Chapter 3 Notes

Chapter 5

Sedimentary Environments

A. The Tectonic Setting

1. Factors that determine the kind of sedimentary rock that will be formed in a particular area:
   a. the climate under which processes of weathering and erosion take place
   b. the method of transport of sedimentary materials
   c. the physical, chemical, and biological processes operating in the place of deposition
   d. changes that occur to sediment as it is being converted to solid rock
   e. the characteristics of the entire assemblage of rocks is also influenced by the tectonics of the region in which deposition takes place

2. Tectonics:
   a. the study of the deformation or structural behavior of a large area of the Earth’s crust over a long period of time.

3. Tectonic setting influences:
   a. the size of clastic particles being carried to sites of deposition
   b. the thickness of the accumulation deposit

4. The type of tectonic setting often can be inferred from a rock's textural and structural features and from its color, composition, and fossils.

B. Environments of Deposition

Environment of deposition are where sediments are deposited. Characterized by geographic and climatic conditions that modify or determine the properties of sediment that is deposited within it.

1. Continental
   a. river floodplains: deposits of elongate lenses oriented downstream and grade abruptly in sediment size consisting of sand, silt and clay
      1. Braided stream - high sediment load - coming out of mountains.
      2. Meandering - lower sediment loads - mature stream or river in coastal plain.
   b. alluvial fan: an accumulation of stream-transported materials when a rapidly flowing river emerges from a mountainous areas onto a flat plain
   c. lakes: ideal sediment traps composed of silt and clay
      • sediment deposited depends upon water depth, climate, and the character of the surrounding land areas
      • playa lakes: shallow temporary lakes that occur in arid regions
   d. glaciers: most dramatic environments of deposition
      • Tills have the ability to transport and deposit huge volumes and large fragments of rock detritus
      • deposits are characteristically unsorted mixtures of boulders, gravel, sand, and clay
      • when reworked by glacial meltwater deposits and resemble stream deposits
   e. eolian environments: environments where wind is an important agent of sediment transport and deposition. Deserts and Sand dunes
      • characterized by an abundance of sand and silt, little plant cover, and strong winds typical of desert regions
   f. transitional shoreline of a continent: transitional zone between marine and nonmarine environments
      • beaches, shoreline accumulations of sand or gravel
      • tidal flats: mud-covered areas that are alternately inundated and drained of water by tides
      • deltas: form when streams enter bodies of standing water, undergo an abrupt loss of velocity, and drop their load of sediment
      - grows seaward if shoreline currents and waves do not remove the deposits as quickly as they are supplied
      - progressively finer sediment will be deposited in progressively deeper or quieter water as the current provided by the stream diminished
- the stream channel is extended at the same time, branching out to form new branches of the delta
  • barrier islands: built parallel to shorelines by wave and current action
  • lagoons: often found between the mainland and a barrier island
  • swamps: frequent features of low-lying areas adjacent to the sea

2. Marine environments
   a. shallow corresponds to the oceanic topographic regions termed **continental shelves** are nearly flat, smooth surfaces that fringe the continents in widths that range from only a few kilometers to about 300 km, and depths that range from low tide to about 200 m
     • not part of the oceanic crust
     • smoothness produced by wave action during the last Ice Age
     • all of the sediment eroded from the continents are carried to the sea are ultimately cross the shelves or is deposited on them
     factors that influence the type of sediment deposited
     • nature of the source rock on adjacent land masses
     • elevation of source areas
     • presence of carbonate-secreting organisms
   b. slopes: correspond to the areas of the ocean floor that extend from the seaward edge of the continental shelves down to the ocean deeps termed **continental slopes** and **rises**
     surface inclination 3-6° ocean floor range from 1400-3200 meters sediment deposited are mostly fine sand, silt, and clay
     • turbidity currents: dense, suspended sediment laden water that deposits sediment away from the continent forming submarine fans at the base of the continental slope
   c. deep: corresponds to the oceanic topography regions far from the continents deposits are limited to only very fine clay, volcanic ash, and the calcareous or siliceous remains of microscopic organisms that have settled to the sea floor

C. Color of Sedimentary Rocks
Color is useful in providing clues to the environment of deposition of sedimentary rocks. Of the sedimentary coloring agents, carbon and the oxides and hydroxides of iron are the most important.

1. **Black** Coloration
   Results from the presence of compounds containing organic carbon and iron. Implies an abundance of organisms in or near the depositional areas as well as environmental circumstances that kept the remains of those organisms from being completely destroyed by oxidation or bacterial action
   • present in many marine, lake, and estuarine environments today
   • accumulation of the remains of organisms that lived near or in the depositional basin
   • lack of dissolved oxygen to break down organic matter and to provide oxygen to scavengers limiting organic decay
   • results in incompletely decomposed material rich in black carbon
   • iron combines with sulfur to form finely divided iron sulfide (pyrite, FeS2)
   • environment will also yield lethal doses of hydrogen sulfide (H2S) solutions to further poison the environment
   Do not always form in restricted basins.
   • may develop in relatively open areas where the rate of accumulation of organic matter exceeds the ability of the environment to cause its decomposition

2. Coloration
   Hues of **brown, red, and green** often occurs in sedimentary rocks as a result of their **iron oxide** content.
   • <0.1% iron can color a sediment a deep red
   • iron pigments are ubiquitous in sediments
     Often occurs as either ferrous or ferric iron compounds
   • **ferrous iron oxide** (FeO) frequently occurs in oxygen-deficient environments
• unstable, oxidizes to form ferric iron oxide (Fe2O3)
• lack of oxygen can change ferric iron into ferrous
• ferric minerals (hematite) tends to color the rock red, brown, or purple
• ferrous compounds impart hues of gray and green
• hydrous ferric oxide (limonite) is often yellow in color

3. Red Beds
Strata colored in shades of red brown, or purple by ferric iron
Oxidizing conditions are required
• nonmarine environments such as floodplain alluvial fan or deltaic deposits
• marine red beds originally reddish sediment may be carried into the open sea development
  after deposition from oxygen in underground water circulation Paleoenvironmental
  interpretations of red beds should be based to a large degree on the associated rocks and
  sedimentary structures
• red beds interspersed with evaporite layers indicate warm and arid conditions

D. Clastic Sedimentary Rocks
Texture
  the size shape and arrangement of mineral and rock grains
The textural appearance of a rock is also influenced by the materials that hold the particles
  together
1. Size and Sorting of Clastic Grains
Categorize clastic sediments by use of the Wentworth Scale a scale of particle sizes

<table>
<thead>
<tr>
<th>Wentworth Scale (mm)</th>
<th>Fractional Equivalents (mm)</th>
<th>Particle Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;256</td>
<td></td>
<td>Boulder</td>
</tr>
<tr>
<td>256 - 64</td>
<td></td>
<td>Cobble</td>
</tr>
<tr>
<td>64 - 4</td>
<td></td>
<td>Pebble</td>
</tr>
<tr>
<td>4 - 2</td>
<td></td>
<td>Granules</td>
</tr>
<tr>
<td>2 - 1.0</td>
<td></td>
<td>Very coarse sand</td>
</tr>
<tr>
<td>1.0 - 0.5</td>
<td></td>
<td>Coarse sand</td>
</tr>
<tr>
<td>0.5 - 0.25</td>
<td>1/2</td>
<td>Medium sand</td>
</tr>
<tr>
<td>0.25 - 0.125</td>
<td>1/4</td>
<td>Fine sand</td>
</tr>
<tr>
<td>0.125 - 0.0625</td>
<td>1/8</td>
<td>Very Fine sand</td>
</tr>
<tr>
<td>0.0625 - 0.0313</td>
<td>1/16</td>
<td></td>
</tr>
<tr>
<td>0.0313</td>
<td>1/32</td>
<td>Silt</td>
</tr>
<tr>
<td>0.0156</td>
<td>1/64</td>
<td></td>
</tr>
<tr>
<td>0.0078</td>
<td>1/128</td>
<td></td>
</tr>
<tr>
<td>0.0039</td>
<td>1/356</td>
<td>Clay</td>
</tr>
</tbody>
</table>

a. Size distribution of grains provides information of the turbulence and velocity of currents - Energy
  • can also be an indicator of the mode and extent of transportation
  • sand silt and clay particles supplied by a stream to a coastline will show a gradation from
    sandy nearshore deposits to offshore silty and clayey deposits
  • sandstones formed nearshore may retain considerable porosity and provide void space for
    petroleum accumulations
b. One aspect of a clastic rock’s texture that involves grain size is sorting
• an expression of the range of particle sizes deviating from the average size
• well-sorted: rocks composed of particles that are all about the same average size
• poorly-sorted, those rocks that include grains with a wide range of sizes
• provides clues to conditions of transportation and deposition
• wind winnows the dust particles from sand producing grains that are all of about the same size
• windblown deposits are better sorted than deposits formed in an area of wave action
• wave-washed sediments are better sorted than stream deposits
• if a source sediment is already well sorted the resulting deposit will be similarly well sorted
• poor sorting occurs when sediment is rapidly deposited without being selectively separated into size by currents
• poorly sorted conglomerates and sandstones are deposited at the foot of mountains when streams velocity is suddenly checked
• tillite: a poorly sorted conglomerate deposited by glacial ice

2. **Shape of Clastic Grains**
Useful in determining the history of a clastic sedimentary rock.
   a. **Rounding** of particle edges
      • becomes rounded by having sharp corners and edges removed by impact with other particles
      • heavy impacts occur between pebbles and granules being transported by water causing rapid rounding
      • lighter impacts occur between sand grains in water transport for slower rounding
   b. The roundness of a particle can be used to infer the history of abrasion
      • a reflection of the distance the particle has traveled, the transporting medium, and the rigor of transport
      • used as evidence for recycling of older sediments
   c. **Sphericity**
      • how closely the grain approaches the shape of a sphere

3. **Arrangement of Clastic Grains**
Third element in the definition of texture.
   a. Determination whether the grains are the same size and if they are clustered into zones or heterogeneously mixed.
      • help to determine whether the sediment had been winnowed and sorted by currents or had been dumped rapidly
      • controlling factors of grain orientation medium of transport surface of deposition direction and velocity of currents
      • study of grain orientation useful as a means of determining the current direction of the transporting medium
      • determination of the existence of preferred orientation
      • wind-blown sand is well developed than water-carried sands
      • beach sands orientations are mainly controlled by backwash so grains become aligned parallel to the shoreline
      • in stream-deposited sands grain orientation is usually parallel to the elongation of the sand body
      • in glacial sediment both elongate sand grains and pebbles show a longitudinal orientation parallel to the direction of ice movement
   b. Useful in determining sediment distributional patterns in the geologic past
      • occasionally provide important clues to the subsurface location and trend of petroleum-bearing sandstone strata

Inferences from Sedimentary Structures
Sedimentary structures are those larger features of sediments that formed during or shortly after deposition and before lithification.

1. Useful for reconstructing ancient environments
   a. **mud cracks** indicate drying after deposition
   b. **cross-bedding** is an arrangement of beds or lamination in which one set of layers is inclined relative to the others
      • formed by the advance of a delta or a dune
      • indicates wind or water currents
      • inclination of the beds is an indicator of the direction taken by the current
      • determine the pattern of prevailing winds at various times in the geologic past
   c. **graded bedding** consists of repeated beds each of which has the coarsest grains at the base and successively finer grains nearer the top
      • form as the result of faster settling of coarser, heavier grains in a sedimentary mix as characteristic of turbidity currents
      • often triggered by submarine earthquakes and landslides that occur along steeply sloping regions of the sea floor
      • the forward part to the turbidity current contains coarser debris than does the tail
      • frequently characterize unstable, tectonically active environments
   d. **ripple marks** are commonly seen sedimentary features that developed along the surfaces of bedding planes
      • symmetric ripple marks are formed by the oscillatory motion of water beneath waves
      • asymmetric ripple marks are formed by air or water currents and are useful in indicating the direction of movement of currents
      • occur most frequently in shallow water areas and in streams