OCN 201
Deep Sea Sediments

Question

What caused the recent explosive eruptions of hot ash and gas at Kilauea's Halema'uma'u crater:

A. The interaction of lava with seawater

B. Drainage of the lava lake in Halema'uma'u Crater below the water table

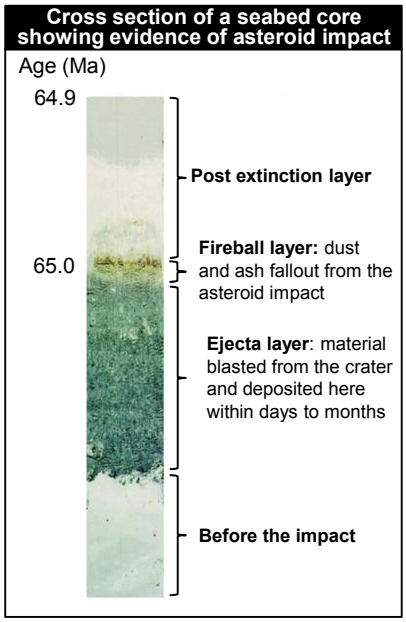
C. The release of old viscous colder magma from fissures

D. The release of fresh hot lava from fissures

E. Earthquakes

Ocean sediments

- Sediments are an accumulation of loose and unconsolidated particles (organic or inorganic)
- Marine sediments come from:
  - **Land**: weathering and erosion of rocks, volcanic eruptions
  - **Biological activity** in the ocean
  - **Chemical processes** in the water
  - **Space**
- Seafloor sedimentary deposits can provide information about Earth's recent history → they are **the memory of the ocean**
- Sediment can be compacted and lithified into rock



Where is the Sediment?

- Continental Margins: 87% (covers ~21% of ocean area)
- Deep-ocean floor: 13%

Table 5.3 The Distribution and Average Thickness of Marine Sediments

Region	Percent of Ocean Area		Percent of Total Volume of Marine Sediments		Average Thickness
Continental shelves	9		15		2.5 km (1.6 mi)
Continental slopes	6	~21%	41	~87%	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

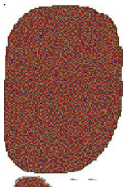
Sediment classified based on size

Table 5.1 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 (>2 $\frac{1}{2}$ in.)		
Pebble	4–64 mm ($\frac{1}{6}$–2 $\frac{1}{2}$ in.)		
Granule	2–4 mm ($\frac{1}{12}$–$\frac{1}{6}$ 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 ($\frac{1}{100}$ in./sec)	6 months
Clay	<0.004 mm	0.00025 cm/sec	50 years[a]

Most marine sediment is made of finer particles

[a] 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 5.16.



Boulder: >256 mm

Cobble: 64-256 mm

Pebble: 4-64 mm

Granule: 2-4 mm

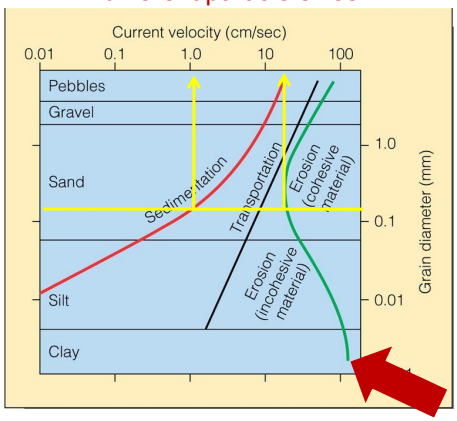
Sand: 0.062-2 mm

Silt: 0.004-0.062 mm

Clay:<0.004 mm

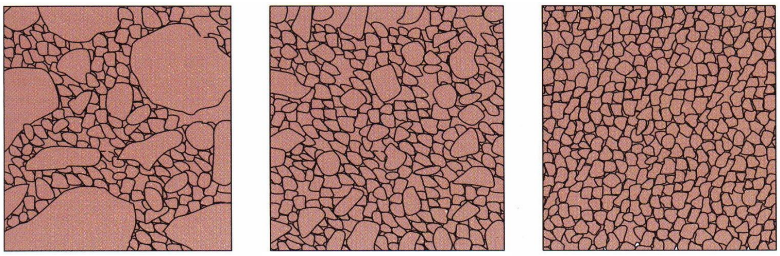
Sediment classified based on size

Velocity of currents required for erosion, transportation, and sedimentation of the different particle sizes



- Large particles settle fast, small particles settle slowly
- Weak currents move small particles, stronger currents are needed for larger particles
- Currents generally transport smaller particles farther than larger particles→ sediment get sorted
- Clays need relatively high current velocity to dislodge them, but very low to be deposited

Well-sorted vs poorly-sorted sediments



Poorly sorted | Moderately sorted | Well sorted

Well-sorted sediments — composed of particles that are mostly the same size. Found in environments with small energy fluctuations

Poorly sorted sediments — contain a variety of different sized particles. Found in environments with large energy fluctuations

Sediment classified based on source

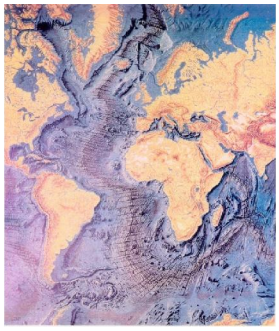
Sediment type	Source	Examples	Distribution	Percent of all ocean floor area covered
Terrigenous	Erosion of land, volcanic eruptions, wind-blown dust	Quartz sand, clays, estuarine mud	Dominant on continental margins, abyssal plains	~45%
Biogeneous	Organic matter and hard skeletal parts of marine organisms	Calcareous and siliceous oozes	Dominant on deep-ocean floor (siliceous ooze below ~5 km)	~55%
Hydrogenous (authigenic)	Precipitation of dissolved minerals (often by bacteria)	Manganese nodules, phosphite 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	~1%

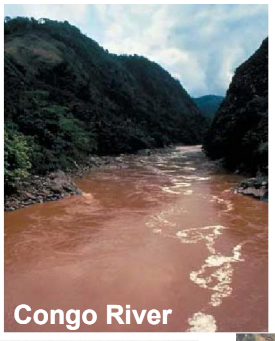
The most aboundant marine sediments are terrigenous and biogenous

Terrigenous Sediments

- Most originate from the **weathering** (process by which rocks breakdown and decompose at the Earth's surface) and **erosion** (movement of weathered material from the original source) of terrestrial rocks
- **Transported from land by**
  - Rivers
  - Turbidity currents (= mudslides, graded deposits)
  - Wind
  - Floating ice ("ice rafted", poorly sorted)

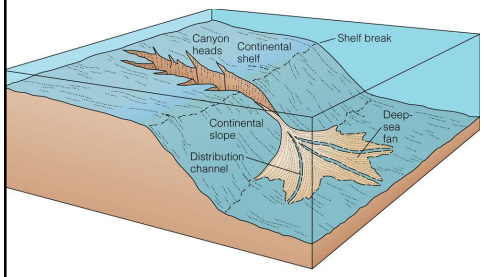
Sediment from Rivers

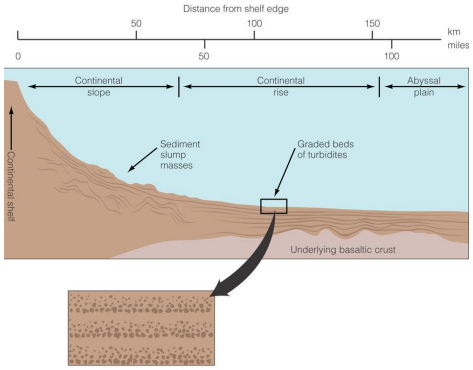




- Most terrigenous sediments are transported to the sea by rivers
- Three rivers account for most of sediment input to Atlantic Ocean:
  - Amazon River
  - Congo River
  - Mississippi River

Turbidity Currents



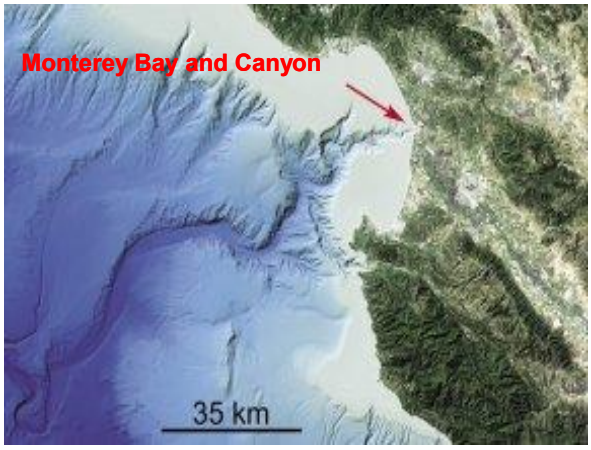


- Density driven mudslides off continental shelf
- Triggered by earthquakes or other physical disturbance
- Fast moving (multiple 100 km/hr), extend long distances
- Produce submarine canyons, fans and graded deposits

Formation of turbidites: When the material is deposited, it sorts into layers with coarse sediment at the bottom and finer sediment above. Each distinct layer is the result of one turbidity current event.

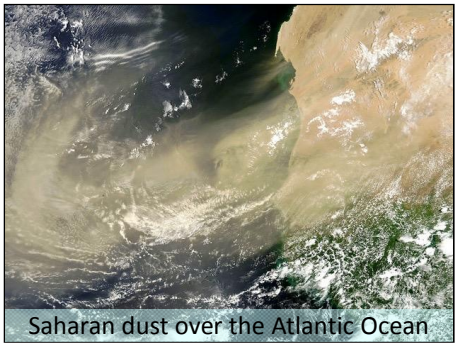
Hyperpycnal currents

- Hyperpycnal currents: freshwater whose **density** is increased above saltwater by suspended sediment load
- Are probably a major mechanism for transporting sediments from continents to the offshore seafloor



Sediment Carried by Wind

Terrigenous sediments are also transported to the ocean by wind blown dust and volcanic eruptions


Saharan dust over the Atlantic Ocean


Kilauea, Hawaii

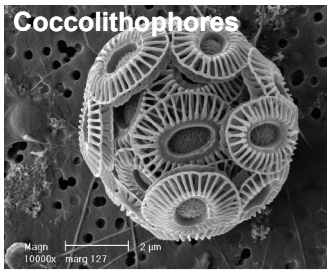
Ice Rafted Sediment

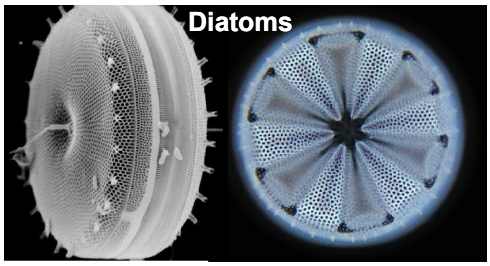
Ice from marine glaciers can transport sediment to the continental margin and deep-ocean floor

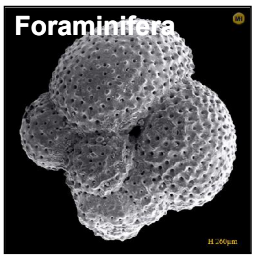
Biogenous Sediments

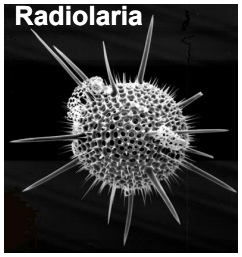
Calcareous: containing calcium carbonate ($CaCO_3$)

Silicious: containing silica (SiO_2)





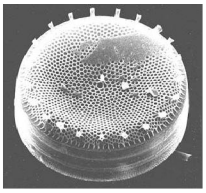


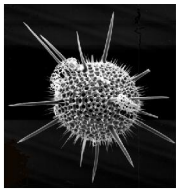


Biogenous Oozes

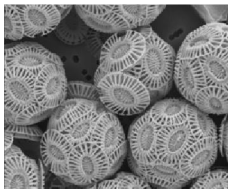
Pelagic sediment containing **>30% skeletal material**

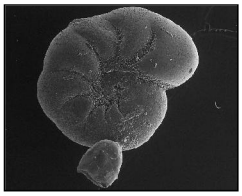
- **Siliceous oozes**: silicon-containing sediments, mostly remains of diatoms and radiolarians





- **Calcareous oozes**: calcium-containing sediments, mostly remains of coccolithophores and foraminiferans





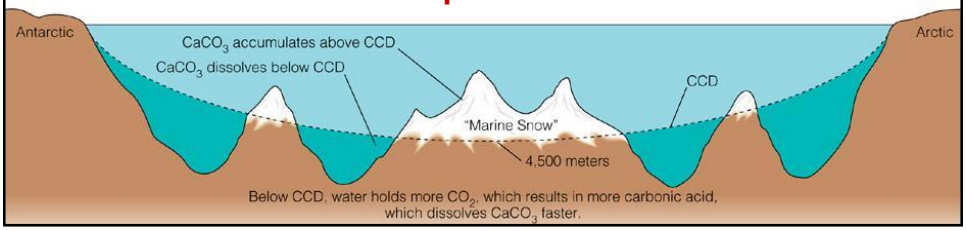
Carbonate Compensation Depth

Water depth where the rate at which calcareous sediments are delivered to the seabed is equal to the rate at which those sediments dissolve

- $CaCO_3$ is more soluble at **lower temperatures**
- $CaCO_3$ is more soluble at **lower pH** (higher acidity)

$CaCO_3$ dissolves more readily in deep ocean waters (colder, more acidic)

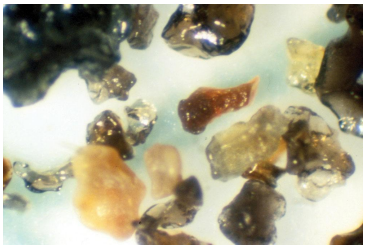
Calcareous oozes accumulate in shallower and less cold areas of deep ocean basins



Cosmogenous sediments

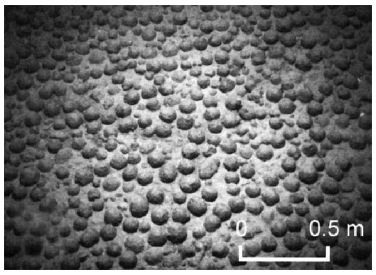
Material from **outer space**: interplanetary dust falling to Earth or debris ejected by impact from large asteroid or comet

Microtektites — translucent, oblong particles of cosmogenic glass. Ejected material from Earth's crust (when hit by an asteroid) melted when re-entered through atmosphere



Hydrogeneous sediment

- Minerals precipitated directly from seawater
- Also called **authigenic**: formed in place, within the sediment
  - **Iron-manganese nodules**: layers of manganese and iron hydroxides around a core (also cobalt, nickel, chromium, molybdenum, copper, zinc)

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  - **Non-biogenic carbonates→ oolite sands**: calcium carbonate granules precipitated abiotically from seawater
  - **Evaporites:** salt deposits formed as water evaporates from isolated arms of the ocean, landlocked seas, or lakes
  - **Hydrothermal:** precipitated from hot water (typically polymetallic sulfides, anhydrite, barite, metalliferous Fe-rich sediments)

Question

The two dominant types of biogenic sediment in the deep sea are:

A. Glacial sediments and hydrothermal vent deposits

B. Hydrogenous material and sand

C. Terrigenous silt and manganase nodules

D. Calcareous ooze and siliceous ooze

E. Clay and ferro-manganese nodules

Classification by *Location*

- **Neritic**: Nearshore, continental shelf, mostly terrigenous sediment. Sand and larger particles along the coast, clay and silts in deeper water
- **Pelagic**: Found in open ocean, greater proportion of biogenic material (calcareous oozes, siliceous oozes, abyssal clays)

Table 5.3 The Distribution and Average Thickness of Marine Sediments

Region	Percent of Ocean Area		Percent of Total Volume of Marine Sediments		Average Thickness
Continental shelves	9		15		2.5 km (1.6 mi)
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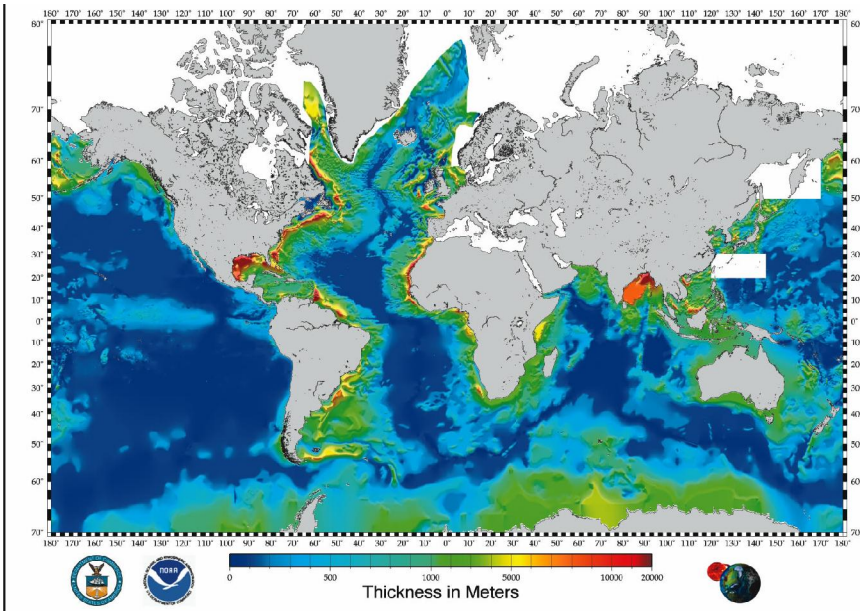
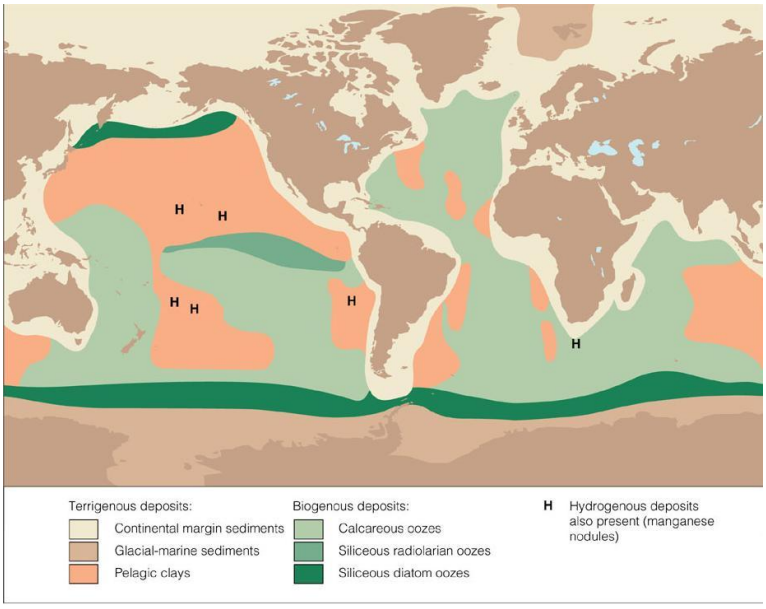
Sources: Emery in Kennett, *Marine Geology*, 1982 (Table 11-1); Weihaupt, *Exploration of the Oceans*, 1979; Sverdrup, Johnson, and Fleming, *The Oceans: Their Physics, Chemistry, and General Biology*, 1942

Sediment thickness

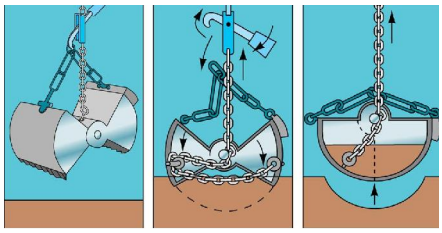


Distribution of deep sea sediments



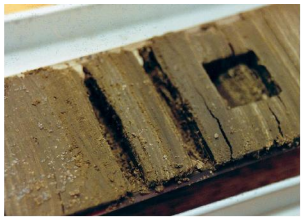
Deep-Sea Sediment: Sampling

- Grab sampling
- Gravity coring
- Piston coring
- Drilling



Deep-Ocean Drilling

- International deep-sea sampling program
- Oil-drilling technology/ships
- DSDP, then ODP, now IODP
- Key to confirmation of plate tectonics
- Recovered many 1000's of meters of sediment and seafloor rock



Question

Deep ocean sediments are dominated by:

A. Volcanic and terrigenous materials carried to the ocean by rivers

B. Abyssal clays and calcareous and siliceous oozes

C. Hydrothermal sediments and manganese nodules

D. Volcanic and cosmogenic material

E. None of the above