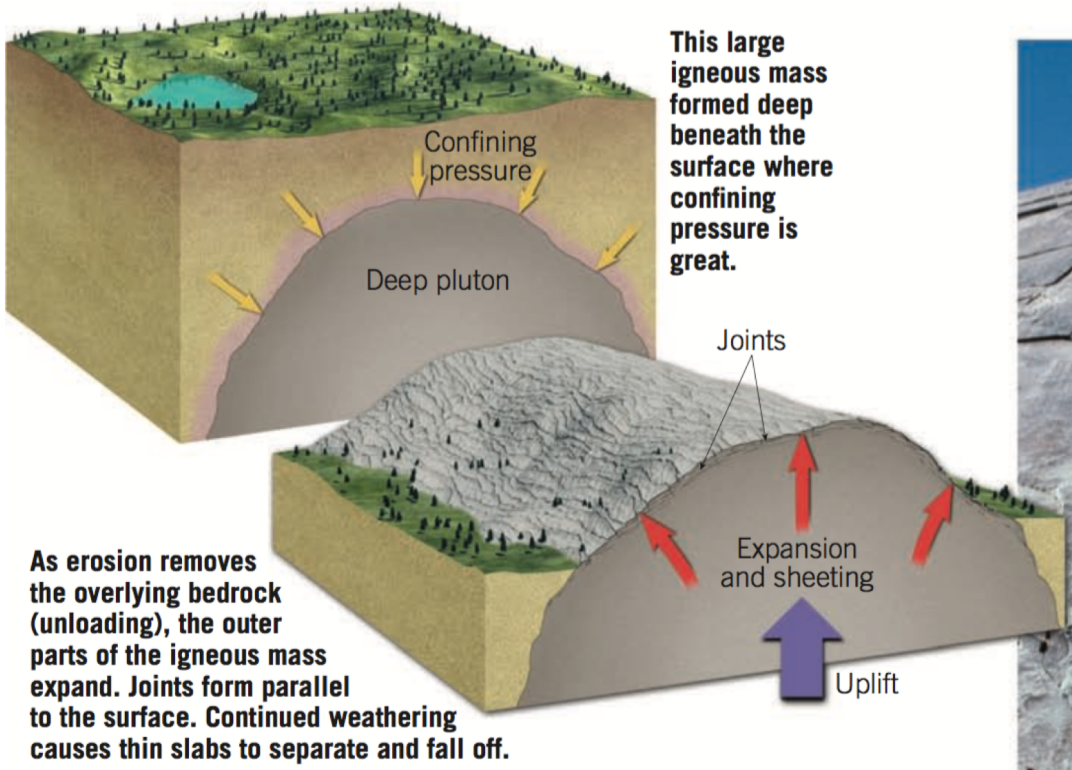
- **Frost wedging:** When liquid water freezes, it expands by 9% and expands cracks producing fragments of rocks
- **Salt crystal growth:** Salty groundwater penetrates pores or crevices. As water evaporates, salt crystals form and grow pushing surrounding grains, opening up of tiny cracks.
- **Biological activity:** Plant root grows into fractures and wedge rocks apart.
- Plant roots, algae, and decaying animals occupy fractures in rocks and produces acids promoting decomposition





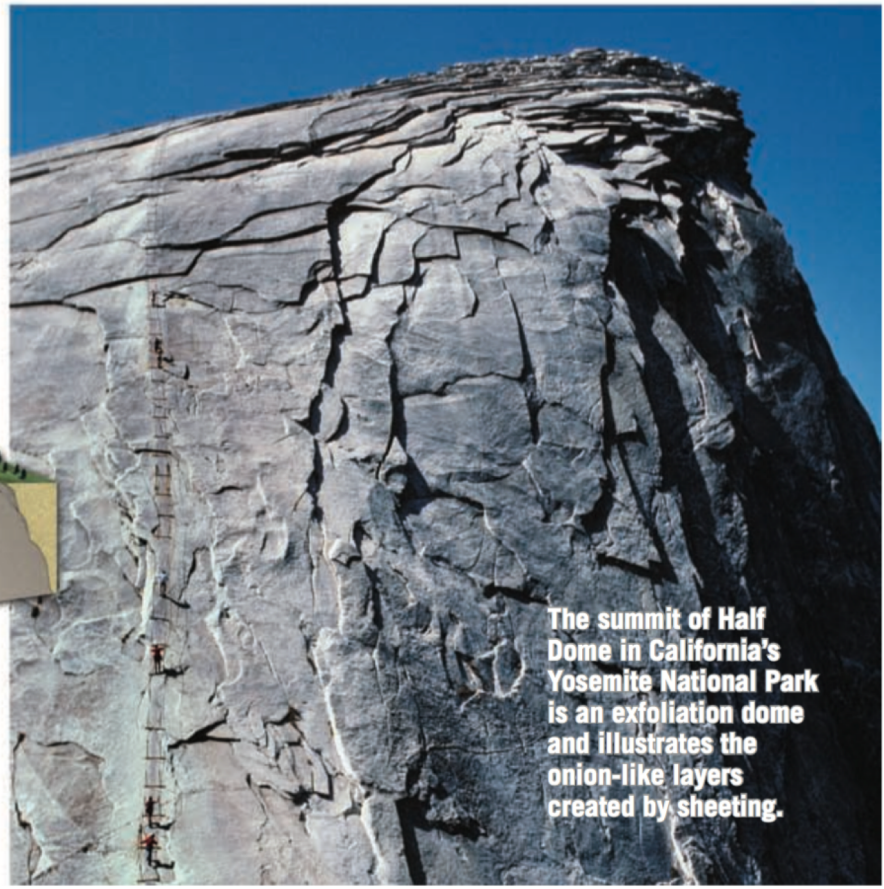
Physical Weathering

Sheeting: If large mass of igneous rocks are exposed to erosion, the outer part of igneous mass expands. Continued weathering causes thin slabs to fall off.



This large igneous mass formed deep beneath the surface where confining pressure is great.

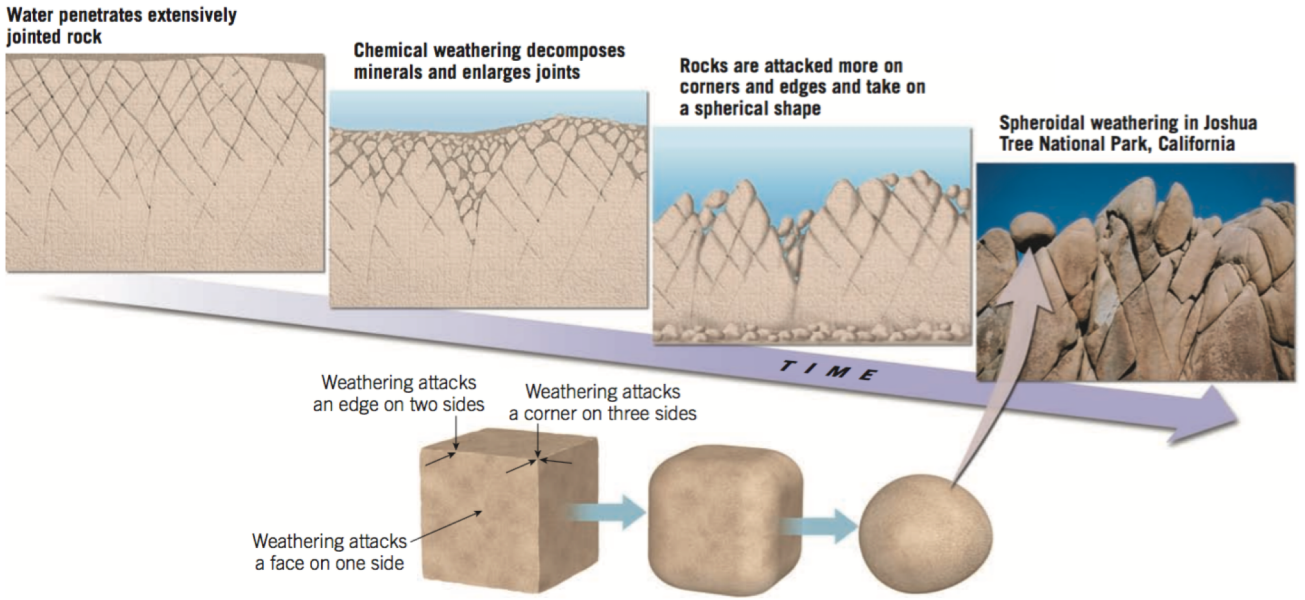
As erosion removes the overlying bedrock (unloading), the outer parts of the igneous mass expand. Joints form parallel to the surface. Continued weathering causes thin slabs to separate and fall off.



The summit of Half Dome in California's Yosemite National Park is an exfoliation dome and illustrates the onion-like layers created by sheeting.

Chemical Weathering

- In chemical weather the structure of minerals changes
- H_2O is most important agent of chemical weathering. It can liberate and transport ions from some minerals through dissolution.
- Water may also directly react with exposed minerals, producing new minerals that are stable at Earth's surface. The hydrolysis of feldspar to form kaolinite clay is an example. Clays are stable minerals at Earth's surface conditions, and they are profusely generated by the hydrolysis of silicate minerals.
- CO_2 dissolves in H_2O and forms acids that can decompose many minerals
- Spheroidal weathering: Many rock outcrops have a rounded appearance. This occurs because chemical weathering works inward from exposed surfaces.



Turning Sediment into Rock

- Many changes occur to sediment after it is deposited.
- Diagenesis—chemical, physical, and biological changes that take place after sediments are deposited
    - Occurs within the upper few kilometers of Earth's crust at temperatures < 150^{O} -200^{O}C

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Turning Sediment into Rock

Diagenesis

- **Includes:**
  - **Recrystallization—development of more stable minerals from less stable ones (e.g., aragonite → calcite).**
  - **Lithification—sediments are transformed into solid rock by:**
    - **Compaction and cementation**
    - **Natural cements, which include calcite, silica, and iron oxide**

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An outline of the portion of the rock cycle that pertains to the formation of sedimentary rocks.

E.J.Tarbuck

Bob Gibbons/Alamy Images

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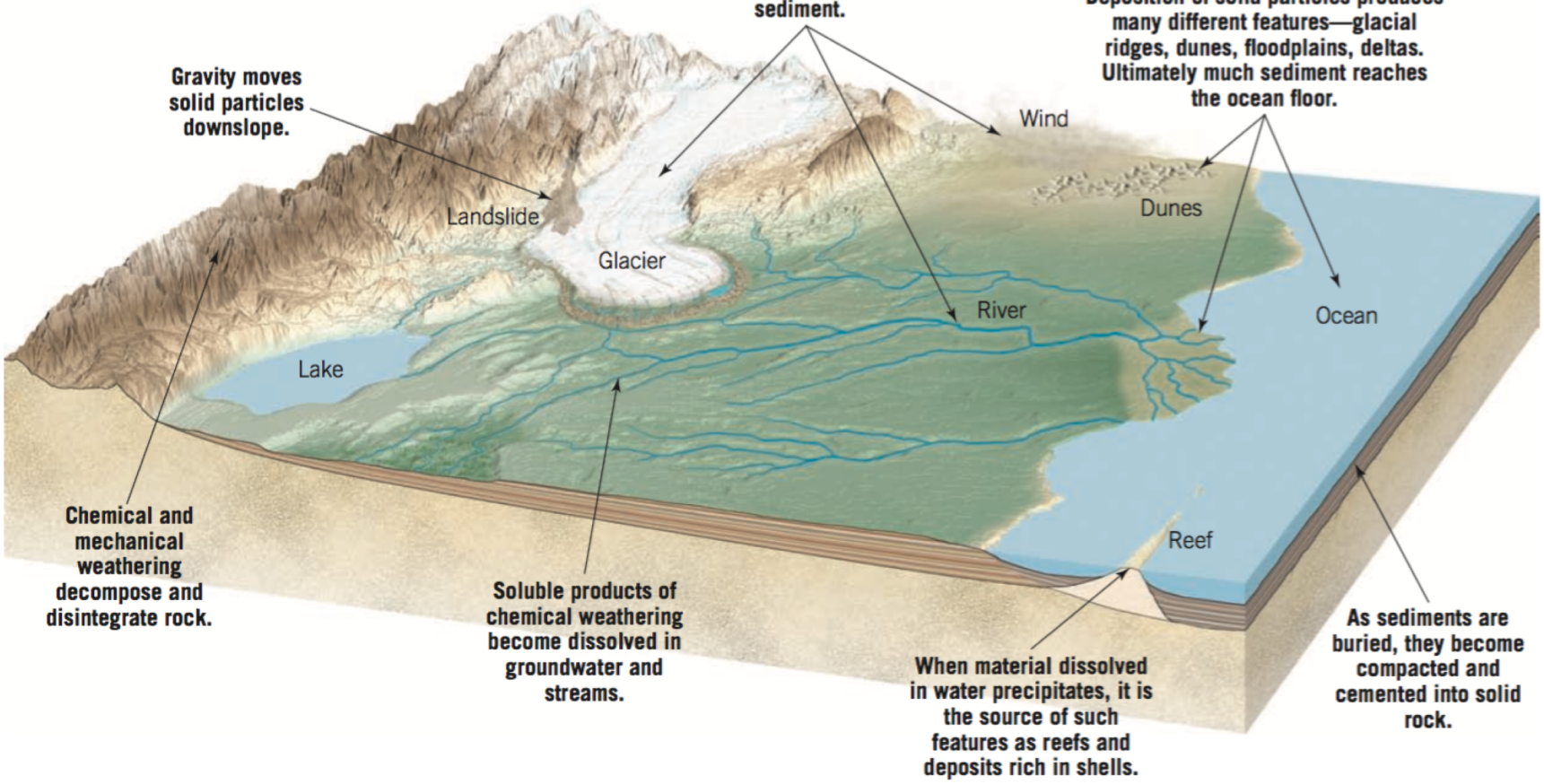

Types of Sedimentary Rocks

- **Sediment originates from mechanical and/or chemical weathering, or accumulation of remains of plants.**
- **Rock types are based on the source of the material.**
  - ***Detrital sedimentary rocks*** **- transported sediment as solid particles**
  - ***Chemical sedimentary rocks*** **- sediment that was once in solution and was precipitated by either inorganic or biologic processes**
  - ***Organic sedimentary rocks***

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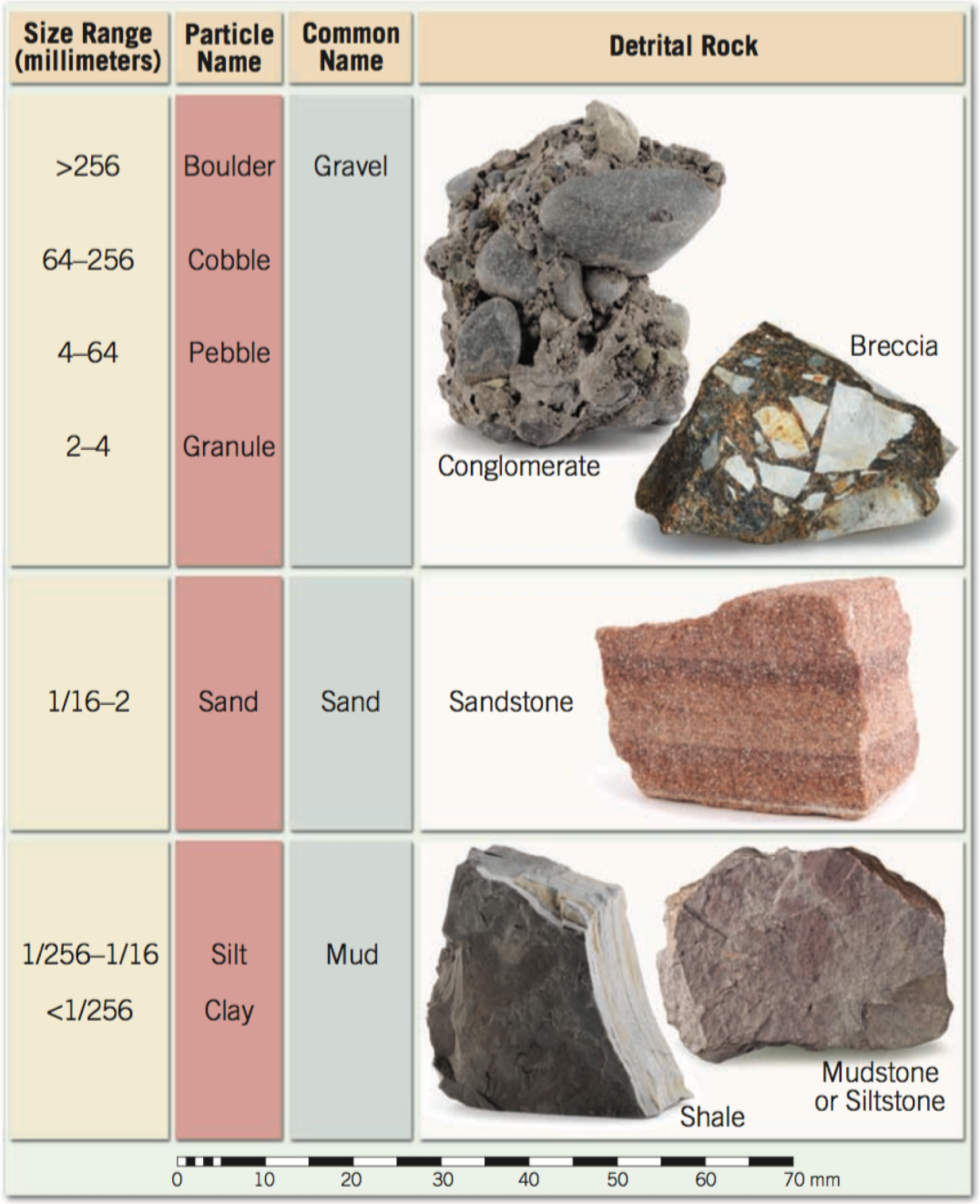
I. Detrital Sedimentary Rocks

- The chief constituents of detrital rocks include:
  - Clay minerals
  - Quartz
  - Feldspars
  - Micas
- Particle size is used to distinguish among the various rock types.



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Detrital Sedimentary Rocks

Common detrital sedimentary rocks

- **1. Shale**
  - **Mud-sized particles in thin layers that are called lamina (→ fissibility)**
  - **Most common sedimentary rock**
  - **Environments of deposition: lake, lagoons, deep-ocean basins**
  - **Impermeable rock**

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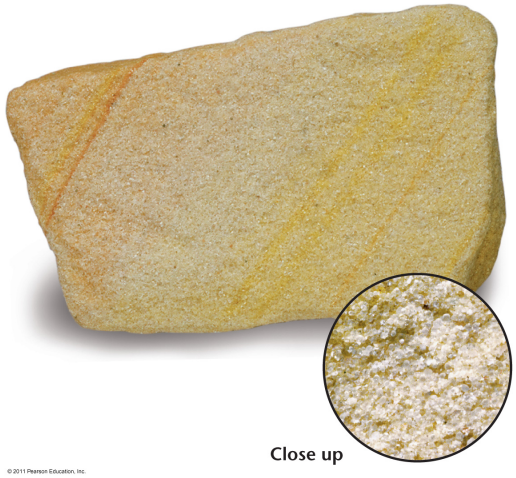
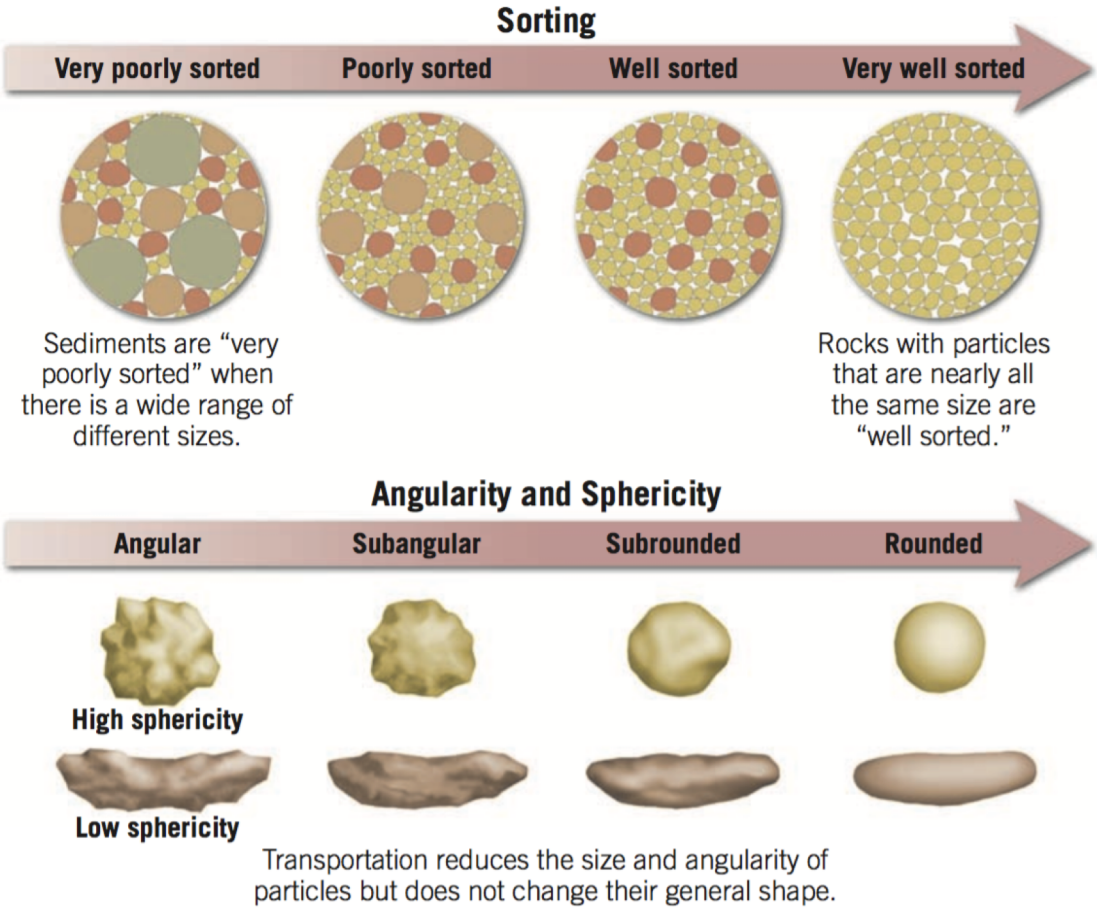
Detrital Sedimentary Rocks

2. Sandstone

- Sand-sized particles
- Forms in a variety of environments
- Predominant mineral = quartz
- Quartz-rich sandstone with highly rounded grains implies a long transport and several cycles of weathering
- Sandstone with feldspar and angular fragments of ferromagnesian minerals implies little chemical weathering and transport





Detrital Sedimentary Rocks

- **3. Conglomerate and breccia**
  - **Both are composed of particles greater than 2 millimeters in diameter (gravel).**

  Conglomerate **consists largely of rounded gravels (imply long transport from their source area)**
  - **Poorly sorted**
  - **Gravels indicate turbulent currents and action of energetic mountain streams**

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Gravel Deposits, if Lithified, Would Become Conglomerate

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Detrital Sedimentary Rocks

- **3. Conglomerate and breccia**
  - **Both are composed of particles greater than 2 millimeters in diameter (gravel).**

Breccia **is composed mainly of large angular particles (imply short transport from their source area)**

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Question

This detrital rock consists of angular grains and is rich in potassium feldspar and quartz. (Photo by E. J. Tarbuck)

Question 1 What do the angular grains indicate about the distance the sediment was transported?

Question 2 The source of the sediment in this rock was an igneous mass. Name the likely rock type.

Question 3 Did the sediment in this sample undergo a great deal of chemical weathering? Explain.

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II. Chemical Sedimentary Rocks

- **Consist of precipitated material that was once in solution and carried to lakes and seas**
- **Classified according to their mineralogical composition**
- **Precipitation of material occurs by:**
  - **Inorganic processes (chemical origin)**
  - **Organic processes (biochemical origin)**

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Chemical Sedimentary Rocks

- **Common chemical sedimentary rocks**
  - **1. Limestone ($CaCO_3$)**
    - **Most abundant chemical rock**
    - **Composed mainly of the mineral calcite ($CaCO_3$)**
    - **Marine *biochemical* limestones form as coral reefs, coquina (broken shells), and chalk (hard parts of microscopic organisms).**
    - **Inorganic limestones (*chemical*) include travertine and oolitic limestone (spherical grains with concentric layers of calcite/aragonite around a central nucleus).**

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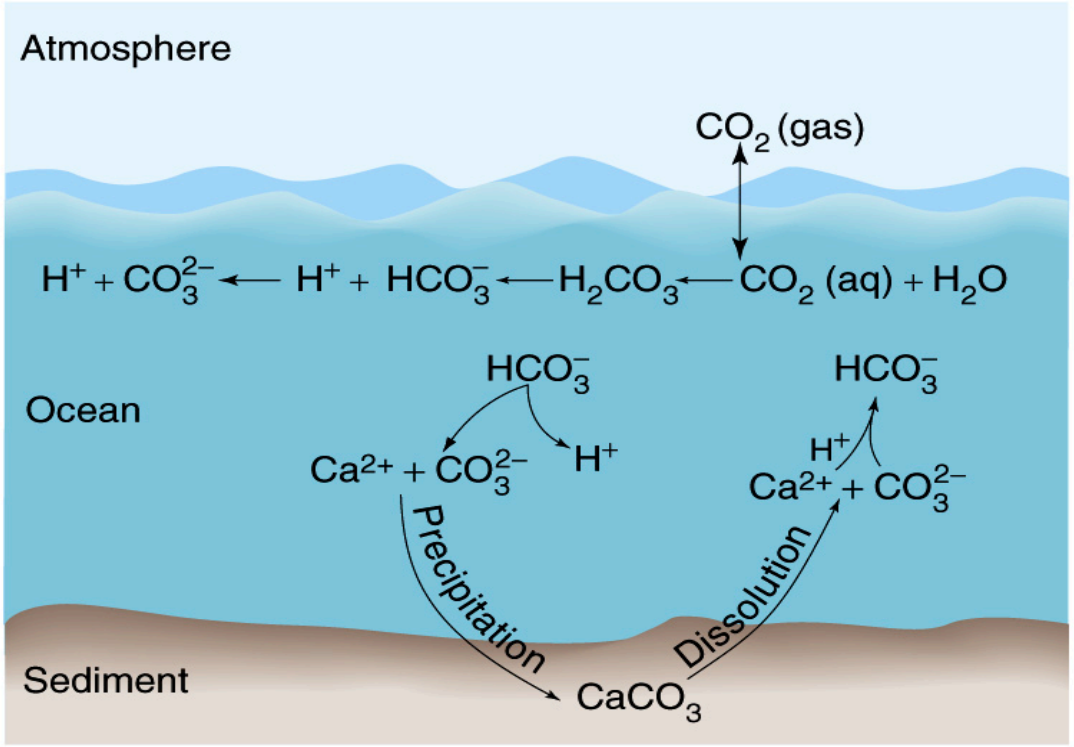
Example of Shells for limestone

Carbonate buffering

- Oceans can absorb CO_2 from atmosphere without much change in pH
- Keeps ocean pH about same (8.1)
- pH too high, carbonic acid releases H+
- pH too low, bicarbonate combines with H+
- Precipitation/dissolution of calcium carbonate $CaCO_3$ buffers ocean pH

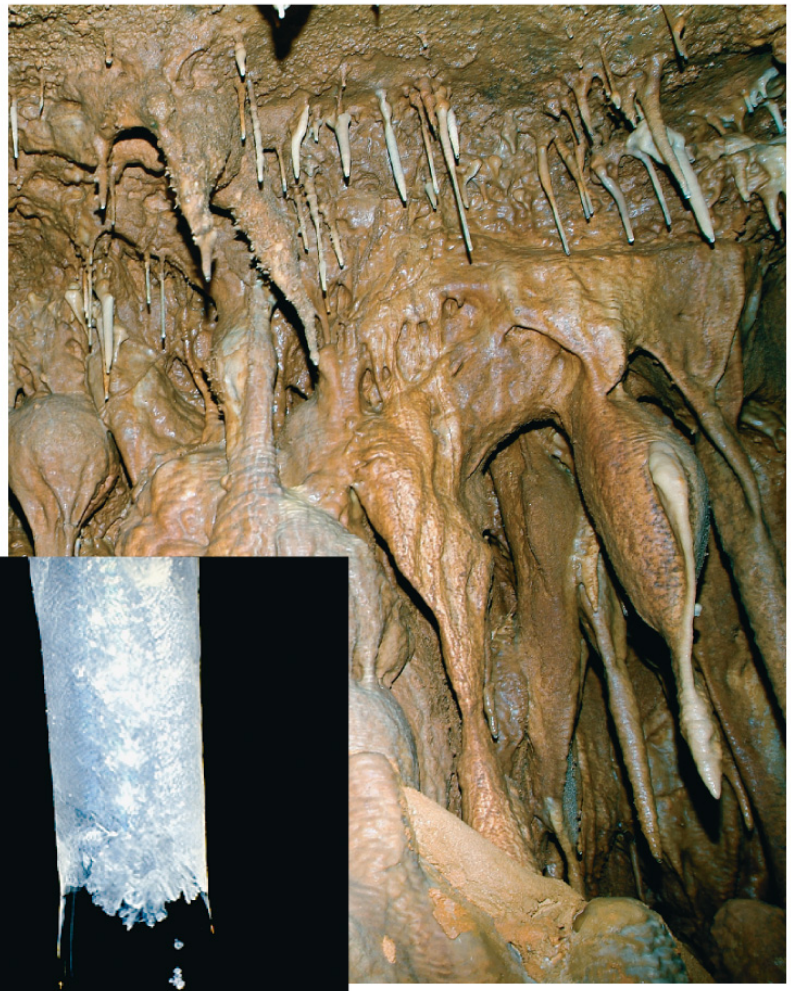


Travertine

It is formed by a process of rapid precipitation of calcium carbonate, often at the mouth of a hot spring or in a limestone cave.

- **Commonly deposited in caves**

- **Groundwater is the source of $CaCO_3$**



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$$CaCO_3(s) + H_2O(l) + CO_2(aq) \rightarrow Ca(HCO_3)_2(aq)$$

Ca bicarbonate

$$Ca(HCO_3)_2(aq) \rightarrow CaCO_3(s) + H_2O(l) + CO_2(aq)$$

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Chemical Sedimentary Rocks

- **Common chemical sedimentary rocks**
  - **2. Dolostone [$CaMg(CO_3)_2$]**
    - **Typically formed secondarily from limestone when Mg-rich waters circulate through limestone**
  - **3. Chert (SiO_2)**
    - **Extremely hard and compact**
    - **Precipitated by *Diatoms* and *Radiolarians* (marine microorganisms)**
    - **Varieties include agate, flint and jasper.**

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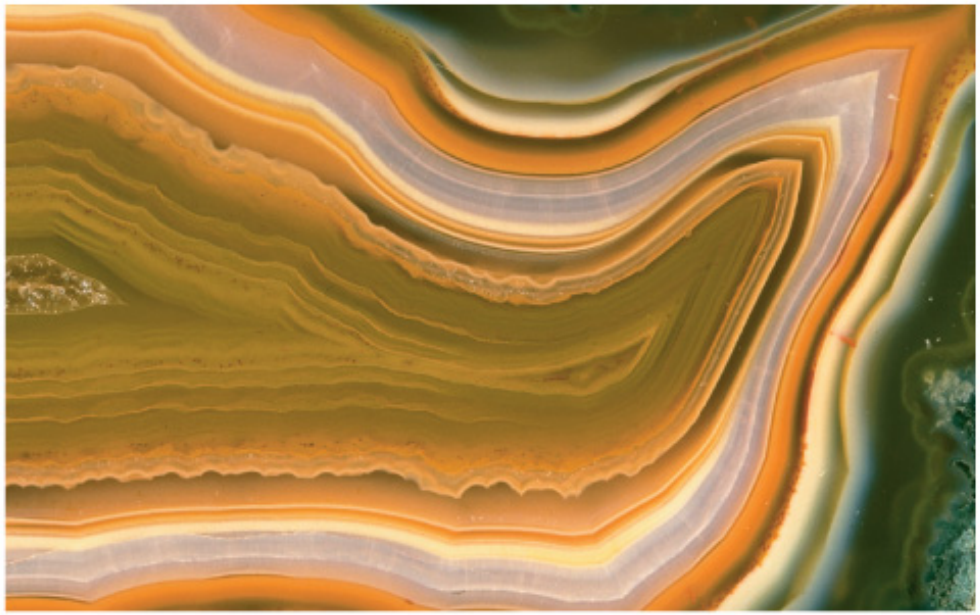
Varieties of Chert



A. Agate

B. Flint

C. Jasper

D. Chert arrowhead

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Chemical Sedimentary Rocks

Common chemical sedimentary rocks

- **4. Evaporites**
  - **Evaporation triggers deposition of chemical precipitates.**
  - **Examples include rock salt (NaCl) and rock gypsum ($CaSO_4 \cdot 2H_2O$).**
  - **Sequence of precipitation:**
    - **» 80% of seawater evaporates → gypsum**
    - **» 90% of seawater evaporates → halite**

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III. Organic Sedimentary Rocks

- **Common chemical sedimentary rocks**
  - **Coal**
    - **Different from other rocks because it is composed of organic material.**
    - **The end product of large amounts of plant material, buried for millions of years**
    - **Stages in coal formation (in order):**
      1. **Plant material**
      2. **Peat**
      3. **Lignite (sedimentary rock)**
      4. **Bituminous (sedimentary rock)**
      5. **Anthracite (metamorphic rock)**

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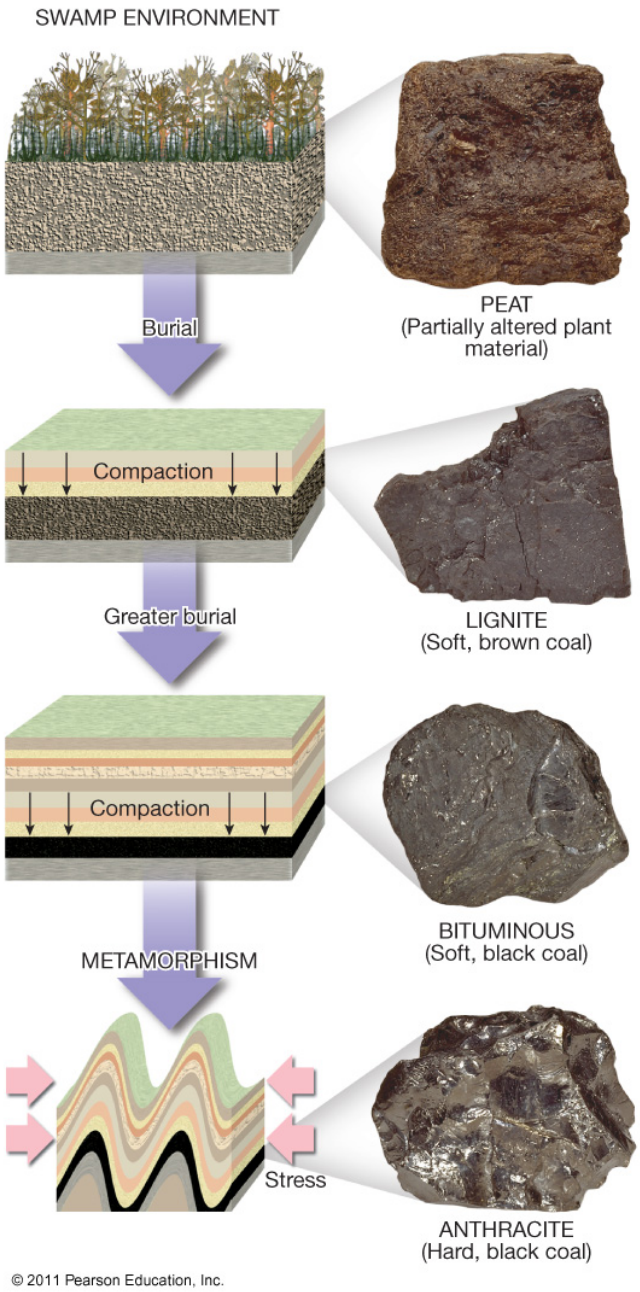

Stages of Coal Formation

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Classification of Sedimentary Rocks

- **Sedimentary rocks are classified according to the type of material.**
- **Two major groups**
  1. **Detrital – classified according to particle size**
  2. **Chemical / Organic – classified according to mineral composition**

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Classification of Sedimentary Rocks

Two major textures are used in the classification of sedimentary rocks:

1. **Clastic**
   - **Discrete fragments and particles**
   - **All detrital rocks have a clastic texture**
   - **Some chemical rocks (e.g., Coquina, Oolitic L.)**
2. **Nonclastic or Crystalline**
   - **Pattern of interlocking crystals**
   - **Evaporites, some Limestone**
   - **May resemble an igneous rock – however, easy to distinguish**

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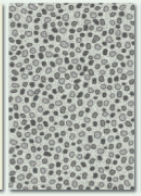
Classification of Sedimentary Rocks

Detrital Sedimentary Rocks

Clastic Texture (particle size)		Sediment Name	Rock Name
Coarse (over 2 mm)		Gravel (Rounded particles)	**Conglomerate**
		Gravel (Angular particles)	**Breccia**
Medium (1/16 to 2 mm)		Sand (If abundant feldspar is present the rock is called **Arkose**)	**Sandstone**
Fine (1/16 to 1/256 mm)		Mud	**Siltstone**
Very fine (less than 1/256 mm)		Mud	**Shale or Mudstone**

Chemical and Organic Sedimentary Rocks

Composition	Texture	Rock Name	
Calcite, $CaCO_3$	Nonclastic: Fine to coarse crystalline	**Crystalline Limestone**	
		Travertine	
	Clastic: Visible shells and shell fragments loosely cemented	**Coquina**	**Biochemical Limestone**
	Clastic: Various size shells and shell fragments cemented with calcite cement	**Fossiliferous Limestone**	
	Clastic: Microscopic shells and clay	**Chalk**	
Quartz, SiO_2	Nonclastic: Very fine crystalline	**Chert (light colored) Flint (dark colored)**	
Gypsum $CaSO_4 \cdot 2H_2O$	Nonclastic: Fine to coarse crystalline	**Rock Gypsum**	
Halite, NaCl	Nonclastic: Fine to coarse crystalline	**Rock Salt**	
Altered plant fragments	Nonclastic: Fine-grained organic matter	**Bituminous Coal**	

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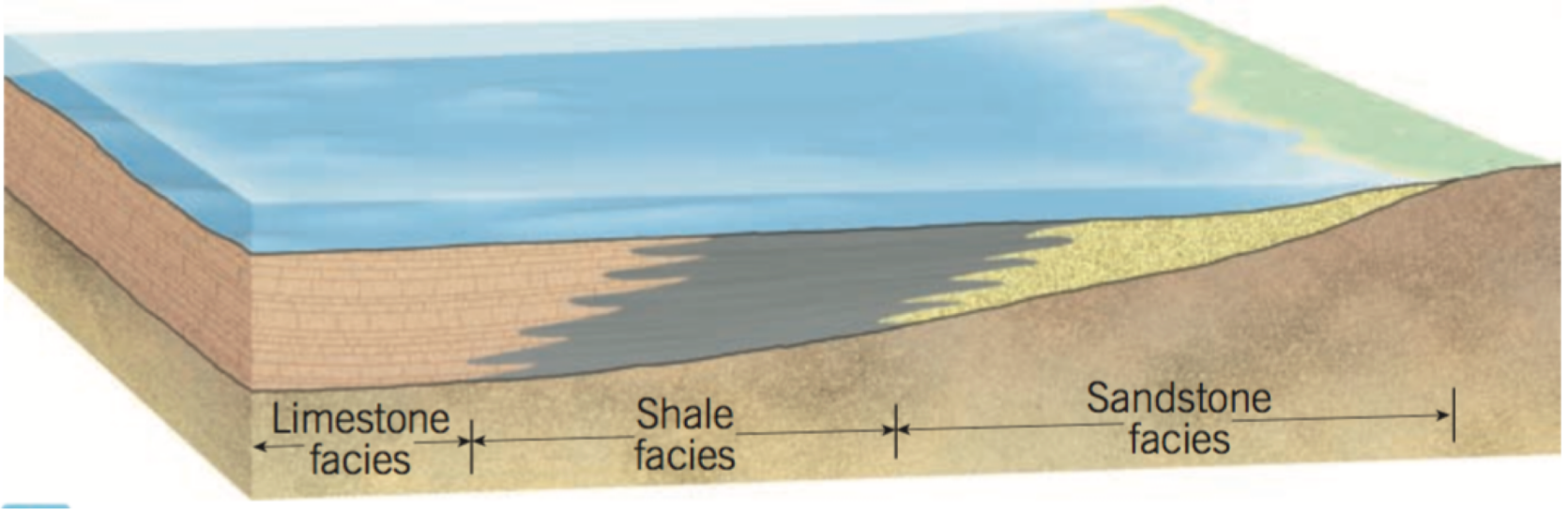
Sedimentary Facies



When a sedimentary layer is traced laterally, we may find that it is made up of several different rock types. This occurs because many sedimentary environments can exist at the same time over a broad area. The term facies is used to describe such sets of sedimentary rocks. Each facies grades laterally into another that formed at the same time but in a different environment.

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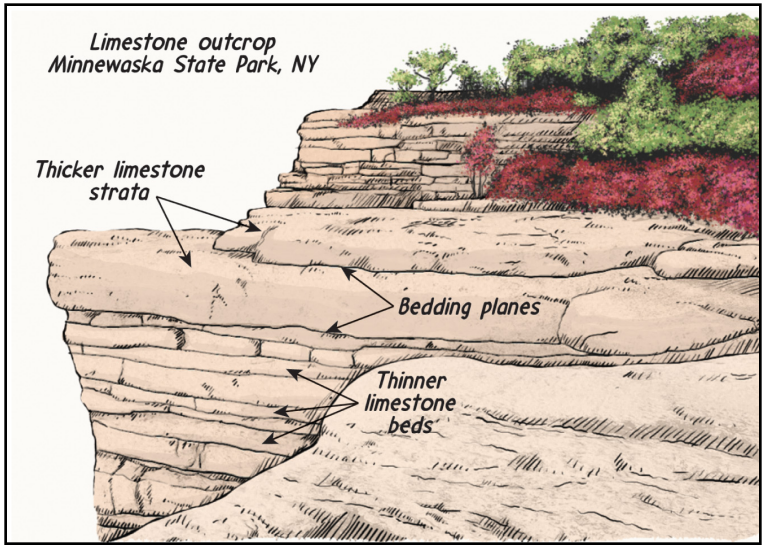
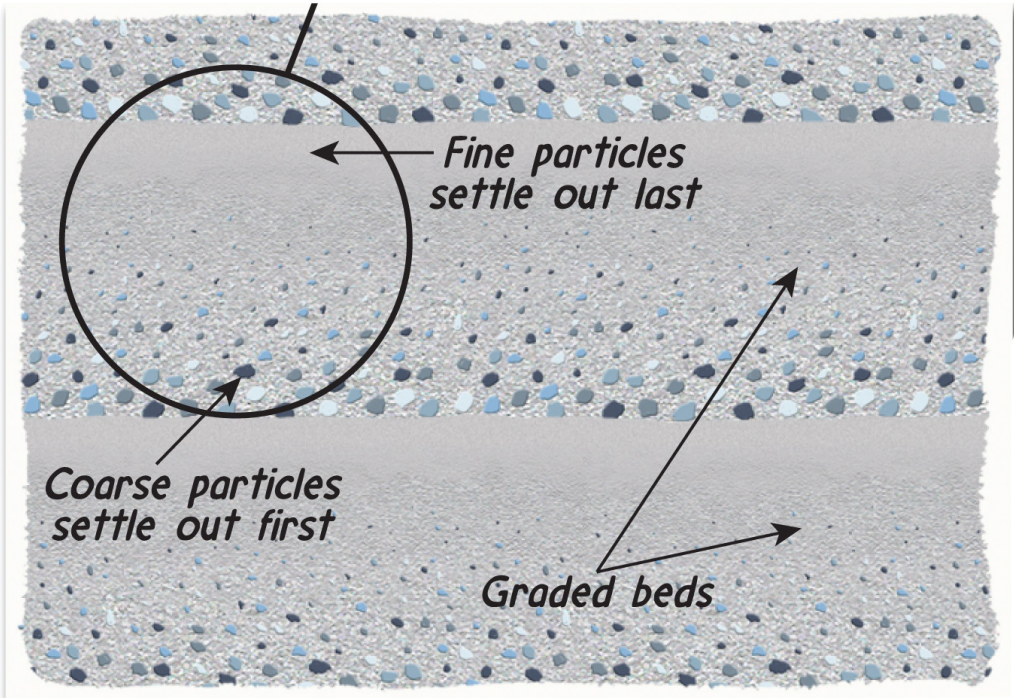
Sedimentary Structures

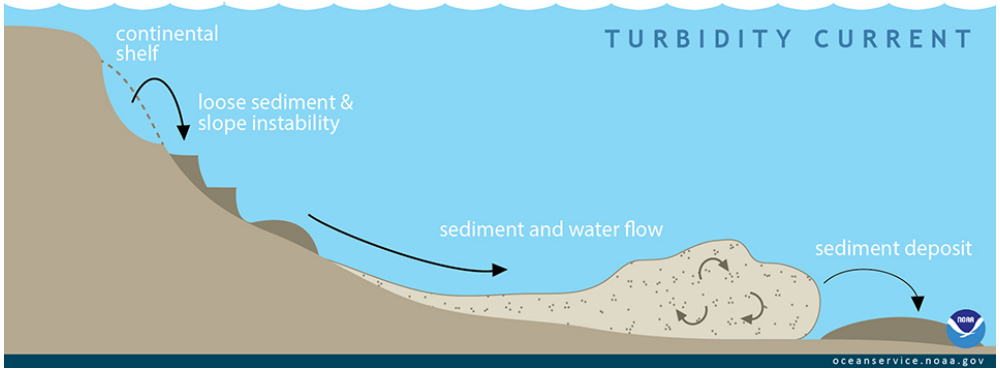
- **Provide information useful in the interpretation of Earth's history**
- **Types of sedimentary structures**
  - ***Strata*, or beds (most characteristic of sedimentary rocks, which form as layer upon layer of sediment accumulates in various depositional environments)**
  - ***Bedding planes* separate strata**



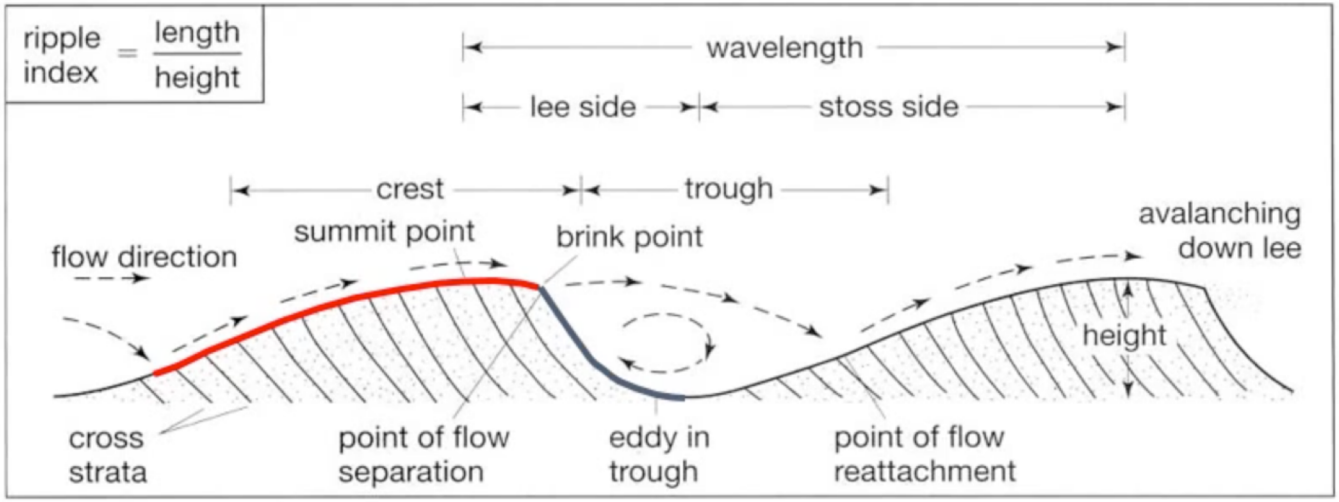
Sedimentary Structures

- **Types of sedimentary structures**
  - **Graded beds (characteristic of rapid deposition from water containing sediment of different sizes)**





Cross-bedding (characteristic of sand dunes, river deltas)



B.

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Flow Direction
Mode of grain transport

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Sedimentary Structures

- **Types of sedimentary structures**
  - **Ripple marks (small waves of sand developed on the surface of a sediment layer by the action of moving water or air)**

A.

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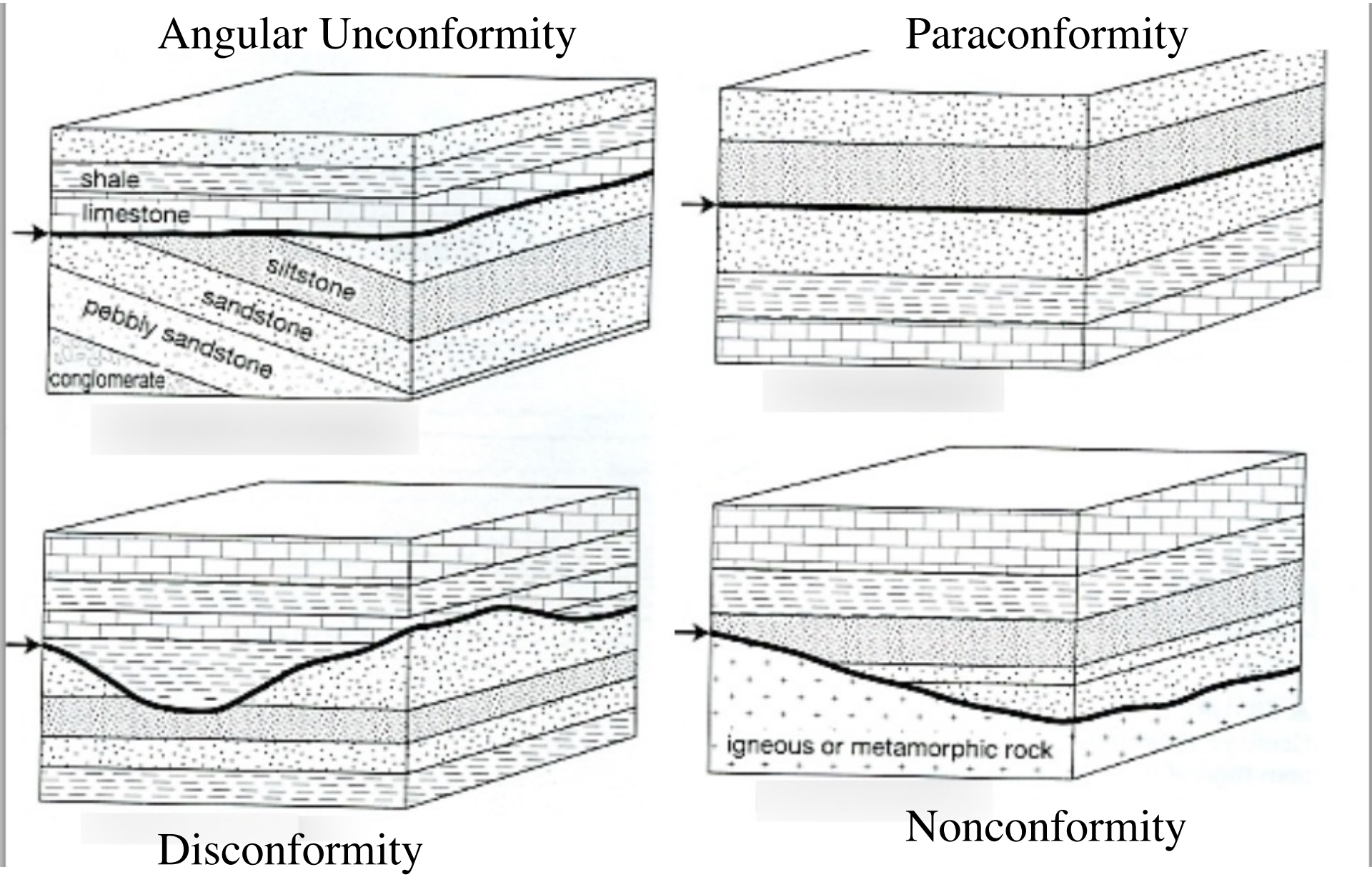
Unconformity



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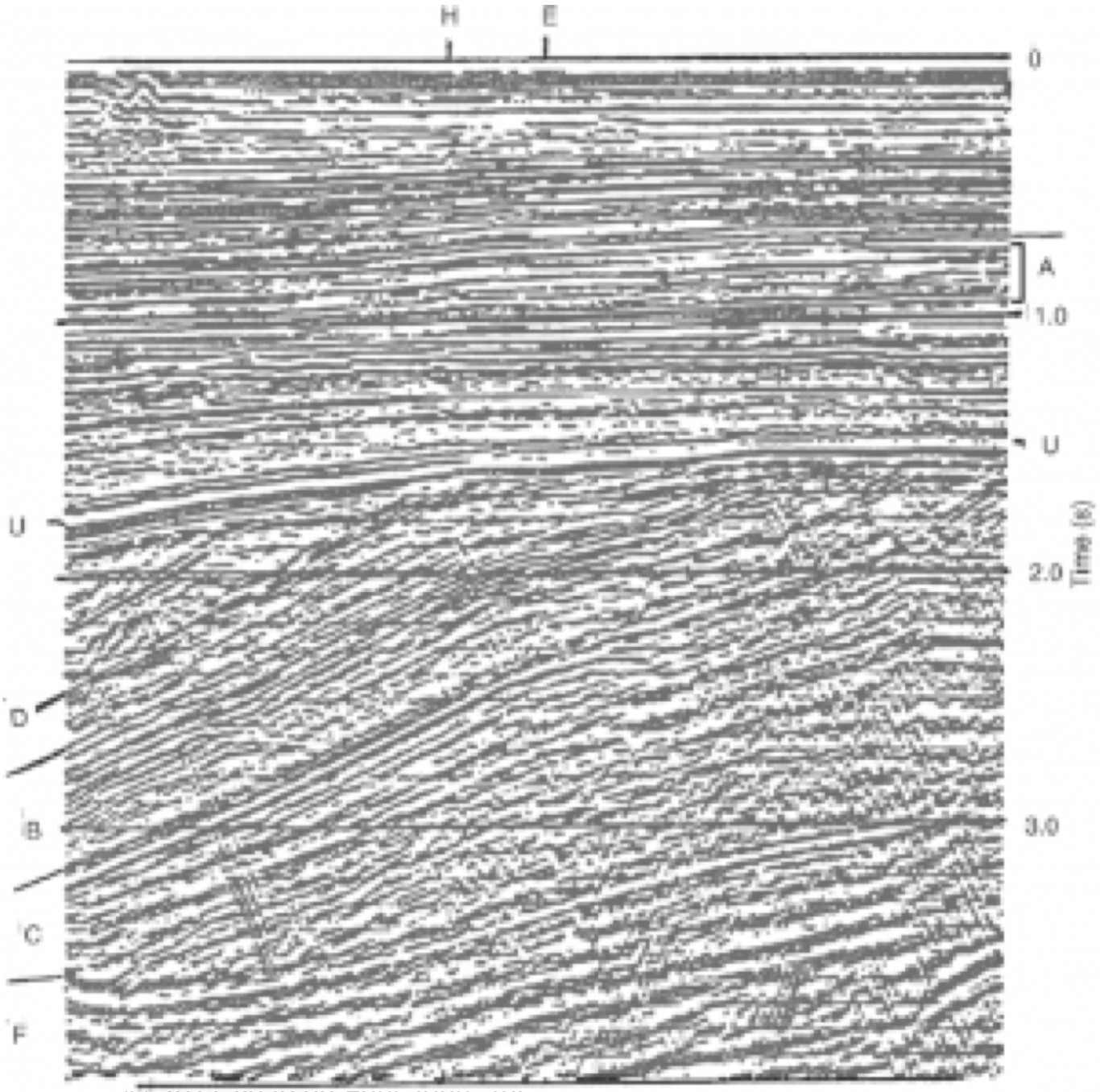
Example of angular unconformity



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Question

Q1: One of the labeled sedimentary layers in the photo is sandstone and the other is mostly shale. How can you determine which one is which just by looking at the photo?
Q2: How does such a geologic setup develop?
Q3:Is there any unconformity present?

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Question

INTERPRET THEM

Identify and describe each of the sedimentary structures shown here.