Chapter Overview

- Marine sediments contain a record of Earth history.
- Marine sediments provide many important resources.
- Marine sediments have origins from a variety of sources.

Marine Sediments

- Provide clues to Earth history
  - Marine organism distribution
  - Ocean floor movements
  - Ocean circulation patterns
  - Climate change
  - Global extinction events

Marine Sediments

- Texture—size and shape of particles
- Sediment origins
  - Worn rocks
  - Living organisms
  - Minerals dissolved in water
  - Outer space
- Sediments lithify into sedimentary rock

Approaching the bottom (Alvin)
Marine Sediment Collection

- Early exploration used dredges.
- Modern exploration
  - Cores – hollow steel tube collects sediment columns
  - Rotary drilling – collects deep ocean sediment cores

Marine Sediment Collection

- National Science Foundation (NSF) – formed Joint Oceanographic Institutions for Deep Earth Sampling (JOIDES) in 1963
  - Scripps Institution of Oceanography
  - Rosenstiel School of Atmospheric and Oceanic Studies
  - Lamont-Doherty Earth Observatory of Columbia University
  - Woods Hole Oceanographic Institution

Marine Sediment Collection

- Deep Sea Drilling Project (DSDP) – 1968
  - Glomar Challenger drilling ship
  - Core collection in deep water
  - Confirmed existence of sea floor spreading
    - Ocean floor age
    - Sediment thickness
    - Magnetic polarity

Marine Sediment Collection

- DSDP became Ocean Drilling Project (ODP) in 1983
  - JOIDES Resolution replaced Glomar Challenger
- Integrated Ocean Drilling Program (IODP)
  - Replaced ODP in 2003
  - Chikyu – new exploration vessel in 2007
    - Expedition to Japan Trench after 2011 earthquake

Paleoceanography and Marine Sediments

- Paleoceanography
  - 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 Sediment Classification

- Classified by origin
- Lithogenous – derived from land
- Biogenous – derived from organisms
- Hydrogenous or Authigenic – derived from water
- Cosmogenous – derived from outer space

Lithogenous Sediments

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

Lithogenous Sediments

- Small particles eroded and transported
- Carried to ocean
  - Streams
  - Wind
  - Glaciers
  - Gravity
- Greatest quantity around continental margins

Relationship of fine-grained quartz and prevailing winds

Lithogenous Sediment Transport
Lithogenous Sediments

- Reflect composition of rock from which derived
- Coarser sediments closer to shore
- Finer sediments farther from shore
- Mainly mineral quartz (SiO₂)

Hawaiian Green Sand
Figure 4.4c

Grain Size

- One of the most important sediment properties
- Proportional to energy of transportation and deposition
- Classified by Wentworth scale of grain size

Figure 4.4d

Grain Size

- One of the most important sediment properties
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Wentworth Scale of Grain Size

- Larger particles closer to shore

Texture and Environment

- Texture indicates environmental energy
  - High energy (strong wave action) – larger particles
  - Low energy – smaller particles
- Larger particles closer to shore
**Sorting**

- Measure of grain size uniformity
- Indicates selectivity of transportation process
- Well-sorted – all same size particle
- Poorly sorted – different size particles mixed together

**Sediment Distribution**

- **Neritic**
  - Shallow-water deposits
  - Close to land
  - Dominantly lithogenous
  - Typically deposited quickly
- **Pelagic**
  - Deeper-water deposits
  - Finer-grained sediments
  - Deposited slowly

**Neritic Lithogenous Sediments**

- **Beach deposits**
  - Mainly wave-deposited quartz-rich sands
- **Continental shelf deposits**
  - Relict sediments
- **Turbidite deposits**
  - Graded bedding
- **Glacial deposits**
  - High-latitude continental shelf
  - Currently forming by ice rafting

**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

**Pelagic Deposits**

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

- Hard remains of once-living organisms
- Two major types:
  - **Macroscopic**
    - Visible to naked eye
    - Shells, bones, teeth
  - **Microscopic**
    - Tiny shells or tests
    - Biogenic ooze
- Mainly algae and protozoans

Biogenous Sediment Composition

- Two most common chemical compounds:
  - Calcium carbonate (CaCO₃)
  - Silica (SiO₂ or SiO₂·nH₂O)

Silica in Biogenous Sediments

- **Diatoms**
  - Photosynthetic algae
  - Diatomaceous earth
- **Radiolarians**
  - Protozoans
  - Use external food

Silica in Biogenous Sediments

- **Tests** – shells of microscopic organisms
- Tests from diatoms and radiolarians generate siliceous ooze.
Diatomaceous Earth

- Siliceous ooze lithifies into diatomaceous earth.
- Diatomaceous earth has many commercial uses.

Calcium Carbonate in Biogenic Sediments

- Coccolithophores
  - Also called nanoplankton
  - Photosynthetic algae
  - Coccoliths — individual plates from dead organism
  - Rock chalk
    - Lithified coccolith-rich ooze

Calcium Carbonate in Biogenic Sediments

- Foraminifera
  - Protozoans
  - Use external food
  - Calcareous ooze

Distribution of Biogenous Sediments

- Depends on three processes:
  - Productivity
    - Number of organisms in surface water above ocean floor
  - Destruction
    - Skeletal remains (tests) dissolve in seawater at depth
  - Dilution
    - Deposition of other sediments decreases percentage of biogenous sediments

Pelagic Deposits

- Siliceous ooze
- Accumulates in areas of high productivity
- Silica tests no longer dissolved by seawater when buried by other tests

Neritic Deposits

- Dominated by lithogenous sediment, may contain biogenous sediment
- Carbonate Deposits
  - Carbonate minerals containing CO₃
  - Marine carbonates primarily limestone
    - CaCO₃
  - Most limestones contain fossil shells
    - Suggests biogenous origin
  - Ancient marine carbonates constitute 25% of all sedimentary rocks on Earth.
**Carbonate Deposits**
- **Stromatolites**
  - Fine layers of carbonate
  - Warm, shallow-ocean, high salinity
  - Cyanobacteria
- Lived billions of years ago
- Modern stromatolites live near Shark Bay, Australia

**Calcareous Ooze**
- **CCD** – Calcite compensation depth
  - Depth where CaCO₃ readily dissolves
  - Rate of supply = rate at which the shells dissolve
- Warm, shallow ocean saturated with calcium carbonate
- Cool, deep ocean undersaturated with calcium carbonate
  - Lysocline – depth at which a significant amount of CaCO₃ begins to dissolve rapidly

**Calcareous Ooze and the CCD**
- Scarce calcareous ooze below 5000 meters (16,400 feet) in modern ocean
- Ancient calcareous oozes at greater depths if moved by sea floor spreading

**Sea Floor Spreading and Sediment Accumulation**
Hydrogenous Marine Sediments

- Minerals precipitate directly from seawater
  - Manganese nodules
  - Phosphates
  - Carbonates
  - Metal sulfides
- Small proportion of marine sediments
- Distributed in diverse environments

Manganese Nodules

- Fist-sized lumps of manganese, iron, and other metals
- Very slow accumulation rates
- Many commercial uses
- Unsure why they are not buried by seafloor sediments

Phosphates and Carbonates

- Phosphates
  - Phosphorus-bearing
  - Occur beneath areas in surface ocean of very high biological productivity
  - Economically useful as fertilizer
- Carbonates
  - Aragonite and calcite
  - Oolites
Metal Sulfides

- Metal sulfides
  - Contain:
    - Iron
    - Nickel
    - Copper
    - Zinc
    - Silver
    - Other metals
  - Associated with hydrothermal vents

Evaporites

- Evaporites
  - Minerals that form when seawater evaporates
  - Restricted open ocean circulation
  - High evaporation rates
  - Halite (common table salt) and gypsum

Evaporative Salts in Death Valley

Cosmogenous Marine Sediments

- Macroscopic meteor debris
- Microscopic iron-nickel and silicate spherules (small globular masses)
  - Tektites
  - Space dust
- Overall, insignificant proportion of marine sediments

K/T Boundary Core, Gulf of Mexico

Death Star? (look at the scale)
**Marine Sediment Mixtures**

- Usually mixture of different sediment types
- Typically one sediment type dominates in different areas of the sea floor.

**Pelagic and Neritic Sediment Distribution**

- Neritic sediments cover about \(\frac{1}{4}\) of the sea floor.
- Pelagic sediments cover about \(\frac{3}{4}\) of the sea floor.

**Pelagic and Neritic Sediment Distribution**

- Distribution controlled by
  - Proximity to sources of lithogenous sediments
  - Productivity of microscopic marine organisms
  - Depth of water
  - Sea floor features

**Sea Floor Sediments Represent Surface Ocean Conditions**

- Microscopic tests sink slowly from surface ocean to sea floor (10–50 years)
- Tests could be moved horizontally
- Most biogenous tests clump together in fecal pellets
  - Fecal pellets large enough to sink quickly (10–15 days)

**Worldwide Marine Sediment Thickness**
Resources from Marine Sediments

- Both mineral and organic resources
- Not easily accessible
  - Technological challenges
  - High costs

Energy Resources

- Petroleum
  - Ancient remains of microscopic organisms
  - More than 95% of economic value of oceanic nonliving resources
- More than 30% of world’s oil from offshore resources
- Future offshore exploration will be intense
  - Potential for oil spills

Offshore Drilling Platform

Energy Resources

- Gas Hydrates
  - Also called clathrates
  - High pressures squeeze chilled water and gas into ice-like solid
  - Methane hydrates most common

Energy Resources

- Gas hydrates resemble ice but burn when lit
- May form on sea floor
  - Sea floor methane supports rich community of organisms
- Most deposits on continental shelf

Energy Resources

- Release of sea floor methane may alter global climate.
- Warmer waters may release more methane.
- Methane release may cause underwater slope failure.
  - Tsunami hazard
Energy Resources
- Gas hydrates may be largest store of usable energy.
- Rapidly decompose at surface pressures and temperatures

Other Resources
- Sand and gravel
  - Aggregate in concrete
  - Some is mineral-rich

Other Resources
- Evaporative salts
  - Gypsum – used in drywall
  - Halite – common table salt

Other Resources
- Phosphorite – phosphate minerals
  - Fertilizer for plants
  - Found on continental shelf and slope

Other Resources
- Manganese nodules
  - Lumps of metal
  - Contain manganese, iron, copper, nickel, cobalt
  - Economically useful

Distribution of Sea Floor Manganese Nodules
Other Resources

- Rare Earth elements
  - Assortment of 17 metals
  - Used in technology, e.g., cell phones, television screens, etc.
- Sea floor may hold more rare Earth element deposits than found on land