Sediments on the Sea Floor

Why is the sediment on the oceanic crust thicker near the continents?

Sediments

Based on data from core samples, scientists have determined the age of portions of the Pacific floor, measured in mega-annums, or millions of years.
Deep-Ocean Basins

**Island Arcs** - chains of volcanic islands and seamounts, usually found parallel to the edges of ocean trenches.

As two oceanic plates converge, an island arc is formed by volcanic activity.

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**Studying Sediments: Key Ideas**

- Ocean sediment includes particles from land, biological activity, chemical processes and space.
- Ocean sediment is thickest over continental margins and thinnest over active oceanic ridges.
- Sediment deposited on a quiet seafloor can provide a sequential record of recent events in the water column above. Sediments are recycled into earth at subduction zones.
- Sediments are an important source of crude oil and natural gas.
Studying Sediments

- Deep-water cameras
- Clamshell samplers
- Piston Corers
- Seismic profilers

What can we learn by studying sediments?

- Historical information
- Location of natural resources, especially crude oil and natural gas

Classification of Marine Sediments: Size or Origin.

**Size** classification divides sediment by grain size into gravel, sand, silt and clay.
- Mud is a mixture of silt and clay.

**Origin** classification divides sediment into five categories: terrigenous, biogenic, authigenic, volcanogenic and cosmogenic sediments.
Classifying Sediment

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

Table 3.1 Particle Sizes and Settling Rates in Sediment

<table>
<thead>
<tr>
<th>Type of Particle</th>
<th>Diameter</th>
<th>Settling Velocity</th>
<th>Time to Settle 4 km (2.5 mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder</td>
<td>0.256 mm (10 in.)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Cobble</td>
<td>64–256 mm (.2 1/2 in.)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Pebble</td>
<td>4–64 mm (1/8–2 1/2 in.)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Granule</td>
<td>2–4 mm (1/12–1/6 in.)</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Sand</td>
<td>0.062–2 mm</td>
<td>2.5 cm/sec (1 in./sec)</td>
<td>1.8 days</td>
</tr>
<tr>
<td>Silt</td>
<td>0.004–0.062 mm</td>
<td>0.025 cm/sec (1/100 in./sec)</td>
<td>6 months</td>
</tr>
<tr>
<td>Clay</td>
<td>&lt; 0.004 mm</td>
<td>0.000025 cm/sec</td>
<td>50 years*</td>
</tr>
</tbody>
</table>

*Though the theoretical settling time for individual clay particles is usually very long, under certain conditions clay particles in the ocean can interact chemically with seawater, clump together, and fall at a faster rate. Small biogenous particles are often compressed by organisms into fecal pellets that can fall more rapidly than would otherwise be possible. A fecal pellet is shown in Figure 5.11.

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Comparison of Poorly-Sorted and Well-Sorted Sediments

Factors that Control Sedimentation: Source, Particle Size, Turbulence

Terrigenous sediments strongly reflect their source and are transported to the sea by wind, rivers and glaciers. Average grain size reflects the energy of the depositional environment.
Hjulstrom’s Diagram

Hjulstrom’s Diagram graphs the relationship between particle size and energy for erosion, transportation and deposition.

![Hjulstrom's Diagram](image)

Note how weaker currents can move smaller particles of sediment, while stronger currents are needed to erode larger sediment.

Classifying Sediment

Sediment can also be classified according to its source.

<table>
<thead>
<tr>
<th>Sediment Type</th>
<th>Source</th>
<th>Examples</th>
<th>Distribution</th>
<th>Percent of All Ocean Floor Area Covered</th>
</tr>
</thead>
<tbody>
<tr>
<td>Terrestrial</td>
<td>Erosion of land, volcanic eruptions, blown dust</td>
<td>Quartz sand, clay, estuarine mud</td>
<td>Dominant on continental margins, abyssal plains, polar ocean</td>
<td>&lt;45%</td>
</tr>
<tr>
<td>Biogenic</td>
<td>Organic, accumulation of hard parts of some marine organisms</td>
<td>Calcareous and siliceous ooze</td>
<td>Dominant on deep-ocean ooze (siliceous ooze below about 6 km)</td>
<td>&lt;66%</td>
</tr>
<tr>
<td>Hydrogenous</td>
<td>Precipitation of dissolved minerals from water, often by bacteria</td>
<td>Manganese nodules, phosphorite deposits</td>
<td>Present with other, more dominant sediments</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Cosmogenous</td>
<td>Dust from space, meteorite debris</td>
<td>Tektite spheres, glassy nodules</td>
<td>Mixed in very small proportion with more dominant sediments</td>
<td>0%</td>
</tr>
</tbody>
</table>

Sources: Kennett, 1982; Welsink, 1979; Swain, Johnson, and Flemming, 1942.

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Distribution of Sediments

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>8%</td>
<td>41%</td>
<td>9 km (5.6 mi)</td>
</tr>
<tr>
<td>Continental rises</td>
<td>6%</td>
<td>31%</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>

Sources: Emery in Kennett, Marine Geology, 1982 (Table 11.1); Weihaupt, Exploration of the Oceans, 1979; Sverdrup, Johnson, and Fleming, The Oceans: Their Physics, Chemistry and General Biology, 1942

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Shelf Sedimentation: Controlled by Tides, Waves and Currents

Shoreline turbulence prevents small particles from settling and transports them seaward where they are deposited in deeper water. Particle size decreases seaward for modern sediments. Past fluctuations of sea level have stranded coarse sediment (relict sediment) across the shelf including most areas where only fine sediments are deposited today.

Time Frames for Continental Shelf Sedimentation

For a time frame up to 1000 years, waves, currents and tides control sedimentation. For a time frame up to 1,000,000 years, sea level lowered by glaciation controlled sedimentation and caused rivers to deposit their sediments at the shelf edge and onto the upper continental slope. For a time frame up to 100,000,000 years, plate tectonics has determined the type of margin that developed and controlled sedimentation.
Distribution of Modern Shelf Sediments: Related to latitude and climate


Sediments of Deep-Ocean Basins

- Red Clays - very fine, slowly settling deposits
- Turbidites – deposits made by turbidity currents
- Oozes – deep-ocean sediment containing at least 30% biogenous material
  - Siliceous ooze
  - Calcareous ooze
- Hydrogenous sediments - originate from chemical reactions that occur in the existing sediment
Biogenous Oozes

Ooze is classified by the type of life form from which it is derived.

- Calcareous ooze is formed by organisms, such as foraminifera, which contain calcium carbonate in their shells or skeletons.

- Siliceous ooze is formed by organisms that contain silica in their shells. Diatoms are one type of organism whose remains contribute to siliceous ooze.

- Hydrogenous sediments are usually the result of chemical reactions. Hydrogenous sediments are often found in the form of nodules containing manganese and iron oxides.

Calcite (or Calcium Carbonate) Compensation Depth (CCD)

- CaCO$_3$ dissolves in deeper water due to the higher CO$_2$ content in deep water
- Deepest sediments have little or no CaCO$_3$
- The CCD is deeper (less dissolution) in the Atlantic Ocean than in the Pacific. Why?
Sedimentation in the Ocean

- Major sedimentary processes in the deep sea include: Bulk emplacement, Debris flows, Turbidity currents
- Major pelagic sediments in the ocean are red clay and biogenic oozes.
- Authigenic deposits are chemical and biochemical precipitates that form on the sea floor and include ferromanganese nodules and phosphorite.

Distribution of Sediments in the Deep Ocean: Related to Latitude, Distance from Landmasses, and the CCD

- Glacial marine sediments occur in the high latitudes.
- Pelagic clays occur far from land and in the deepest water.
- Calcareous oozes occur above the calcium carbonate composition depth.
- The rate of sedimentation depends on the type of sediment in deep sea.
Evaporites

- Evaporites are precipitates that form as water evaporates or as the conditions in the water change.
- Evaporites include many salts with economic importance.
- Evaporites currently form in the Gulf of California, the Red Sea, and the Persian Gulf.

Drying Up of the Mediterranean Sea

- The Mediterranean basin is located where plates are colliding as Africa moves northward relative to Europe.
- Anhydrite and stromatolites of Miocene age indicate that the Mediterranean sea “dried” out between 5 and 25 million years ago.
- Two models have been suggested to account for this emptying of the Mediterranean Sea of its water.
  - The “Uplift” Model
  - The “Drying-Out” Model