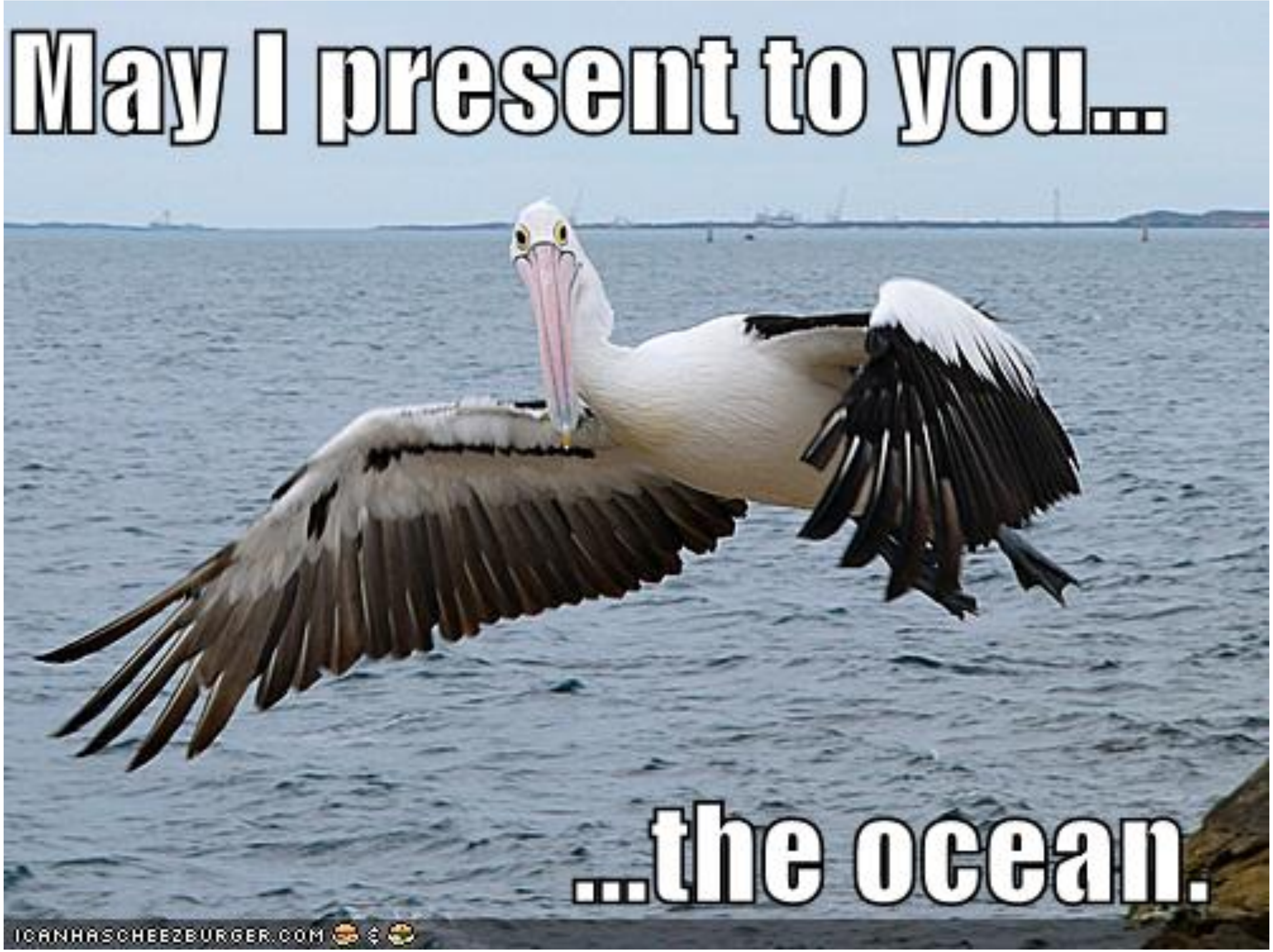
Oceanic Sediments


May I present to you...
...the ocean.
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Oceanic Sediments

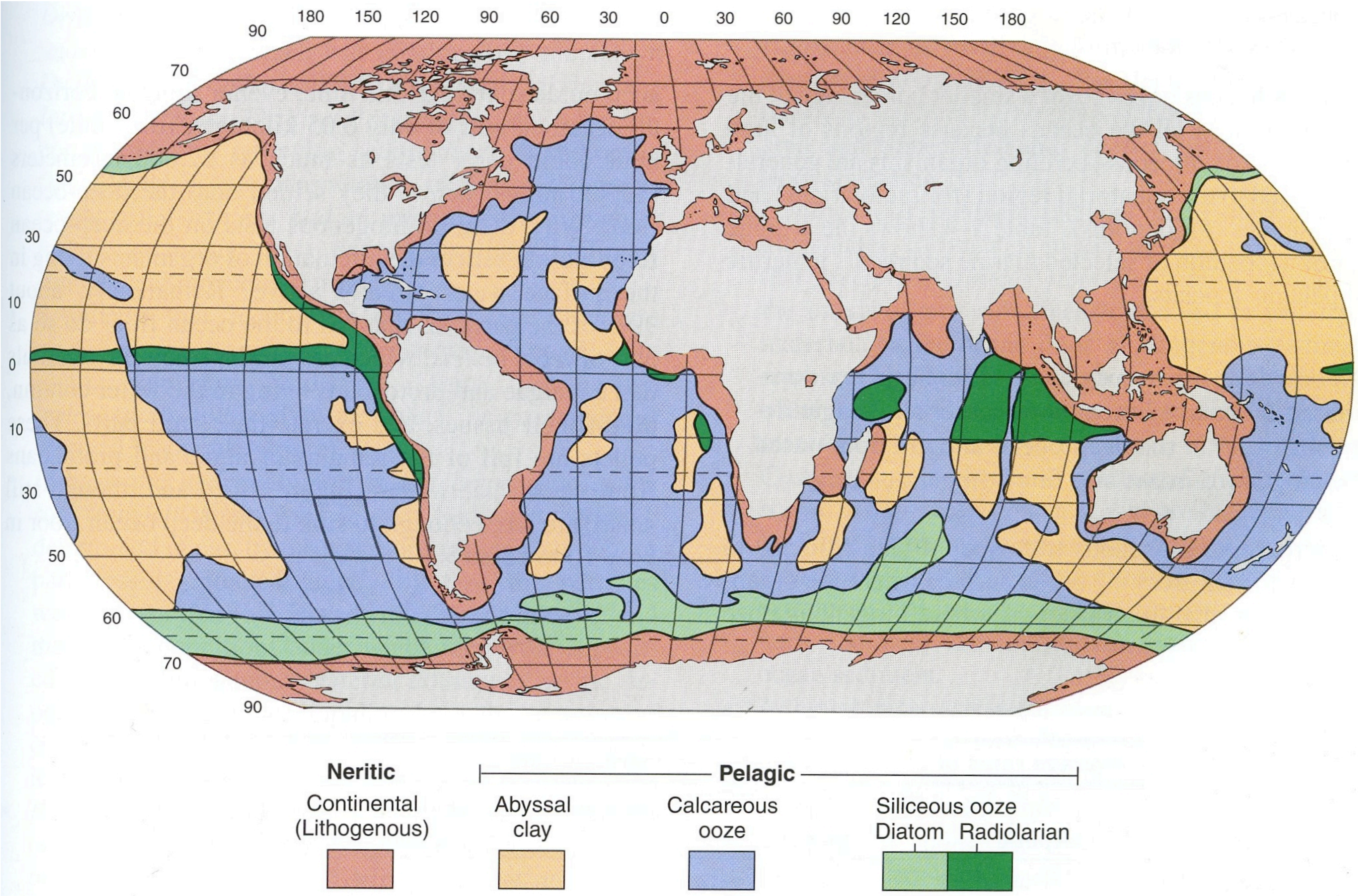
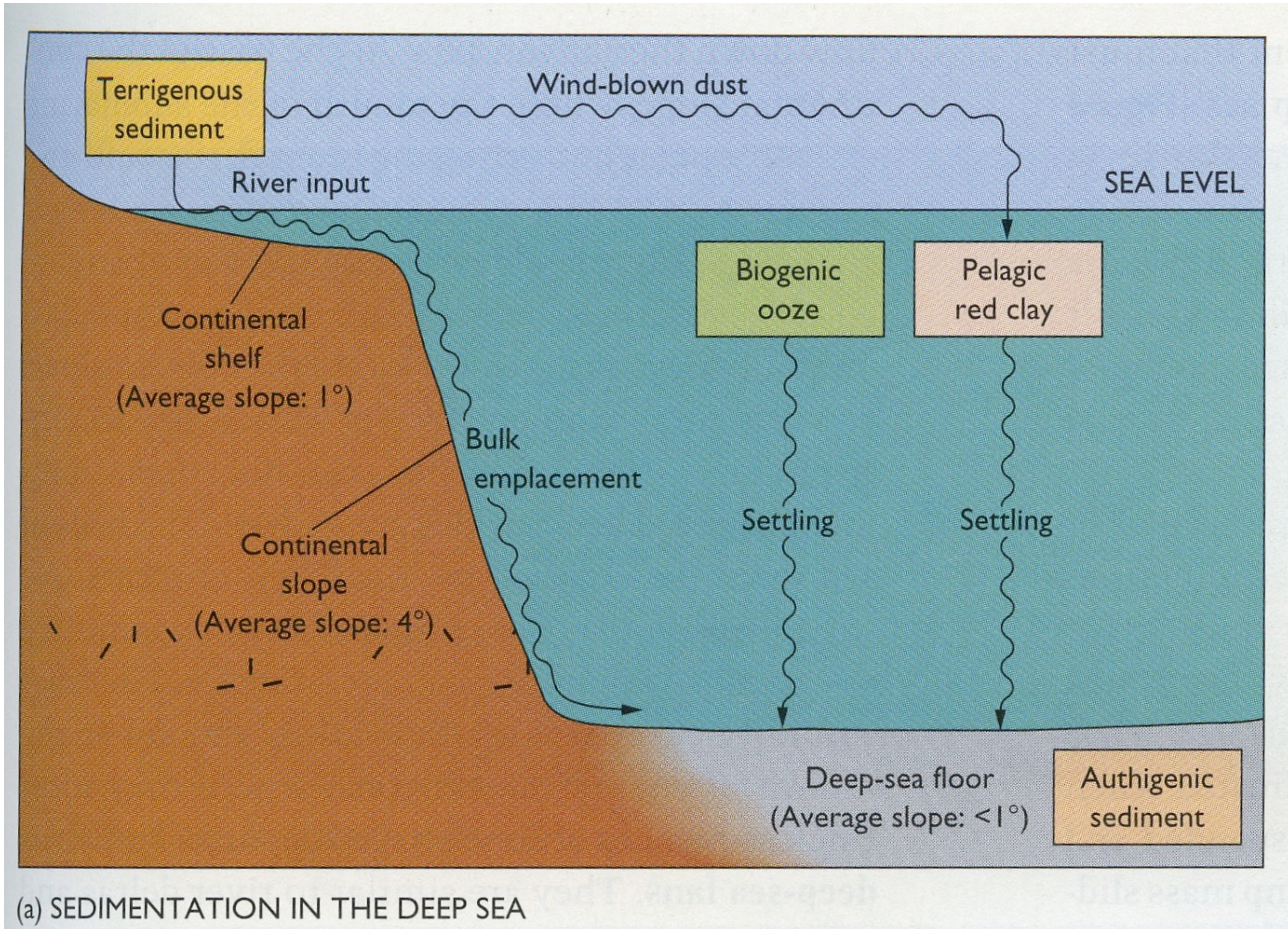


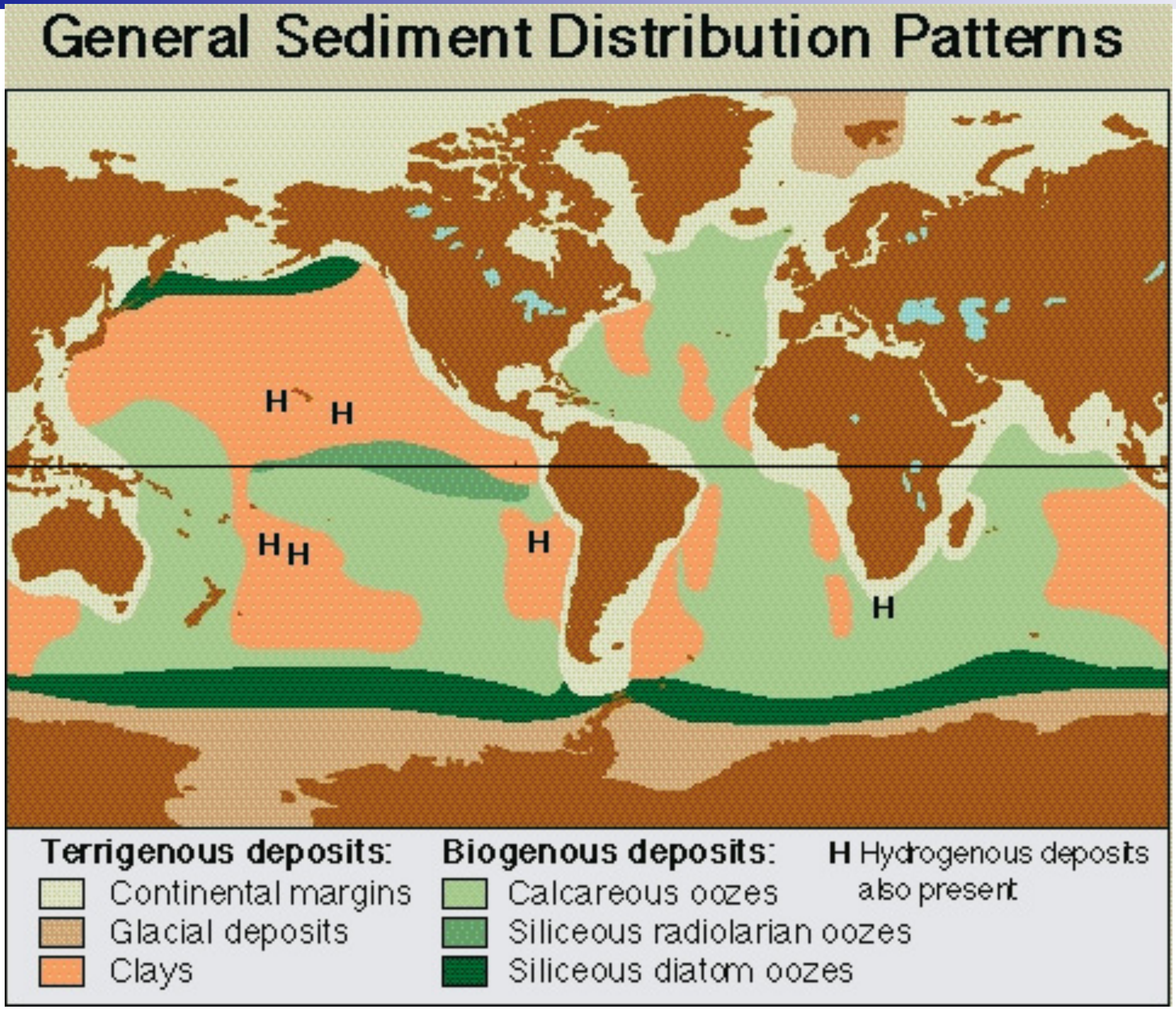
TABLE 5-1 **Classification of marine sediments.**

Type		Composition	Sources		Main locations found
Lithogenous	Continental Margin	Rock fragments	Rivers; coastal erosion; landslides		Continental shelf
		Quartz sand	Glaciers		Continental shelf in high latitudes
		Quartz silt Clay	Turbidity currents		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 of volcanic peaks
		Shell/coral fragments (macroscopic)		Macroscopic shell-producing organisms	Continental shelf; beaches
				Coral reefs	Shallow low-latitude regions
	Silica ($SiO_2 \cdot nH_2O$)	Siliceous ooze	Cold surface water	Diatoms (algae); Radiolarians (protozoans)	High-latitude regions; sea floor below CCD; surface current divergence near the Equator
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

Sedimentation process



From Pinet, P.R., 2003. Introduction to Oceanography. Jones and Barlett Publishers, 3rd Ed, p. 111.


General Sediment Distribution Patterns
H
H
H
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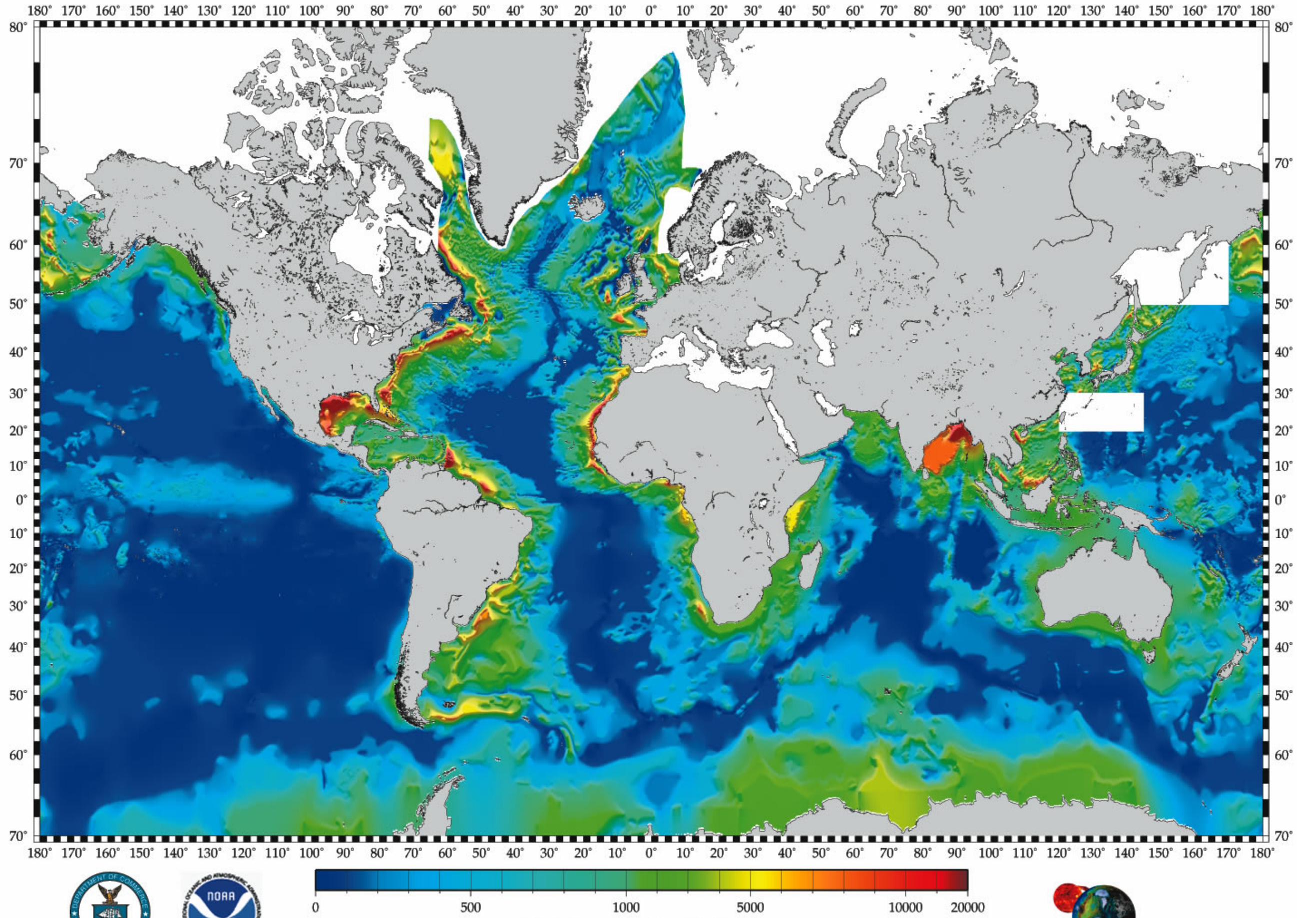
Terrigenous deposits:
Continental margins
Glacial deposits
Clays
Biogenous deposits:
Calcareous oozes
Siliceous radiolarian oozes
Siliceous diatom oozes
H Hydrogenous deposits also present

Total Sediment Thickness of the World's Oceans & Marginal Seas



A digital total sediment thickness database for the world's oceans and marginal seas is being compiled by the National Geophysical Data Center (NGDC) ,Marine Geology & Geophysics Division. The data are gridded with a spacing of 5 arc-minutes by 5 arc-minutes. Sediment thickness data were compiled from three principle sources: previously published isopach maps; ocean drilling results, both ODP and DSDP; and seismic reflection profiles archived at NGDC as well as seismic data and isopach maps available as part of the IOC's Geological/Geophysical Atlas of the Pacific (GAPA) project.

The distribution of sediments in the oceans is controlled by five primary factors:

1) Age of the underlying crust
2) Tectonic history of the ocean crust
3) Structural trends in basement
4) Nature and location of sediment sources, and
5) The nature of the sedimentary processes delivering sediments to depocenters

The data values are in meters and represent the depth to acoustic basement. It should be noted that acoustic basement may not actually represent the base of the sediments. These data are intended to provide a minimum value for the thickness of the sediment in a particular geographic region.

http://www.ngdc.noaa.gov/mgg/sedthick/sedthick.html

Sediment Sources

- Allochthonous sediments
  - Suspended load of rivers ($\geq$ 90%)
  - Aeolian dust ($\leq$ 1%)
- Autochthonous sediments (biogenic) ~ 10%

Transport processes

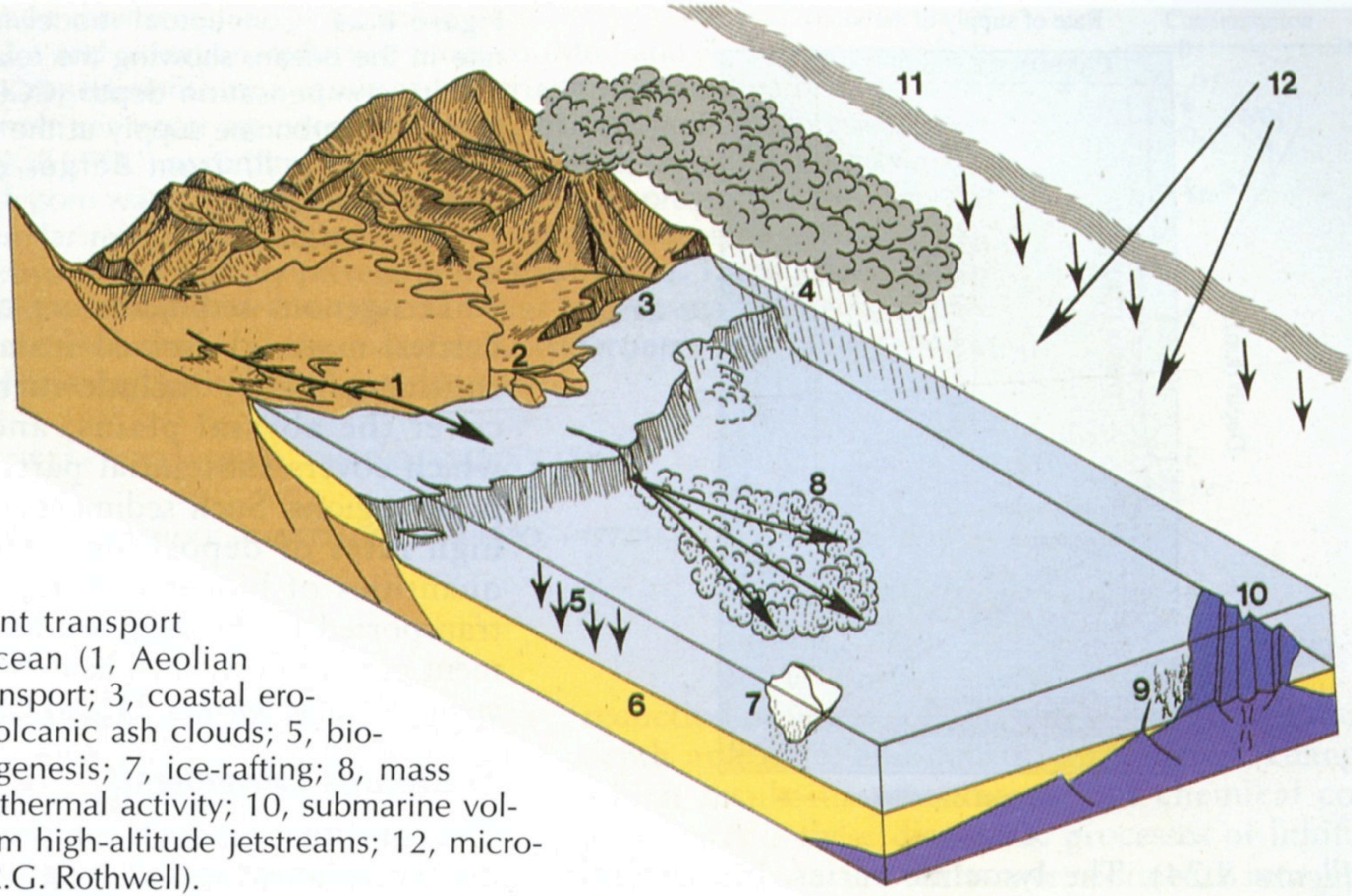
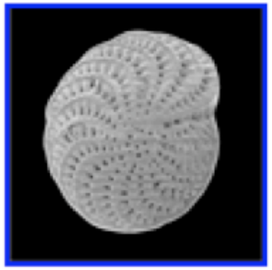


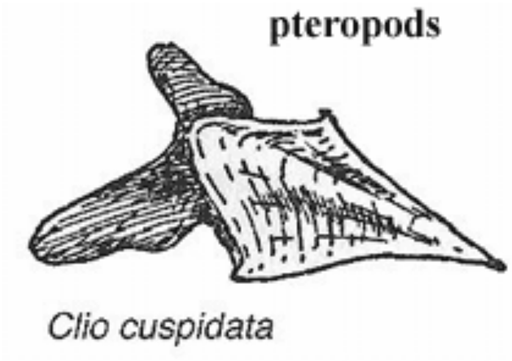
Figure 8.22 Sediment transport routes to the deep ocean (1, Aeolian transport; 2, fluvial transport; 3, coastal erosion; 4, fallout from volcanic ash clouds; 5, biogenic debris; 6, authigenesis; 7, ice-rafting; 8, mass gravity flows; 9, hydrothermal activity; 10, submarine volcanism; 11, fallout from high-altitude jetstreams; 12, micrometeorites; drawn by R.G. Rothwell).

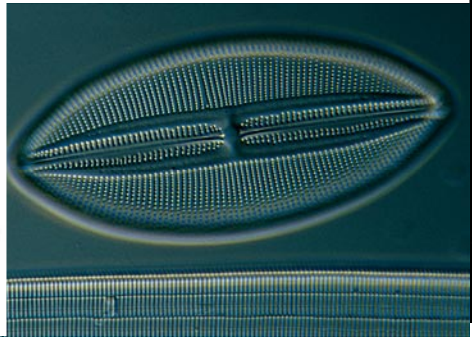
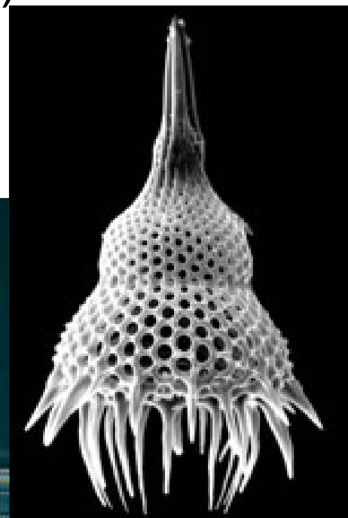
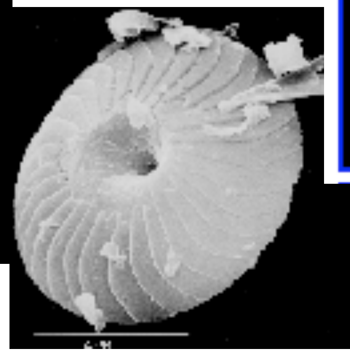
Transport Processes

- Physical Processes (ocean margins)
- Active Sedimentation (gravitational energy)
- Passive Sedimentation
  - Slow pelagic settling
- Biological Process
  - $CaCO_3$ (foraminiferal, coccolith and pteropod ooze)
  - SiO_2 (diatom, radiolarian ooze)
- Chemical Processes







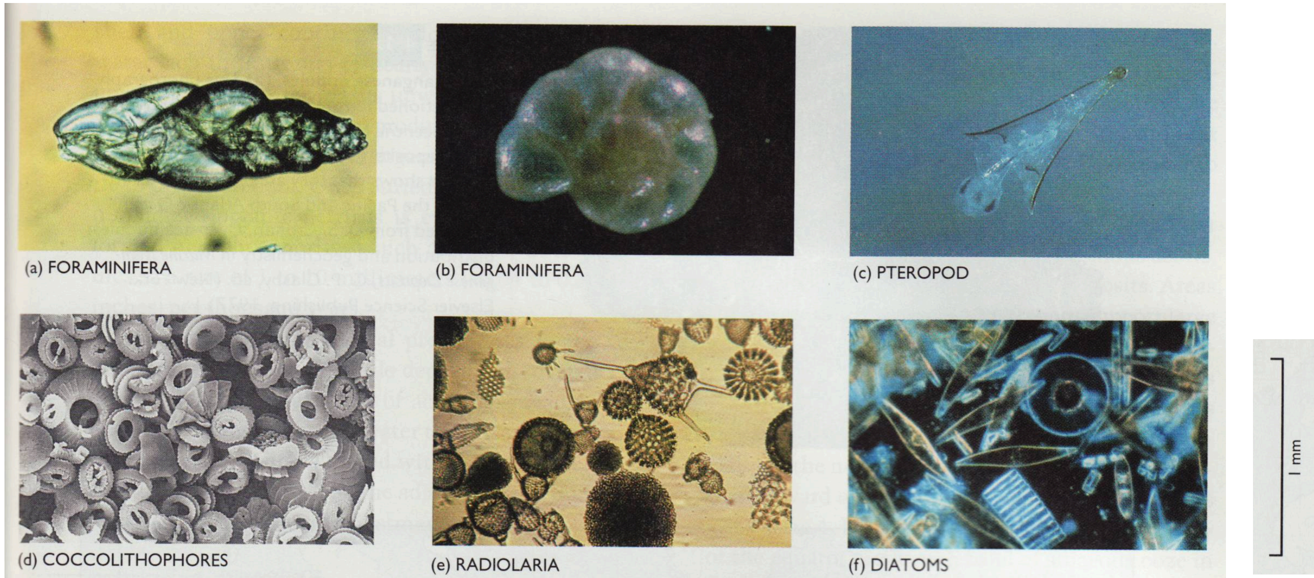




Pelagic sediments

Distribution of pelagic sediment

Type	Composition	Atlantic (%)	Pacific (%)	Indian (%)	Global (%)
Foraminiferal 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

Source: Adapted from W. H. Berger, Biogenous deep sea sediments: production, preservation and interpretation in *Chemical Oceanography*, vol. 5, J.P. Riley and R. Chester, eds. (New York: Academic Press, 1976), 265–388; and J. Kennett, *Marine Geology* (Englewood Cliffs, N.J.: Prentice-Hall, 1982).



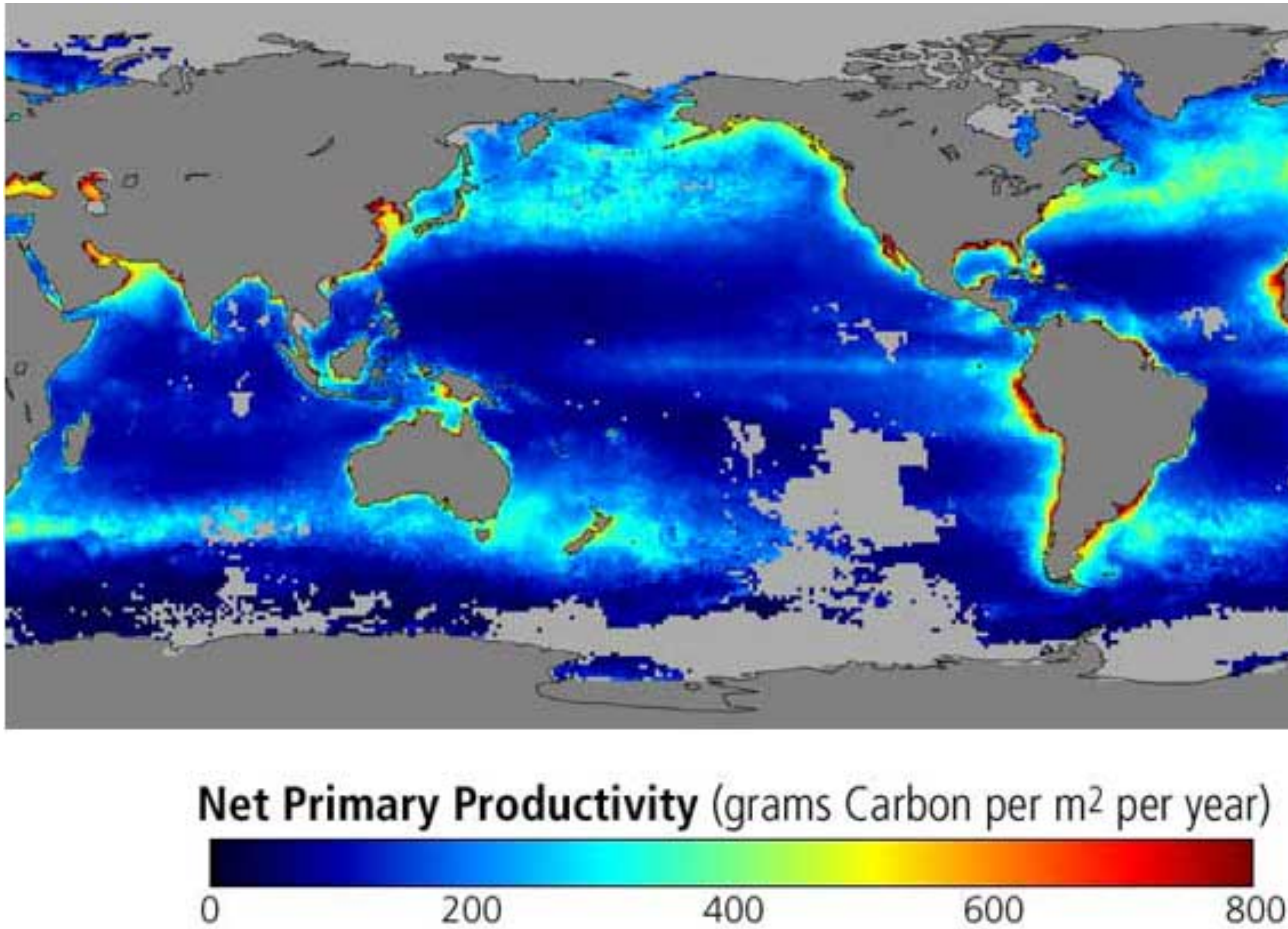
From Pinet, P.R., 2003. Introduction to Oceanography. Jones and Barlett Publishers, 3rd Ed, p. 117.

Ooze

Distribution of Oozes

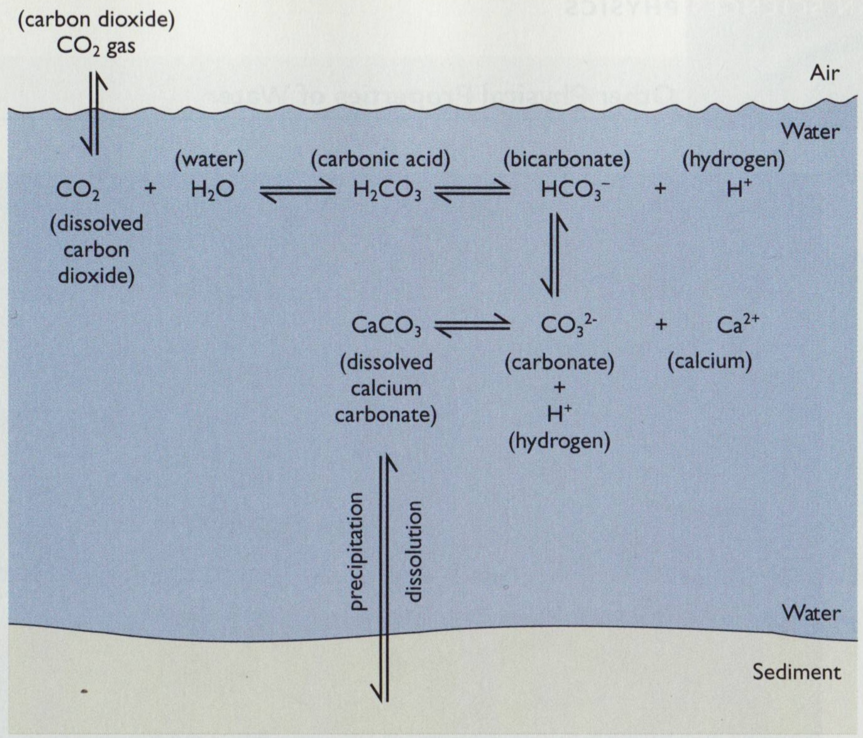
- rates of production of biogenic particles in the surface waters
- dissolution rates of those particles in the water column and after they reach the bottom
- rates of dilution by terrigenous sediments

Global map of the primary productivity by oceanic phytoplankton



From: http://oceanworld.tamu.edu

Carbonate dissolution



(c) THE CO_2 SYSTEM

Seawater too basic: $H_2CO_3 \longrightarrow HCO_3^- + H^+$ pH drops

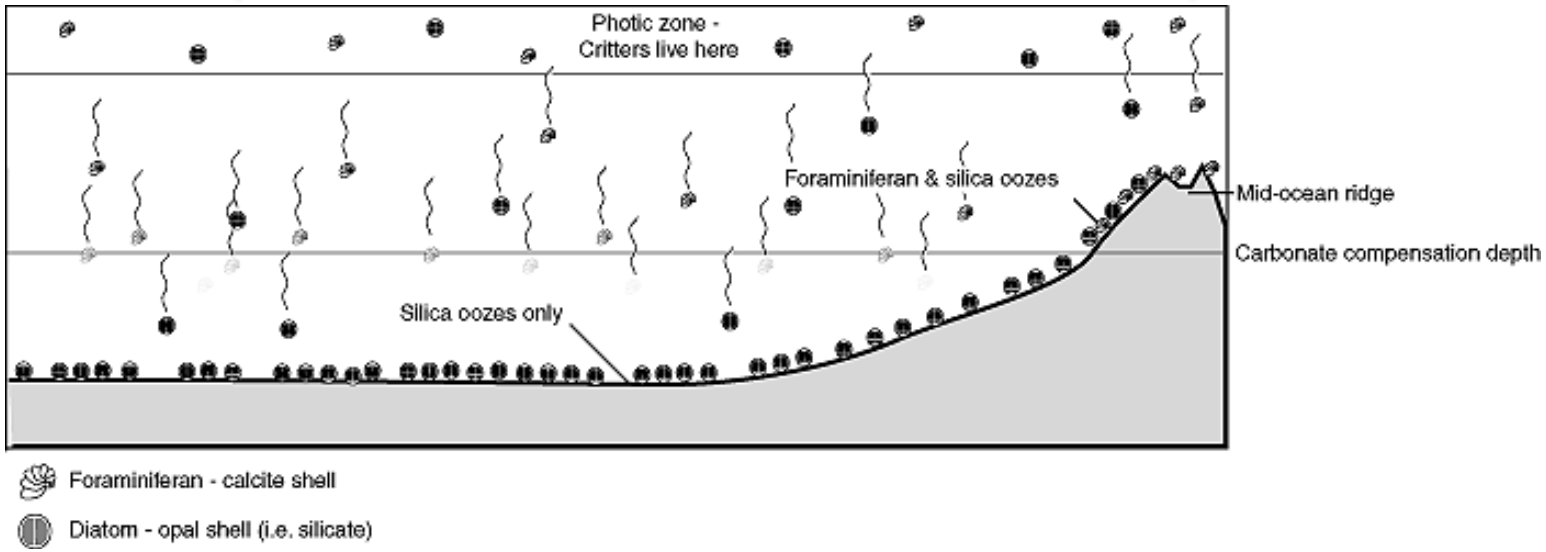
Seawater too acidic: $HCO_3^- + H^+ \longrightarrow H_2CO_3$ pH rises

(d) CARBONATE BUFFER

Carbonate Dissolution

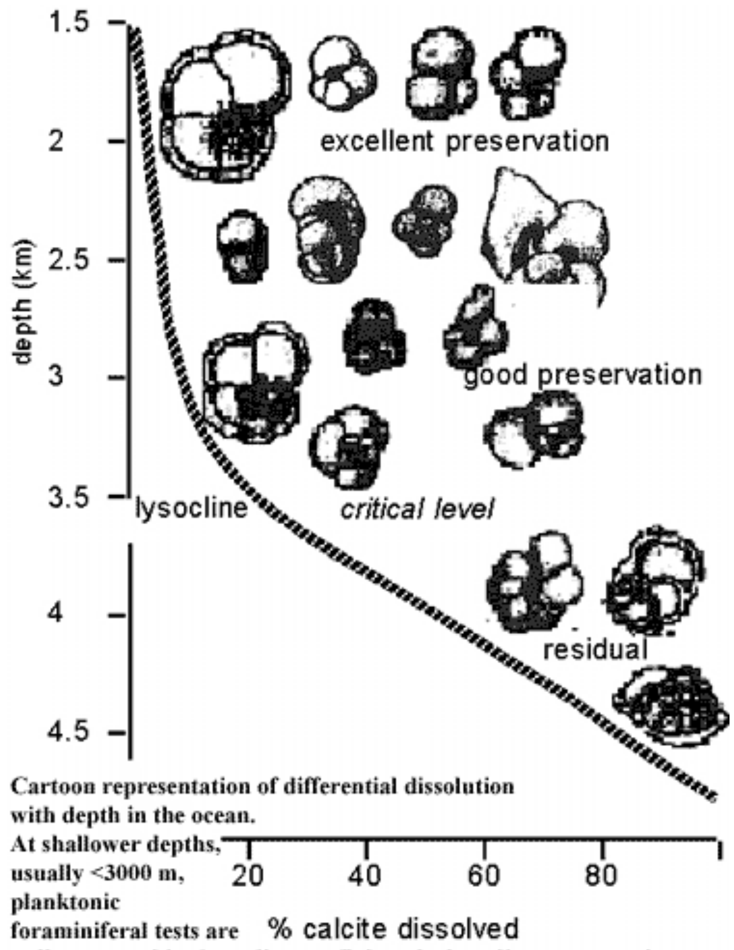
- Temperature
- Pressure
- Partial pressure CO_2
- The more CO_2, the more dissolution
- More CO_2 in solution at higher P (and greater depth)

$$CaCO_3 + H_20 + CO_2 <====> Ca^{++} + 2HCO_3^-$$



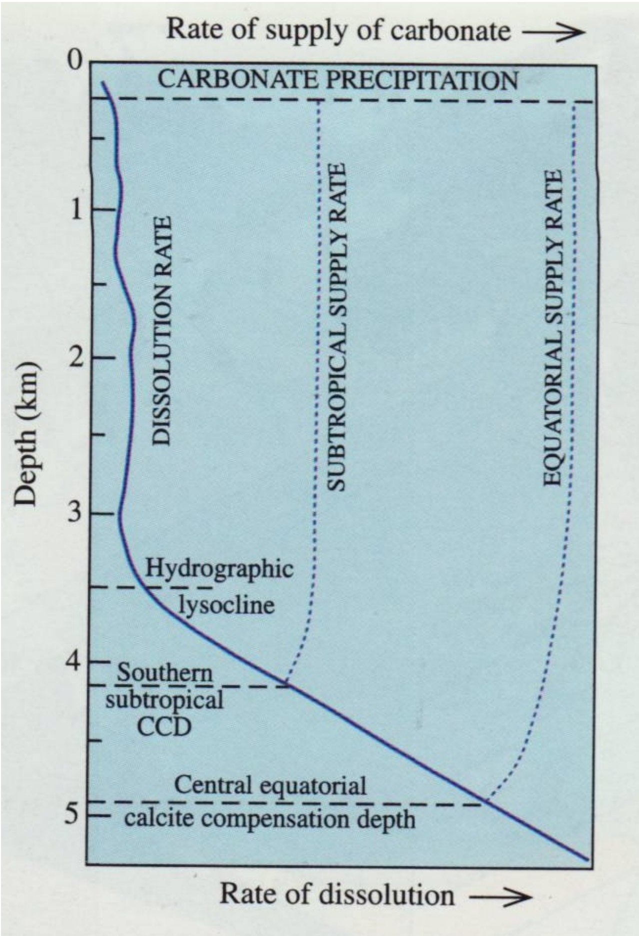
CCD

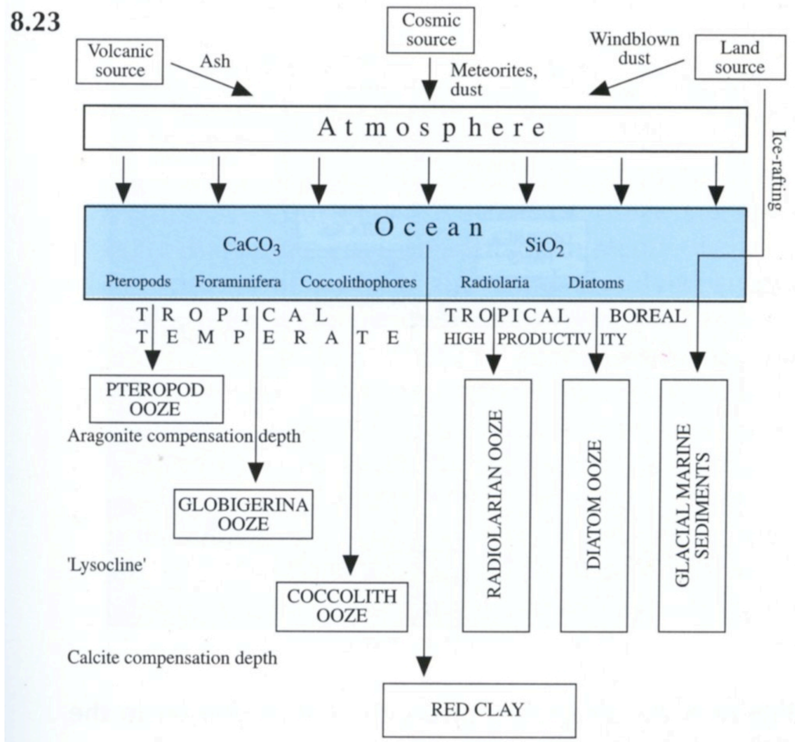
- Cold pressurized water can hold more CO_2 in solution than warm water.
- Consequently, deep ocean water has more CO_2 in solution.
- This recombines to form carbonic acid.
- Hence, below a certain depth (typically around 3.5 km.) carbonates dissolve.
- If you find calcite in deep ocean sediments, you know that they were deposited above the CCD.
- Preservation of different kinds of shells differs

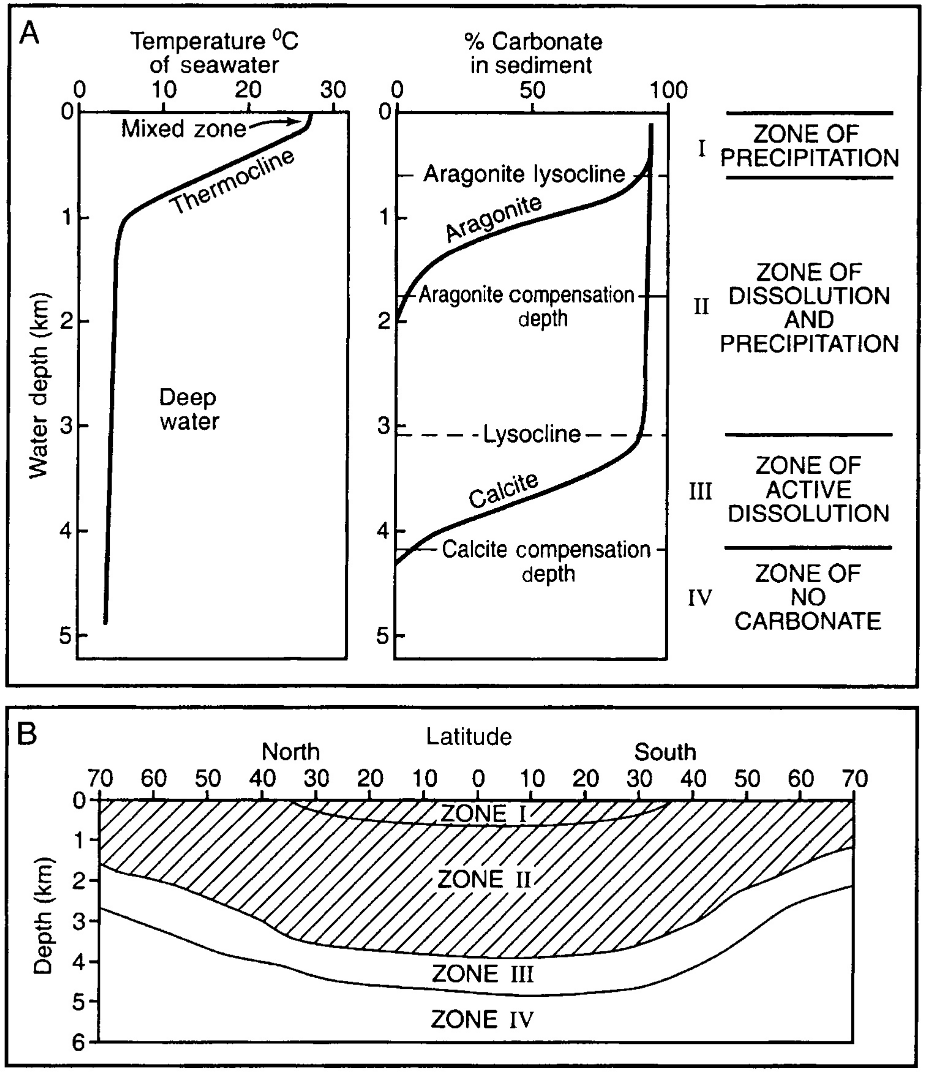


Cartoon representation of differential dissolution with depth in the ocean. At shallower depths, usually <3000 m, planktonic foraminiferal tests are well preserved in the sediment. Below the lysocline, preservation rapidly deteriorates with depth. Below the CCD, tests are not preserved.

Carbonate compensation depth

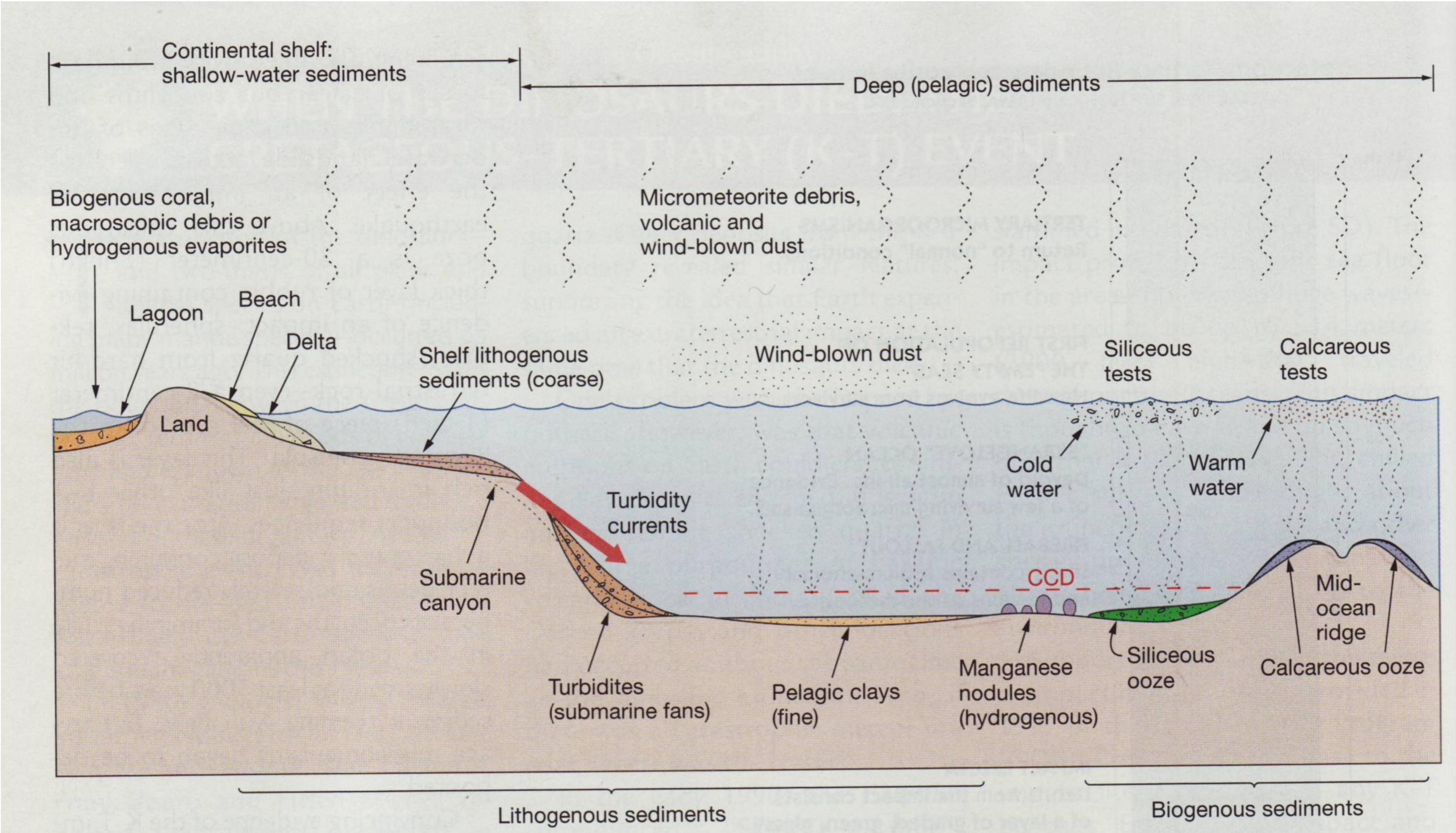




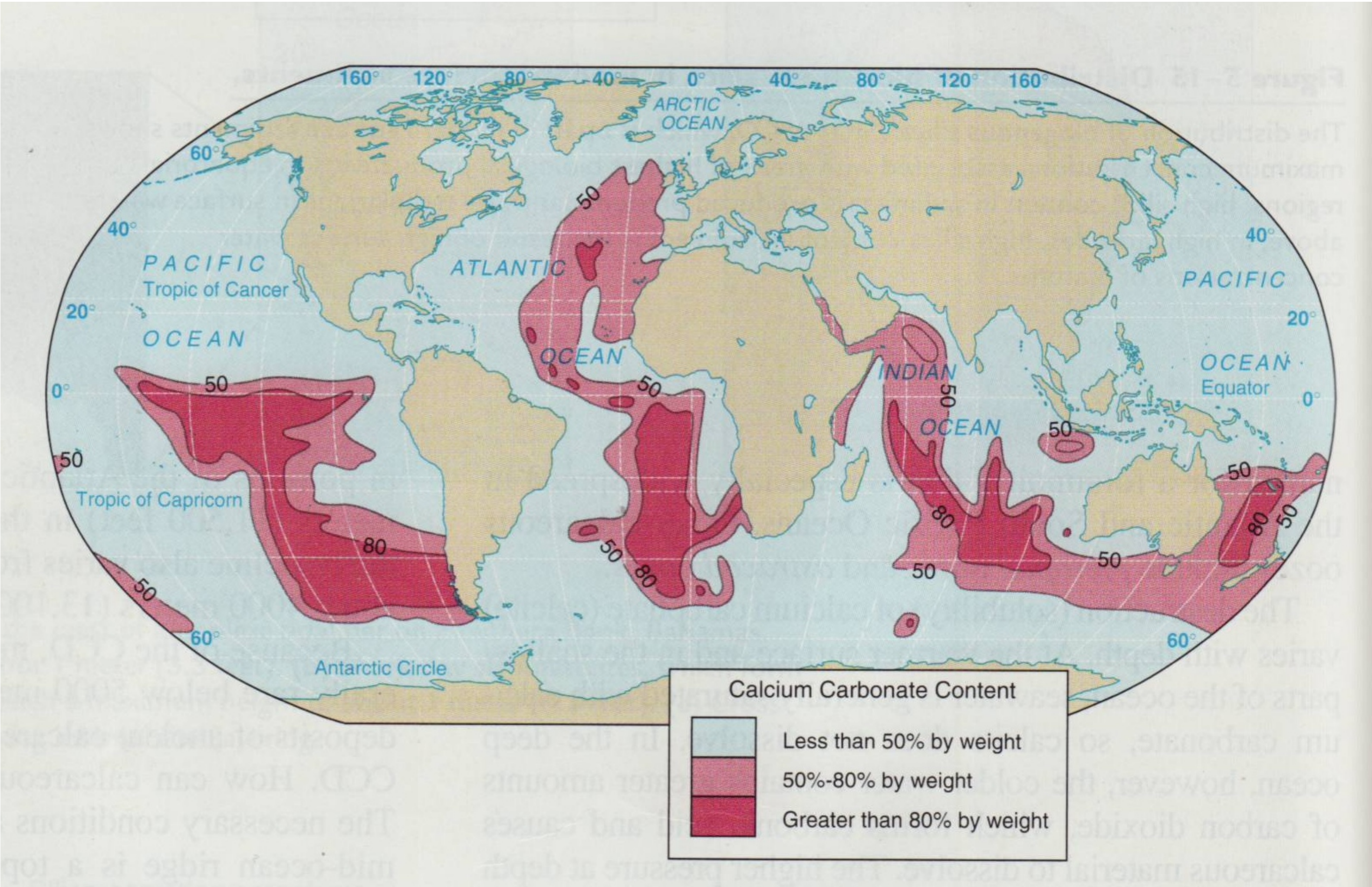


Generalized plots showing variations in seawater temperature with water depth and the relative positions of the aragonite and calcite lysoclines and compensation depths. Major zones of seafloor diagenesis are plotted to the right. (From James N. P. and P. W. Choquette, 1983b, Diagenesis 6. Limestones – The sea floor diagenetic environment: *Geosci. Can.*, **10**, Fig. 1, p. 163 and Fig. 2, p. 164, reprinted by permission of the Geological Association of Canada.)

From: Boggs (1987)

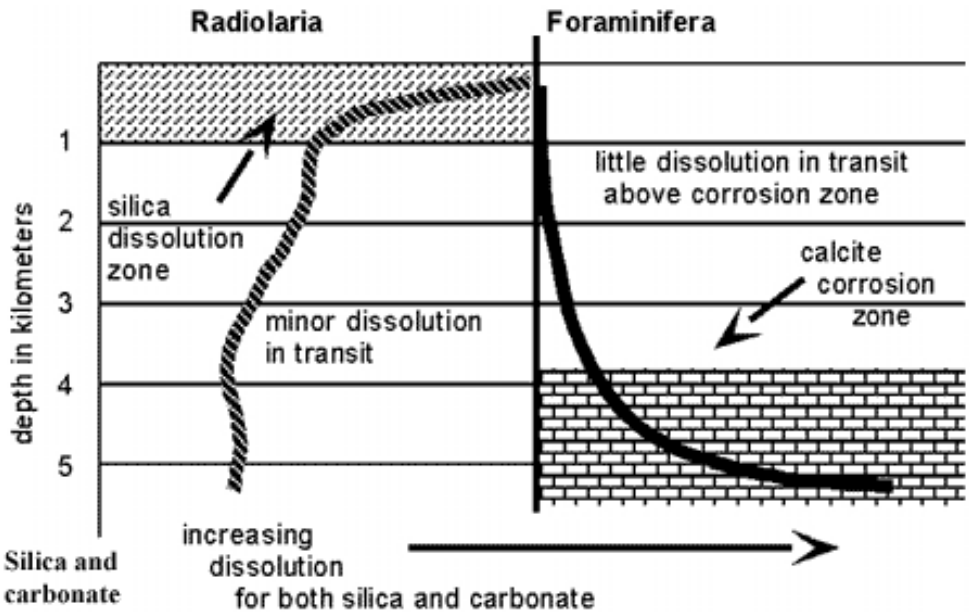

Continental shelf:
shallow-water sediments
Deep (pelagic) sediments
Biogenous coral,
macroscopic debris or
hydrogenous evaporites
Micrometeorite debris,
volcanic and
wind-blown dust
Lagoon
Beach
Delta
Land
Shelf lithogenous
sediments (coarse)
Wind-blown dust
Siliceous
tests
Calcareous
tests
Cold
water
Warm
water
Turbidity
currents
Submarine
canyon
CCD
Mid-
ocean
ridge
Turbidites
(submarine fans)
Pelagic clays
(fine)
Manganese
nodules
(hydrogenous)
Siliceous
ooze
Calcareous ooze
Lithogenous sediments
Biogenous sediments

Calcium carbonate distribution



Silica

- Diatoms, radiolarians, silicoflagellates, sponges
- Most oceans undersaturated wrt silica (esp. surface water)
- Higher concentrations in old deep seawater, volcanic islands and island arcs
- Silica solubility increases with decreasing P and increasing T
- Preservation enhanced by rapid burial
- Some ooze will dissolve and reprecipitate as chert



Silica and carbonate solubility curves in sea water. In contrast to the increasing solubility of carbonate with temperature decrease and pressure increase (increasing depth) silica solubility decreases with depth.

Sources of Silica

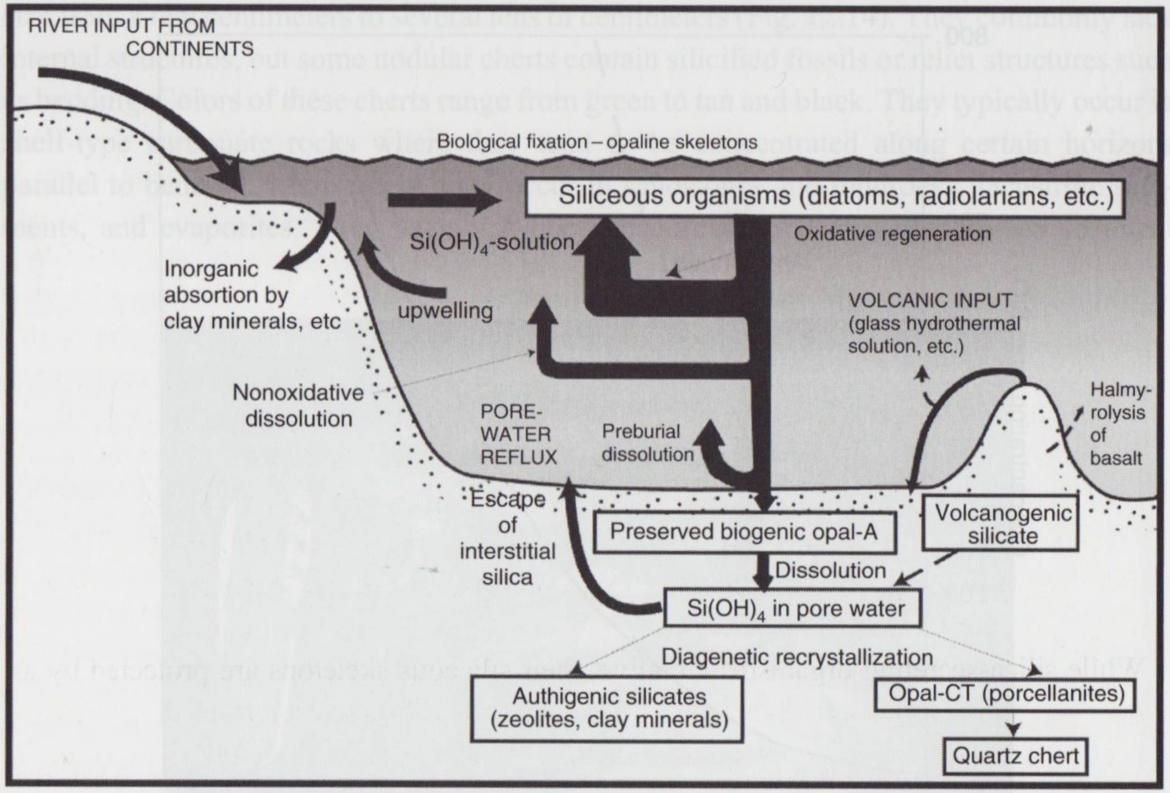
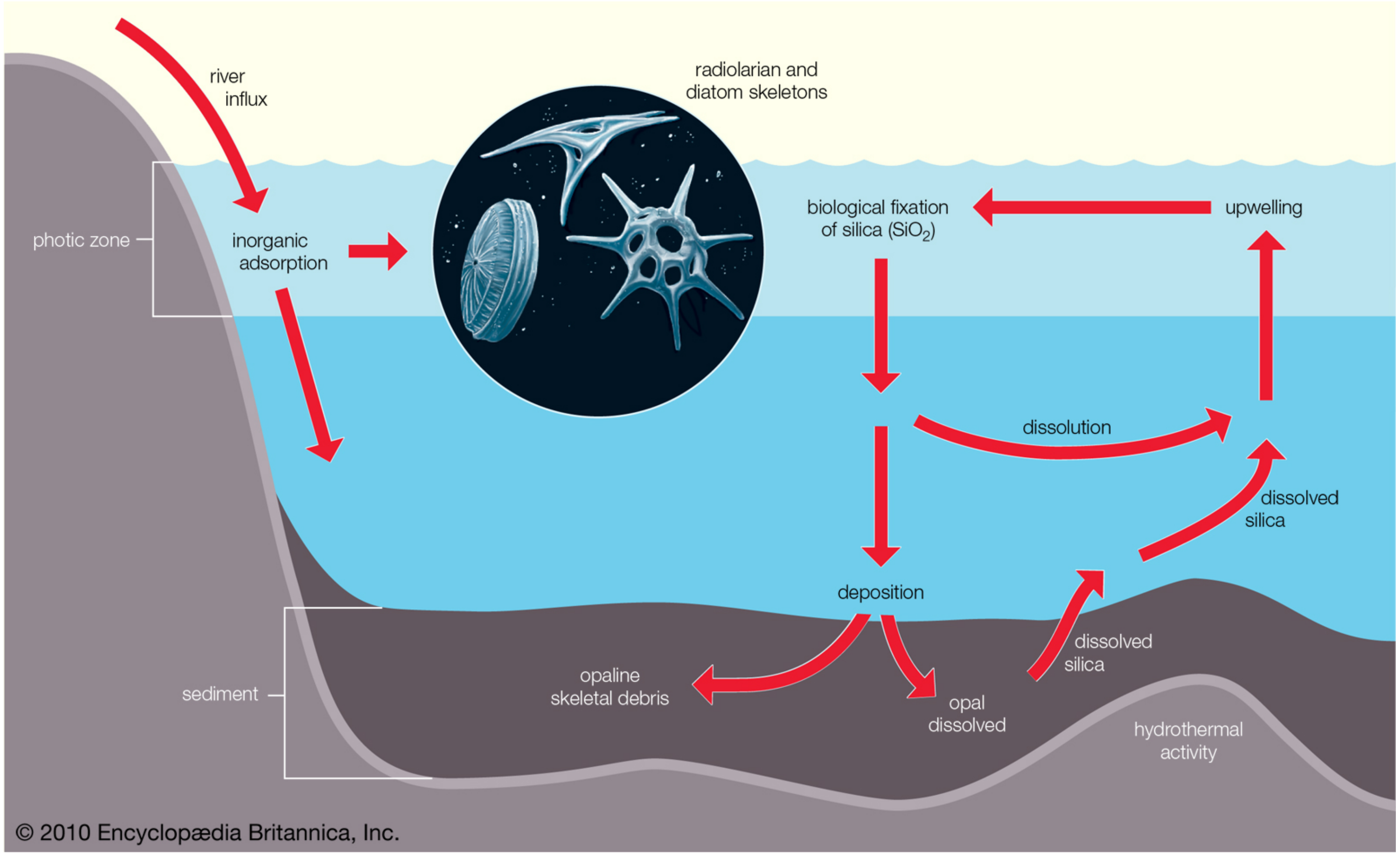


Figure 12.16 Sources of dissolved silica in seawater. {After Riech, V. and U. von Rad, 1979, Silica diagenesis in the Atlantic Ocean: Diagenetic potential and transformations, in Talwani M., W. Hay, and W. B. F. Ryan (eds.), *Deep Drilling Results in the Atlantic Ocean: Continental Margins and Paleoenvironment*: American Geophysical Union, Maurice Ewing Series 3, Fig. 2, p. 322, modified from Heath, G. R., 1974, Dissolved silica and deep-sea sediments, in Hay, W. W. (ed.), *Studies in Paleo-Oceanography*: SEPM Special Publication 20, Fig. 7, p. 81, reprinted by permission of SEPM, Tulsa, OK.)


river
influx
radiolarian and
diatom skeletons
photic zone
inorganic
adsorption
biological fixation
of silica (SiO_2)
upwelling
dissolution
dissolved
silica
deposition
dissolved
silica
sediment
opaline
skeletal debris
opal
dissolved
hydrothermal
activity
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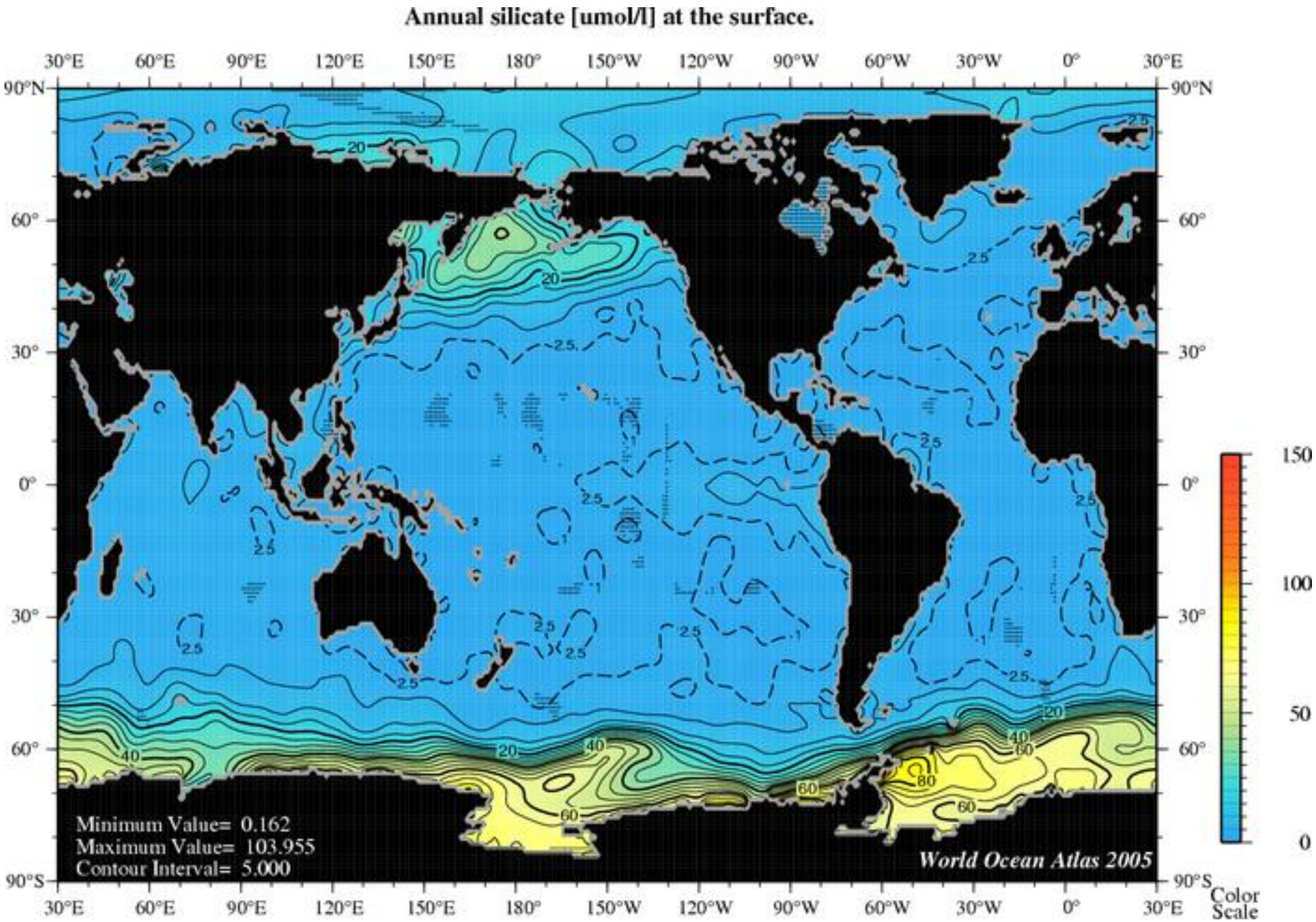
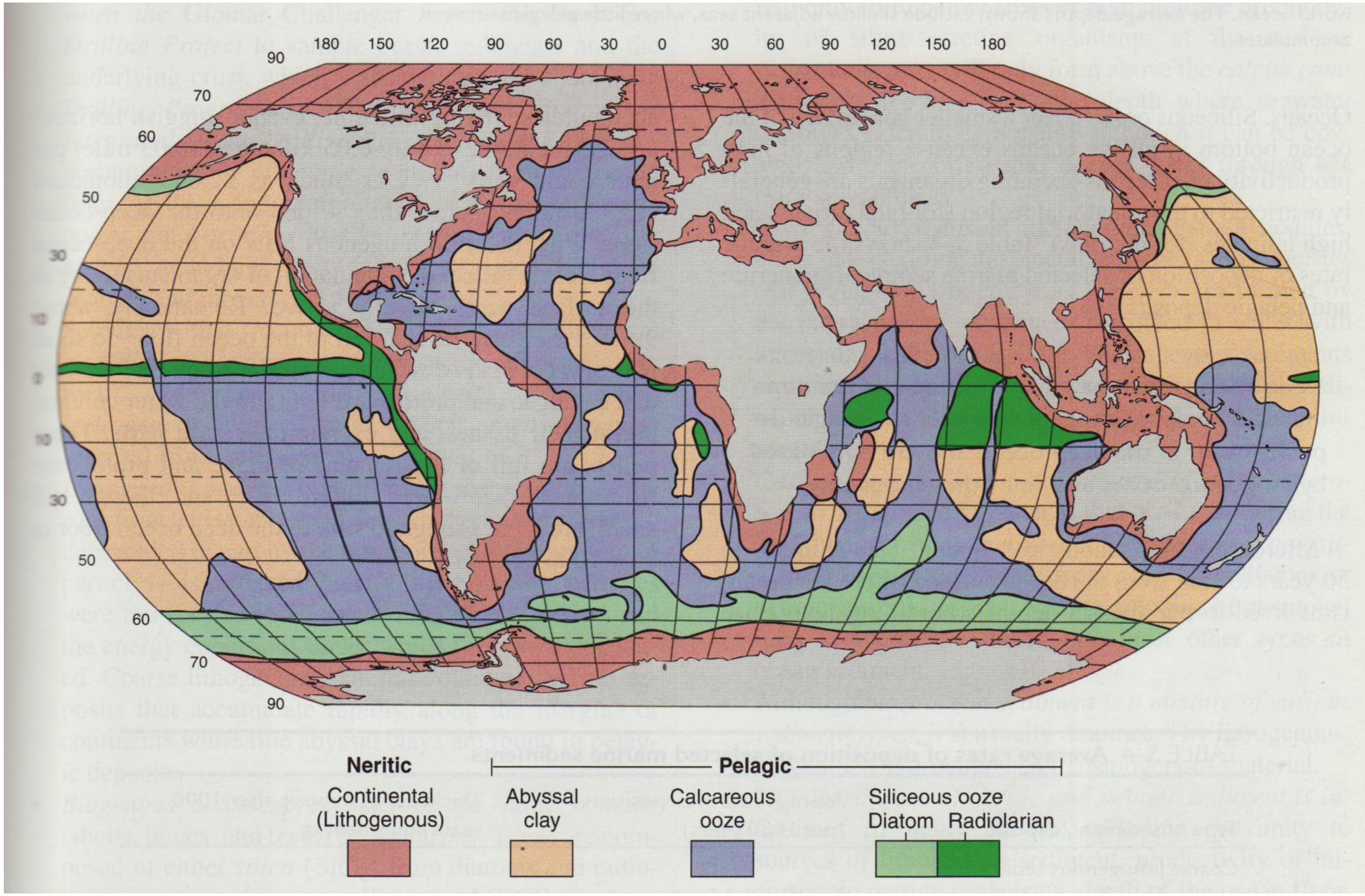
Silica distribution – ocean surface



Silica Distribution



Siliceous ooze

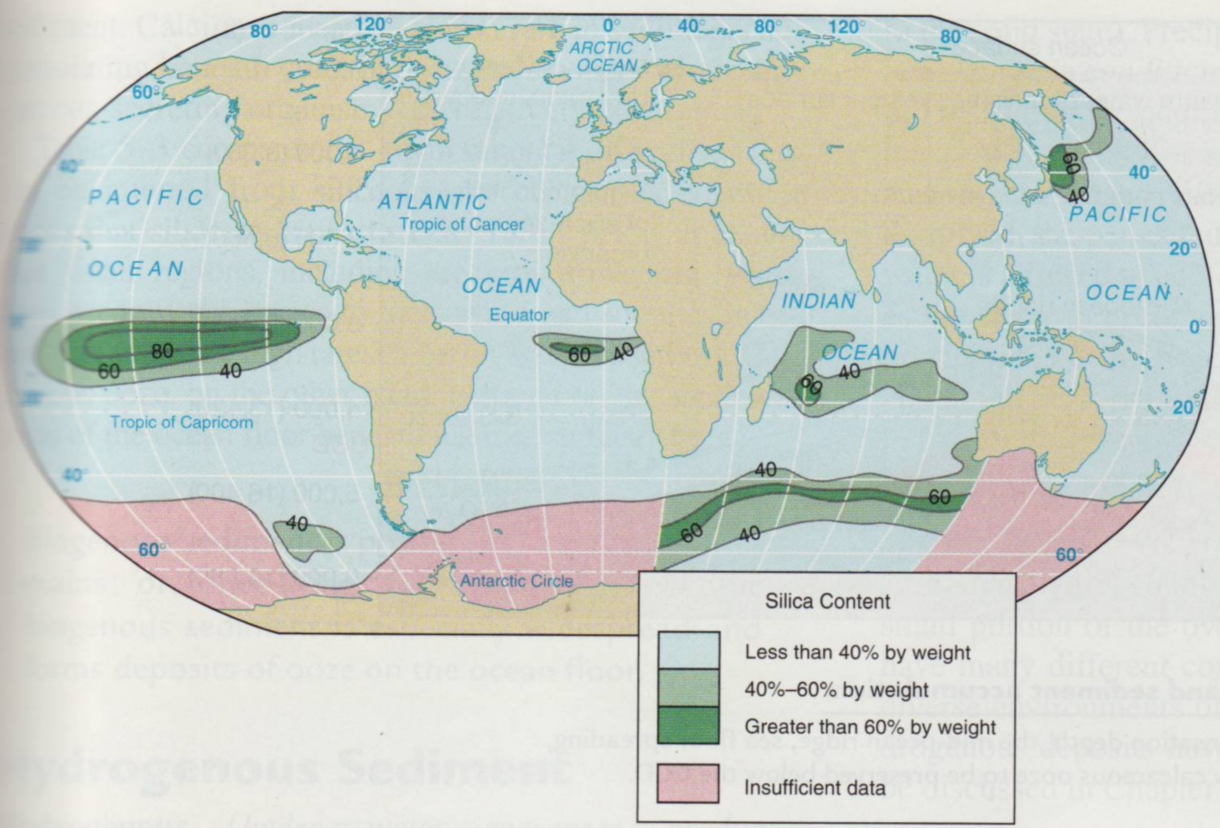
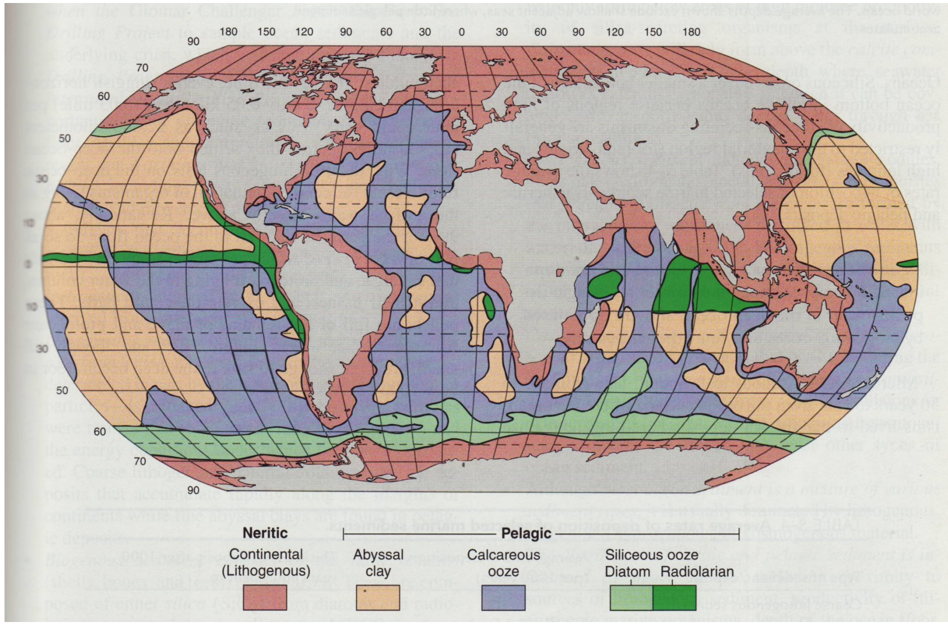


Figure 5–15 Distribution of biogenous silica in modern surface sediments.

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.

High concentrations of opaline silica

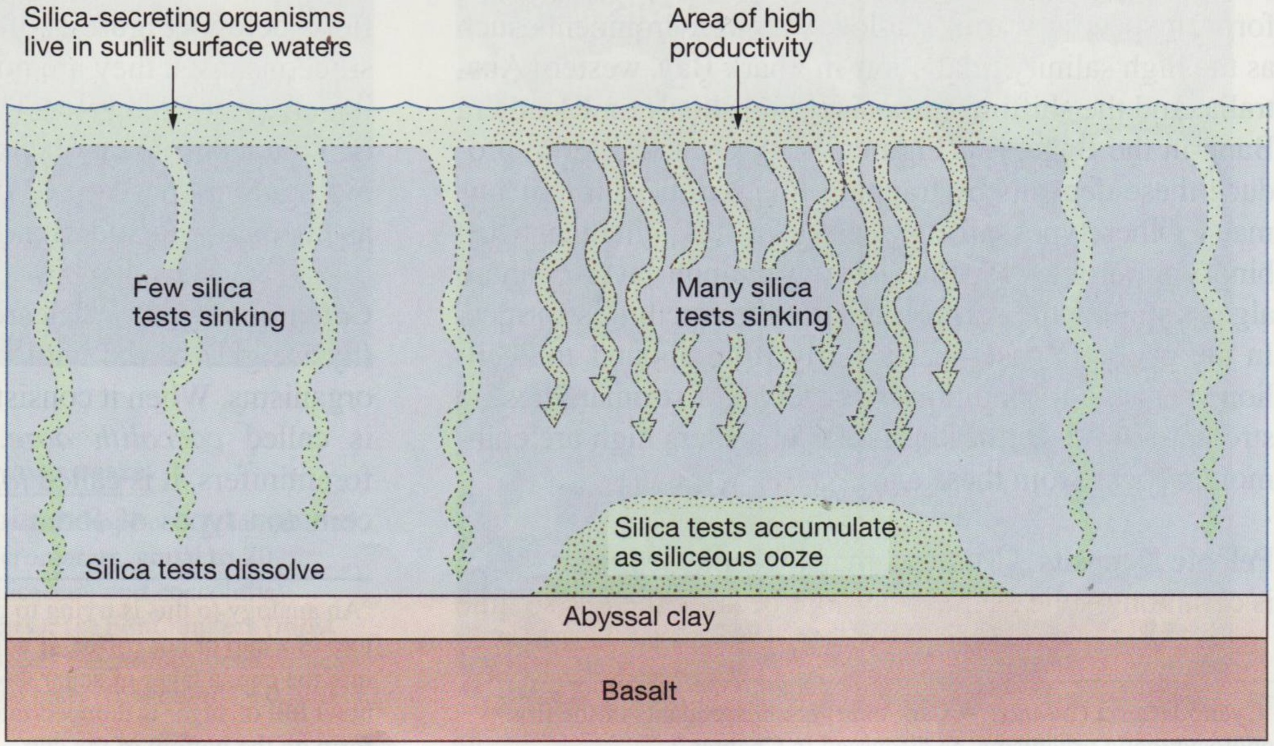
- High primary productivity (e.g., upwelling)
- Low terrigeneous input (dilution effect)
- Low carbonate production
- And/or high CCD and lysocline



Silica ooze accumulation

Figure 5–14 Accumulation of siliceous ooze.

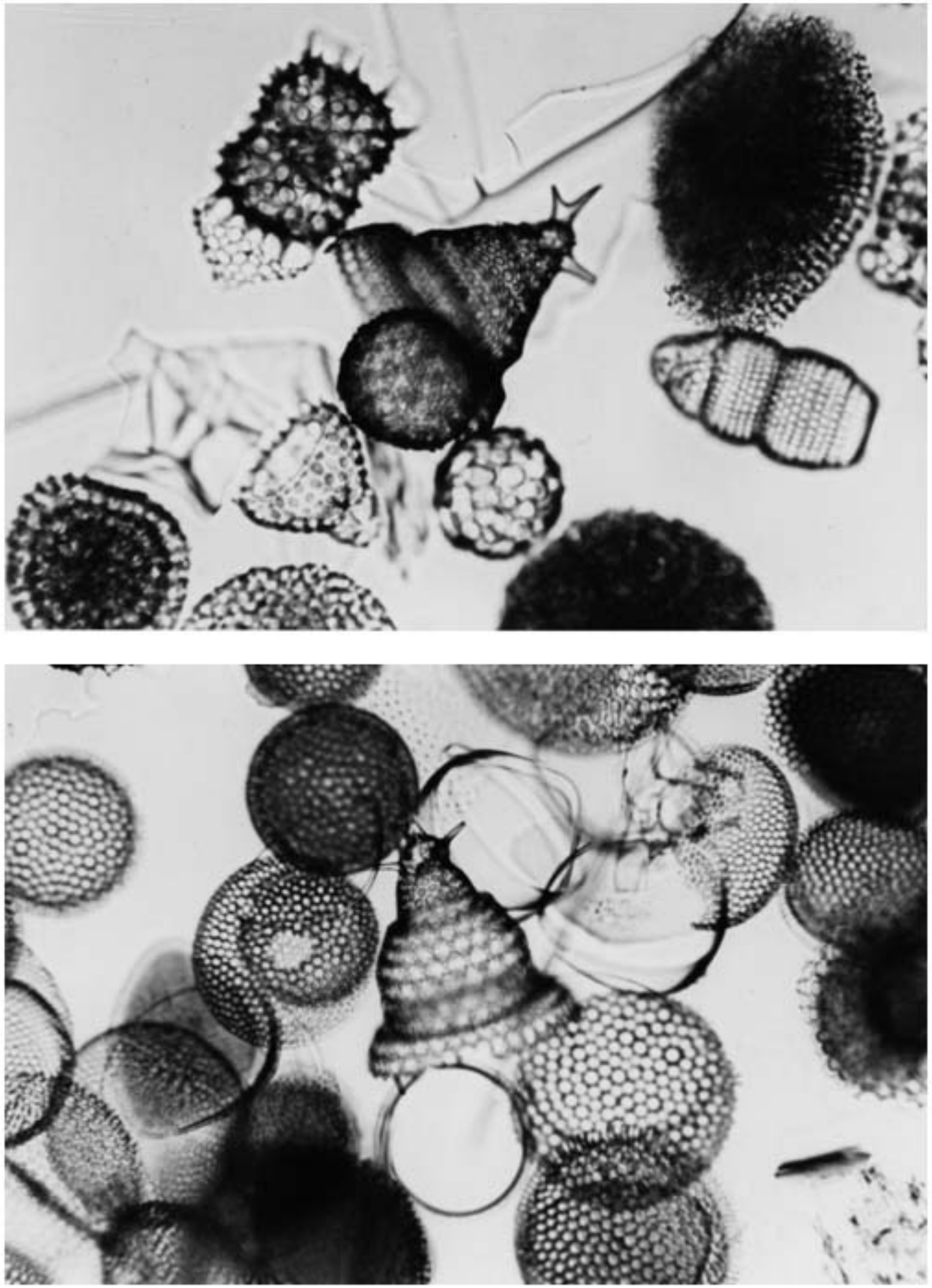
Siliceous ooze accumulates on the ocean floor beneath areas of high productivity, where the rate of accumulation of siliceous tests is greater than the rate at which silica is being dissolved.



Chert

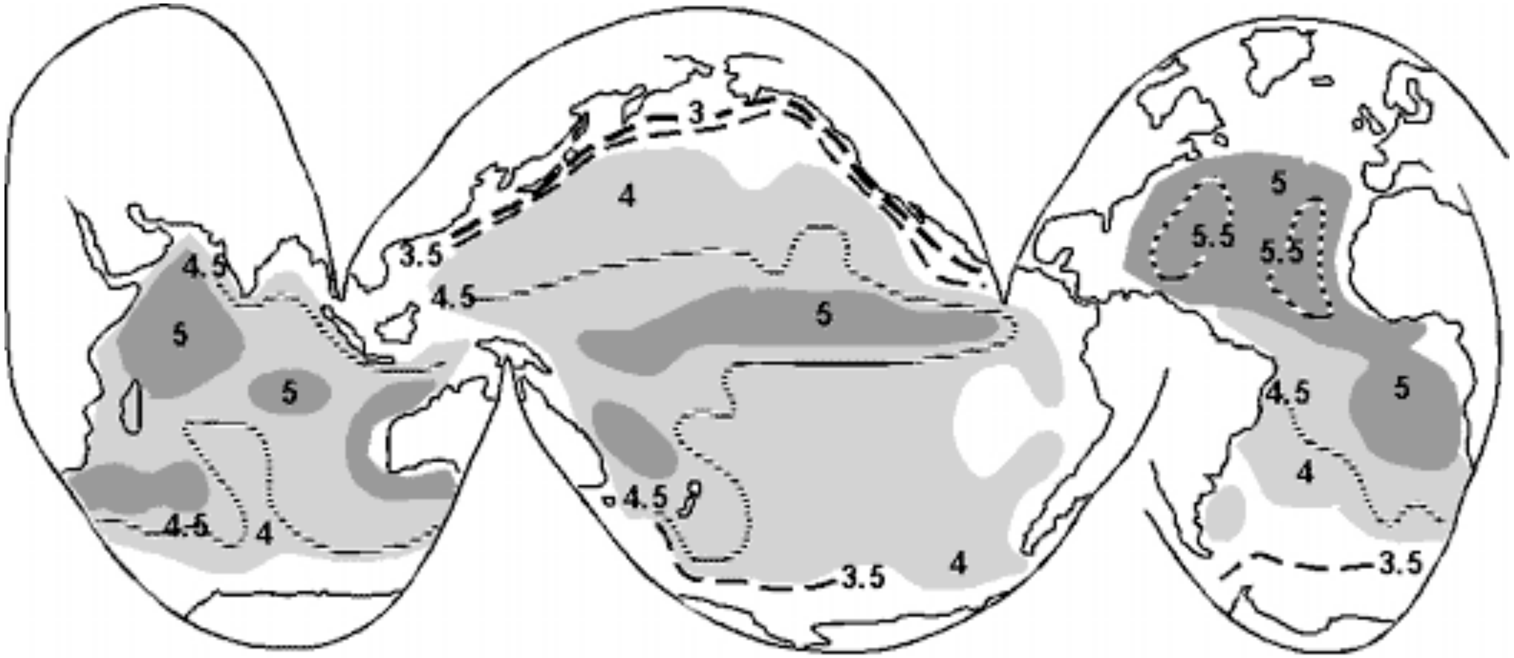
Some microorganisms secrete *silica* shells.

When these pile up on the deep ocean floor, they lithify to become a micro-crystalline quartz rock called *chert* (the same stuff as the substance flint).



diatoms and radiolaria

Topography of the CCD



Topography of the calcium carbonate compensation depth (CCD), i.e., the depth in kilometers below which little or no CaCO3 accumulates

- High production of carbonate means lower/deeper CCD
- Low production of carbonate means higher/shallower CCD
- Deep sea sediments associated with equatorial upwelling will still contain biogenic carbonate and silica compared to other regions

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