Chapter 5
The Sedimentary Archives
Factors affecting Sedimentary Characteristics

1. Tectonic setting
2. Physical, chemical, and biological processes in the depositional environment
3. Method of sediment transport
4. Rocks in the source area from which the sediment is derived
5. Climate (and its effect on weathering)
6. Post-depositional processes of lithification (cementation, compaction)
7. Time
Tectonics

The forces controlling deformation or structural behavior of a large area of the Earth's crust over a long period of time.

- **Tectonically stable** - midwestern U.S.
- **Subsiding** (sinking) - New Orleans or Mexico City
- **Rising gently** - New England and parts of Canada after glacial retreat
- **Rising actively** to produce mountains and plateaus - parts of Oregon in the Cascade mountains
Principle tectonic elements of a continent

- **Craton**
  - Shield
  - Platform
- **Orogenic belt**
Principle tectonic elements of a continent – the craton

- **Craton** – the stable interior of a continent.
  - **Shields** - Large areas of exposed crystalline rocks.
  - **Platforms** - Ancient crystalline rocks covered by flat-lying or gently warped sedimentary rocks.
Principle tectonic elements of a continent

- **Orogenic belts** - Elongated regions bordering the craton which have been deformed by compression since Precambrian. Orogenic belts are mountain belts.
Depositional Environments

All of the physical, chemical, biological and geographic conditions under which sediments are deposited.

By comparing modern sedimentary deposits with ancient sedimentary rocks, the depositional conditions can be interpreted.
Depositional Environments

Sediments and sedimentary rocks may be:

• **Extrabasinal** in origin - formed from the weathering of pre-existing rocks outside the basin, and transported to the environment of deposition.

• **Intrabasinal** in origin - formed inside the basin; includes chemical precipitates, most carbonate rocks, and coal.
Depositional Environments

There are three broad categories of depositional environments:

- **Marine** environments (ocean)
- **Transitional** environments (along contact between ocean and land)
- **Continental** environments (on land)
Depositional Environments
Marine Depositional Environments

1. Continental shelf
2. Continental slope
3. Continental rise
4. Abyssal plain
Continental Shelf

The flooded edge of the continent. Flooding occurred when the glaciers melted about 10,000 years ago.

a. Relatively flat (slope < 0.1°)

b. Shallow water (less than 200 m deep)

c. May be up to 300 km wide (averages 80 km wide)

d. Exposed to waves, tides, and currents
e. Covered by sand, silt, and clay
f. Larger sedimentary grains are deposited closer to shore.
g. Locally cut by submarine canyons (eroded by rivers during Ice Age low sea level stand)
h. Coral reefs and carbonate sediments may accumulate in tropical areas
Continental Slope

The steeper slope at edge of the continent.

a. Located seaward of the continental shelf
b. Boundary between continental and oceanic crust
c. May be about 20 km wide
d. Deeper water
e. More steeply inclined (3 - 6°)
f. Rapid sediment transport down the slope by dense, muddy turbidity currents
g. Passes seaward into the continental rise
Continental Rise

At the base of the continental slope.

a. More gradual slope
b. May be hundreds of km wide
c. Water depths of 1400 to 3200 m
d. Submarine fans form off submarine canyons
e. Turbidity currents transport sediment downslope from continental shelf (turbidites)
f. Passes seaward into the abyssal plain
Deep Marine Realm

The deep ocean floor.

a. Nearly flat

b. Water depths of 3 to 5 km + (2 - 3 miles +)

c. Covered by very fine-grained sediment and shells of microscopic organisms
   - Clay
   - Volcanic ash
   - Foraminifera (calcareous)
   - Radiolarians (siliceous)
   - Diatoms (siliceous)
Transitional Depositional Environments

Environments at or near the transition between the land and the sea.

1. Deltas
2. Beaches and barrier Islands
3. Lagoons
4. Tidal flats
5. Estuaries
Deltas

a. Fan-shaped accumulations of sediment
b. Formed where a river flows into a standing body of water, such as a lake or the sea
c. Coarser sediment (sand) tends to be deposited near the mouth of the river; finer sediment is carried seaward and deposited in deeper water.
d. The delta builds seaward (or progrades) as sediment is deposited at the river mouth.
Deltas

Mississippi River delta

Niger River delta
Beaches and Barrier Islands

a. Shoreline deposits
b. Exposed to wave energy
c. Dominated by sand
Beaches and Barrier Islands

d. Marine fauna

e. A few km or less in width but may be more than 100 km long

f. Separated from the mainland by a lagoon (or salt marsh)

g. May be associated with tidal flat deposits
Lagoons

a. Bodies of water on the landward side of barrier islands
b. Protected from the pounding of the ocean waves by barrier islands
c. Contain finer sediment than the beaches (usually silt and clay)
d. Lagoons are also present behind reefs, or in the center of atolls.
Tidal flats

a. Nearly flat, low relief areas that border lagoons, shorelines, and estuaries
b. Periodically flooded and exposed by tides (usually twice each day)
c. May be cut by meandering tidal channels
d. May be marshy, muddy, sandy or mixed sediment types (terrigenous or carbonate)
e. Laminations and ripples are common
f. Sediments are intensely burrowed
g. Stromatolites may be present (if conditions are appropriate)
Estuaries

a. Mouth of a river drowned by the sea
b. Brackish water (mixture of fresh and salt)
c. May trap large volumes of sediment
d. Sand, silt, and clay may be deposited depending on energy level
e. Many estuaries formed due to sea level rise as glaciers melted at end of last Ice Age
f. Some formed due to tectonic subsidence, allowing sea water to migrate upstream
Continental Environments

1. Rivers or fluvial environments
2. Alluvial fans
3. Lakes (or lacustrine environments)
4. Glacial environments
5. Eolian environments
Fluvial Environments

a. Braided and meandering river and stream systems
b. River channels, bars, levees, and floodplains are subenvironments

c. Channel deposits are coarse, rounded gravel, and sand.

d. Bars are sand or gravel.

e. Levees are fine sand or silt.

f. Floodplains are covered by silt and clay.
Alluvial Fans

a. Fan-shaped deposits at base of mountains.
b. Most common in arid and semi-arid regions with rapid erosion.
c. Sediment is coarse, poorly- sorted gravel and sand.
Lacustrine Environments (Lakes)

a. May be large or small
b. May be shallow or deep
c. Filled with terrigenous, carbonate, or evaporitic sediments
d. Sediments are typically fine grained but may be coarse near the edges
e. Fine sediment and organic matter settling in some lakes produced laminated oil shales
f. **Playa lakes** are shallow, temporary lakes that form in arid regions. They periodically dry up as a result of evaporation
Glacial Environments

a. Sediment is eroded, transported, and deposited by ice (glaciers)

b. Glacial deposits called **till** contain large volumes of unsorted mixtures of boulders, gravel, sand and clay
Eolian Environments

a. **Wind** is the agent of sediment transport and deposition

b. Dominated by sand and silt

c. Common in many desert regions
Color of Sedimentary Rocks

- **Black** and dark gray coloration in sedimentary rocks generally indicates the presence of *organic carbon* and/or iron.
- Organic carbon in sedimentary requires **anoxic** environmental conditions.
Color of Sedimentary Rocks

- **Red** coloration in sedimentary rocks indicates the presence of iron oxides.
- Red beds typically indicate deposition in well-oxygenated continental sedimentary environments. May also be transitional or marine.
- **Green and gray** coloration in sedimentary rocks indicates the presence of iron, but in a reduced (rather than an oxidized) state.
- Ferrous iron (Fe$^{+2}$) generally occurs in oxygen-deficient environments.
Textural Interpretation of Clastic Sedimentary Rocks

**Texture** = size, shape, sorting, and arrangement of grains in a sedimentary rock.

The texture of a sedimentary rock can provide clues to the depositional environment.

- Fine-grained textures typically indicate deposition in quiet water.
- In general, it takes higher energy to transport larger grains.
Three "textural components" to most clastic sedimentary rocks:

1. **Clasts** - the larger grains in the rock (gravel, sand, silt)
2. **Matrix** - the fine-grained material surrounding clasts (often clay)
3. **Cement** - the "glue" that holds the rocks together
   a. Silica (quartz, SiO2)
   b. Calcite (CaCO3)
   c. Iron oxide
   d. Other minerals
Grain Size

Sedimentary grains are categorized according to size using the **Wentworth Scale**.

<table>
<thead>
<tr>
<th>Grain Size</th>
<th>Size Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>&gt; 2 mm</td>
</tr>
<tr>
<td>Sand</td>
<td>1/16 - 2 mm</td>
</tr>
<tr>
<td>Silt</td>
<td>1/256 - 1/16 mm</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt; 1/256 mm</td>
</tr>
</tbody>
</table>
Sorting refers to the distribution of grain sizes in a rock.
The range of grain sizes in a sedimentary rock can provide clues to help interpret the depositional environment.
For example, turbulence from waves will winnow out finer grain sizes such as silt and clay, leaving sands on the beach.
Sorting

• If all of the grains are the same size, the rock is "well sorted."

• If there is a mixture of grain sizes, such as sand and clay, or gravel and sand, the rock is "poorly sorted."
Sorting

Well-sorted sands tend to have higher porosity and permeability than poorly-sorted sands (if they are not tightly cemented), and may be good reservoirs for petroleum and natural gas, or good aquifers.

Poor sorting is the result of rapid deposition of sediment without sorting by currents. Examples of poorly-sorted sediment include alluvial fan deposits and glacial till.
Grain Shape

Grain shape is described in terms of **rounding** of grain edges and **sphericity** (equal dimensions, or how close it is to a sphere).
Rounding

- Rounding results from **abrasion** against other particles and grain impact during transport.
- Very well rounded sand grains suggest that a sand may have been recycled from older sandstones.
Sedimentary Structures

Some sedimentary structures are created by the water or wind which moves the sediment. Other sedimentary structures form after deposition - such as footprints, worm trails, or mudcracks.

Sedimentary structures can provide information about the environmental conditions under which the sediment was deposited.

Some structures form in quiet water under low energy conditions, whereas others form in moving water or high energy conditions.
Sedimentary Structures

**Stratification** (= layering or *bedding*) is the most obvious feature of sedimentary rocks. The layers (or beds or strata) are visible because of differences in the color, texture, or composition of adjacent beds.
Graded Bedding

The grain size in a graded bed is coarser at the bottom and finer at the top.

Graded bedding results when a sediment-laden current (such as a turbidity current) begins to slow down.
Cross-bedding or cross-stratification

An arrangement of beds or laminations in which one set of layers is inclined relative to the others.
Ripple marks

Undulations of the sediment surface produced as wind or water moves across sand. 
Symmetric ripple marks are produced by waves.
Ripple marks

Asymmetric ripples form in unidirectional currents (such as in streams or rivers).
Mud cracks

A polygonal pattern of cracks produced on the surface of mud as it dries.

Modern mudcracks

Fossil mudcracks
Determining "up direction"

Rocks can be overturned by tectonic forces. Examine sedimentary structures to determine "up direction."

- Graded beds
- Cross beds
- Mudcracks
- Scour marks

- Symmetrical ripples
- Stromatolites
- Burrows
- Tracks