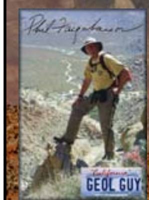
Sedimentary Rocks

Earth 12th Edition, Chapter 7



Chapter 7 – Sedimentary Rocks

Lithification -
glue particles together.
Was sand, now sandstone.

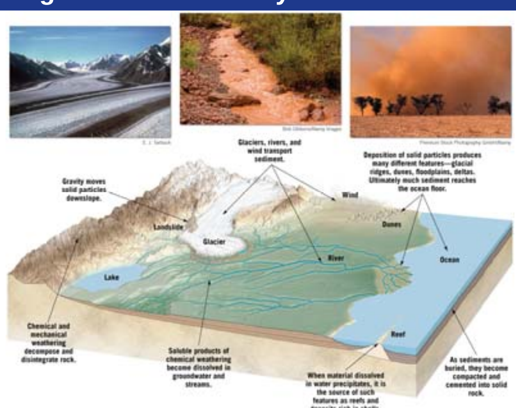
The Importance of Sedimentary Rocks

- Sediments and sedimentary rocks cover approximately 75% of land and virtually ALL of the ocean basins
- However, those only comprise about 5 percent (by volume) of Earth's outer 10 miles
- Those contain evidence of past environments
- Those contain important economic resources
  - Coal, oil, and other fossil fuels
  - Uranium, iron, aluminum, manganese, phosphate
  - Groundwater resources

Origins of Sedimentary Rock

- **Sedimentary rocks** are products of mechanical and chemical weathering
  - Sediments and soluble constituents are typically transported downslope by gravity (*mass wasting*)
  - The sediments are then deposited and subsequently buried
  - As deposition continues, the sediments are lithified into sedimentary rocks
- There are three types of sedimentary rocks:
  - **Detrital**, **chemical**, and **organic sedimentary rocks**

Origins of Sedimentary Rock



Detrital Sedimentary Rocks

- **Detrital sedimentary rocks** form from sediments that have been weathered and transported
  - Chief constituents of detrital rocks include clay minerals, quartz, feldspars, and micas
  - Particle size is used to distinguish among the various rock types
    - It also presents important information about the environment of deposition
  - Common detrital sedimentary rocks include
    - Shale, sandstone, conglomerate, and breccia

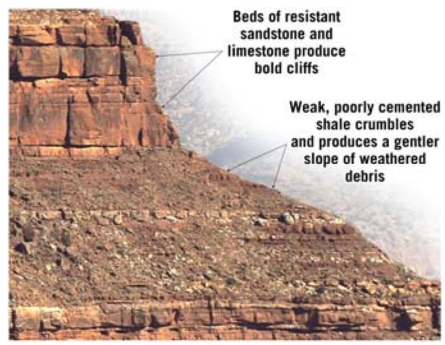
Particle Size Categories

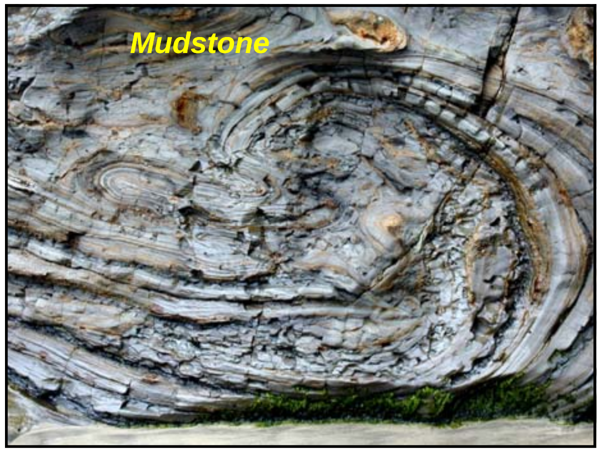
Detrital Sedimentary Rocks

- **Shale**
  - Silt- and clay-sized (fine-grained) particles
  - Form from gradual settling of sediments in quiet, non-turbulent environments (e.g., lakes, floodplains, deep ocean basins)
  - Sediments form in thin layers that are called laminae
  - Has **fissility** (meaning the rock can be split into thin layers)
  - Crumbles easily and tends to form gentle slopes
  - Most abundant sedimentary rock

Shale

Shale



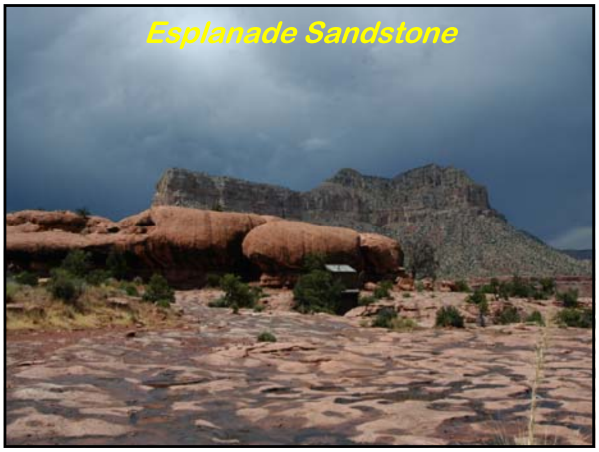


Detrital Sedimentary Rocks

- **Sandstone**
  - Sand-sized particles
  - Forms in a variety of environments
  - Second most abundant sedimentary rock
  - Quartz is the most abundant mineral
    - Quartz sandstone is predominately composed of quartz
    - Arkose sandstone contains appreciable quantities of feldspar
    - Graywacke contains rock fragments and matrix, in addition to quartz and sandstone

Quartz Sandstone

Esplanade Sandstone

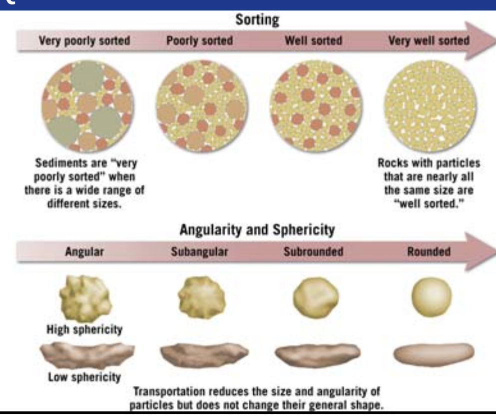


Esplanade Sandstone

Detrital Sedimentary Rocks

- Sandstone (continued)
  - Particles are classified by sorting and shape
    - **Sorting** is the degree of similarity in particle size
      - If all the grains in a rock are of similar size, the rock is well sorted
      - If the grains in a rock are different sizes (both large and small grains), the rock is poorly sorted
      - Sorting can help decipher the depositional environment of the rock
    - **Particle shape** varies from rounded to angular
      - The degree of rounding is indicative of how far the sediments have been transported
      - Rounded sediments are typically transported to great distances
      - Angular sediments are only transported a short distance

Quartz Sandstone



Quartz Sandstone

A. The orange and yellow cliffs of Utah's Zion National Park expose thousands of feet of Jurassic-age Navajo Sandstone.

B. The quartz grains composing the Navajo Sandstone were deposited by wind as dunes similar to these in Colorado's Great Sand Dunes National Park. The sand is well sorted because all of the particles are practically the same size.

Detrital Sedimentary Rocks

- **Conglomerate** and **Breccia**
  - Conglomerate consists of rounded, gravel-sized sediments
  - Breccia consists of angular, gravel-sized sediments
  - Both types of rocks are usually poorly sorted

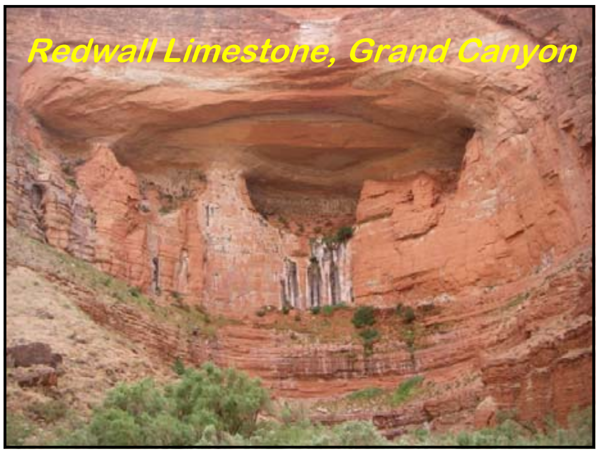
Conglomerate and Breccia

Chemical Sedimentary Rocks

- **Chemical sedimentary rocks** form from precipitated material that was once in solution
  - Precipitation of material occurs by:
    - Inorganic processes: evaporation or chemical activity
    - Organic processes from water-dwelling organisms form **biochemical** sedimentary rocks
  - Chemical sedimentary rocks include:
    - Limestone, chert, rock salt

Chemical Sedimentary Rocks

- **Limestone**
  - Most abundant chemical sedimentary rock
  - Mainly composed of the mineral calcite
  - Can form from inorganic and biochemical origins
  - Has economic value



Chemical Sedimentary Rocks

- Limestone (continued)
  - **Biochemical limestone** originates from the shells of marine organisms
    - Large quantities of marine limestone are formed from corals
      - Corals secrete a calcium carbonate skeleton and create reefs
        - » Australia's Great Barrier Reef is the largest coral reef on Earth
    - *Coquina* is composed of cemented fragments of shell material
    - *Chalk* is composed of the hard parts of microscopic marine organisms

Biochemical Limestone

coquina

Biochemical Limestone

Aerial view showing a small portion of Australia's Great Barrier Reef. Located off the coast of Queensland, it extends for 2600 kilometers and consists of more than 2900 individual reefs.

Biochemical Limestone

View of a group of plankton called *coccolithophores* from a scanning electron microscope. Individual plates shaped like hubcaps are only three one-thousandths of a millimeter in diameter; so tiny they could pass through the eye of a needle.

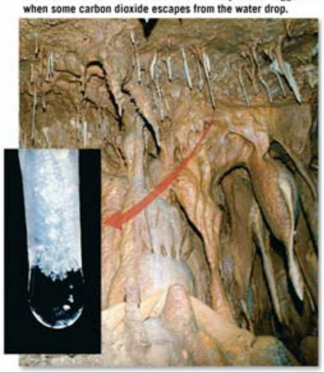
Chalk – Dover, England

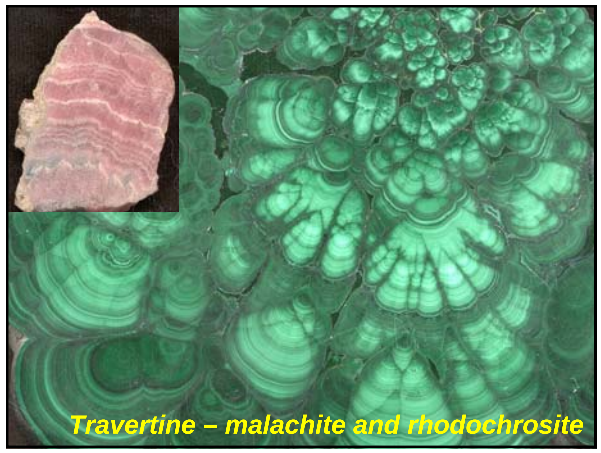
Chemical Sedimentary Rocks

- Inorganic Limestone
  - **Inorganic limestone** forms when chemical changes increase the calcium carbonate content of the water until it precipitates
    - *Travertine* is a type of limestone found in caves
      - Is precipitated when the water in the cave loses carbon dioxide
    - *Oolitic limestone* is composed of small spherical grains called ooids
      - *Ooids* form as tiny "seeds" roll in shallow marine water supersaturated with calcium carbonate

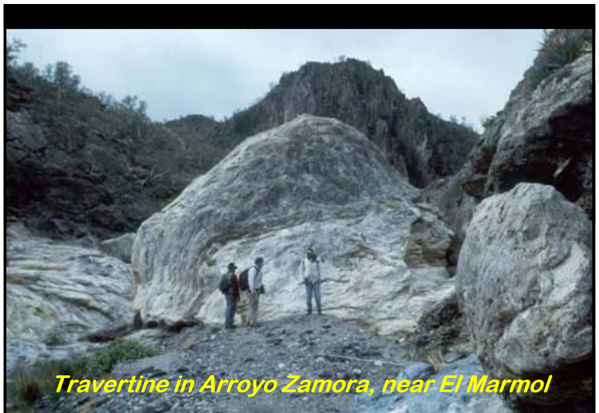
Inorganic Limestone

Delicate calcite crystals forming in a drop of water at the tip of soda straw stalactite. The formation of crystals is triggered when some carbon dioxide escapes from the water drop.





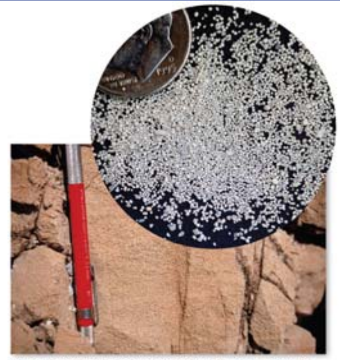
Travertine – malachite and rhodochrosite



Travertine in Arroyo Zamora, near El Marmol

Travertine in Elves' Chasm, GCNP

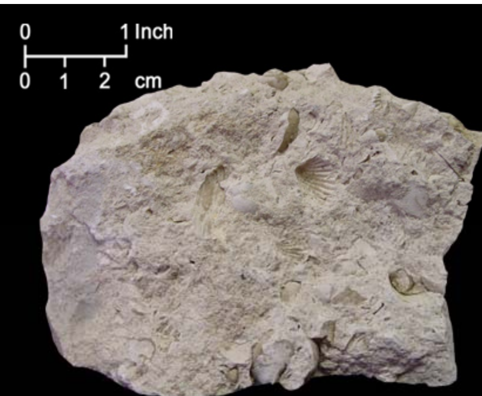
Inorganic Limestone



Small spherical grains called *ooids* are formed by chemical precipitation of calcium carbonate around a tiny nucleus and are the raw material for oolitic limestone.

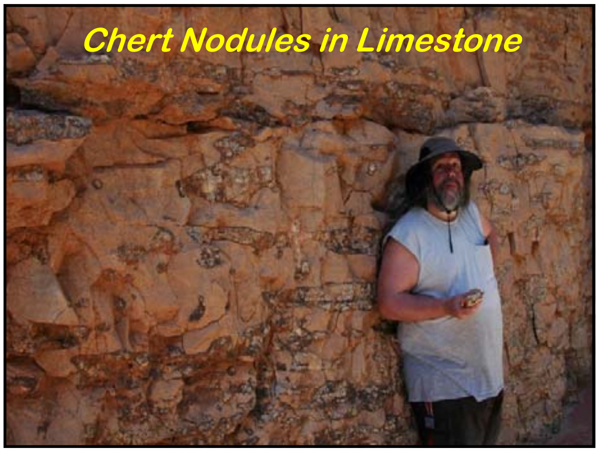
Chemical Sedimentary Rocks

- **Dolostone**
  - Similar to limestone but contains magnesium
  - Origin of dolostone is unclear
    - Significant quantities of dolostone are created when magnesium-rich waters circulate through limestone
- **Chert**
  - Composed of microcrystalline quartz
  - Forms when dissolved silica precipitates
    - Flint, jasper, and agate are varieties of chert

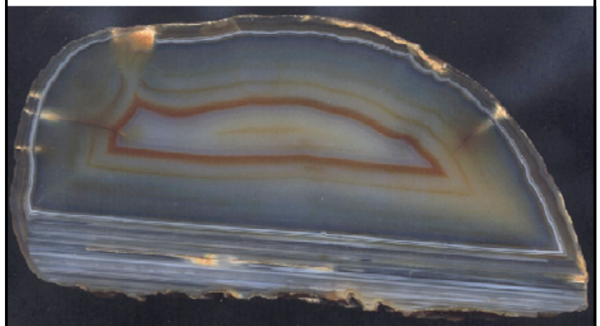


dolostone

Chert



Chert (agate)



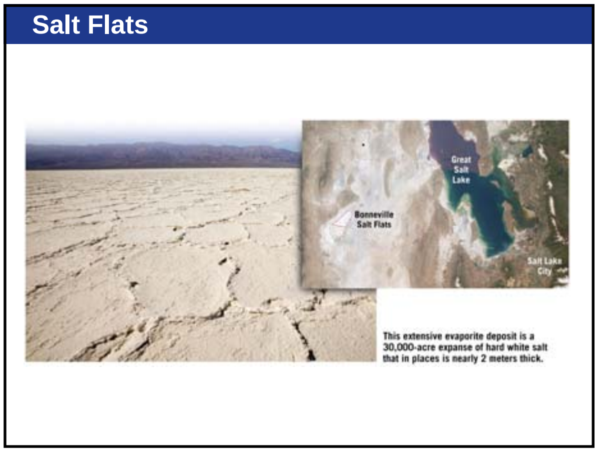
Chert (agate)

Chert ("coprolite")

Chemical Sedimentary Rocks

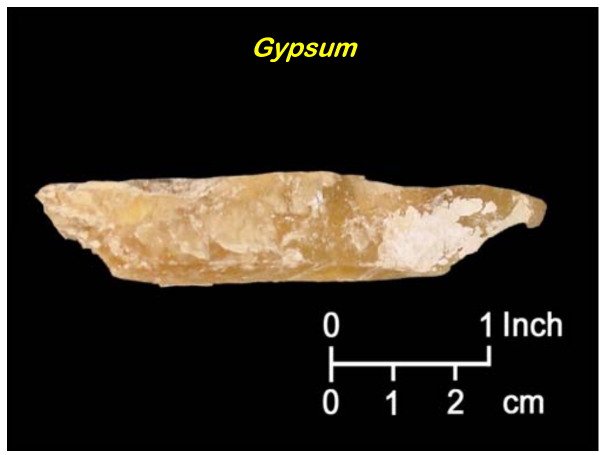
- **Evaporites**
  - Form when restricted seaways become over-saturated and salt deposition starts
  - *Rock salt* and *rock gypsum* are two common evaporites
  - Occasionally, evaporites form on **salt flats** when dissolved materials are precipitated as a white crust on the ground

Salt Flats


Salt Flats
Great Salt Lake
Bonneville Salt Flats
Salt Lake City
This extensive evaporite deposit is a 30,000-acre expanse of hard white salt that in places is nearly 2 meters thick.


Rock salt (halite)


Halite "soda straws***" in the Grand Canyon
*** hollow stalactites of NaCl !!!


Gypsum
0
1 Inch
0
1
2
cm


Gypsum


Fish Creek Gypsum Mine
gypsum is hauled by rail to Plaster City
(for what, you ask?)

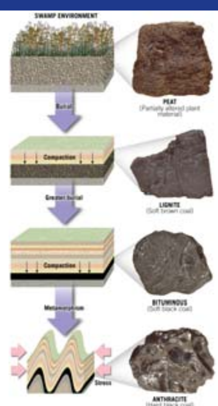
Coal: An Organic Sedimentary Rocks

- **Coal** is different from other sedimentary rocks
- Organic sedimentary rocks form from the carbon-rich remains of organisms
- Occasionally, plant structures (leaves, bark, and wood) are identifiable in coal

Coal: An Organic Sedimentary Rocks

- Four stages of Coal Formation
  1. **Accumulation of plant remains**
  2. **Formation of peat and lignite**
  3. **Formation of bituminous coal**
  4. **Formation of anthracite coal**

From Plants to Coal



Coal depositional environment ?

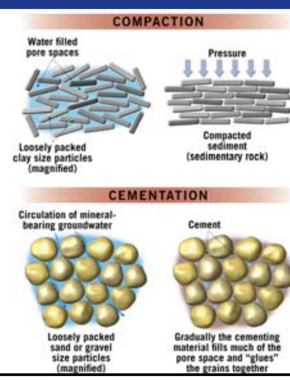
Turning Sediments into Sedimentary Rock: Diagenesis and Lithification

- 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
    - Examples:
      - *Recrystallization* of more stable minerals from lass stable ones (e.g., aragonite to calcite)
      - Formation of coal

Turning Sediments into Sedimentary Rock: Diagenesis and Lithification

- Many changes occur to sediment after it is deposited
  - **Lithification**—unconsolidated sediments are transformed into solid sedimentary rocks
    - **Compaction**—as sediments are buried, the weight of the overlying material compresses the deeper sediments
    - **Cementation**—involves the crystallization of minerals among the individual sediment grains

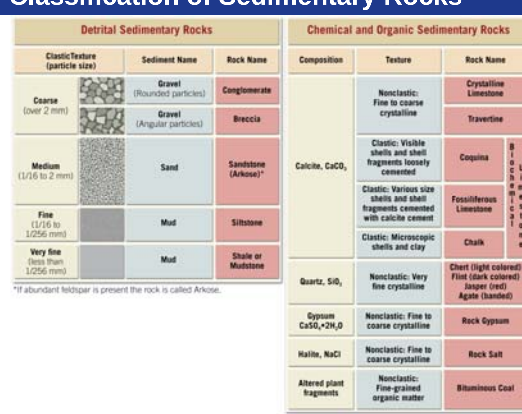
Turning Sediments into Sedimentary Rock: Diagenesis and Lithification



Classification of Sedimentary Rocks

- Sedimentary rocks are classified according to the type and texture of material
  - Two major groups:
    - Detrital
      - Has **clastic** texture
      - Composed of discrete fragments cemented together
    - Chemical/organic
      - Has **nonclastic** or **crystalline** texture
      - The minerals form patterns of interlocked crystals

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	Sandstone (Arkose)*
Fine (1/16 to 1/256 mm)	Mud	Siltstone
Very fine (less than 1/256 mm)	Mud	Shale or Mudstone

*If abundant feldspar is present the rock is called Arkose.

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) Jasper (red) Agate (banded)	
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	

Classification of Sedimentary Rocks

Sedimentary Rocks Represent Past Environments

- An **environment of deposition** or a **sedimentary environment** is a geographic setting where sediment is accumulating
  - Sites are characterized by particular combinations of geologic processes and environmental conditions
- Determines the nature of the sediments that accumulate (grain size, grain shape, etc.)
  - Three broad categories of sedimentary environments
    - Continental
    - Marine
    - Transitional

Sedimentary Rocks Represent Past Environments

- **Continental Environments**
  - Dominated by stream erosion and deposition
    - Streams are the dominant agent of landscape alteration
  - Glacial
    - Deposits are typically unsorted mixtures of sediments that range from clay to boulder-sized
  - Wind (eolian)
    - Well-sorted, fine sediments

Sedimentary Rocks Represent Past Environments

- **Marine Environments**
  - *Shallow marine* (to about 200 m)
    - Borders the world's continents
    - Receives huge quantities of terrestrial sediments
    - Warm seas with minimal terrestrial sediments have carbonate-rich muds and debris from coral reefs
  - *Deep marine* (seaward of continental shelves)
    - Primarily fine sediments that accumulate on the ocean floor
    - Turbidity currents—submarine landslides—are the exception

Sedimentary Rocks Represent Past Environments

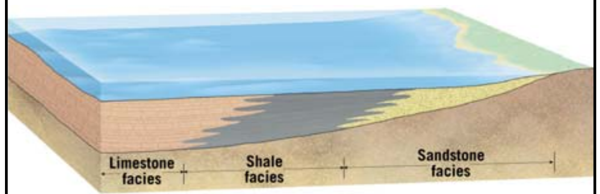
- **Transitional Environments**
  - The shoreline is the transition zone between marine and continental environments
    - Examples include:
      - *Beaches*
      - *Tidal flats*
      - *Spits, bars, and barrier islands*
      - *Lagoons*
      - *Deltas*

Sedimentary Environments

Sedimentary Rocks Represent Past Environments

- Sedimentary Facies
  - Different sediments often accumulate in adjacent environments
    - For example, when sand is depositing on a beach, mud is being deposited offshore
  - Changes in past environments can be seen when a single layer of sedimentary rock is traced laterally
    - Each unit (**facies**) possesses a distinctive set of characteristics reflecting the conditions of a particular environment
    - Transitions between different facies are gradual

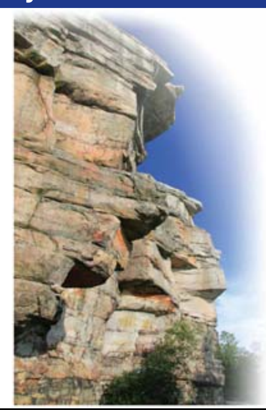
Sedimentary Facies



Sedimentary Structures

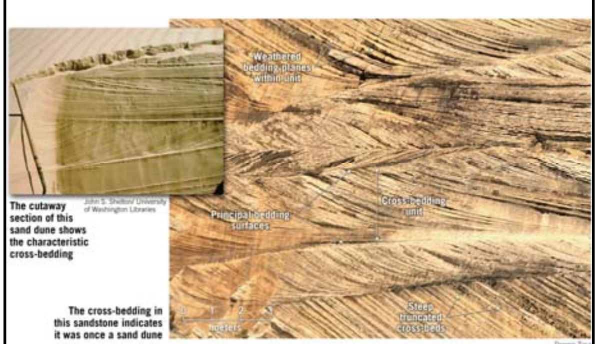
- When present, they provide additional information for interpreting Earth's history
- Types of sedimentary structures
  - The layers of the sedimentary rocks are called **strata** or **beds**
    - Single most common and characteristic feature of sedimentary rocks
  - **Bedding planes** separate strata
  - **Cross-bedding** occurs when the layers in the sedimentary rocks are inclined
    - Characteristic of sand dunes, deltas, and some stream deposits

Sedimentary Strata



Strata, or beds

Sedimentary Strata

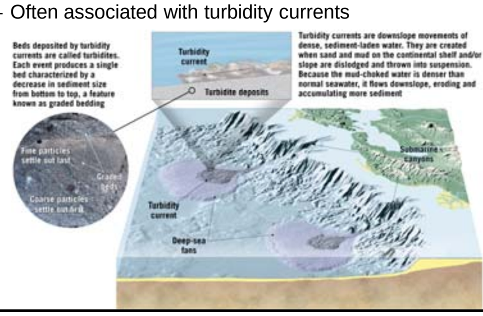


The cutaway section of this sand dune shows the characteristic cross-bedding

The cross-bedding in this sandstone indicates it was once a sand dune

Sedimentary Structures

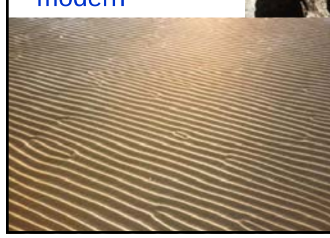
- **Graded beds** are a unique situation where the sediments in a strata gradually change from coarse at the bottom to fine at the top
  - Often associated with turbidity currents



Sedimentary Structures

- **Ripple marks** are small waves that are lithified in the sedimentary rocks
- **Mud cracks** indicate sediments form in an alternatively wet and dry environment
- **Fossils** are the remains of prehistoric life

Ripple marks



modern

ancient

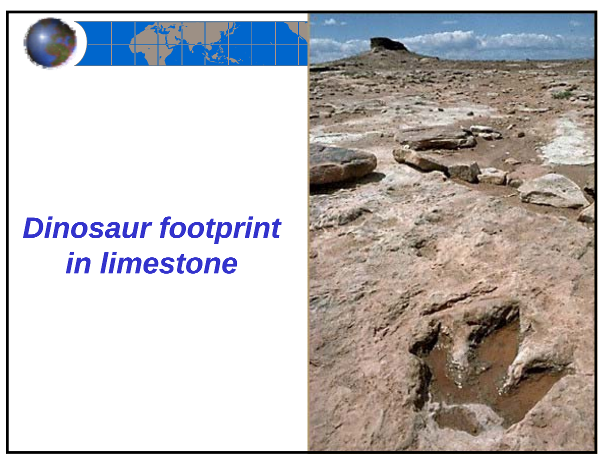

Mud cracks (modern)


Mud cracks (ancient)


Natural casts of shelled invertebrates


Natural casts of shelled invertebrates


Dinosaur footprint in limestone


Dinosaur footprint
in limestone

More trace fossils

The Carbon Cycle and Sedimentary Rocks

- CO_2 moving from the atmosphere to the biosphere and back again is one of the most active parts of the carbon cycle
  - Plants absorb CO_2 through photosynthesis
  - When plants die, some CO_2 is deposited in sediments
    - *Over geologic time*, a small amount of CO_2 is deposited as sediment—but considerable amounts of plant biomass is **converted into fossil fuels**
    - When fossil fuels are burned, the CO_2 is released back into the atmosphere
    - Volcanoes also release CO_2
  - Limestone is Earth's largest repository of carbon

The Carbon Cycle and Sedimentary Rocks