Origin and Distribution of Marine Sediments

What's all that squishy muck at the bottom of the ocean?

What can we learn from it?

Marine Sediments are:

- Particles of various sizes derived from a variety of sources that are deposited on the ocean floor
- A vast "library" recording geologic, oceanographic and climatic conditions
- Remarkably complete compared to land

Where do these come from?

☞Inputs are:
-- rivers
-- atmosphere
-- surface waters
-- volcanoes (both on land and submarine) -- dee
p ocean water
-- outer space

Classification of marine sediments

- Lithogenic – from disintegration of rock on land aeolian, FLUVIAL, and glacial sources

- Biogenic – organic precipitation of dissolved components dominated by single-celled plants and animals (create oozes)

  calcium carbonate (limestone) = calcareous

  silicon dioxide (opal) = siliceous

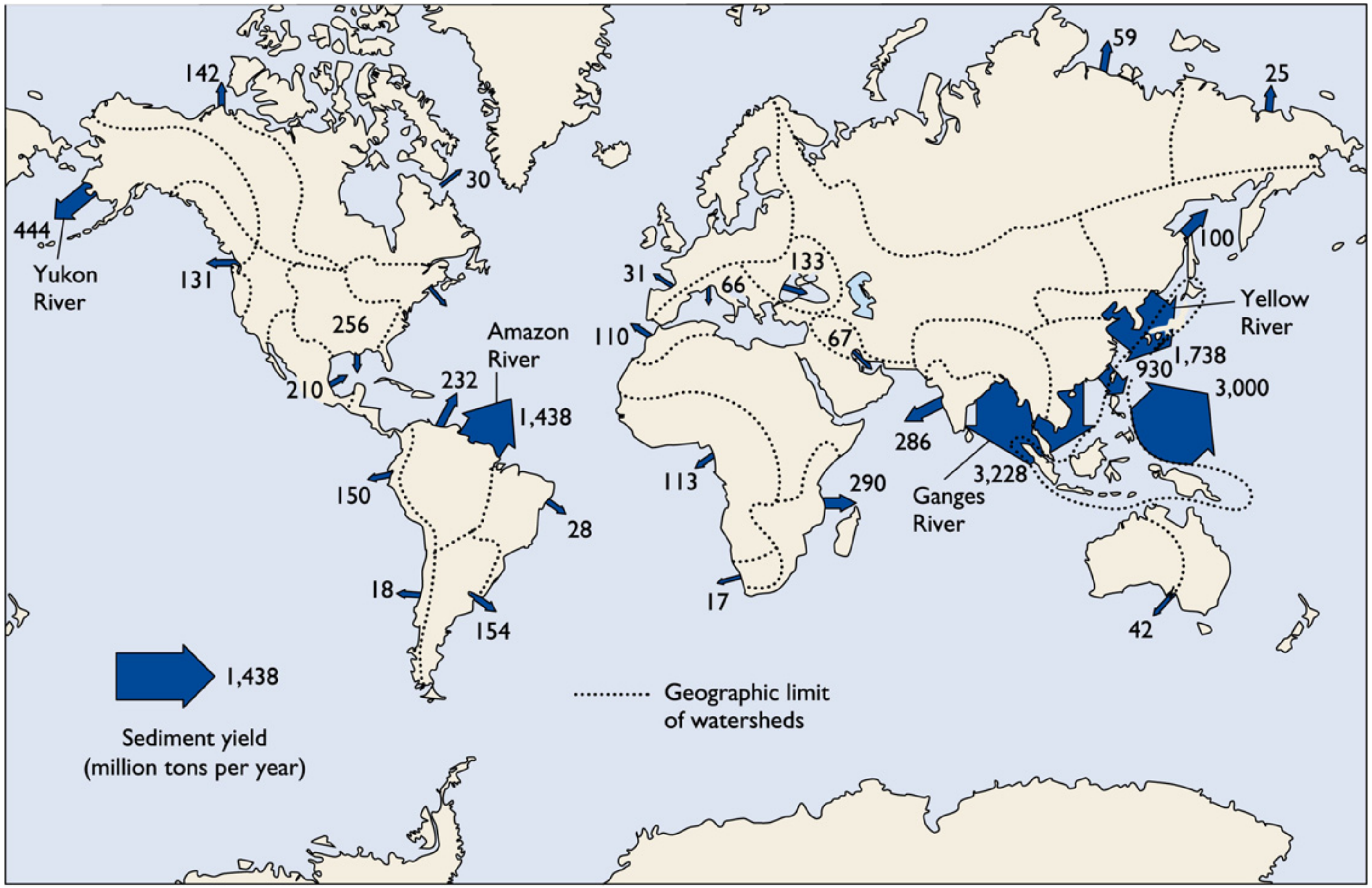
- Authigenic (hydrogenous) – inorganic precipitation of dissolved components seawater becomes supersaturated with regard to some chemicals

- Cosmogenic – from outside Earth meteorites, usually very small (tektites)

Terrigenous sediments (from land)

- Rivers
- Winds (eolian)
- Glaciers (ice-rafted debris, IRD)
- Turbidites
- Sea level changes

River sediment loads (units 10^6 tons/yr)

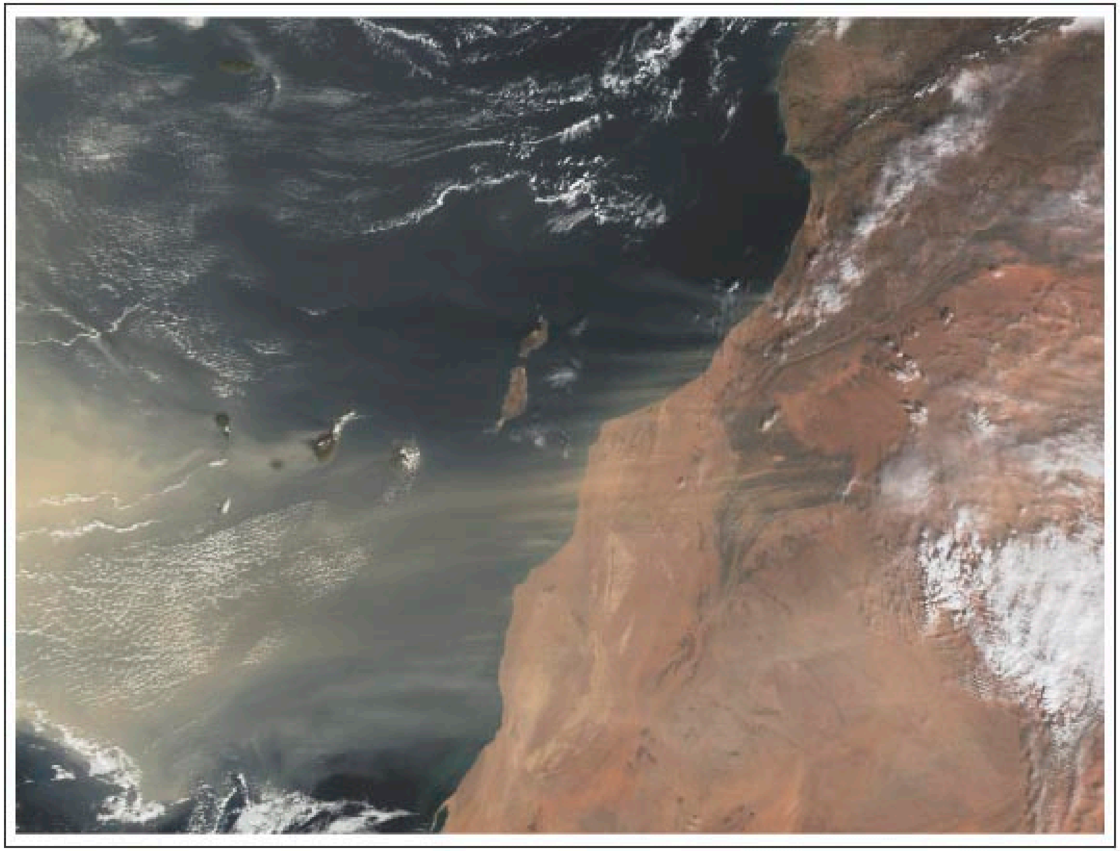


(b) RIVER INPUT OF SILT TO OCEANS

Wind transport of sediment

This satellite image reveals the presence of dust plumes stretching from Africa into the Atlantic Ocean.

Figure 4.B4-4a



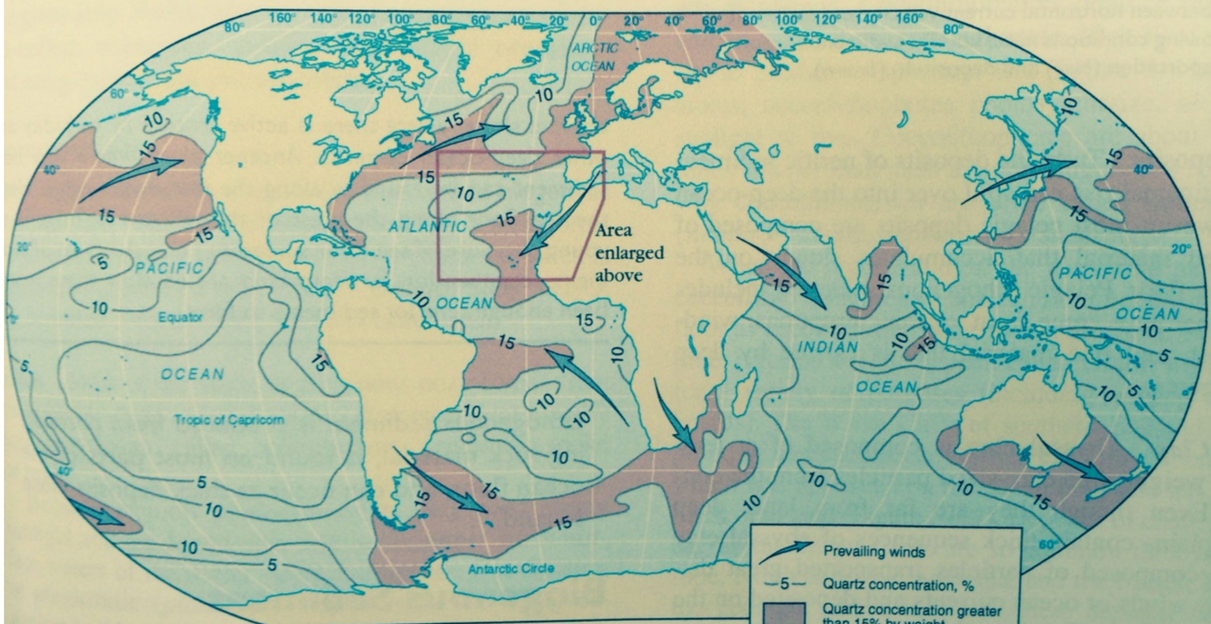
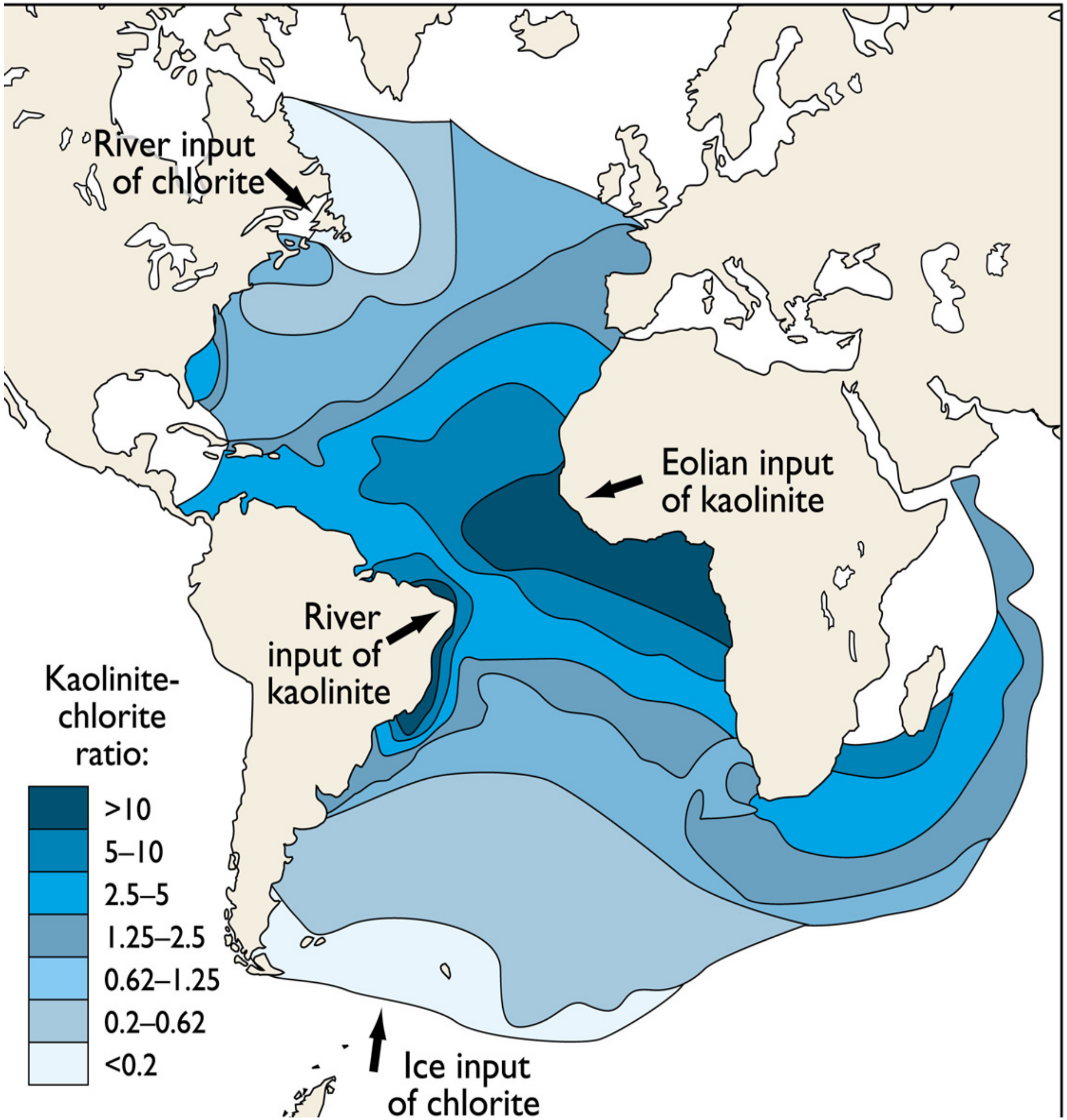
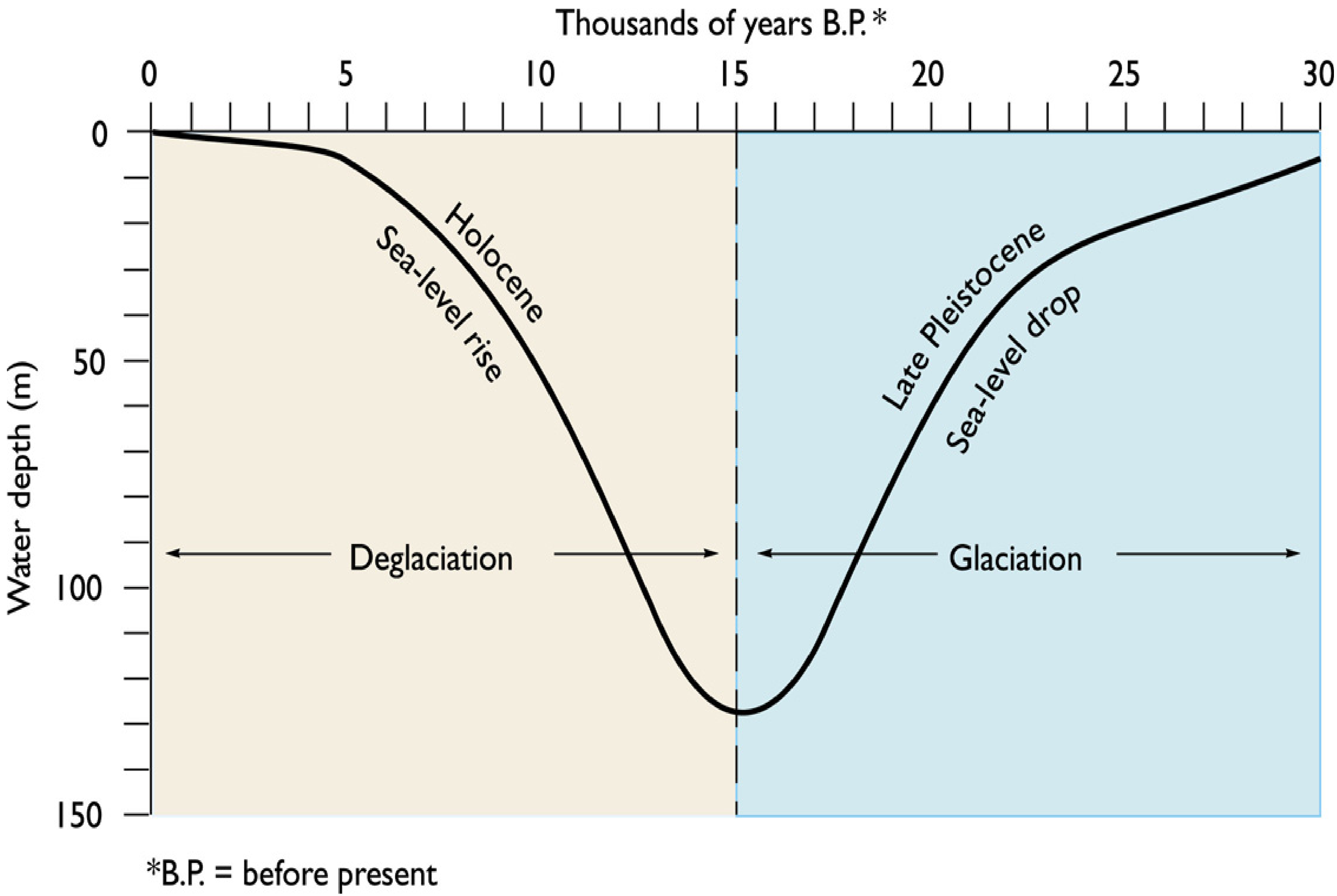


Figure 5–7 Lithogenous quartz in surface sediments of the world's oceans.

High concentrations of microscopic lithogenous quartz in deep-sea sediment match prevailing winds from land (*arrows*). SeaStar SeaWiFS satellite photo (*inset*) on February 26, 2000, shows a Sahara dust storm off the northwest coast of Africa that has spread out for 1000 miles (1600 kilometers) across the Atlantic Ocean.

TABLE 5–2 **Wentworth scale of grain size for sediments**


River input of chlorite
Eolian input of kaolinite
River input of kaolinite
Kaolinite-chlorite ratio:
>10
5–10
2.5–5
1.25–2.5
0.62–1.25
0.2–0.62
<0.2
Ice input of chlorite

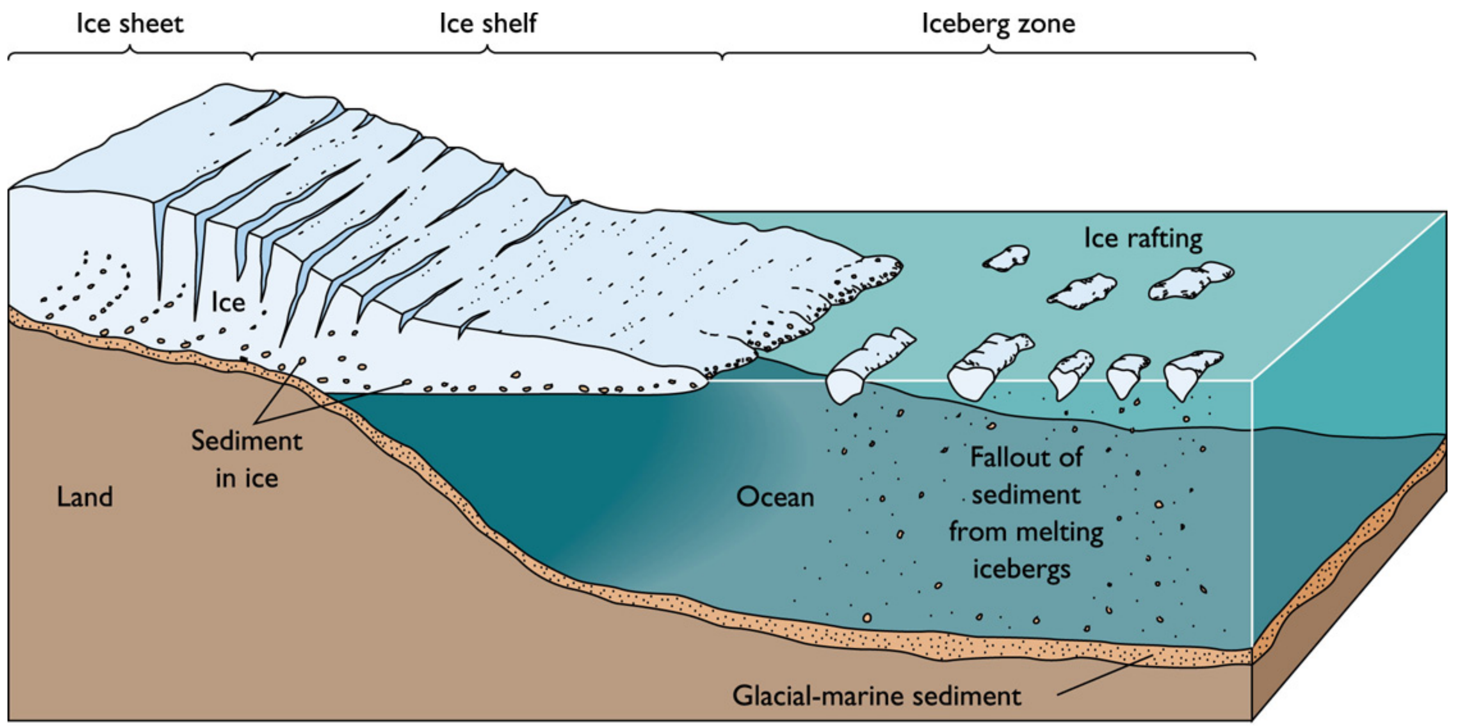


(b) POSITION OF SEA LEVEL FOR PAST 30,000 YEARS

Sea Level Changes

(a) COASTLINES PAST AND FUTURE

Glacial (Ice-rafted debris)

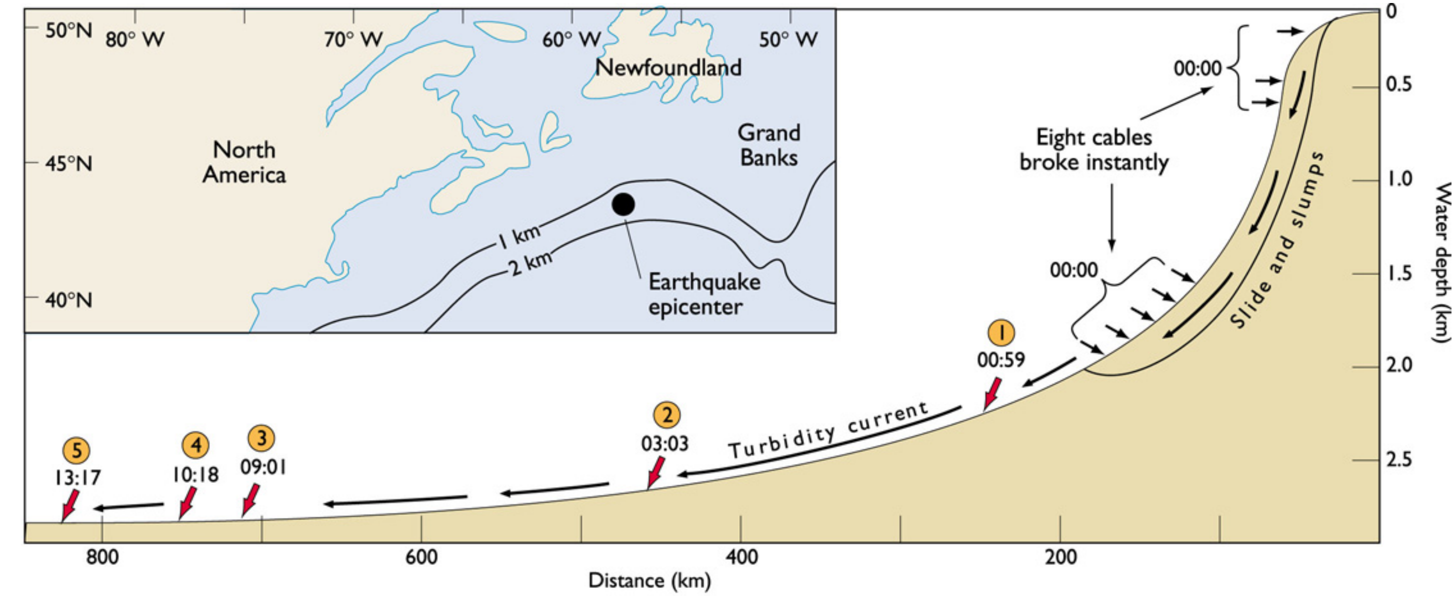


(a) ICE RAFTING

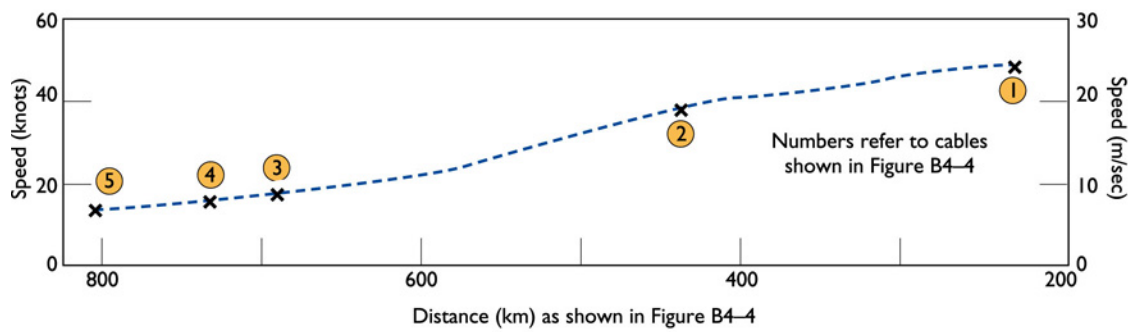
Turbidites

- Rapidly-accumulated terrestrial sediments
- Earthquake-triggered submarine avalanches
- High velocity (~50 mph!), erosive events
- Good examples preserved on Mary's Peak

Turbidites
(submarine avalanches)



(a) GRAND BANKS EARTHQUAKE (NOVEMBER 1929)



(b) SPEED OF TURBIDITY CURRENT

Classification of marine sediments based upon *size*

Sediment	Type	Diameter (mm)
Gravel	Boulder	>256
	Cobble	65-256
	Pebble	4-64
	Granule	2-4
Sand	Very coarse	1-2
	Coarse	0.5-1
	Medium	0.25-0.5
	Fine	0.123-0.25
	Very fine	0.0625-0.125
Mud (silt & clay)		0.0002-0.004
Colloid		<0.0002

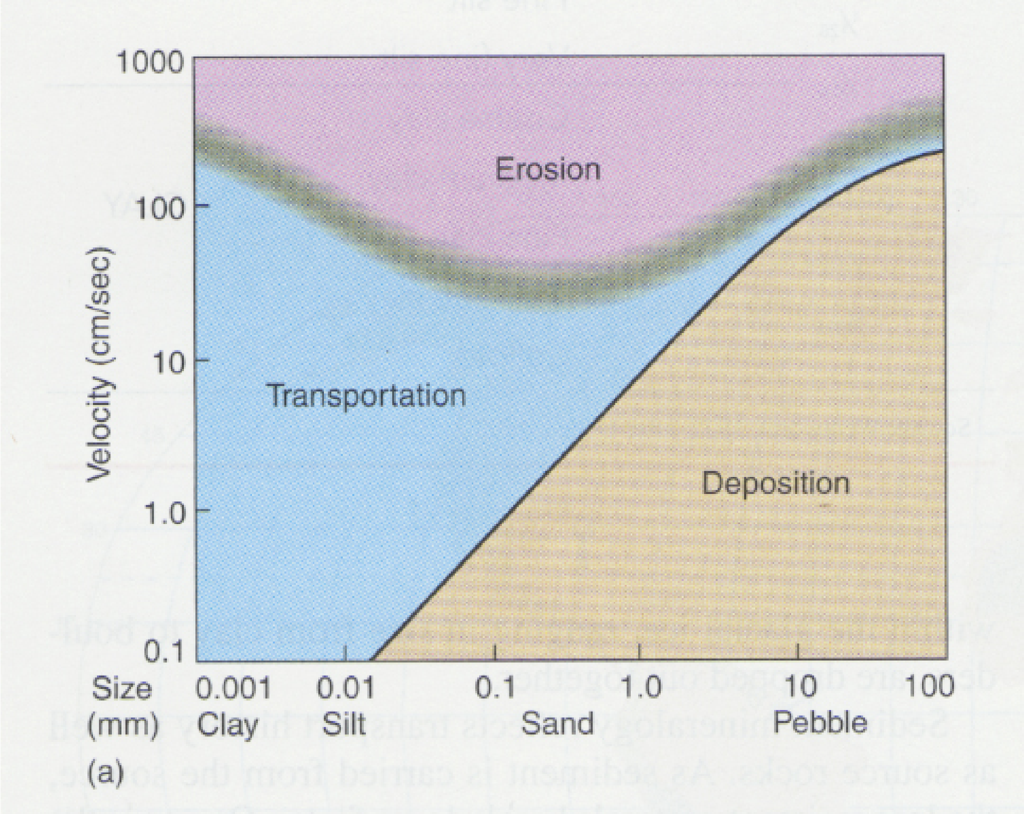
Classifications

- By Size
  Clay -- Silt -- Sand -- Pebble -- Cobble

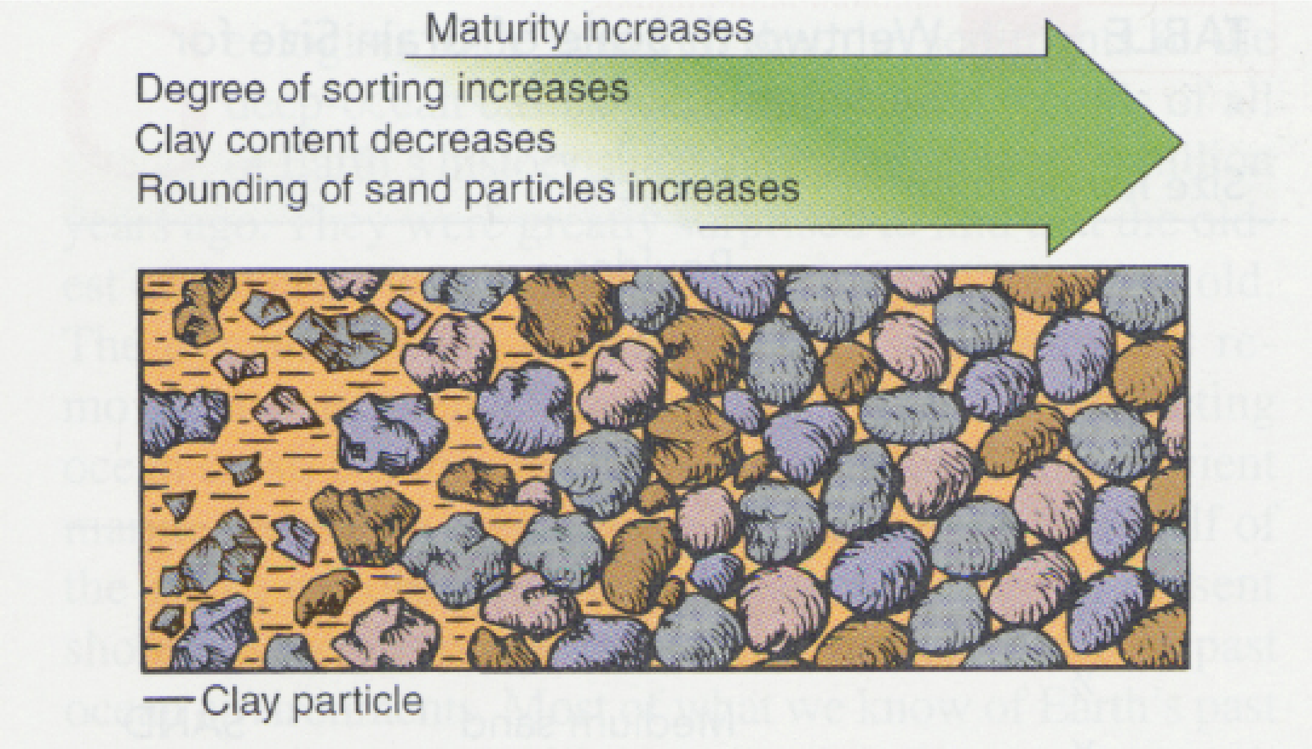
  0.001 mm 1 mm 100 mm
- Effects of water velocity on transport: rivers and near-shore vs open ocean

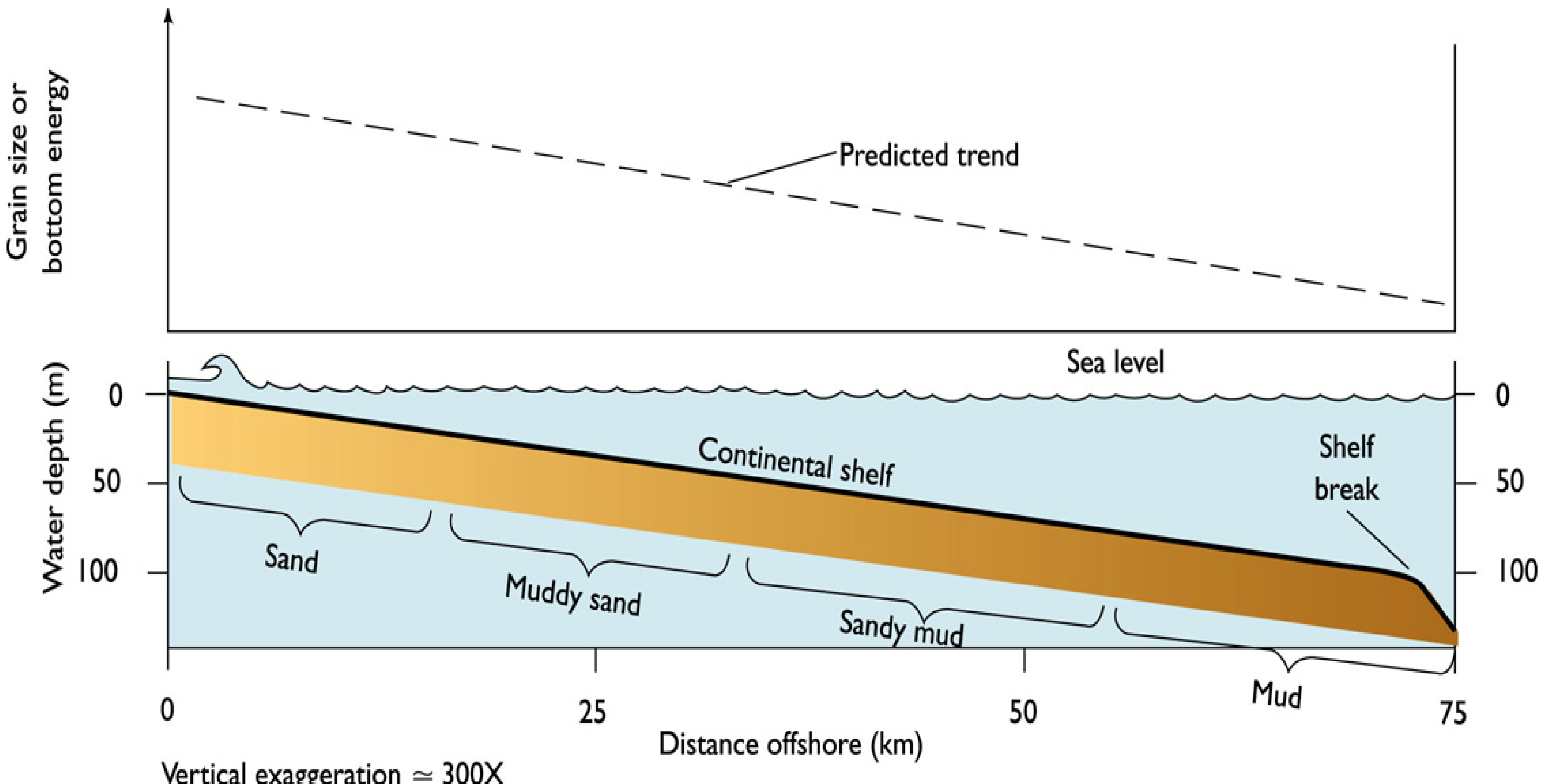
Sediment Transport

- Fluid velocity determines the size of the particles that can be moved



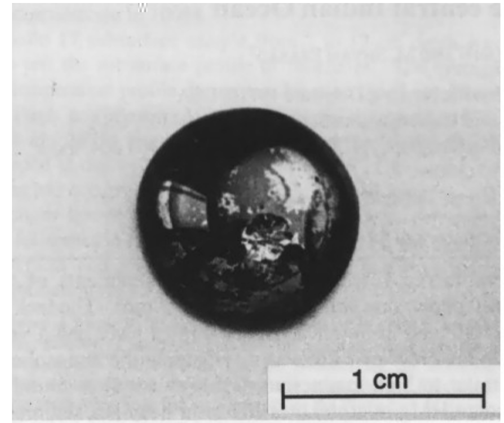
Size Sorting

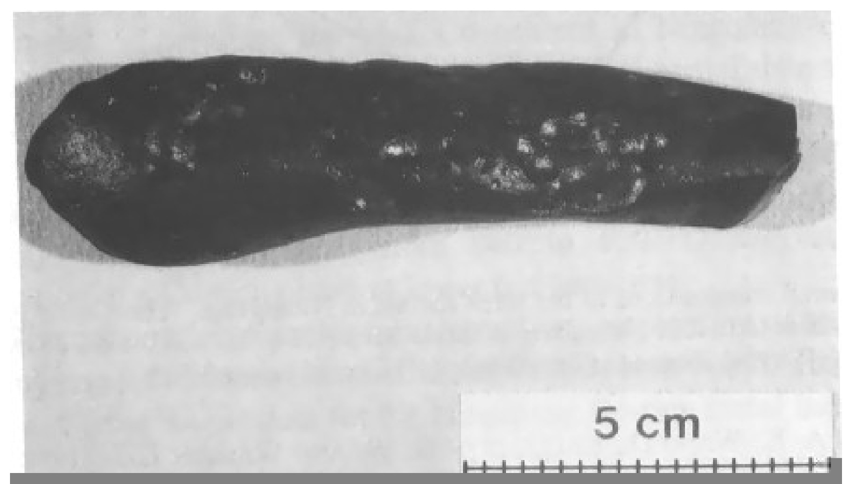




(a) MODEL PREDICTION OF SHELF SEDIMENTS

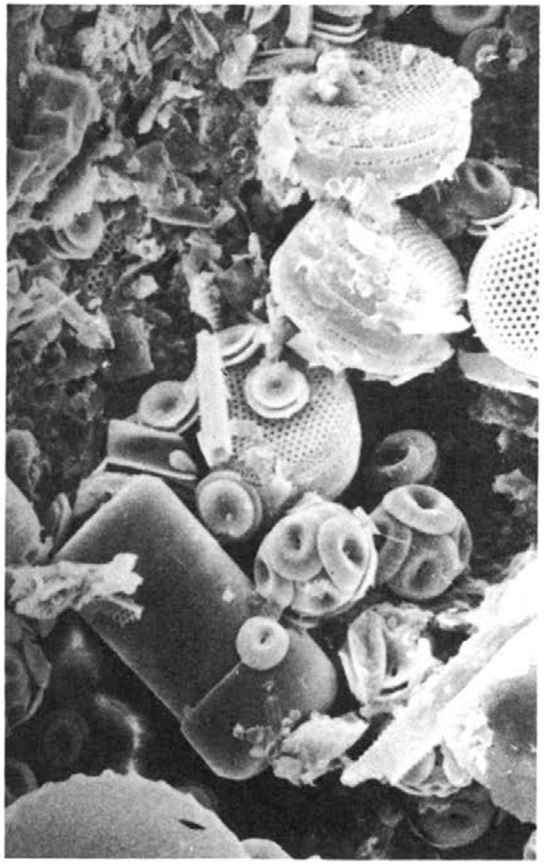
- **Cosmogenous Sediments:**
- sediments derived from extraterrestrial materials
- includes micrometeorites and tektites
- tektites result from collisions with extraterrestrial materials
  - fragments of earth's crust melt and spray outward from impact crater
  - crustal material re-melts as it falls back through the atmosphere
  - forms 'glassy' tektites

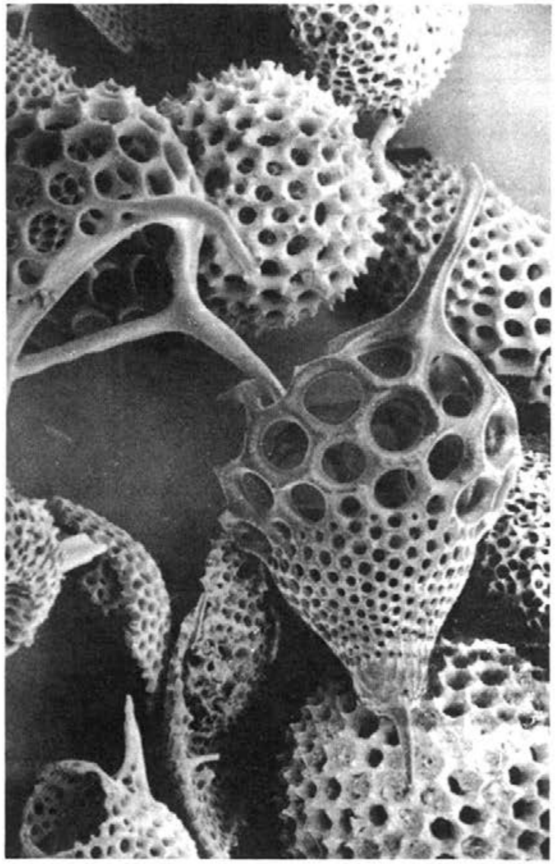




Biogenic Sediments, microscopic in size

(single-celled plants and animals)

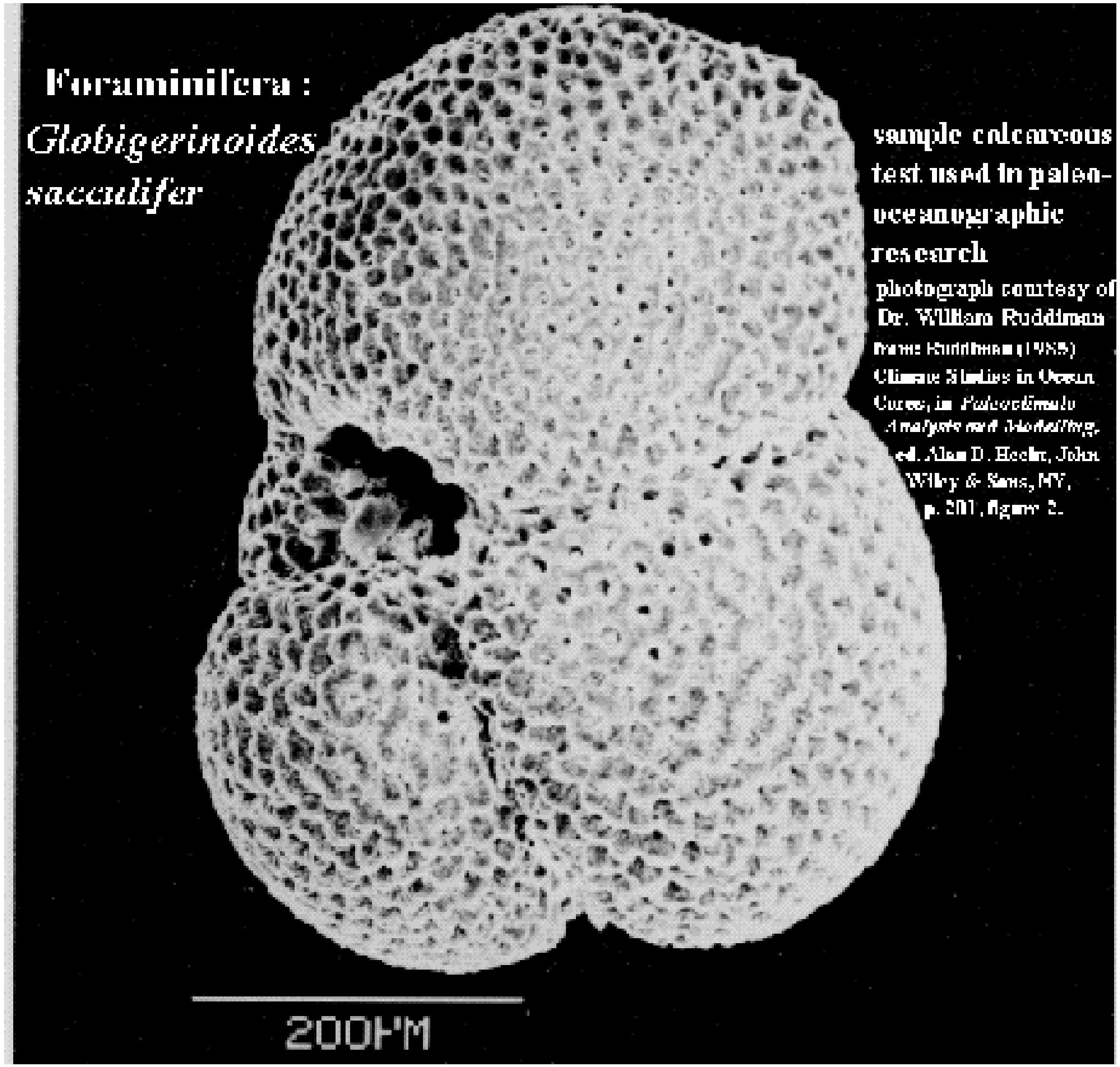




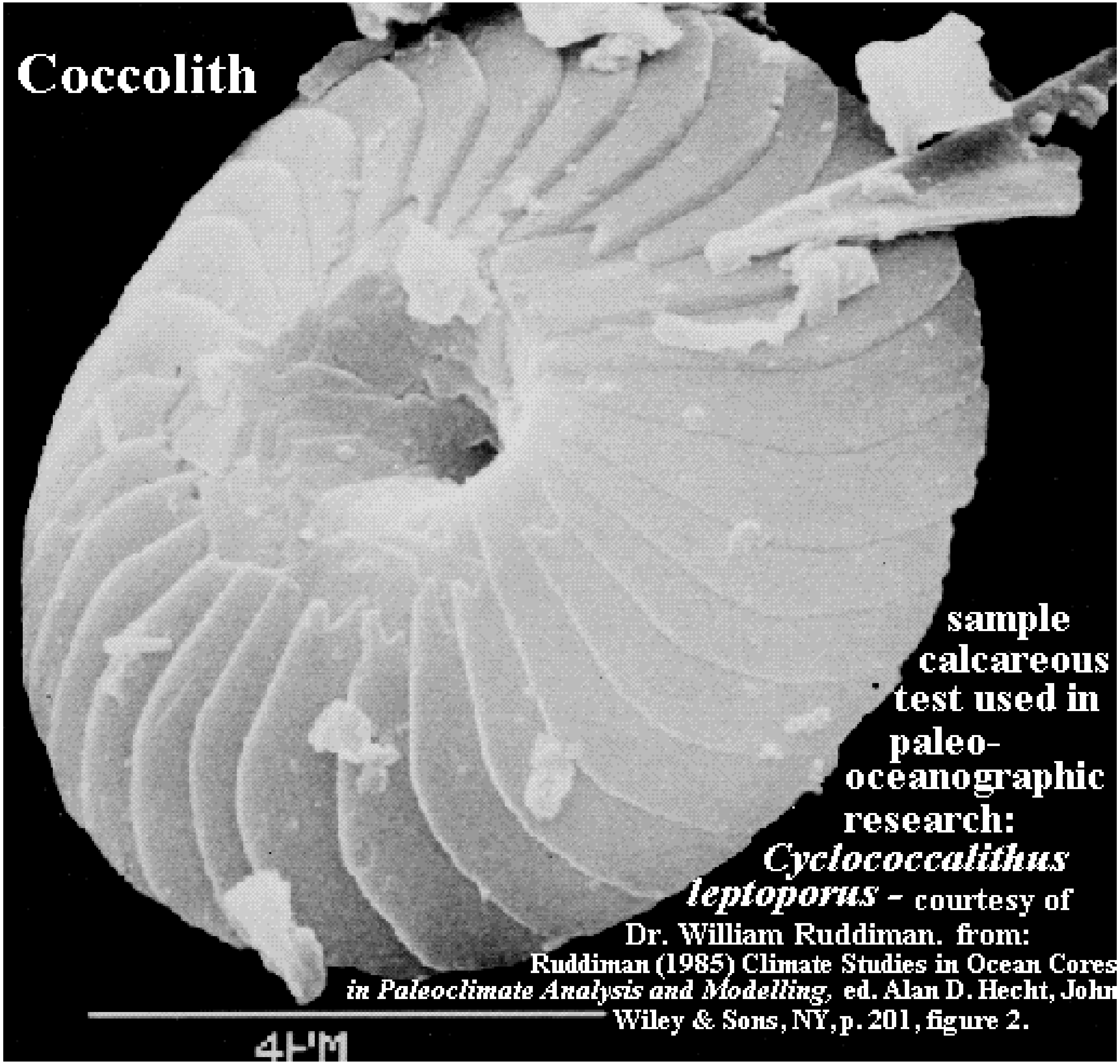
Biogenous sediments (from living things)

- ☞ Calcareous ($CaCO_3$)
  - Foraminifera -- animals
  - Coccolithophores -- plants
- ☞ Siliceous (SiO_2)
  - Radiolaria -- animals
  - Diatoms -- plants

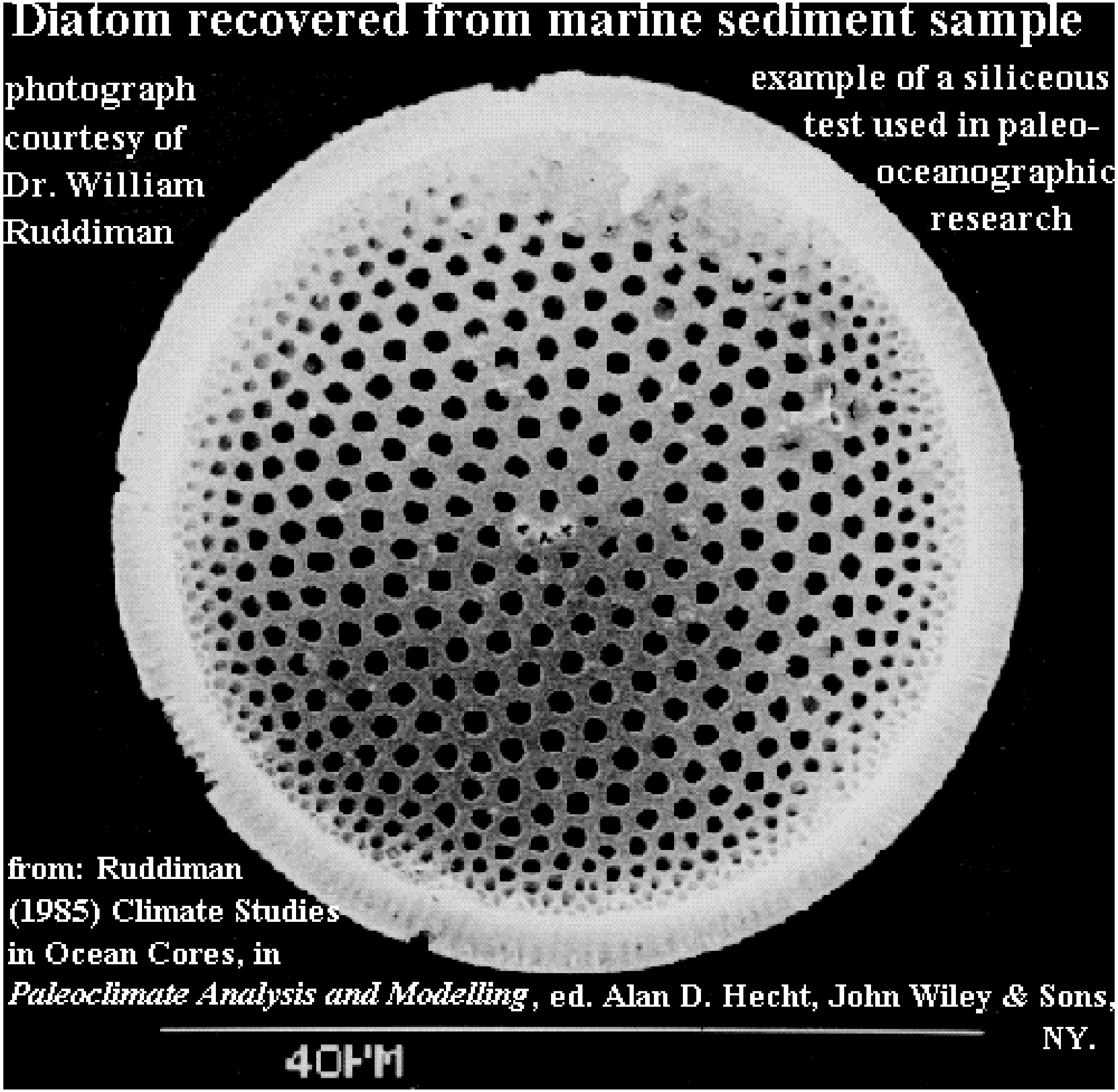
μm = micron = millionth of a meter!



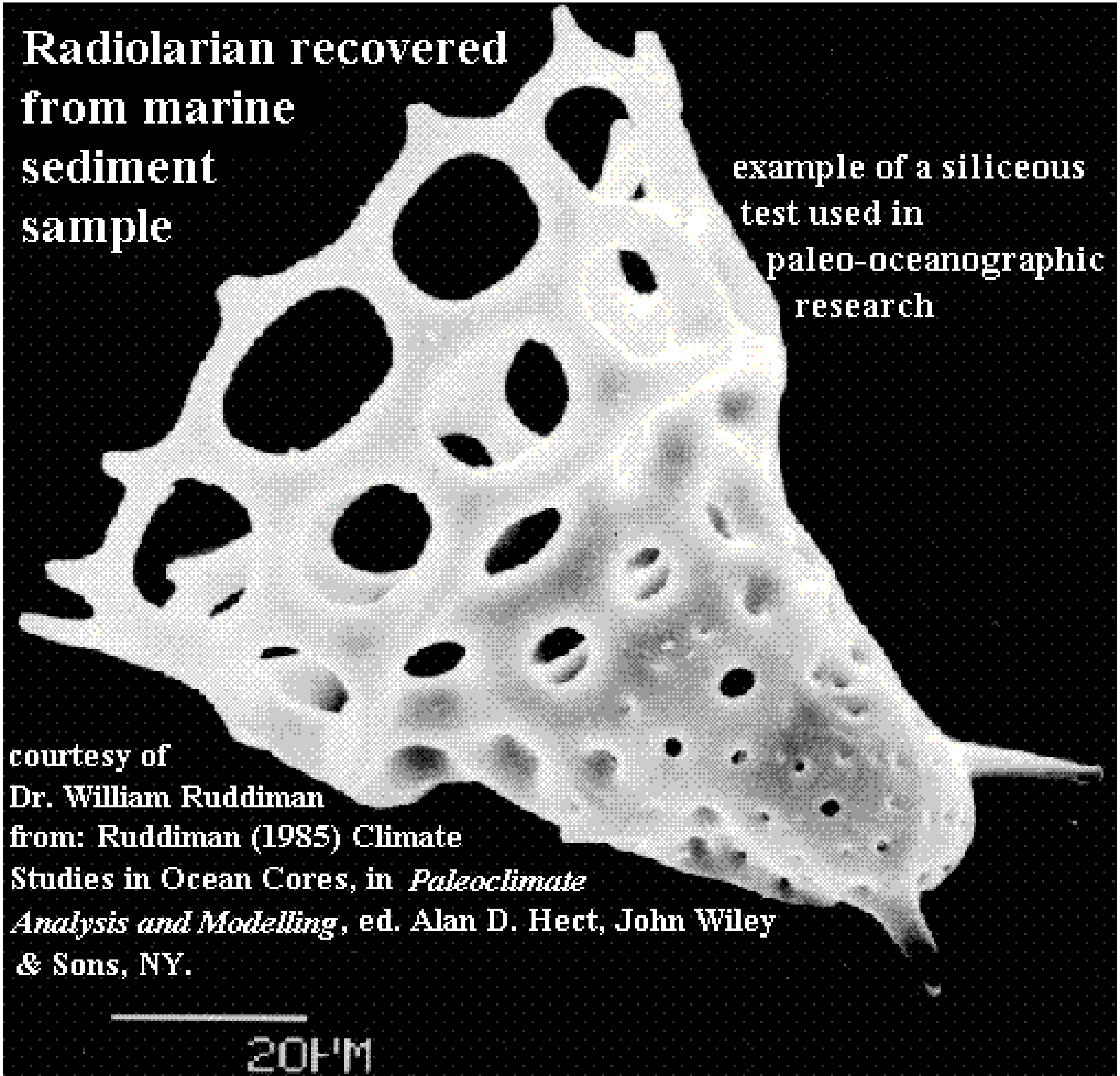
μm = micron = millionth of a meter!



μm = micron = millionth of a meter!

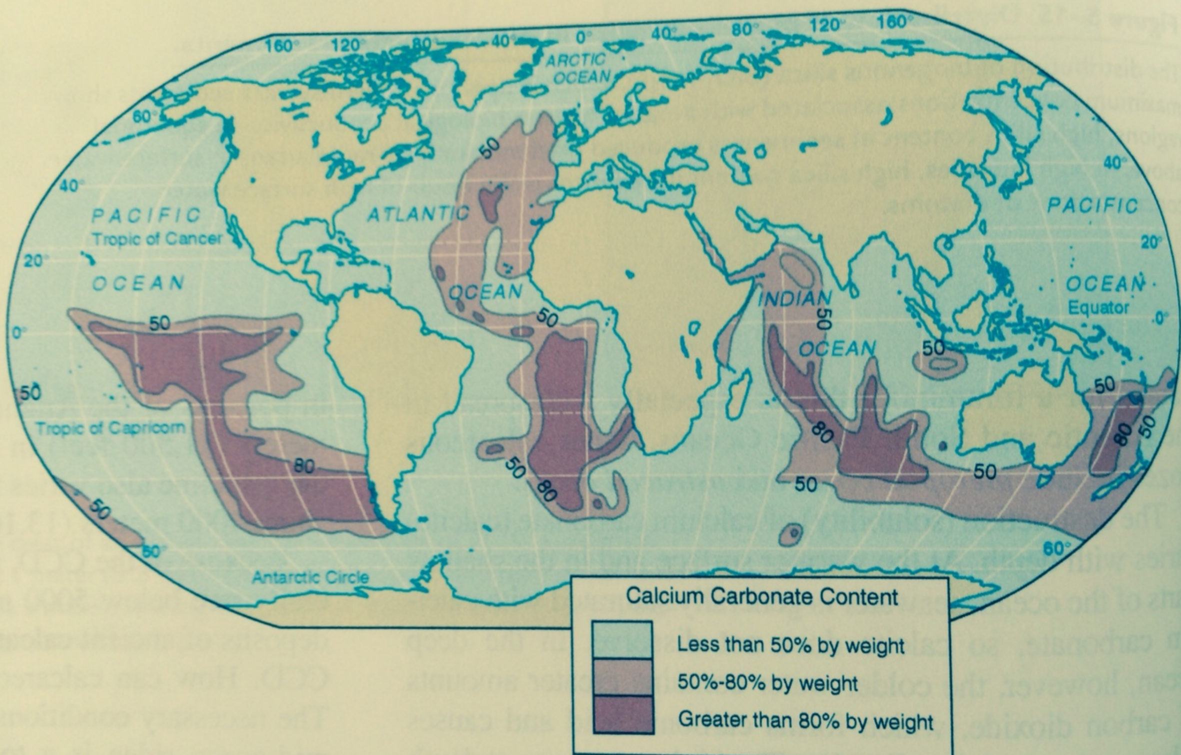


μm = micron = millionth of a meter!



Calcium carbonate distribution

ensation depth, the mid-ocean ridge, ...
w calcareous ooze to be preserved below the CCD.



Relationships among carbonate compensatio...
productivity, and destruction that allow calca...

Figure 5–17 Distribution of calcium carbonate in modern surface sediments.

The distribution of calcium carbonate ($CaCO_3$) in modern surface sediments shows that high percentages of calcareous ooze closely follow the mid-ocean ridge, which is above the CCD.

Silicate distribution

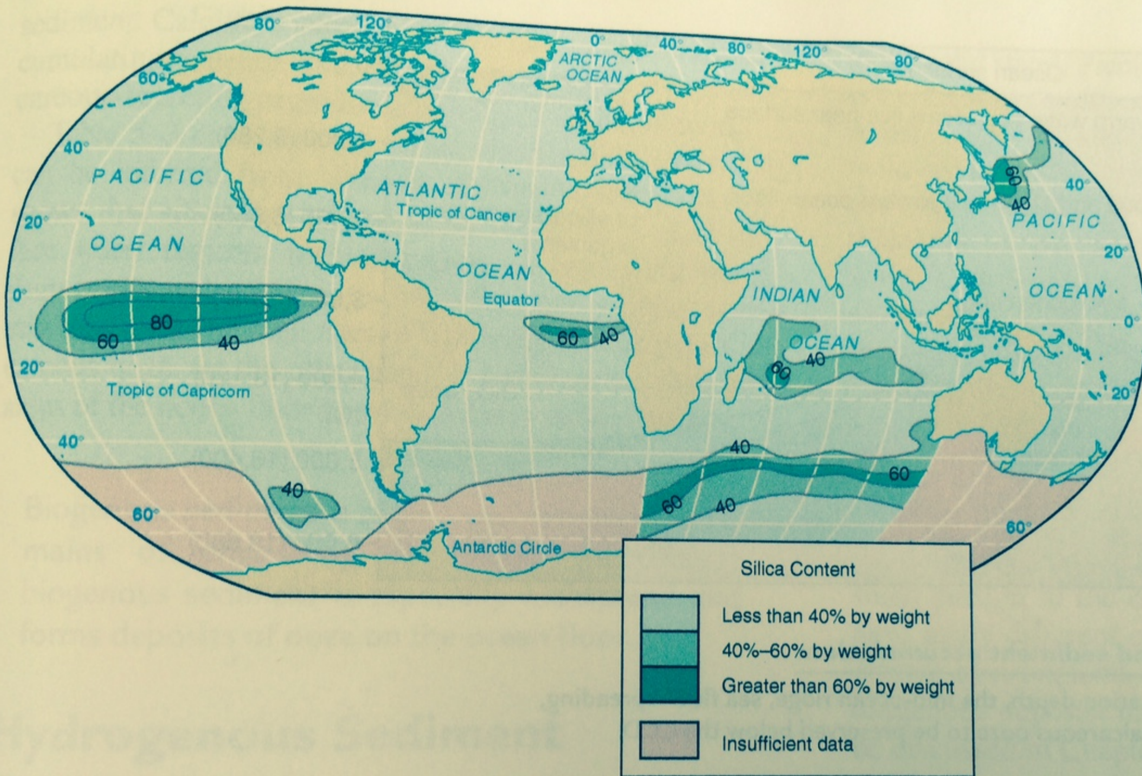
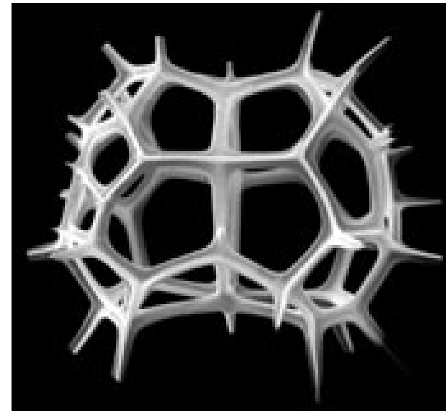
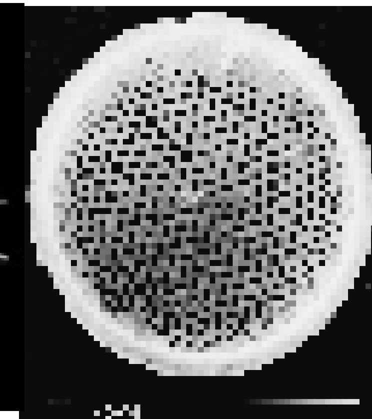


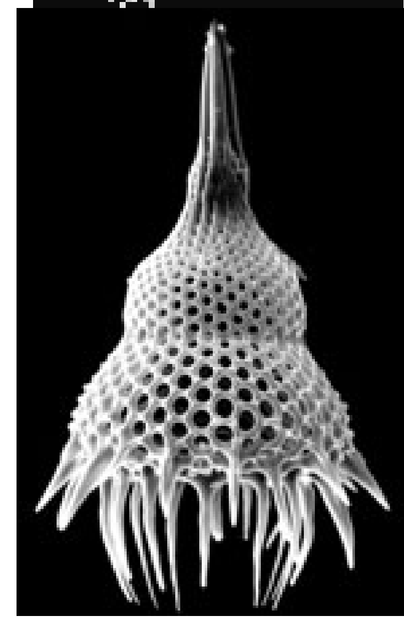
Figure 5–15 Distribution of biogenous silica in modern surface sediments.

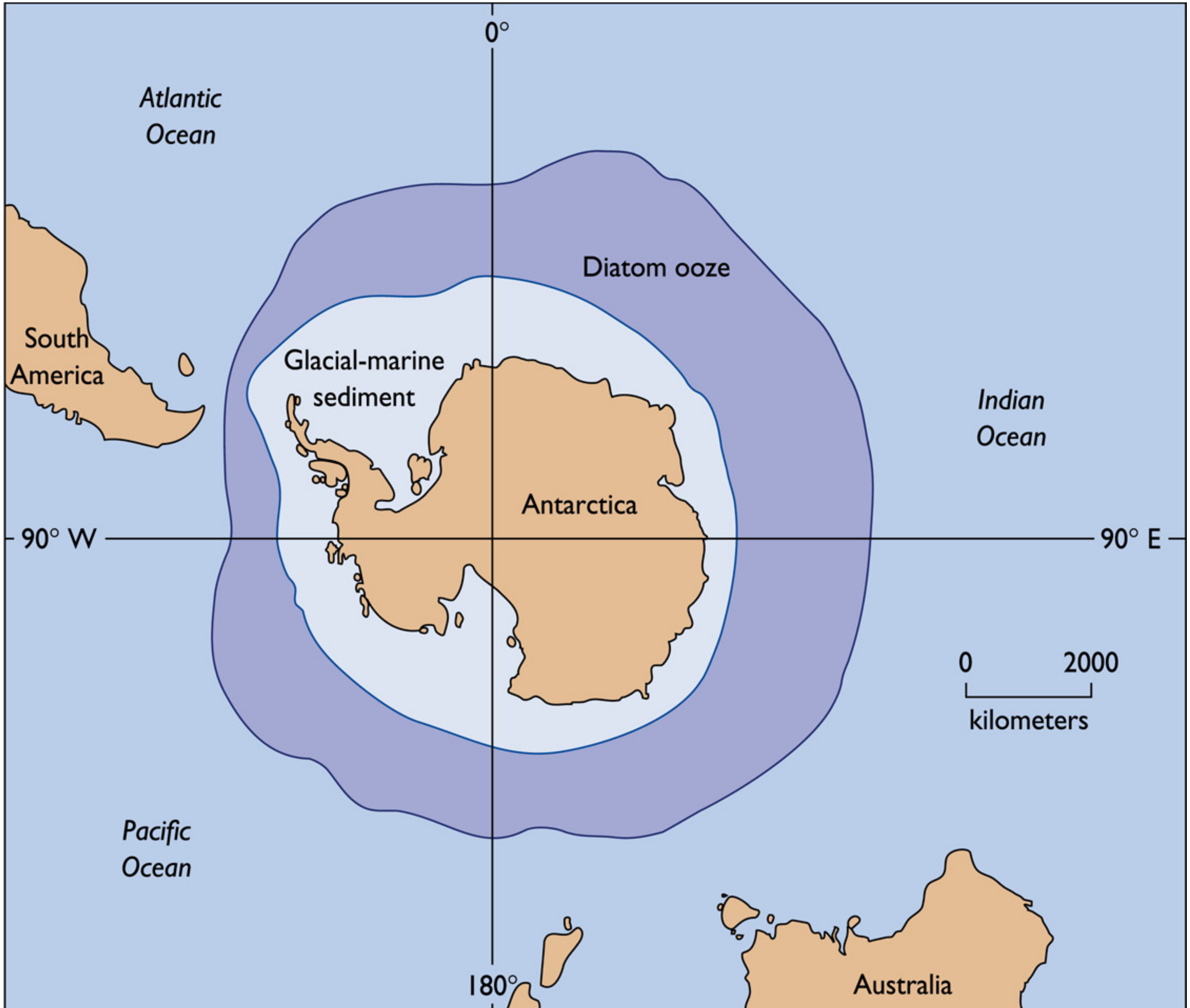
The distribution of biogenous silica ($SiO_2 \cdot nH_2O$, which is opal) in modern surface sediments shows maximum concentrations associated with areas of highest biological productivity. In equatorial regions, high silica content in sediment is produced predominantly by radiolarians in surface waters above; in high latitudes, high silica content in sediment is the result of high surface water concentrations of diatoms.

- siliceous oozes (primarily diatom oozes) cover ~15% of the ocean floor
  - distribution mirrors regions of high productivity
  - common at high latitudes, and zones of upwelling
  - radiolarian oozes more common in equatorial regions









(b) DEEP-SEA DEPOSITS AROUND ANTARCTICA

Accumulation Rates for Oozes

☞ *Productivity*

- reproduction of planktonic organisms

☞ *Preservation*

- silica dissolves only very slowly
- calcium carbonate varies with depth

☞ *Rates* are variable: <1 to 15mm/1000 yr

Productivity = skeletons and soft tissue

- Accumulation depends on production and preservation
- SiO_2 is preserved everywhere
- $CaCO_3$ is variable, depending on P, T, pH

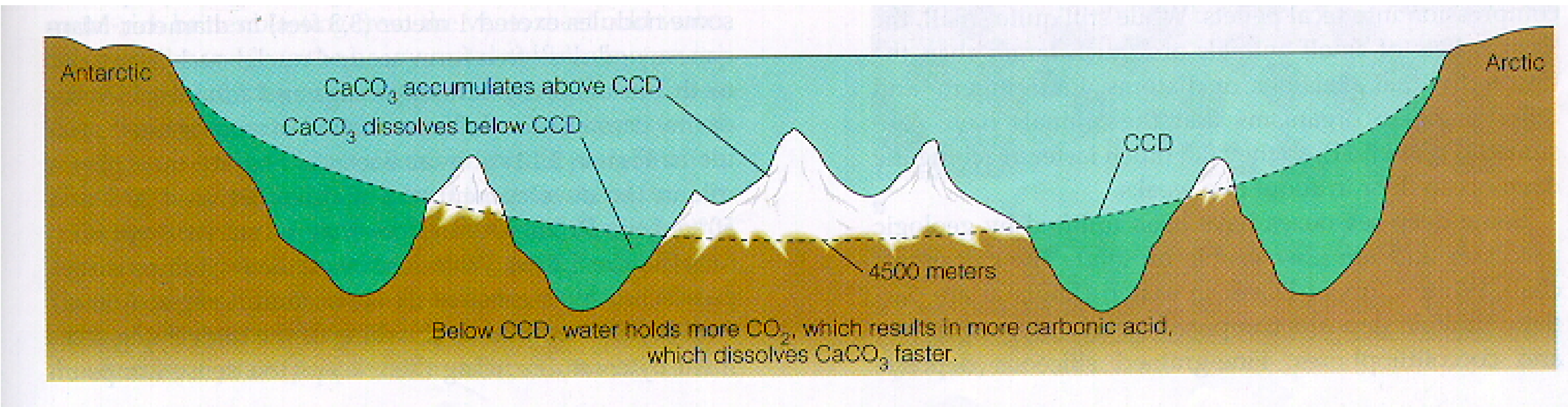
Carbonate Compensation Depth

- The depth at which carbonate input from the surface waters is balanced by dissolution in corrosive deep waters
- In today's ocean this depth (CCD) varies between 3 km (polar) and 5 km (tropical)
- Thus, accumulation rates vary a lot!

Carbonate Compensation Depth

South

North



Carbonate Chemistry

- $CaCO_3$ (calcite) is a solid material produced by biological or abiological processes in seawater:

$$Ca^{2+} + CO_3^{2-} \rightleftharpoons CaCO_3$$

  - The reaction can go both ways, depending on the pH, pressure.
  - When the seawater is undersaturated with respect to $CaCO_3$, calcite will dissolve:

$$Ca^{2+} + CO_3^{2-} \longleftarrow CaCO_3$$

  - But when seawater is saturated with respect to $CaCO_3$, calcite will remain in its solid form and not dissolve:

- calcareous oozes (foraminifera, coccolithophores) cover ~50% of the ocean floor
  - distribution controlled largely by dissolution processes
  - cold, deep waters are undersaturated with respect to $CaCO_3$
  - deep water is slightly acidic as a result of elevated CO_2 concentrations
  - solubility of $CaCO_3$ also increases in colder water and at greater pressures (**lysocline**)
  - $CaCO_3$ therefore readily dissolved at depth
- level below which no $CaCO_3$ is preserved is the '**carbonate compensation depth (CCD)**'
- typically occurs at a depth of 3000 to 4000 m

Carbonate Compensation Depth, CCD

- Depth in ocean at which seawater becomes *undersaturated* with respect to calcite and rate of dissolution of $CaCO_3$ equals its rate of delivery.
  - CCD ~ 4500 m (or deeper in regions of high surface productivity).

  - Depths below CCD:
    - Seawater undersaturated w.r.t. $CaCO_3$
    - Chemical properties of deep water dissolves calcite
    - $CaCO_3$ oozes less common than SiO_2 oozes.

  - Depths above CCD:
    - Seawater saturated w.r.t. $CaCO_3$
    - $CaCO_3$ remains intact.
    - $CaCO_3$ oozes more common than SiO_2 oozes.

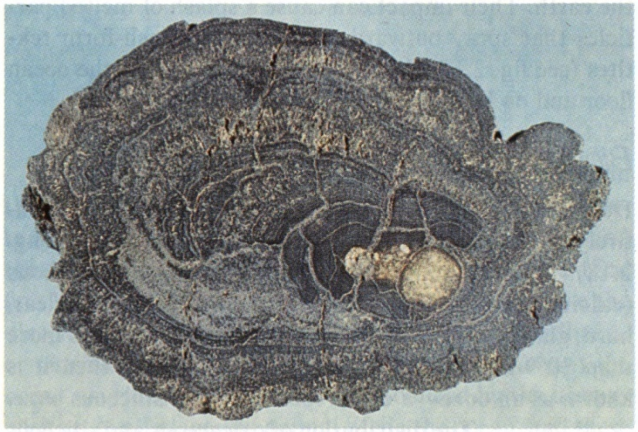
Hydrogenous (from sea water)

- ☞ Metalliferous sediments at spreading ridges -- "black smokers"
- ☞ Manganese nodules
- ☞ Evaporites -- Salt deposits

Authigenic Sediments

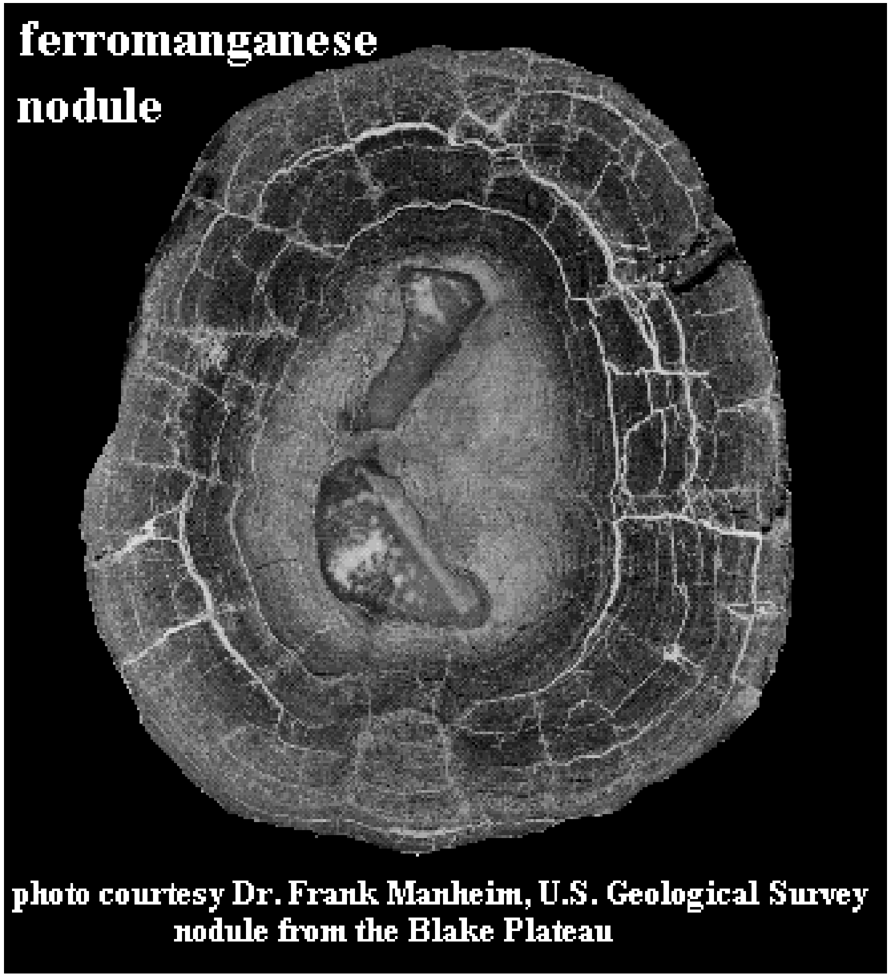
(manganese nodules)

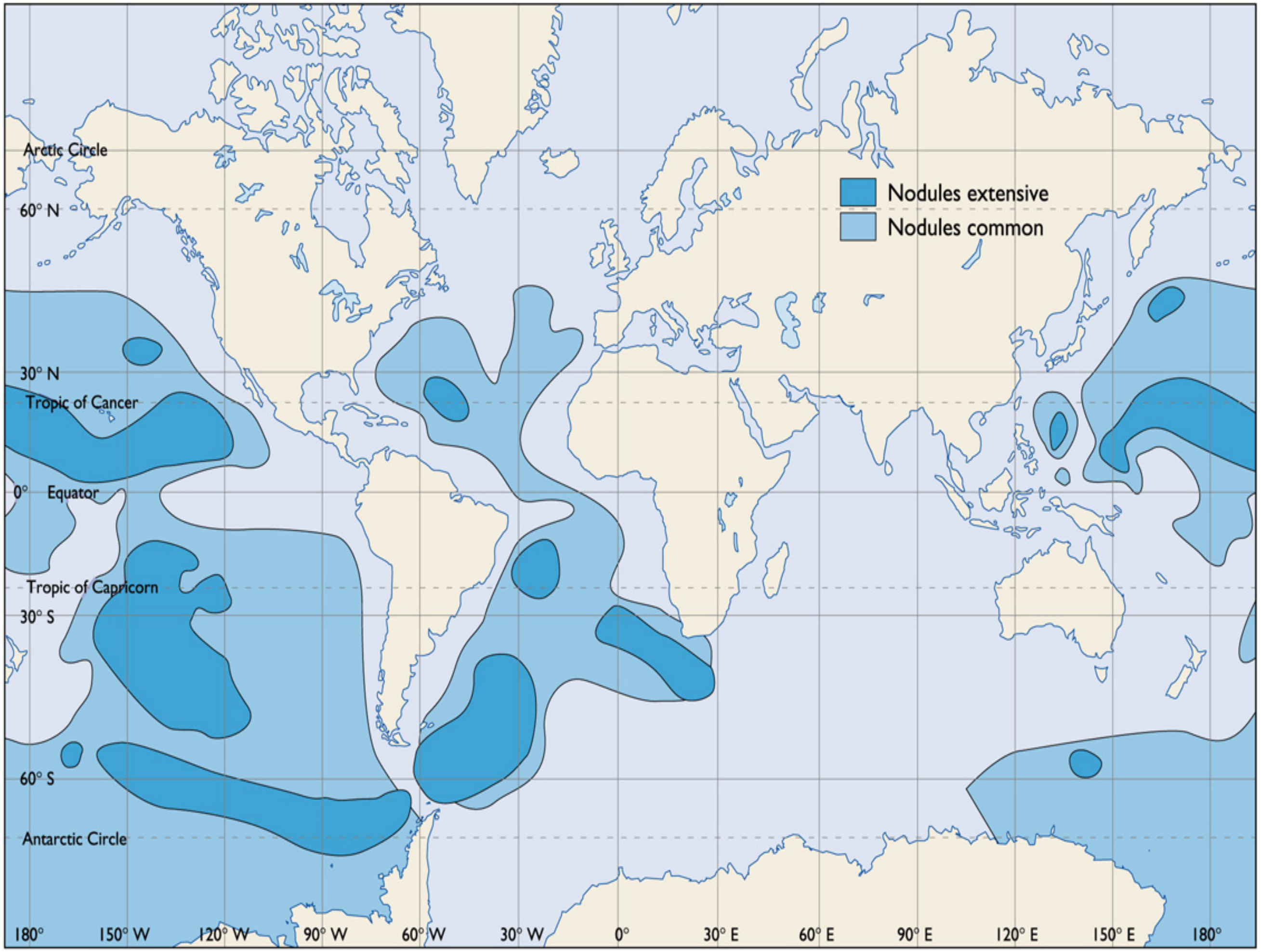
and red clay



- **Hydrogenous (or Authigenic) Sediments:**
- produced by chemical processes in seawater
- essentially solid chemical precipitates of several common forms
- non-biogenous carbonates
  - form in surface waters supersaturated with calcium carbonate
  - common forms include short aragonite crystals and oolites
- phosphorites
  - phosphate crusts (containing greater than 30% P_2O_5) occurring as nodules
  - formed as large quantities of organic phosphorous settle to the ocean floor
  - unoxidized material is transformed to phosphorite deposits
  - found on continental shelf and upper slope in regions of high productivity

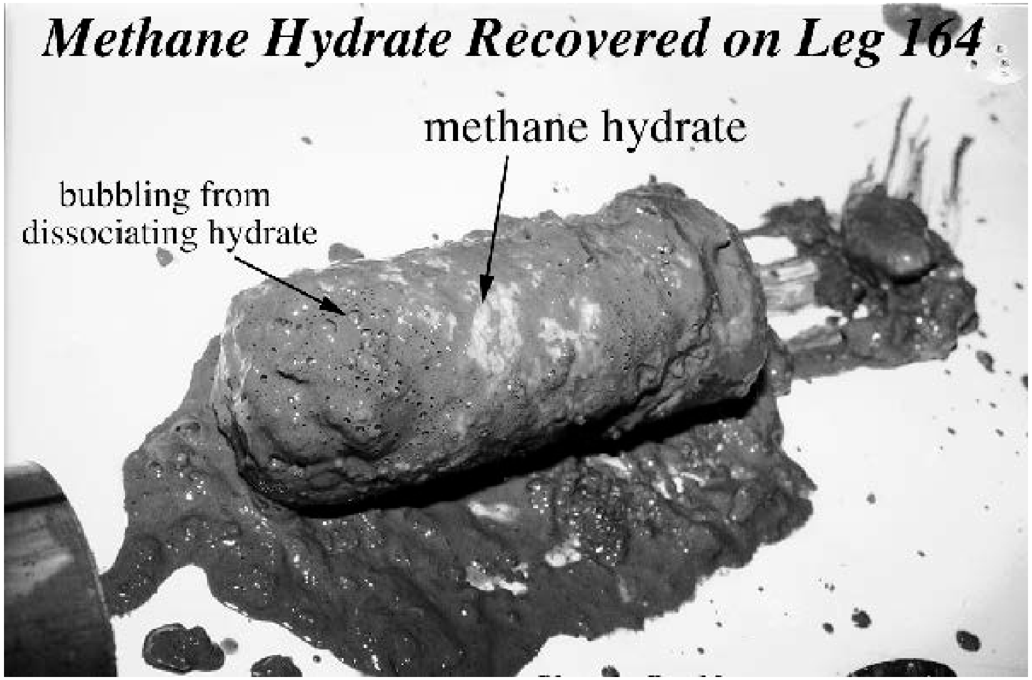
baseball to bowling ball size!



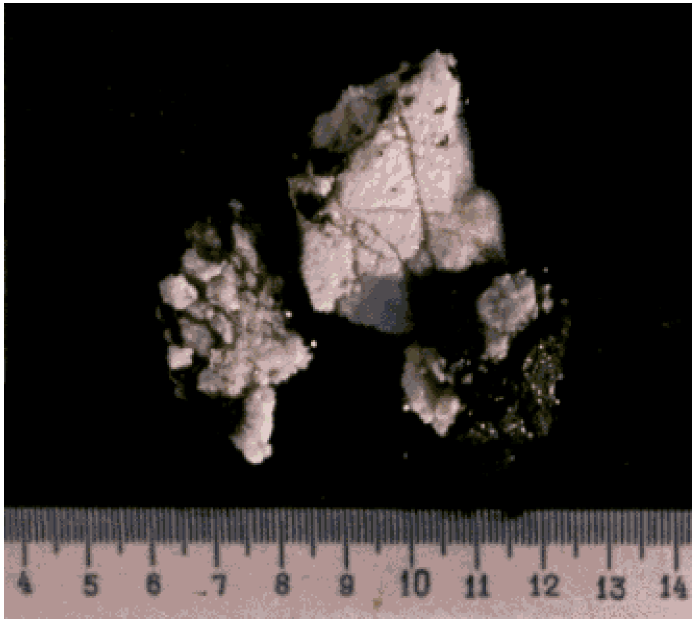


(b) GLOBAL DISTRIBUTION OF FERROMANGANESE NODULES

- Gas Methane Hydrates (Clathrates)
- Hydrates store immense amounts of methane, with major implications for energy resources and climate, but the natural controls on hydrates and their impacts on the environment are very poorly understood



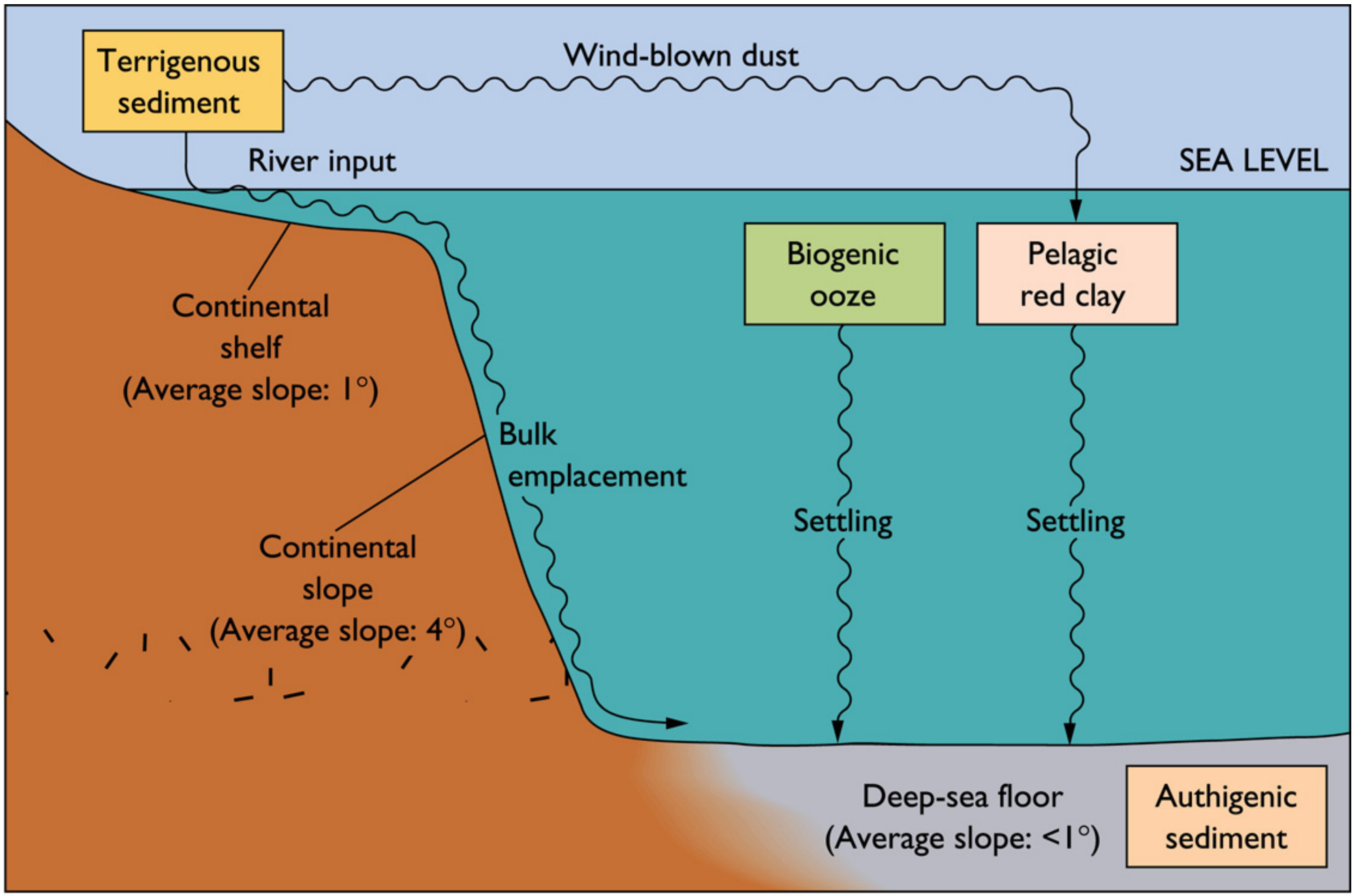
- The worldwide amounts of carbon bound in gas hydrates is conservatively estimated to total twice the amount of carbon to be found in all known fossil fuels on Earth (USGS).



- Methane bound in hydrates amounts to approximately 3,000 times the volume of methane in the atmosphere.

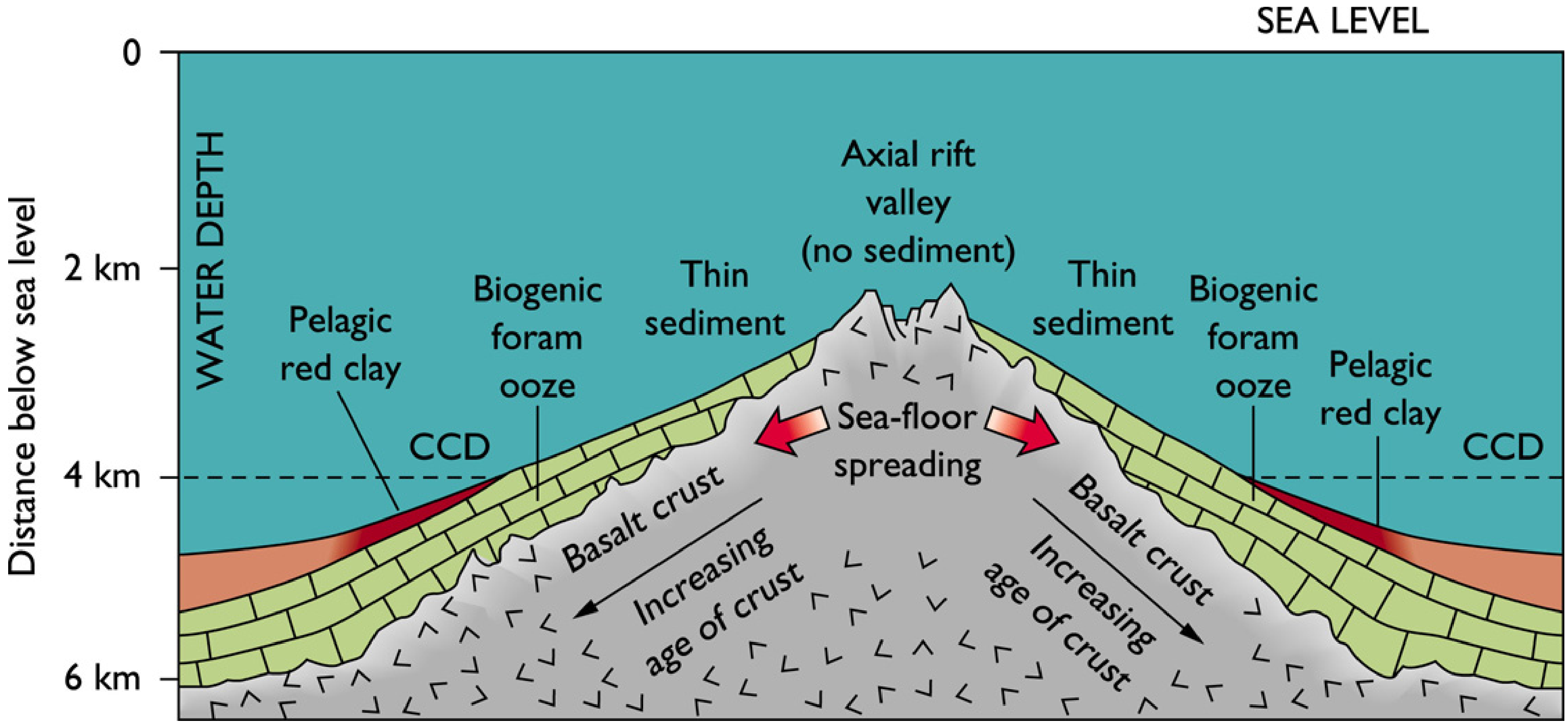

1995. 1.30
PM 5:05

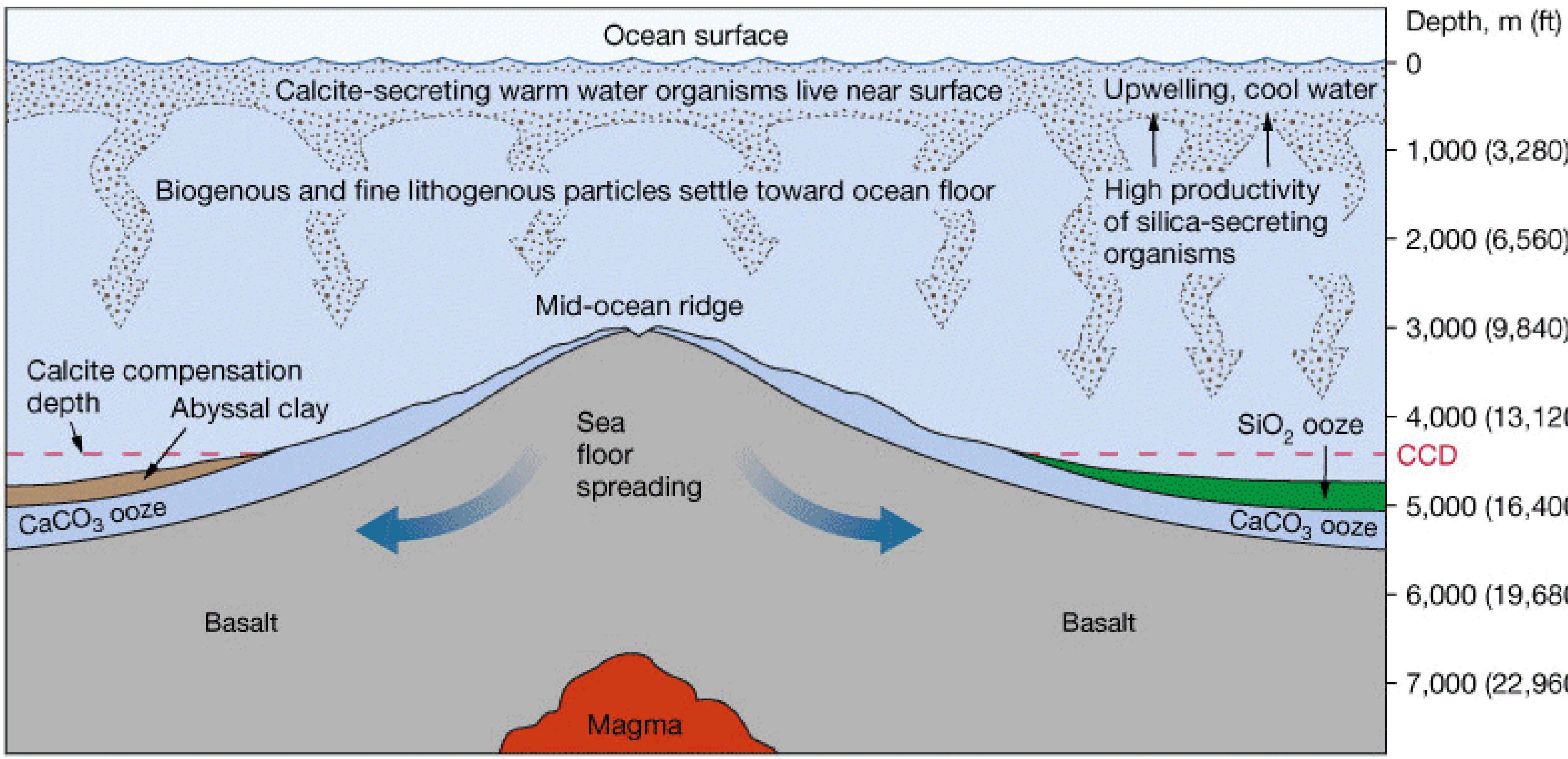
Sediment Accumulation



(a) SEDIMENTATION IN THE DEEP SEA

Sediment succession




Ocean surface
Depth, m (ft)
0
Calcite-secreting warm water organisms live near surface
Upwelling, cool water
1,000 (3,280)
Biogenous and fine lithogenous particles settle toward ocean floor
High productivity
of silica-secreting
organisms
2,000 (6,560)
Mid-ocean ridge
3,000 (9,840)
Calcite compensation
depth
Abyssal clay
Sea
floor
spreading
SiO_2 ooze
4,000 (13,120
CCD
$CaCO_3$ ooze
$CaCO_3$ ooze
5,000 (16,400
6,000 (19,680
Basalt
Basalt
7,000 (22,960
Magma

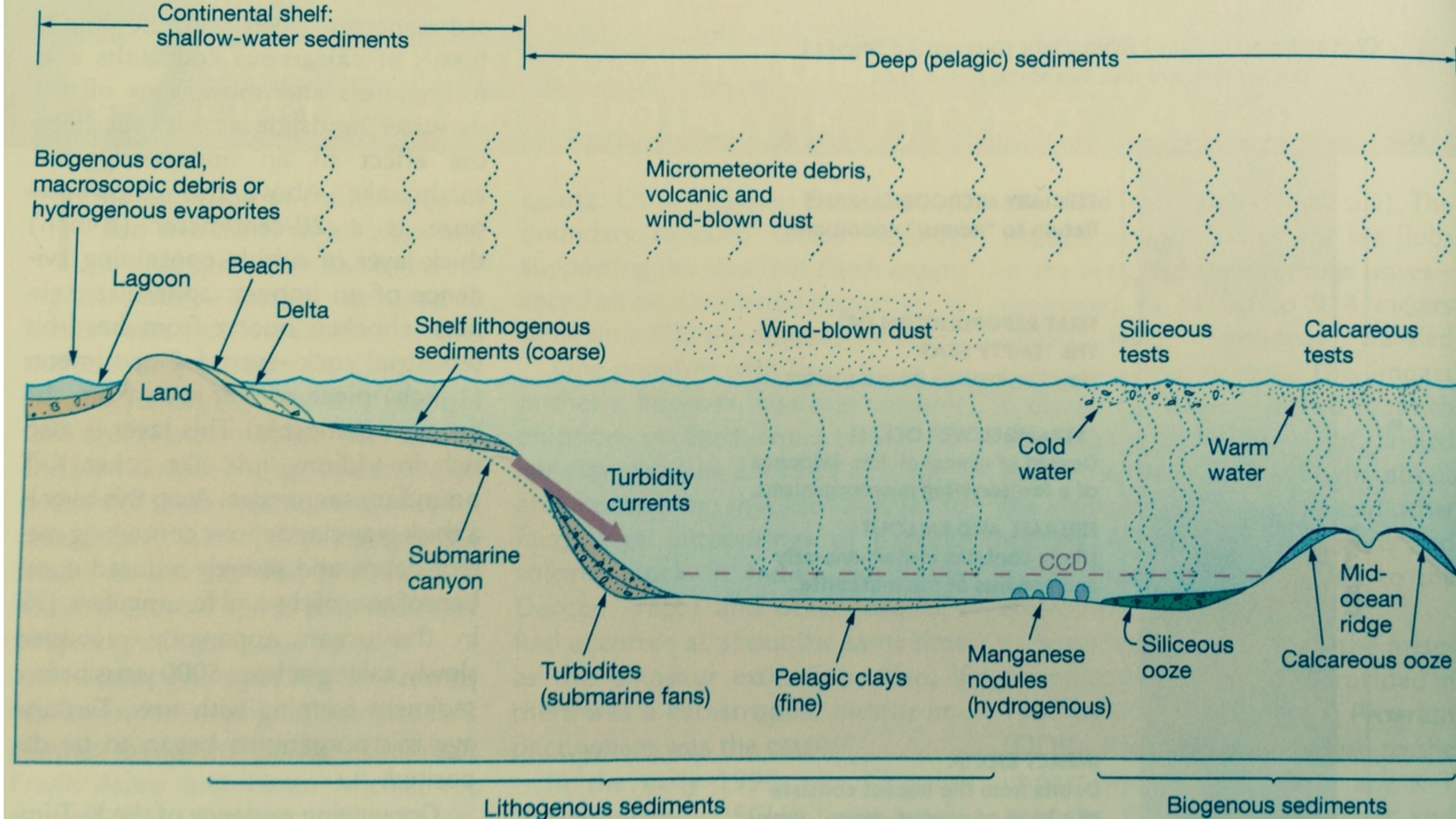
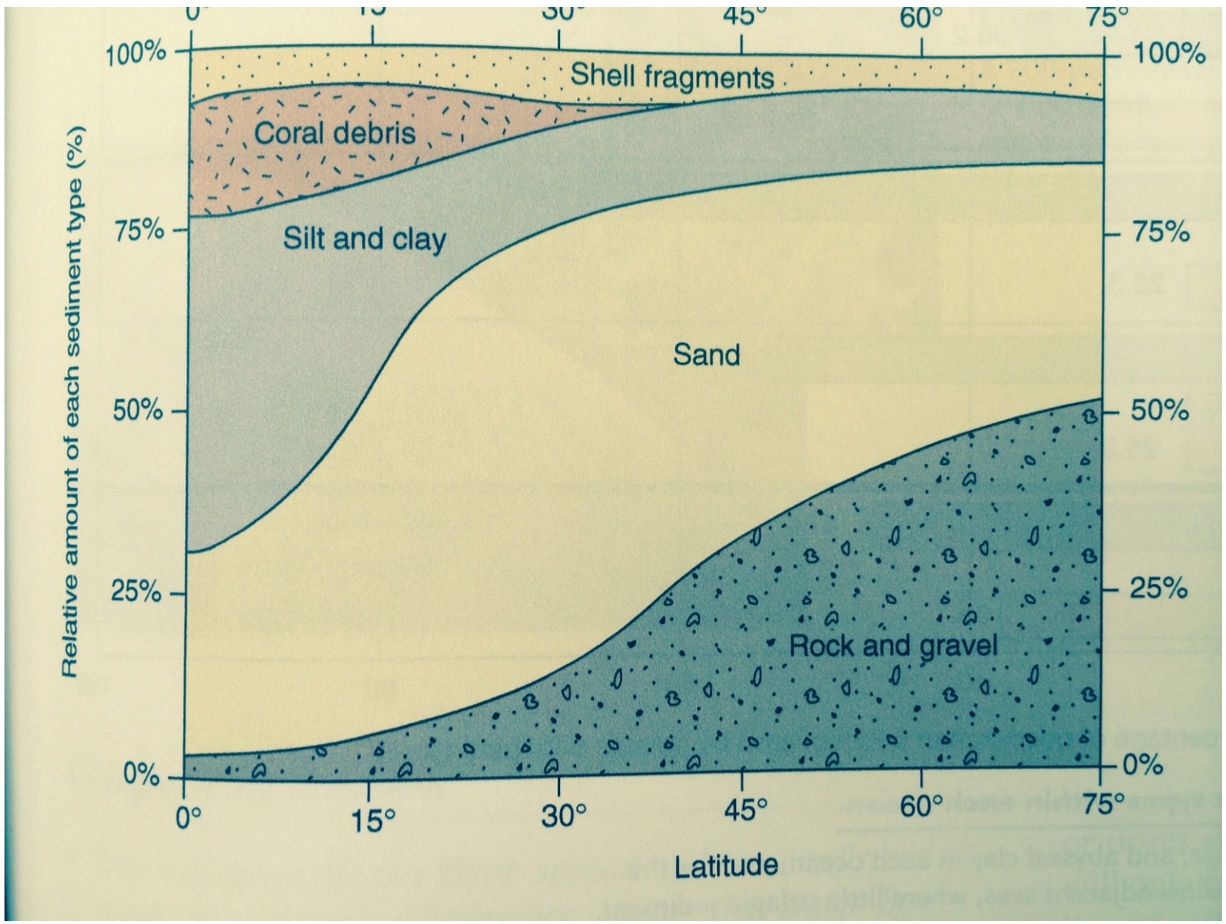
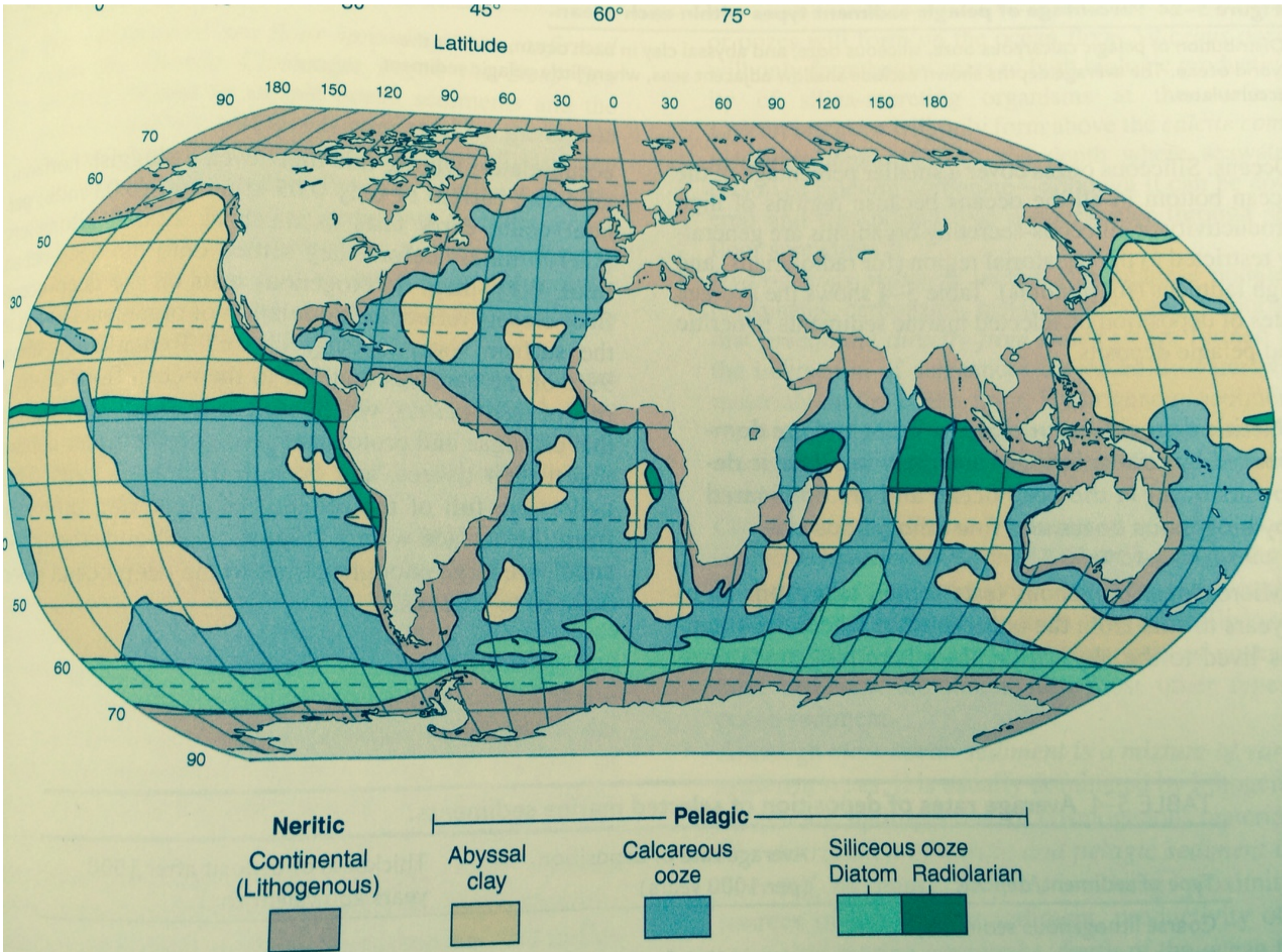


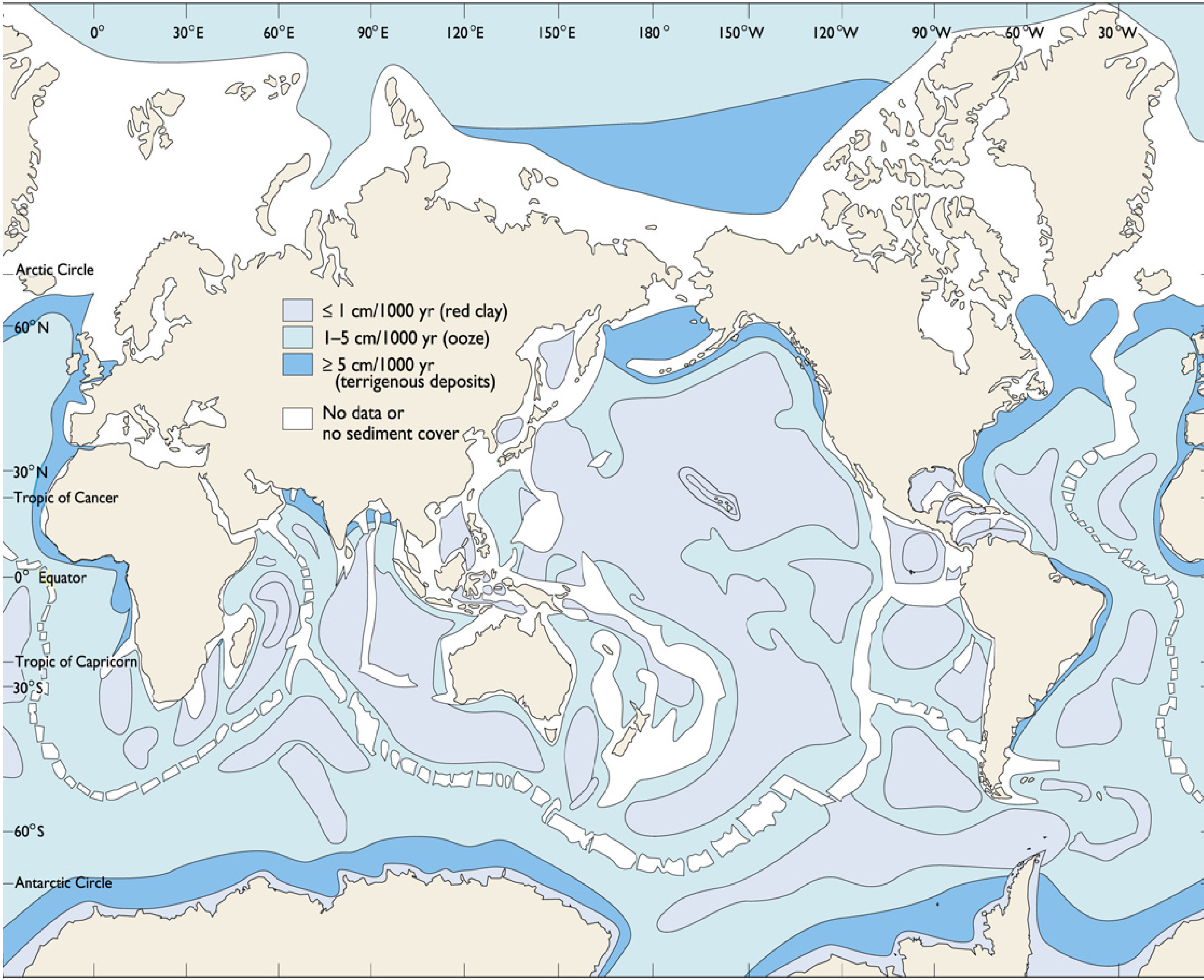
Figure 5–21 Distribution of sediment across a passive continental margin.

Figure 5–22 also shows that coral reef debris is signif-

Latitudinal change of sediment composition




45°
60°
75°
Latitude
Neritic
Continental
(Lithogenous)
Pelagic
Abyssal
clay
Calcareous
ooze
Siliceous ooze
Diatom
Radiolarian



(b) SEDIMENTATION RATES

Deep-sea Sediment Distribution

TYPE	COMPO-SITION	ATLANTIC (%)	PACIFIC (%)	INDIAN (%)	GLOBAL (%)
Foram. ooze	Carbonate	65	36	54	47
Pteropod ooze	Carbonate	2	0.1	-	0.5
Diatom ooze	Silica	7	10	20	12
Radiolarian ooze	Silica	-	5	0.5	3
Red clay	Aluminum silicate	26	49	25	38

TABLE 5-4 **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

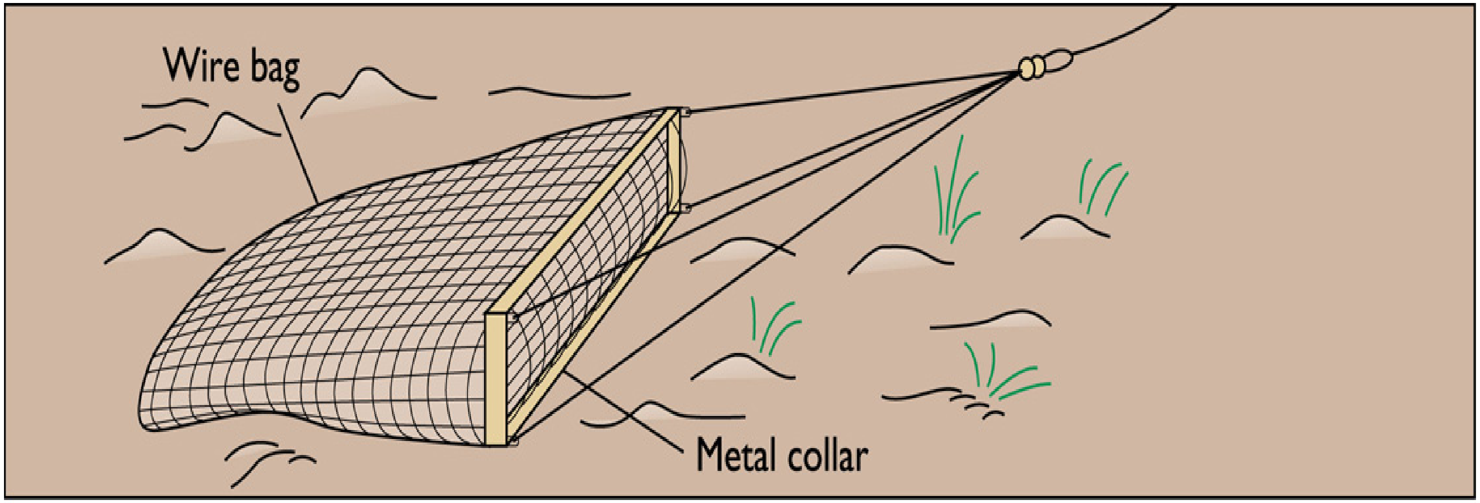
TABLE 5-3 **Comparison of environments interpreted from deposits of siliceous and calcareous ooze in surface sediments.**

	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

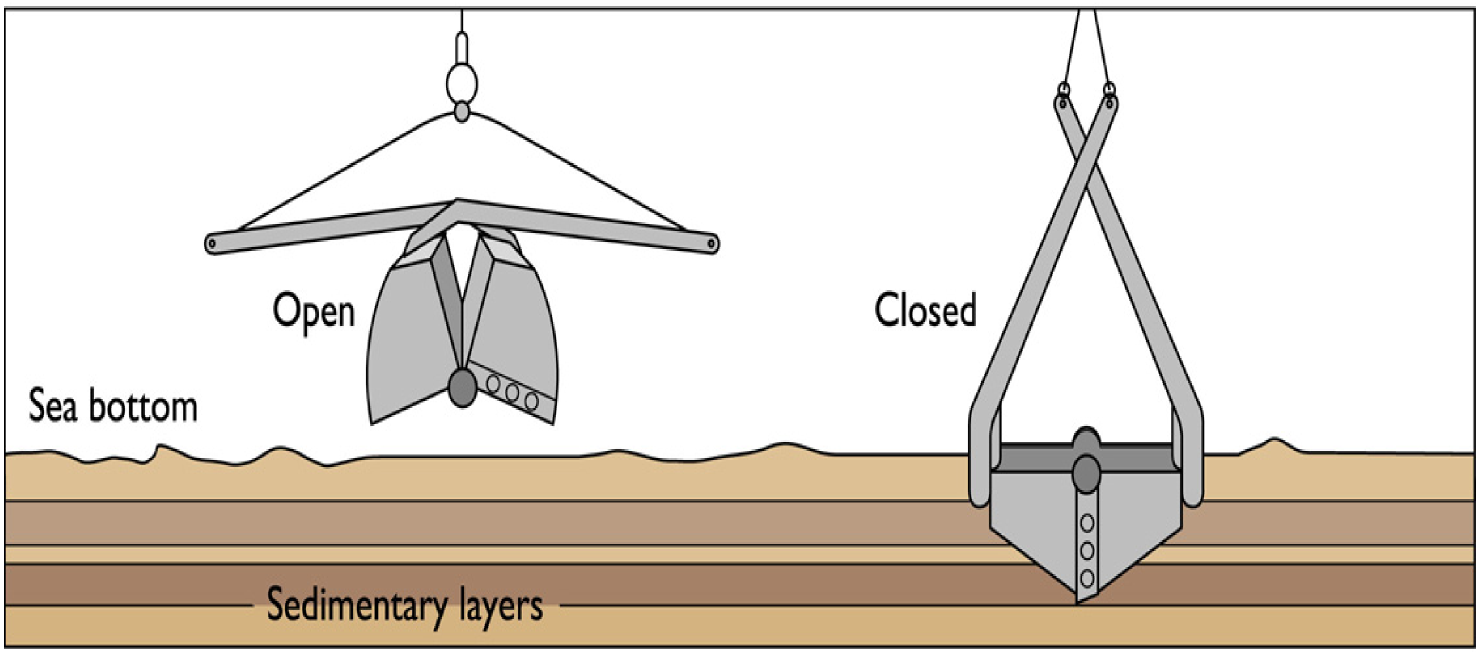
Coastal waters are often highly productive, with abundant planktonic organisms thriving in the surface waters.

Why then are biogenous oozes rarely found nearshore??

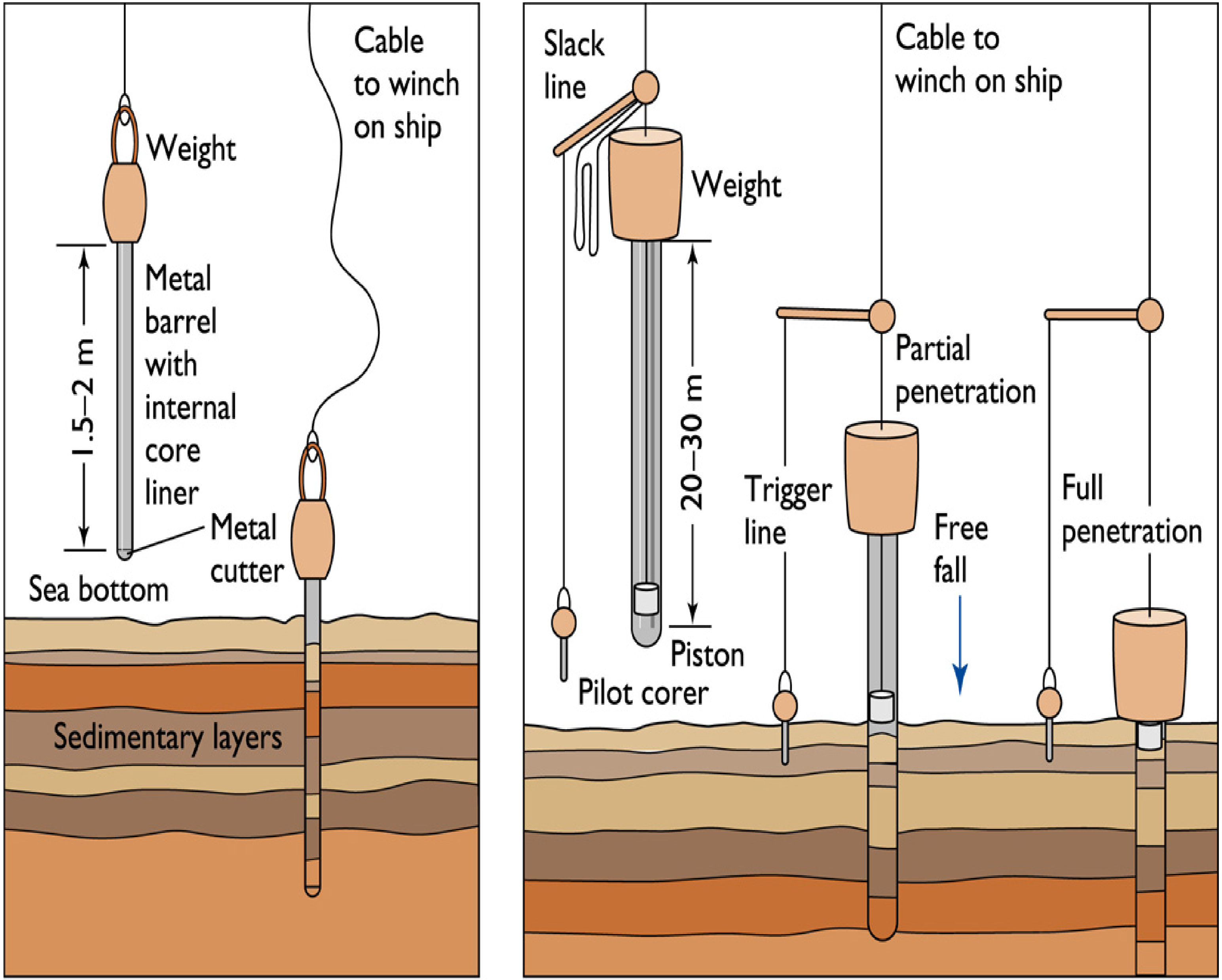
- ✓ the large input of terrigenous sediment to the continental margin overwhelms the biogenous component in the sediment.



(a) BOTTOM DREDGE



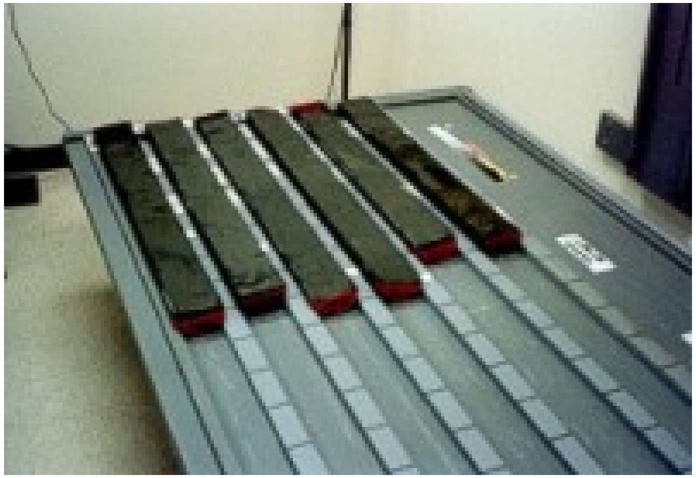
(b) GRAB SAMPLER



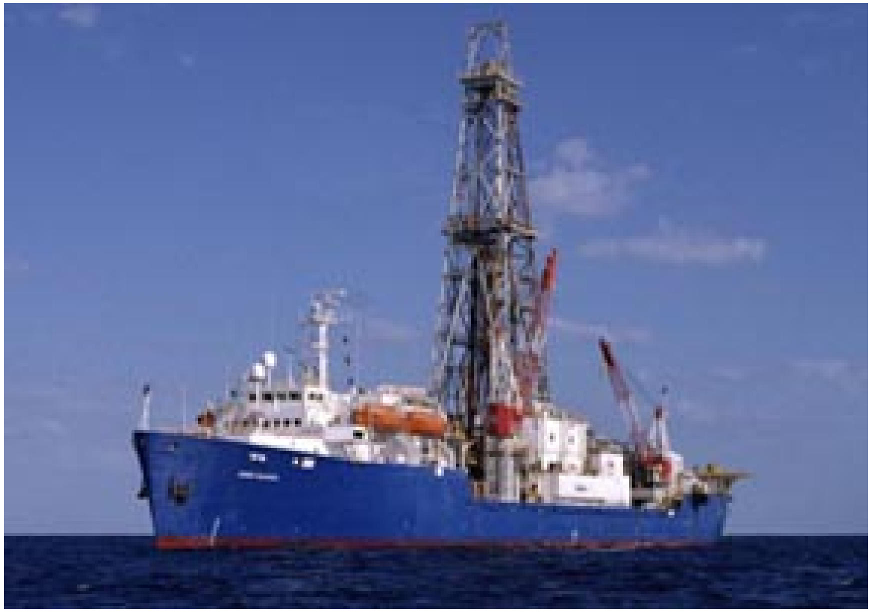
(a) GRAVITY CORER (b) PISTON CORER











5
4


PELICAN