Sea-Level Change

Reference:

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

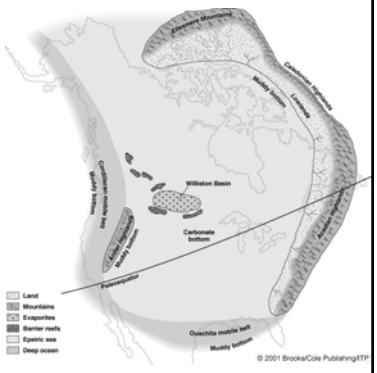
Sea-Level Change

- Observations
- Mechanisms
- Relationships between sea level and sedimentation

Observations - 1

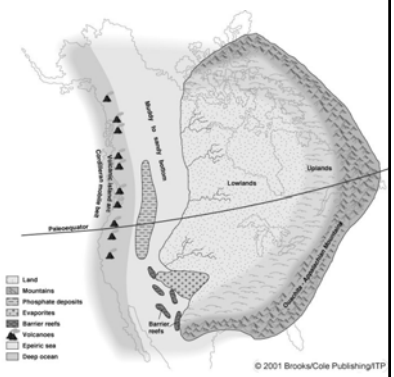
- Mapping of sedimentary rocks of different ages suggests that the sea (ocean) has repeated covered than drained from significant portions of North America
  - Periods of 10s to 100s of millions of years
  - "Sloss Sequences"

- Devonian Period

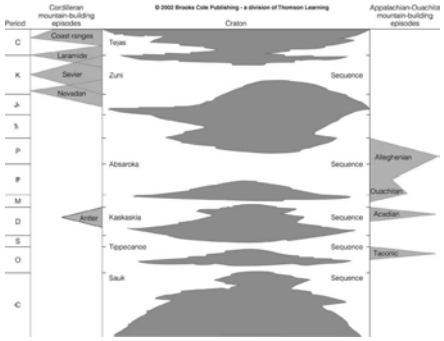


- Mississippian Period

- Permian Period



White areas represent sequences of rocks that are separated by large-scale unconformities shown in brown

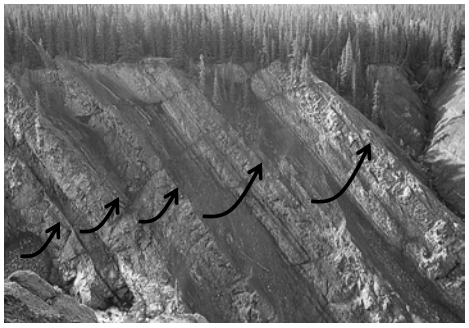


Western N.A. Eastern N.A.

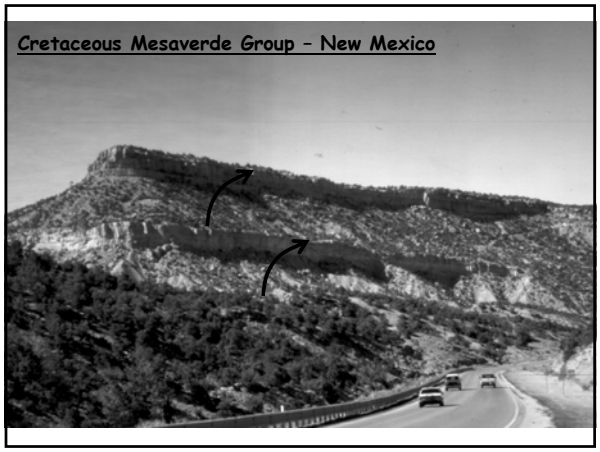
Observations - 2

- Examination of outcrops shows "cycles" which suggest that sea level has changed on periods of 10s of thousands to several million years

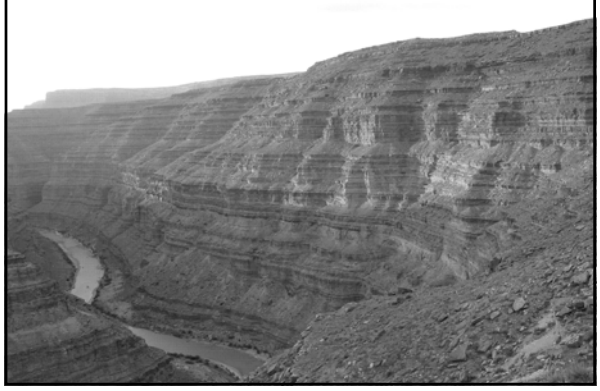
Cretaceous Cardium Formation – Alberta



Cretaceous Mesaverde Group – New Mexico

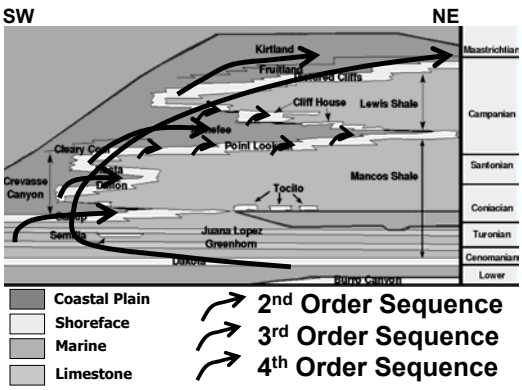


Pennsylvanian Paradox Group - Utah



Observations - 3

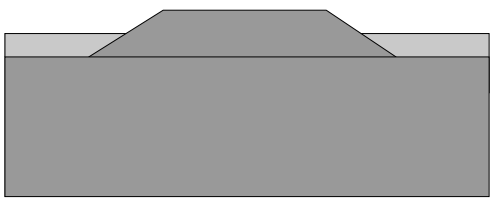
- **Sea level fluctuations of different timescales may be superimposed**



Mechanisms

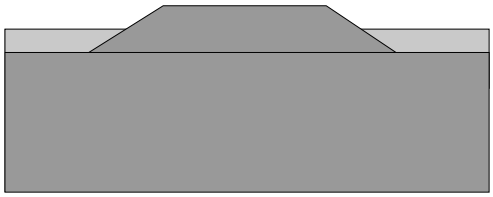
- Changes in sea level at one location may be caused by:
  - Changes in global sea level
  - Vertical uplift/subsidence of the crust
  - Combinations of the two

Option 1:
Global sea level rises and falls

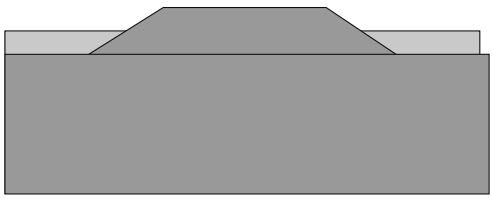


"Eustatic" Sea level changes (Eustacy)

Option 2:
Crust rises and falls

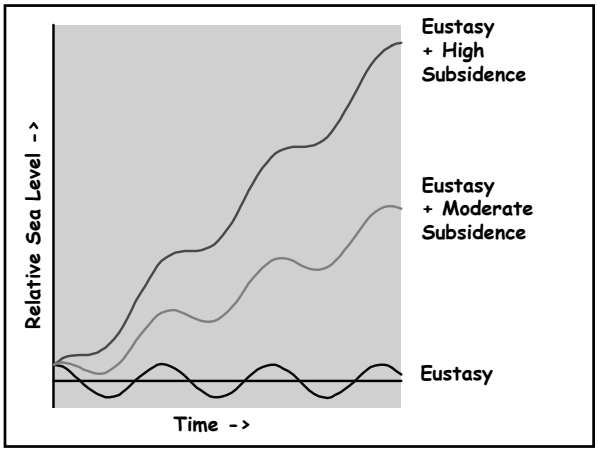


Option 3:
Tectonic movements and global sea level change simultaneously



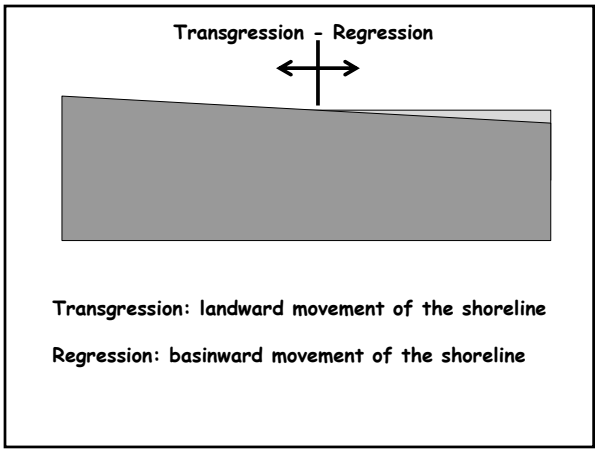
Mechanisms

- 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



Mechanisms

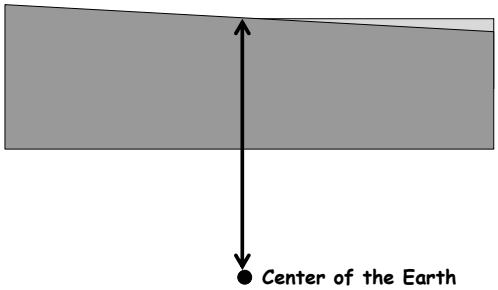
- **As relative sea level rises and falls, the shoreline will move landward or basinward**



Transgression: landward movement of the shoreline

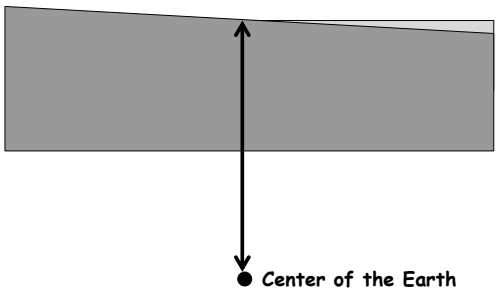
Regression: basinward movement of the shoreline

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

Mechanisms

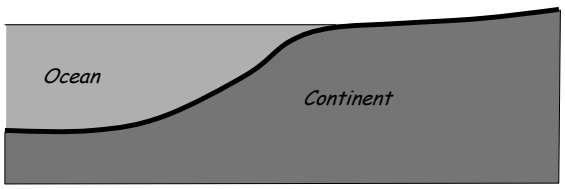
- The processes that cause changes in global sea level are varied
- Each has characteristic timescales over which it operates
- We will focus on two processes:
  - Glacial cycles
  - Spreading ridges

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**

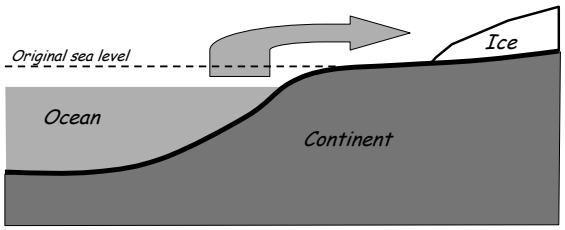
"Interglacial"

- Few/no glaciers
- Most "surface water" in oceans

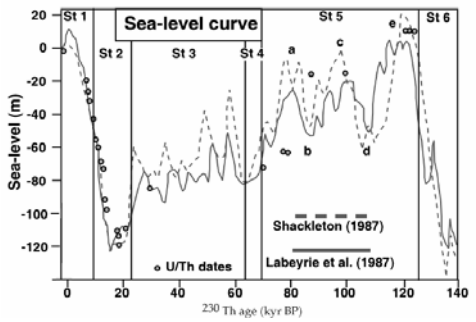


"Glacial"

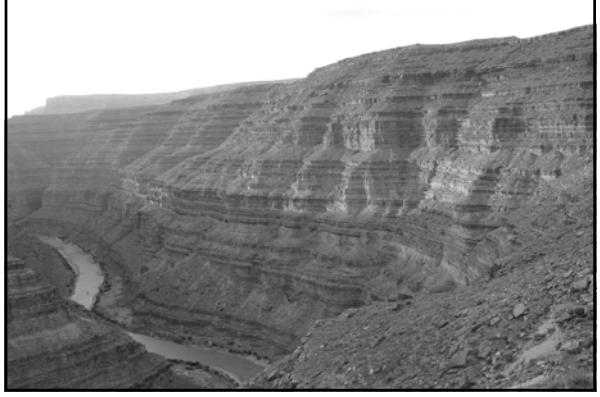
- Growth of continental glaciers takes water out of oceans
- Global sea level drops



Changes in sea level associated with the last glacial cycle

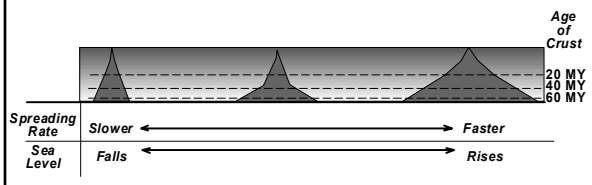


Pennsylvanian Paradox Group - Utah



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



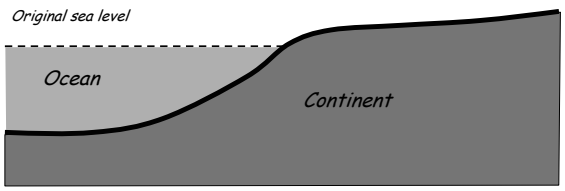
Cross-sections through a spreading ridge

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.

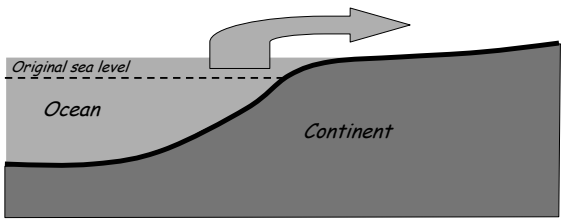
"Slow Spreading"

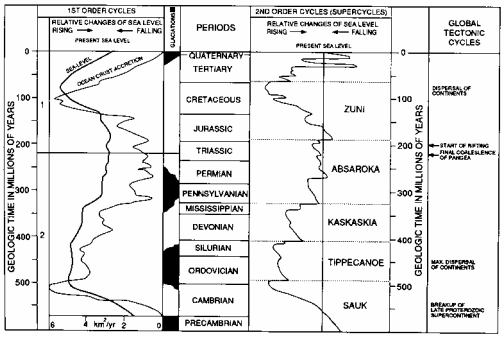
- Small mid-ocean ridge
- Low global sea level



"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 Reveille (1990).*

MECHANISMS	Time Scale (years)	Order of Magnitude
1) ***Ocean Steric (thermohaline) Volume Changes***		
Shallow (0-500 m)	0.1 – 100	0 – 1 m
Deep (500-4000 m)	10 – 10,000	0.01 – 10 m
2) ***Glacial Accretion and Wastage***		
Mountain Glaciers	10 – 100	0.1 – 1 m
Greenland Ice Sheet	100 – 100,000	0.1 – 10 m
East Antarctic Ice Sheet	1,000 – 100,000	10 – 100 m
West Antarctic Ice Sheet	100 – 10,000	1 – 10 m
3) ***Liquid Water on Land***		
Groundwater Aquifers	100 – 100,000	0.1 – 10 m
Lakes and Reservoirs	100 – 100,000	0.01 – 0.1 m
4) ***Crustal Deformation***		
Lithosphere Formation and Subduction	$100,000 – 10^8$	1 – 100 m
Glacial Isostatic Rebound	100 – 10,000	0.1 – 10 m
Continental Collision	$100,000 – 10^8$	10 – 100 m
Seafloor and Continental Epirogeny	$100,000 – 10^8$	10 – 100 m
Sedimentation	$10,000 – 10^8$	1 – 100 m

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

- 2nd 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

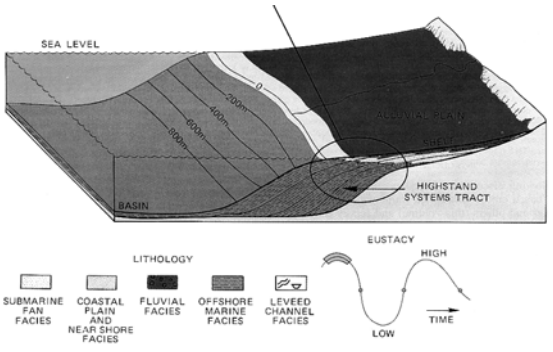
- 3rd Order Cycles: changes of sea level over millions of years
  - Eustatic? No mechanism that seems to "work" throughout much of Phanerozoic
  - Regional subsidence/uplift?
  - Difficult to correlate globally (biostratigraphy, absolute dating often not accurate enough)
  - May be correlated regionally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

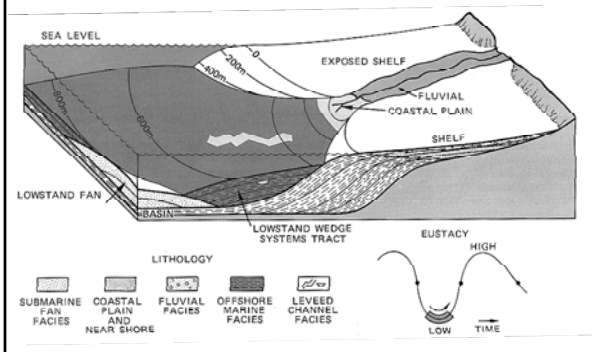
Mechanisms

- 4th 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