SHORELINES

Where the Sea Meets the Land

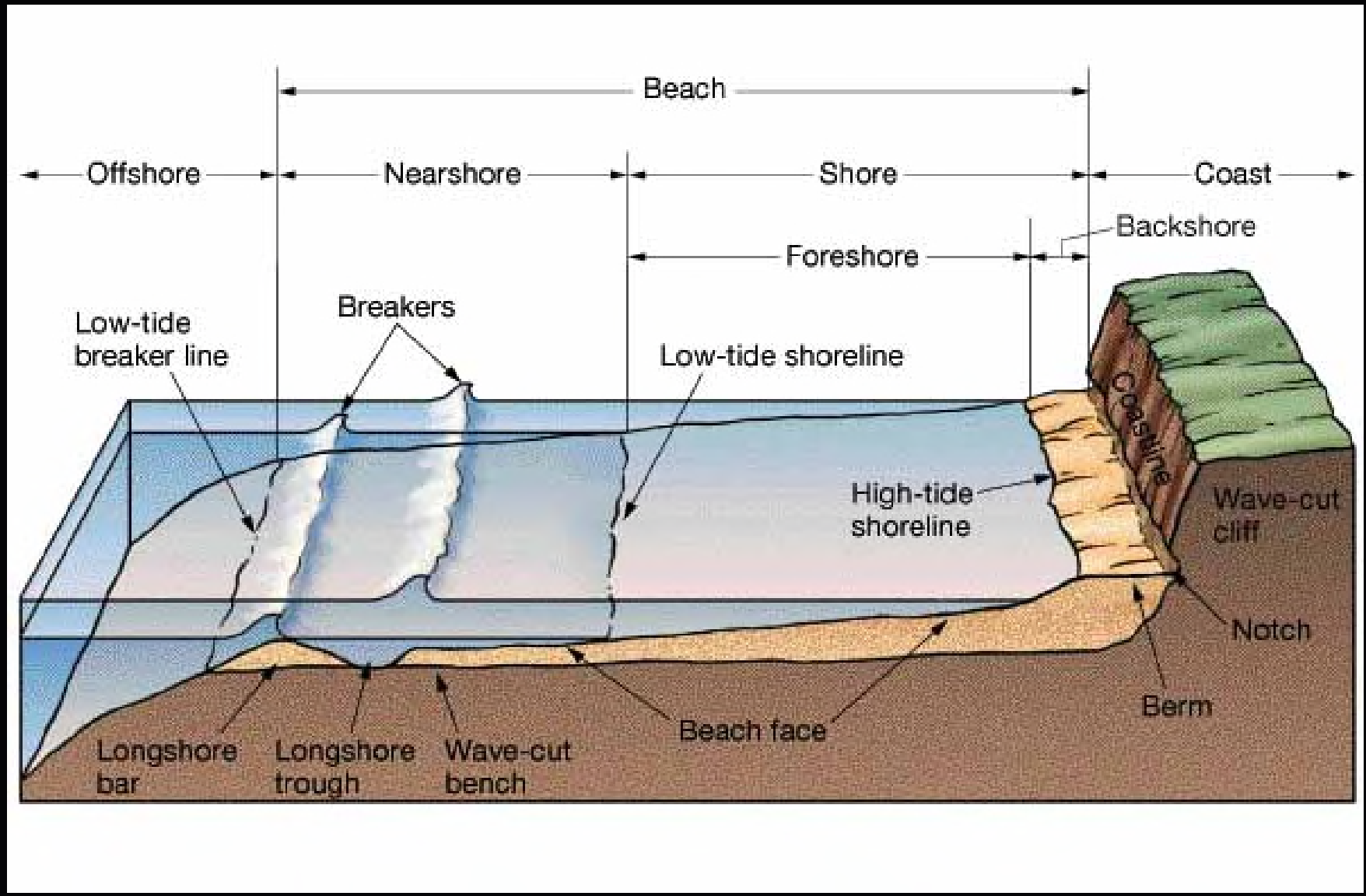
Physical Geology – GEOL 100

Ray Rector - Instructor

Shoreline Concepts

- Coastlines are geologically **very** temporary structures - subject to rapid change
- The *location* of the coastline depends primarily on two factors: *tectonic activity* and the *volume of water* in the ocean
- The *shape* of the coastline is a product of many factors: regional uplift, subsidence, and faulting, land- and sea-based erosion, transport, and deposition of earth materials, and biological activity
- Eustatic sea level is controlled by global climate and ocean basin volume
- Coasts are shaped by erosional and depositional processes
- Changes in sea level has the greatest influence on coastal processes
- Erosional coasts are typically new coasts in which the land is being actively eroded
- Depositional coasts are typically mature coasts in which coastal sediment materials are either in stable equilibrium (steady), or are being deposited (growing)
- Erosional coasts have characteristic features: sharp bluffs, sea caves and stacks, natural bridges, pocket beaches, and wave-cut terraces
- Depositional coasts have characteristic features: long/broad sandy beaches, dunes, barrier islands, sand spits, tombolos, and reef systems

SHORELINE ANATOMY 101



Forces That Shape Coastlines

1) Plate Tectonic Setting

- ✓ **Near or at a plate boundary = Active coastline**
- ✓ **Far from a plate boundary = Passive coastline**

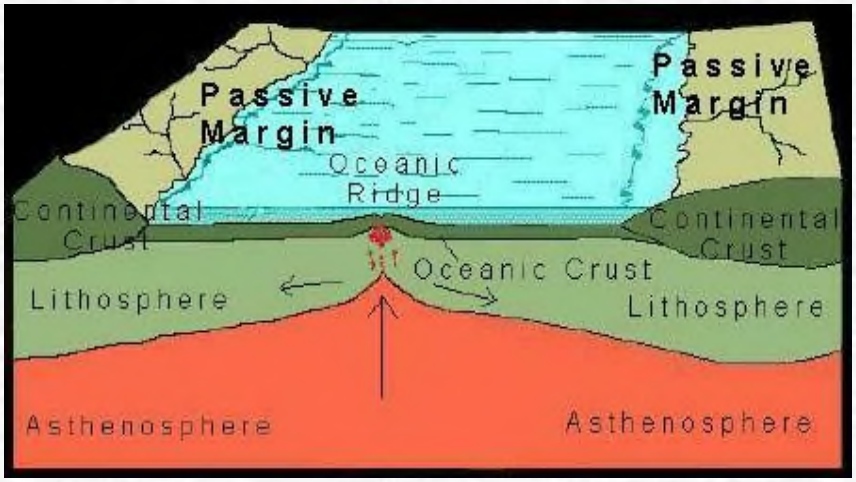
2) Land-based Shaping Agents

- ✓ **Uplift, Folding, and Faulting**
- ✓ **Volcanism**
- ✓ **Rivers**
- ✓ **Glaciers**
- ✓ **Humans**

3) Sea-based Shaping Agents

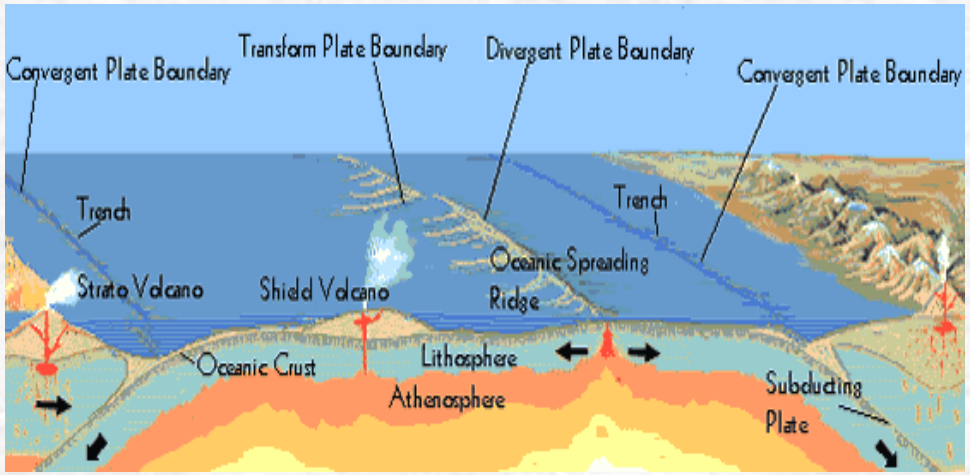
- ✓ **Breaking Waves**
- ✓ **Tides**
- ✓ **Storm surge**
- ✓ **Currents**
- ✓ **Eustatic sea level fluctuation**

Passive Versus Active Coasts



Atlantic-type Margins

- Far from plate boundary
- Little to no tectonic activity
- Mature coastlines



Pacific-type Margins

- Close to plate boundary
- Lots of tectonic activity
- Young coastlines

Agents of Change

Land Versus Ocean

Land-dominant Shaping Agents

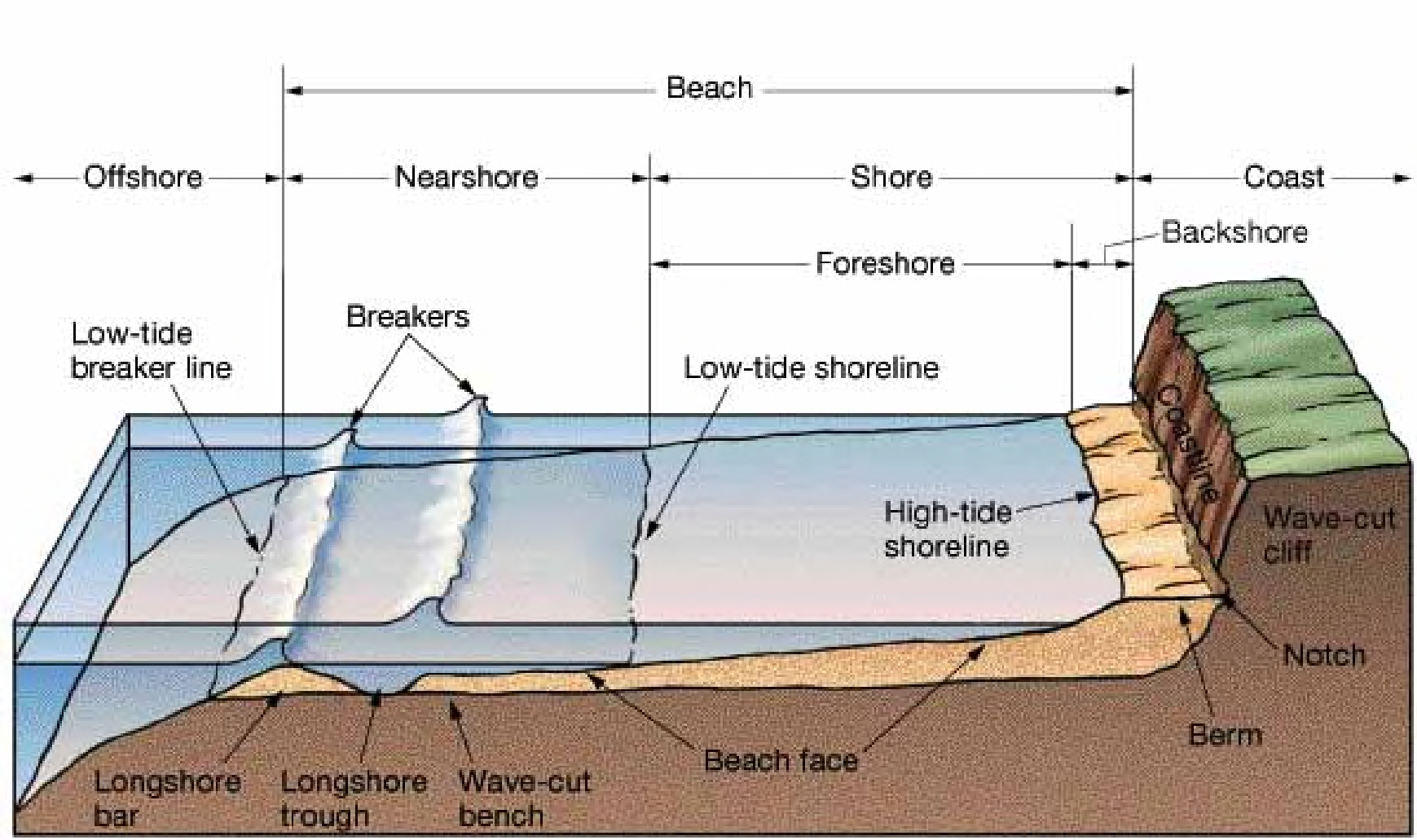
1) Tectonics = Uplift and Faulting
2) Rivers
3) Volcanism
4) Glaciers

Sea-dominant Shaping Agents

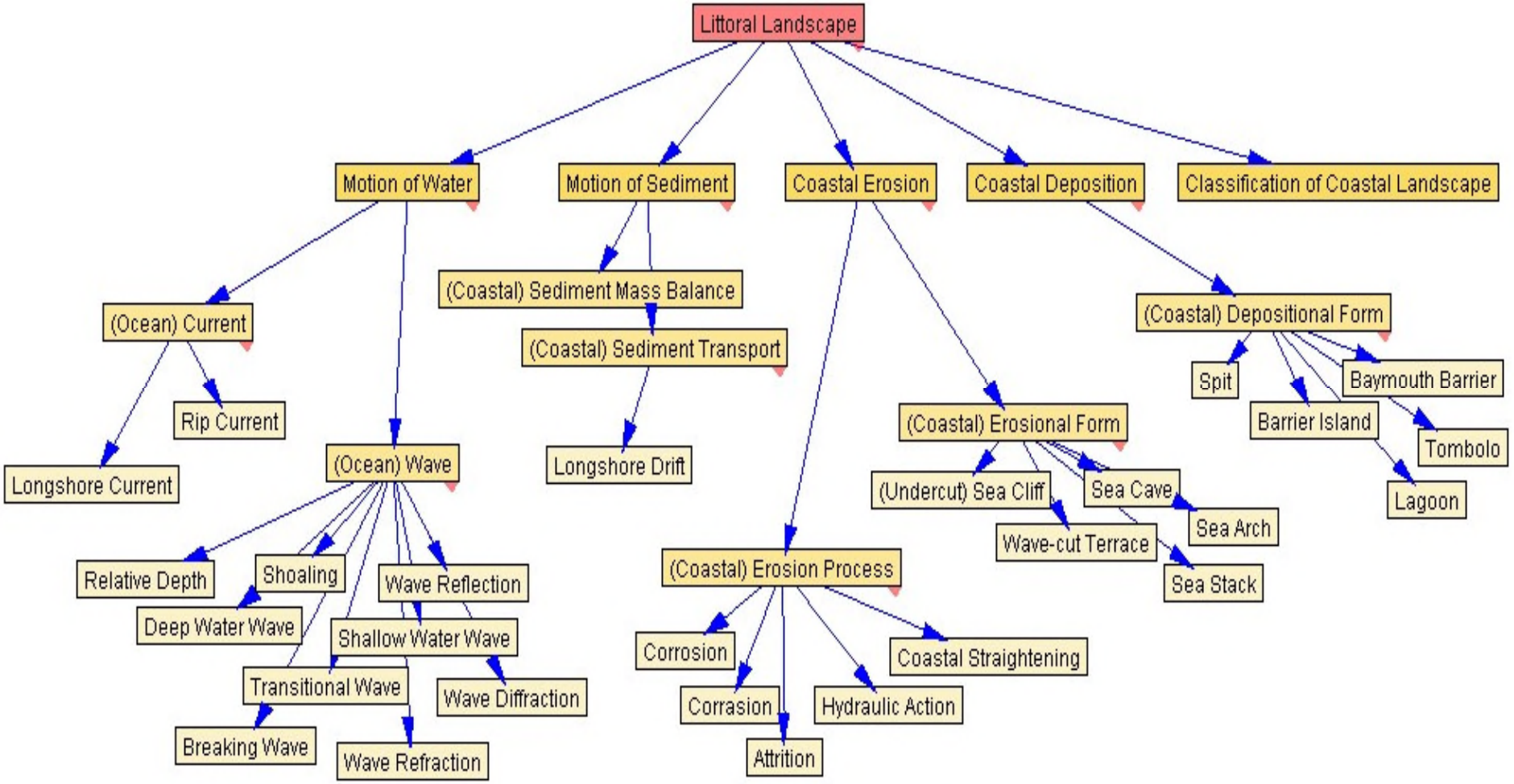
1) Breaking Waves
2) Tides and storm surges
3) Shoreline currents
4) Eustatic sea level change

What Do Beaches Have in Common with Life?

Beach Anatomy 101



Coastal Processes Concept Map



1) Beaches controlled by a number of factors:

- ✓ Water motion (waves, tides, and currents)
- ✓ Sediment motion (longshore drift, surf zone ingress and egress)
- ✓ Sediment Input (rivers, bluffs, reefs, and artificial enrichment)
- ✓ Sediment Output (submarine canyons, coastal dunes, and artificial extraction)
- ✓ Offshore bottom contour (narrow vs. broad shelf; gradual vs. steep)
- ✓ Shoreline shape (irregular vs. straight; low relief vs. high relief)

2) The two primary processes affect the beach:

- ✓ Erosion = removal of sediment from beach
- ✓ Deposition = addition of sediment to beach

3) Humans attempt to control beach erosion and deposition by building artificial shoreline structures

- ✓ Groins, jetties, breakwaters, seawalls, and reefs
- ✓ Most structures ultimately produce negative effects
- ✓ Major debate over what and what not to do to a shoreline

Controls on Beach Form/Dynamics

1) Water Movement (Surf zone Waves and

- ***Wave size***
- ***Wave direction***
- ***Wave shape***
- ***Wave frequency***
- ***Longshore and Rip Currents***
- ***Tidal flux***

2) Sand movement

- ***Sediment size***
- ***Sediment abundance***
- ***Longshore drift***
- ***Rip current load***

3) Shape of Shoreline

4) Offshore bathymetry

5) Human Structures

- *Groins, jetties, breakwaters*
- *River dams, seawalls, rip rap*

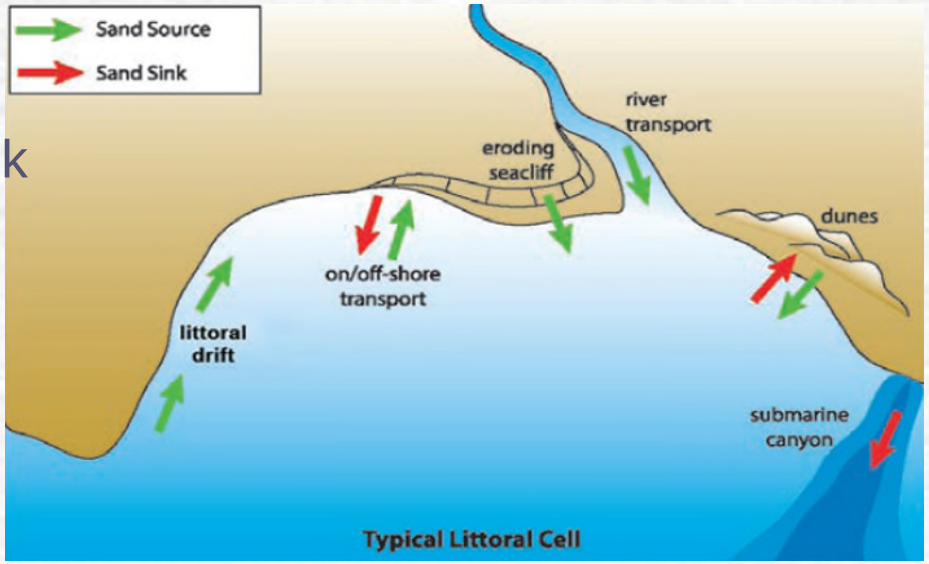
Beach (Littoral) System's Dynamic Sand Account

Beach sand generated from the weathering (breakdown) and erosion (removal and transport) of source rock material – from far inland sources to sources at the shoreline

Most sand gets added to the beach system from either rivers or sloughing of eroded seacliffs

Once sand gets into the beach system, it is moved by surf, tides, longshore currents (as littoral drift) and rip currents (as rip load)

Eventually the beach sand will permanently leave the beach system via submarine canyon, coastal dunes, or offshore deposits



Sand Sources = Deposits

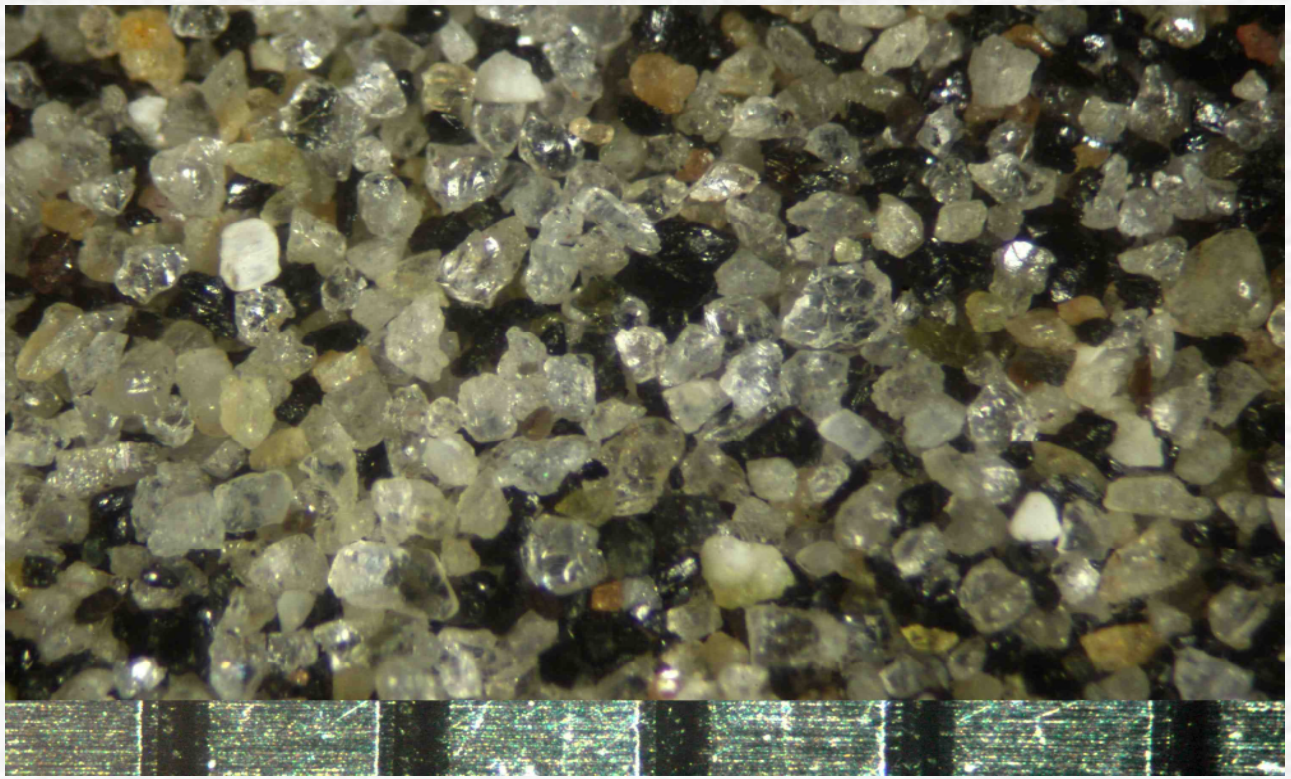
1) River sediment
2) Seacliff sediments
3) Offshore reefs

Sand Sinks = Withdrawals

1) Submarine canyons
2) Coastal dunes
3) Offshore seabottom

Continental Beach Sand

San Diego Beach Sand



1 millimeter

Sand Mineralogy = Granitic Source

Light-colored Minerals

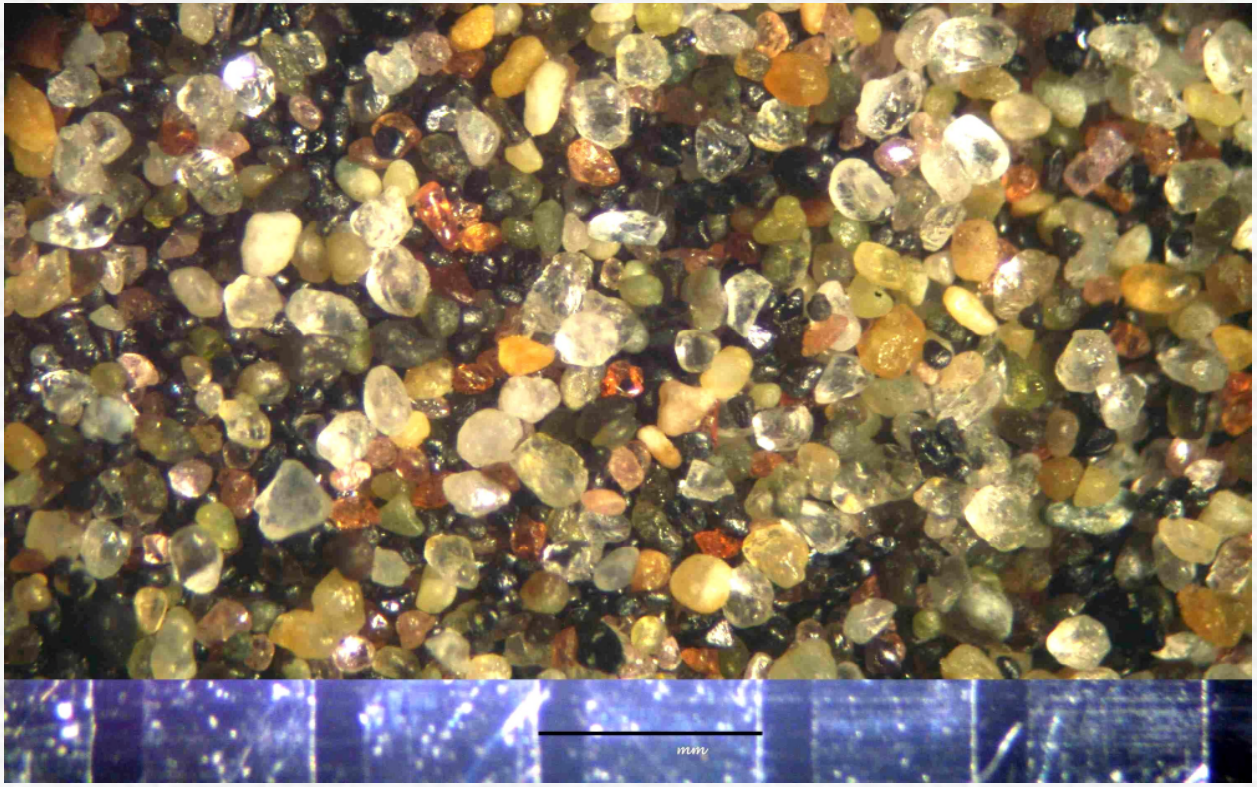
1) Quartz
2) Feldspar
3) Muscovite

Dark-colored Minerals

1) Hornblende 2) Magnetite
3) Biotite 4) Augite 5) Garnet

Continental Beach Sand

Oregon Coast Beach Sand



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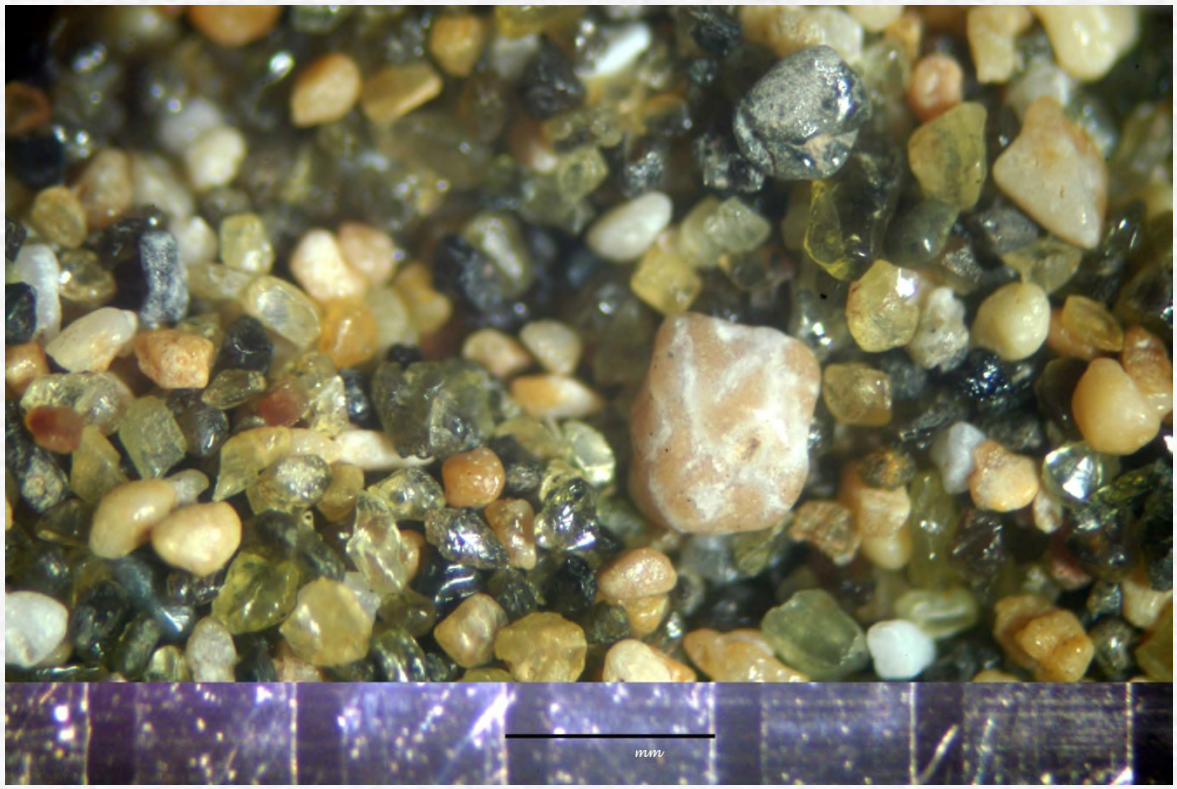
Oceanic Island Beach Sand

Maui Beach Sand



1 millimeter

Sand Mineralogy = Basaltic and Bio Source

Light-colored sand

1) **Coral**
2) **Shells**
3) **Feldspar**

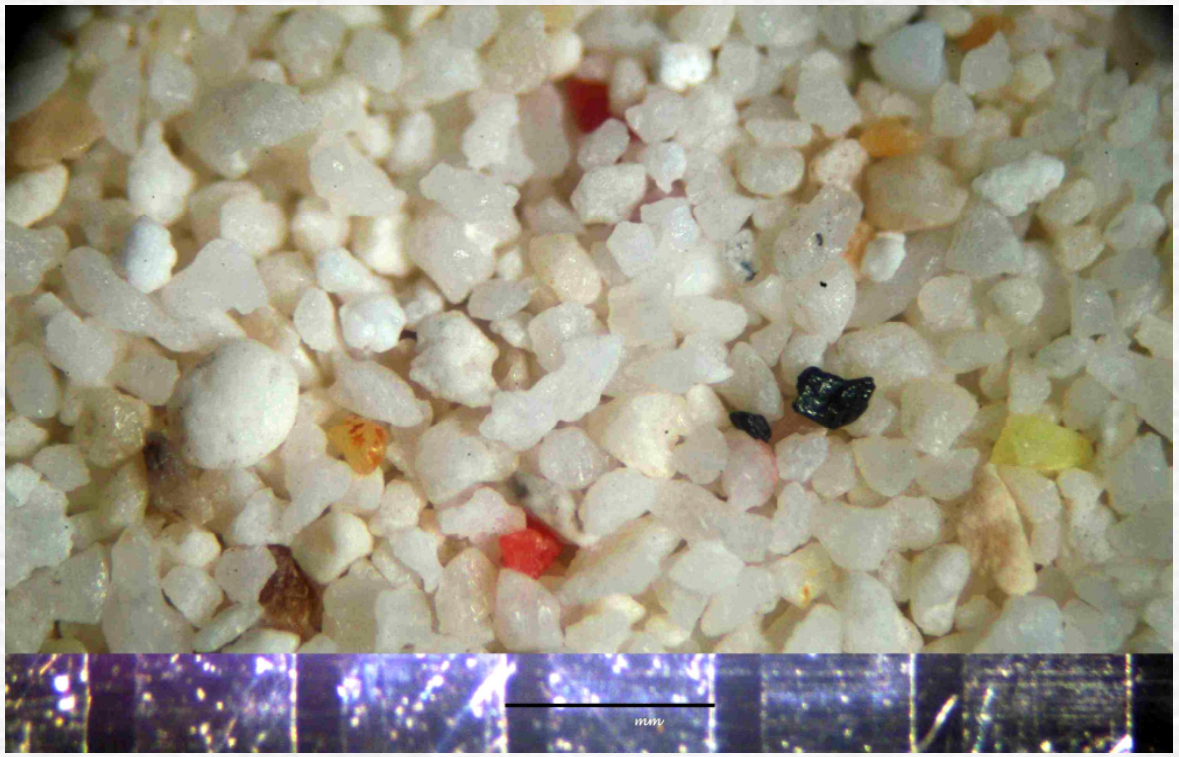
Dark-colored sand

1) **Olivine**
2) **Volcanic glass**
3) **Basalt**

Oceanic Island Beach Sand

Kwajalein Island

Beach Sand



1 millimeter

Sand Mineralogy = Bio Sources

Light-colored sand

1) **Coral**
2) **Shells**

Dark-colored sand

1) **Shell**

Beach Profile and Sand Size

Table 12.1 The Relationship Between the Particle Size of Beach Material and the Average Slope of the Beach

Type of Beach Material	Size (mm)	Average Slope of Beach
*V*ery fine sand	0.0625–0.125	1°
Fine sand	0.125–0.25	3°
Medium sand	0.25–0.50	5°
Coarse sand	0.50–1.0	7°
*V*ery coarse sand	1–2	9°
Granules	2–4	11°
Pebbles	4–64	17°
Cobbles	64–256	24°

Source: Shepard, 1973.

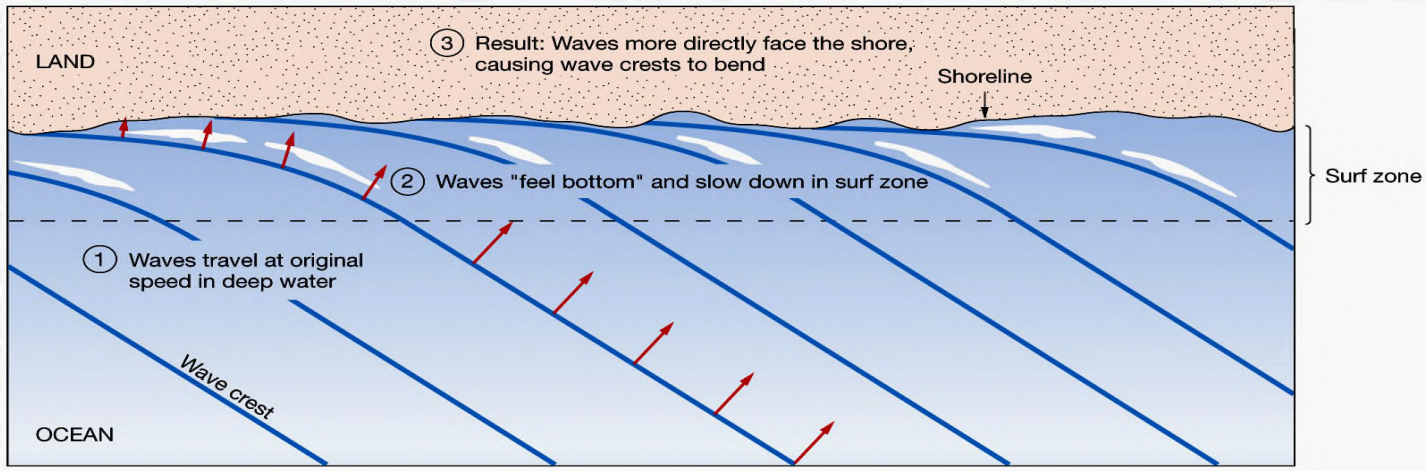
- Coarser the beach sediment the steeper beach
- Coarser the sediment the stronger the wave conditions

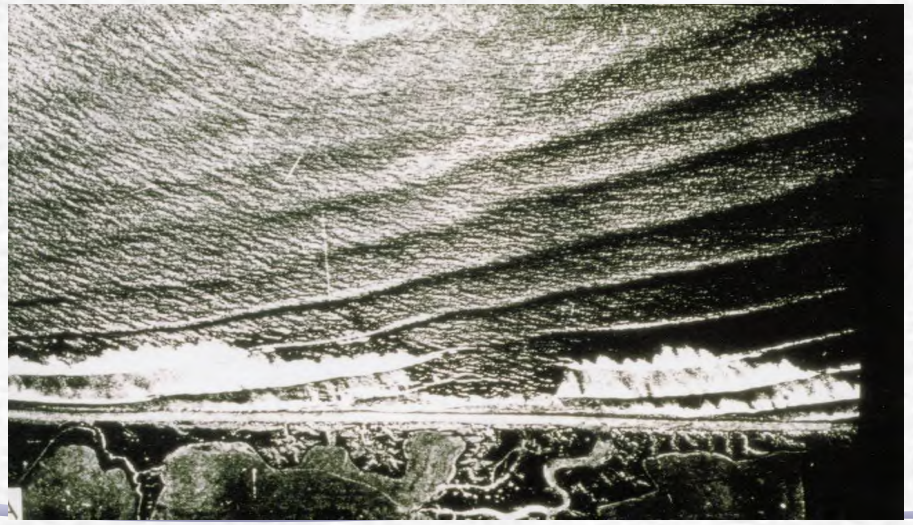
Breaking Waves

Wave Refraction and Surf Energy Along Shorelines

The Swash Zone and Longshore Currents

Wave Refraction and Surf Energy Along Shorelines

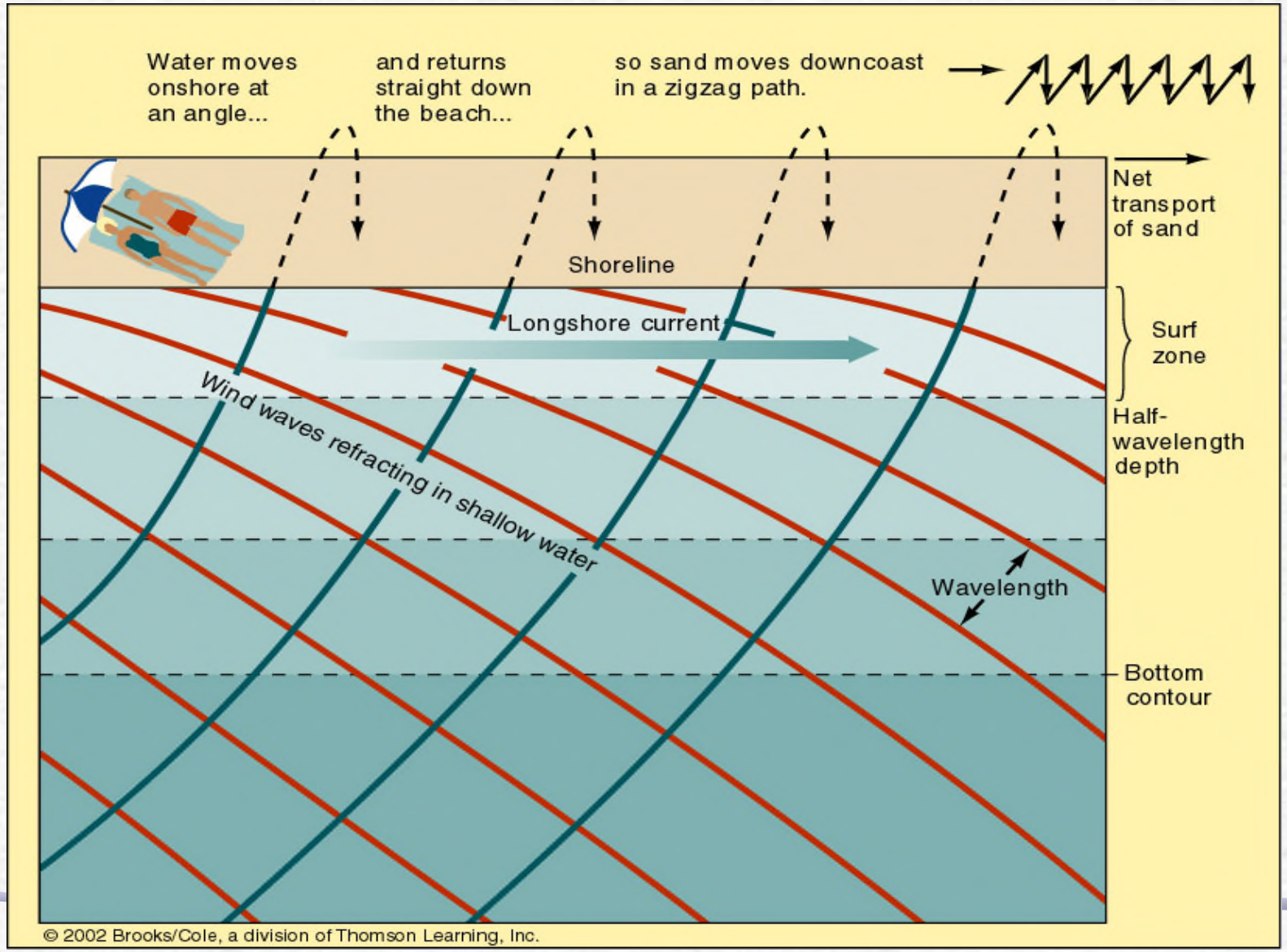




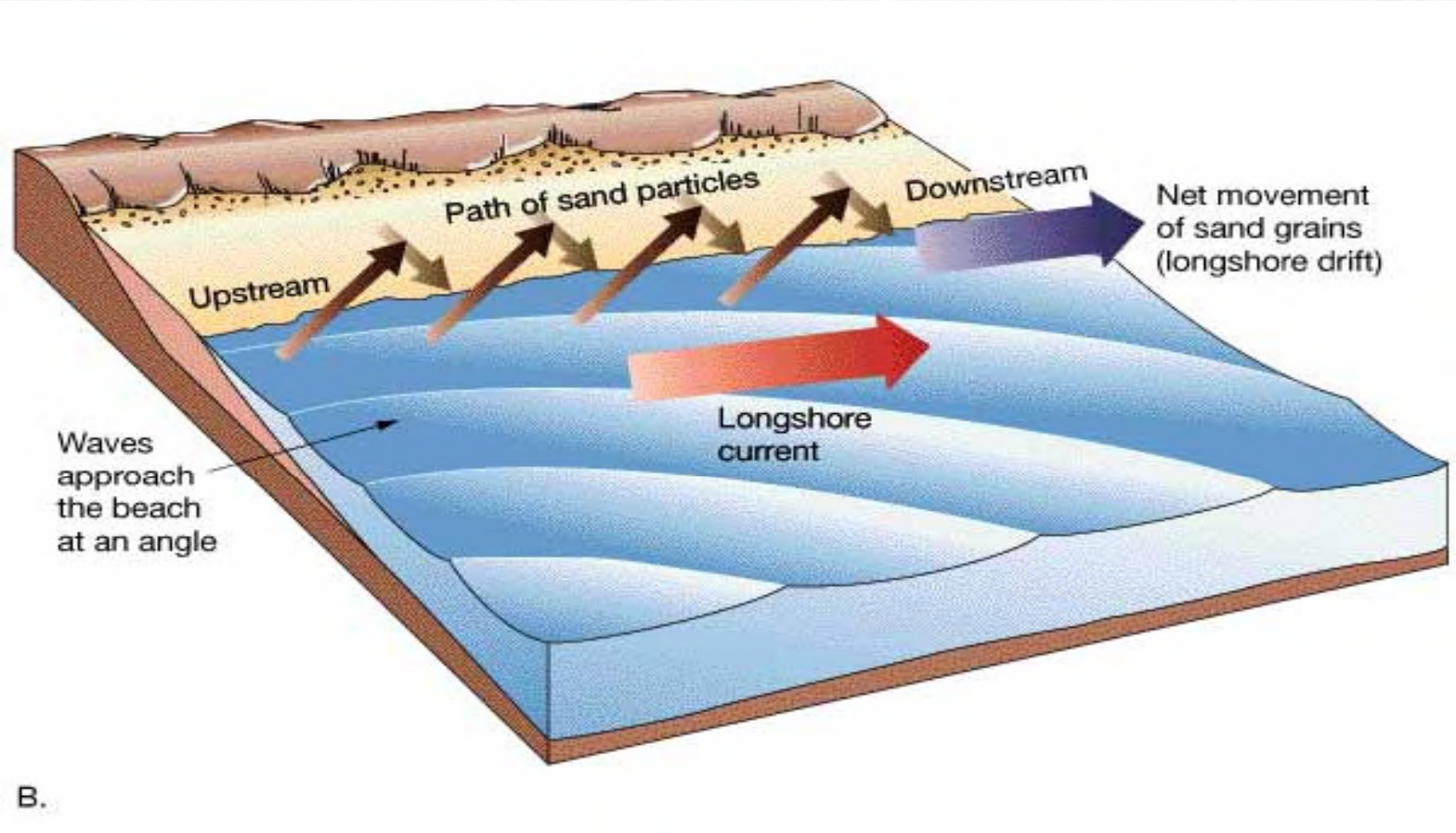
Wave Refraction

- ✓ Waves bend as they approach shore
- ✓ Tends to make waves break more parallel to beach
- ✓ Development of longshore current within the surf zone
- ✓ Longshore current moves longshore drift material parallel along shoreline

Beaches and the Longshore Current



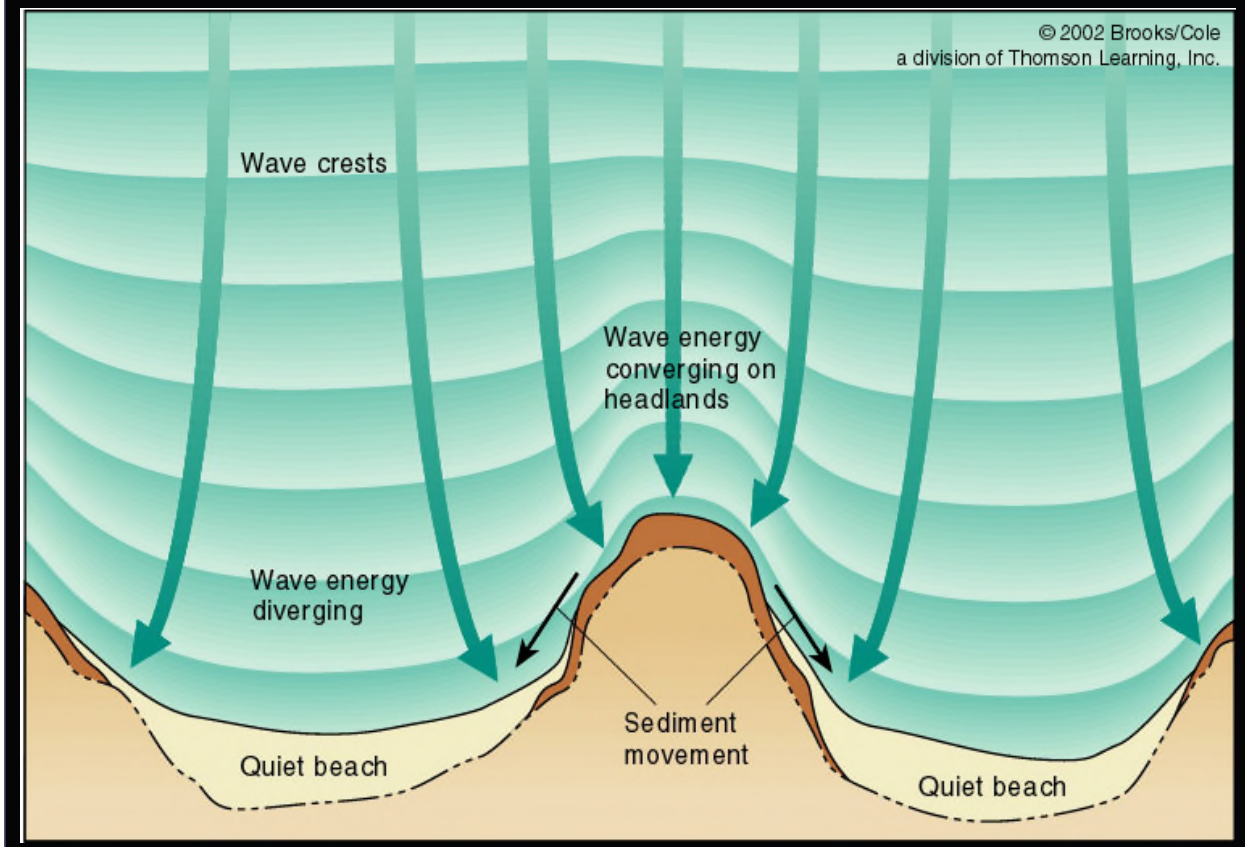
Beaches and the Longshore Current



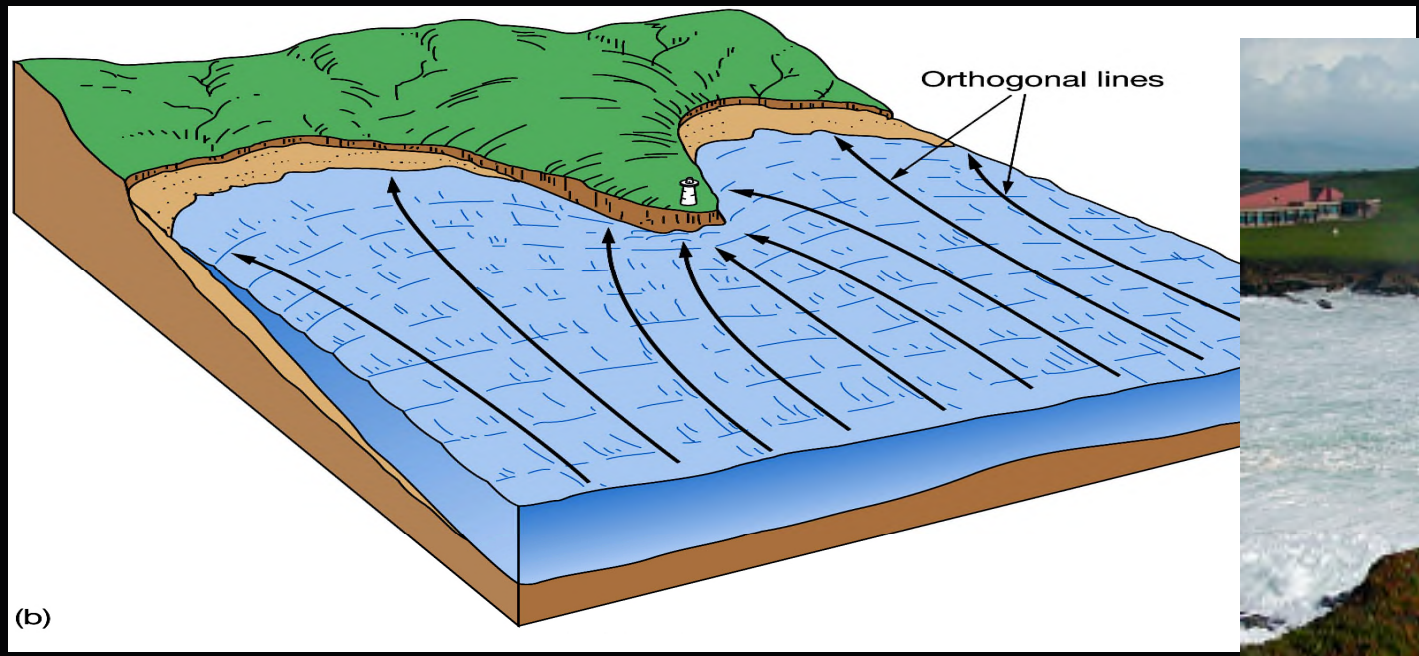
- **In San Diego, net sand movement is from north to south**

Wave and Tidal Affects on Shorelines

- Refraction causes wave energy to converge on the headlands = EROSION
- Refraction causes wave energy to diverge in the bays = DEPOSITION
- Longshore current transports eroded sediment from headlands and moves it to bays
- Long term effect of breaking wave processes is to straighten the shape of coastline



Wave Refraction Along an Irregular Shoreline



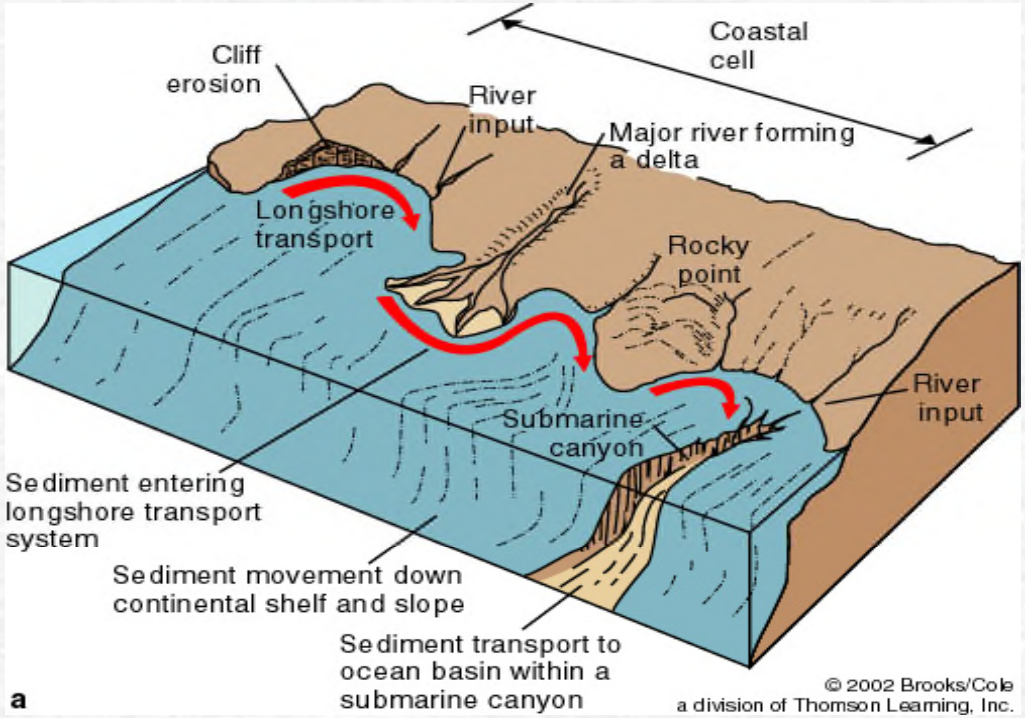
Effects on the Coastline

- ✓ Magnification of wave energy at headlands
- ✓ Diffusion of wave energy along bays and coves
- ✓ Erosion of headlands
- ✓ Sediment deposition in bays

Beach Sand Compartments

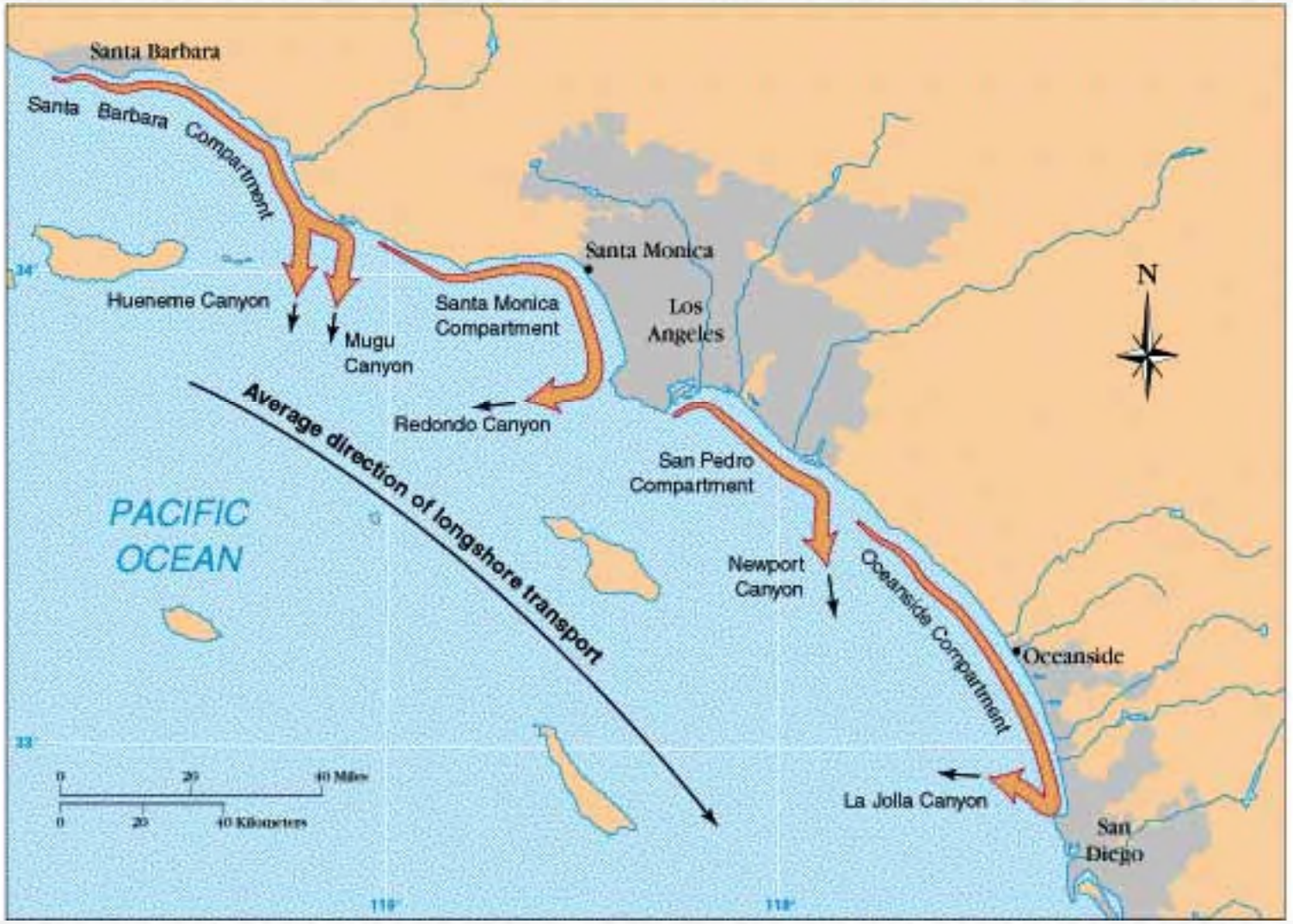
Beaches are grouped into larger sand cells or compartments

- **Sand enters the coastal cell from rivers and bluffs**
- **Sand moves from beach to beach via predominant longshore current**
- **Sand leaves the coastal cell down submarine canyons**

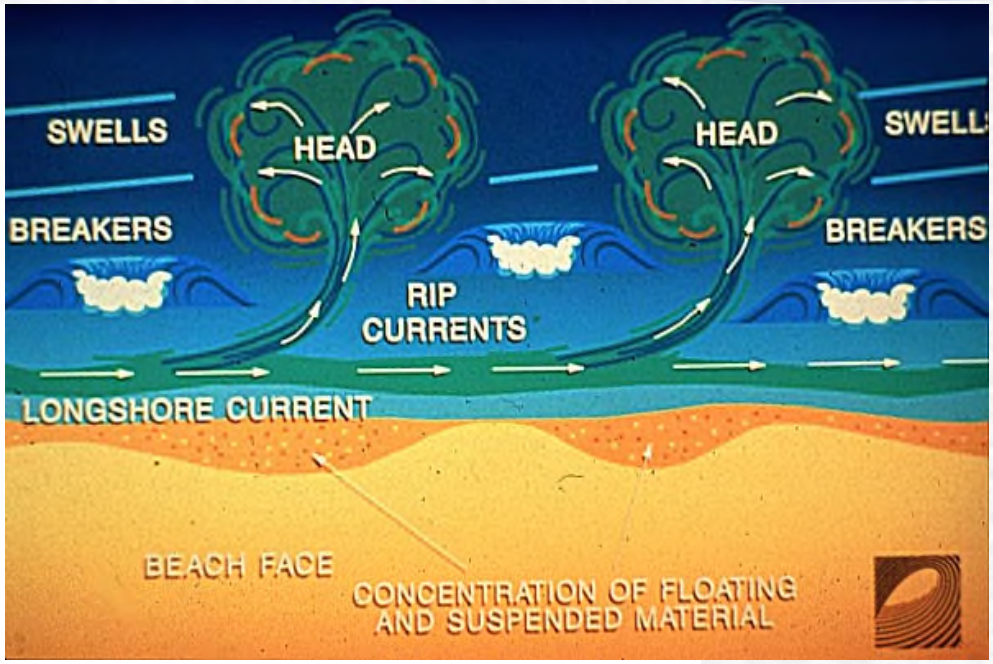


- **If sand input = sand outflow, then the beaches will stay about the same size.**
  - Along most coasts, sand input is much less mainly because of rivers being dammed

Sand Compartments

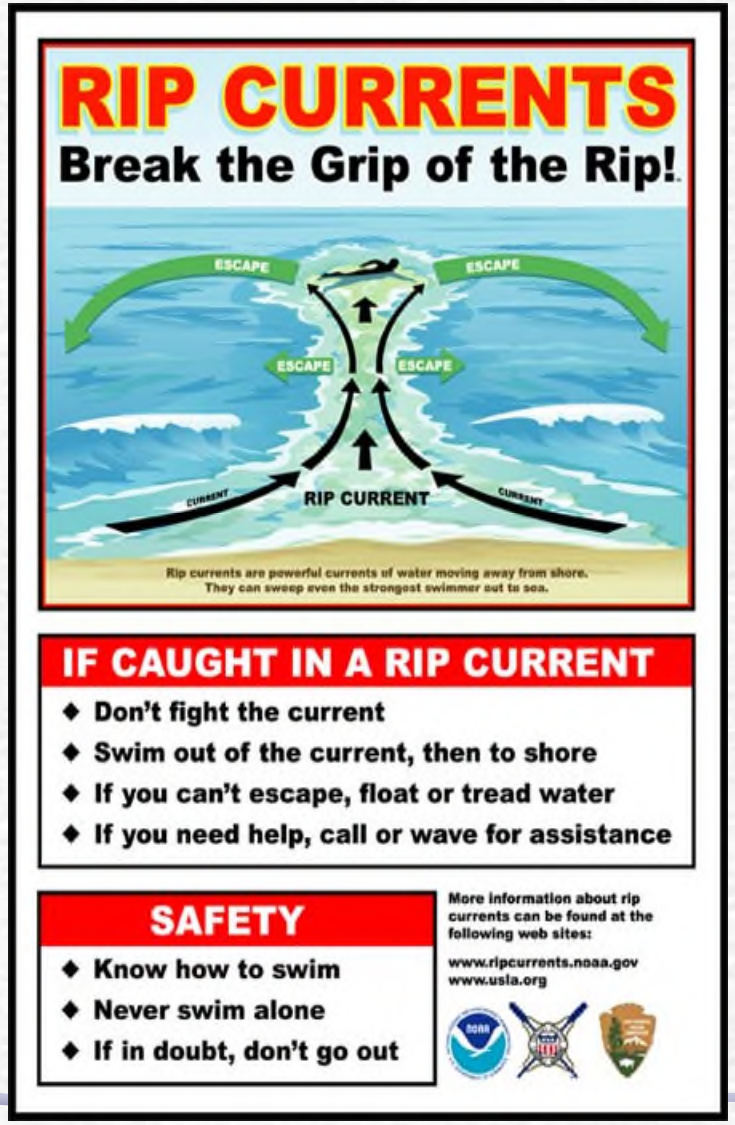


Rip Currents and Rip Load



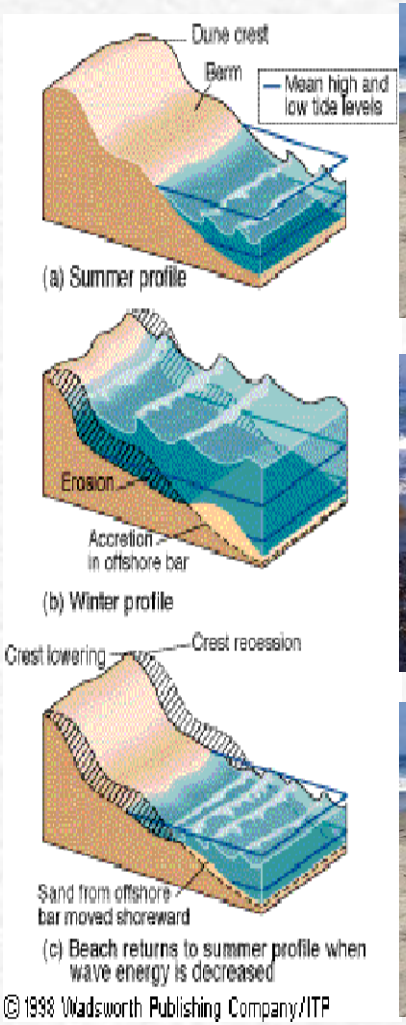
- Rip currents are narrow, plume-like currents flowing perpendicular to the shore - seaward through the surf zone along channels in nearshore
- Rip currents form when a group of incoming waves (whitewater) piles water up onto the beach face, causing excess water height and resultant water pressure forcing water to be pushed back out to sea
- Rip currents move seaward along channeled low spots beneath the surf zone, carrying sand with it (rip load) into the offshore region

Break the Grip of the Rip!



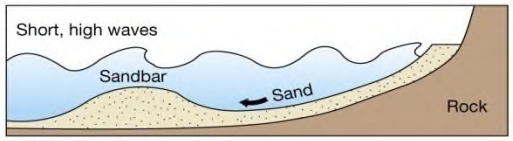
Winter Beach vs. Summer Beach

- *Summer ocean is relatively calm, lacking large waves*
  - *The sand in the longshore bar is brought back onto the beach face, creating a flatter, wider, sandier beach*
- *Winter ocean wave activity is stronger and more consistent because of winter storms*
  - *This causes sand to be removed from the berm and taken out to the longshore bar, creating a steeper, narrower, cobble-rich beach*



Scripps Beach, La Jolla CA

Seasonal Changes at Point La Jolla



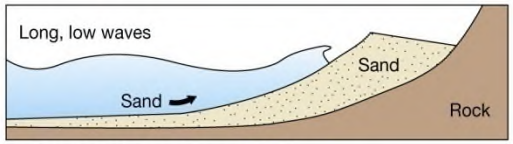
(b) Wintertime beach (storm)

Winter Beach

Sand is removed from the berm and taken out to the longshore bar, under the surf zone, where it finds stable purchase. The underlying cobbles are stubborn to move, and are left behind on the berm.

Summer Beach

The sand in the longshore bar is brought back onto the beach face and recover the cobbles, creating a larger, sandier beach

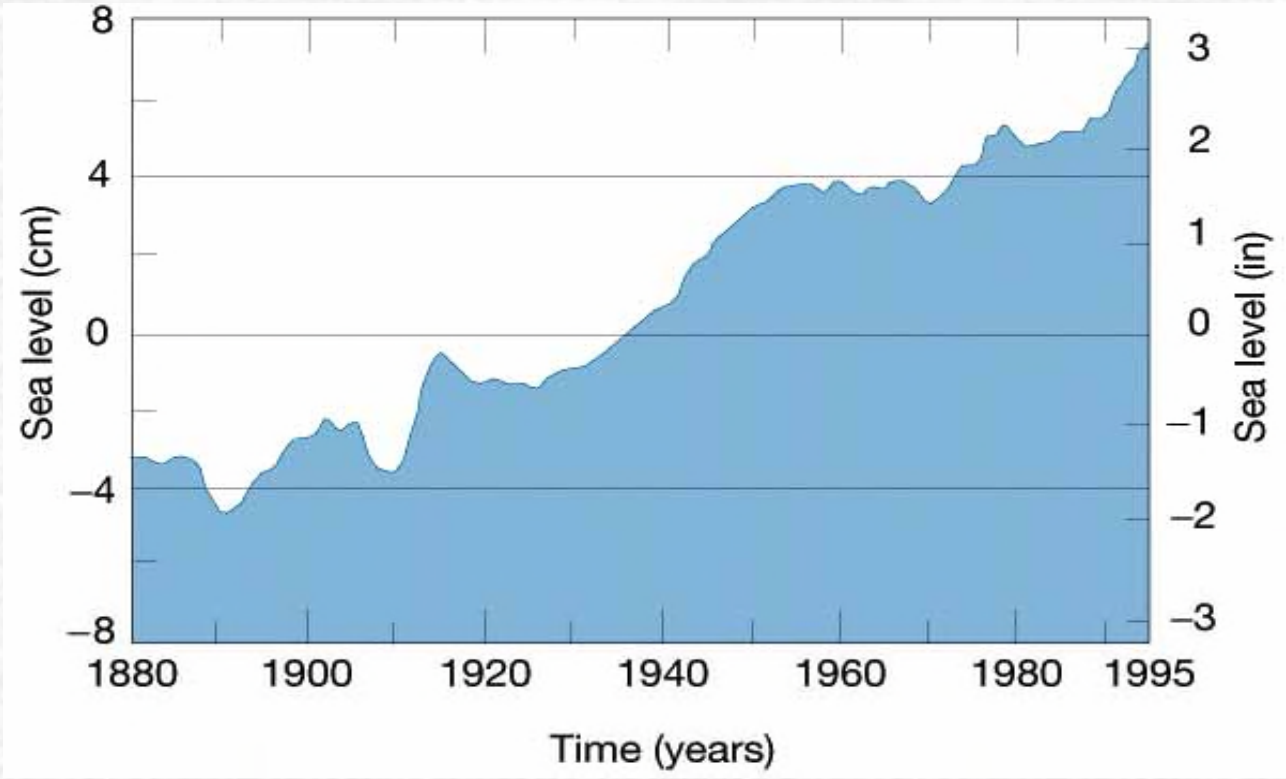


(a) Summertime beach (fair weather)

Why does this happen every year?

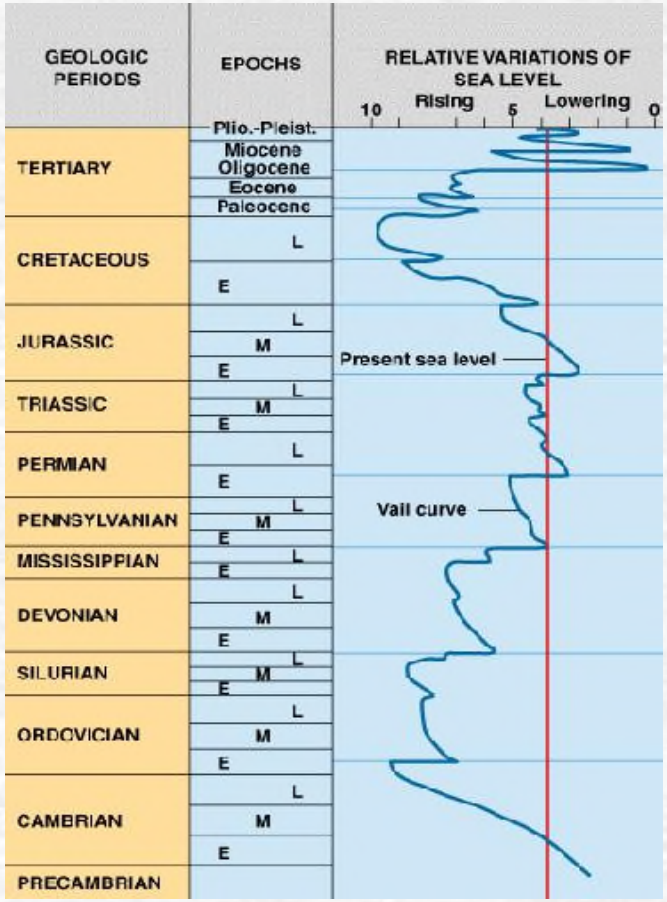
Think about seasonal changes in coastal weather and wave activity, and their affect on beach sediments

Eustatic Sea Level Changes



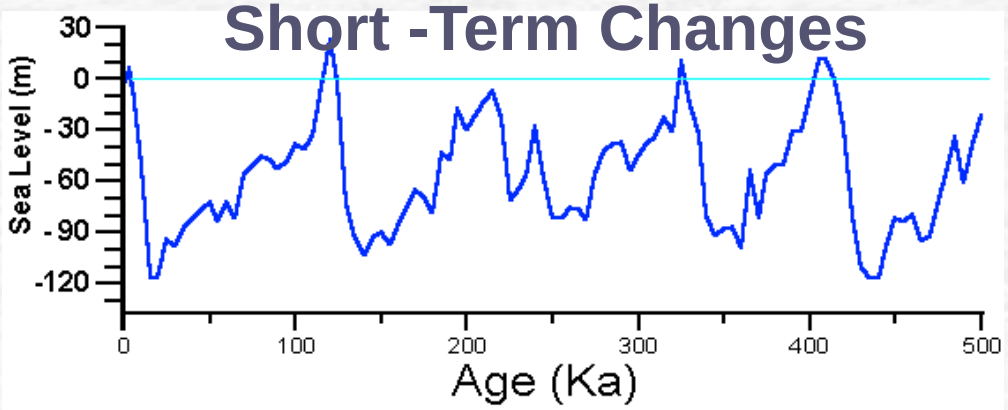
- ***Sea level has been slowly rising over the past 100 – 150 years***
  - ***With higher sea level and increased damming of rivers, beach erosion is a big problem***

Eustatic Sea Level Change

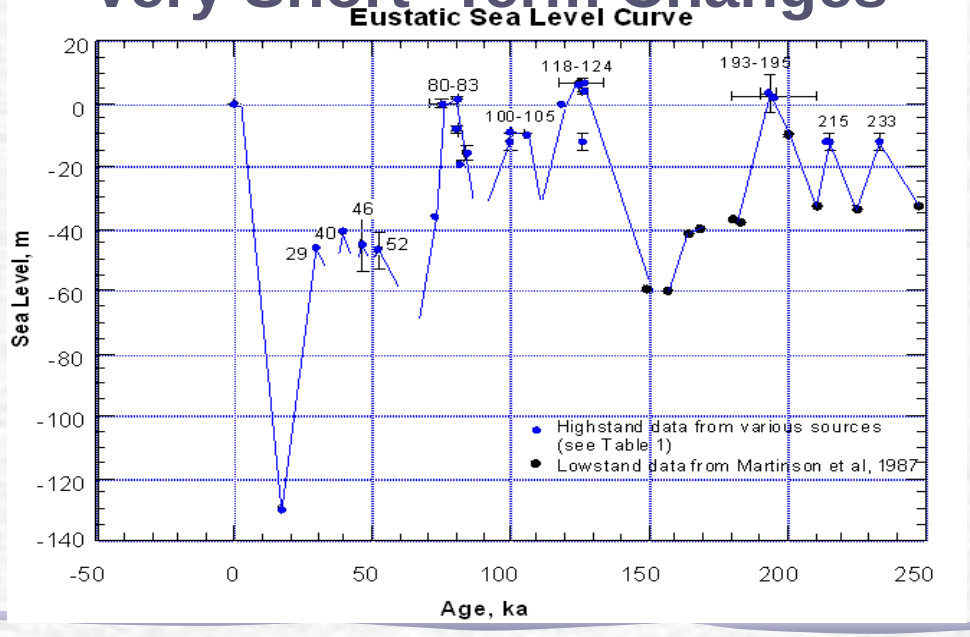


Long-Term Changes

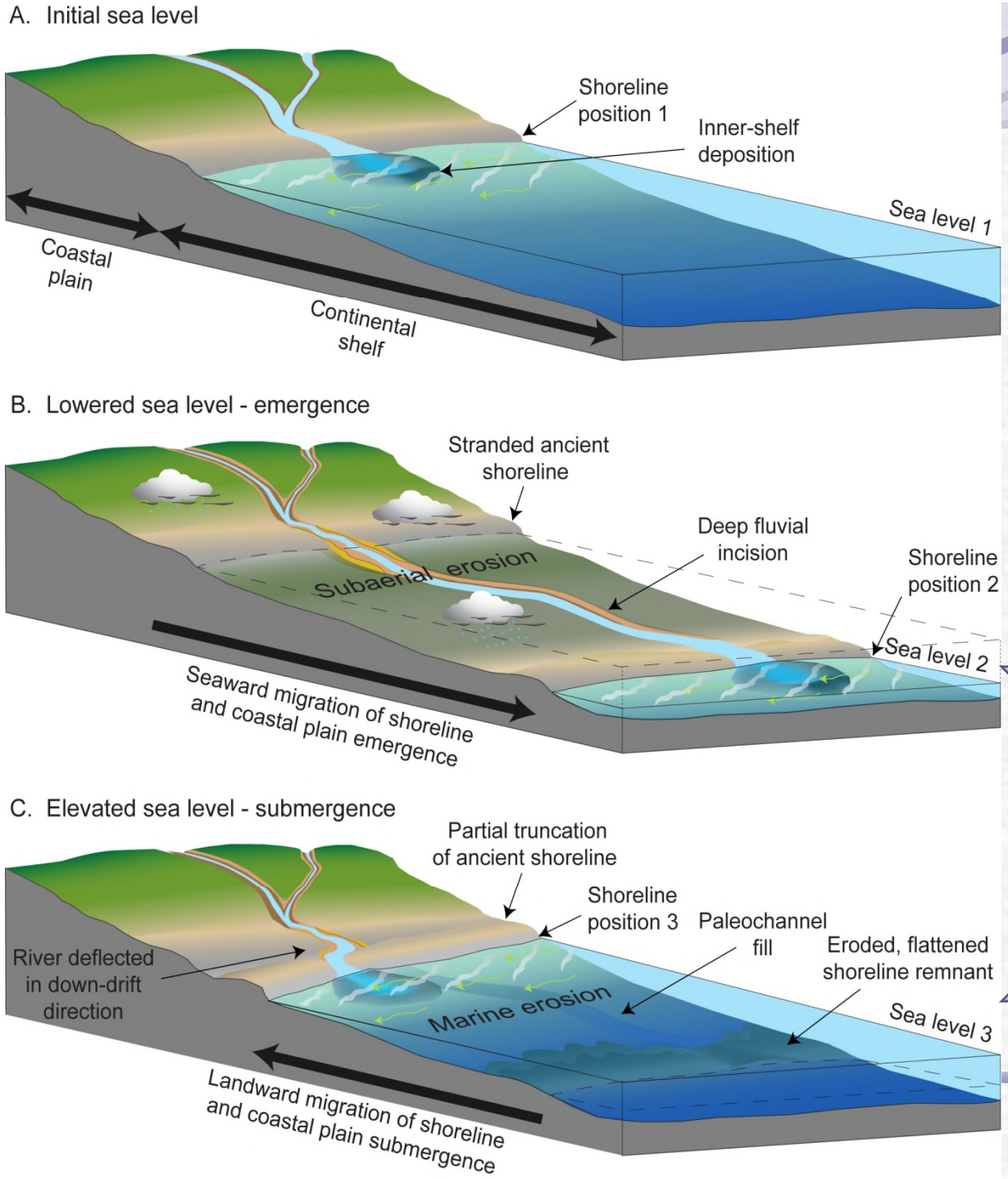
Short -Term Changes



Very Short -Term Changes



Eustatic Sea Level Changes on a Coastline



Falling Sea Level

Rising Sea Level

Sea Level Changes Affect on Coasts

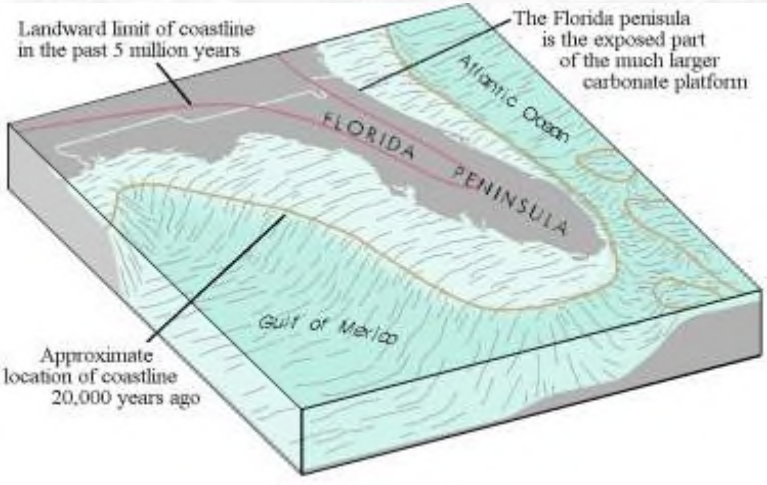
San Clemente Island, CA

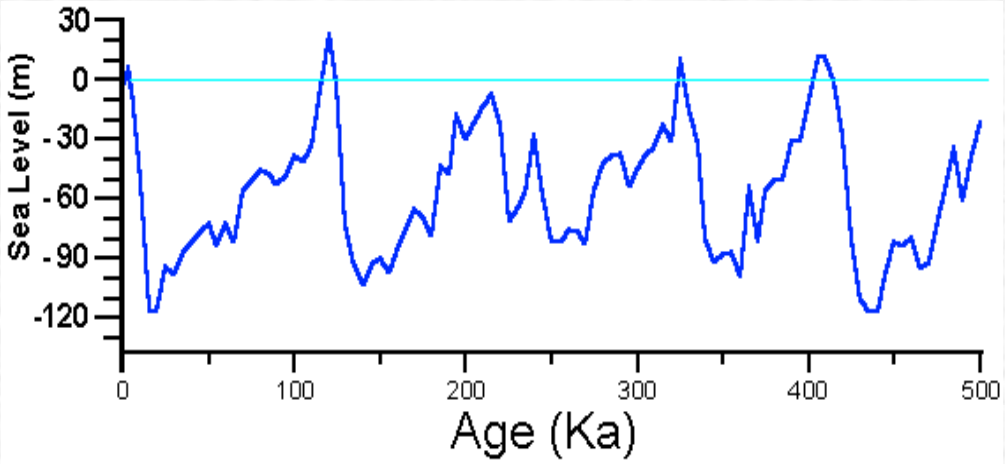
- Land uplift or sea level drop
- Progressive exposure of seabed
- Coastlines shift seaward

Cape Hatteras, NC

- Land subsidence or sea level rise
- Progressive submergence of land
- Coastlines shift landward

Rising Sea Level's Effect on Florida





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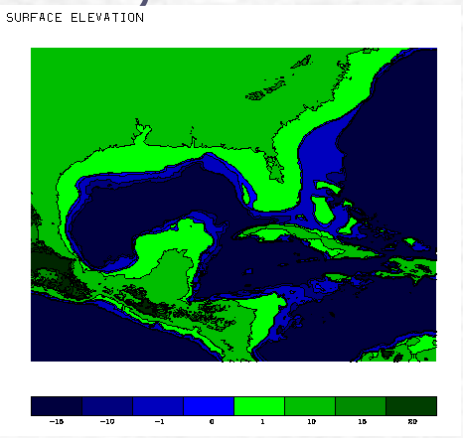	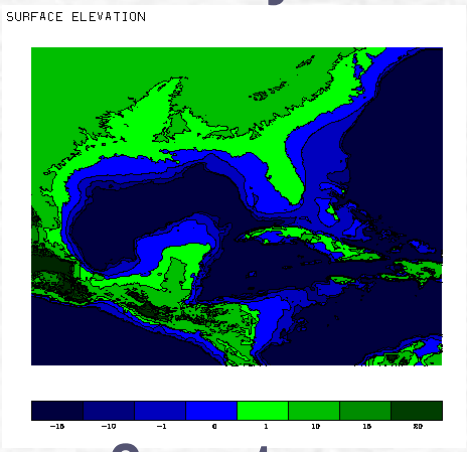	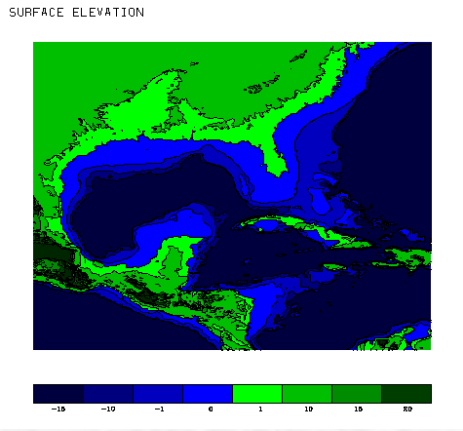	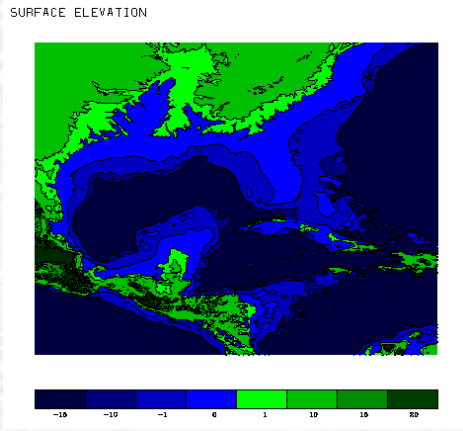
- 80 meters	0 meters	+ 10 meters	+ 80 meters

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- ✓ Most structures ultimately produce negative effects
- ✓ Major debate over what and what not to do to a shoreline

Erosional Processes Along Coastlines

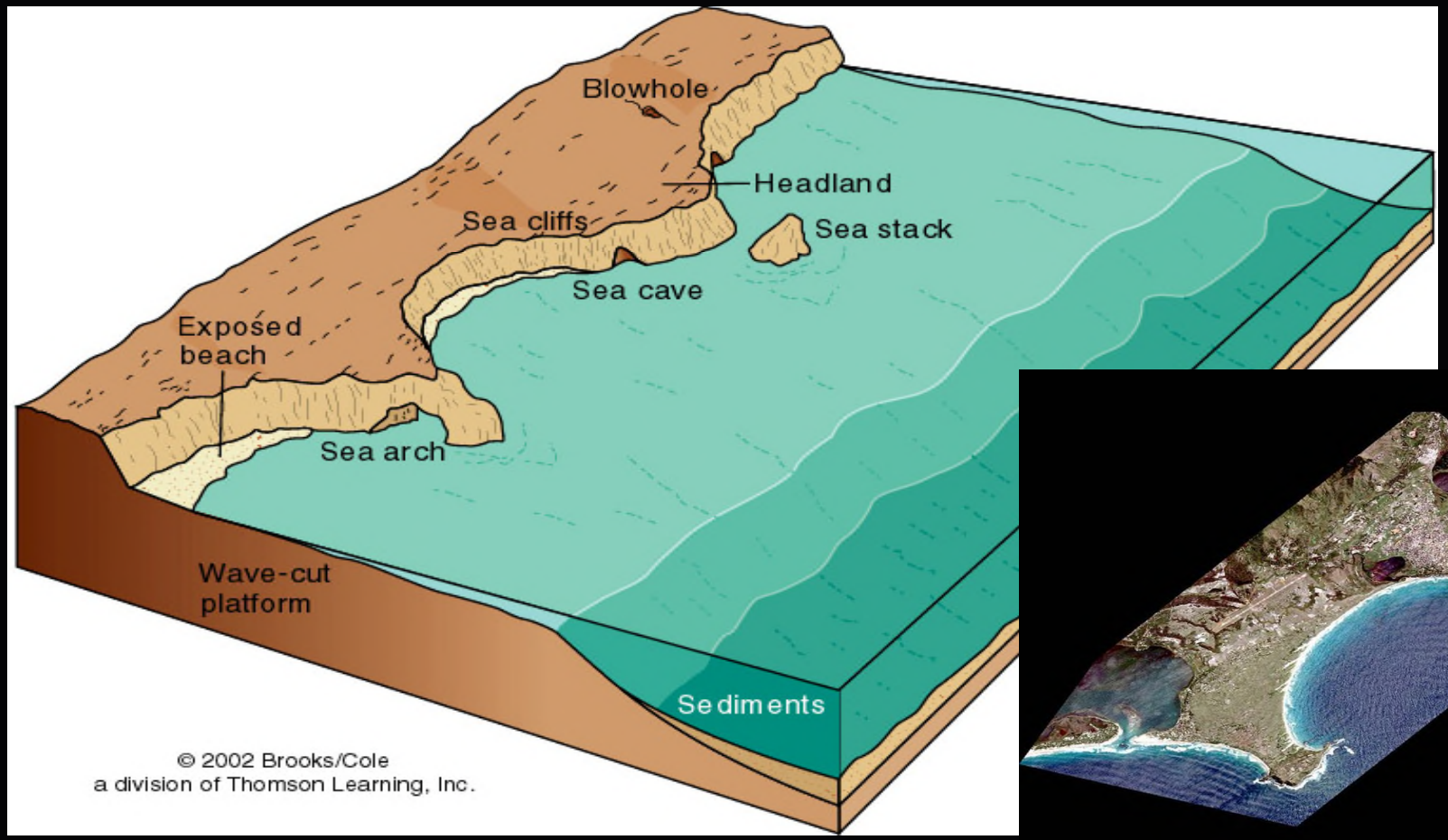
- Ocean Waves
- Tidal Action
- Surface Runoff from Land
- Wind-blown Sediment

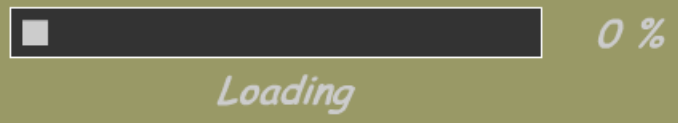
Erosional Coasts

- ✓ Land- and marine-based erosional processes dominate
- ✓ Coastline is typically rocky and irregular
- ✓ Characteristic features are steep rugged sea cliffs, caves, stacks, natural bridges, wave-cut terraces, and cobble-rich pocket beaches

Erosional Features of Coastlines

- Erosional features formed by the removal of coastal terrigenous and biologic materials
- Materials derived from rivers, sea cliffs, submerged coral and rock reefs
- Transport and deposition of coastal materials by longshore current

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Erosional Coastal Features

Beach-free Wave-Cut Platform

Erosional Coastal Features

Beach-free Wave-Cut Platform

Erosional Coastal Features

Rocky Shoreline

Erosional Features of Coastlines

Sea Caves, Sea Arches, and Sea Stacks

Erosional Coastal Features

Rocky Irregular Shoreline – No Beach

Erosional Coastal Features

Steep Rugged Sea Cliffs and Shoreline Rip Rap

Erosional Coastal Features

Storm Runoff Erosion of a Beach

Depositional Coasts

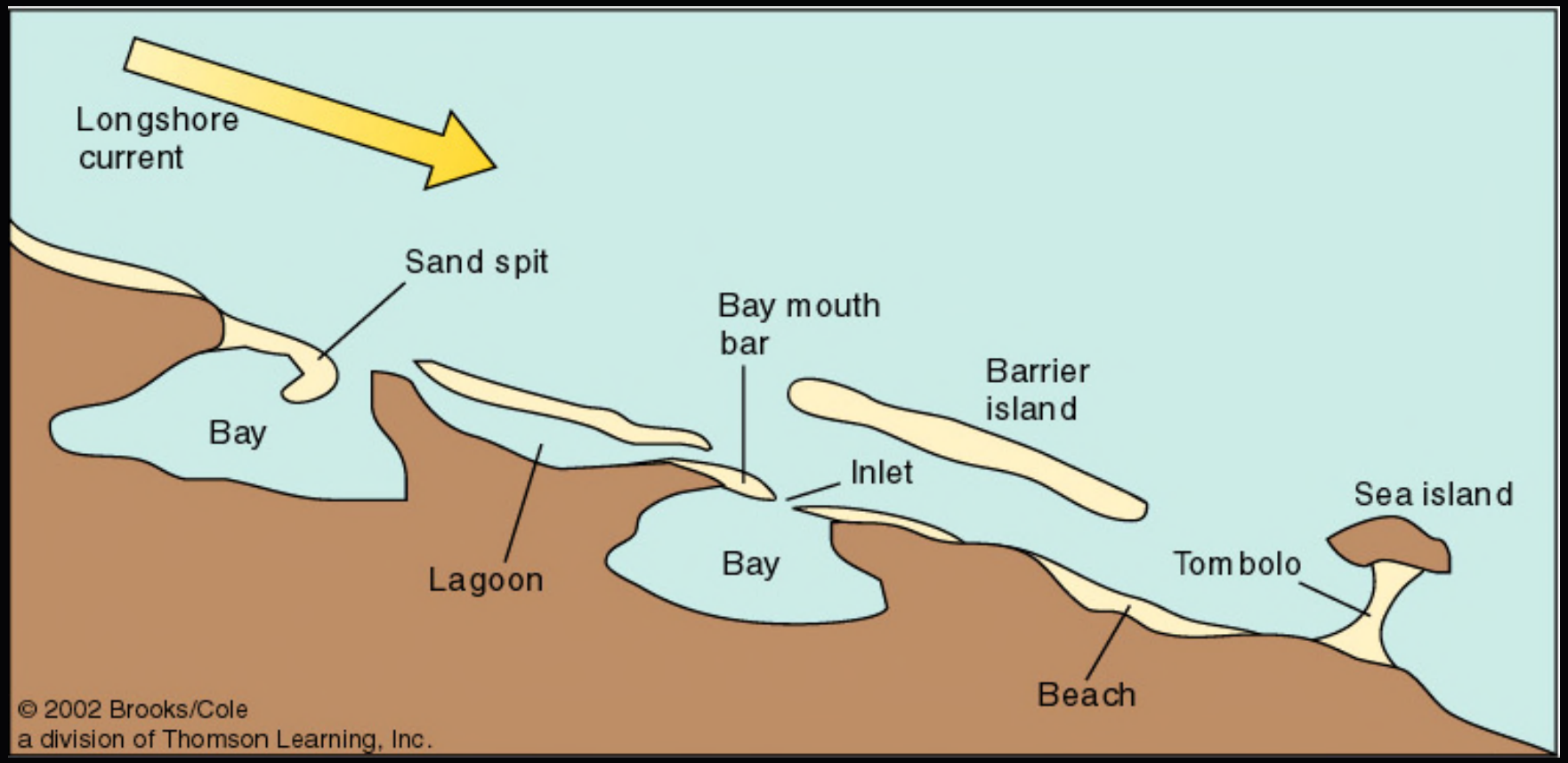
- ✓ Land- and marine-based depositional processes dominate
- ✓ Coastline is typically subdued, broad, beach-lined, straight, and regular
- ✓ Characteristic features are broad sandy beaches, dunes, sand spits, tombolos, and barrier islands

Depositional Agents of Coastlines

- Rivers and Streams
- Longshore Currents
- Surf and Rip Currents
- Biological Activity
- Volcanic Activity

Depositional Features of Coastlines

- Depositional features constructed from loose terrigenous and biologic materials
- Materials derived from rivers, sea cliffs, submerged coral and rock reefs
- Transport and deposition of coastal materials by longshore current



Depositional Coastal Features

Beaches, Sand Spits, and River Deltas

Depositional Coastal Features

Broad Sandy Beach

Depositional Coastal Features

Coarse-Sand / Gravel Beach

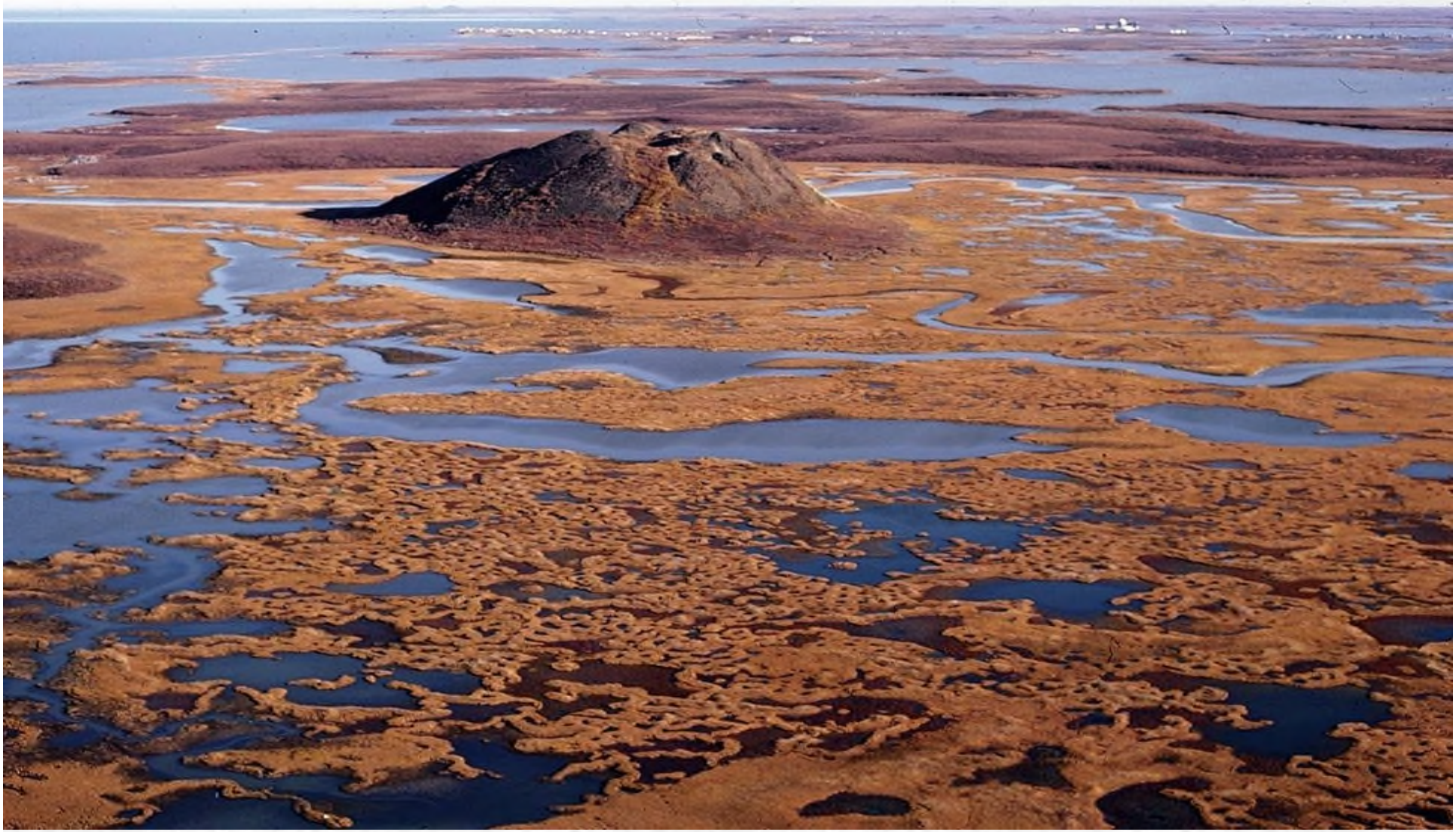
DEPOSITIONAL COASTAL FEATURES

Cobblestone Beach

DEPOSITIONAL COASTAL FEATURES

Sandy Beach and Backbeach Sand Dunes

Depositional Coastal Features



Coastal Wetlands - Estuary

DEPOSITIONAL COASTAL FEATURES

Salt Marsh- Estuary

DEPOSITIONAL COASTAL FEATURES

Figure Mangrove shoreline Puerto Rico south coast. Most of the mangrove has saline water over a 0.5 to 1.0 meter deep bottom.

Coastal Mangroves

Depositional Coastal Features

Coastal Mangroves

Depositional Coastal Features

Coral Reef Structures

Depositional Coastal Features

Erosional Headlands and Depositional Bays

Composite Coasts

San Diego's Coastline

1) Beaches controlled by a number of factors:

- ✓ Water motion (waves, tides, and currents)
- ✓ Sediment motion (longshore drift, surf zone ingress and egress)
- ✓ Sediment Input (rivers, bluffs, reefs, and artificial enrichment)
- ✓ Sediment Output (submarine canyons, coastal dunes, and artificial extraction)
- ✓ Offshore bottom contour (narrow vs. broad shelf; gradual vs. steep)
- ✓ Shoreline shape (irregular vs. straight; low relief vs. high relief)

2) The two primary processes affect the beach:

- ✓ Erosion = removal of sediment from beach
- ✓ Deposition = addition of sediment to beach

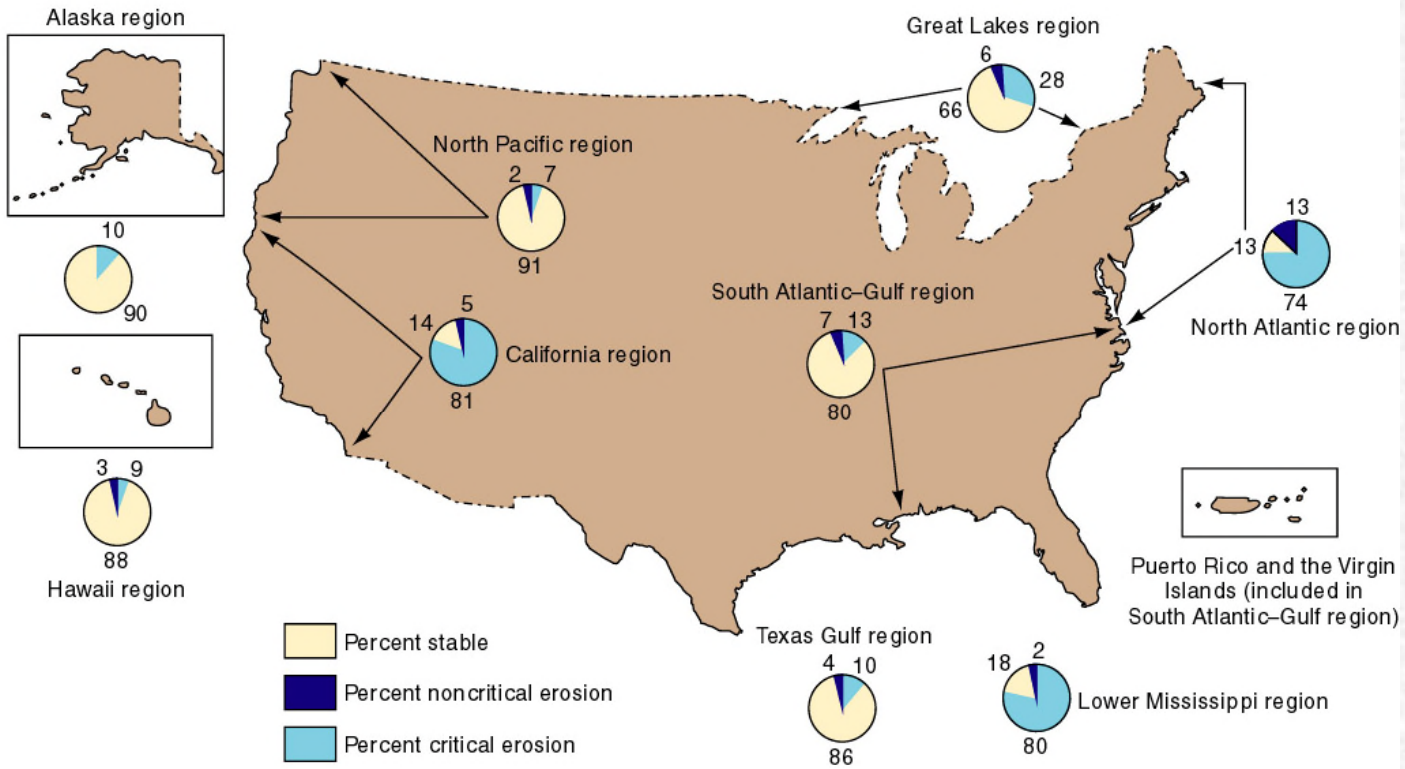
3) Humans attempt to control beach erosion and deposition by building artificial shoreline structures

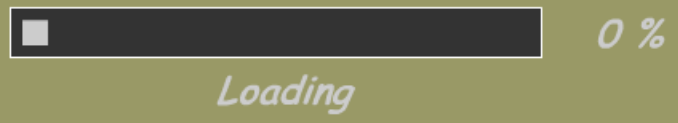
- ✓ Groins, jetties, breakwaters, seawalls, and reefs
- ✓ Most structures ultimately produce negative effects
- ✓ Major debate over what and what not to do to a shoreline

US Coastlines

- East Coast of US is a passive, predominantly depositional coast
- West Coast of US is an active, predominantly erosional coast
- Gulf Coast is a passive, overwhelmingly depositional coast

Stability of US Coastlines

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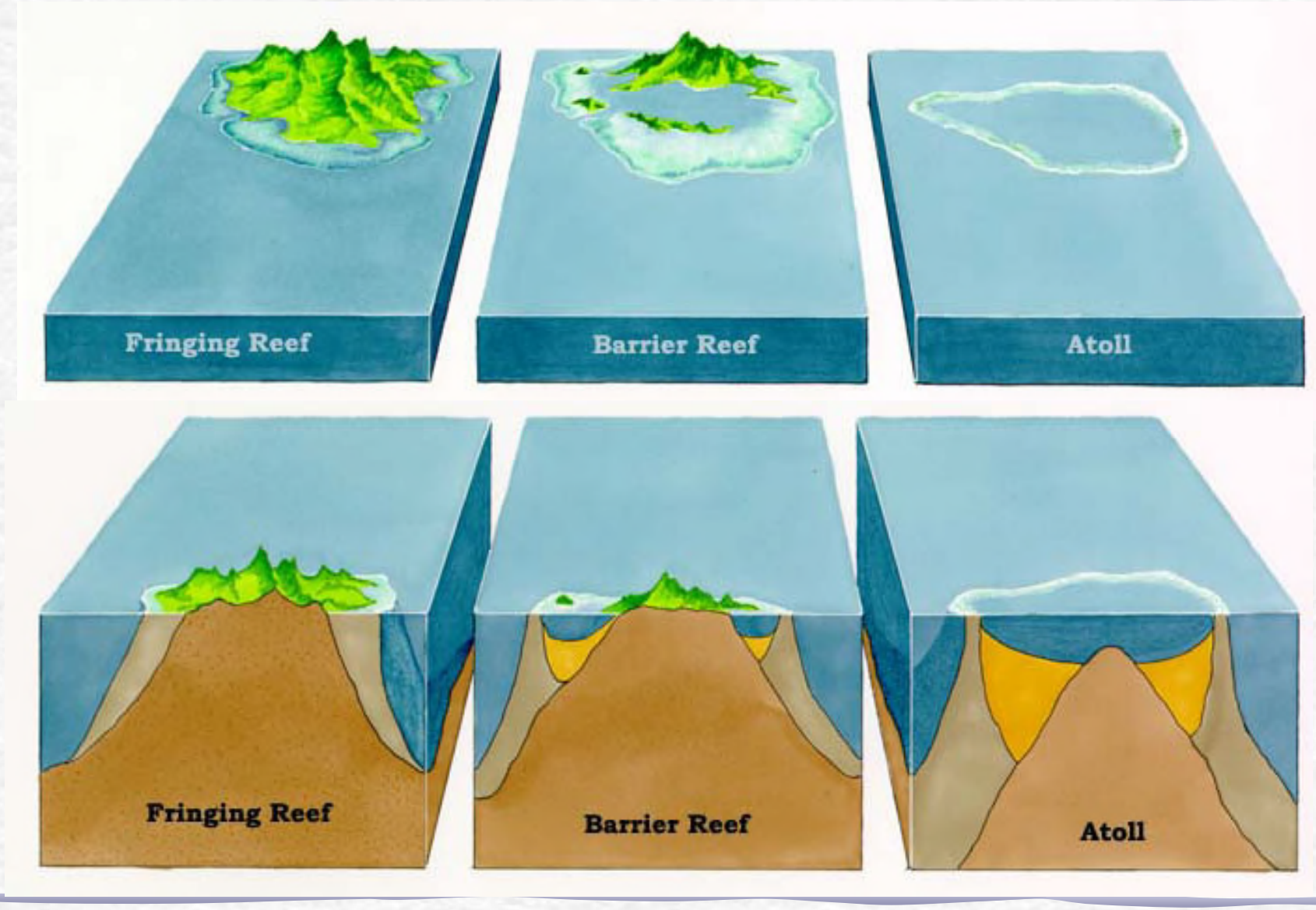
Reef Systems

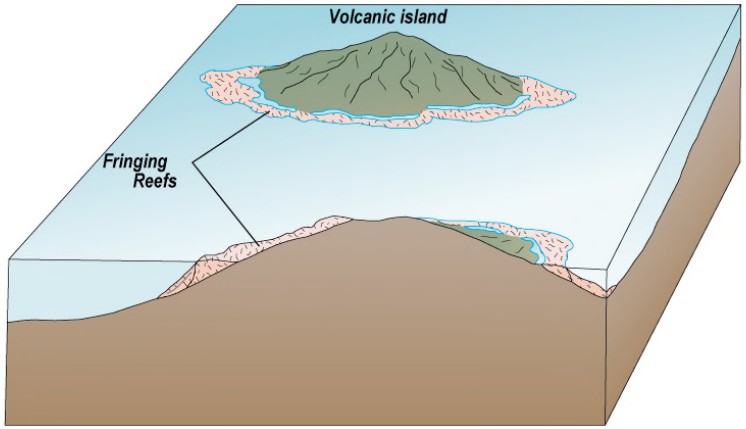
Evolution of Coral Reef Structures

Three Types of Coral Reef Systems



Fringing Reef Systems

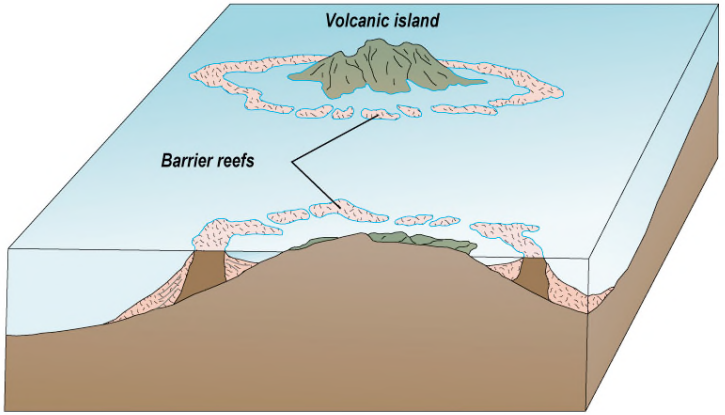
Hanama Bay, Oahu



(a) Initial Stage of Reef Growth

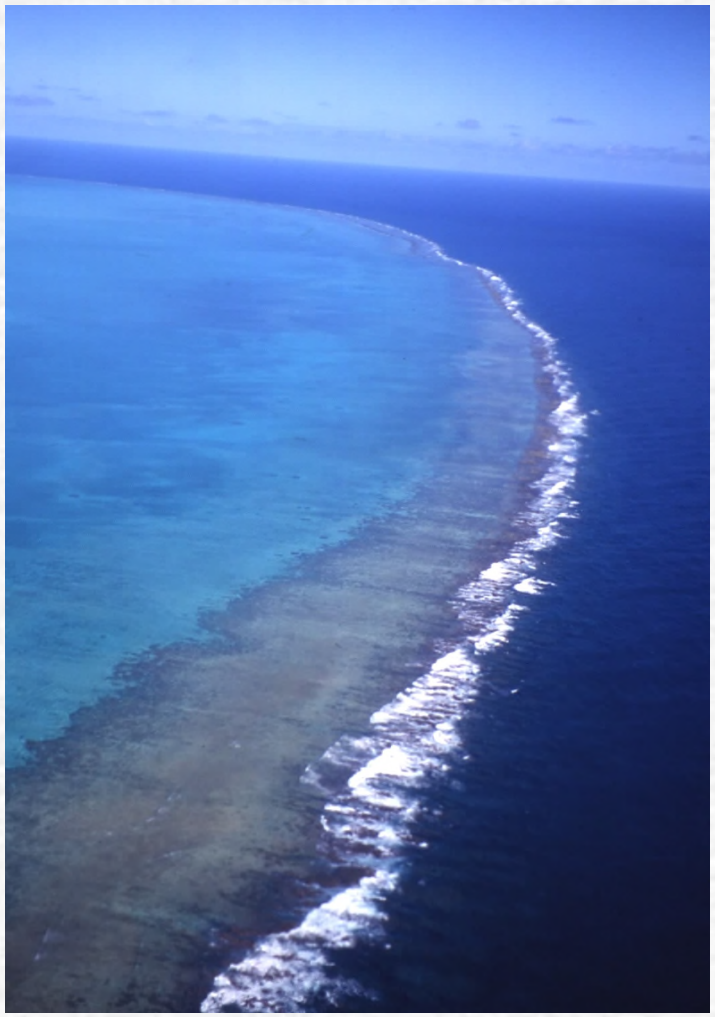
Barrier Reef Systems

Great Barrier Reef, Australia

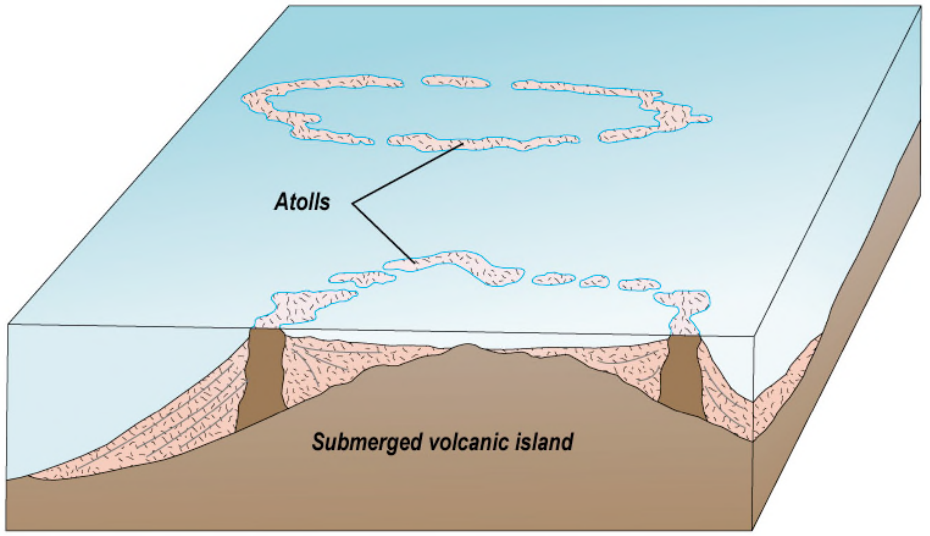


Second Stage of Reef Growth

Atoll Reef Systems

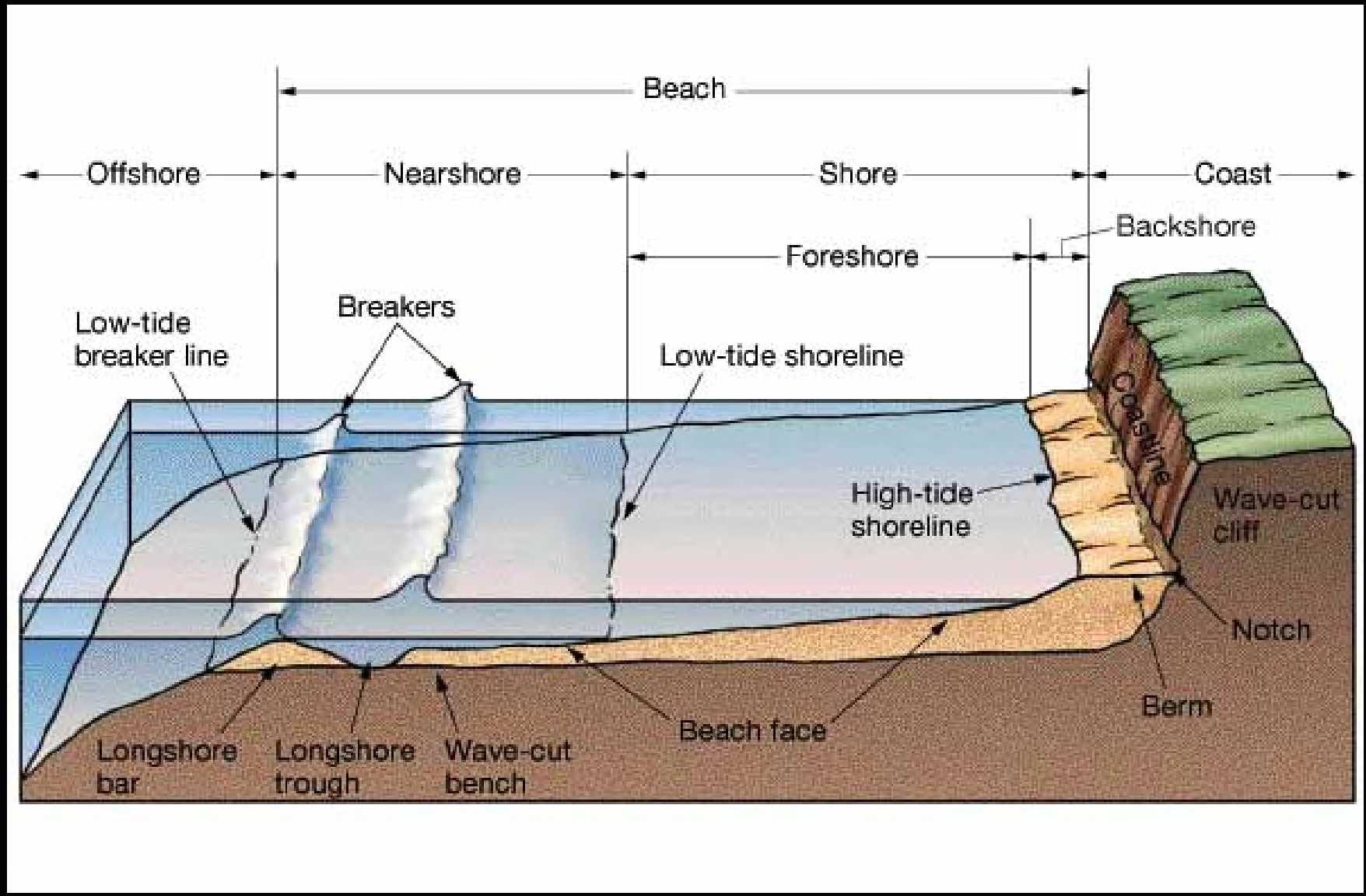


Midway Reef, Midway Island



(c) Final Stage of Reef Growth

Beach Anatomy 101



Coastal Concepts

- Beaches are shifting ribbons of sediment occurring along shorelines
- Coasts are geologically very temporary structures, subject to rapid change
- The *location* of the coastline depends primarily on two factors: tectonic activity and the volume of water in the ocean
- The *shape* of the coastline is a product of many factors: regional uplift, subsidence, and faulting, land- and sea-based erosion, transport, and deposition of earth materials, and biological activity
- Changes in sea level has the greatest influence on coastal processes
- Eustatic sea level is controlled by global climate and ocean basin volume
- Coasts are classified by whether erosion or deposition is the dominant process
- Erosional coasts are typically new coasts in which the land is being actively eroded
- Depositional coasts are typically mature coasts in which coastal sediment materials are either in stable equilibrium (steady), or are being deposited (growing)
- Erosional coasts have characteristic features: sharp bluffs, sea caves and stacks, natural bridges, pocket beaches, and wave-cut terraces
- Depositional coasts have characteristic features: long/broad sandy beaches, dunes, barrier islands, sand spits, and tombolos

Shoreline Discussion