Chapter 5 - Sediments

- Distribution of sediments on the sea floor
- Seabed Resources

Sediments are particles of organic or inorganic matter that accumulate in a loose, unconsolidated form. Record of geologic/oceanographic history

- Types (Classification)
- Location or distribution of sediments
- Rates of Deposits/Accumulation

Study of Sediments is important to oceanography because:

1. Sediments and volcanism are the most important agents of physical change on the deep-ocean floor
2. Study of sediments is important to ocean's chemistry, morphology and history as well as to Earth's climate (paleoclimate)

The position and nature of sediments provide important clues to Earth's recent history, and valuable resources can sometimes be recovered from them.

The ages of portions of the ocean floor can be determined by studying core samples of sediments just above the basalt seabed, (see Fig. 5.26 for an example). The youngest sediments are found near the ridges and rises and the oldest close to the trenches.

Sediment Classification

- Particle Size (Grain Size)
- Location (where the grains are deposited)
- Source and Chemistry

Sediments May Be Classified By Particle Size

The velocities of currents required for erosion, transportation, and deposition (sedimentation) of sediment particles of different sizes.

To dislodge and carry a particle of size A, the speed of a current must exceed 20 centimeters per second (8 inches per second). When the current falls below 1 centimeter per second (1/2 inch per second), the particle will be deposited.

Grain Size Classification

<table>
<thead>
<tr>
<th>Descriptive Name</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gravel</td>
<td>&gt; 256</td>
</tr>
<tr>
<td>Boulder</td>
<td>&gt; 256</td>
</tr>
<tr>
<td>Cobble</td>
<td>64-256</td>
</tr>
<tr>
<td>Pebble</td>
<td>4-64</td>
</tr>
<tr>
<td>Granule</td>
<td>2-4</td>
</tr>
<tr>
<td>Sand</td>
<td>Very coarse</td>
</tr>
<tr>
<td>Coarse</td>
<td>0-2</td>
</tr>
<tr>
<td>Medium</td>
<td>0.5-1</td>
</tr>
<tr>
<td>Fine</td>
<td>0.125-0.25</td>
</tr>
<tr>
<td>Very fine</td>
<td>0.0625-0.125</td>
</tr>
<tr>
<td>Mud</td>
<td>Silt</td>
</tr>
<tr>
<td></td>
<td>0.0039-0.00625</td>
</tr>
<tr>
<td></td>
<td>Clay</td>
</tr>
<tr>
<td></td>
<td>&lt; 0.0029</td>
</tr>
</tbody>
</table>

Sediment can be classified by particle size. Waves and currents generally transport smaller particles farther than larger particles.

How far sediments go horizontally and how long it takes to get to bottom of sea depends on size. Shape is also important to how sediments go around and settle in the bottom.
**Poorly Sorted vs. Well Sorted**

Well sorted: uniform grain size
Poorly sorted: variable grain size

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**Sources of Sand For Littoral Transport**

- **Bluff Erosion**
- Offshore Glacially Deposited Sand Ridges, Relict Ebb Shoals

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**Sediment Size Classification**

Wentworth grain-size scale (Wentworth, 1922).

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**Maximum Amount of Material Derived From Bluff Erosion**

- Historic estimates 81,100 yd³/yr to 132,100 yd³/yr
- The bluffs at Montauk Point are receding at 1 ft/yr
- This recession rate has been well documented due to endangerment of the historic Montauk Light House constructed in 1796.
Analysis of the bluff composition and historic rates of recession have determined Montauk (Ronkonkoma Moraine) bluffs could not account for all of the material contained within the littoral system.

Based on sieve analysis data, 63-percent of the size fraction (by weight) is similar in composition (fine to medium sand) to the barrier beaches to the west.

Littoral Transport reaches a maximum rate of 463,015 to 601,657 yd³/yr at Democrat Point (Fire Island Inlet). 6 to 29% of Longshore transport at Fire Island Inlet. 109,868 to 517,948 yd³/yr of sediment may be coming from offshore, however the exact mechanism for the material transport into the littoral zone has not been determined (Schwab et al., 1999).

Classification Based on Location (where sediments are found)

Neritic: near continental margins & islands
Pelagic: deep sea floor
Marine Sediments Are Usually Combinations of Terrigenous (from rocks) and Biogenous (organic) Deposits

The sediment of continental shelves is called neritic sediment, and contains mostly terrigenous material. Sediments of the slope, rise, and deep-ocean floors are pelagic sediments, and contain a greater proportion of biogenous material.

<table>
<thead>
<tr>
<th>Region</th>
<th>Percent of Ocean Area</th>
<th>Percent of Total Volume of Marine Sediments</th>
<th>Average Thickness</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continental shelves</td>
<td>9</td>
<td>15</td>
<td>2.5 km (1.6 mi)</td>
</tr>
<tr>
<td>Continental slopes</td>
<td>6</td>
<td>41</td>
<td>9 km (5.6 mi)</td>
</tr>
<tr>
<td>Continental rises</td>
<td>6</td>
<td>33</td>
<td>8 km (5 mi)</td>
</tr>
<tr>
<td>Deep-ocean floor</td>
<td>78</td>
<td>13</td>
<td>0.6 km (0.4 mi)</td>
</tr>
</tbody>
</table>

Classification Based on Source & Chemistry

<table>
<thead>
<tr>
<th>Type</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrigenous</td>
<td>pre-existing rock</td>
</tr>
<tr>
<td>Biogenous</td>
<td>living organisms</td>
</tr>
<tr>
<td>Hydrogenous</td>
<td>precipitation from sea water</td>
</tr>
<tr>
<td>Cosmogenous</td>
<td>space</td>
</tr>
</tbody>
</table>

- Terrigenous: From rocks, wood, waste sludge, volcanic stuff. Results from erosion by air & water. Transported by winds, water, ice and gravity. Also by glaciers and icebergs.
  - Dominates the neritic sediments because it is the largest source for these sediments.
  - Pelagic lithogenous sediments → abyssal clay (about 75% of clay), very slow accumulation, rich in Fe → red clay.

The Sediment Cycle.

Over geological time, mountains rise as lithospheric (crustal) plates collide, fuse, and subduct. Water and wind erode the mountains and transport resulting sediment to the sea. The sediments are deposited on the seafloor, where they travel with the plate and are either uplifted or subducted. Thus, the material is eventually made into mountains again.

Biogenous

Oozes - sediment containing at least 30% biogenous material. Dominant on deep-ocean floor, 2 types of oozes:

* Calcareous (CaCo₃) oozes: formed by organisms which contain calcium carbonate in their shells or skeletons → dominant pelagic sediment (coccolithophorids, pteropods, foraminifers).

* Siliceous (SiO₂) oozes: formed by organisms that contain silica in their shells. Diatoms are one type of organism whose remains contribute to siliceous oozes. The ocean is under-saturated with respect to Si, so it can dissolve everywhere. (large contribution from photosynthetic organisms)
Calcereous Oozes

The line shows the calcium carbonate (CaCO₃) compensation depth (CCD). At this depth, usually about 4,500 meters (14,800 feet – about the height of some of the peaks in the Colorado Rocky Mountains, known as ‘the fourteeners’), the rate at which calcareous sediments accumulate equals the rate at which those sediments dissolve.

Hydrogenous

Originates from chemical reactions with water that occur in the existing sediment. Hydrogenous sediments are often found in the form of nodules containing manganese and iron oxides. Hydrogenous sediments can be:
- Carbonates → direct deposition
- Phosphorites → abundant in continental shelf
- Evaporites - salts that precipitate as evaporation occurs
- Evaporites include many salts with economic importance
- Manganese nodules → Mn, Fe, Cu, Ni, Co. These are found in abyssal seafloor and continental margins, around ocean ridges and seamounts (but at higher concentrations than those found on land). The Co (cobalt) content is of strategic importance to US (used in aircraft’s manufacture).
- Lithogenous (or terrigeneous) (abyssal clay, red clay Fe)

Rates of Sedimentation

- Continental Margin: rapid, neritic sediments
  - Major Rivers: Ganges, Yangtze, Yellow, Brahmaputra
  - 8 m/yr
  - ½ of all land derived sediment
- Bays: 500 cm/1000 years (0.5 cm/yr)
- Shelf/Slope: 10 - 40 cm/1000 years
Rates of Sedimentation

- Ocean Basins: slow, pelagic sediments
  - 0.5 – 1.0 cm/1000 years
  - Average Accumulation 500 – 600 m (during geological history, in about 100 my)
  - Thickness depends on age
  - Oldest sea floor is 200 million years

Compare:

- Neritic Sediments
  1. Rivers  800,000 cm/1000 years
  2. Bays           500 cm/1000 years
  3. Shelf             40 cm/1000 years

- Pelagic Sediments
  1 cm/1000 years!

Map of distribution of sediment

Recall (from Chapter 4) that turbidity currents can deposit Turbidites - Where would you expect to find turbidites?

Distribution of sediments is determined by climate (temperature), environmental factors (nutrients, possible chemical reactions, activity of physical environment), supply, size and rate of accumulation.

- Terrigenous sediments are deposited along the coastal boundaries
- 75% of marine sediments are from land – coarser sediments closer to coasts and finer sediments at further distances offshore
- Higher latitudes - coarser sediments; lower latitudes - finer sediments
- At higher latitudes rafting by glaciers and ice contribute significant amounts of sediments from land (coarse)
- Red clay (fine, pelagic lithogenous) found where there is not much of anything else - deep ocean basins
- Calcareous are not found in deep-sea areas below 4500 m or where ocean primary productivity is low. Found in warm, tropical latitudes, shallow areas (Caribbean), elevated ridges and seamounts
- Siliceous (photosynthesis) found below areas of very high biological productivity - abound in areas of N. Pacific and Antarctic Ocean: cold but nutrients and sun light good for photosynthesis.

Sampling the seafloor

Coring: vibracore & box core

Dredges and Grab Samplers
Resources

- Sand and Gravel → construction
- Phosphorite → fertilizers
- Sulfur → sulfuric acid for industry
- Coal → energy
- Oil and Gas → energy, transportation (20-25% of US production comes from offshore areas)
- Maganese Nodules → Mn, Fe, Co, Cu, Ni
- Gas Hydrates → energy in the future?

http://www.ornl.gov/info/reporter/no16/methane.htm

The fuel of the future may be ice that burns

Methane hydrates, a promising natural gas resource, are believed to reside throughout the globe in sea floor sediments and permafrost.

http://www.gnu.nasa.gov/research/features/methane/45

When brought to the surface, methane gas will escape from the hydrate and can be burnt off as seen in this picture. (Photo: Gary Klinkhammer)

Chapter 5 - Sediments - Summary
Sediment is particles of organic or inorganic matter that accumulate in a loose, unconsolidated form. Sediment may be classified by grain size or by the origin of the majority of the particles.

Marine sediments are broadly classified by origin into four categories. Terrigenous sediments are of geological origin and arise on the continents or islands near them; they are the most abundant. Biogenous sediments are of biological origin. Hydrogenous sediments are formed directly from seawater. Of less importance are cosmogenous sediments, which come from space.

Though there are exceptions, the sediments of continental margins tend to be mostly terrigenous, whereas the generally finer sediments of the deep-ocean floor contain a larger proportion of biogenous material.

Deep sea oozes—forms of biogenous sediment—contain the remains of some of the ocean’s most abundant and important organisms.

Sediment deposited on a quiet seabed can provide a sequential record of events in the water column above. In a sense sediments act as the recent memory of the ocean. The memory does not extend past about 200 million years because sediments are relatively young and recycled into Earth at subduction zones.