Sedimentary Rocks

What are they and where do they form?
Guiding Questions

- What characteristics of sedimentary rocks can we use to identify the environment of deposition, i.e., where it was formed?

- How does vertical stacking of distinctive types of strata provide clues to changes in environments of deposition that indicate larger changes in the Earth such as sea level rise and fall and changes in the environment?

  \[ \rightarrow \text{the latter is} \ Stratigraphy \]
Paleogeography

• Reconstruction of ancient environments from the stratigraphic record
  – Distribution of land and sea
  – Identification of local and regional environments
  – Changes in tectonics
  – Framework for interpretation of past life
Three Basic Depositional Environments: Marine, Non-marine and Marginal Marine
### Three Basic Depositional Environments:

<table>
<thead>
<tr>
<th>Environment</th>
<th>Deposits</th>
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</thead>
<tbody>
<tr>
<td>Marine</td>
<td>the ocean</td>
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<tr>
<td>Non-marine</td>
<td>lakes, rivers, floodplains, glaciers</td>
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<tr>
<td>Marginal Marine</td>
<td>beaches, lagoons, estuaries</td>
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<tr>
<td>Marine</td>
<td>Limestones and Shales</td>
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<tr>
<td>Non-marine</td>
<td>Sandstones and Shales</td>
</tr>
<tr>
<td>Marginal Marine</td>
<td>Sandstones and Mudstones</td>
</tr>
</tbody>
</table>
Nonmarine Environments

• Soil
  – Loose sediment containing organic matter and accumulated in contact with atmosphere
  – Topsoil
    • Upper zone of many soils
    • Sand and clay mixed with humus
  – Humus
    • Organic matter that gives topsoil its dark color
    • Derived from decay of plant debris by bacteria
Nonmarine Environments

- **Soils**
  - Type of soil depends on climatic conditions

- **Caliche**
  - Calcium carbonate produced by evaporation of groundwater

- **Laterite**
  - Iron oxide rich soil produced in moist tropical regions
Nonmarine Environments

• Burrows
  – Plant
  – Animal
  – Aid in identifying ancient soils
  – “Devil’s corkscrews”
Nonmarine Environments

- **Lakes**
  - Lower elevation, more likely preservation
  - Indicates abundant precipitation
- **Sediments**
  - Coarsest around lake margin
  - Finest at center
    - Often layered, i.e., non-bioturbated
- **Freshwater fossils**
- **Less bioturbation**
  >>> laminated
Nonmarine Environments

- Glaciers
  - Indicate cold climates
- Scratches produced by glacial motion
  - Record direction of motion
Nonmarine Environments

- **Meltwater**
  - Transports sediments from glacier
  - Forms streams and lakes

- **Outwash**
  - Well-stratified layers of sediment

- **Varve**
  - Annual layers of alternating coarse and fine sediments
Nonmarine Environments

- **Till**
  - Unsorted, heterogeneous material
- **Tillite**
  - Lithified till
- **Moraine**
  - Ridges of till plowed up at the farthest edge of the glacier
Moraines - Till
Till

Tillite
Nonmarine Environments

- **Varves**
  - Annual record
  - Count!

- **Dropstones**
  - Scattered coarse sediments found in sediment matrix
  - Ice-rafted debris
Nonmarine Environments

- Desert soils
  - Little organic matter
  - Evaporite minerals
- Interior drainage
  - Precipitation does not leave the basin
  - Playa lake
    - Temporary lakes
    - Associated with evaporites
Nonmarine Environments

- Dunes
  - Piles of sand
  - < 1% of deserts
  - Moves with prevailing wind direction
  - Associated with deserts and beaches
Desert Dunes
Desert Dunes
Rocks from Desert Dunes
Cross Beds
Zion National Park, UT
Wind current development

Cross-bed #1

Cross-bed #2

Cross-bed #1

Cross-bed #3

Cross-bed #2

Cross-bed #1
Cross bedding: Zion National Park
Rocks from Desert Dunes
Rocks from Desert Dunes

Cross bedding: Kaibab Sandstone, Zion National Park
Rocks from Desert Dunes
Rivers and Beaches

Aeolian (deserts)

Crossbeds
Nonmarine Environments

- Dune migration
  - Moves downwind
  - Sands move up and over top; accumulate on downwind side

- Trough cross-stratification
  - Direction changes with prevailing winds
  - Beds accumulate on curved surface cut through older beds
Nonmarine Environments

- Alluvial fans
  - Low, cone-shaped structures
  - Develop where mountain slope meets valley floor
  - Change in slope reduces stream velocity
    - Sediments settle out
    - Braided streams form
Alluvial Fans
Nonmarine Environments

- Mudcracks
  - Polygonal shape
  - Form from alternate wetting and drying
  - Associated with evaporites
    - Halite
    - Gypsum
    - Anhydrite
Nonmarine Environments

- RIVERS and STREAMS
Waters move from mountains to sea through a variety of depositional environments
- Braided streams
- Meandering rivers
- Marginal marine systems
Nonmarine Environments

- Braided streams
  - More sediment available than the water can transport
  - Forms numerous channels and bars
The North Platte River: A Braided Stream
A braided stream in its floodplain: Alaska
Nonmarine Environments

- **Meandering River**
  - Abundant water relative to sediment

- **Backswamps**
  - Flood plain
  - Mud settles out when stream overflows
Nonmarine Environments

- **Point bar**
  - Slowest flow on inner bend
  - Accumulate sands
  - Fastest flow on the outer bank
  - Cuts away bank

- **Natural levees**
  - Form during floods
  - Coarsest sands deposited first, then fines
A braided stream in its floodplain: Laramie River
Oxbow lakes in a floodplain
River channels
River channels
Riparian foliage in a floodplain
Marginal Marine

- **Delta**
  - Depositional body of sand, silt, and clay formed when river empties into the sea
  - Sediments settle out in sequence

What did the ocean say to the land?
The Ganges River Delta
Marginal Marine

- Delta plain
  - Layers of sand and silt deposited as river nears sea
  - Distributary channels
    - Separated by levees

- Delta front
  - Silt and clay slope deposits

- Prodelta
  - Clays often deposited by a freshwater plume

- Progrades into basin
  - Sediments coarsen upward
Marginal Marine

- Mississippi River Delta
  - River dominated delta
  - Progrades into Gulf of Mexico
  - Lobes
    - Growing portion of the delta
Marginal Marine

- **Mississippi River Delta**
  - Active lobe
    - Growing portion of delta
    - Switched lobes in the past
  - Abandoned lobe
    - Sediments compact
    - Lobe sinks
    - New lobe forms on top
Aside: What happens when sea level changes?

Marine Transgression = Sea Level Rise

Marine Regression = Sea Level Fall
Figure 6-21

Earth System History, Second Edition

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Walther’s Law

Sedimentary environments that started out side-by-side will end up overlapping one another over time due to transgressions and regressions.

Facies

Limestone  Shale  Siltstone  Sandstone

Reef    Lagoon    Near Shore    Beach

Environment
Marine Regression
Fig 5.26. Sequence of sediments deposited by transgression and regression of shallow sea
“The sea goes in, the sea goes out.”
Marginal Marine

• Deltaic Cycles
  – Sequence of deposition
  – Coarsens upward
  – Erosion can remove tops
Marginal Marine

- Barrier-Island Lagoon Complex
- Barrier Islands
  - Waves and currents pile up sands
  - Longshore Current
- Lagoons
  - Protected from strong waves behind barriers
  - Muds and muddy sands
Marginal Marine

- Progradation
  - Shoreline builds out into sea
    - High supply of sediment
  - Builds over deeper water environments
  - Illustrates Walther’s Law
Marginal Marine

- Fossils
  - Useful in reconstructing environments of past
Marine

- Tempestites
  - Storm deposits on shelf
  - Sands deposited within normal muds and muddy sands
Carbonate Systems

- Organic reefs
  - Modern reefs formed from coral
  - Ancient reefs formed from different organisms
Carbonate Systems

- Reef front
  - Seaward side
  - Often rubble called talus

- Reef flat
- Lagoon
  - On leeward side
  - Patch reef
Carbonate Systems
Carbonate Systems

• Barrier reefs
  – Elongate reefs with lagoon behind

• Fringing Reefs
  – Grow along coast
  – Lack lagoon
Carbonate Systems

• Atolls
  – Reefs on volcanic islands
  – Darwin
    • Formed by sinking island
  – Up to 65 km across
  – Often open at one end
Carbonate Systems

- Buried atolls
- Often important petroleum reservoirs
Carbonate Systems

- Carbonate Platform
  - Broad carbonate structure above seafloor
  - Windward side
    - Nutrient rich
    - Abundant reefs

- Buffered system
  - \( \text{CO}_2 + \text{H}_2\text{O} = \text{H}_2\text{CO}_3 \)
  - \( \text{HCO}_3^- + \text{CaCO}_3 = 2\text{HCO}_3^- \)
Carbonate Systems

- Stromatolites
  - Cyanobacteria mats trap sediments
  - Grows up through sediments to produce new one
  - Layered organic-rich and organic-poor muds
Carbonate Systems

• Living Stromatolites
  – Found in hypersaline, supratidal and intertidal settings
  – Little competition and predation
  – Shark Bay, Australia
Deep Sea Environments

- Turbidity current
  - Dense sediment-laden flow driven by gravity

- Turbidite
  - Produces graded deposit
  - Poorly sorted coarse grains at base
  - Fine grains at top
Deep Sea Environments

- Turbidites are common in canyons
- Drop sediment load at base
  - Form deposit similar to alluvial fan
Deep Sea Environments

- Pelagic sediment
  - Fine-grained sediments that accumulate by settling through the water column
  - Calcium carbonate
  - Silica
  - Clay
Deep Sea Environments

- Calcareous ooze
  - Accumulations of single-celled planktonic organisms
    - Foraminifera
    - Calcareous nannoplankton
- Common < 4 km w.d.
  - Dissolution increases below 4 km w.d.
Deep Sea Environments

- Siliceous ooze
  - Diatoms
  - Radiolarians
- Common in upwelling regions
- Accumulations can alter to opal then chert
Alluvial fans in Death Valley
Coral Reefs
Great Barrier Reef
Australia
Reefs

- Coastal feature of biological origin
- Complex community of coral, algae & other marine animals living in warm seas
- Reef structure has large influence on coastal processes