1 **Marine Sediments**
Chapter Four

2 **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.

3 **Marine Sediments**

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

4 **Approaching the bottom (Alvin)**

5 **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

6 **Classification of Marine Sediments**

7 **Marine Sediment Collection**

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

8 **Drill Ship:**
JOIDES Resolution

9 **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

10 **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

11 **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

12 **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.

13 **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
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14 **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
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15 **Lithogenous Sediments**
- Small particles eroded and transported
- Carried to ocean
  - Streams
  - Wind
  - Glaciers
  - Gravity
- Greatest quantity around continental margins

16 **Relationship of fine-grained quartz and prevailing winds**

17

18 **Lithogenous Sediment Transport**

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

20 **Figure 4.3**

21

22 **Lithogenous sediments**

23 **Lithogenous sediments**

24 **Lithogenous sediments**

25 **Lithogenous Quartz and Wind Transport**

26 **Figure 4.4c**

27 **Figure 4.4d**

28 **Grain Size**
- One of the most important sediment properties
- Proportional to energy of transportation and deposition
- Classified by Wentworth scale of grain size
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29 **Wentworth Scale of Grain Size**

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

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

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

33 **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
-

34 **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

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

36 **Figure 4.6 (top)**

37 **Figure 4.6 (top)**

38 **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

39 **Biogenous Sediment Composition**

- Two most common chemical compounds:
  - Calcium carbonate ($CaCO_3$)
  - Silica (SiO_2 or $SiO_2 \cdot nH_2O$)

40 **Biogenous sediments**

41 **Silica in Biogenous Sediments**

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

42 **Silica in Biogenous Sediments**

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

43 **Diatomaceous Earth**

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

44 **Calcium Carbonate in Biogenic Sediments**

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

45 **Calcium Carbonate in Biogenic Sediments**

- Foraminifera
  - Protozoans
  - Use external food
  - Calcareous ooze

46 **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

47 **Pelagic Deposits**

- Siliceous ooze

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

48 **Neritic Deposits**
- Dominated by lithogenous sediment, may contain biogenous sediment
- Carbonate Deposits
  - – Carbonate minerals containing CO_3
  - – Marine carbonates primarily limestone
    - $CaCO_3$
  - – Most limestones contain fossil shells
    - Suggests biogenous origin
  - – Ancient marine carbonates constitute 25% of all sedimentary rocks on Earth.
    -

49 **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

50 **Calcareous Ooze**
- CCD – Calcite compensation depth
  - – Depth where $CaCO_3$ 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* $CaCO_3$ begins to dissolve rapidly
  - –
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51 **Calcareous Ooze and the CCD**

52 **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
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53 **Sea Floor Spreading and Sediment Accumulation**

54 **<u>Calcareous Ooze and the Calcite Compensation Depth</u>**

55 **Distribution of Modern Calcium Carbonate Sediments**

56 **Environmental Conditions for Oozes**

57 **Hydrogenous Marine Sediments**
- Minerals precipitate directly from seawater
  - – Manganese nodules
  - – Phosphates
  - – Carbonates
  - – Metal sulfides
- Small proportion of marine sediments
- Distributed in diverse environments
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58 **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

59 **Manganese Nodules**

60 **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
-

61 **Metal Sulfides**

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

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

63 **Evaporative Salts in Death Valley**

64 **Cosmogenous Marine Sediments**

- Macroscopic meteor debris
- Microscopic iron-nickel and silicate spherules (small globular masses)
  - Tektites
  - Space dust
- Overall, insignificant proportion of marine sediments
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65 **K/T Boundary Core, Gulf of Mexico**

66 **Death Star?**
(look at the scale)

67 **Marine Sediment Mixtures**

- Usually mixture of different sediment types
- Typically one sediment type dominates in different areas of the sea floor.
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68 **Pelagic and Neritic Sediment Distribution**

- Neritic sediments cover about ¼ of the sea floor.
- Pelagic sediments cover about ¾ of the sea floor.
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69 **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

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70 **Pelagic Sediment Types**

71 **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)

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72 **Worldwide Marine Sediment Thickness**

73 **Resources from Marine Sediments**

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

74 **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

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75 **Offshore Drilling Platform**

76 **Energy Resources**

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

77 **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

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78 **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

79 **Energy Resources**

- Gas hydrates may be largest store of usable energy.
- Rapidly decompose at surface pressures and temperatures

80 **Other Resources**

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

81 **Other Resources**

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

82 **Other Resources**

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

83 **Other Resources**

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

84 **Distribution of Sea Floor Manganese Nodules**

85 **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

86 **Figure 4.E**

87 **Figure 4.E**

88 **Figure 4.E**