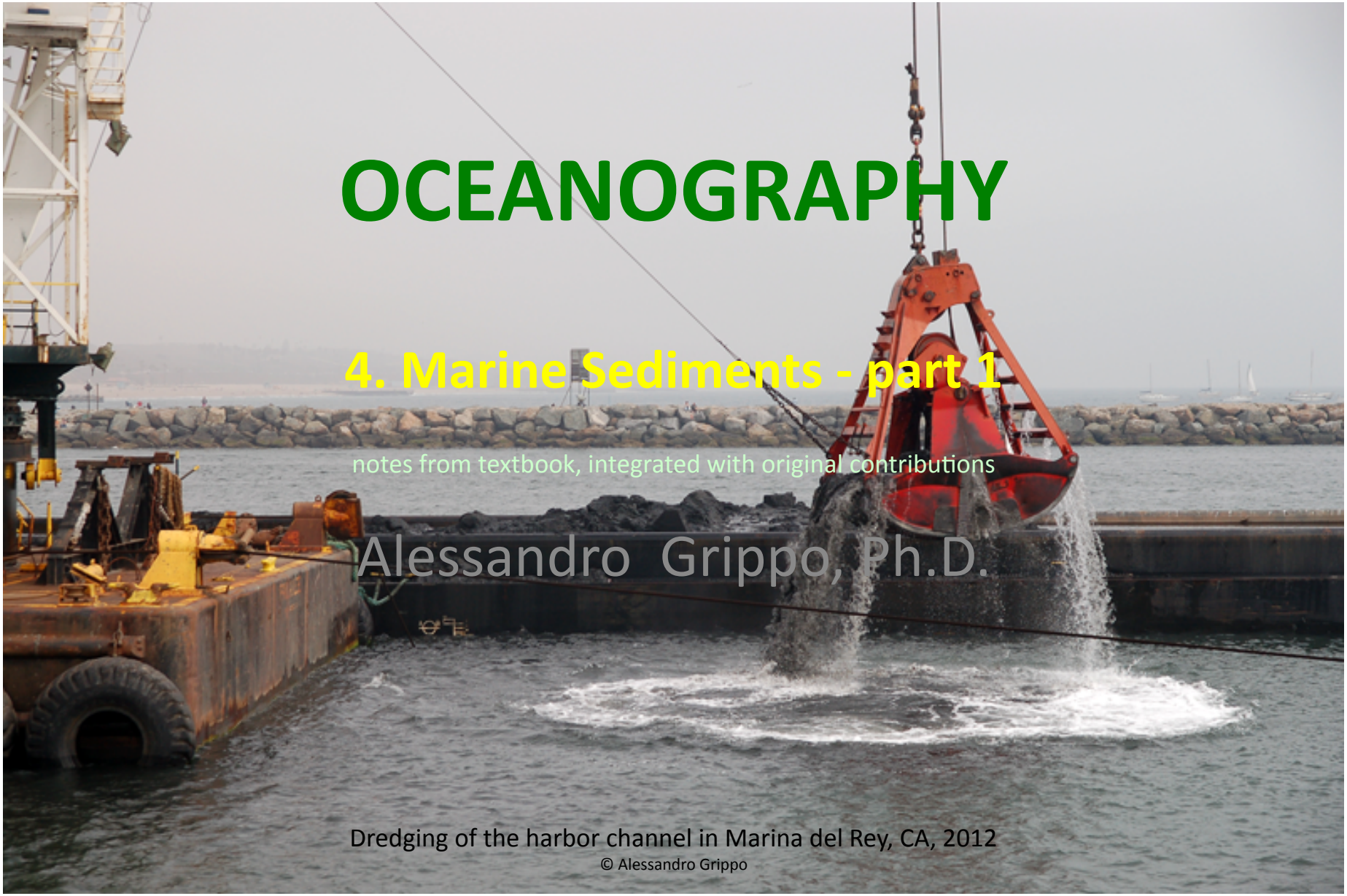


OCEANOGRAPHY

4. Marine Sediments - part 1

notes from textbook, integrated with original contributions

Alessandro Grippo, Ph.D.

Dredging of the harbor channel in Marina del Rey, CA, 2012

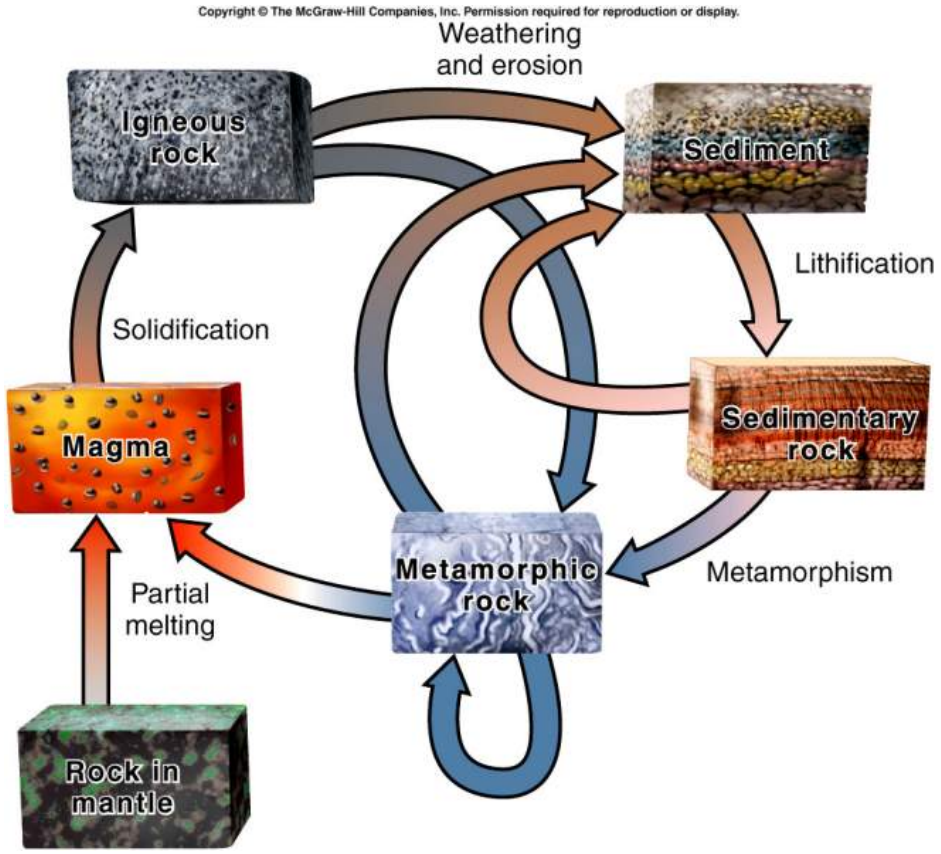
Chapter Overview

- Marine sediments contain a record of Earth history
- Marine sediments provide a variety of important resources
- Marine sediments have a variety of origins

what are sediments?

- there are **three kind of rocks**
  - igneous (from cooling of magma or lava)
  - metamorphic (from exposure to high temperatures and/or pressures)
  - sedimentary (from cementation of rock fragments and/or precipitation from a solution)

- all rocks can be weathered, producing **sediments**
  - mechanical weathering
  - chemical weathering



mechanical weathering

– all physical processes that **break down** rocks in smaller fragments

– fragments are identified by their size as gravel, sand, silt, and clay (silt and clay together are defined as mud)

chemical weathering: action of oxygen

- all chemical processes that change the composition of rocks
- two agents: oxygen and acids
- the action of oxygen in the atmosphere and in water causes iron minerals present in rocks to "rust" (**iron oxides**)
- $4Fe + 3O_2 \rightarrow 2Fe_2O_3$ (hematite)

chemical weathering: action of acids

- the action of acids "corrodes" rocks and turns them into quartz, clay minerals, and ions in solution

- **Quartz**
  - a very common, resistant mineral
  - typical component of sand at the beach
- **Clay Minerals**
  - a very common byproduct of weathering
  - have special properties: they are flat, they absorb water and ions, they "swell",
- **Ions in solution**
  - anything mineral that can be dissolved in water (Ca^{2+}, Mg^{2+}, Fe^{2+}, Na^{+}, K^{+}, CO_3^{2-}, etc.)

what is next?

- now we have a bunch of loose fragments at earth's surface, and ions in solution

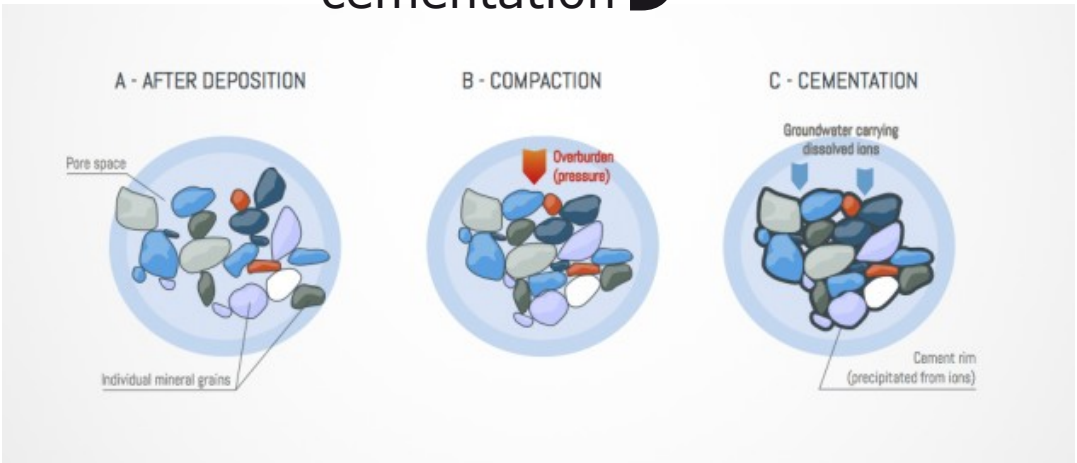
- they are picked up (eroded), moved around (transported) and resettled somewhere else (deposition) by:
  - water (rivers)
  - wind
  - glaciers
  - directly by rockfall/landslides

erosion

transportation

deposition

burial
compaction
cementation
} (lithification)



EXAMPLE

sand is picked up

↓

then it is moved around
by rivers, wind, waves;
it gets more weathered

↓

it is then deposited
(but it can also be picked up again)

↓

it will get finally buried
by more recent sediment

the weight compacts the sand

water enters the pores

ions in solution are released (cement),
turning the sand into a sandstone

and what about ions in solution?

- they need to “stay hydrated” (ions surrounded by water molecules)
- if there is not enough water, ions crystallize and form rocks (or cement, as seen before)
- main types:
  - carbonates (most common type; limestone)
  - siliceous rocks (rich in silica; chert)
  - evaporites (form in dry environments – not in the ocean; halite, or rock salt, gypsum)

Marine Sediments

- In the end, many sediments are produced on land (lithogenous sediments)
- While some of these are deposited on land, most are carried to the ocean (marine sediments)
- Some other types of sediments (biogenous and hydrogenous) are produced directly in the ocean
- Whatever type of sediment reaches or is produced in the ocean would eventually settle through the water column
- Oceanographers decipher Earth history through studying sediments

4.1 – How Are Marine Sediments Collected, and What Historical Events Do They Reveal?

- Marine sediments of today can be collected directly from the ocean bottom
  - difficult to get to

- Marine sediments of the past that have turned into sedimentary rocks can be found in land outcrops
  - easier to get to but scattered samples

collecting Marine Sediments

- dredge
- gravity corer
- rotary drilling
  - NSF funded a program for borrowing drilling technologies from the industry
  - Four oceanographic institutions (Scripps, Rosenstiel, Woods Hole, Lamont-Doherty) united to form JOIDES (Joint Oceanographic Institutions for Deep Earth Sampling)
  - Other schools later joined JOIDES

collecting Marine Sediments

- JOIDES programs
  - DSDP (Deep Sea Drilling Project)
    - 1966, Glomar Challenger, sampled to 6000 m of depth
    - evidence of spreading (age of sediment, thickness of sediments, magnetic reversals)
  - ODP (Ocean Drilling Program)
    - 1975, 1983 became international, under Texas A& M
    - broader objective of drilling close to shelf
    - in 1985, JOIDES Resolution replaced Glomar Challenger
    - new ship can drill up to 2100 m below sea floor

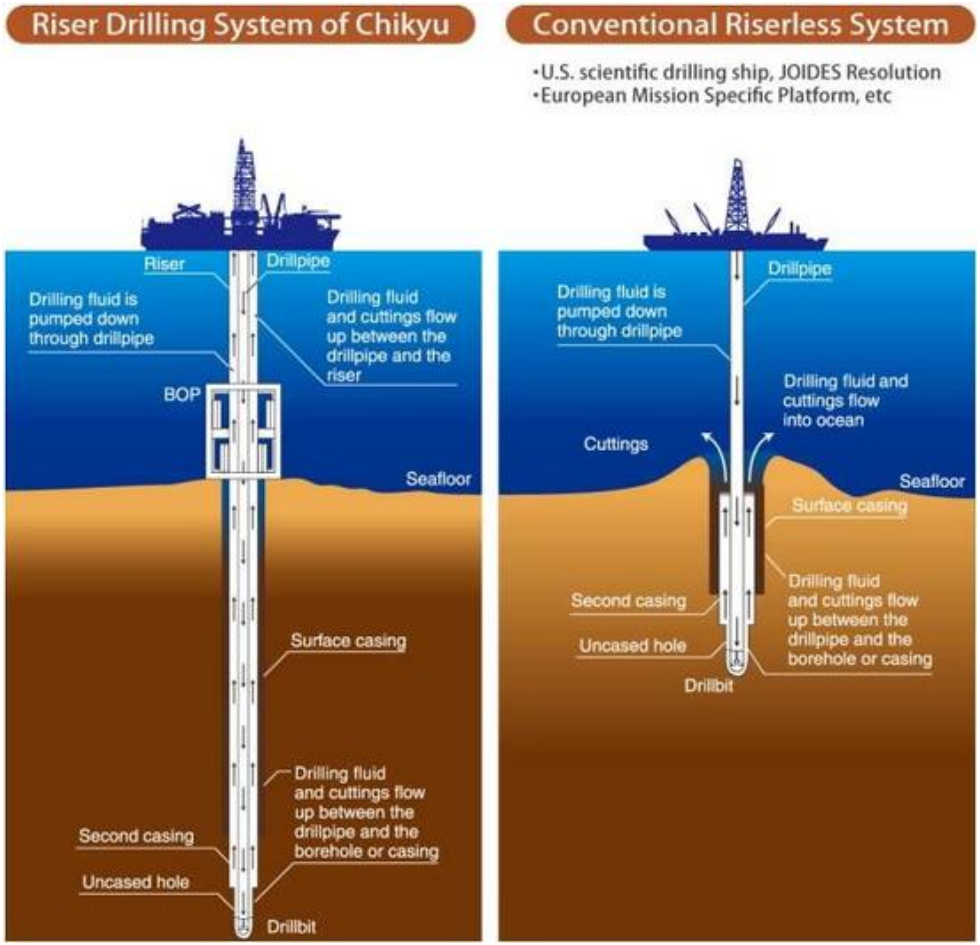
Glomar Challenger & JOIDES Resolution

- IODP (Integrated Ocean Drilling Program)
  - 2003, then in 2013 as Integrated Ocean Discovery Program
  - multiple vessels, including Chikyu
  - collection of sediments cores from all over the world

Chikyu

- “Planet Earth”
- how do we drill
  - (www.youtube.com/watch?v=yuu0QcnOVbo)

The drilling system of Chikyu



Upper left: drilling pipes on the deck of JOIDES Resolution

Upper right: diamond drilling bit (a drilling bit would not give us a core, but rather “rock cuttings’, or fragments

Bottom left: analysis of halved cores on board the JOIDES Resolution

Environmental Conditions Revealed by Marine Sediments

- Marine Sediments preserve materials that existed in the overlying water columns

- These materials are function of the conditions of the environment

- Analysis of cores provides us with info about:
  - ancient sea surface temperature
  - abundance of marine life and major extinction events
  - atmospheric winds and volcanic eruptions
  - ocean current patterns and changes in Earth's climate
  - movement of tectonic plates

Paleoceanography

- The study of how ocean, atmosphere, and land interactions have produced changes in ocean chemistry, circulation, biology, and climate

- Marine sediments provide clues to past changes

Marine sediments also exist on land: turned into rocks, and brought above sea level by plate tectonics

These are turbidites from the Great Falls of the Missouri, by the city of Great Falls, Montana

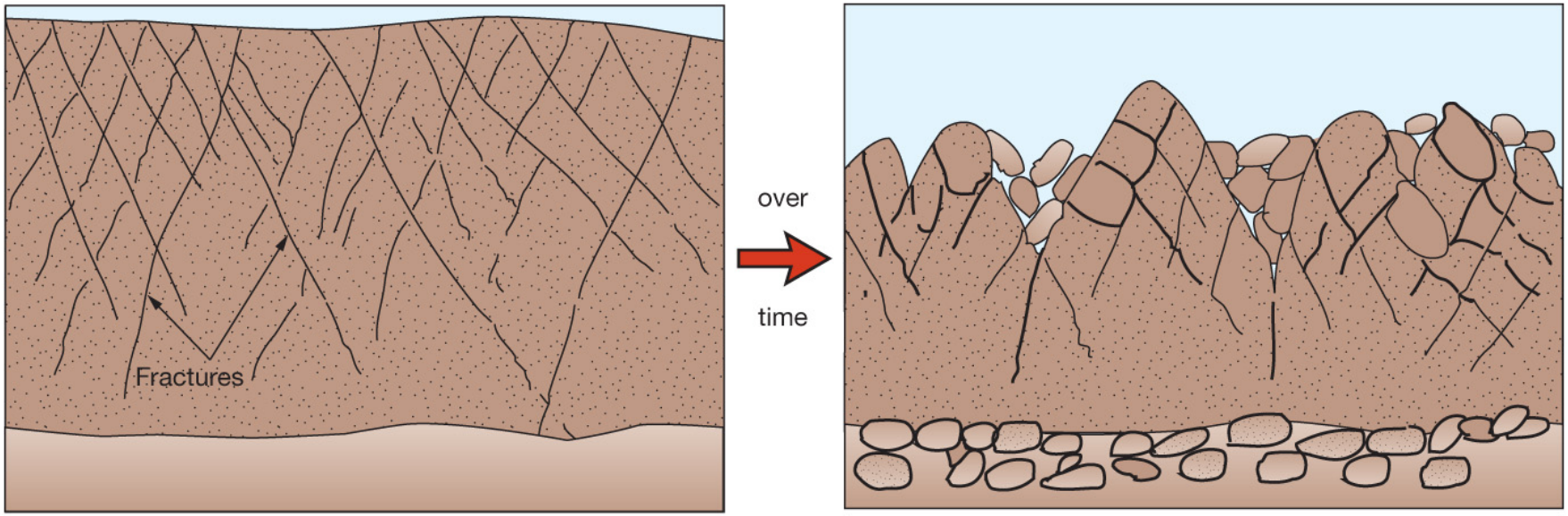
(at this location the explorer Lewis and Clark could not proceed any further on the river, and had to start their portage on the Great Plains)

Marine Sediment Classification

- Classified by origin
  - Lithogenous – derived from land (lithos = rock)
    - gravel, sand, silt, clay
    - ions in solution
  - Biogenous – derived from organisms
    - shells, reefs, animal and algal structures
  - Hydrogenous or *Authigenic* – derived from water
    - forming chemically in the ocean
  - Cosmogenous – derived from outer space
    - cosmic “dust”

4.2 – What Are the Characteristics of Lithogenous Sediment?

- Eroded rock fragments from land
- Also called terrigenous
- Reflect composition of rock from which derived
- Produced by weathering
  - Breaking of rocks into smaller pieces



- Particles are eroded, transported, deposited
- Carried towards the ocean by:
  - Streams, Wind, Glaciers, Gravity

- Greatest quantity found around continental margins
  - mostly on shelves
  - also in continental rises or trenches

(a)

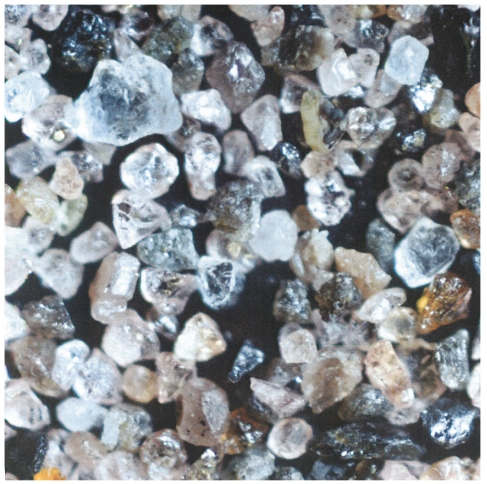
(b)

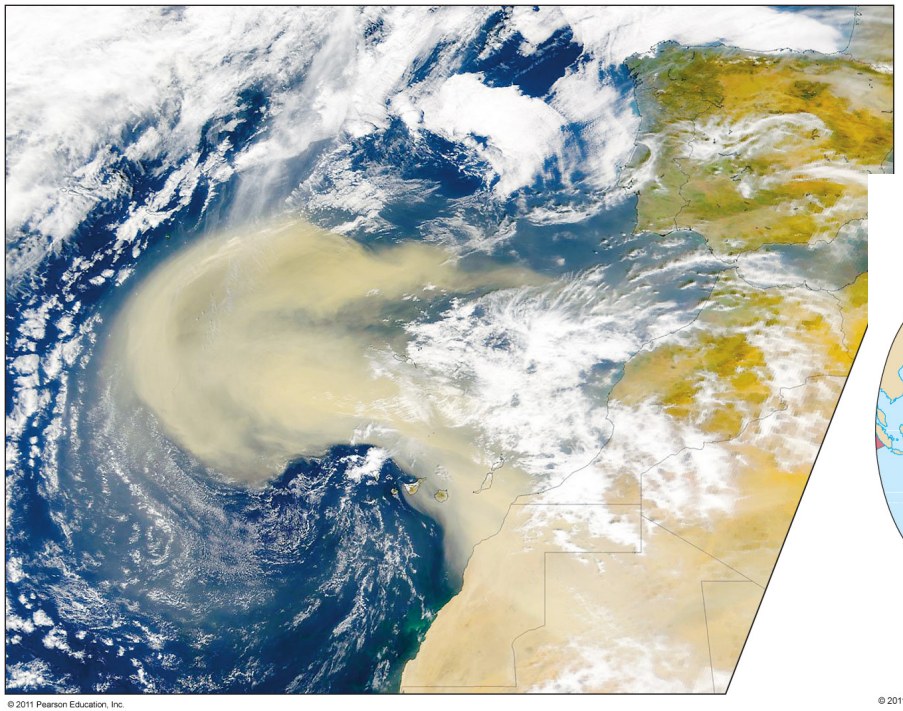
(c)

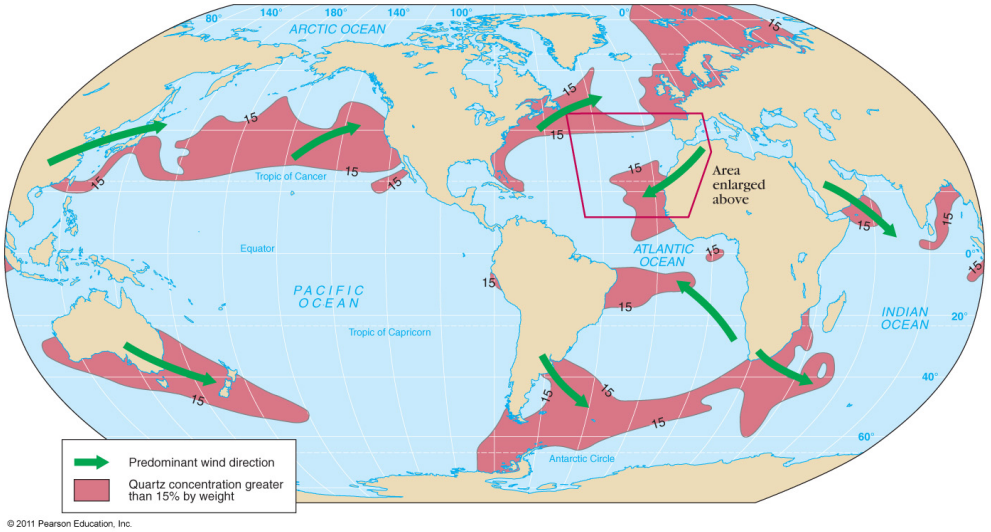
(d)

Composition and Texture

- Reflect composition of rock from which derived
- Coarser sediments closer to shore
- Finer sediments farther from shore
- Mainly mineral quartz (SiO_2)



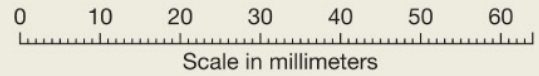




- Grain size proportional to energy in the environment of deposition

TABLE 4.2 WENTWORTH SCALE OF GRAIN SIZE FOR SEDIMENTS

Size range (millimeters)	Particle name		Grain size	Example	Energy of the depositional environment
Above 256	Boulder	↑ Gravel	Coarse-grained	Coarse material found in streambeds near the source areas of rivers	High energy
64 to 256	Cobble				
4 to 64	Pebble				
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



- Grain size sorting
  - Indication of selectivity of transportation and deposition processes
- Textural maturity
  - Increasing maturity if
    - Clay content decreases
    - Sorting increases
    - Non-quartz minerals decrease
    - Grains are more rounded (abraded)

Where do we find these sediments in our oceans?

- Marine sedimentary deposits can be found in virtually all places on the ocean floor, even if sometimes in very minor percentages.
- The can be categorized as either neritic or pelagic

- **Neritic Deposits** are are found on continental shelves and in shallow waters around islands
  - usually coarse-grained (sands)

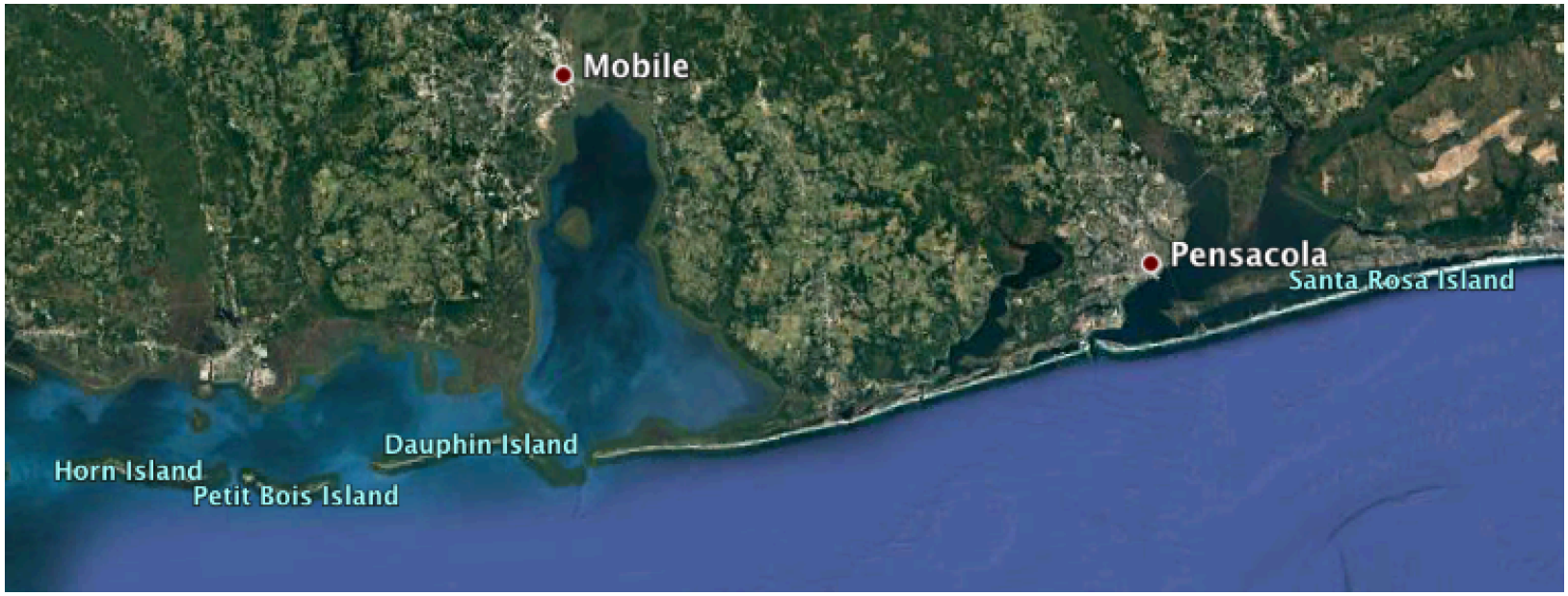
- **Pelagic Deposits** are found in deep-ocean basins
  - usually fine-grained (silts and clays)

Neritic Deposits

- Beach deposits
  - Grains of all kinds brought to the coast by rivers
  - Weathering slowly modifies grain composition into quartz-rich sands
  - Wave motion causes transportation

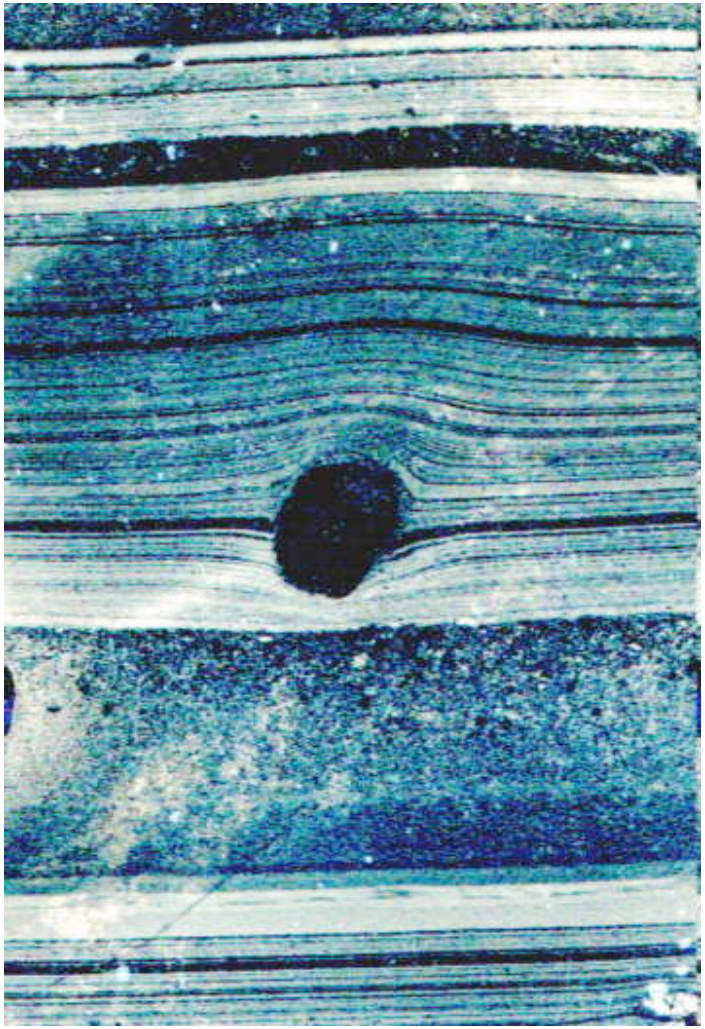
Slough and beach in Goleta, CA

- Continental shelf deposits
  - Relict sediments: left over as underwater former beach sediment
  - formed during the last (or any previous) ice age peak, then flooded during the interglacial
  - sometimes showing above sea level as barrier islands



- Turbidite deposits
  - Sands and muds in Continental Rise
  - Graded bedding

- Glacial deposits
  - High latitude continental shelf
  - Currently forming by ice rafting (icebergs carrying rocks into ocean, called dropstones)



Above: an iceberg carrying sediment to the ocean in Portage Lake, Chugach National Forest, Chugach Mountains, Alaska.

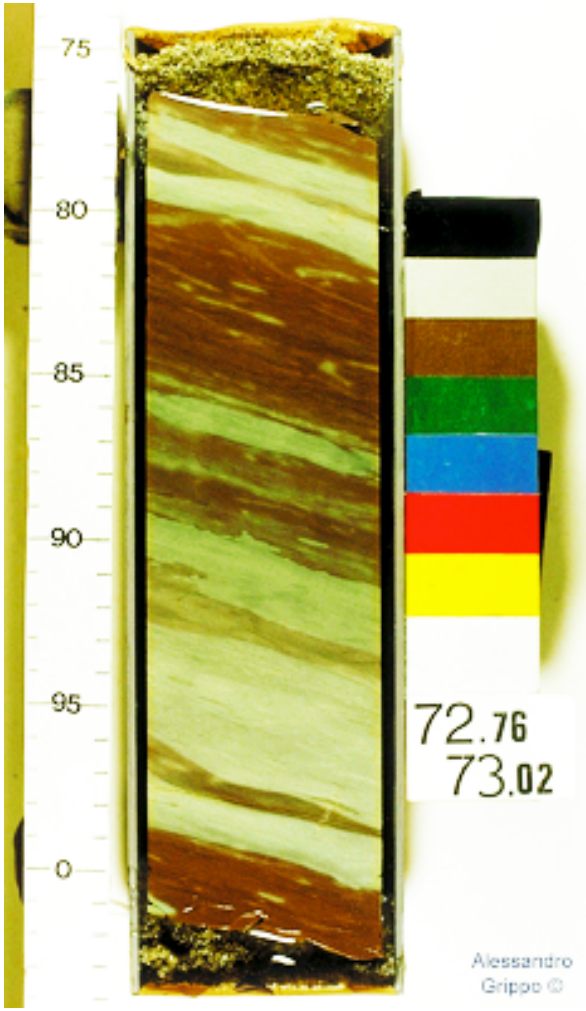
Right: a dropstone in cross-sectional view, Namibia

both images from:
http://serc.carleton.edu/NAGTWorkshops/sedimentary/images/dropstones.html

Pelagic Deposits

- Fine-grained material
- Accumulates slowly on deep ocean floor
- Pelagic lithogenous sediment from
  - Volcanic ash (volcanic eruptions)
  - Wind-blown dust
  - Fine-grained material transported by deep ocean currents

- Abyssal Clay
  - At least 70% clay sized particles from continents
  - Red from oxidized iron (Fe)
  - Abundant if other sediments absent



Rhythmic alternations of deep-marine (pelagic) biogenous (white limestones) and terrigenous (red abyssal clays) sediments

Mid Cretaceous
Piobbico Core, Pesaro-Urbino, Italy

- **end of part 1**