

The Dynamic Ocean

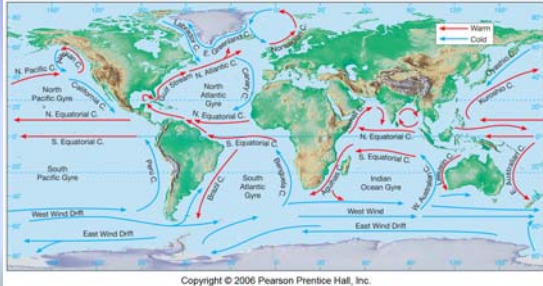
Ocean Circulation

- Ocean currents are masses of ocean water that flow from one place to another
- Some currents develop from the friction between the wind and the water
- Some are short-lived and affect a small area; others are larger and permanent
- Thus winds are highly influential in ocean circulation patterns
 - The global pattern of ocean circulation closely matches the global pattern of wind circulation
- Other influences include
 - Landmasses
 - Gravity
 - Friction
 - The Coriolis affect.

Ocean Circulation

- Huge, circular moving currents dominate the surface of the oceans
 - These large whirls of water are called **gyres**
- Gyres rotate clockwise in the northern hemisphere and counterclockwise in the southern hemisphere
- This is due to the Coriolis affect
 - Because of the earth's rotation, currents in the northern hemisphere are deflected to the right and those in the southern hemisphere are deflected to the left

Ocean Circulation



Ocean Circulation

- From tracking objects in the oceans, it has been determined that it typically takes about 6 years to completely circle the Pacific Gyre and about 3 years to completely circle the Atlantic Gyre
- The movements of the ocean currents have been determined largely from tracking objects that have intentionally, or accidentally, been dropped overboard a ship.
- The center of a gyre usually includes a relatively large area of calmer water.

Ocean Circulation



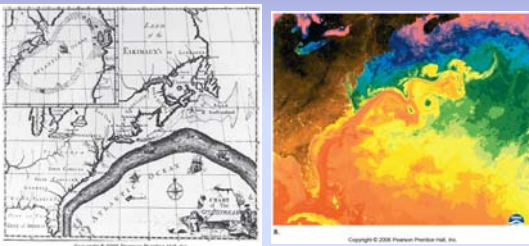
Ocean Circulation

- Ocean currents play an important role in affecting the climate of any given area
- When currents from low latitude areas flow to higher latitude areas, they transfer heat from relatively warm climates to cooler climates
- When currents bring relatively cool air to nearby continental deserts, the aridity of the desert increases
 - As the air is cooled, it resists the upward movement that initiates cloud formation and precipitation

Currents and Climate

- A good example of how climate is affected by currents can be found in Europe and the Gulf Stream and North Atlantic currents
- The Gulf Stream is a current of warm water that flows northward along the eastern seaboard of the United States
 - First identified by Benjamin Franklin
- The current then flows eastward across the Atlantic and approaches Europe
- The climate of Europe, which is affected by this warm water current, exhibits temperate conditions unlike what is expected at such high latitudes

Currents and Climate



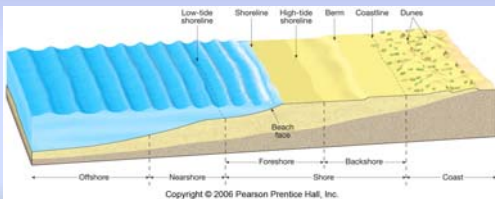
The Shoreline

- The **shoreline** is the line that marks the contact between the earth and the sea
- The **shore** is regarded as the area that extends between the lowest tide and the highest tide
- The area exposed when the tide is out and submerged when the tide is in is the **foreshore**
- The **backshore** is inland from the high-tide shoreline (usually dry unless subjected by storm waves)

The Shoreline

- The **coast** extends from the shore inland to as far as ocean-related features can be found
 - The coastline marks the coast's seaward edge
- The **nearshore** zone lies between the low tide shoreline and the line where waves break at low tide
- **Offshore** represents the area seaward of the nearshore
- Technically, the **beach** is an accumulation of sediment found along the landward margin of an ocean or lake
- Beaches consist of one or more **berms**
 - Relatively flat platforms often composed of sand that are adjacent to dunes marked by a change in slope at the seaward edge

The Shoreline



Beaches



http://image06.webshots.com/6/099/11/81309911UCRUJ_fs.jpg



<http://www.flickr.com/photos/robertmiller/343100440/>



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Beach Sand

- Beaches are composed of whatever sediment is most abundant
- Most beaches are dominated by the presence of quartz
 - Very durable, can withstand weathering
- Other minerals may also be present
 - Feldspar
 - Calcium carbonate fragments (biogenic)
 - Gypsum
 - Mica
 - Others

Beach Sand

- The material found on beaches is not considered stagnant
- The action of the waves at the shore act to constantly move the sediment

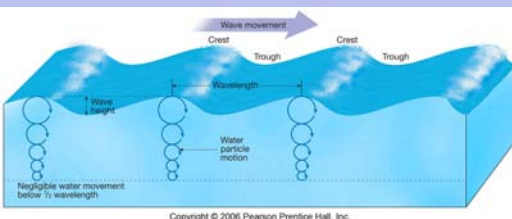
Waves

- Energy traveling along the interface of the ocean and the atmosphere is represented as waves
- This energy can travel from thousands of kilometers
 - Which is why waves can occur in otherwise calm conditions
- Wind-generated waves provide most of the energy that shapes and modified shorelines
- At this location, energy that has traveled thousands of kilometers suddenly encounters a barrier that will not let the energy advance and thus the energy is absorbed.

Wave Characteristics

- The tops of the waves are **crests**
- The crests are separated by **troughs**
- The vertical distance between the crest and the trough is the **wave height**
- And the horizontal distance between crests is the **wavelength**
- The time it takes for one complete wave – one wavelength – to pass a fixed position is the **wave period**

Wave Characteristics



Wave Characteristics

- The height, length, and period of a wave are determined by three criteria:
 - Wind speed
 - Length of time the wind has blown
 - Fetch – the distance the wind has traveled across open water
- As the quantity of energy the wind transfers to the water increases, both the height and steepness of the waves increase
- Eventually, a critical point is reached where waves grow so tall they topple over, forming whitecaps.

Wave Characteristics



<http://www.flickr.com/photos/63861396@N00/4273139/>



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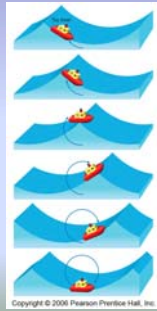
Waves

- For a particular wind speed, there is a maximum fetch and duration of wind beyond which waves will no longer increase in size
- At this point, the waves are said to be fully developed
 - The reason they do not grow is because the amount of energy gained from wind is equal to the amount of energy lost through the breaking of whitecaps

Wave Motion

- Waves can travel great distances
 - In one instance >6,000 miles
- The water doesn't travel this distance but the wave form does
- As the wave travels, the water passes the energy along by moving in a circle (circular orbital motion)
- Observation of floating objects shows that objects not only move up and down but also back and forth
- Thus the wave form travels through the water while the particles that make up the water move in a circular pattern

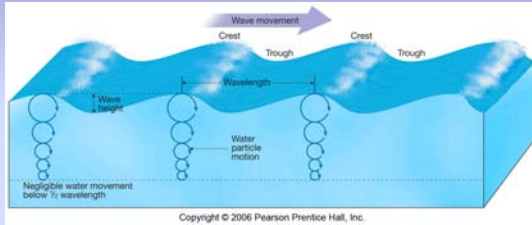
Wave Motion



Wave Motion

- The energy contributed by the wind to the water is not only transmitted laterally but also vertically into the water
- Beneath the surface the circular orbital motion rapidly diminishes until at a depth of equal to $\frac{1}{2}$ the wavelength the movement of water particles becomes negligible
- This depth is known as the **wave base**

Wave Motion



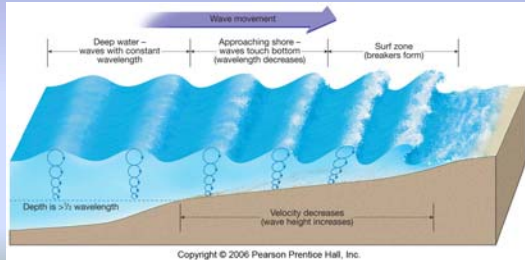
Waves in the Surf Zone

- When a wave is in deep water, it is unaffected by water depth.
- As a wave approaches shore, the water becomes shallower and the land surface interferes with the structure of the wave
 - This interference slows the speed of the wave.
- As the wave approaches shore, the waves further out "catch up", decreasing the wavelength
- As the speed and wavelength of the wave diminishes, the wave gets higher
 - At some point, the wave cannot support itself and it topples over and crashes onto the shore.

Waves in the Surf Zone

- The turbulent water created by breaking waves is called the surf
- The water that flows up the beach is called the swash and the water that flows toward the ocean after a wave crashes onto the shore is the backwash

Waves in the Surf Zone



Wave Erosion

- Wave action from storms can force incredible amounts of energy on the shore
- Thus, cracks and crevices are quickly opened by the force of wave action. Water is forced into every opening, causing the air inside to be compressed. When the wave subsides, the air cools and dislodges rock fragments
- Abrasion of rock particles from the force of waves is also apparent
- Smooth, rounded stones found on the beach are reminders of this action

Sand Movement

- Beaches have been called a "river of sand"
- Energy from breaking waves often causes large quantities of sand to move roughly parallel to the beach face
- How much movement depends on the amount of wave activity.
- When wave activity is light, much swash soaks into the beach and there is less backwash.
 - The swash causes a net movement of sand up the beach
- When high energy waves prevail, the beach is saturated from previous waves and less swash soaks into the beach.
 - The berm erodes because backwash is strong and there is a net movement of sand down the beach

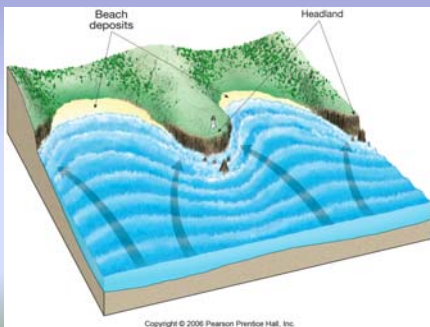
Sand Movement

- Along many beaches, light wave activity is the rule in the summer and a wide, sandy berm develops
- During the winter, when storms are more frequent, strong wave activity narrows the berm.
- A wide berm can take months to build and be reduced in hours by a strong storm

Wave Refraction

- Waves seldom approach the shore straight on; most approach at a slight angle
- When the wave enters shallow water, the crests are refracted (bent) and line up nearly parallel to the shoreline
- This occurs because the part of the wave nearest the shore touches bottom and slows first, whereas the part of the wave in deep water is still moving quickly
- Because of refraction, wave energy is concentrated against the sides and ends of projections into the water.
- Refraction in bays causes waves to diverge and expend less energy, thus, wave energy is less in bays

Wave Refraction



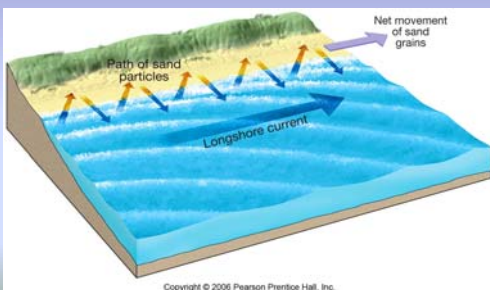
Longshore Transport

- Although waves are refracted, they can still reach the shore at a slight angle
- Thus, the swash from a wave is at a slight angle to the beach; however, the backwash is straight down from a beach
- The cumulative effect of this activity is a zig zag pattern of sediment movement along a beach.
- This movement is called **beach drift** and can transport sediments up to thousands of meters a day (though 5-10 meters is typical).

Longshore Transport

- Waves that approach the shore at an angle also produce currents in the surf zone that flow parallel to the shore and can move much more sediment than beach drift
- These **longshore currents** easily move finer particles suspended in the water and roll larger sediments along the bottom.
- The direction of movement depends on the direction of wave attack
 - But the overall movement for both the Atlantic and Pacific coasts is southward.

Longshore Transport



Shoreline Features

- Some erosional features forming in beach environments include
 - Wave cut cliffs
 - Wave cut platforms
 - Sea arches
 - Sea stacks

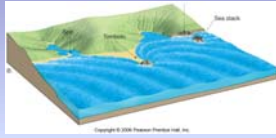


The image contains three photographs illustrating coastal erosion features. The top photo shows a steep, eroded cliff face with a wave-cut platform at its base. The middle photo shows a natural sea arch in a rock formation. The bottom photo shows a sea stack, a rock formation standing in the sea.

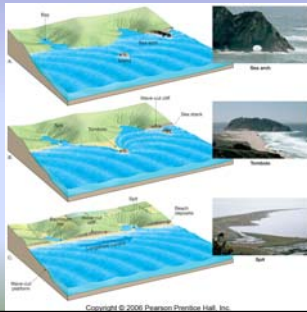
Shoreline Features

- Some depositional features forming in beach environments include
 - Spit
 - An elongated ridge of sand that projects from the land into the mouth of an adjacent bay
 - Baymouth bar
 - A sandbar that completely crosses the mouth of a bay
 - Tombolo
 - A ridge of sand that connects an island to the mainland

Shoreline Features



Shoreline Features



Shoreline Features

- Another depositional feature forming in beach environments include
 - Barrier island
 - Low ridges of sand parallel to the coast
 - Found at distances ranging from 2 – 19 miles from the shore
 - From Cape Cod, MA to Padre Island, TX, there are approximately 300 barrier islands
 - Most are 0.5 – 3 miles wide and 9 – 18 miles long

Barrier Islands



http://www.flickr.com/photos/piedmont_fossil/147355060/



Stabilizing the Shore

- Although the same processes cause change along every coast, not all coasts respond in the same way
- Interactions among different processes depend upon local factors, including
 - Proximity to sediment-laden rivers
 - Degree of tectonic activity
 - Topography and composition of the land
 - Prevailing winds and weather patterns
 - Configuration of the coastline

Stabilizing the Shore

- Hard stabilization includes structures to protect a coast from erosion or prevent the movement of sand along a beach
- Often results in predictable but usually unwanted results
- Can include
 - Jetties
 - Breakwaters
 - Seawalls

Stabilizing the Shore

- Jetties
 - A barrier built at right angles to the shore
 - Sand is built up on upbeach side and worn on downbeach side
 - No longer the preferred method of maintaining beaches





Stabilizing the Shore

- Breakwaters
 - Built parallel to the shoreline
 - Used to protect the shore and ships from the beating of waves
 - Reduced wave action allows sand to accumulate
 - Erosion occurs downbeach of the structure
 - Sand dredging may be required to redeposit sand

Stabilizing the Shore



<http://www.flickr.com/photos/steinsky/24328166/>



<http://www.flickr.com/photos/7826125@N06/215546806/>



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Stabilizing the Shore

- Seawalls
 - Built parallel to the shoreline
 - Used to protect the shore from the pounding of waves
 - Waves expend much of their energy across an open beach but seawalls cut this process short
 - The beach to the seaward side of the wall will experience significant erosion and may be eliminated entirely
 - Once the beach is reduced, the wall is subjected to even more intense pounding and may have to be replaced by a stronger structure

Stabilizing the Shore



<http://www.ikemi.info/old2003/graphics/byzantine/beawalls.jpg>



<http://www.flickr.com/photos/loysterboyz/2211120671/>

Shore Stabilization

- There also exists alternative means of shore stabilization without the use of physical structures
- These include
 - Beach Nourishment
 - Relocation
- Although considered more environmentally sound than hard stabilization, they are also not without consequences

Shore Stabilization

- Beach Nourishment
 - Simply the addition of large quantities of sand to a beach
 - Beach quality and storm protection are improved
 - However, the same effect that removed the original sand will also remove the replacement sand
 - Can be very expensive
 - May have adverse effects
 - Beach nourishment in Hawaii replaced calcareous particles with soft, muddy sand.
 - This increased the waters turbidity and killed off many of the coral reefs

Shore Stabilization



Shore Stabilization

- Beach Nourishment
 - Only economically viable if
 - Dense development
 - Large supplies of sand
 - Low wave energy
 - Reconcilable environmental issues
 - Very few areas possess all of these qualities

Shore Stabilization

- Relocation
 - Relocating storm damaged or at risk buildings
 - Let nature reclaim the beach
 - Controversial
 - Property owners hate to lose the investment
 - Others state that impact of coastal storms will only get worse and the cost is too great
