Sea-Level Change

Reference:
Walker and James, Facies Models, (Ch. 2)

Sea-Level Change

- Observations
- Mechanisms
- Relationships between sea level and sedimentation

Observations - 1
- Mapping of sedimentary rocks of different ages suggests that the sea (ocean) has repeated covered than drained from significant portions of North America
  - Periods of 10s to 100s of millions of years
  - "Sloss Sequences"
White areas represent sequences of rocks that are separated by large-scale unconformities shown in brown.

Observations - 2

- Examination of outcrops shows “cycles” which suggest that sea level has changed on periods of 10s of thousands to several million years.
Observations - 3

- Sea level fluctuations of different timescales may be superimposed
Mechanisms

- Changes in sea level at one location may be caused by:
  - Changes in global sea level
  - Vertical uplift/subsidence of the crust
  - Combinations of the two

Option 1:  
Global sea level rises and falls

“Eustatic” Sea level changes (Eustacy)
Option 2: 
Crust rises and falls

Option 3: 
Tectonic movements and global sea level change simultaneously

Mechanisms
- Conclusion: just by looking at one outcrop/region, we cannot be sure whether changes in sea level were caused by eustatic changes, tectonic movements or some combination of the two
- We use the term “relative sea level” to refer to interplay of eustatic and tectonic factors
As relative sea level rises and falls, the shoreline will move landward or basinward.

- **Transgression** (landward movement of the shoreline)
- **Regression** (basinward movement of the shoreline)
**Factor #1 – Global (Eustatic) Sea-level Change**

Earth's Surface Remains Fixed – Global Sea Level Changes

**Factor #2 – Regional/Local Subsidence/Uplift**

Global Sea Level Remains Fixed – Earth's Surface Changes

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**Mechanisms**

- The processes that cause changes in global sea level are varied
- Each has characteristic timescales over which it operates
- We will focus on two processes:
  - Glacial cycles
  - Spreading ridges
Mechanisms

- During ice ages, water is removed from the oceans and stored on land as glacial ice
  - This causes global sea level to fall
- During interglacials, continental glaciers melt, and water is returned to the oceans
  - This causes global sea level to rise

“Interglacial”

- Few/no glaciers
- Most “surface water” in oceans

“Glacial”

- Growth of continental glaciers takes water out of oceans
- Global sea level drops
Changes in sea level associated with the last glacial cycle

Pennsylvanian Paradox Group – Utah

Mechanisms

- Elevation of oceanic crust is a function of its age
- Young crust is hot, less dense, buoyant
- Crust cools, becomes dense and subsides with age
- Size of mid-ocean ridges is a function of spreading rates
Cross-sections through a spreading ridge

When spreading rates are high, ridges are formed of young, "buoyant" crust (right). The ridge swells and water spills out of the ocean onto land – sea level rises.

When spreading rates drop, the ridges shrink (left) and sea level drops.

"Slow Spreading"

- Small mid-ocean ridge
- Low global sea level

"Rapid Spreading"

- Swollen mid-ocean ridge displaces water onto continents
- Global sea level rises
Comparison between global sea level (deduced from distribution of sedimentary rocks) and spreading rates ("ocean crust accretion"). Tectonic factors cause sea-level changes on periods of 10s to 100s of millions of yrs.

Table 1: Mechanisms of sea-level change. From Bravard, 1983.

<table>
<thead>
<tr>
<th>MECHANISMS</th>
<th>Time Scale (years)</th>
<th>Order of Magnitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Ocean Basins (Reequilibrating Volume Changes)</td>
<td>10^4 - 10^5</td>
<td>0.1 - 10 m</td>
</tr>
<tr>
<td>2. Glacial/Karst and Marine</td>
<td>10^3 - 10^4</td>
<td>0.1 - 10 m</td>
</tr>
<tr>
<td>3. Liquid Water on Land</td>
<td>10^2 - 10^3</td>
<td>0.1 - 10 m</td>
</tr>
<tr>
<td>4. Coastal Erosion</td>
<td>10^1 - 10^2</td>
<td>0.1 - 10 m</td>
</tr>
</tbody>
</table>

Other mechanisms for sea level change

**Mechanisms**

- Sea-level changes on periods of many 10s to 100s of millions of years are known as 1st Order Cycles
  - Eustatic
  - Related to supercontinent cycle – make-up and break-up of Pangea
  - Easy to correlate (biostratigraphy, seismic stratigraphy, absolute dating, etc.)
Mechanisms

2\textsuperscript{nd} Order Cycles: changes of sea level over 10s of millions of years
- Primarily eustatic
- Related to global tectonic factors (e.g., spreading rates)
- “Sloss Sequences”
- Easy to correlate (biostratigraphy, absolute dating, seismic stratigraphy, etc.)

Mechanisms

3\textsuperscript{rd} Order Cycles: changes of sea level over millions of years
- Eustatic? No mechanism that seems to “work” throughout much of Phanerozoic
- Regional subsidence/uplift?
- Difficult to correlate globally (biostratigraphy, absolute dating often not accurate enough)
- May be correlated regionally (biostratigraphy, seismic stratigraphy, etc.)

Mechanisms

4\textsuperscript{th} Order Cycles: changes of sea level over 100s of thousands of years
- Eustatic? Glacial cycles – doesn’t work for all of Phanerozoic
- Changes in sediment supply/deltaic lobe switching/etc. (see later)
- Quaternary cycles may be correlated globally (isotopes, biostratigraphy)
- Local correlations – wireline logs, seismic data, outcrops, etc.
Relationships between sea level and sedimentation

- As (relative) rises and falls, different parts of the continent are exposed/flooded
- Different types of depositional systems are preferentially developed at different times
Relationships between sea level and sedimentation

- In a later section, we will be emphasizing how changes in relative sea level affect how/where different depositional environments develop
- We will develop and use sequence stratigraphic concepts to understand the relationships between sea-level change, sediment accumulation and the nature of the stratigraphic record

Summary

- The sedimentary record holds evidence of sea-level changes on many different timescales
- Global sea level changes – “eustacy”
- Local/regional subsidence or uplift can also cause sea level change in a given area
- Combination of eustacy and vertical tectonic movements causes changes in relative sea level

Summary

- Many different processes can be responsible for causing eustatic or relative sea-level change
- Changes in sea level can affect where/when certain depositional environments develop
- Will expand upon this later in the course