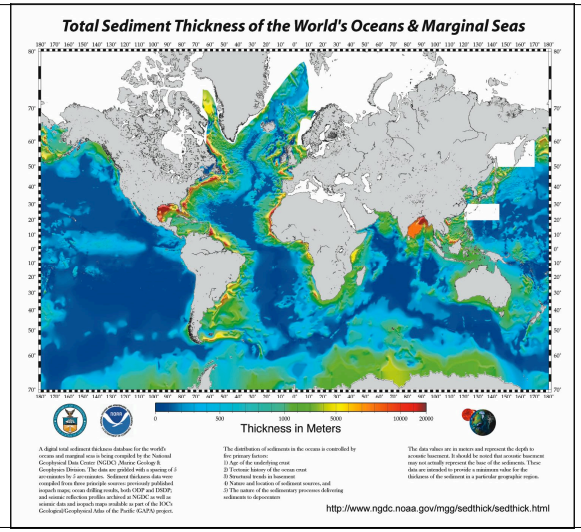
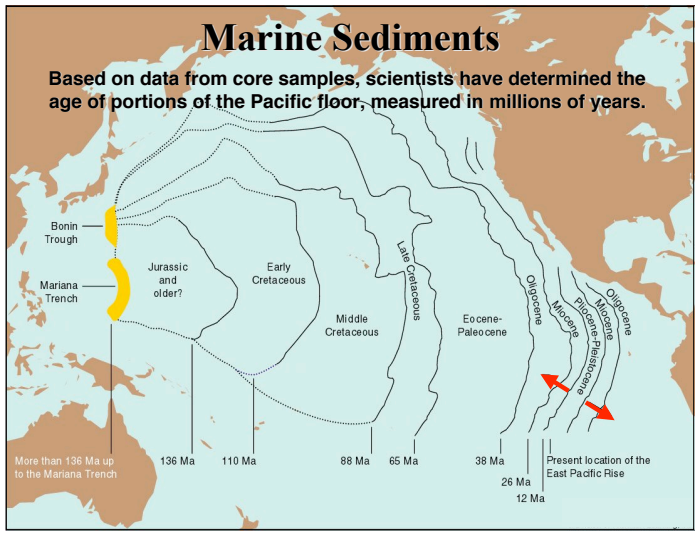
"When I think of the floor of the deep sea, the single, overwhelming fact that possesses my imagination is the accumulation of sediments. I see always the steady, unremitting, downward drift of materials from above, flake upon flake, layer upon layer…For the sediments are the materials of the most stupendous snowfall the Earth has ever seen."

—Rachel Carson, The Sea Around Us (1956)



See Fig. 5.7, p. 107



Some Important Concepts in Chapter 5

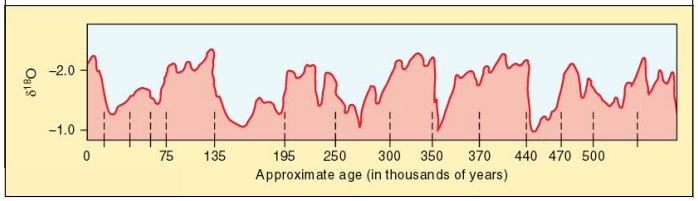
* Ocean sediment includes particles from land, from chemical processes, from biological activity, and from space.
* Ocean sediment is thickest over continental margins and thinnest over active oceanic ridges.
* Sediment deposited on a quiet seafloor can provide a sequential record of recent events in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

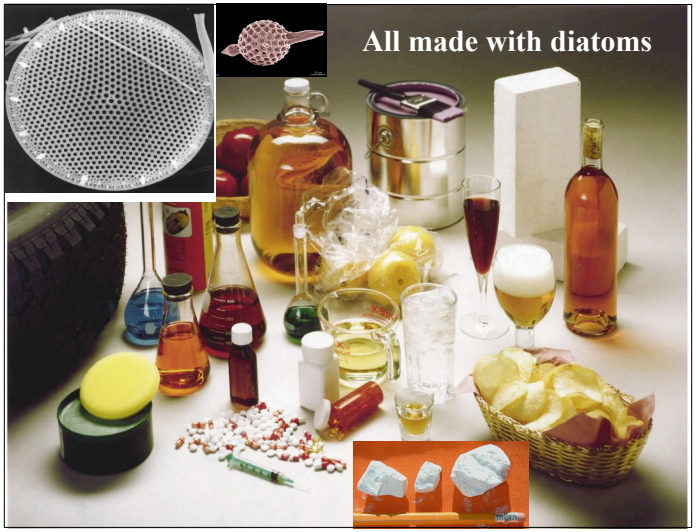
Marine Sediments

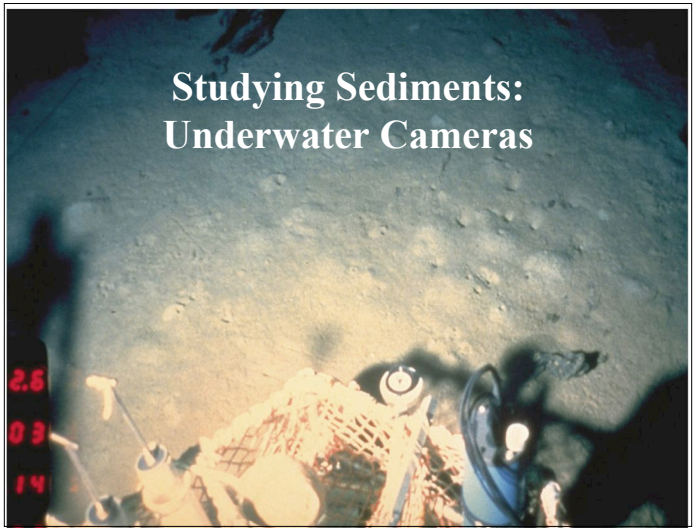
- **What is sediment?**
- **"Who cares?"**
- **Types of sediment**
  - By particle size/texture
  - By origin/formation
- **How is it transported?**
- **Where is it distributed?**

What is sediment, and who cares?

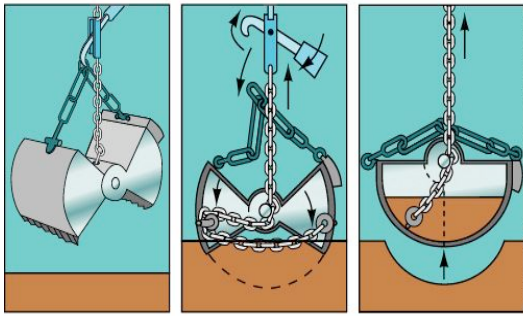
- **Sediment** = Layers of loose material on ocean bottoms (or elsewhere). "Marine snow".
- **Records Earth history** (mineral composition, sediment texture). "Forensics".
  - Past climate
  - Age of seafloor
  - Plate motions
  - Fossil evolution & extinction







Studying Sediments: Clam-shell Samplers



Can be used to obtain a relatively undisturbed sediment sample.

See Fig. 5.17, p. 115

Studying Sediments: Piston Corers

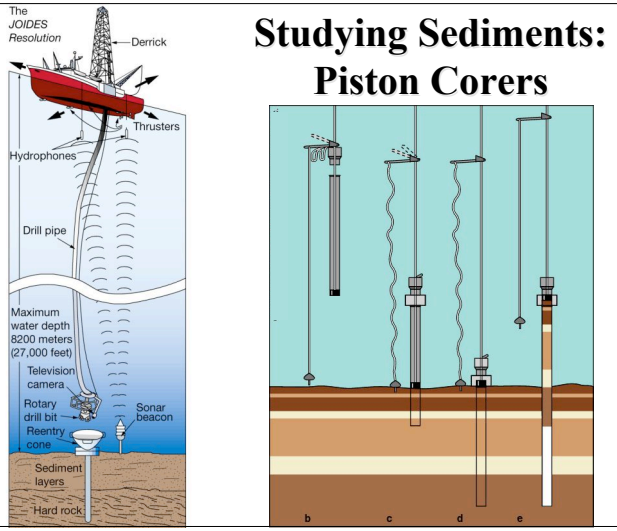
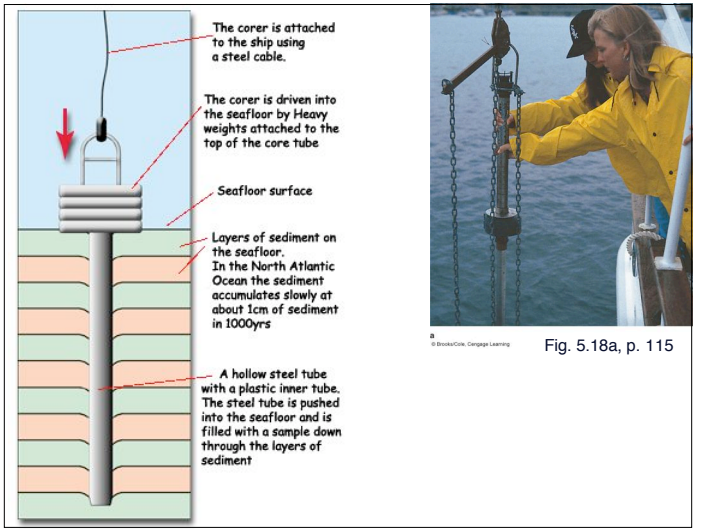


Fig. 5.18b-e, p. 115

a © Brooks/Cole, Cengage Learning

b

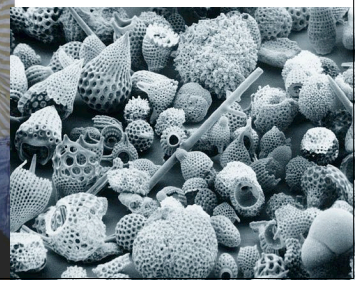
Fig. 5.19, p. 116



a © Brooks/Cole, Cengage Learning

Fig. 5.18a, p. 115

A cylinder of sediment is taken for analysis.
⇒ Age of the material, density, strength, composition, etc.



Distribution of Sediments

The sediment of continental shelves is called neritic (="of the coast") sediment, and contains mostly terrigenous material.

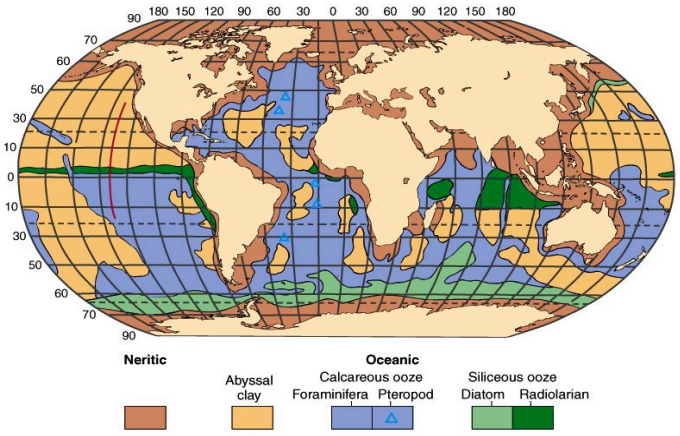
Sediments of the slope, rise, and deep-ocean floors are pelagic (="of the deep sea") sediments, and contain a greater proportion of biogenous material.

The Distribution and Average Thickness of Marine Sediments

Region	Percent of Ocean Area	Percent of Total Volume of Marine Sediments	Percent of Average Thickness
Continental shelves	9	15	2.5 km (1.6 mi)
Continental slopes	6	41	9 km (5.6 mi)
Continental rises	6	31	8 km (5 mi)
Deep-ocean floor	78	13	0.6 km (0.4 mi)

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

Table 5.3, p. 107



Types of Sediment

- **By particle size (texture)**
- **By origin (formation):**
  - **Terrigenous** (Lithogenous)
  - **Biogenous** (Biogenic)
  - **Hydrogenous** (Authigenic)
  - **Cosmogenous** (Cosmogenic)

Classifying Sediment - (a) By Particle Size

Wentworth scale of grain size for sediments

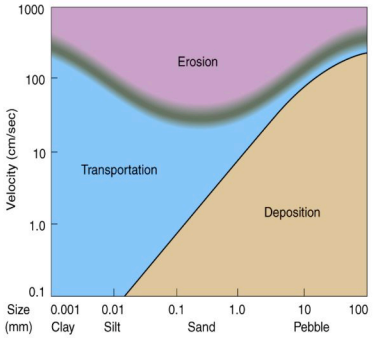
Size range (millimeters)	Particle name		Grain size	Example	Energy conditions
Above 256	Boulder	Gravel	Coarse-grained	Coarse material found in	High energy
64 to 256	Cobble			stream beds near the source	
4 to 64	Pebble			areas of rivers	
2 to 4	Granule				
1/16 to 2	Sand			Beach sand	
1/256 to 1/16	Silt			Feels gritty in teeth	
1/4096 to 1/256	Clay		Fine-grained	Microscopic; feels sticky	Low energy

Sediment size indicates *energy* of transport & deposition.

Wentworth Scale of Grain Size for Sediments.

Size Range (mm)	Particle	
256	Boulder	
64	Cobble	
4	Pebble	
2	Granule	
1	Very coarse sand	
½	Coarse sand	
¼	Medium sand	SAND
⅛	Fine sand	
1/16	Very fine sand	
1/32	Course silt	
1/64	Medium silt	SILT
1/128	Fine silt	
1/256	Very fine silt	
1/512	Coarse clay	
1/1024	Medium clay	CLAY
1/2048	Fine clay	
1/4096	Very fine clay	
1/8192	Colloid	

Source: Wentworth, 1922, after Udden, 1898



Waves & currents generally transport *smaller* particles *farther* than larger particles.

Particle Sizes and Settling Rate in Sediment

Type of Particle	Diameter	Settling Velocity in Still Water	Time to settle 4 km (2.5 mi)
Boulder	>256 mm (10 in.)	—	—
Cobble	64–256 mm (>2½ in.)	—	—
Pebble	4–64 mm (⅛–2½ in.)	—	—
Granule	(2–4 mm (1/12 - ⅛ in.)	—	—
Sand	0.062–2 mm	2.5 cm/sec (1 in./sec)	1.8 days
Silt	0.004–0.062 mm	0.025 cm/sec (1/100 in./sec)	6 months
Clay	<0.004 mm	0.00025 cm/sec	50 years[a]

Table 5.1, p. 103

Textural Maturity

Maturity increases

Degree of sorting increases
Clay content decreases
Rounding of sand particles increases

Clay particle

Classifying Sediment - (b) By Origin

Classification of Marine Sediments by Source of Particles

Sediment Type	Source	Examples	Distribution	Percent of All Ocean Floor Area Covered
Terrigenous	Erosion of land, volcanic eruptions, blown dust	Quartz sand, clays, estuarine mud	Dominant on continental margins abyssal plains, polar ocean floors	~45
Biogenous	Organic; accumulation of hard parts of some marine organisms	Calcareous and siliceous oozes	Dominant on deep-ocean floor (siliceous ooze below about 5 km)	~55
Hydrogenous (authigenic)	Precipitation of dissolved minerals from water, often by bacteria	Manganese nodules, phosphorite deposits	Present with other, more dominant sediments	<1
Cosmogenous	Dust from space, meteorite debris	Tektite spheres, glassy nodules	Mixed in very small proportion with more dominant sediments	0

Cosmogenous

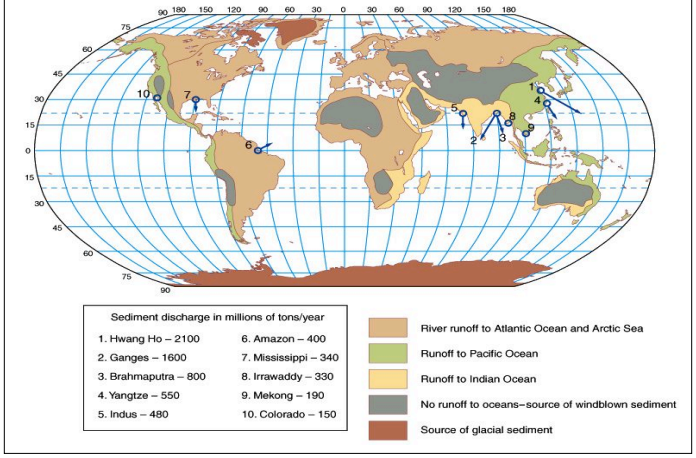
Sources: Kennett, 1982; Weihaupt, 1979; Sverdrup, Johnson, Fleming, 1942.

Table 5.2, p. 104

1. Terrigenous (Lithogenous)

- **Rock fragments from land**
- **Transported to oceans by:**
  - Rivers
  - Ice
  - Wind
  - Gravity flows
- **Mainly quartz (SiO_2)**
  - Chemically stable
  - Abrasion resistant
- **Most accumulates near continental margins**
- **Wind-blown dust makes abyssal clay**

Rivers transport a lot of sediment



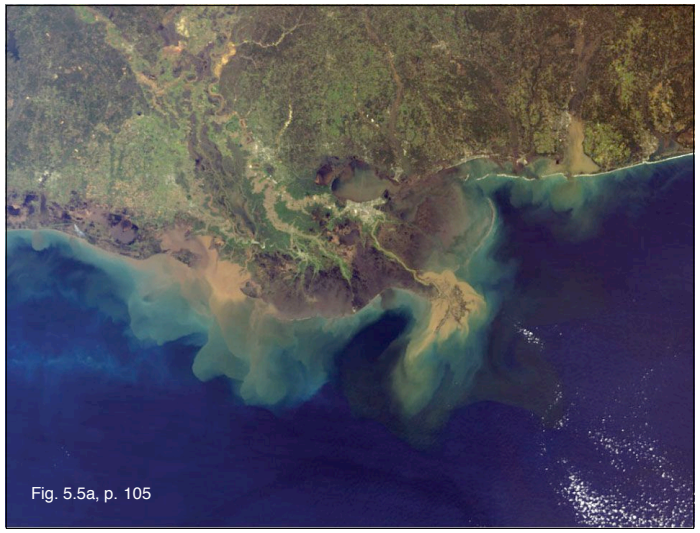
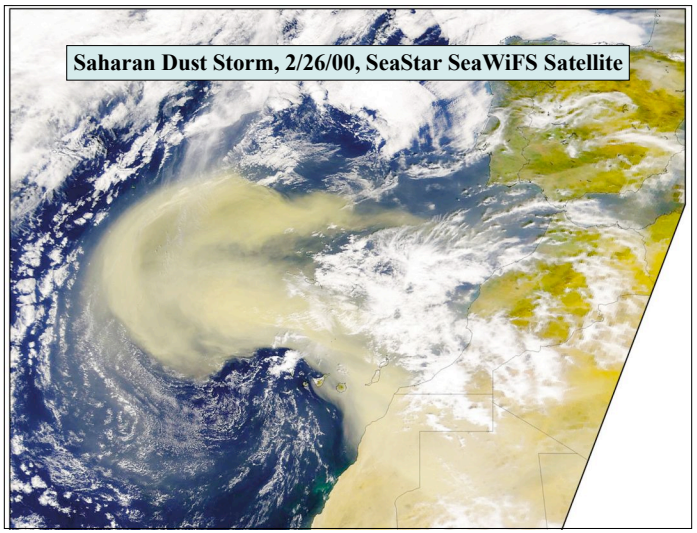
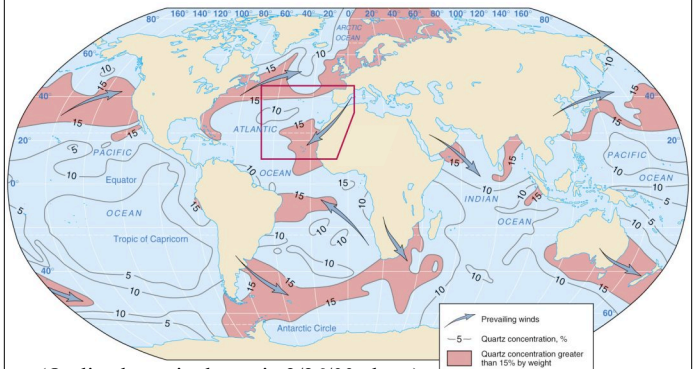


Fig. 5.5a, p. 105



Wind-derived quartz in ocean sediments



(Outlined area is shown in 2/26/00 photo)

Fig. 5.5b, p. 105

Distribution of Terrigenous Sediments

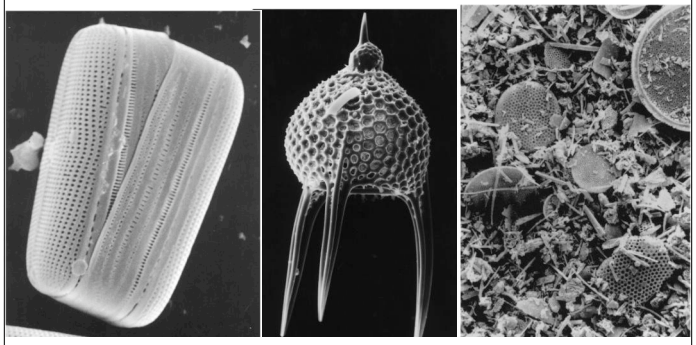
- **Neritic = near-shore**
  - Mainly from breakdown of continental rocks
  - Coarser particles closer to shore
  - Beach sands, continental shelf deposits, turbidite deposits, glacial deposits
  - Shelf sediments may be converted to rock via lithification
- **Pelagic = deep ocean**
  - Finer particles farther from land
  - Wind blown or distal turbidite

2. Biogenous (Biogenic)

- **Hard parts of once-living organisms** (shells, teeth, bones, and even poop!)
- **Calcareous ($CaCO_3$)** = calcium carbonate
- **Siliceous (SiO_2)** = silica
- **"Ooze" is >30% biogenic material** (by weight)

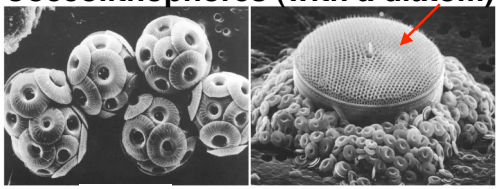
Microscopic Siliceous (SiO_2) Tests

Diatom **Radiolarian** **Ooze**



Microscopic Calcareous ($CaCO_3$) Tests

Coccolithophores (with a diatom)



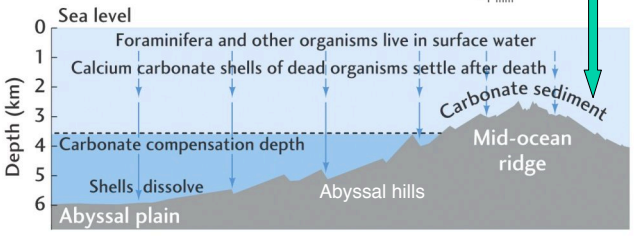
Foraminifera **Ooze**

Distribution of Biogenous Sediments

- **Neritic = near-shore**
  - Carbonates in shallow, warm ocean
    - Coral reefs, ooid shoals, beach sands
  - Stromatolites (carbonate, cyanobacteria, algae)
- **Pelagic = deep ocean**
  - **SiO_2** ooze under areas of surface ocean upwelling (high biologic productivity)
  - **$CaCO_3$** ooze on seafloor <4500 m deep
    - $CaCO_3$ dissolves in *cold* seawater

Carbonate Compensation Depth (CCD)

The depth below which carbonate readily dissolves. Only non-calcareous sediments accumulate below the CCD.



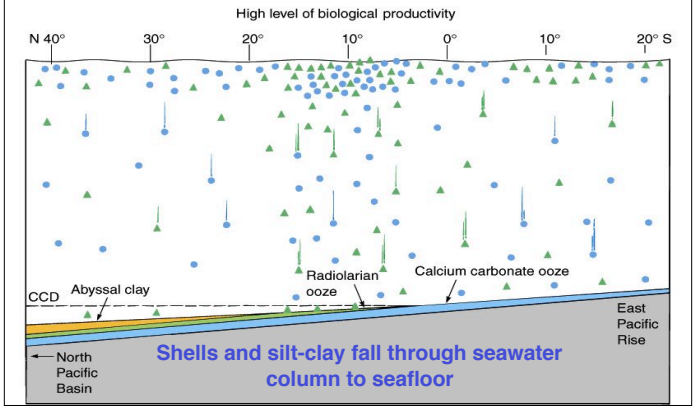
See Fig. 5.12, p. 111

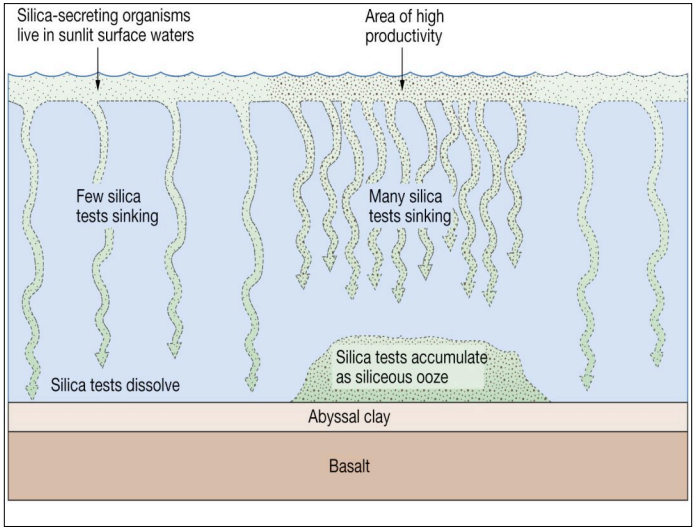
Factors in distribution of biogenous sediments:

–Biologic productivity

–Dissolution as shells settle through ocean

–"Dilution" by non-biogenic material

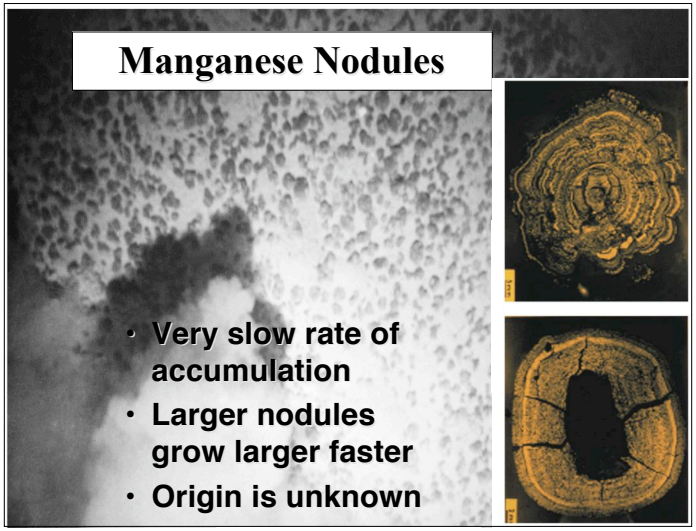




3. Hydrogenous (Authigenic)

Dissolved ions precipitate from seawater

- Manganese nodules
- Inorganic carbonates
- Phosphates
- Metallic sulfides
- Evaporites



4. Cosmogenous (Cosmogenic)

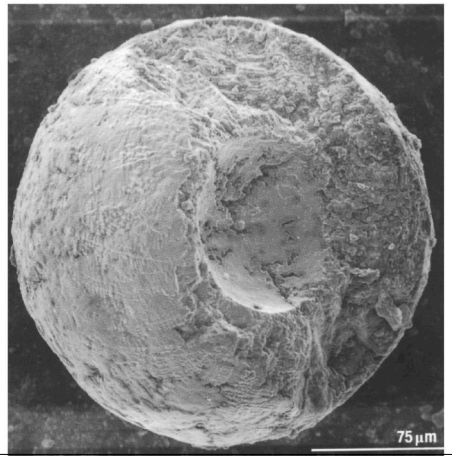
Extraterrestrial fragments

- Glassy tektites
- Fe-Ni micrometeorites
- Found in deep ocean where other sediments accumulate very slowly

Microtektites

Fig. 5.6, p. 106

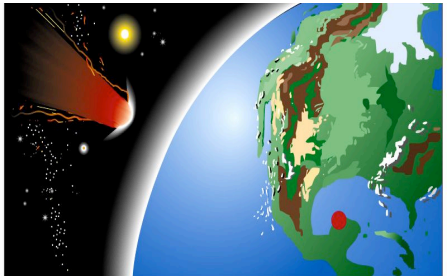
Scanning electron micrograph (SEM) image of an Fe,Ni-rich spherule of cosmic dust

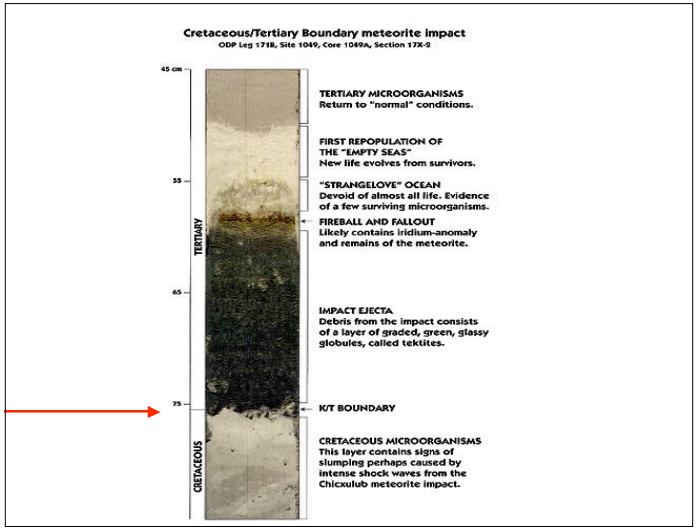


Meteorite Impact

- **K-T* meteorite crater off Yucatan Peninsula**
- **Tektites & spherules found in marine sediments**
- **Shocked quartz in marine sediments**

***Cretaceous -Tertiary boundary (65 Myr ago)**





Mixtures of Sediment Types

- **Most marine sediments are *mixtures* of the 4 types of sediment**
- **Usually one sediment type is *dominant***

Classification of marine sediments.

Type	Composition		Sources		Main locations found
Lithogenous	Continental Margin	Rock fragments Quartz sand Quartz silt Clay	Rivers; coastal erosion; landslides Glaciers Turbidity currents		Continental shelf Continental shelf in high latitudes Continental slope and rise; ocean basin margins
	Oceanic	Quartz silt Clay	Wind-blown dust; rivers		Deep-ocean basins
		Volcanic ash	Volcanic eruptions		
Biogenous	Calcium carbonate ($CaCO_3$)	Calcareous ooze (microscopic)	Warm surface water	Coccolithophores (algae); Foraminifers (protozoans)	Low-latitude regions; sea floor above CCD; along mid-ocean ridges & the tops o volcanic peaks
		Shell/coral fragments (macroscopic)	Warm surface water	Macroscopic shell-producing organisms	Continental shelf; beaches
			Warm surface water	Coral reefs	Shallow low-latitude regions
	Silica	Siliceous ooze	Cold surface water	Diatoms (algae); Radiolarians (protozoans)	High-latitude regions; sea floor below CCD; surface current divergence near theEquator
Hydrogenous		Manganese nodules (manganese, iron, copper, nickel, cobalt)	Precipitation of dissolved materials directly from seawater due to chemical reactions		Abyssal plain
		Phosphorite (phosphorous)			Continental shelf
		Oolites ($CaCO_3$)			Shallow shelf in low-latitude regions
		Metal sulfides (iron, nickel, copper, zinc, silver)			Hydrothermal vents at mid-ocean ridges
		Evaporites (gypsum, halite, other salts)			Shallow restricted basins where evaporation is high in low-latitude regions
Cosmogenous		Iron-nickel spherules Tektites (silica glass)	Space dust		In very small proportions mixed with all types of sediment and in all marine environments
		Iron-nickel meteorites Silicate chondrites	Meteors		Localized near meteor impact structures

Average rates of deposition of selected marine sediments.

Type of sediment/deposit	Average rate of deposition (per 1000 years)	Thickness of deposit after 1000 years equivalent to . . .
Coarse lithogenous sediment, neritic deposit	1 meter (3.3 feet)	A meter stick
Biogenous ooze, pelagic deposit	1 centimeter (0.4 inch)	The diameter of a dime
Abyssal clay, pelagic deposit	1 millimeter (0.04 inch)	The thickness of a dime
Manganese nodule, pelagic deposit	0.001 millimeter (0.00004 inch)	A microscopic dust particle

Distance = Rate x Time

Distribution of Marine Sediments

What differences in the type and distribution of sediments do you note between the Atlantic Ocean and the Pacific Ocean?

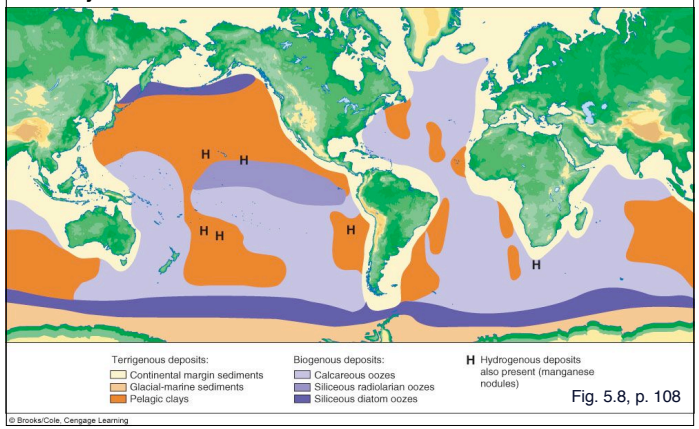
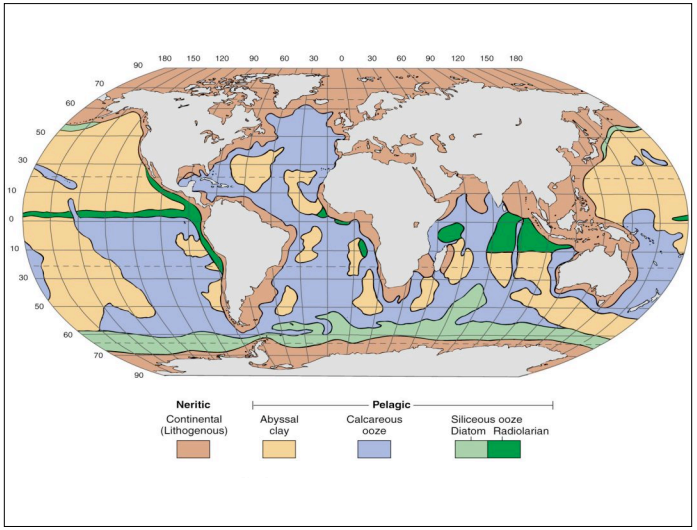
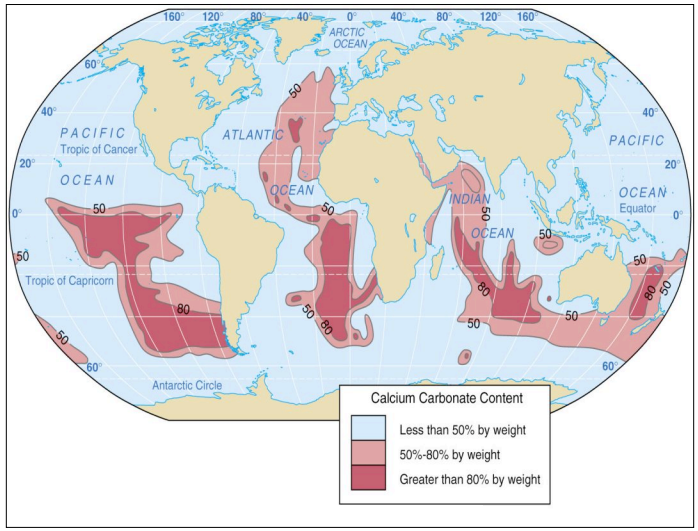
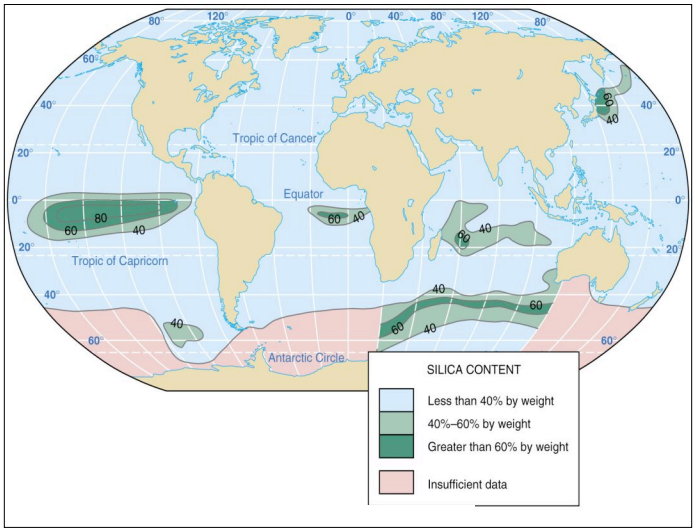
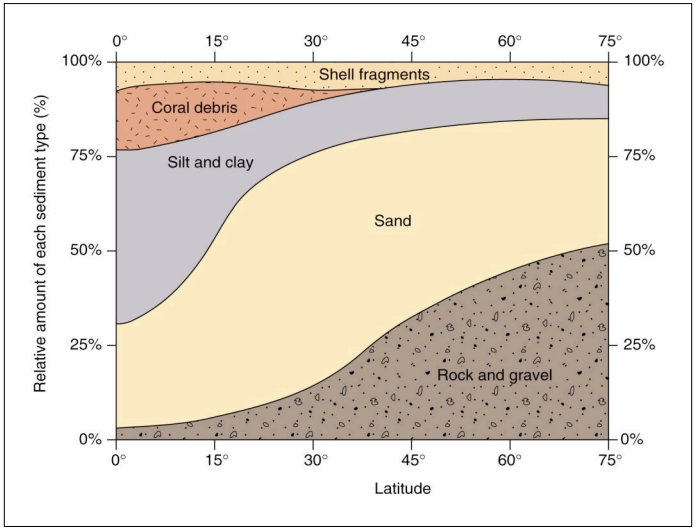


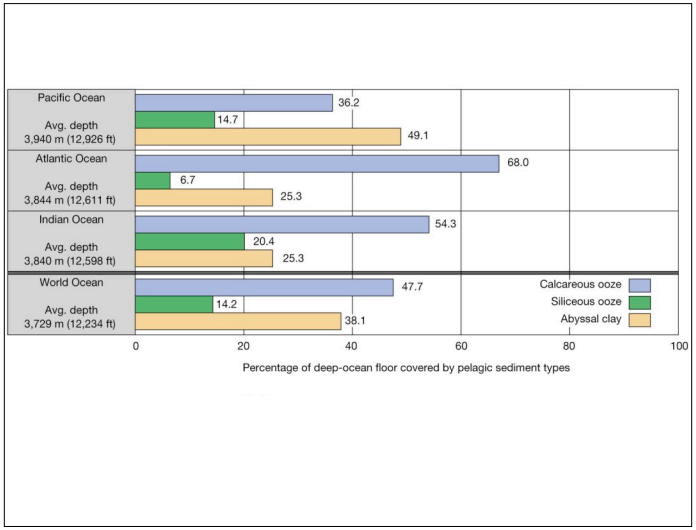
Fig. 5.8, p. 108





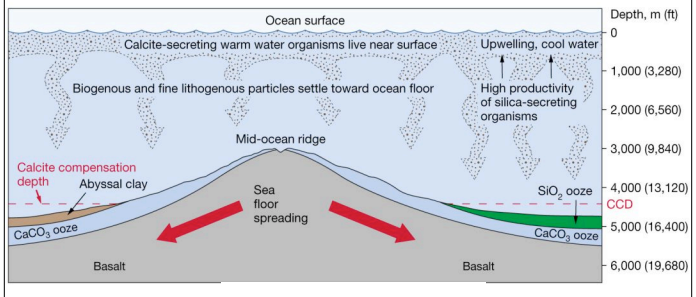


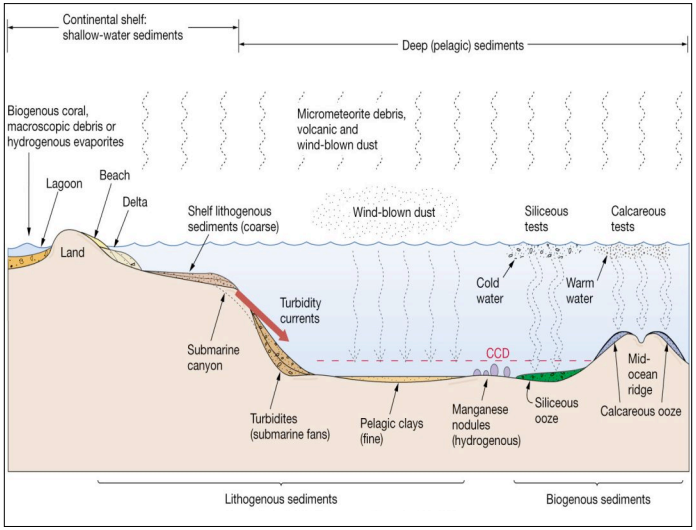




Comparison of environments interpreted from deposits of siliceous and calcareous ooze in surface sediments.

	Siliceous ooze	Calcareous ooze
Surface water temperature above sea floor deposits	Cool	Warm
Main location found	Sea floor beneath cool surface water in high latitudes	Sea floor beneath warm surface water in low latitudes
Other factors	Upwelling brings deep, cold, nutrient-rich water to the surface	Calcareous ooze dissolves below the CCD
Other locations found	Sea floor beneath areas of upwelling, including along the Equator	Sea floor beneath warm surface water in low latitudes along the mid-ocean ridge





" 5-Minute Write "

- **Summarize the <u>main points</u> of today's lecture.**
- **List 3 to 5 <u>questions</u> you have, based on today's lecture.**
- **What did you find most <u>interesting</u> about today's lecture?**
- **How was the lecture <u>relevant</u> to you?**