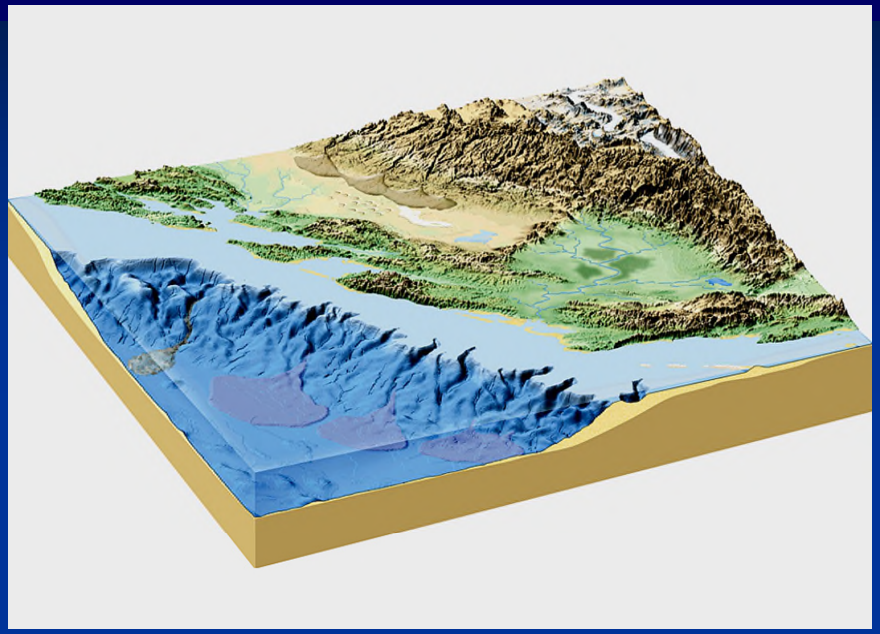
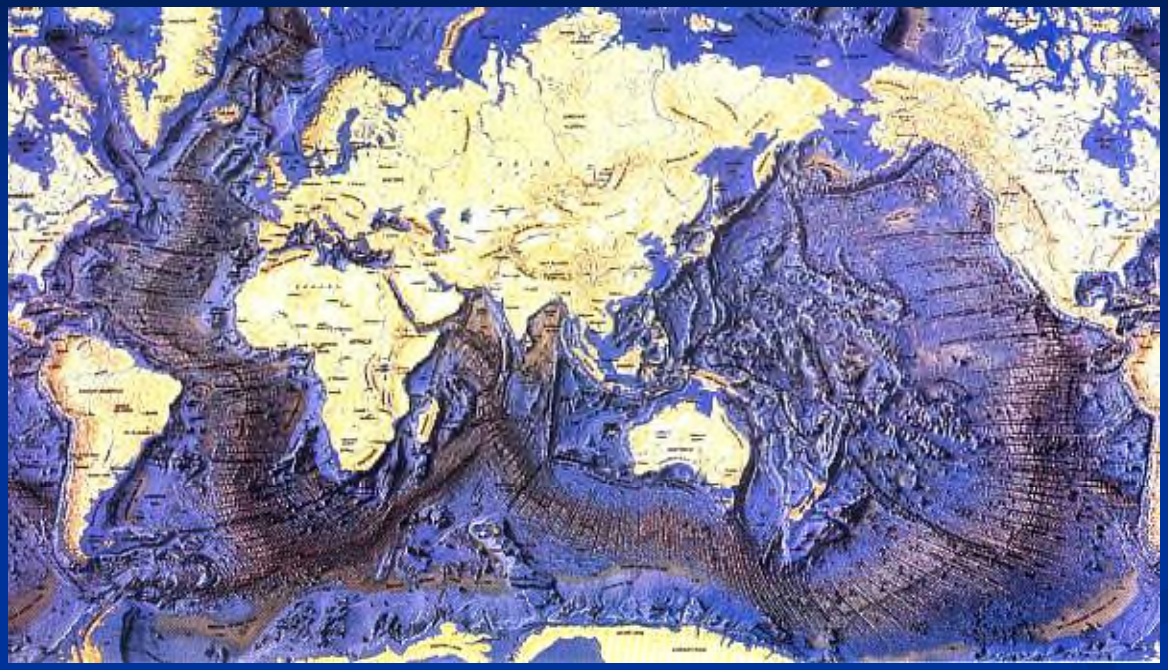
Marine Sediments Lab



Introductory Oceanography Laboratory

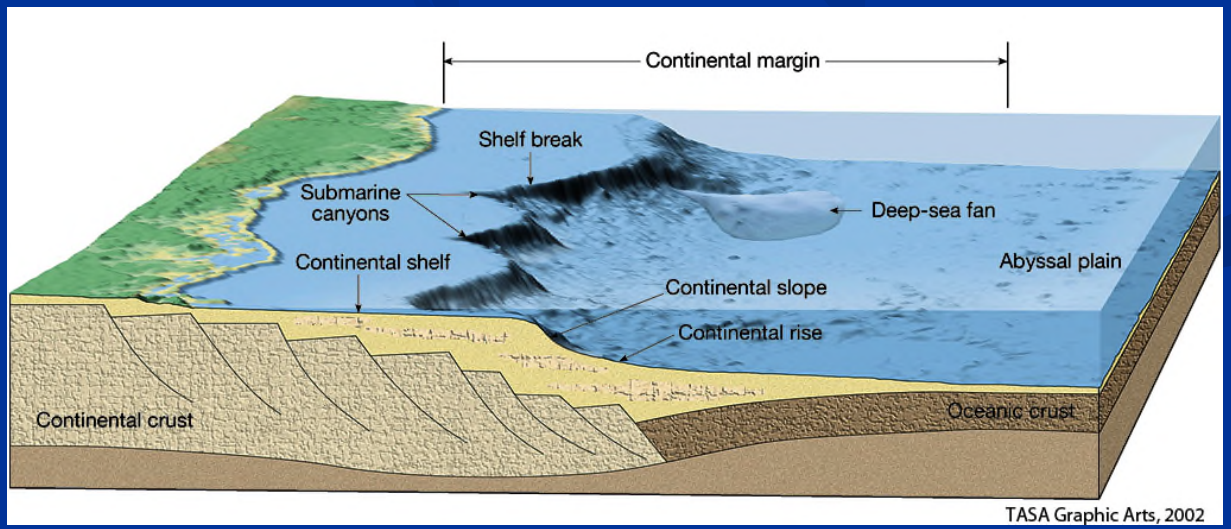
Ray Rector: Instructor

Ocean Basins are Vast Depositories for Huge Amounts of Sediments Coming from Numerous Different Sources

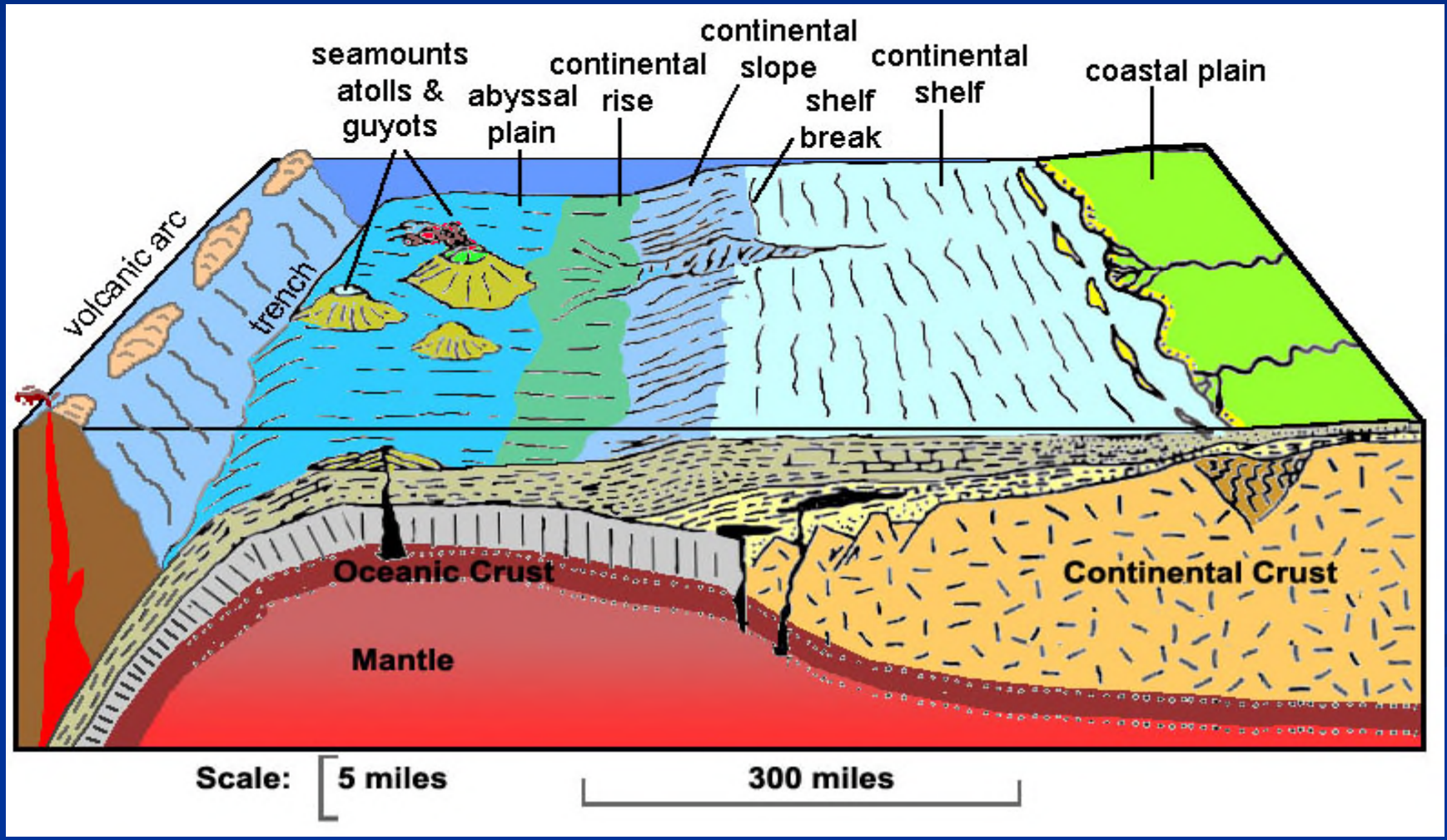


Shallow Inter-Tidal Sea Bottom

Marianas Trench Sea Bottom



Ocean Basins Act as Earth's Memory Files: Recording 100's of Millions of Years of Geologic Events and Sedimentation History



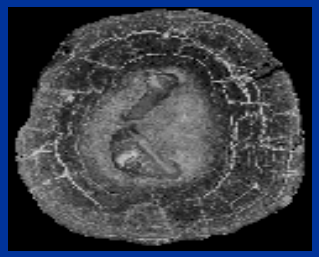
Four Major Origins for Seafloor Sediments

1. Lithogenous

- **Sources:** Erosion of land; volcanic eruptions; wind-blown dust
- **Material:** Gravels, Sands, Silts, and Clays

2. Biogenous

- **Sources:** Organic; accumulation of plant and animal hard parts
- **Material:** Calcareous and Siliceous Oozes



3. Hydrogenous

- **Sources:** Precipitation of minerals from solution
- **Material:** Carbonates, Metal Oxides and Sulfides

4. Cosmogenous

- **Sources:** Extraterrestrial dust and meteorites
- **Material:** Tektite particles, Glassy spheres, Silicate dust

Classification of Marine Sediments

TABLE 4.1 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 and 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; upwelling areas where cold, deep water rises to the surface, especially that caused by 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		Meteors		Localized near meteor impact structures

Origin of Lithogenous Sediments

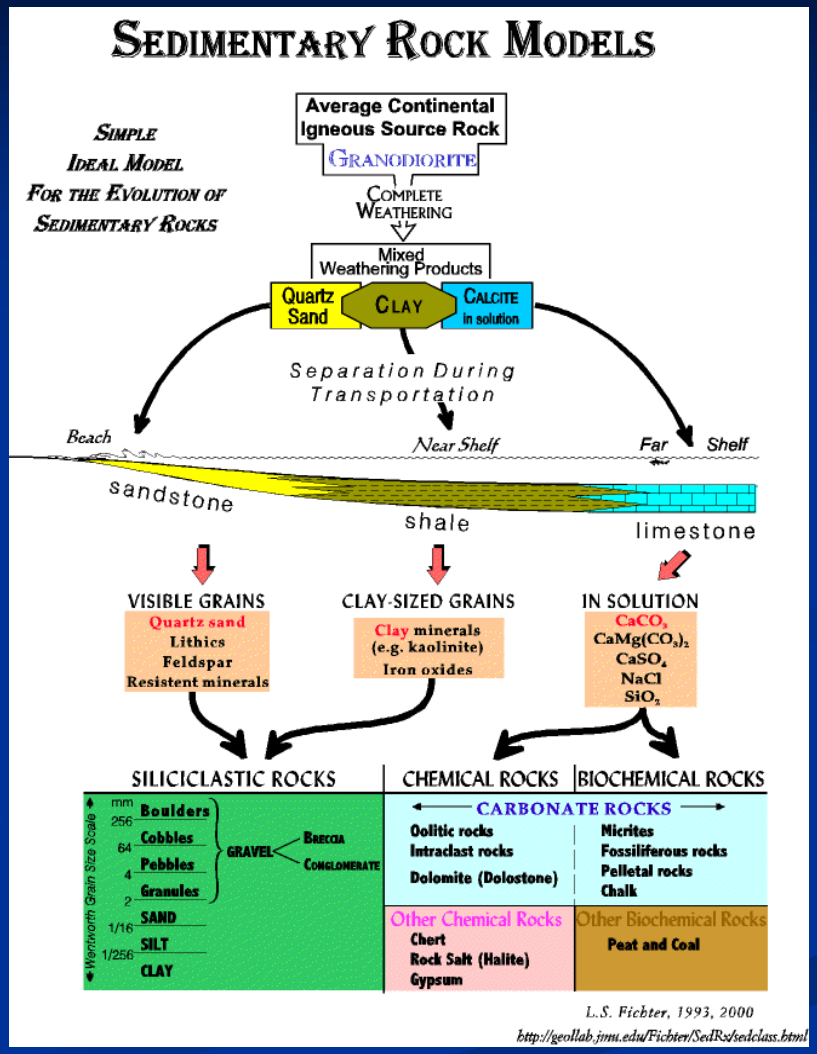
Key Points

1) Primary source is continental rocks
   - Granodiorite most common rock

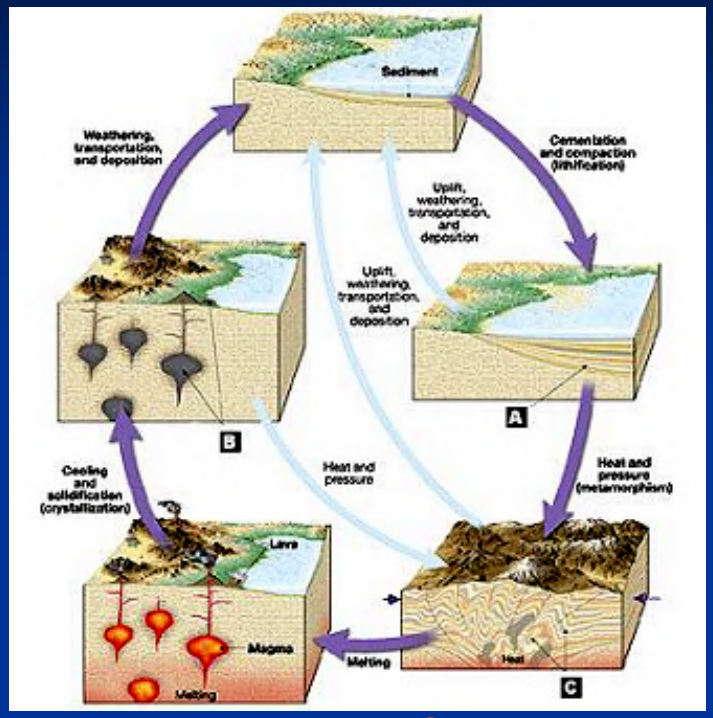
2) Granodiorite is mechanically broken down into smaller and smaller pieces
   - From boulder size to silt size
   - Courser near source, finer farther away

3) Granodiorite is chemically altered where most original minerals turn in clays
   - Feldspars, micas, amphiboles and olivine get altered to clays
   - Quartz is mineral is not altered

4) Weathered rock is then eroded away (removed and transported from source region to region of deposition.

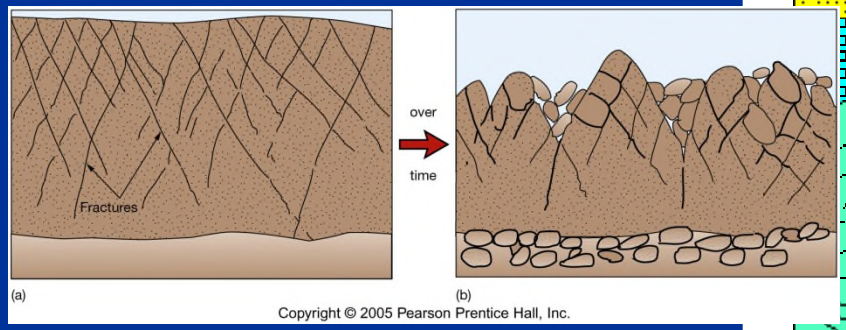


Lithogenous Sediments and the Rock Cycle

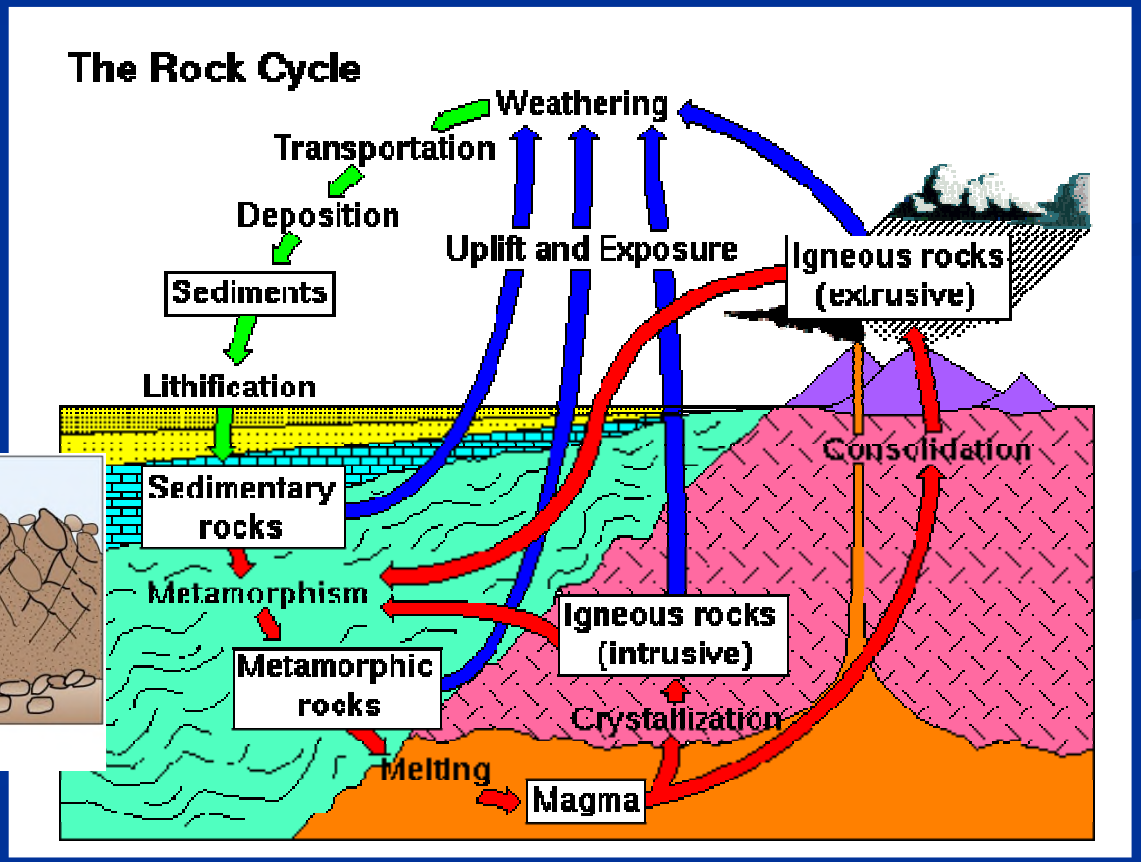


The Rock Cycle

- **Weathering** = Breakdown of Rock
- **Erosion** = Removal and Transport
- **Deposition** = Settling of Material

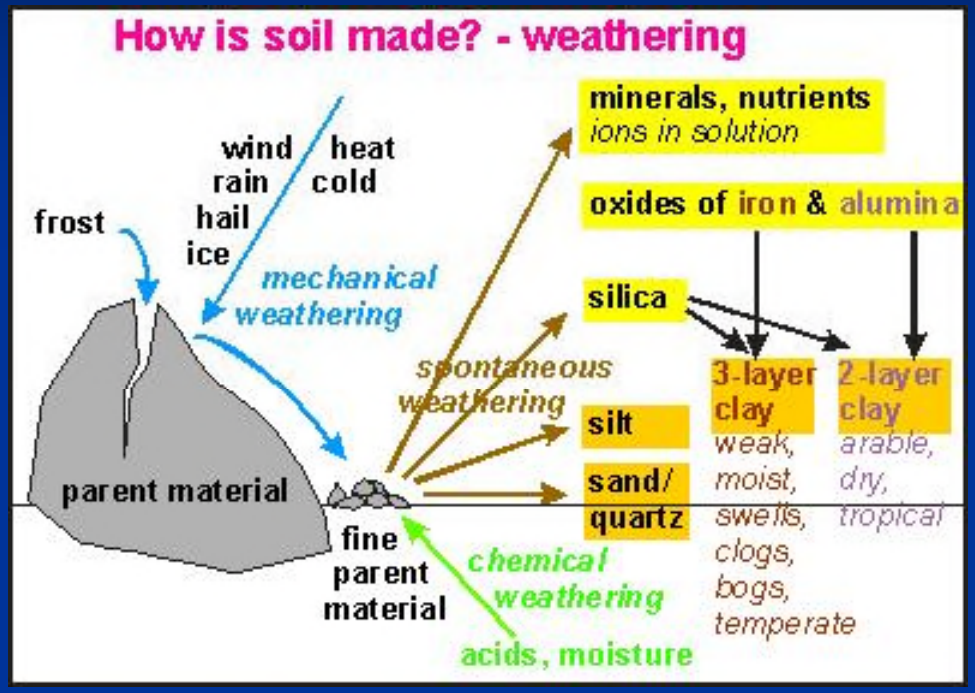


Breakdown and Removal



SEDIMENTARY PROCESSES

The Chemical/Physical Breakdown and Removal of Rock



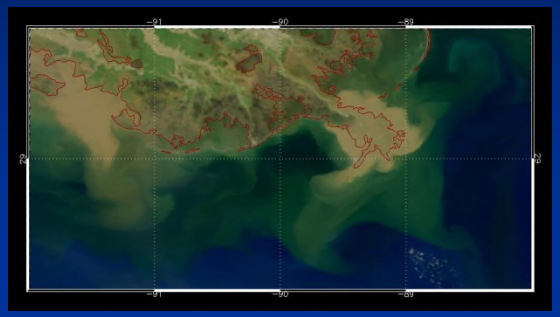
Formation of Lithoenous Sediments

- **Weathered Products**
  - ✓ Clays
  - ✓ Quartz
  - ✓ Dissolved Ions
- **Erosion Methods**
  - ✓ Running water
  - ✓ Moving ice
  - ✓ Blowing wind
  - ✓ Turbidity currents

Lithogenous Sediment Sources

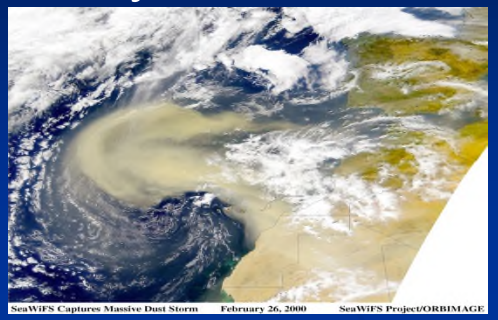
Sources: Rivers; Glaciers; Wind-blown dust; Coastal Erosion; Volcanic eruptions

Materials: Silicate-rich Gravels, Sands, Silts, and Clays



1) Rivers

2) Glaciers



3) Wind-blown dust

Major Sediment Input to the Oceans	
Source	**Estimated Amount (10^9 tons/yr)**
Rivers	18.3
Glaciers	2.0
Wind blown dust	0.6
Coastal erosion	0.25
Volcanic debris	0.15
Groundwater	<0.48

4) Coastal erosion

5) Ash from volcanic eruptions

Origin of Biogenous Sediments

Key Points

1) Primary source is marine life hard parts
   - Shells and skeletons of dead organisms

2) Hard parts from dead planktonic and benthic organisms settle to the bottom
   - From cobble size to microscopic
   - Material may be further broken down by weathering and erosional processes
   - Courser near source, finer farther away

3) Biogenic material is mainly of two types
   - Silica – SiO_2
   - Calcium carbonate – $CaCO_3$

4) Two general biogenous sediment depositional regions are shallow (littoral and shelf) and deep (abyssal pelagic)

Shallow, benthic biogenous material

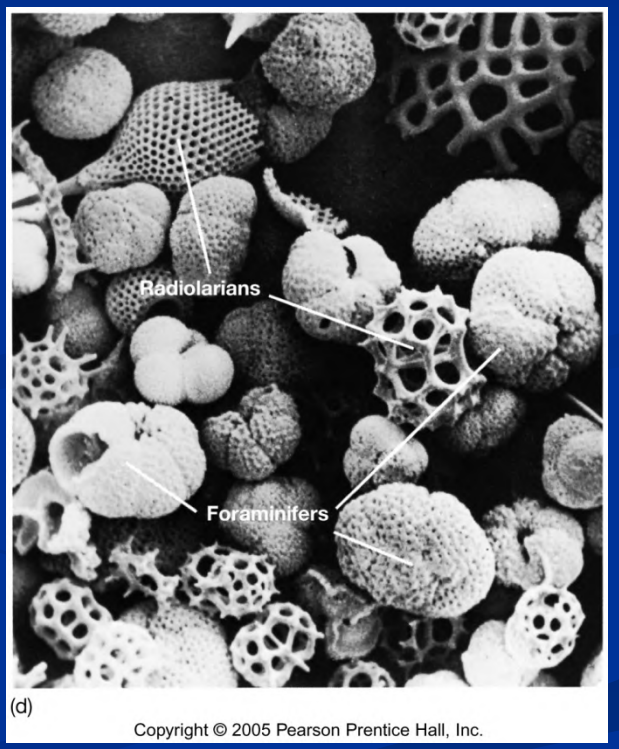
Deep pelagic biogenous material

Biogenous Sediment Sources

Sources: Organic; accumulation of plant and animal hard parts

Material: Mostly Calcareous and Siliceous Shells and Skeletons

Deep Ocean Seafloor



Plankton Tests

Shallow Water Biogenous Sediments

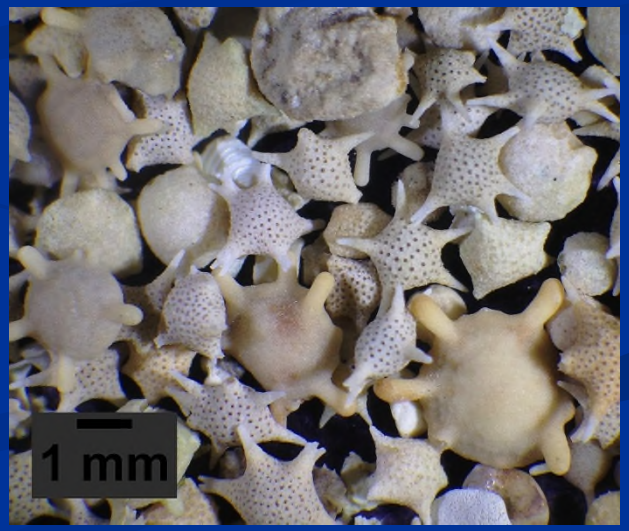
Key Points

1) Remains of invertebrate animal hard parts
   - Shells and skeletons of benthic organisms

2) Organisms living from shore out on the shelf
   - Mollusks, corals, forams, sponges, crustaceans
   - Material collects to form beach and shelf deposits
   - Mostly carbonate in composition

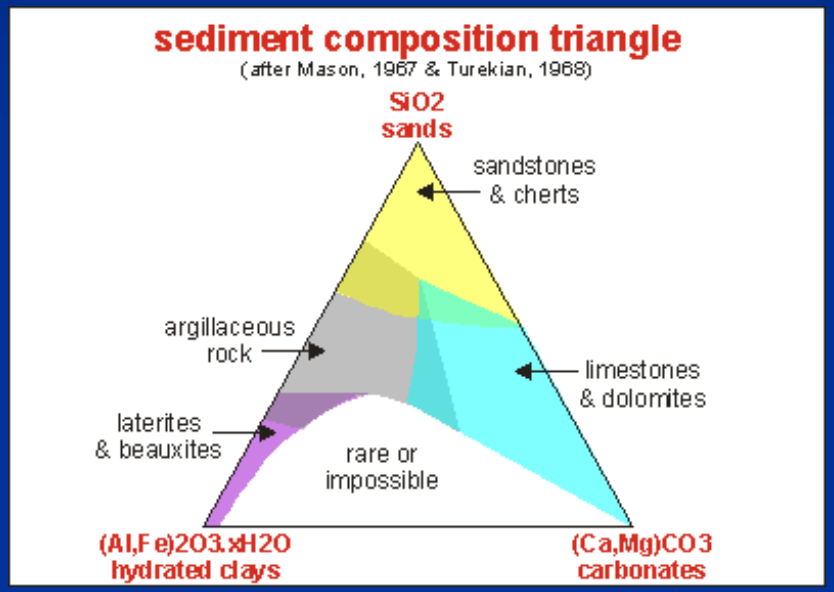
3) Biogenous material can dominate the shoreline and shallow water seafloor if there is little to no lithogenous sediment input in the region
   - Coral sand beaches are a good example
   - Extensive carbonate shelf platforms in tropical regions

Coral-rich beach sand from Molokai, Hawaii



Foraminifera-rich beach sand Hatoma Island Okinawa Japan

The Most Common Minerals in Marine Sediments



Sediment Composition Chart

"Biggie" Sediment Minerals

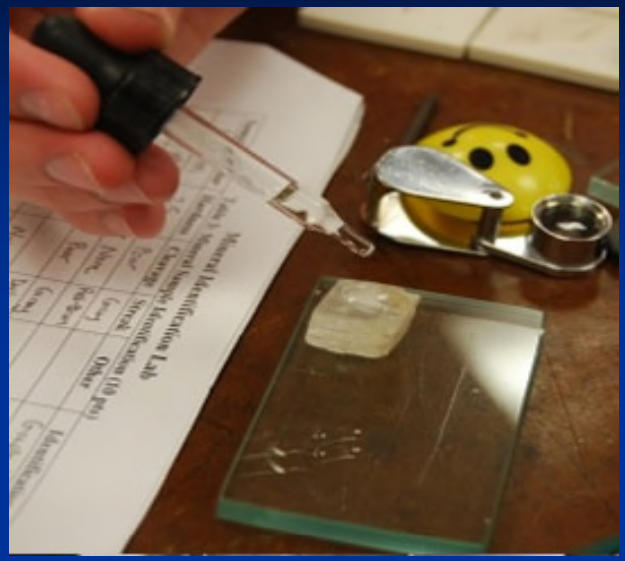
- ✓ Quartz-Silica
- ✓ Clays
- ✓ Carbonates

Other Sediment Minerals

- ✓ Iron Oxides
- ✓ Phosphates
- ✓ Sulfates
- ✓ Sulfides

Reaction to Acid – The "Acid Test"

Defined: Carbonate minerals react to acid solution (HCl): bubble and dissolve



- ✓ Good for positive ID of **carbonates**
- ✓ Typically either calcite or dolomite
- ✓ Limestone & Calcareous oozes will fizz
- ✓ Silicate minerals and rocks do not fizz
- ✓ Use the acid test only if you think that your unknown mineral or rock has low hardness – close to 3.

- http://academic.brooklyn.cuny.edu/geology/grocha/mineral/mineral.html

Sediment Clast Characteristics

Clast Size

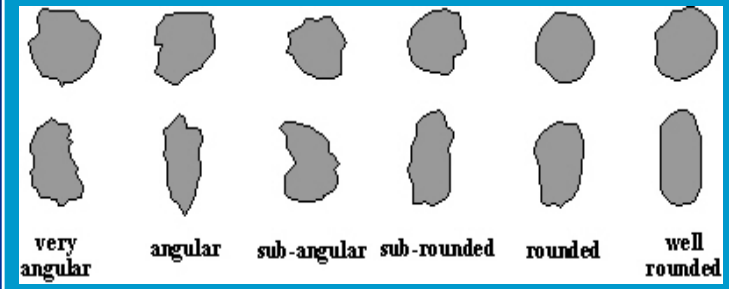
Gravel-size

Sand-size

Silt-size

Clay-size

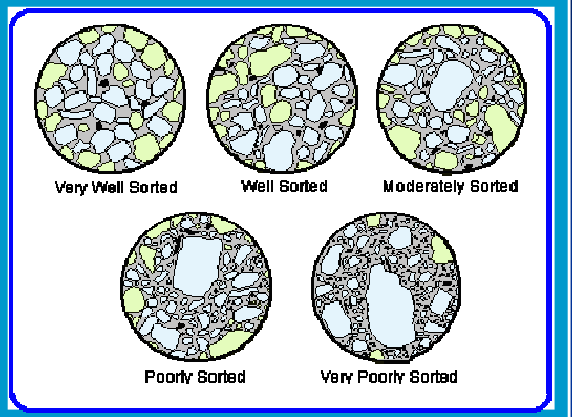
Clast Shape

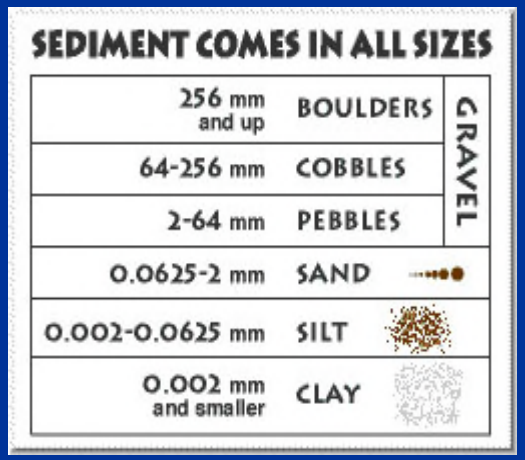


Near-to-source

Far-from-source

Clast Sorting





1) **Clast size** is a function of transport time & transport medium

✓ An indicator of depositional environment

2) **Clast shape** is a function of transport distance and time

✓ An indicator of sediment "maturity"

3) **Clast sorting** is a function of transport medium

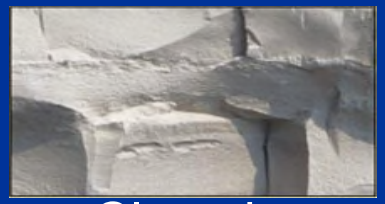
✓ An indicator of depositional environment

Predominant Sediment Types and Grain Sizes at Specific Depositional Settings

Gravel-size

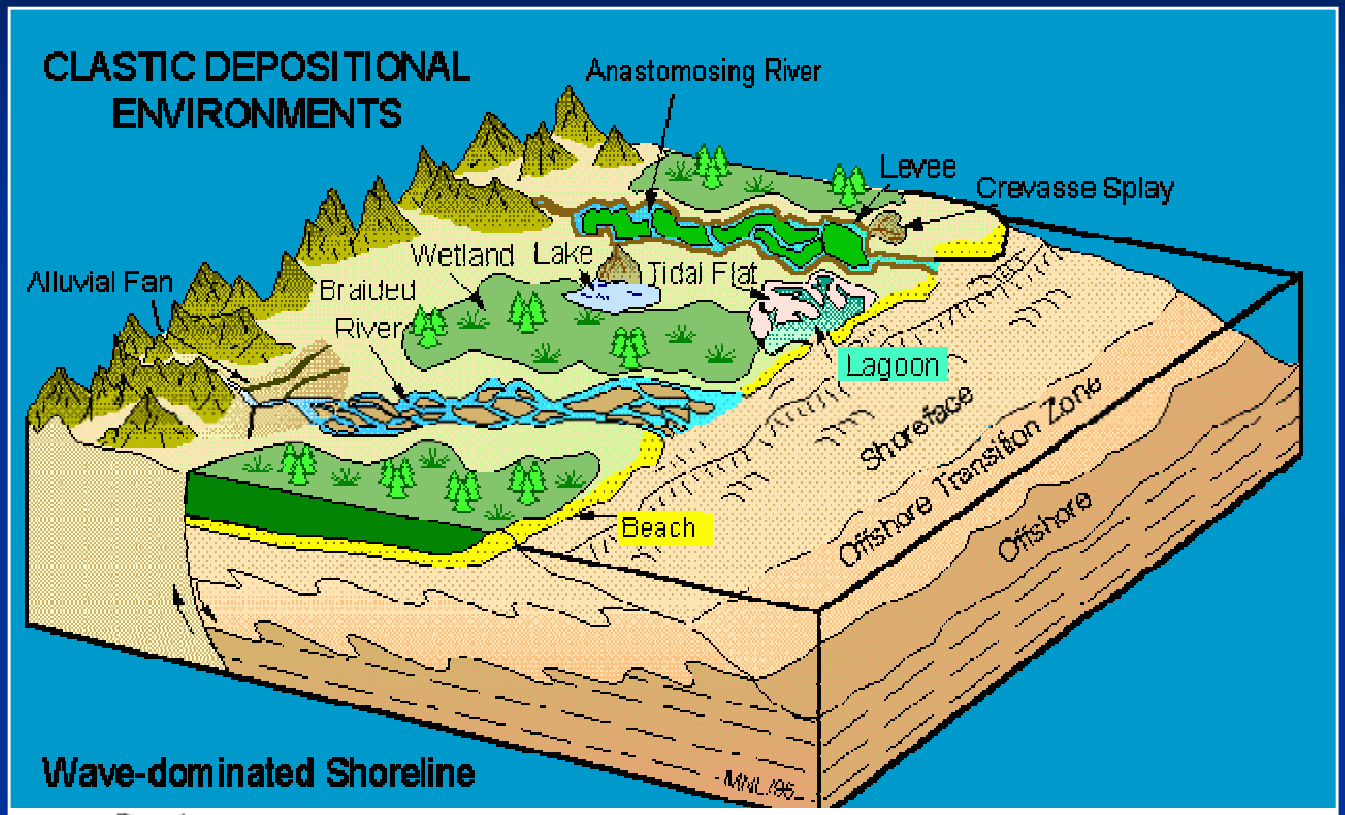
Sand-size

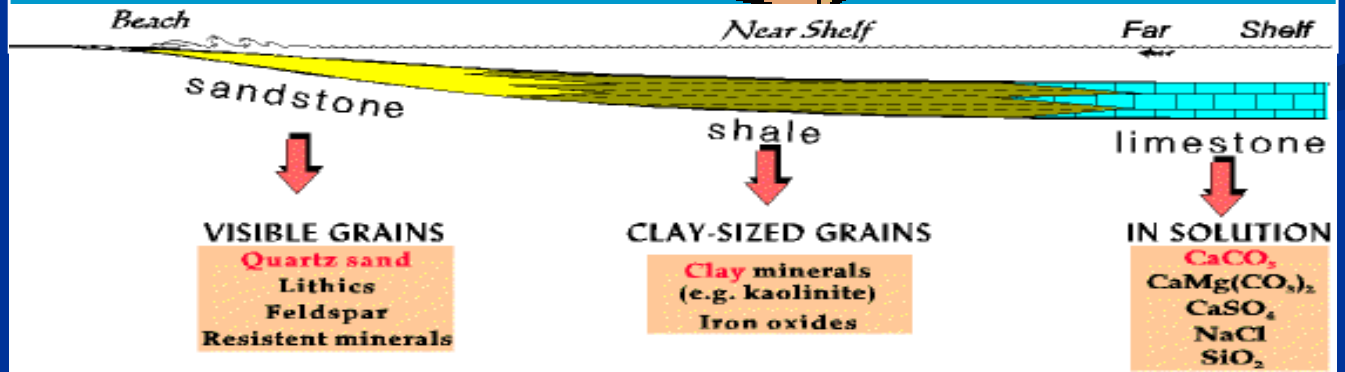
Silt-size



Clay-size

Clast Size



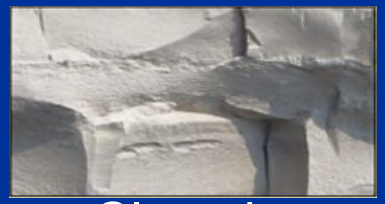


Predominant Sediment Types and Grain Sizes at Specific Depositional Settings

Gravel-size

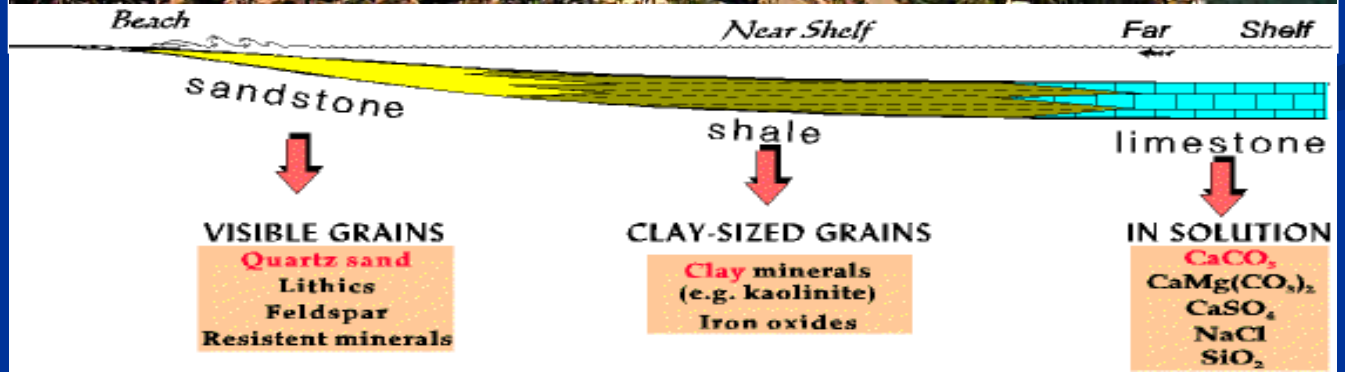
Sand-size

Silt-size

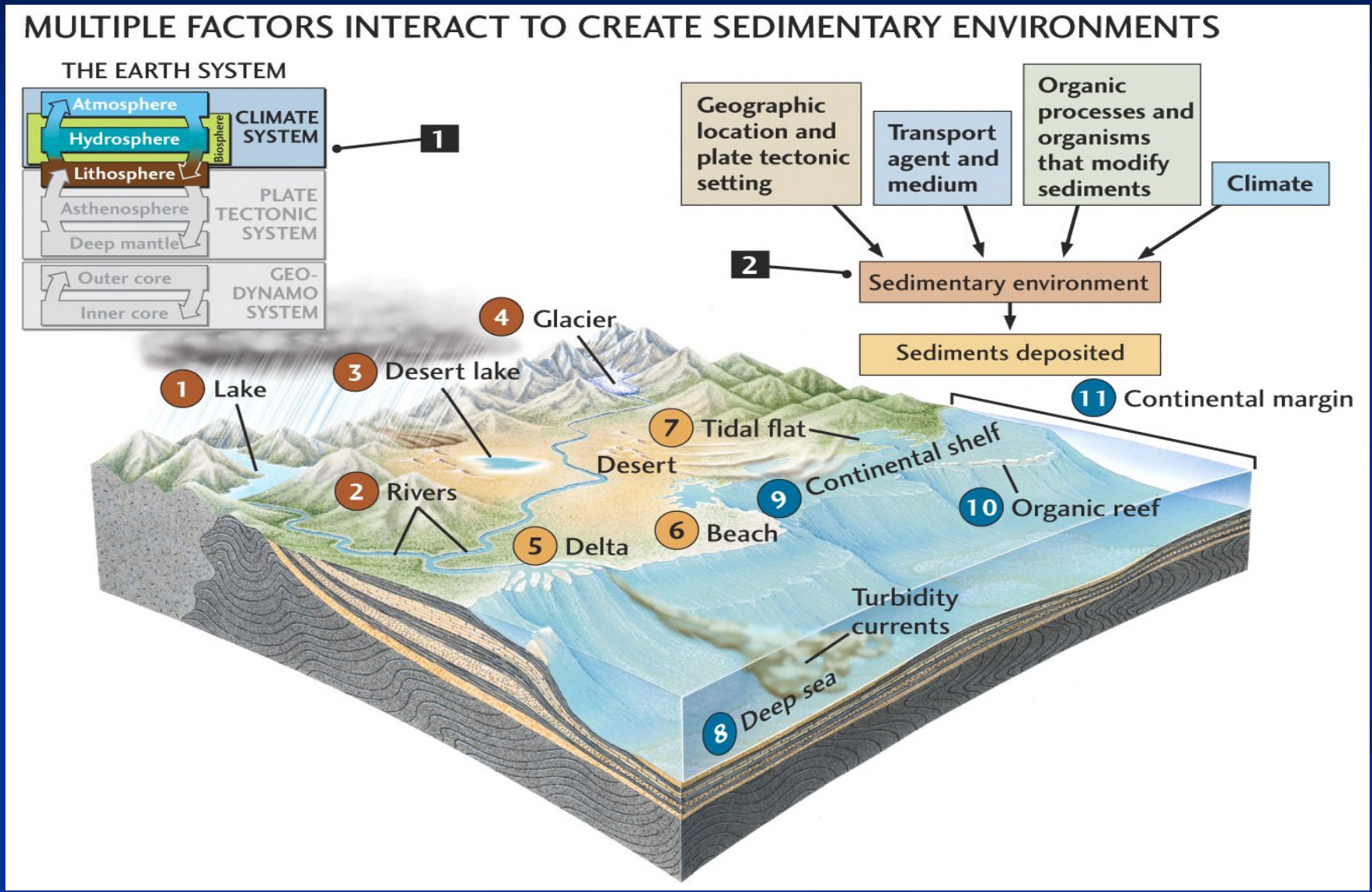


Clay-size

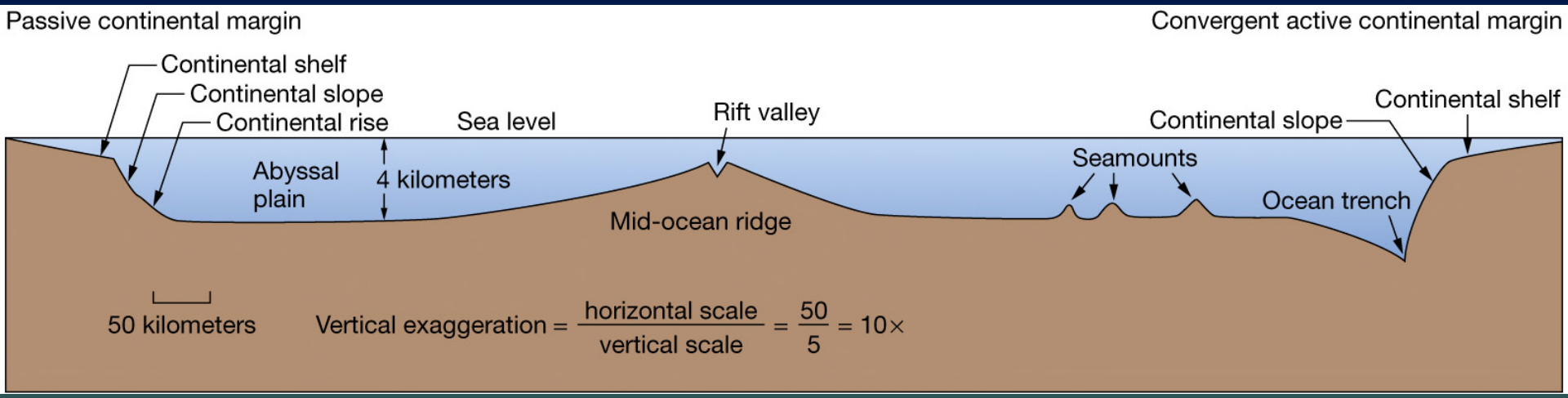
Clast Size



Sedimentary Environments are Where Sediments Deposit and Sedimentary Rocks Form



Seafloor Sediment Provinces



Cross-Section Profile of an Ocean Basin

- ✓ Continental shoreline = Littoral Province
- ✓ Continental shelf = Neritic Province
- ✓ Continental slope to rise = Transitional
- ✓ All deep sea regions = Oceanic

Marine Depositional Environments

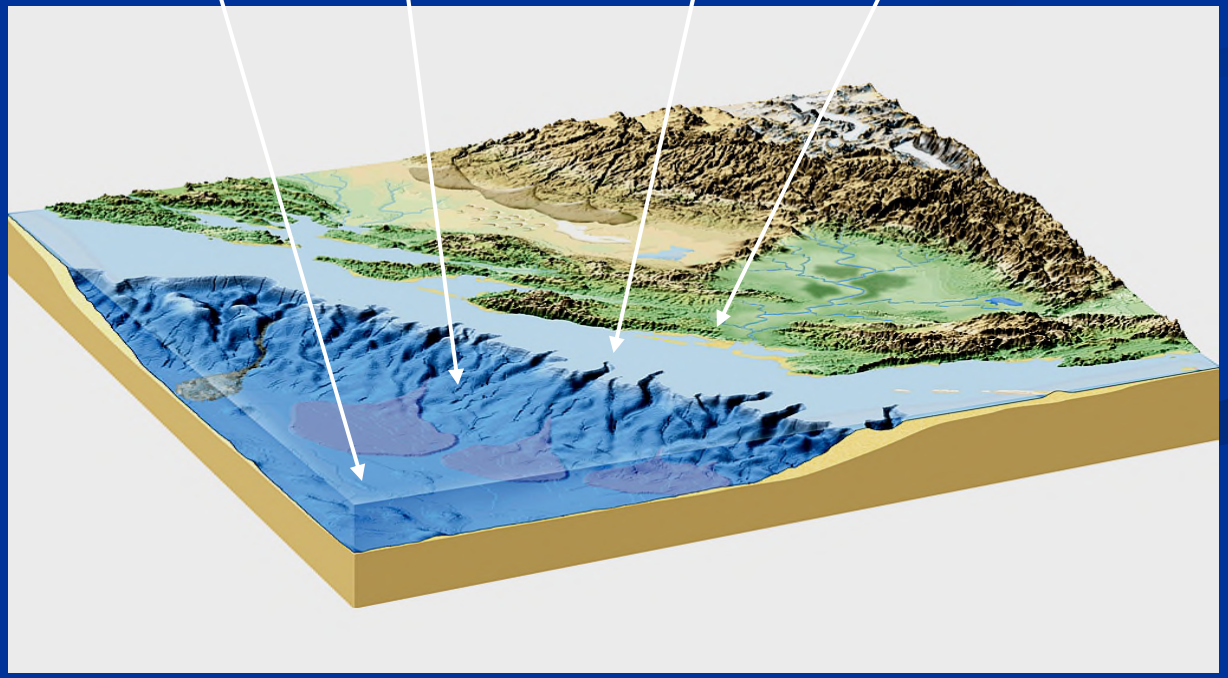
Four Major Depositional Provinces

1) Very Shallow (shoreline and back shoreline) = "Littoral"

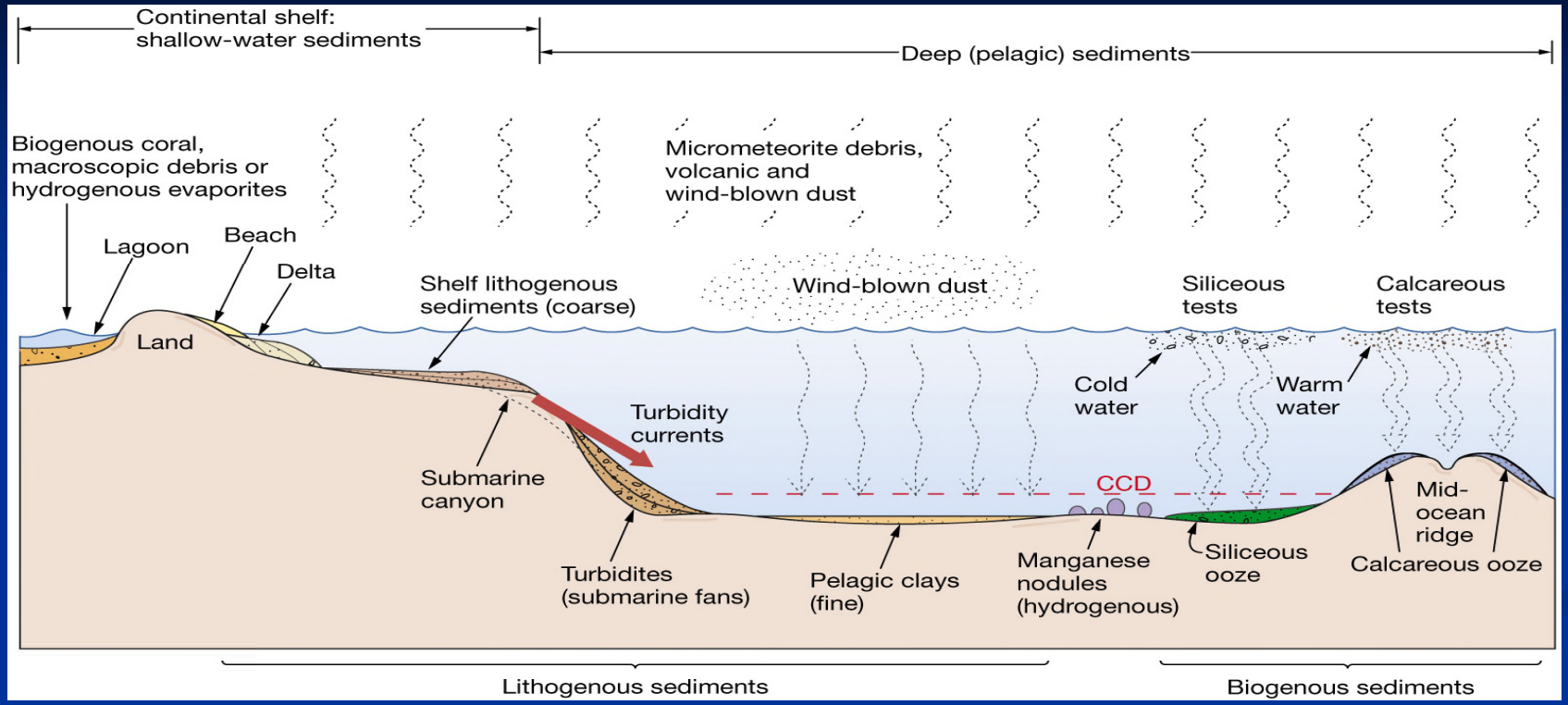
2) Shallow (over the shelf and banks) = "Neritic"

3) Slope/Rise (transitional) or "Bathyl"

4) Deep (the abyss) = "Oceanic"



Type and Locality of Marine Sediments



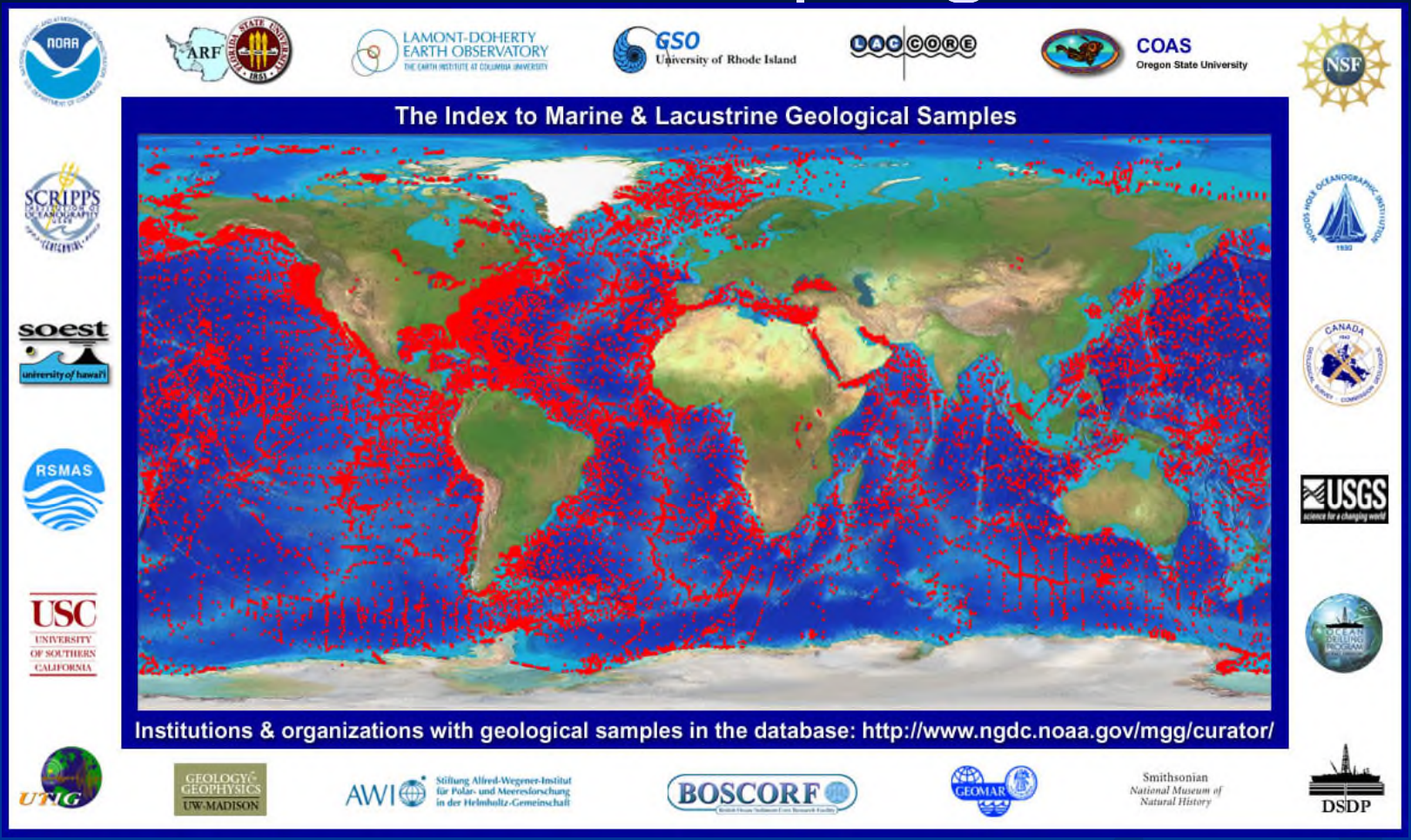
Types

1) Lithogenous
2) Biogenous
3) Hydrogenous
4) Cosmogenous

Localities

1) Littoral
2) Shelf
3) Slope/Rise
4) Pelagic

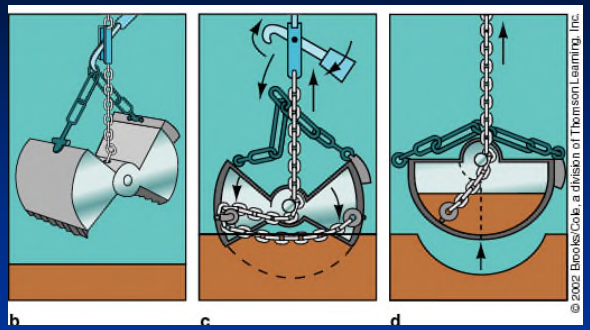
Marine Sediment Sampling Locations



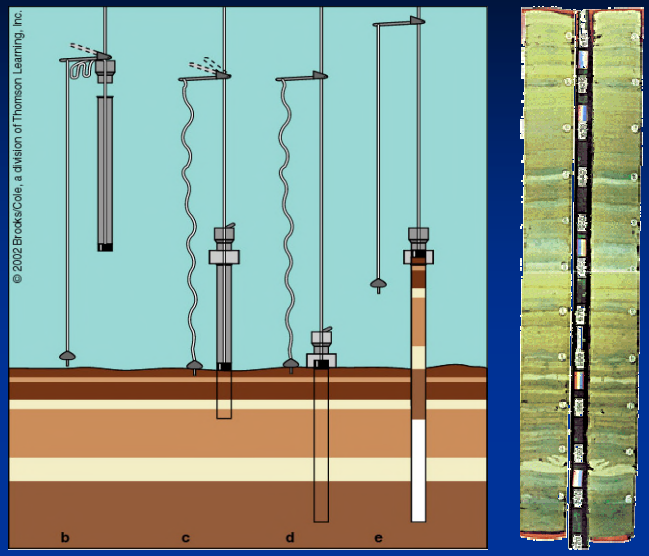
Primary Sampling Institutions:

1) Governments Agencies
2) Academic Institutions
3) Oil Companies

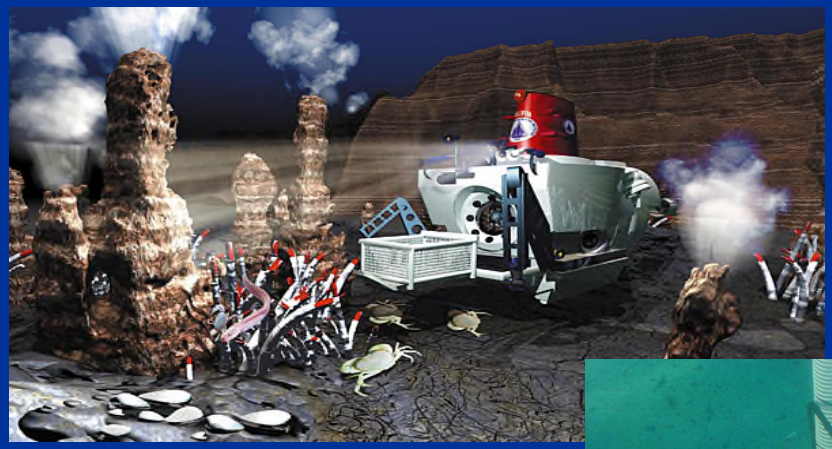
Marine Sediment Sampling Methods



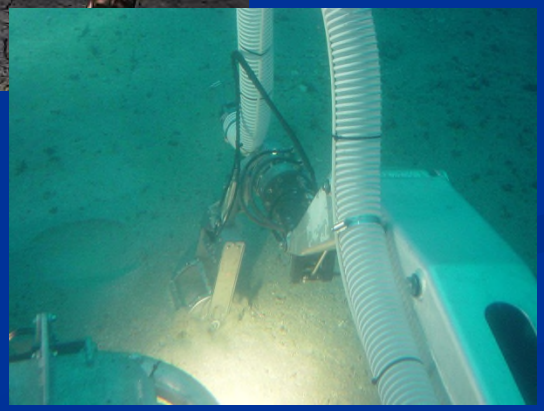
1) Bucket-Scooping



2) Piston Coring



4) Submersible



3) **Drilling**

Continental Margins of the World

1) Seafloor that includes shorelines and continental shelves

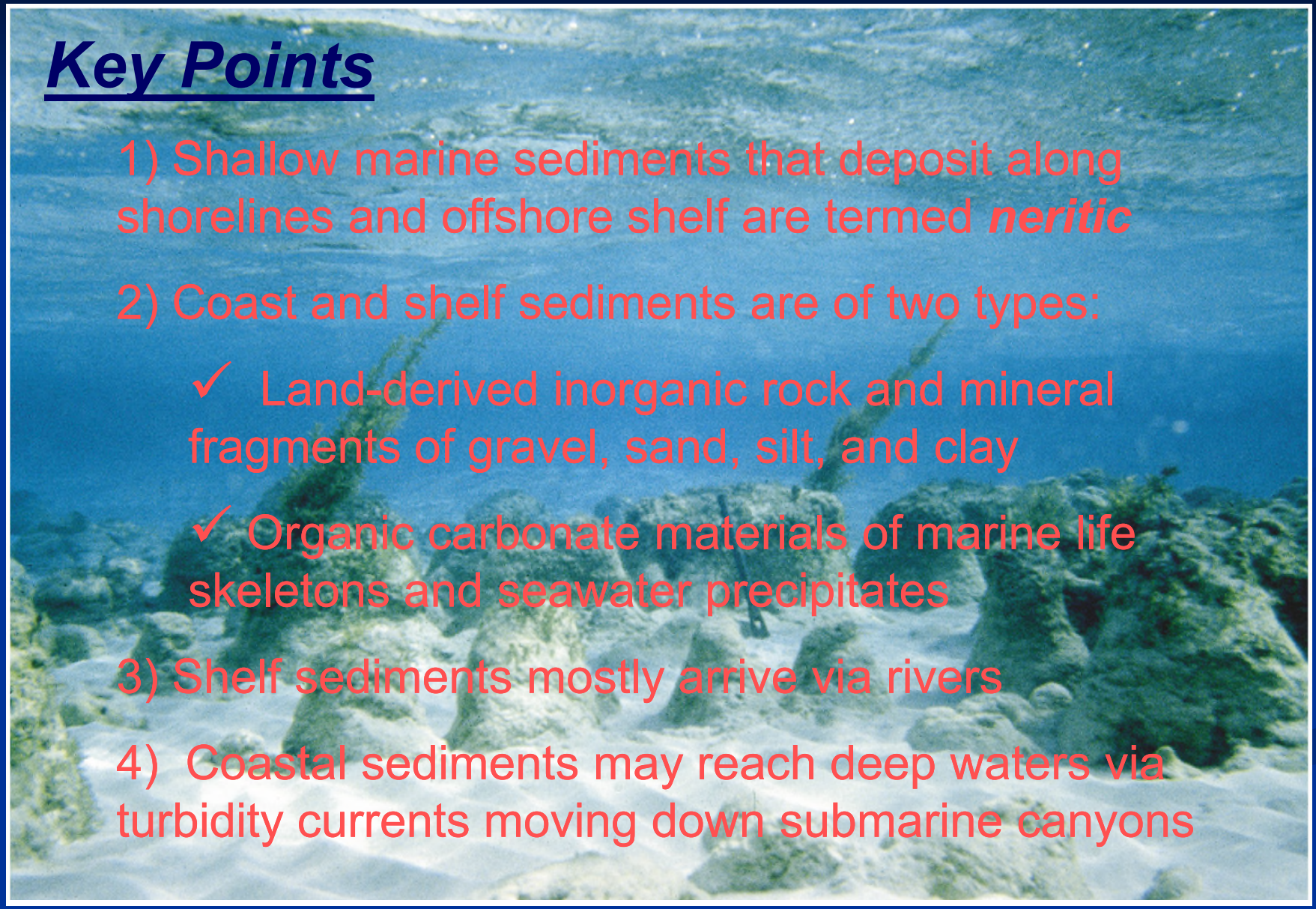
2) Submerged continental margins are colored pale orange

3) Average width of continental margins is 80 km

4) Depths of continental margins typically down to 150 meters

5) Continental margin seafloor bedrock mostly granitic rock

Shoreline and Shelf Sediments



Key Points

1) Shallow marine sediments that deposit along shorelines and offshore shelf are termed ***neritic***

2) Coast and shelf sediments are of two types:

- ✓ Land-derived inorganic rock and mineral fragments of gravel, sand, silt, and clay
- ✓ Organic carbonate materials of marine life skeletons and seawater precipitates

3) Shelf sediments mostly arrive via rivers

4) Coastal sediments may reach deep waters via turbidity currents moving down submarine canyons

Lithogenous Beach Sand

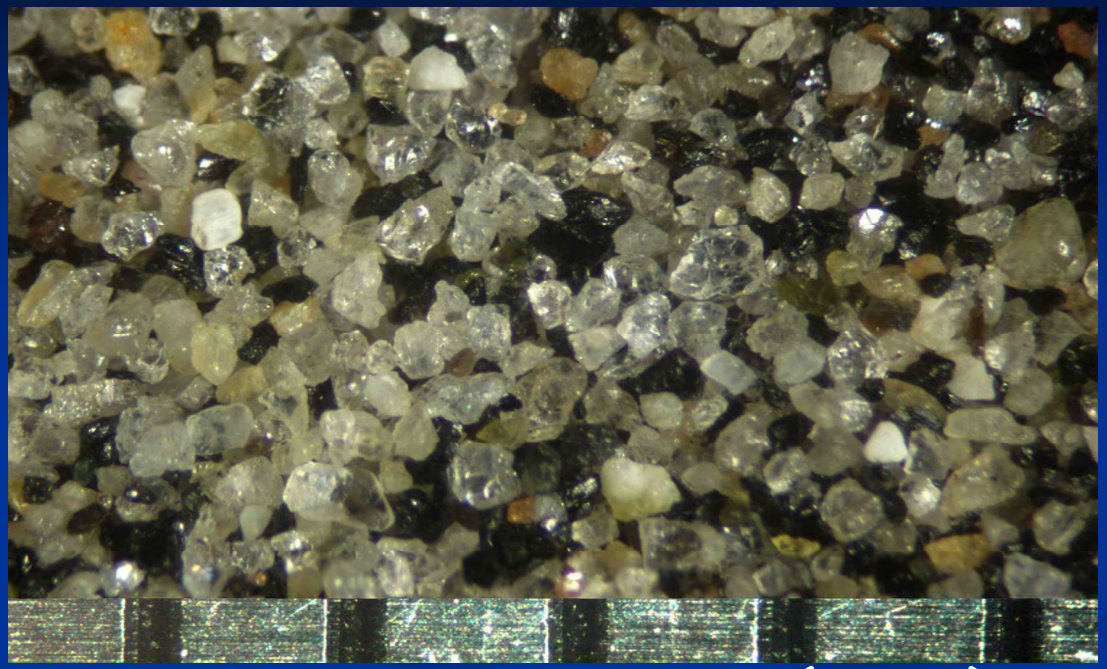
Mineral Composition

Light-Colored Minerals

1) Quartz
2) Feldspar
3) Muscovite mica

Dark-Colored Minerals

1) Hornblende
2) Biotite
3) Pyroxene
4) Garnet
5) Olivine
6) Magnetite



Location: San Diego

1 millimeter

Sediment Grain Size and Shape

Beach Sand Analysis

Do the Following Steps

1) Determine Mineralogy and Mineral Percentages

2) Determine Grain Size – Use this chart

3) Determine Grain Shape (Roundness)

4) Sketch several sand grains

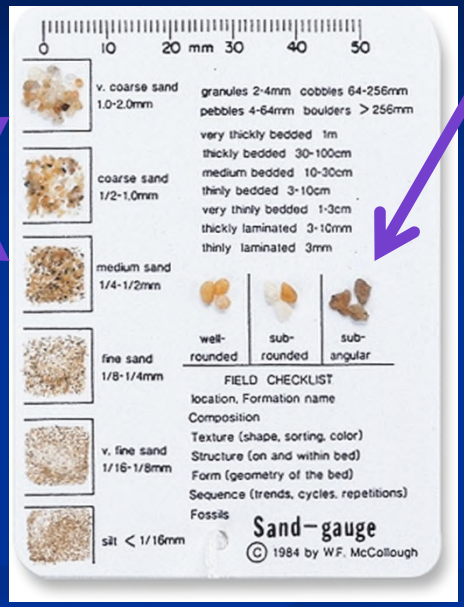
5) Think about sediment sources/origin and how it got transported

6) Think about the relationship between grain size and energy of environment

7) Think about the relationship between grain shape and sediment maturity

Grain Sizes

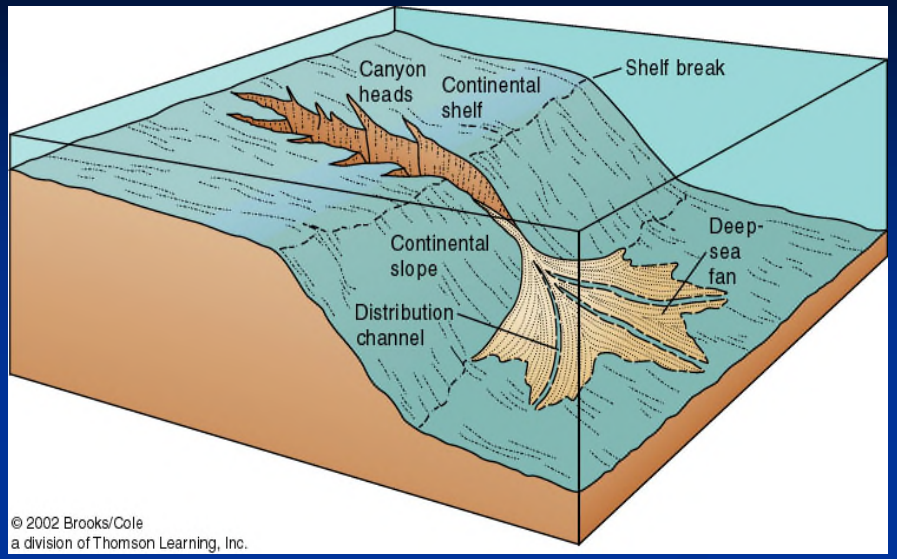
Grain Shape

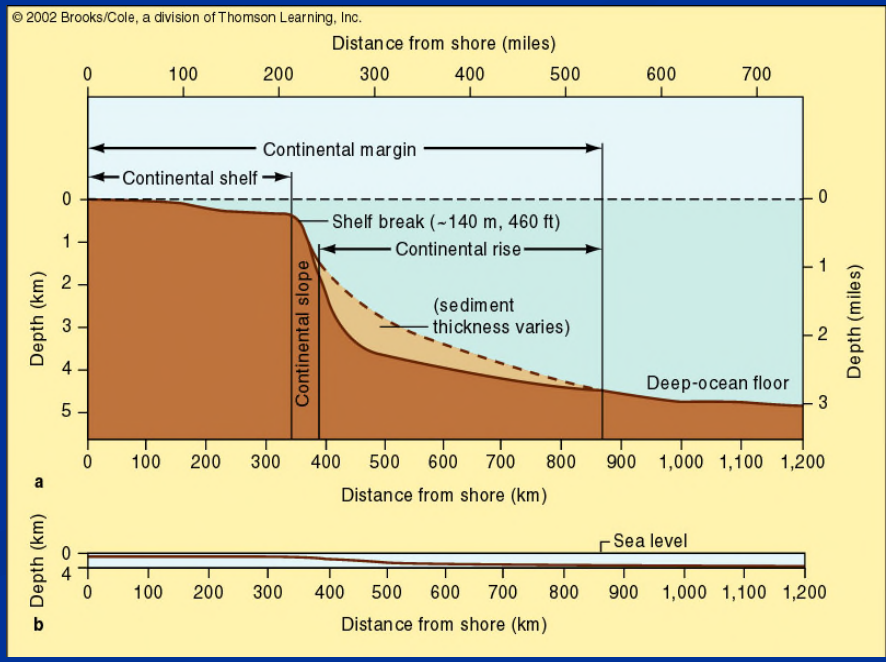


Continental Slope and Rise Sediments

Key Points

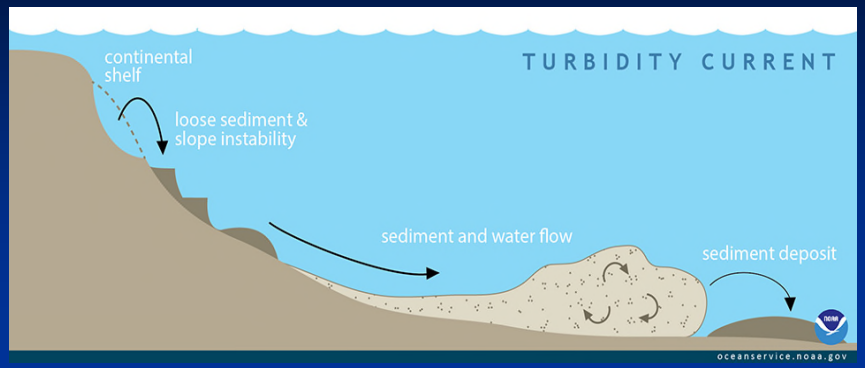
- Thickest ocean sediment piles
  - ✓ Up to 20 km thick!
- Thickest sections found at base of submarine canyons in the form of fan-shape sediment wedges
- Mainly consists of sand, silt and clay within "graded" bedding layers
- Continentally derived, but classified as transitional-deep sediment
- Primarily transported and deposited by **turbidity current processes**
- **Turbidity currents are dense mixtures of sediment and seawater that flow down slopes of seafloor**
- **Associated with submarine canyons**

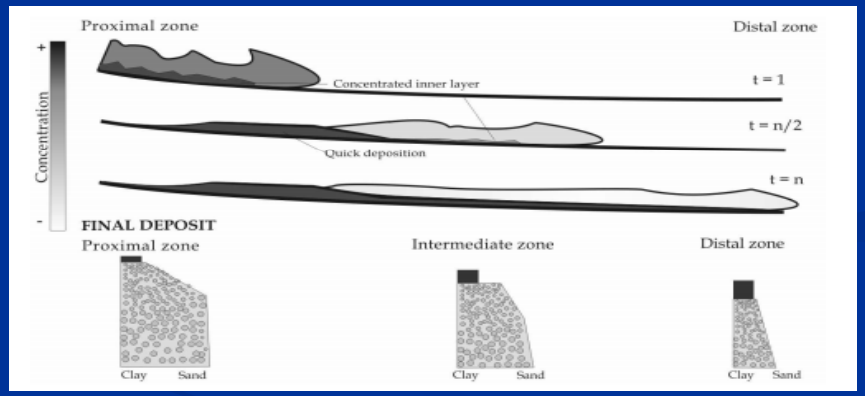


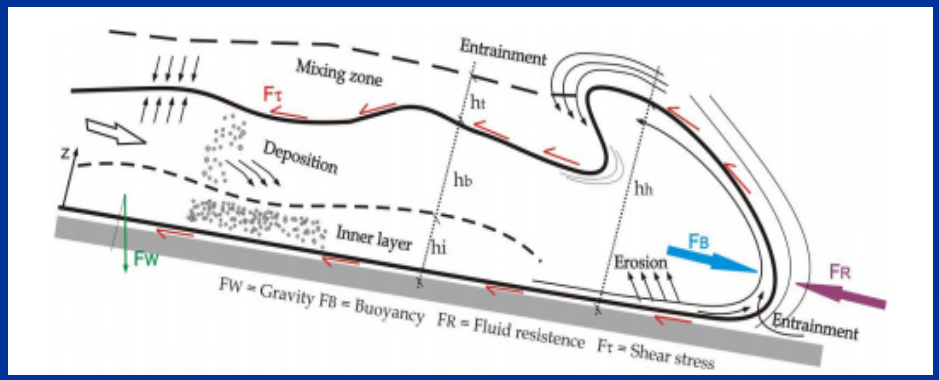


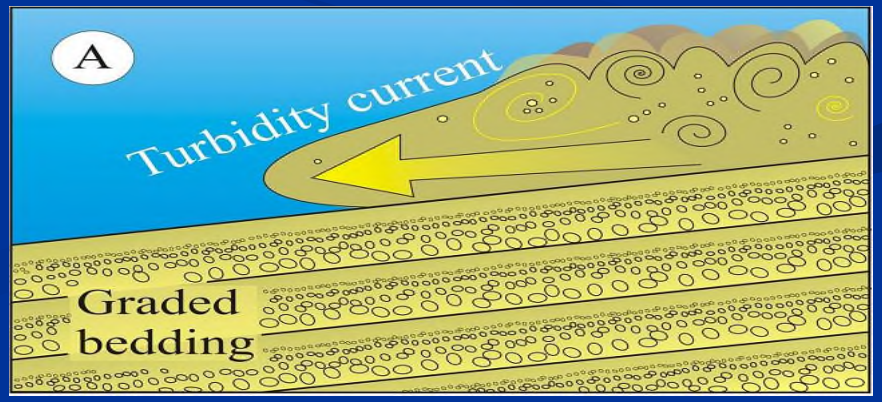
TURBIDITY SEDIMENTATION PROCESSES

Lab Simulation of Turbidity Currents and Deposition of Graded Bedding









Turbidity Current Experiment

Do the Following Steps

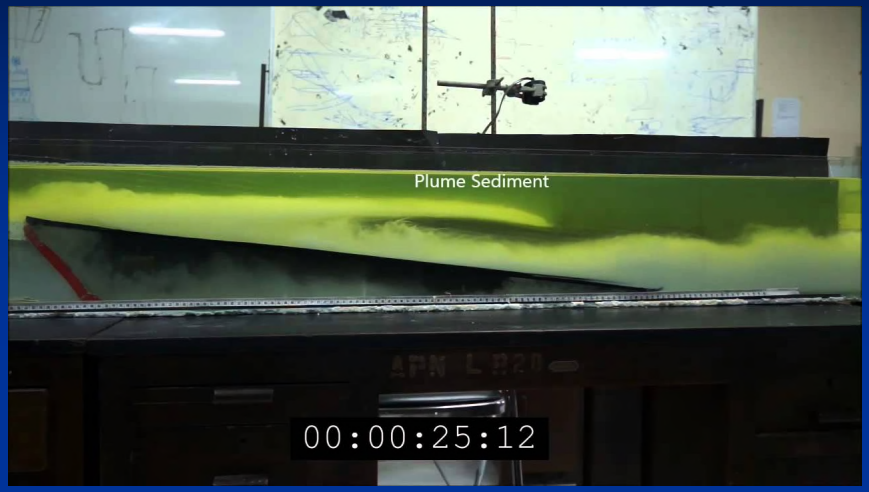
1) Prepare Turbidity Sediment Sample in a graduated beaker:
   - ✓ Mix: 15 mL of sand,
     15 mL of silt, and
     25 mL of vermiculate slurry

2) Carefully, but quickly, pour the sample (all at once) into up-slope end of seawater-filled turbidity tank

3) Record observations of turbidity event

4) Draw cross-section sketch of your turbidity layer

5) Answer set of turbidity question on worksheet



Turbidity Tank Demo

Graded Bedding Experiment

Do the Following Steps

1) Prepare Graded Bed Sample:
   - ✓ Add 50 mL of poorly-sorted sediment mixture in a graduated beaker

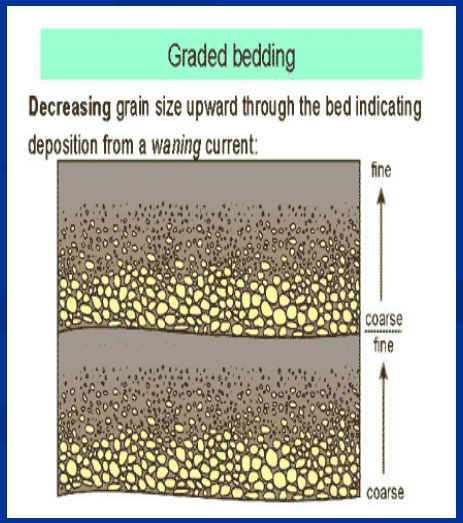
2) Carefully, but quickly, pour sample into top of sediment settling tube

3) Record observations of event

4) Draw cross-section sketch of your graded bed

5) Answer set of graded bedding question on worksheet

Graded Bedding Demo



Deep Ocean Basins

1) Deep seafloors from continental slope to mid-ocean ridge

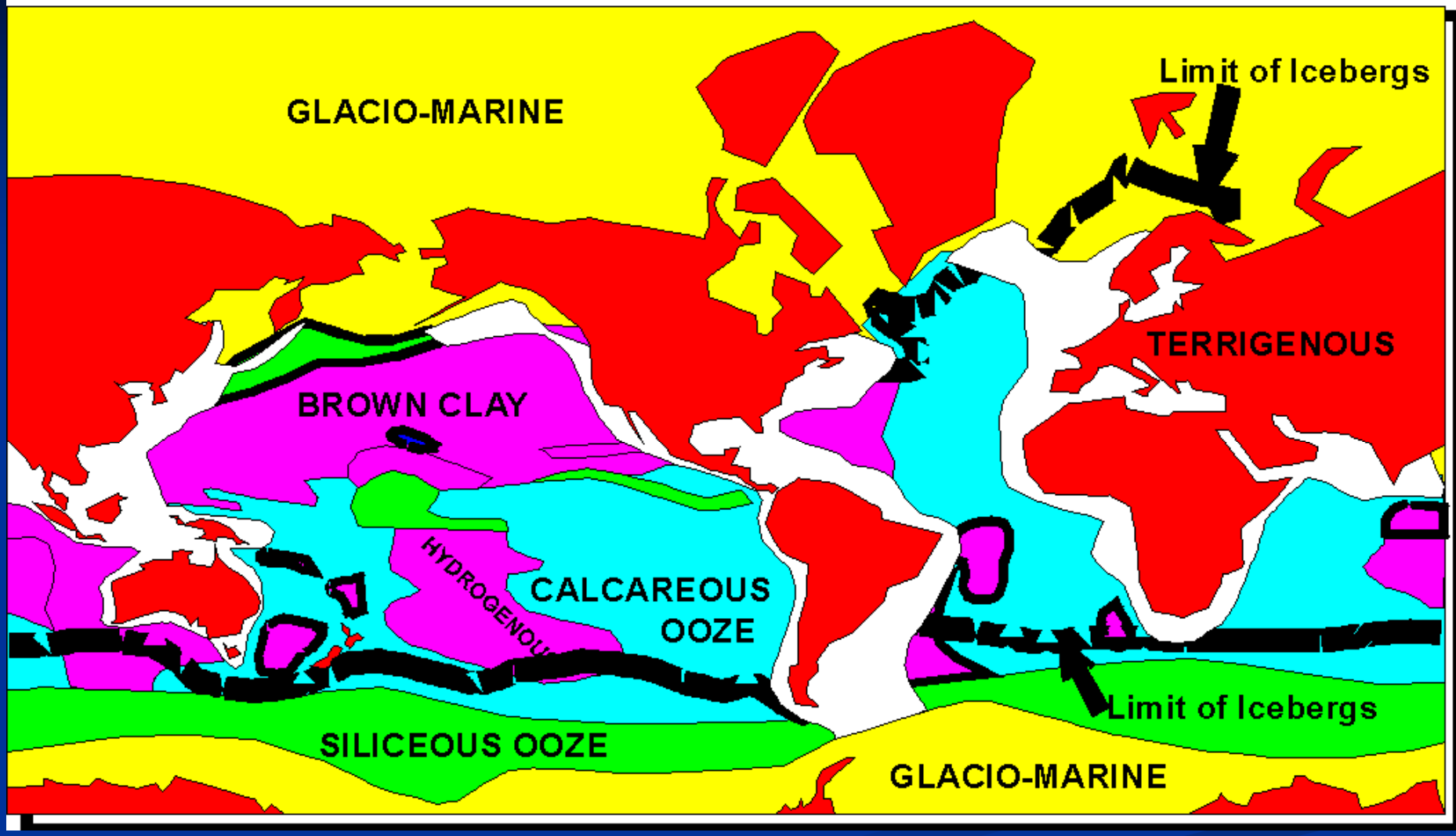
3) Deep ocean bottom is shown in blue color (except for lakes)

4) Average depth of abyssal seafloor is 4000 meters

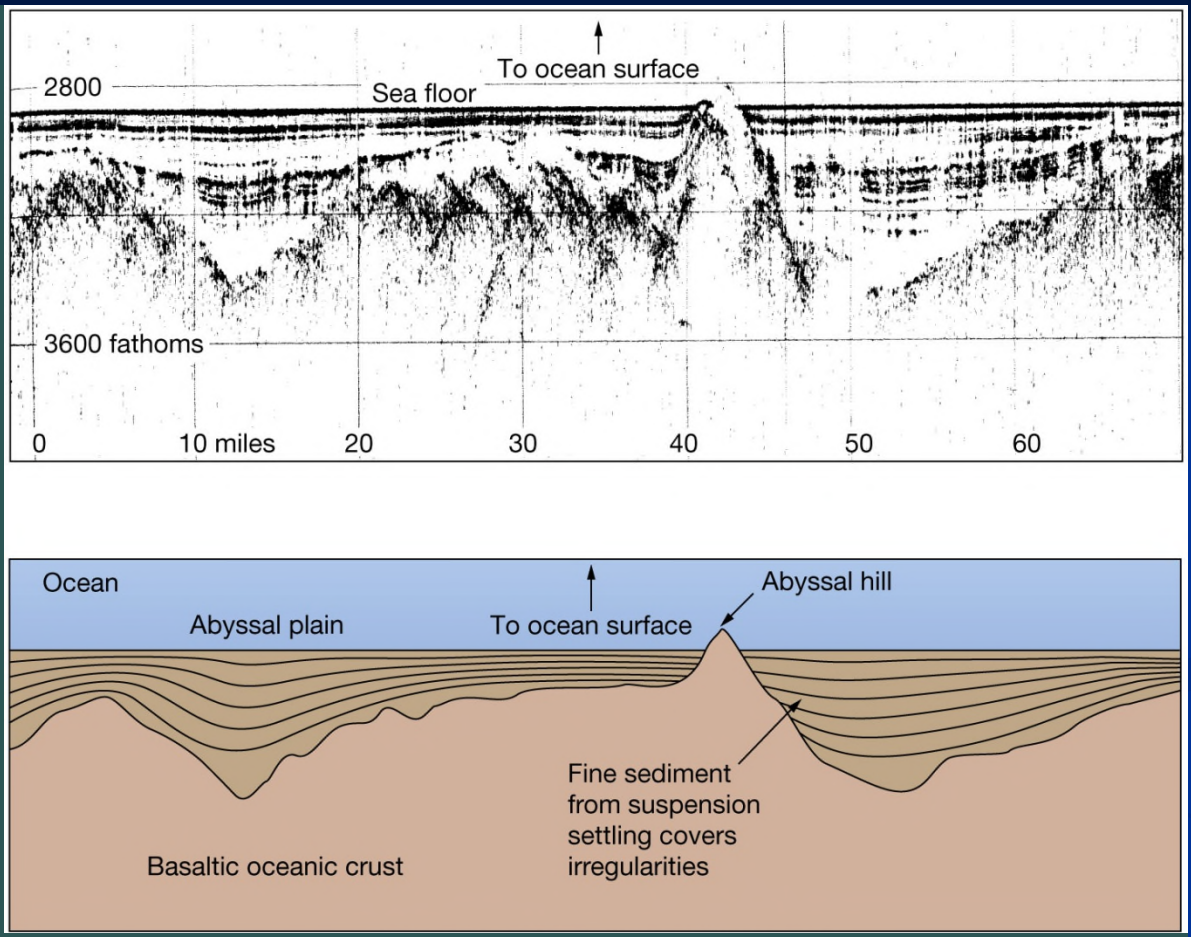
5) Deepest seafloor down to 11,000 meters

6) Deep seafloor bedrock consists of basaltic volcanic rock

DISTRIBUTION OF DEEP-SEA SEDIMENTS



Abyssal Plain and Hill Sediment Province

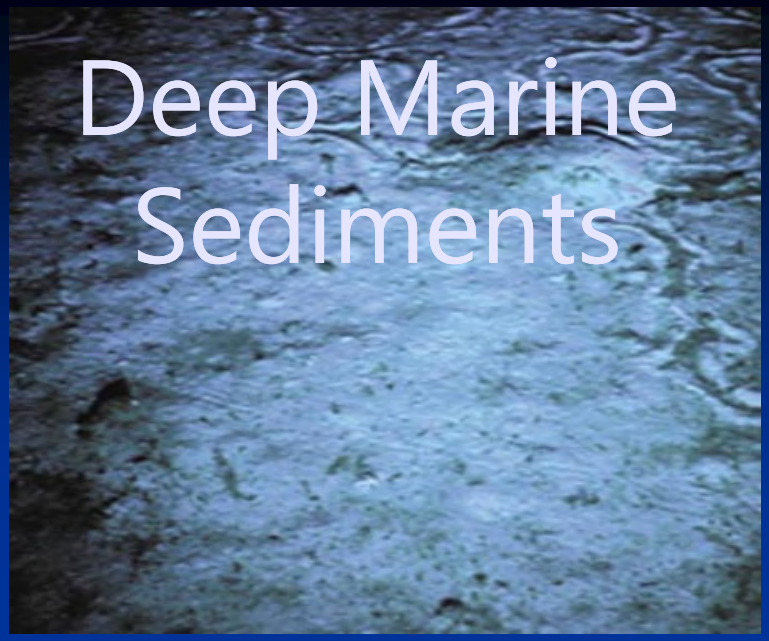


Key Points

- Thick pelagic sediment covers a rugged subsurface bedrock of basalt
- Abyssal plains are the flattest, most featureless provinces on Earth
- Abyssal hills are tops of seamounts sticking out
- Abyssal plains and hills cover the most extensive tracts of ocean seafloor

- Subsurface imaging of abyssal plains and hills from seismic reflection studies and deep sea drilling

Deep Marine Sediments



Key Points

1) Deep ocean sediments are dominantly of "***pelagic***" *origin*

2) Pelagic sediments originate in surface waters, and get to deep ocean by vertical settling through water column

3) Pelagic sediment is very fine-grained

4) Two types of pelagic sediments

- ✓ Inorganic clays
- ✓ Biogenic oozes

5) Two types of biogenic oozes

- ✓Calcareous
- ✓ Siliceous

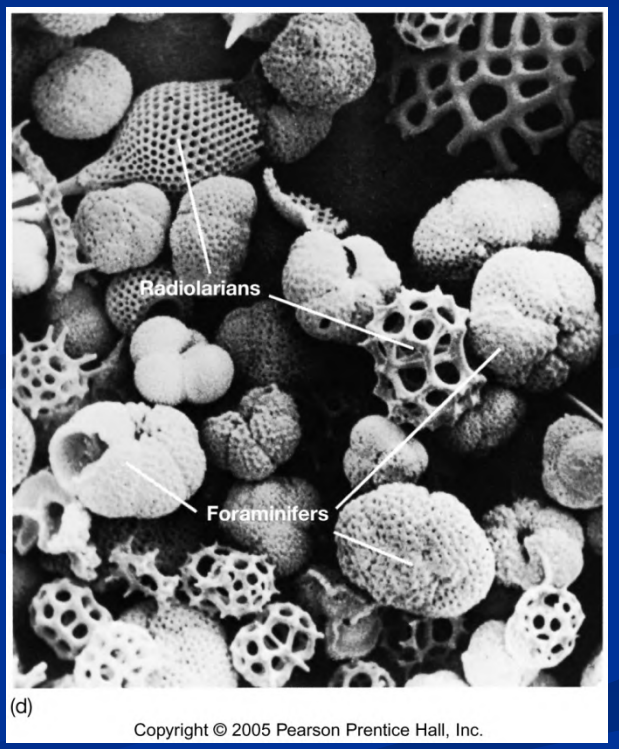
6) Each type of pelagic sediment has a unique region of deep sea floor where it is most abundant

Biogenous Sediment Sources

Sources: Organic; accumulation of plant and animal hard parts

Material: Calcareous and Siliceous Oozes and Detritus

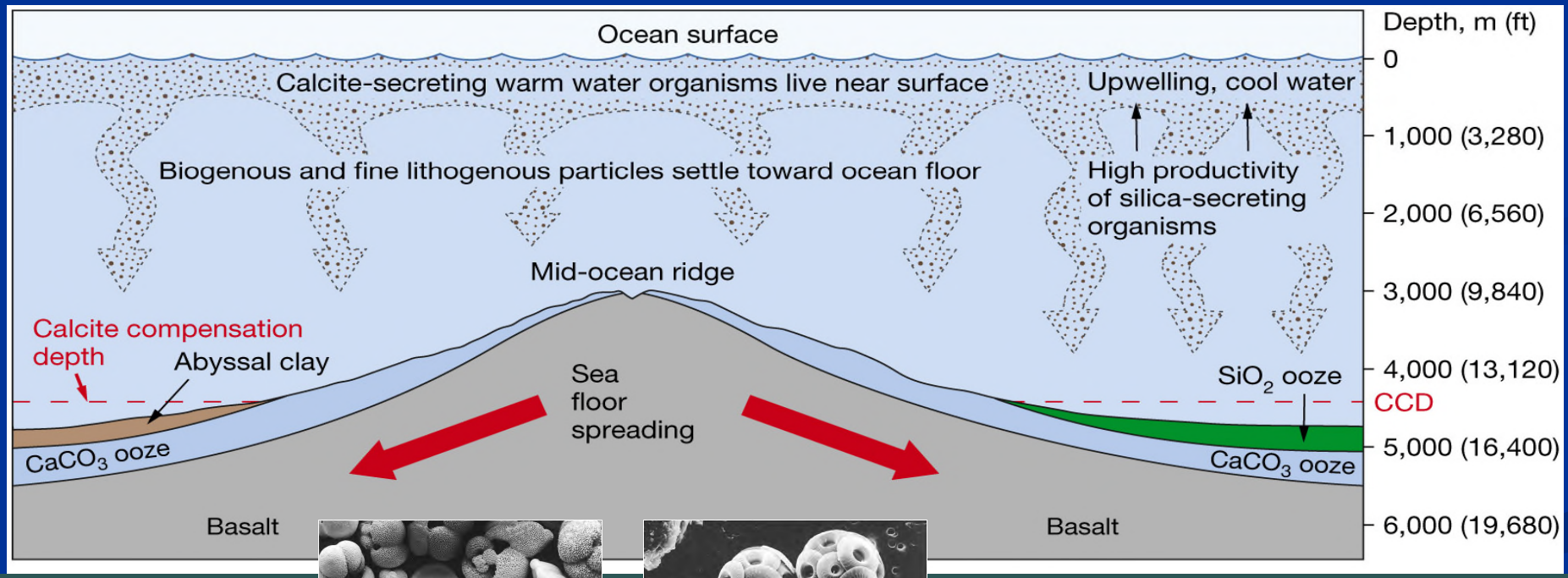
Deep Ocean Seafloor



Plankton Tests

Calcareous Ooze Sediments

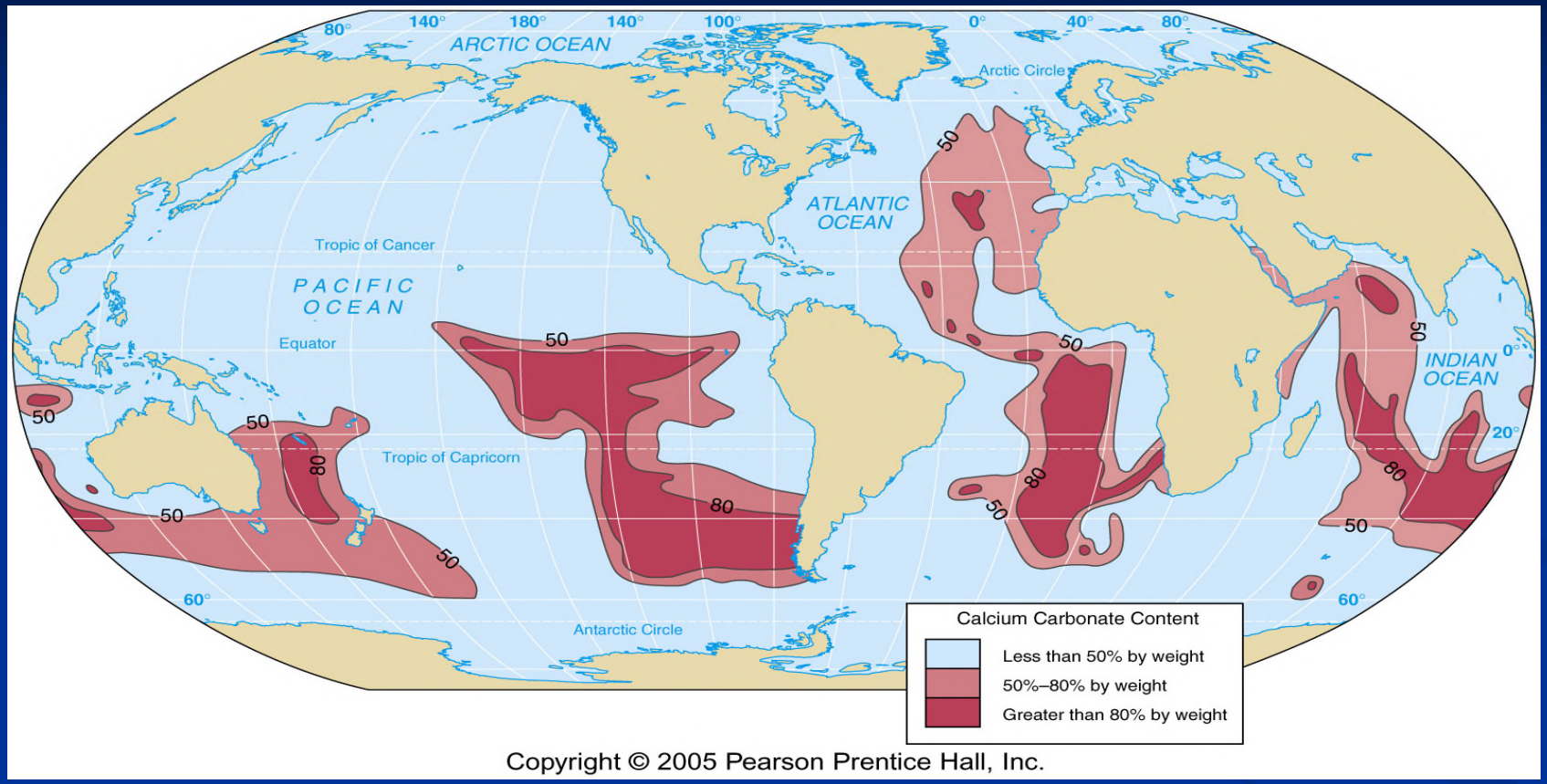
- ✓ Accumulation of calcium carbonate hard parts from dead microscopic plankton
- ✓ Mainly consists of cocolithophores and foraminifera tests
- ✓ Calcite-shelled plankton abundant in warmer surface waters
- ✓ Accumulate above the Carbonate Compensation Depth (CCD)



foraminifera

cocolithophores

Distribution of Calcareous Ooze Sediments

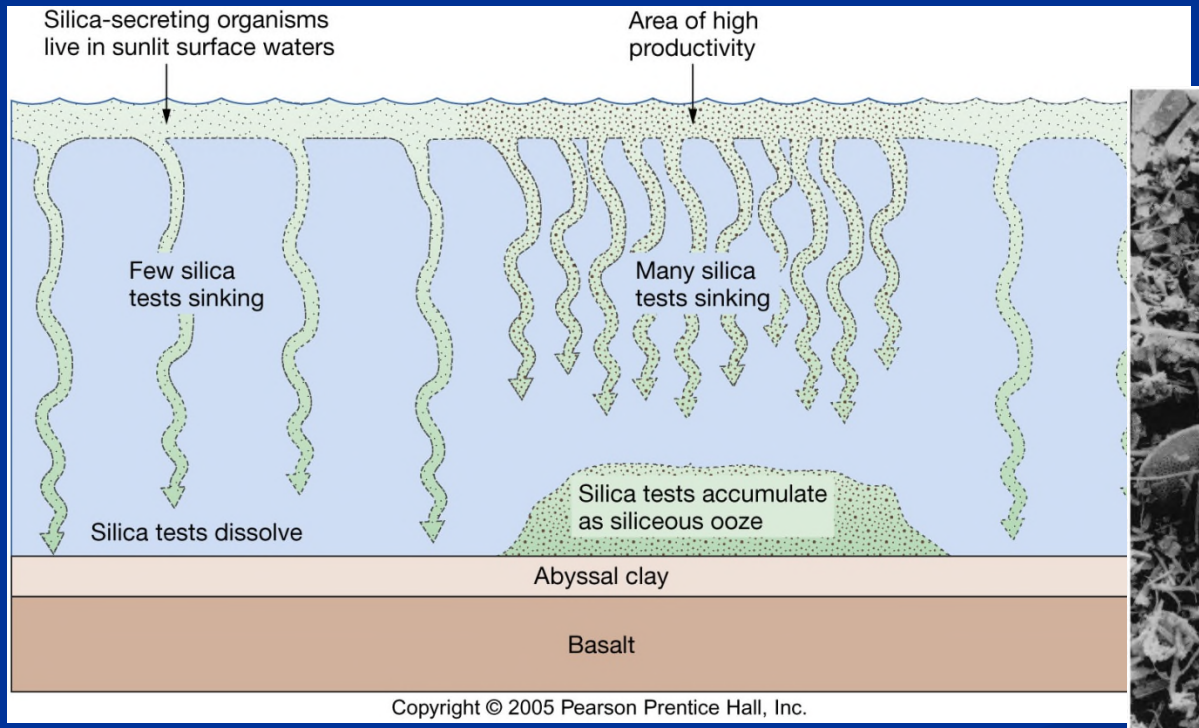


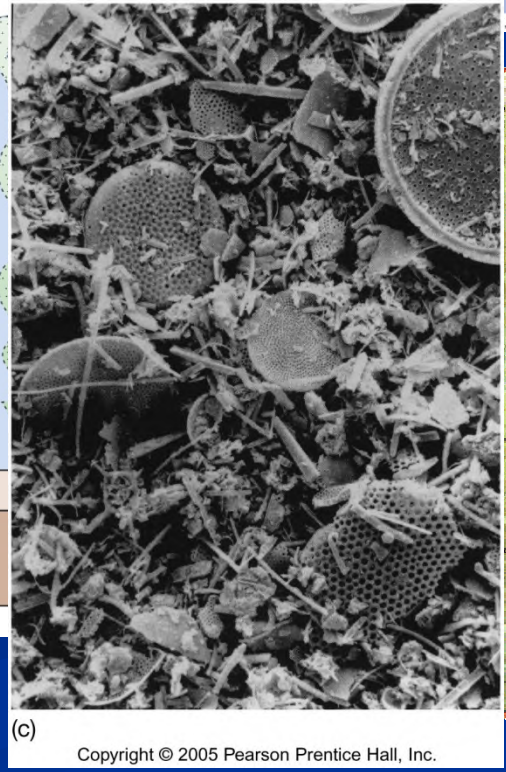
1) Calcareous oozes principally deposit in relatively shallow, low- to mid-latitude regions of deep ocean

2) Concentrated on tops and flanks of mid ocean ridges

Silica Ooze Sediments

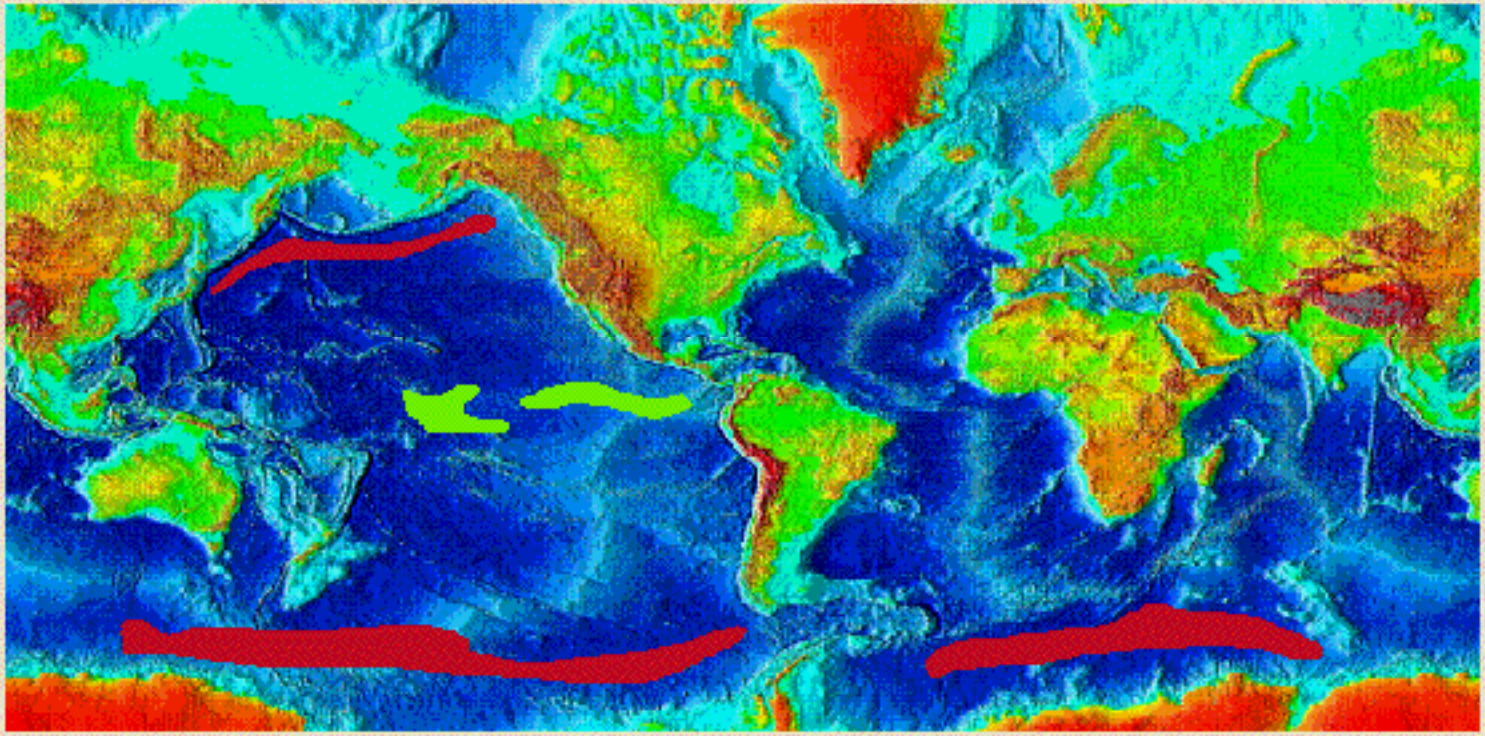
- ✓ Accumulation of silica hard parts from dead plankton
- ✓ Mainly consists of diatoms and radiolarian tests
- ✓ Abundant in deeper, cooler surface waters – high latitude





Siliceous Oozes:

- Areas of high nutrients, cold waters
  - two types: diatomaceous oozes, radiolarian oozes



Comparing Silica and Carbonate Oozes

Table 4.3 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

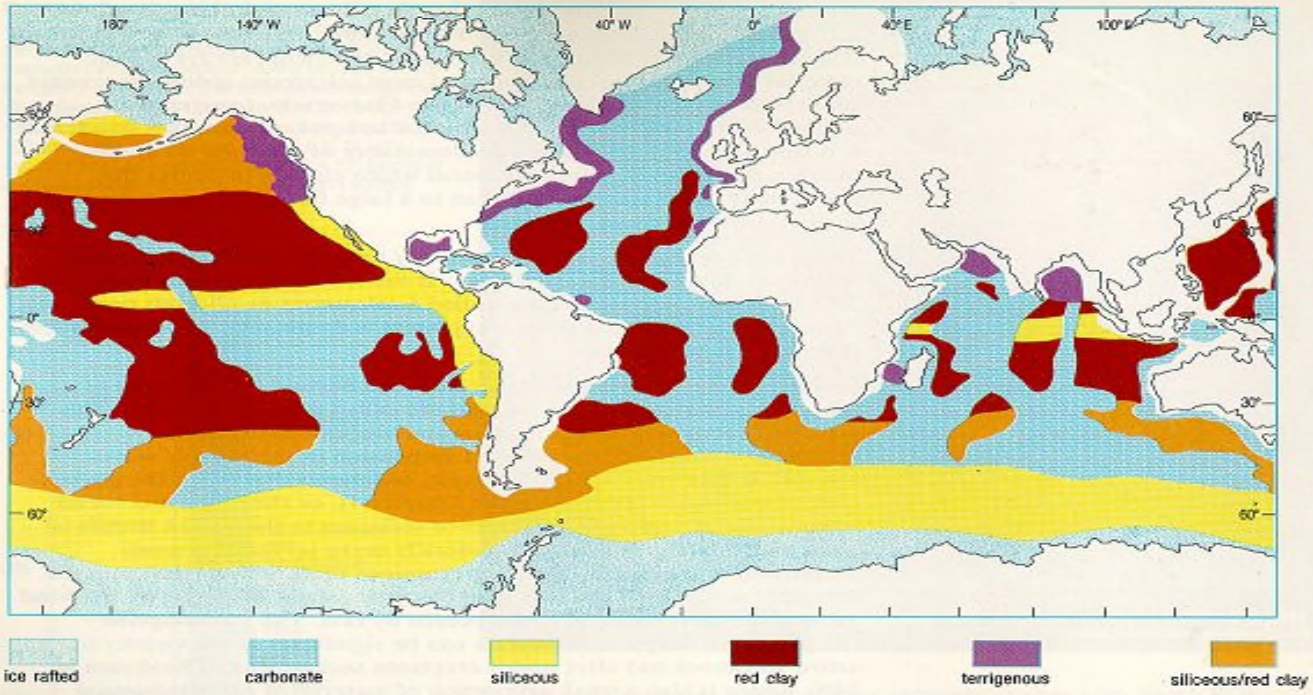
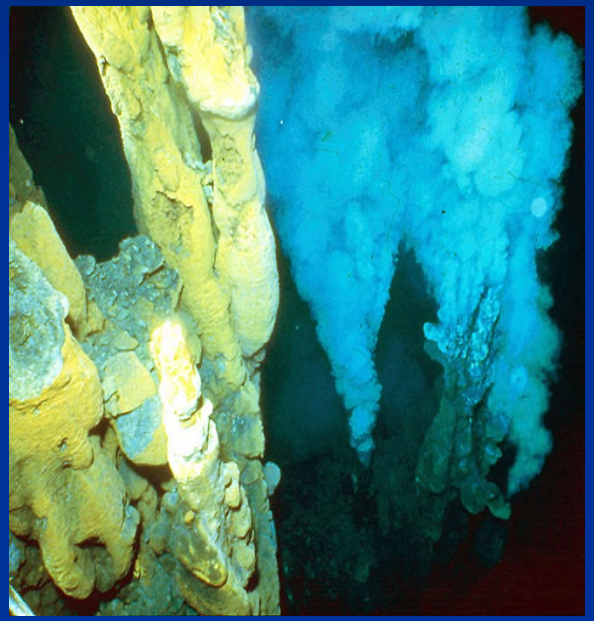


Figure 1.4 Distribution of dominant sediment types on the floor of the present-day oceans. Note that red clays are also terrigenous sediments.

Types of Hydrogenous Sediment

- **Sources:** Precipitation of minerals from solution
- **Minerals:** Carbonates, Phosphates, Metal Oxides and Sulfides



Black Smoker Chimneys Sulfides

Manganese Nodules

Type and Distribution of Marine Sediments

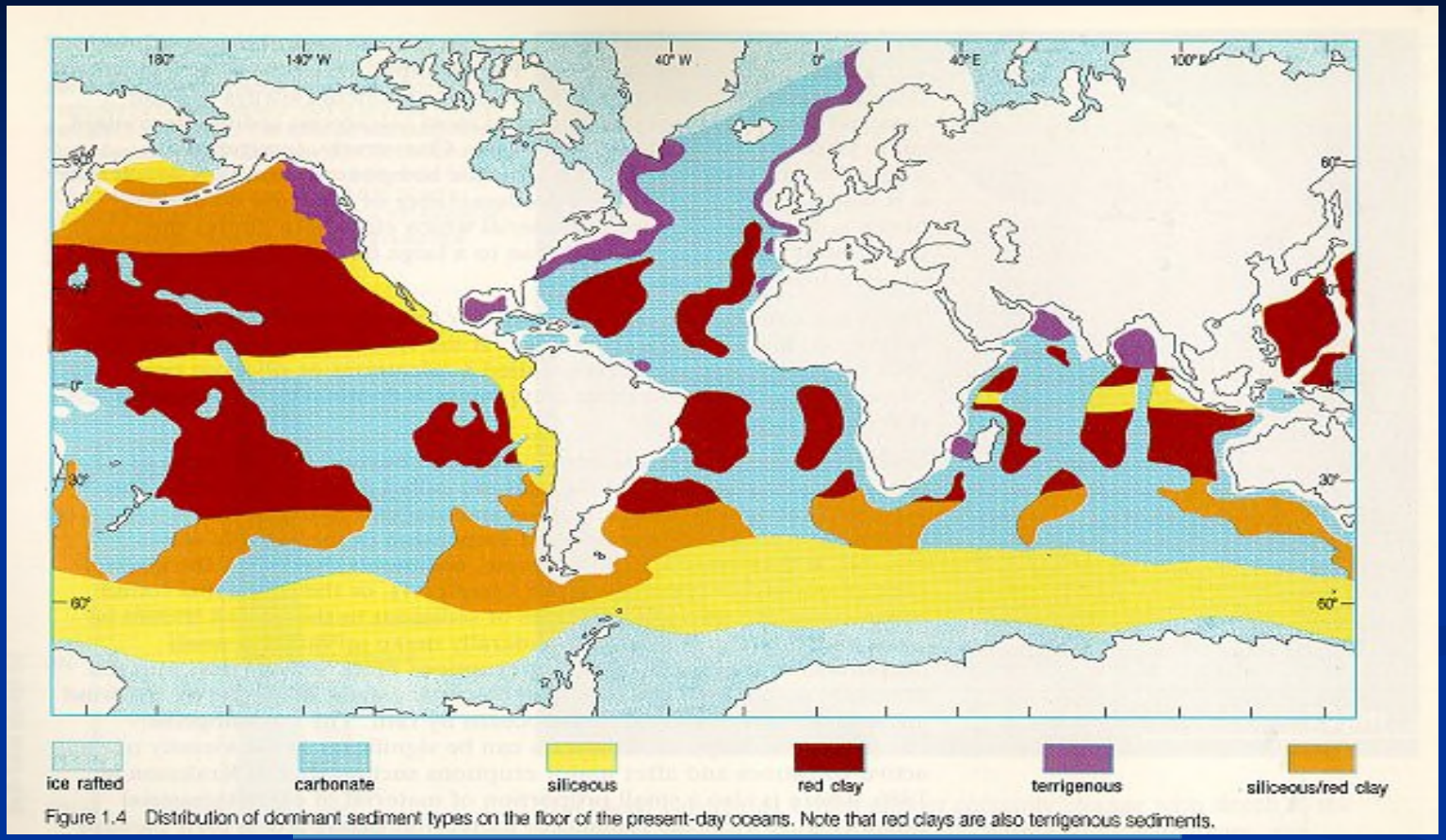


Figure 1.4 Distribution of dominant sediment types on the floor of the present-day oceans. Note that red clays are also terrigenous sediments.

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%	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)

Deep Ocean Sediment Analysis

Do the Following Steps

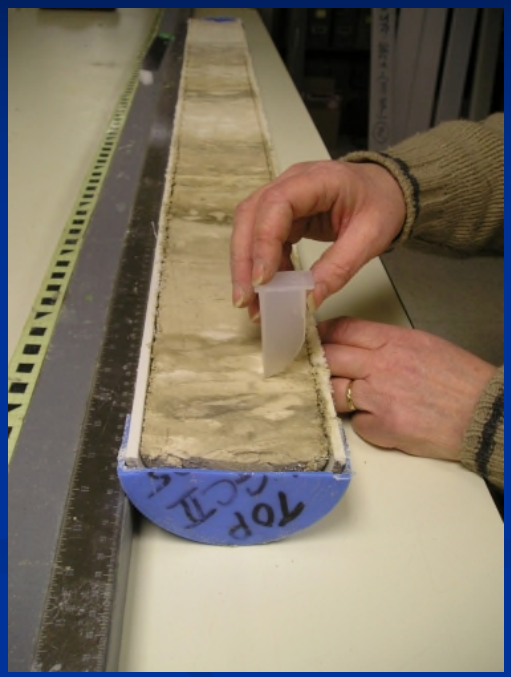
1) Determine Mineralogy of Deep Sea Sediment
   - ✓ Lithogenous? Biogenous? Hydrogenous?

1) Determine mineralogy
   - ✓ Siliceous? (Silica or Clay)
   - ✓ Calcareous? (calcite) Use acid test if you think you might have a carbonate
   - ✓ Oxide? (dark and crusty)

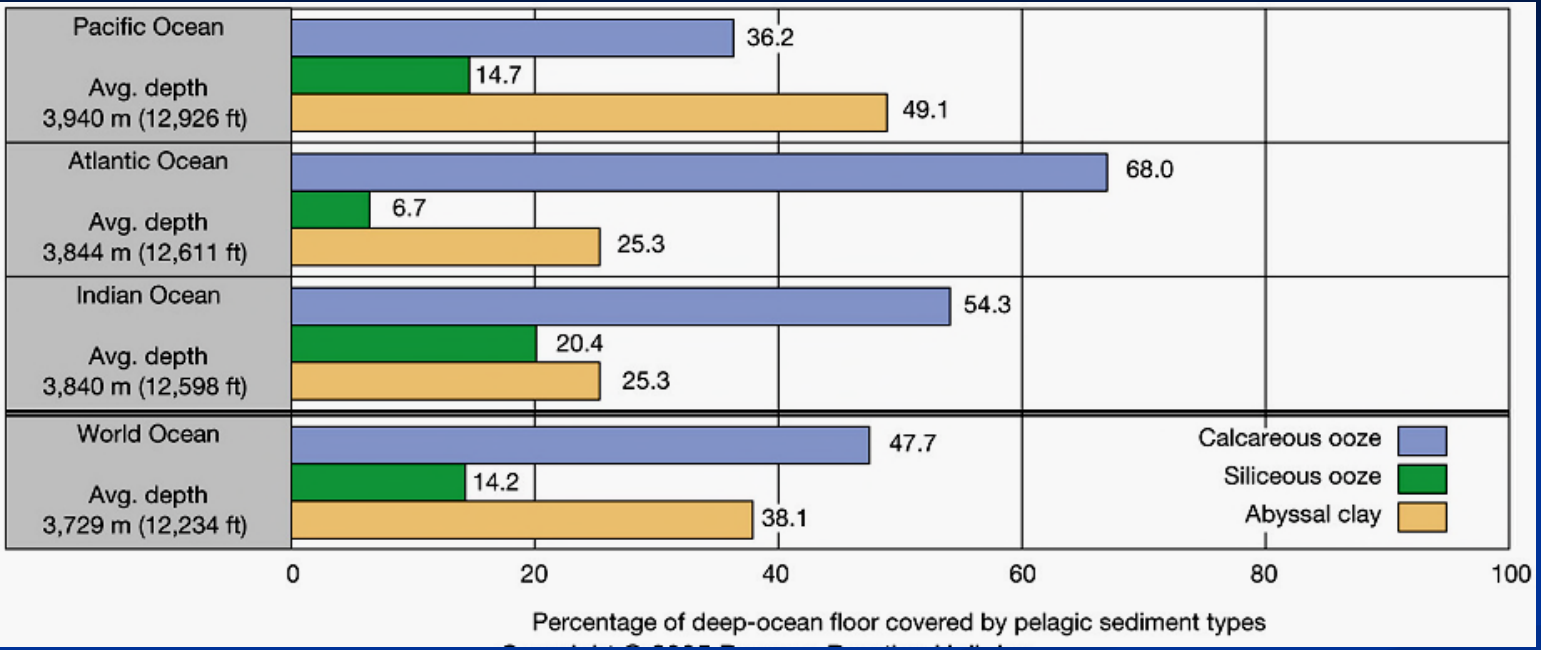
3) Name the type sediment sample
   - ✓ Ooze? Pelagic clay?

4) Sketch sample grains if visible

5) Think about origin and where in the deep ocean would this sediment most likely accumulate
   - ✓ If it's an ooze, would it accumulate above or below the CCD?



Percentage Distribution of Pelagic Sediments



1) **Calcareous Oozes** = covers **48%** of deep seafloor

2) **Siliceous Oozes** = covers **15%** of deep seafloor

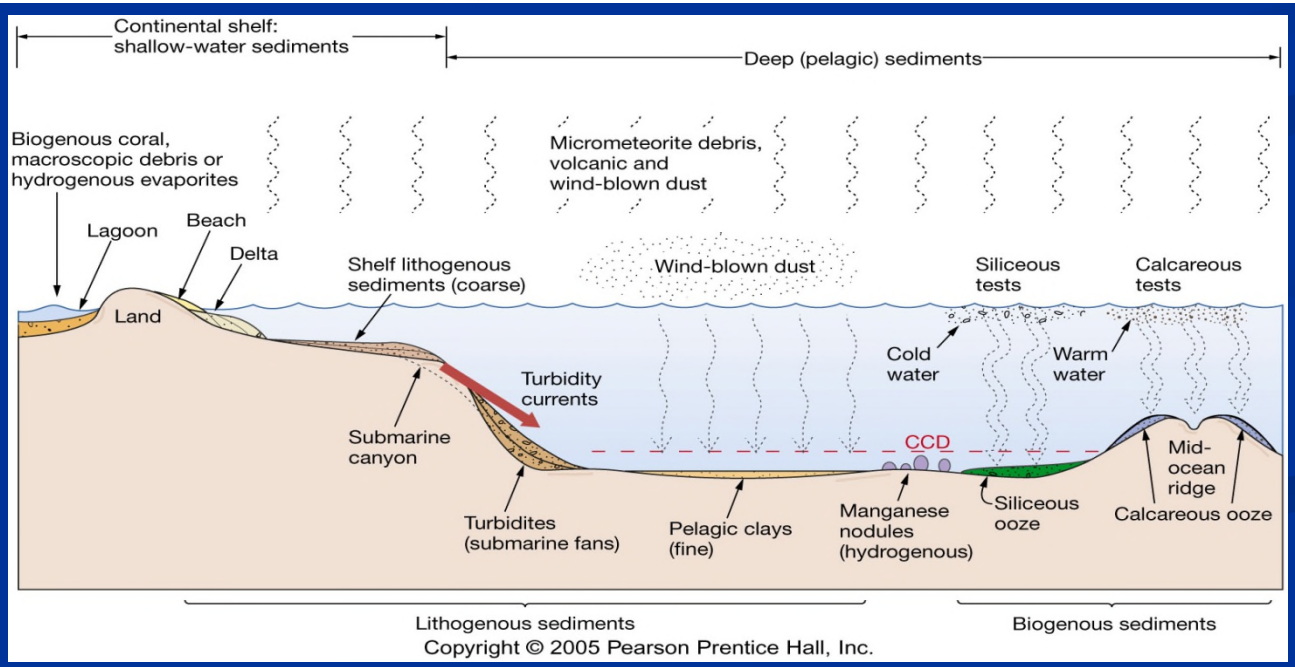
3) **Abyssal Clays** = covers **38%** of deep seafloor

Note the variation in the proportions of the three pelagic sediment types from one ocean basin to another

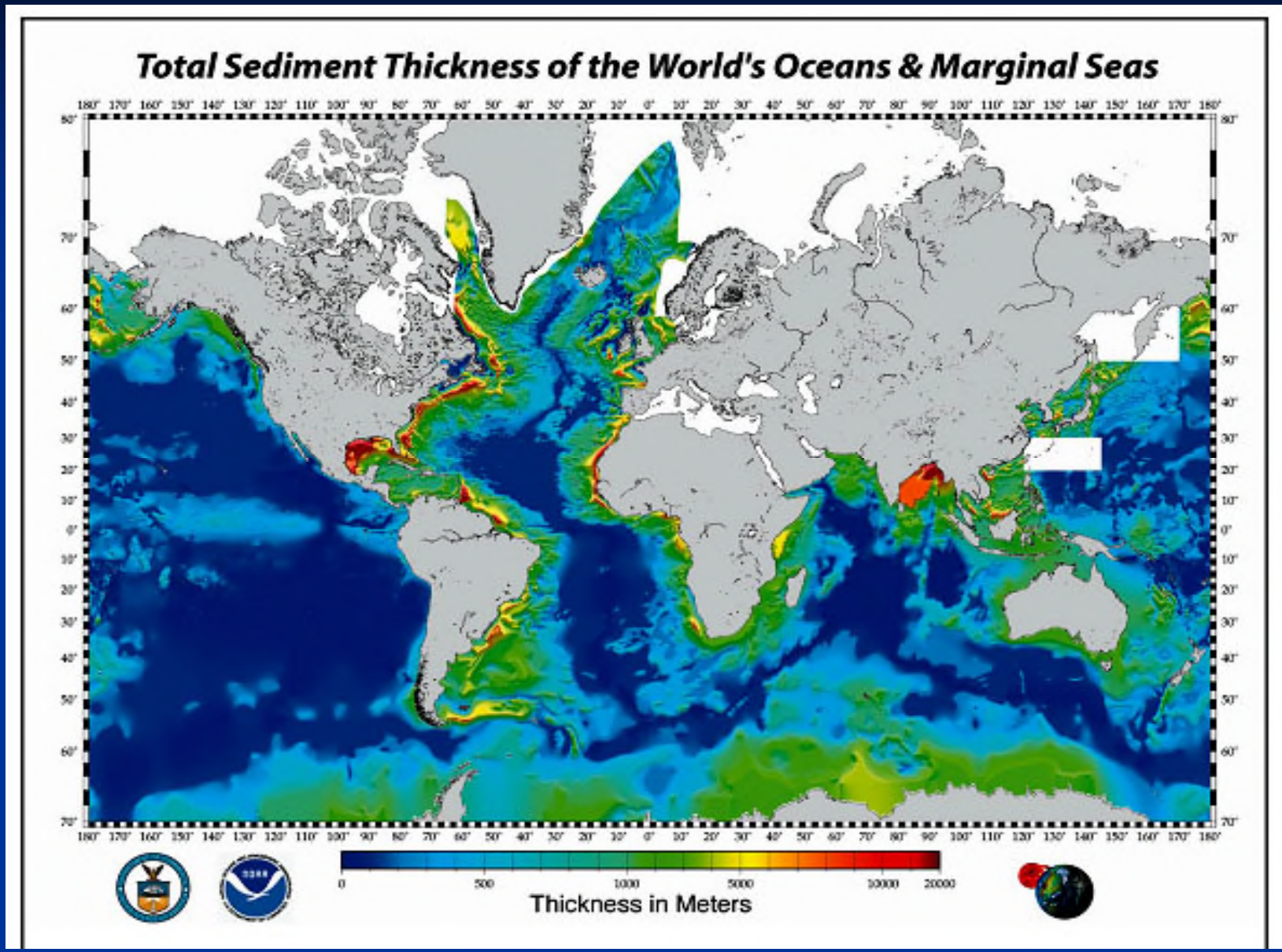
Rates of Deposition of Marine Sediments

Table 4.4 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



Sediment Pile Thickness on Ocean Bottoms



MARINE SEDIMENTS

Lab Discussion