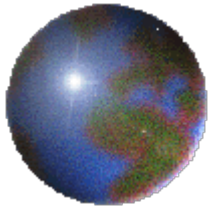
Introduction to Physical Geology



Chapter 18 Coastlines

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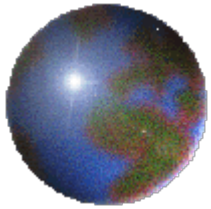
Content

Coastlines

- Coastal regions are cooler in summer and warmer in winter than continental interiors.
- The sea provides both food and transportation.
- Coastlines have become heavily urbanized and industrialized.
- Coastlines are also one of the most geologically active environments on Earth.



18.2 Waves, Tides and Currents

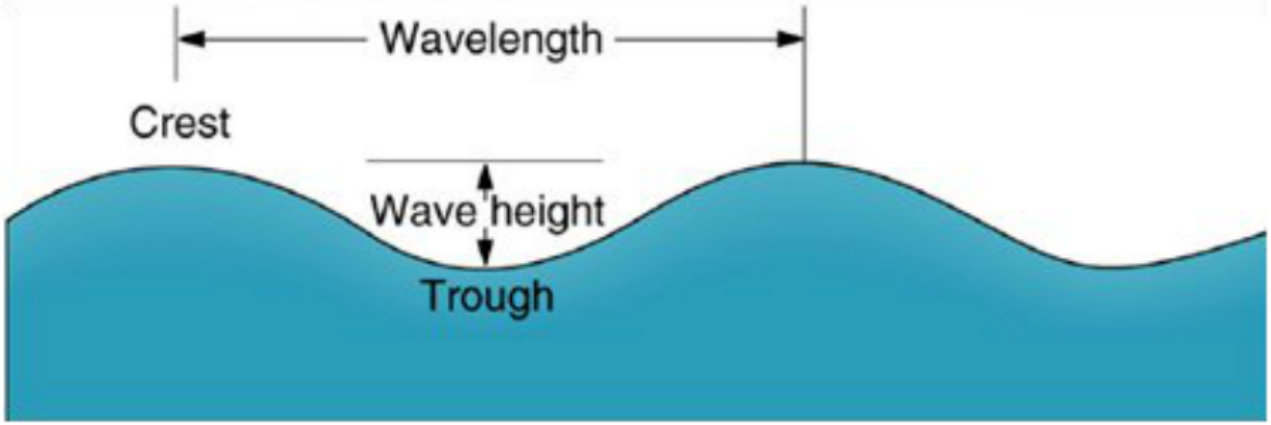
Characteristics of Waves

- Wave generated by wind provide most of the energy that shapes and modifies shorelines
- Height, length, and period of a wave are functions of
  - Wind speed
  - Length of time wind has blown
  - *Fetch:* distance wind travels across open water

Characteristics of Waves

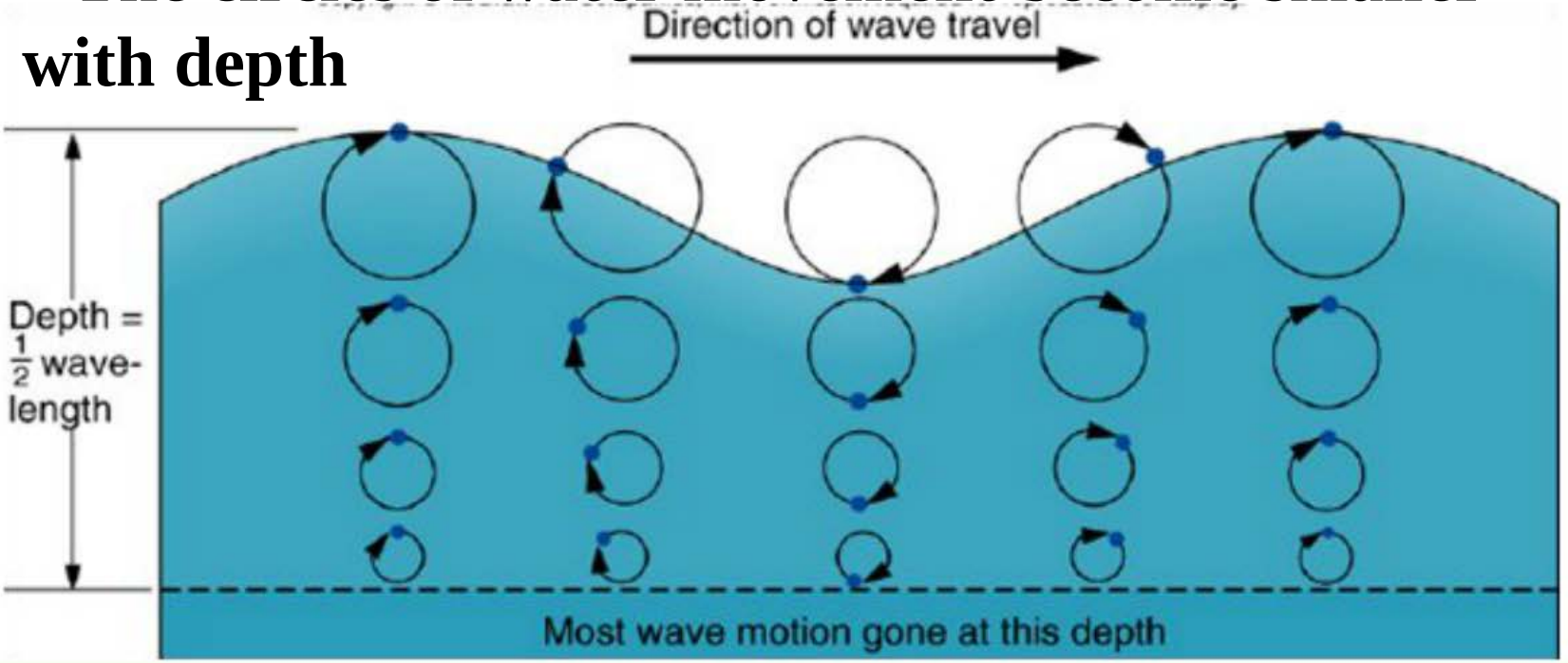
Measurements of a wave

- *Wave height:* vertical distance between trough and crest
- *Wavelength:* horizontal distance between crests
- *Wave period:* the time interval between the passage of two successive crests



Orbital motion of water

- Wave energy moves forward, not the water
- Water move in a circular motion in deep water
- Depth of wave is ½ of the wavelength
- The circles of water movement become smaller with depth



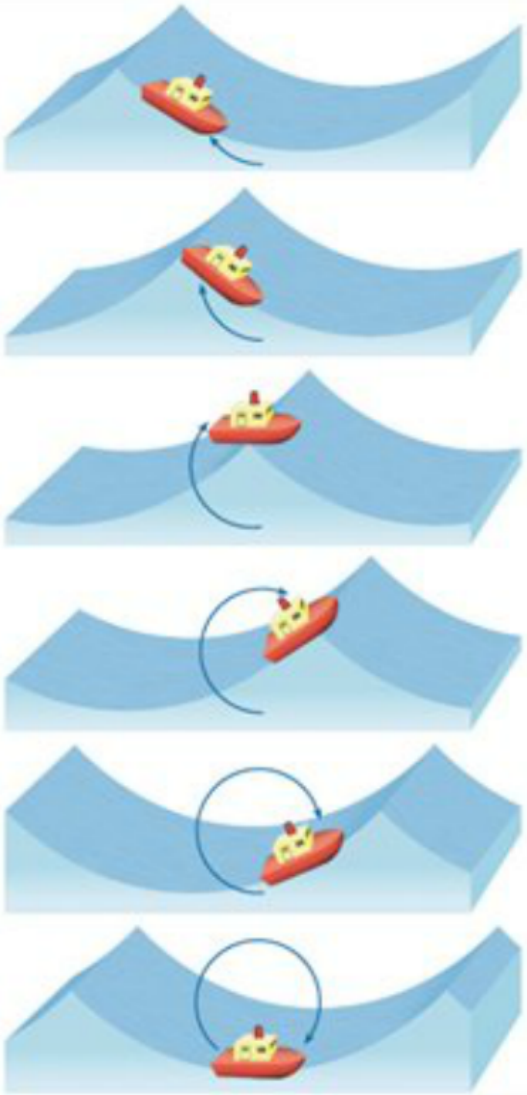
Orbital motion of water

Wave energy advances

Water advances slightly

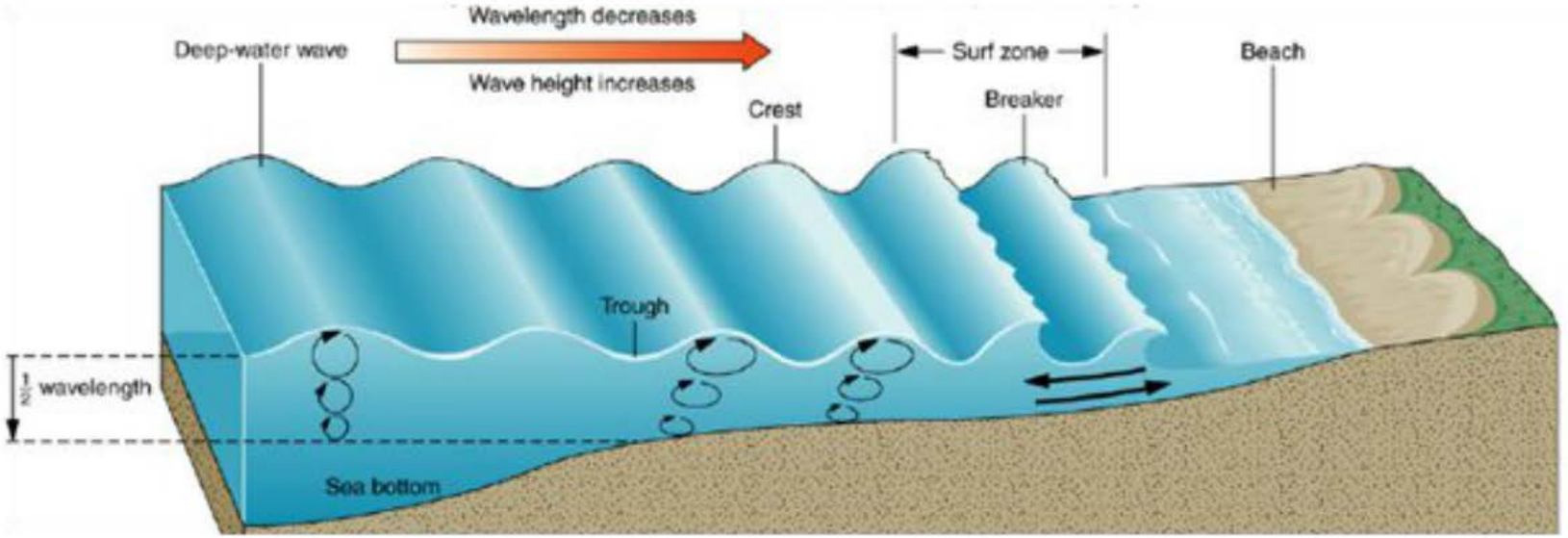
Wave moves from right to left

Water rotates in a circular motion



Formation of Surf

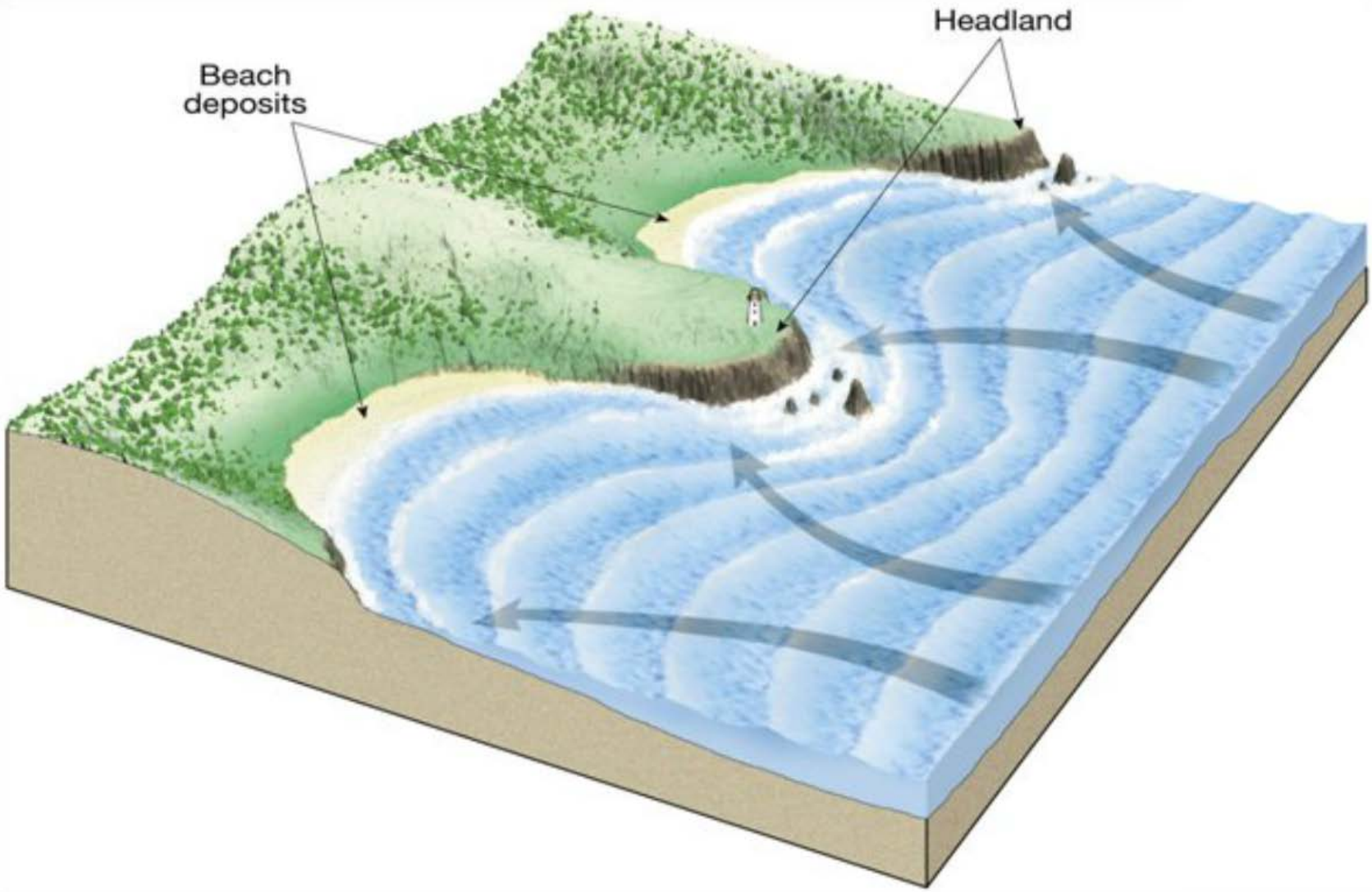
- When water-depth < 1/2 wavelength, wave "feel bottom"
- Due to friction, the bottom of a wave slows down
- As speed and length of wave diminish, wave grows higher
- Steep wave front collapses: wave breaks – Surf.



Wave Refraction

- Bending of a wave
- Waves arrive nearly parallel to shore or the direction of movement perpendicular to shore
- Consequences of wave refraction
  - Head land get eroded faster
  - Bay area predominant by deposition
  - Over time, erosion straightens an irregular

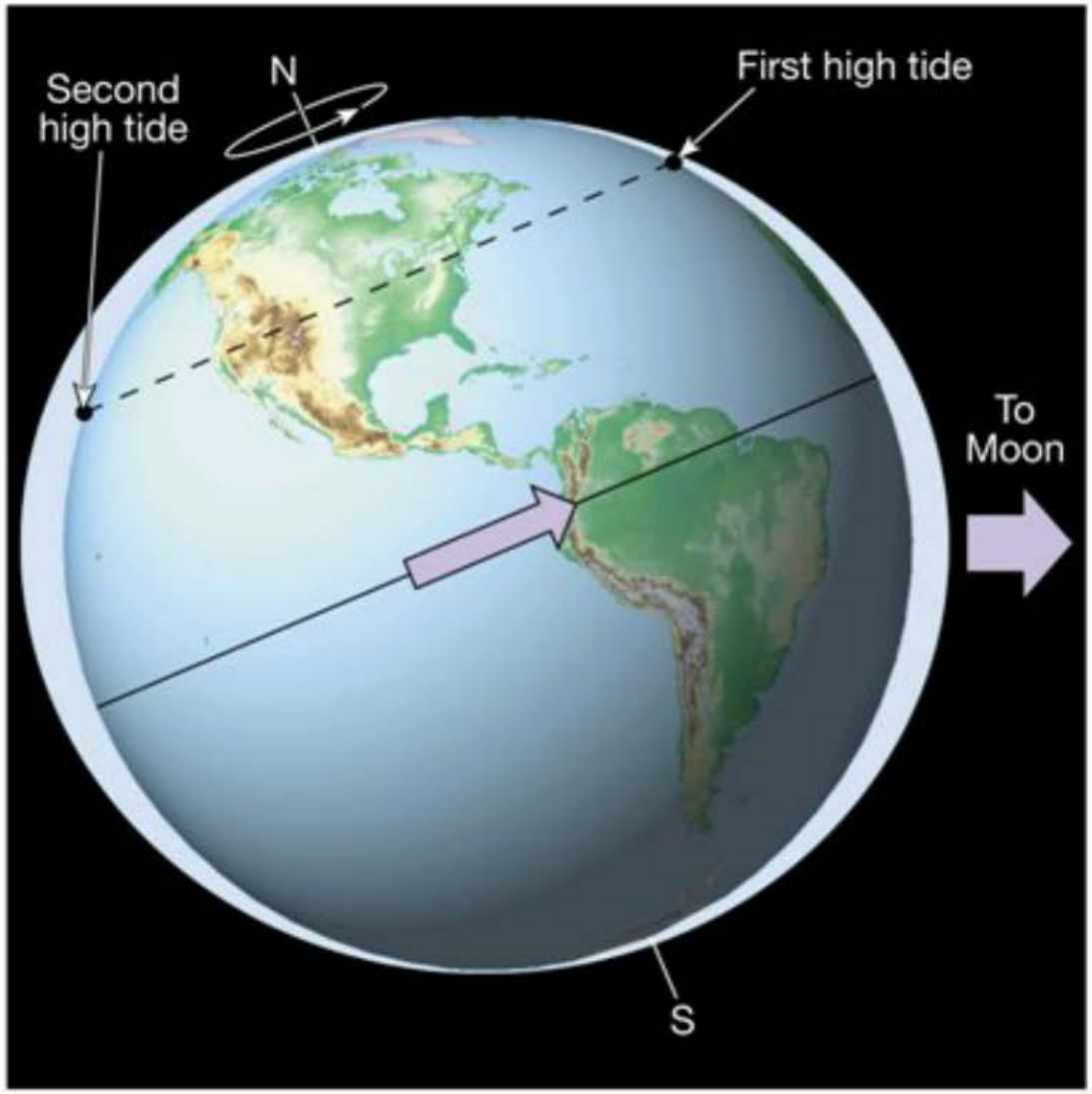
Refraction of Waves



Tides

- Daily changes in the elevation of the ocean surface
  - Diurnal (twice per day)
- Causes of tides
  - Tidal bulges are caused by the gravitational forces of the Moon, and
  - lesser extent the Sun

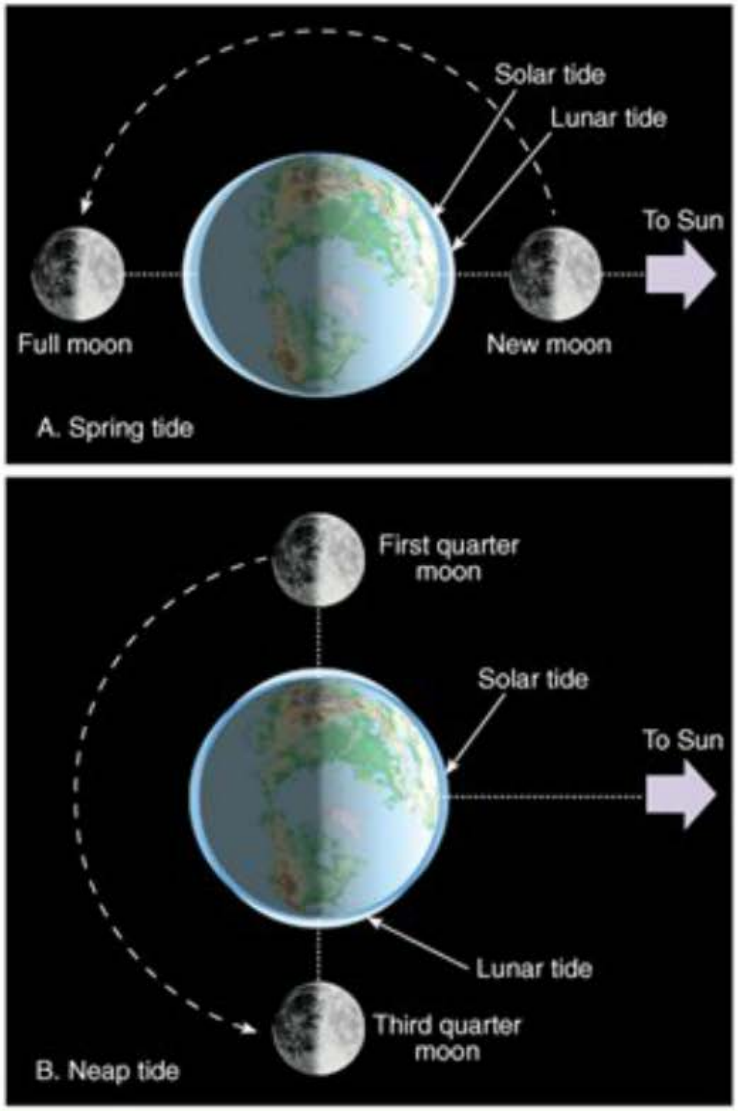
Tides and the Moon



Tides

- **Spring tides**
  - Occur during new and full moons
  - Gravitational forces of the Moon and Sun are added together
  - Especially high and low tides
  - Large daily tidal range
- **Neap tides**
  - Occur in 1st and 3rd quarters of moon
  - Gravitational forces of the Moon and Sun are offset
  - Daily tidal range is least

Spring and Neap Tides



Tidal Range

Bay of Fundy, Nova Scotia

Tides

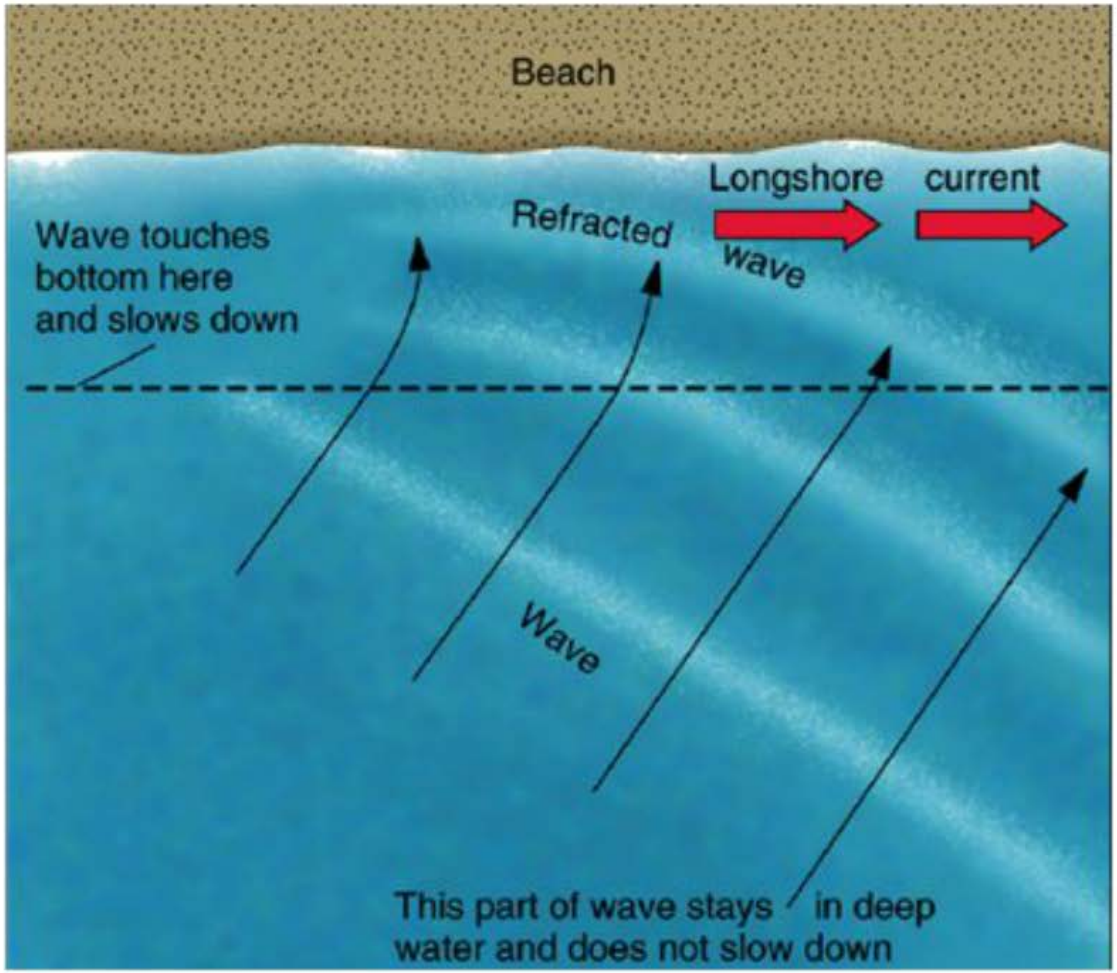
- **Other factors that influence tides**
  - Shape of the coastline
  - Configuration of the ocean basin
- **Tidal currents**
  - Horizontal flow of water accompanying the rise an fall of the tide
  - Types of tidal currents
    - *Flood current:* advances into the coastal zone as the tide rises
    - *Ebb current:* seaward-moving water as the tide falls
  - *Tidal flats:* Areas affected by the tidal currents
  - *Tidal deltas:* forms behind barrier island

Tidal Flat

Bay of Fundy, Nova Scotia

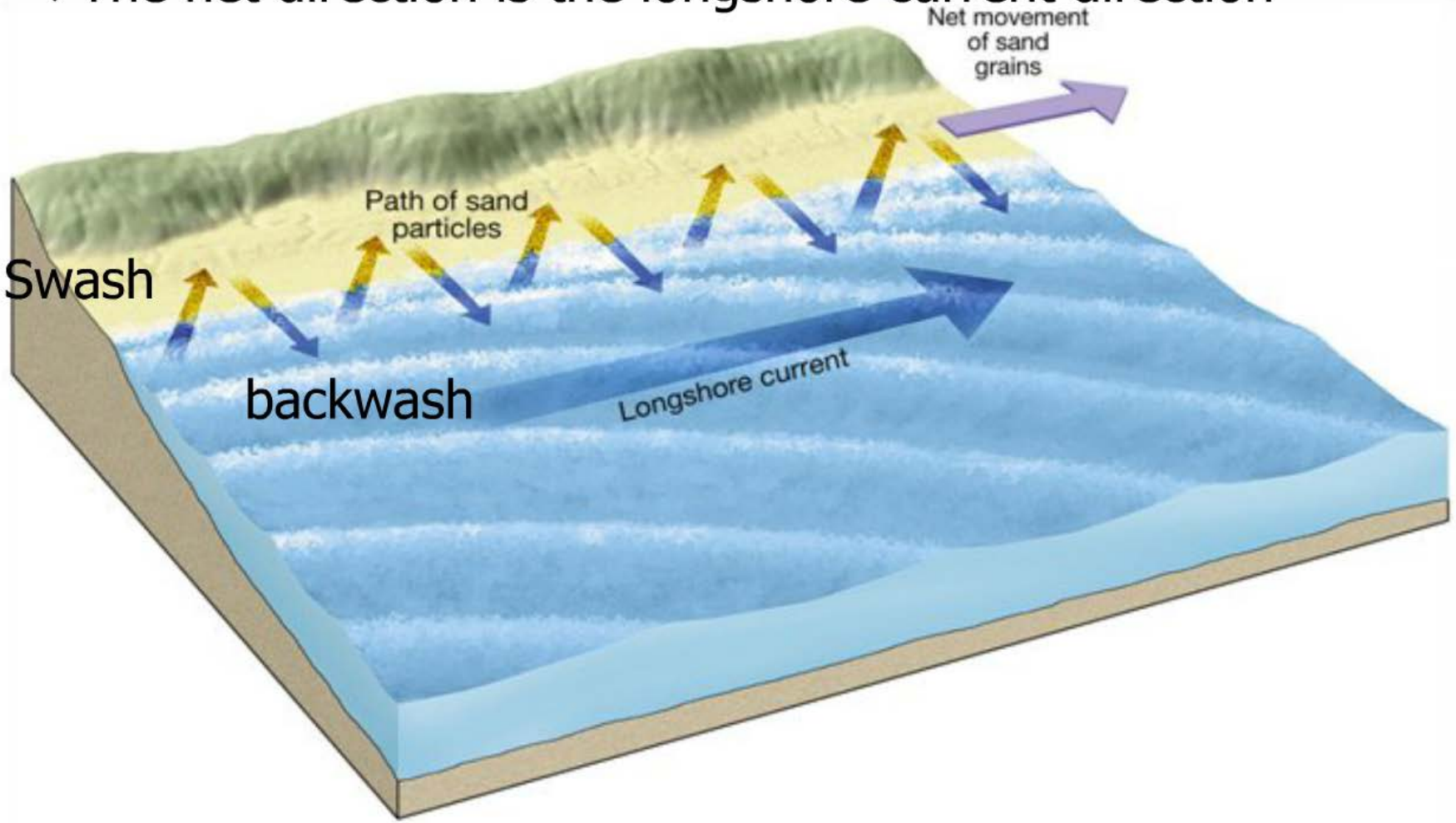
Longshore Current

- The movement of water parallel to the shoreline
- Waves reach shoreline at an angle
- Due to wave refraction, the net direction is parallel to the shore



Longshore drift

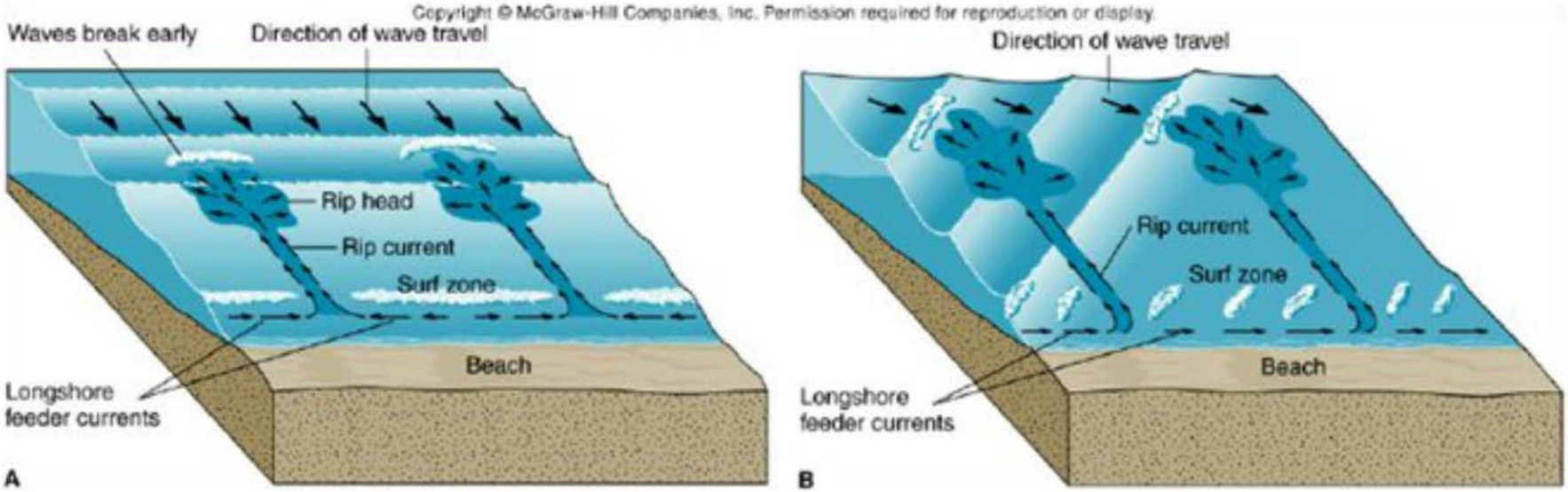
- Sand particles move in a zig-zap pattern
- The net direction is the longshore current direction

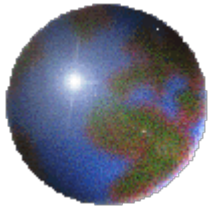


Longshore Drift, OR

Rip Currents

- Narrow currents flow out to sea
- Often perpendicular to the shore
- Important in transporting fine-grained sediments out of surf zone

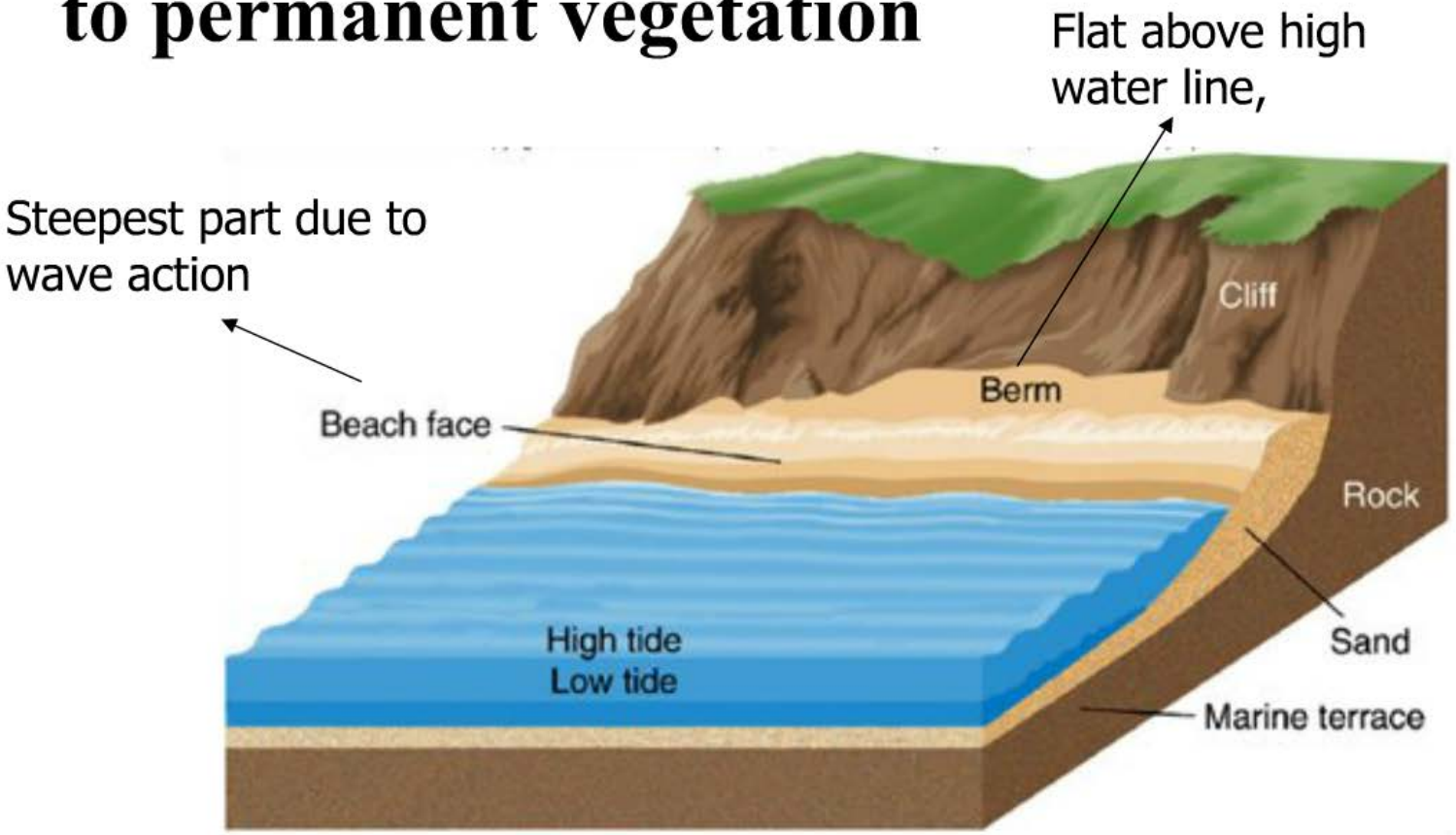




18.3 The Water's edge

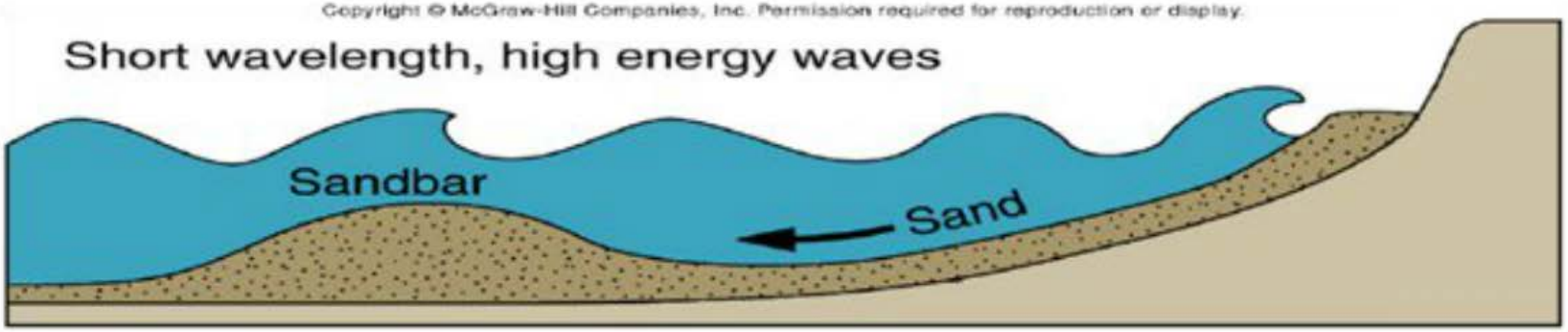
Beaches

- **A strip of sediments from low water line to permanent vegetation**

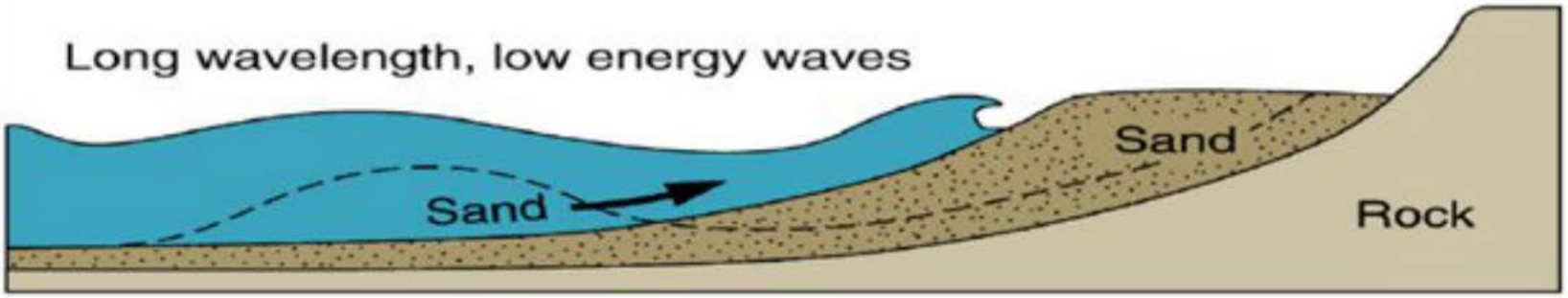


A beach is divided into two zones, the **foreshore** and the **backshore.**

Seasonal effect on beaches



A Winter beach



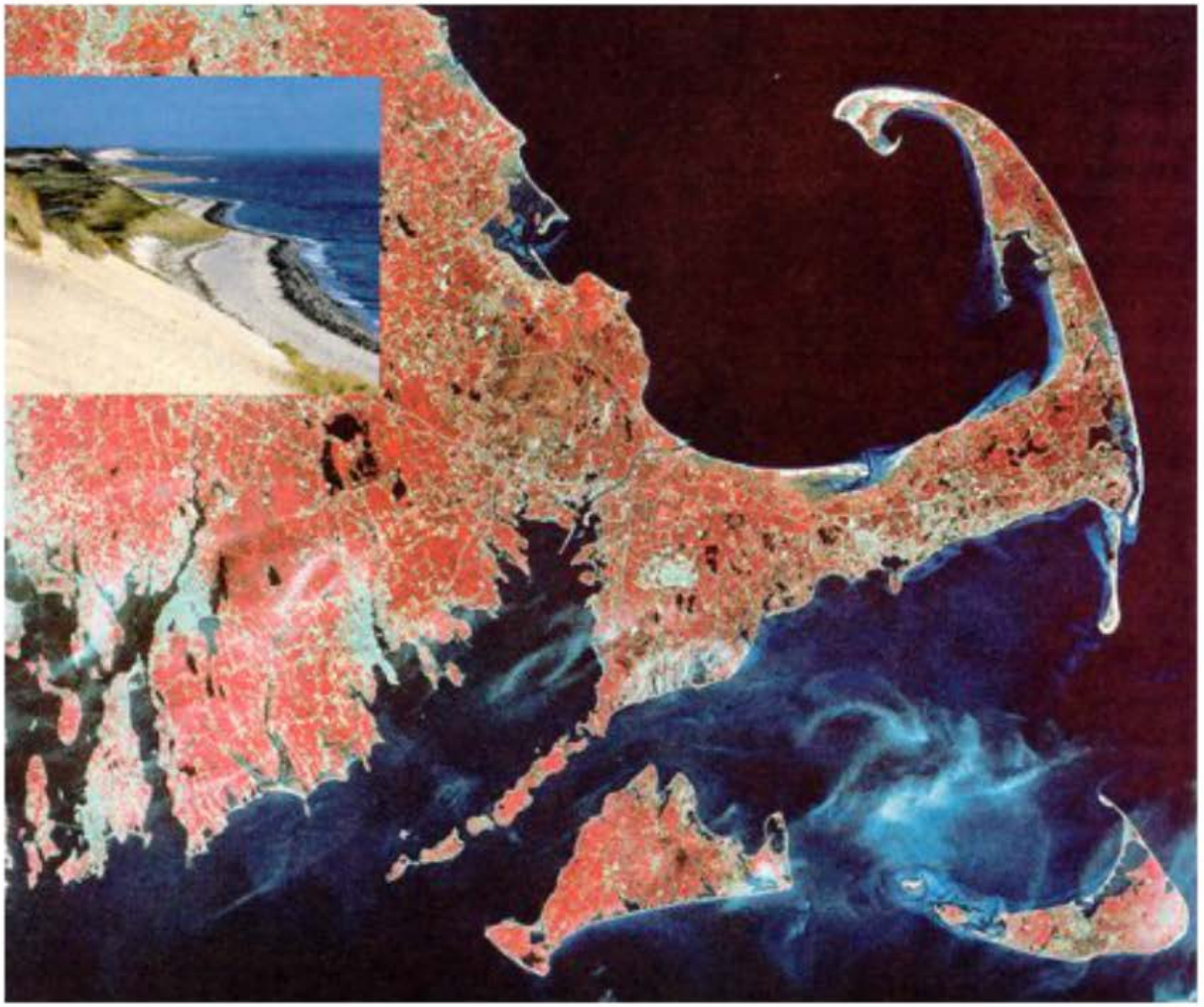
B Summer beach

The Coast

- The coast is a dynamic interface (common boundary) between air, land, and the ocean
- The coast is constantly being modified by waves
- Coasts differ greatly around the world
- Today the coastal zone is experiencing intense human activity

Sandy Beach Coast

Cape Cod, MA



Rock Cliff Coast

Point Reyes, northern CA

Coastal Features

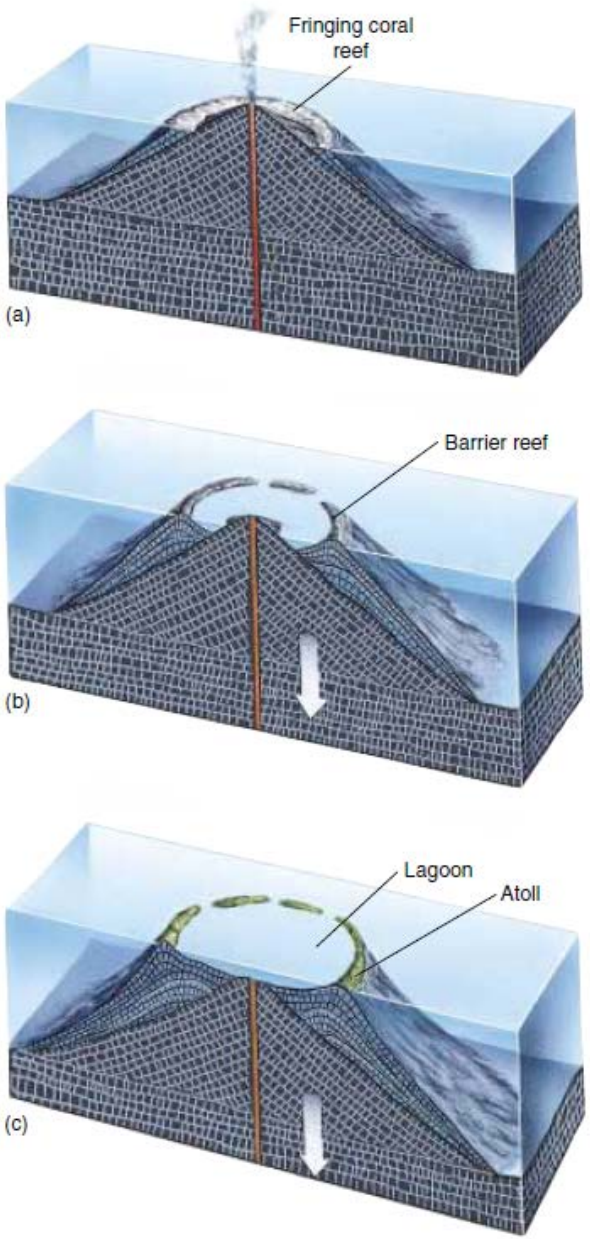
- **Features vary depending on several factors including**
  - **Rocks along the shore**
  - **Currents**
  - **Wave intensity**
  - **Coast stability: sinking, or rising**

Reefs

Reef **is a wave-resistant ridge or mound built by corals, oysters, algae, or other marine organisms.**

Atoll **is a circular coral reef that forms a ring of islands around a lagoon.**

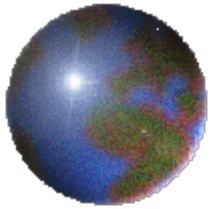
Reefs



(a) When a volcanic island is rising or static, the reef remains attached to the beach and is called a fringing reef.

(b) As the island sinks, the reef continues to grow upward to form a barrier reef.

(c) Finally the island becomes submerged and the reef forms a circular atoll.



18.4 Emergent and Submergent Coastlines

Emergent &Submergent Coasts

- **Emergent (uplifted) coasts**
  - Develop by coastal uplift or sea level drop
  - Features of an emergent coast
    - Wave-cut cliffs
    - Wave-cut platforms
- **Submergent (drowned) coast**
  - From coastal subsidence or sea level rise
  - Features of a submergent coast
    - Highly irregular shoreline
    - *Estuaries:* drown river mouths

Wave-cut Platform, OR

Uplifted Coast

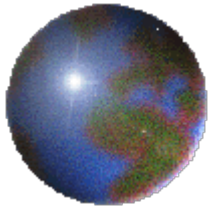
Submergent Coasts

Chesapeake Bay

Emergent & Submergent Coasts

Factors that cause coastal emergence and submergence

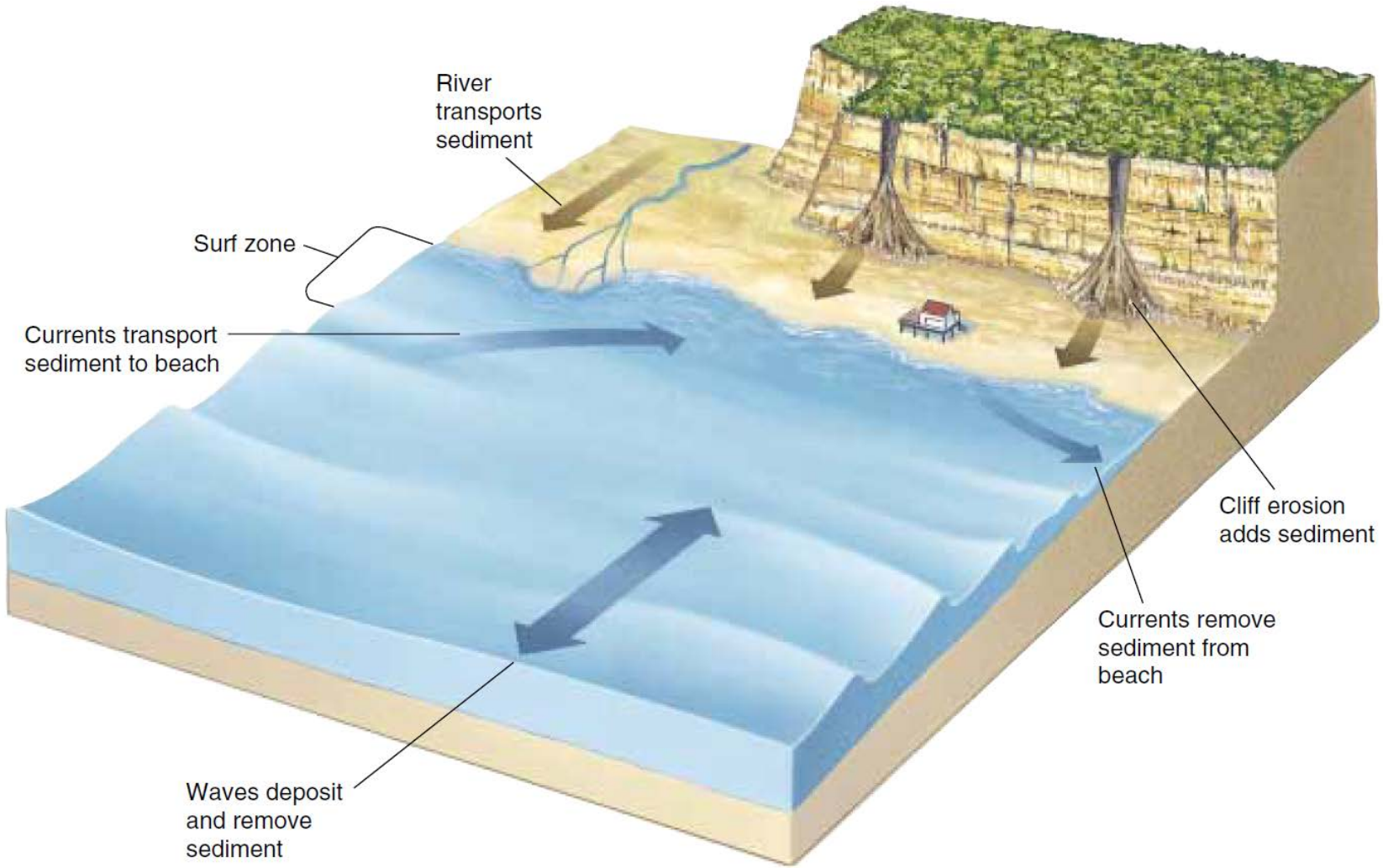
- Tectonic and isostatic processes cause local or regional sea level changes.
- Sea level can also change globally--**eustatic change**, occurs by three mechanisms:
  - Changes in water temperature
  - Changes in the volume of the mid-oceanic ridge
  - Growth and melting of glaciers



18.5 Sandy and Rocky Coastlines

Sandy and Rocky Coastlines

- Coastal weathering and erosion occur by many processes.



Sandy and Rocky Coastlines

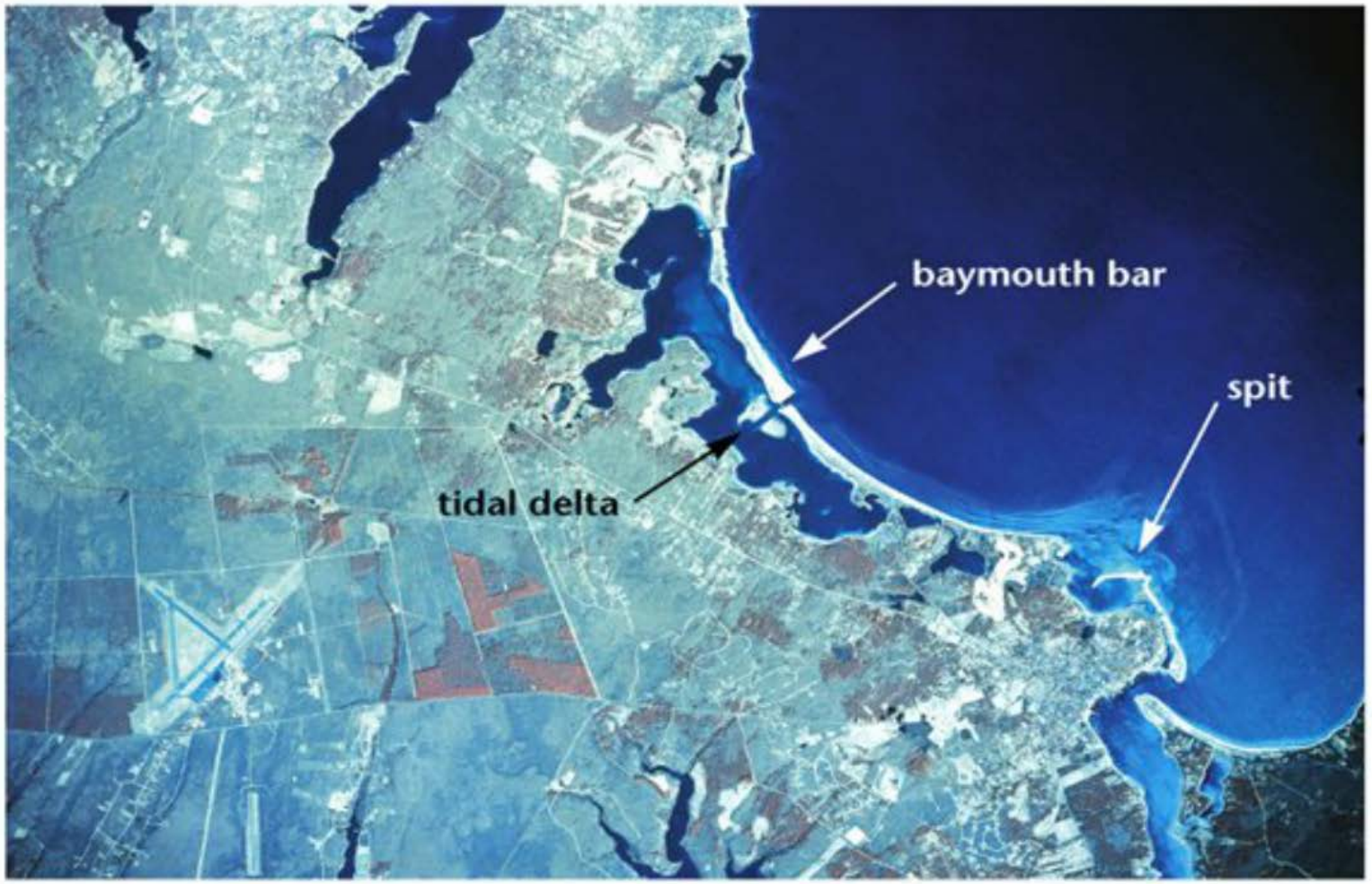
- Most coastal sediment is not formed by weathering and erosion at the beach itself, but is transported from other places.
- Sandy coastlines occur where sediment from any of these sources is abundant;
- Rocky coastlines occur where sediment is scarce.
- Sandy beaches are abundant on emergent coastlines.
- Submergent coastlines are commonly sediment poor and are characterized by steep, rocky shores.

Coastal Features by longshore drift

- **Features related to beach drift and longshore currents**
  - ***Spits:*** **elongated ridges of sand extending from land into mouth of an adjacent bay**
  - ***Baymouth bar:*** **sand bar that completely crosses a bay**
  - ***Tombolo:*** **ridge of sand that connects an island to the mainland or another island**

Shoreline Features

Coast of Massachusetts



Sand Spit

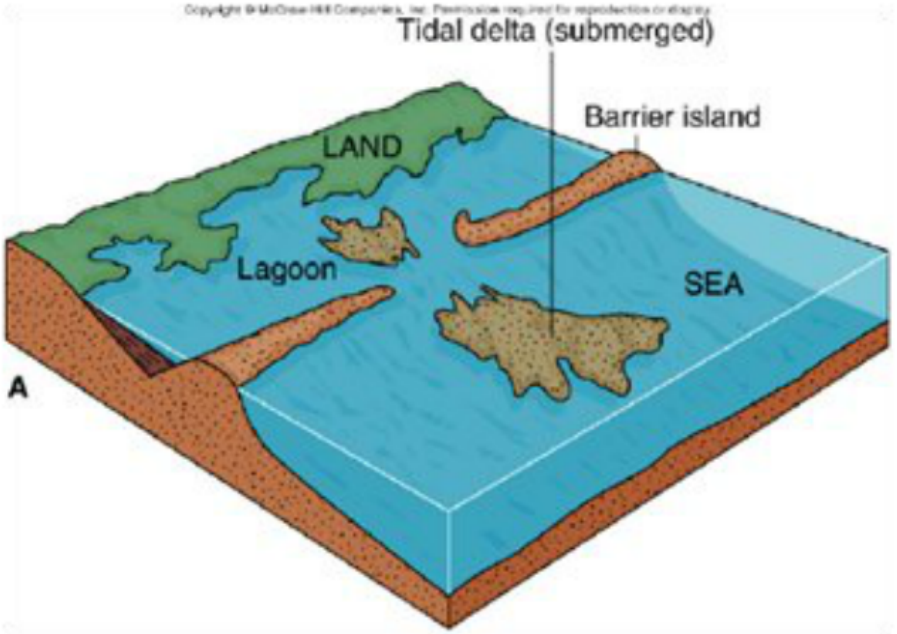
San Diego, CA

Dungeness Spit, WA

Tombolo

Shoreline Features by deposition

- **Barrier islands**
  - Mainly along the Atlantic and Gulf coasts
  - Low ridges of sand that parallel the coast 3 to 30 kilometers offshore
- **Tidal deltas:**

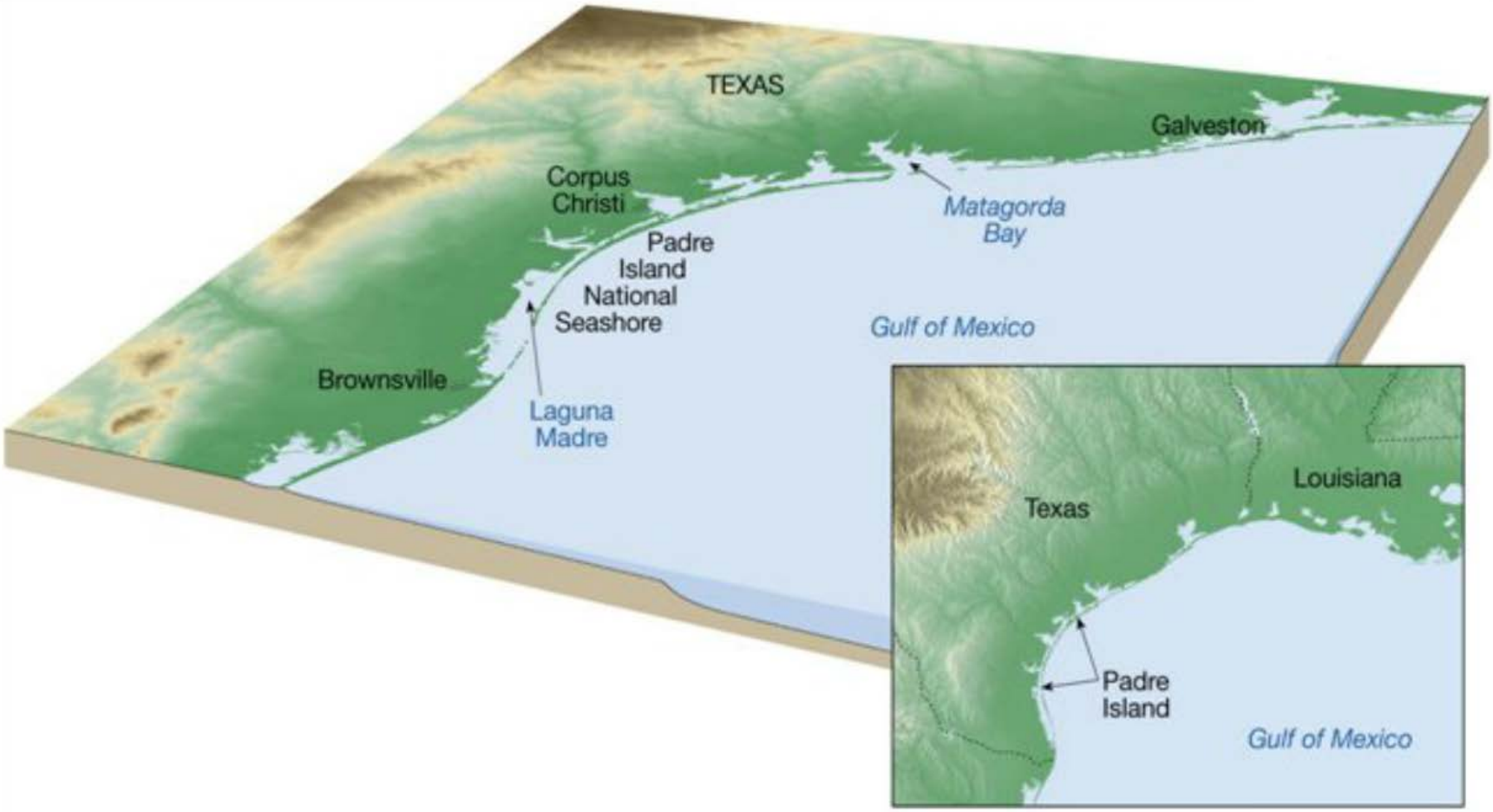


Shoreline Features by deposition

- Barrier islands form in several ways.
- The two essential ingredients are a large supply of sand and waves or currents to transport it.
  - If a coast is shallow, breaking storm waves may carry sand toward shore and deposit it just offshore as a barrier island.
  - If a longshore current veers out to sea, it slows down and deposits sand where it reaches deeper water.
  - Underwater sand bars may be exposed as a coastline emerges. Alternatively, sand dunes or beaches may form barrier islands if a coastline sinks.

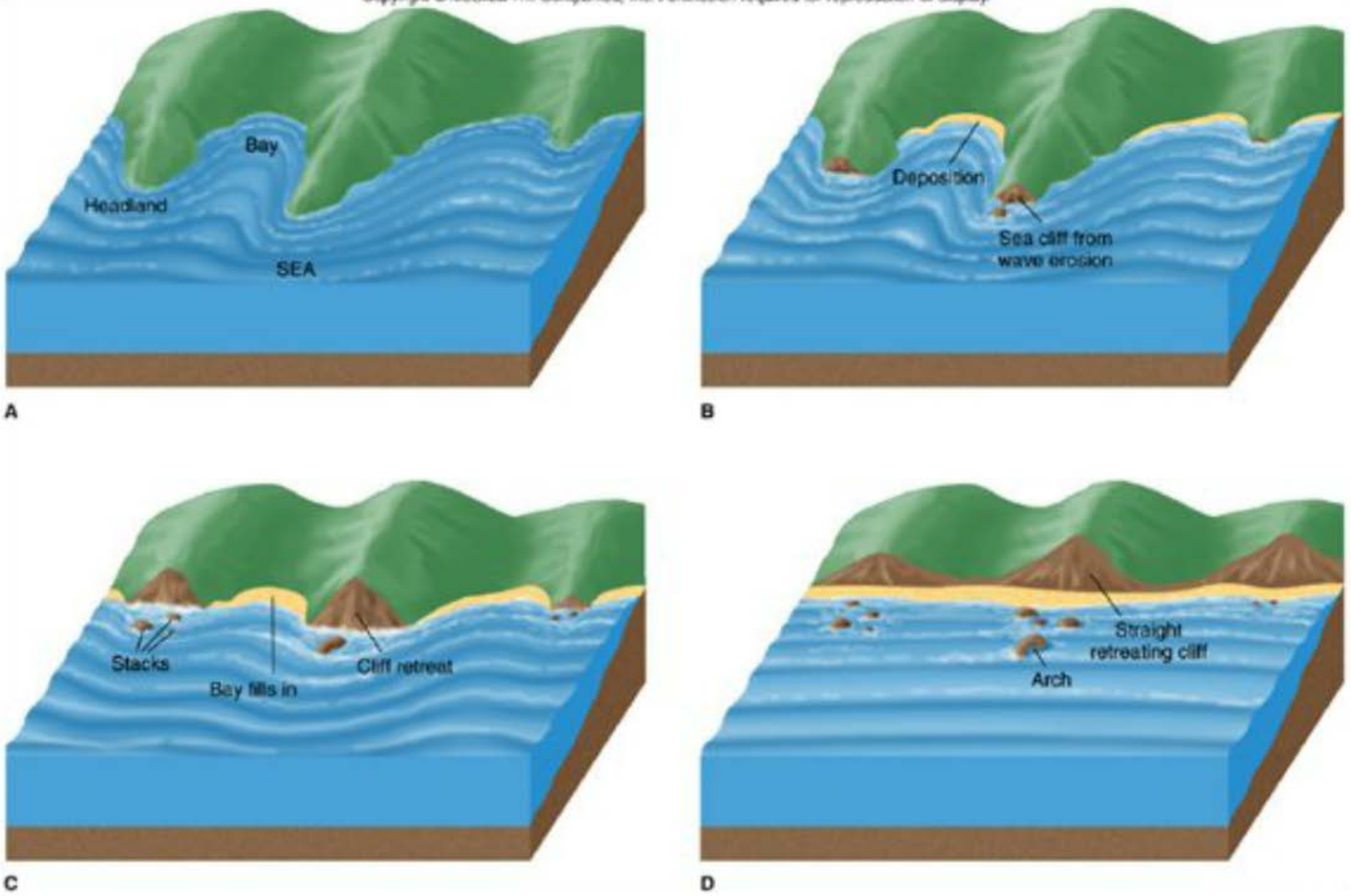
Barrier Islands

Padre Island NS, Texas



Shoreline Features Evolution

Beach Drift & Longshore Currents



Coastal Features by Erosion

- **Features caused by wave erosion**
  - ***Wave-cut cliffs:*** **surf interaction against base of coastal land**
  - ***Wave-cut platform:*** **bench-like surface left by receding cliff**

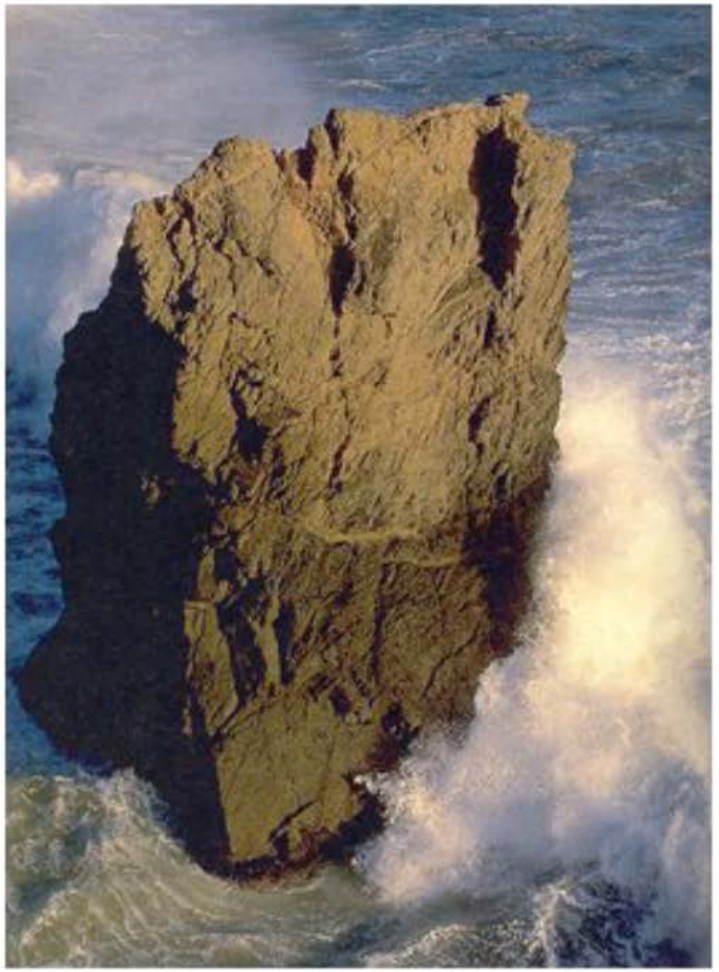
- **Features associated with headlands**
  - **Sea arch: caves on opposite sides of headland unite**
  - **Sea stack: isolated remnant of fallen arch**

Wave Erosion

- **Breaking waves exert great force**

- **Wave erosion causes:**
  - **Wave impact & pressure**
  - **Abrasion by rock pieces**

- **Storms cause rapid erosion**



Wave Erosion by Storms

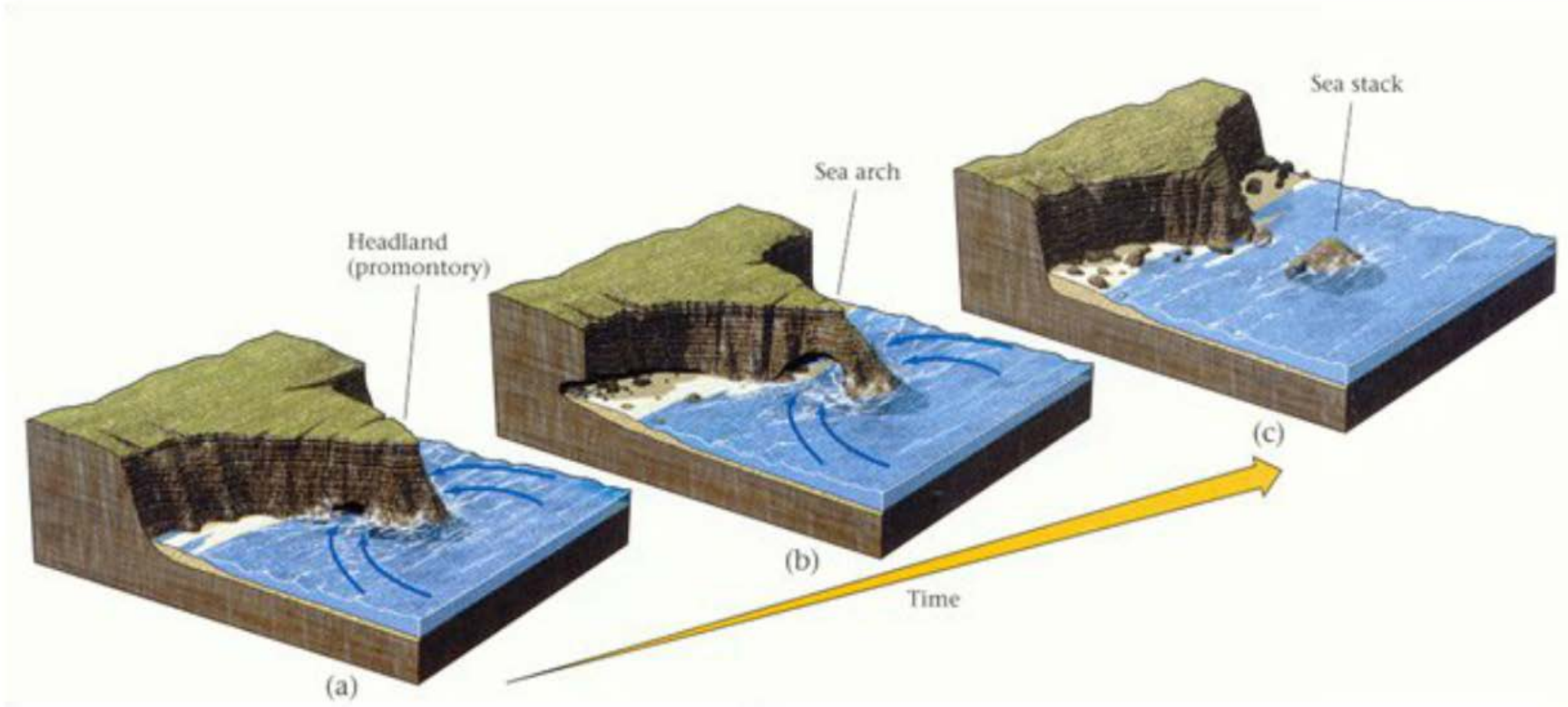
Before

After Hurricane

Wave-Cut Cliff

Wave-Cut Platform

Sea Arch and Stack Formation



Sea Arch

Sea Arch and Stack

French Shore of English Channel

Sea Stacks

Twelve Apostles, Austraila

Shoreline Erosion Problems

- **Shoreline erosion is influenced by several local factors including**
  - **Proximity to sediment-laden rivers**
  - **Degree of tectonic activity**
  - **Topography and composition of the land**
  - **Prevailing wind and weather patterns**
  - **Configuration of the coastline and nearshore areas**

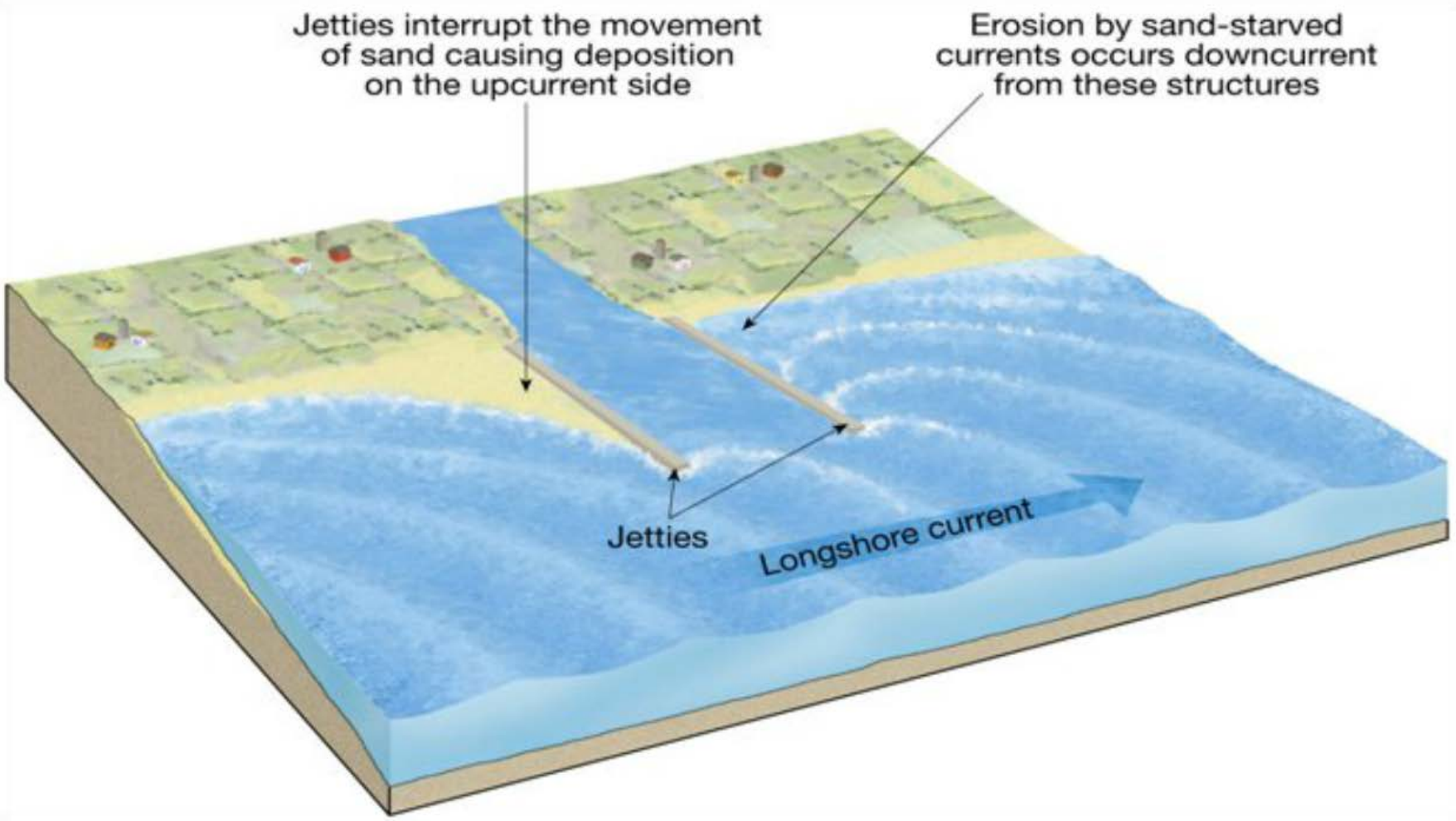
Shoreline Erosion Problems

- Three basic responses to erosion problems
  - Engineered structures
  - Beach nourishment
    - The addition of large quantities of sand to the beach system
    - Only an economically viable long-range solution if a few areas
  - Abandon and relocate buildings away from the beach

Engineered Structures

- ***Jetties***
  - Built in pairs to develop and maintain harbors
  - Extend into water at entrances to rivers & harbors
- ***Groins***
  - Built to maintain or widen beaches
  - Constructed at right angle to beach to trap sand
- ***Breakwater***
  - Barrier built offshore and parallel to the coast
  - Protects boats from the force of large breaking waves
- ***Seawall***
  - Barrier parallel to shore and close to the beach to
  - Protects property by stopping waves from reaching the beach areas behind the wall

Jetties for Navigation Channels



Groins

Cape May, New Jersey

Breakwater

Santa Monica, southern CA

Breakwaters

Tel Aviv, Israel

Seawall (on a lake)

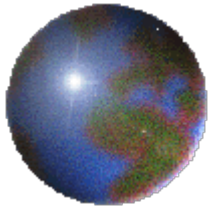
Illinois State Beach

Beach Nourishment

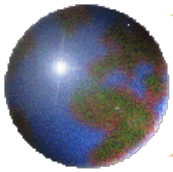
Miami Beach, FL

A. B.

$ 64 millon every 10-12 years



18.6 Global Warming and Sea-level Rise



Global Warming and Sea-level Rise

- Sea level has risen and fallen repeatedly in the geologic past, and coastlines have emerged and submerged throughout Earth history.
- Many climatologists predict that the greenhouse effect will raise global temperature during the next century.
- If global warming occurs, sea level will rise because of melting polar ice sheets and expansion of seawater.
- many scientists predict a 1-meter rise in sea level by the year 2100.

Global Warming and Sea-level Rise

A 1-meter sea level rise would flood 17 percent of the land area of Bangladesh and displace 38 million people.