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.

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.

Sediment Classification

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

<table>
<thead>
<tr>
<th>Descriptive Name</th>
<th>Diameter (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravel</strong></td>
<td></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><strong>Granule</strong></td>
<td>2-4</td>
</tr>
<tr>
<td><strong>Sand</strong></td>
<td></td>
</tr>
<tr>
<td>Very coarse</td>
<td>1-2</td>
</tr>
<tr>
<td>Coarse</td>
<td>0.5-1</td>
</tr>
<tr>
<td>Medium</td>
<td>0.25-0.5</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><strong>Mud</strong></td>
<td></td>
</tr>
<tr>
<td>Silt</td>
<td>0.0039-0.04625</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt; 0.0039</td>
</tr>
</tbody>
</table>

Large (L), Medium (M), Small (S)

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

<table>
<thead>
<tr>
<th>Type of Particle</th>
<th>Diameter in mm</th>
<th>Setting Velocity in Still Water cm/day</th>
<th>Time to Settle 4 km (2.5 mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>&gt;256</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Cobble</td>
<td>64-256</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Pebble</td>
<td>4-64</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td><strong>Granule</strong></td>
<td>2-4</td>
<td>2.5 cm/day</td>
<td>1.8 days</td>
</tr>
<tr>
<td><strong>Sand</strong></td>
<td>0.0625-2 mm</td>
<td>0.065 cm/day</td>
<td>6 months</td>
</tr>
<tr>
<td>Silt</td>
<td>&lt;0.0039</td>
<td>0.00025 cm/day</td>
<td>50 years</td>
</tr>
</tbody>
</table>

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.

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 5.3 The Distribution and Average Thickness of Marine Sediments

<table>
<thead>
<tr>
<th>Region</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>2.5 km (1.6 mi)</td>
</tr>
<tr>
<td>Continental slopes</td>
<td>6</td>
<td>9 km (5.6 mi)</td>
</tr>
<tr>
<td>Continental rises</td>
<td>6</td>
<td>8 km (5 mi)</td>
</tr>
<tr>
<td>Deep-ocean floor</td>
<td>78</td>
<td>0.6 km (0.4 mi)</td>
</tr>
</tbody>
</table>

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!

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>(or Lithogenous)</td>
<td>all land derived material</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>

Lithogenous

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
Neritic or pelagic - dominates the neritic sediments because it is the largest source for these
Pelagic lithogenous sediments → abyssal clay (about 75% of clay), very slow accumulation, rich in Fe → red clay
**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, foraminifera)

* **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)

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**Calcareous Oozes**

CCD (~4500 meters) depth where rate of dissolution of calcium carbonate is equals to its rate of accumulation

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.

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**Hydrogenous**

Originate from chemical reactions with water that occur in the existing sediment. Hydrogenous sediments are often found in the form of nodules containing manganese and ironoxides. Hydrogenous sediments can be:

- **Carbonates** → direct deposition
- **Phosphorites** → abundant in continental shelf
- **Salts** → by evaporation
  - Evaporites - salts that precipitate as evaporation occurs. Evaporites include many salts with economic importance. Evaporites currently form in the Gulf of California, the Red Sea, and the Persian Gulf
- **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).
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 farther 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.

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?
Methane hydrate consists of a cage of water molecules trapping a methane molecule within. This can form large crystals of hydrate in cold and heavily pressurized situations (mainly on the continental slope in the oceans). (Image: Slim Films for Suess et al., Scientific American, Nov. 1999, pp. 76-83)

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)

http://www.giss.nasa.gov/research/features/methane/

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 ooze 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 seafloors are relatively young and recycled into Earth at subduction zones.