Chapter 14

Coasts

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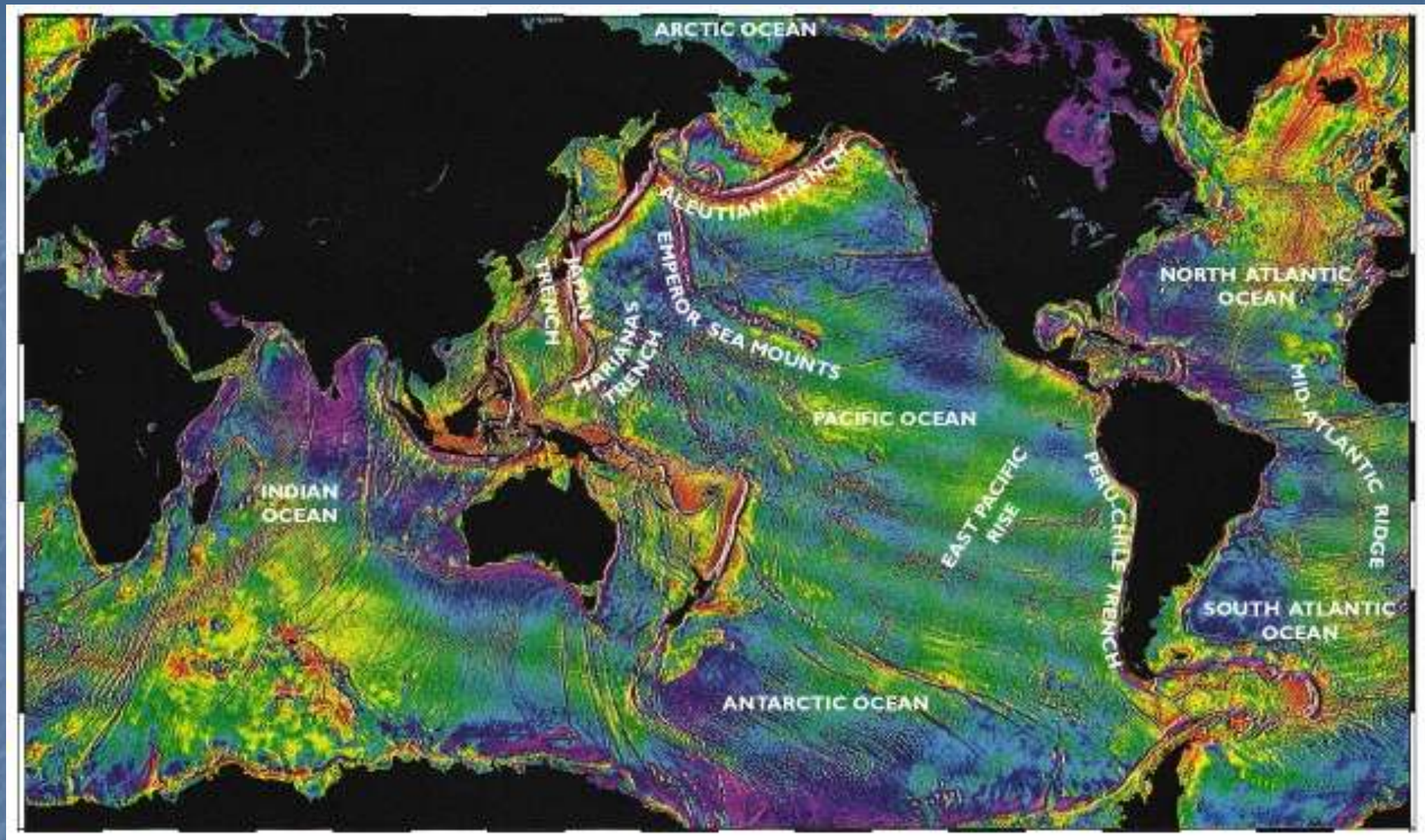
St. Lawrence
ISLAND OF NEWFOUNDLAND
–42
CAPE BRETON ISLAND
GRAND BANKS OF NEWFOUNDLAND
–228
Boston
–12
New York
Washington
SOHM ABYSSAL PLAIN
–17400
CORNER SEAMOUNTS
HUDSON CANYON
HATTERAS ABYSSAL PLAIN
BERMUDA ISLANDS
BERMUDA RISE
MID-ATLANTIC RIDGE
–12000
BAHAMA ISLANDS
CUBA
–19200
PUERTO RICO TRENCH
–27500
Atlantic Ocean's deepest point
–12844
KRYLOV SEAMOUNT
CAPE VERDE ISLANDS
–4500
RIFT VALLEY
AZORES
BISCAY ABYSSAL PLAIN
–15400
IBERIAN PENINSULA
Lisbon
AMPERE SEAMOUNT
–17820
MADEIRA ISLANDS
CANARY ISLANDS



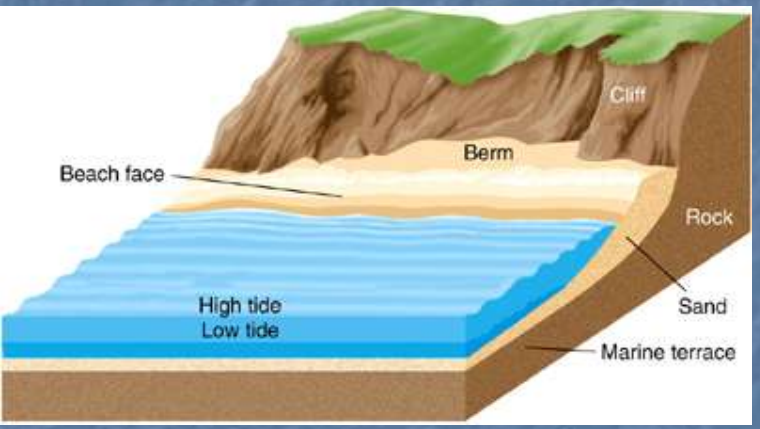
- Surface of ocean from radar satellite altimeter
- Gravitational field affects water surface level
- Gravity influenced by sea floor topography

Coasts and Coastal Features

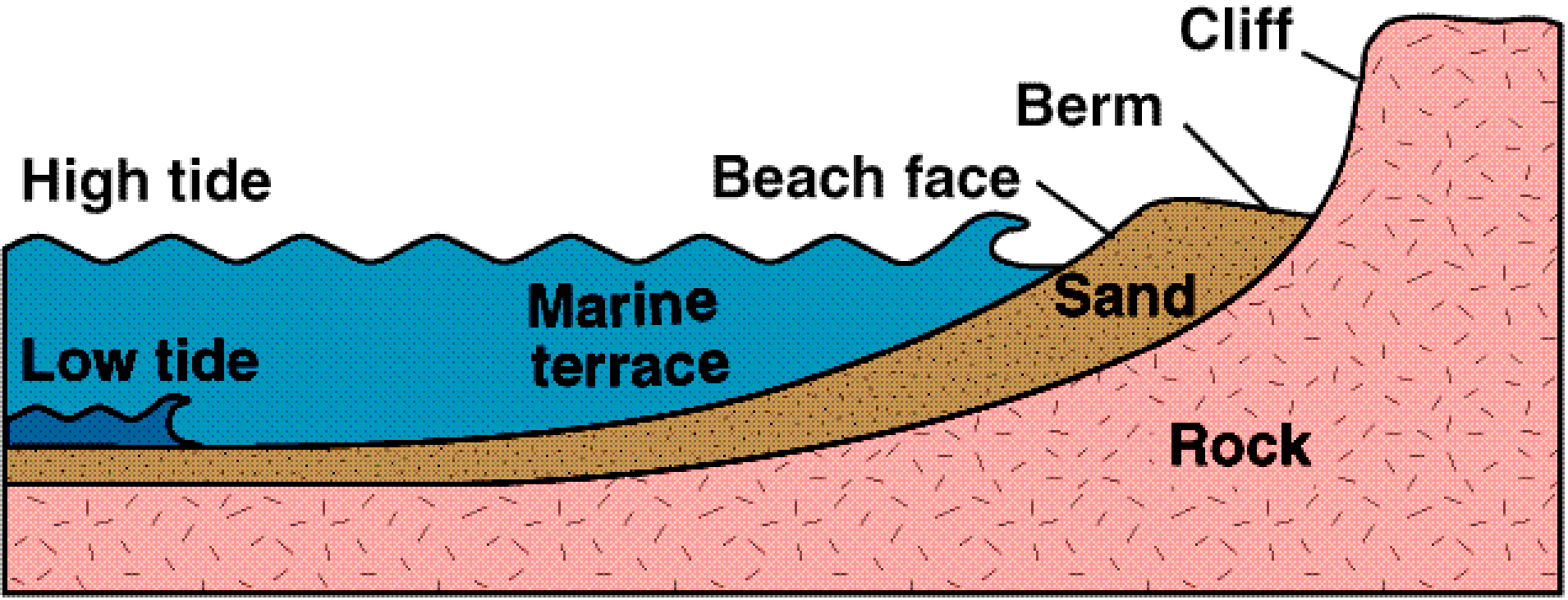
- The *coast* is all the land near the sea
  - Includes beach and the strip of land just inland of it
- Coasts can be rocky, mountainous and cliffed (Pacific coast of North America), or broad gentle plains (south Atlantic coast of North America)
- Coasts can be *erosional*, depositional, *drowned*, or *emergent*

Beaches

- A *beach* is a strip of sediment (usually sand or gravel) from the low-water line inland to a cliff or zone of permanent vegetation

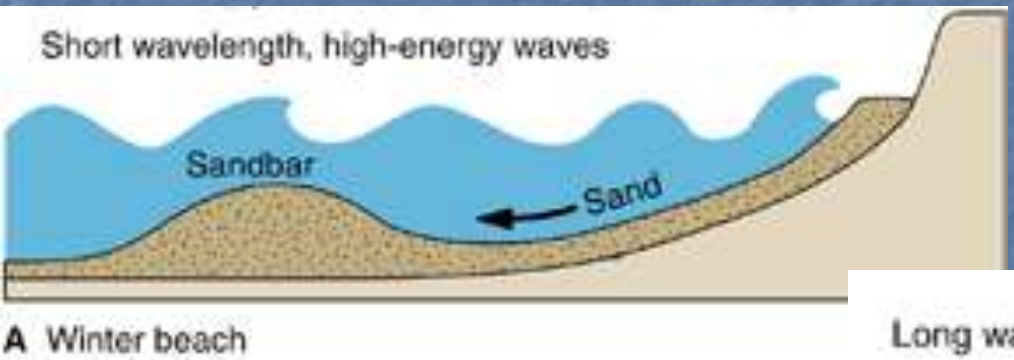


Parts of a Beach

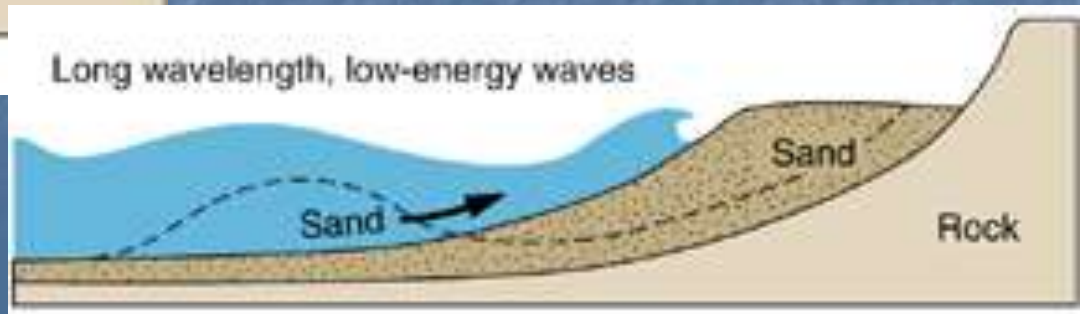


Beaches

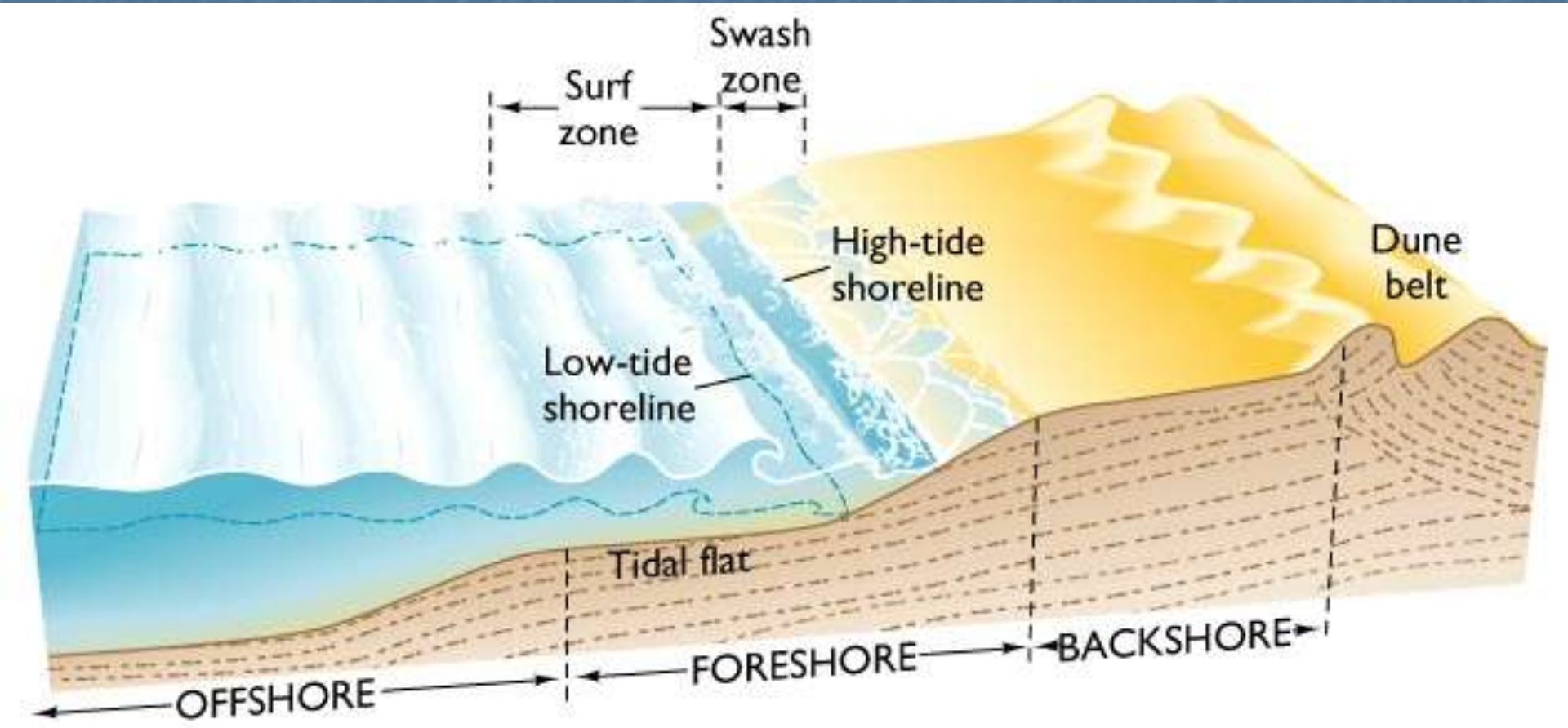
- Above and landward of the beach face is a flat or gently inland-sloping platform of sediment called the ***berm***
  - Berms are narrowed by wave erosion during the stormy season and rebuilt by gentler waves in calm weather
- Just offshore from the beach face is broad, gently sloping platform of rock or sediment called the ***marine terrace***



A Winter beach



B Summer beach


Swash
zone
Surf
zone
High-tide
shoreline
Dune
belt
Low-tide
shoreline
Tidal flat
OFFSHORE
FORESHORE
BACKSHORE

Beach Sand Sources

Sand supplies for beaches

- erosion of *local rock*
- sand stored *seaward of surf zone*
- *carbonate remains* of marine organisms (shells)
- ***river sediment*** arriving at the ocean
  - ***largest sand source*** for most beaches
  - upstream dams
    - *cuts off* the river sand supply
    - causes ***severe beach erosion***
  - coastal communities with eroding beaches
    - move sand to coastline by pipeline or truck

Water Waves

- Seas, Swells, Surf
- Wave Height
- Crest
- Trough
- Wavelength
- Surf
  - Breaker

Waves and Energy Transfer

- Ordinary ***ocean waves*** (*not* tsunamis) are created by ***wind*** blowing over the surface of the water
- When waves strike coastlines, wind ***energy is transferred*** to the rocks and sediments on beaches
  - This energy is available to erode coastlines and transport sediments

Water Waves

- Wave height determined by
  - wind **speed**
  - **length of time** wind blows
  - **distance** wind blows over the water (***fetch***)
- Wave ***height***
  - **vertical** distance between crest (top) and trough (bottom)
  - determines ***wave energy***

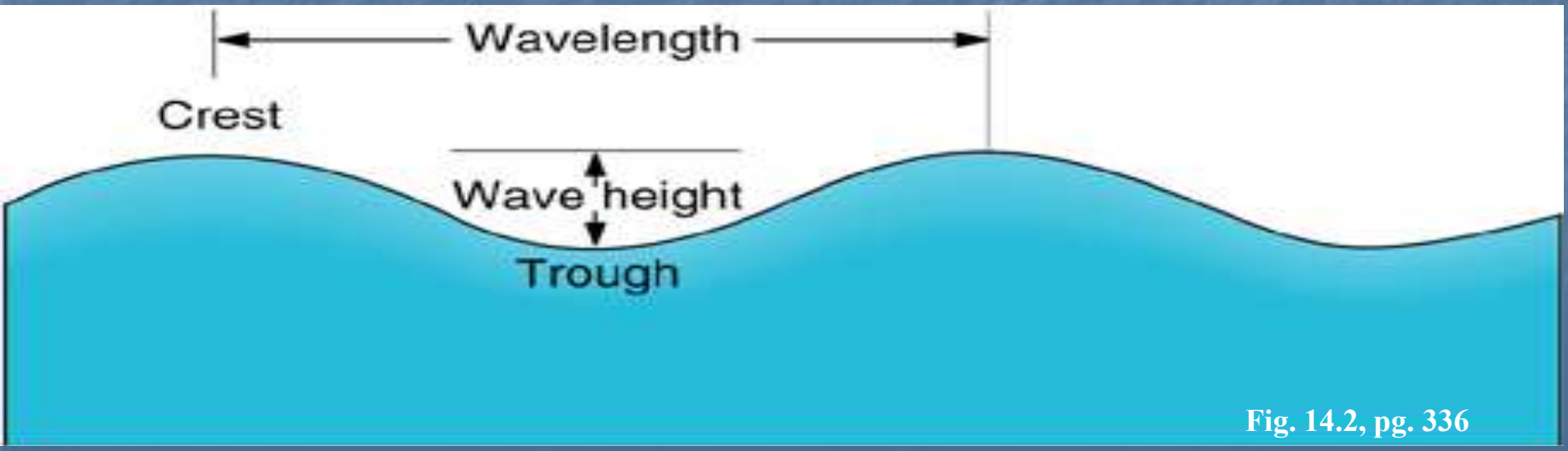


Fig. 14.2, pg. 336

Water Waves

- ***Wavelength***
  - **horizontal** distance between two crests (or troughs)
- Waves
  - "break" on shore as ***surf***
  - spend energy *moving sand* along the beach

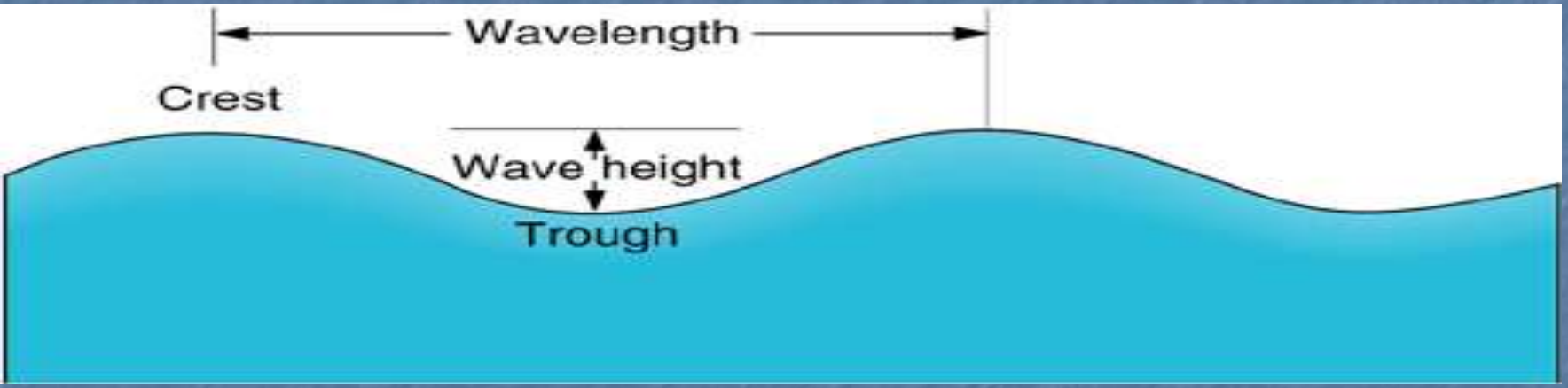
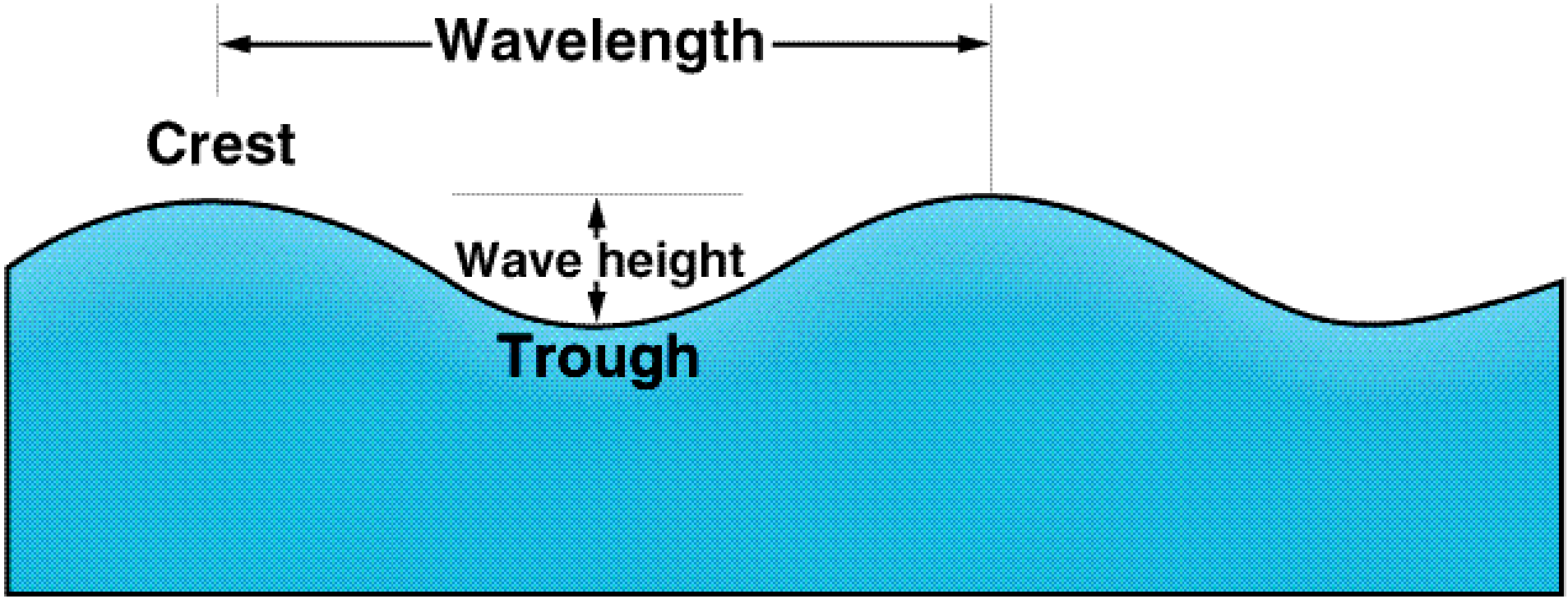


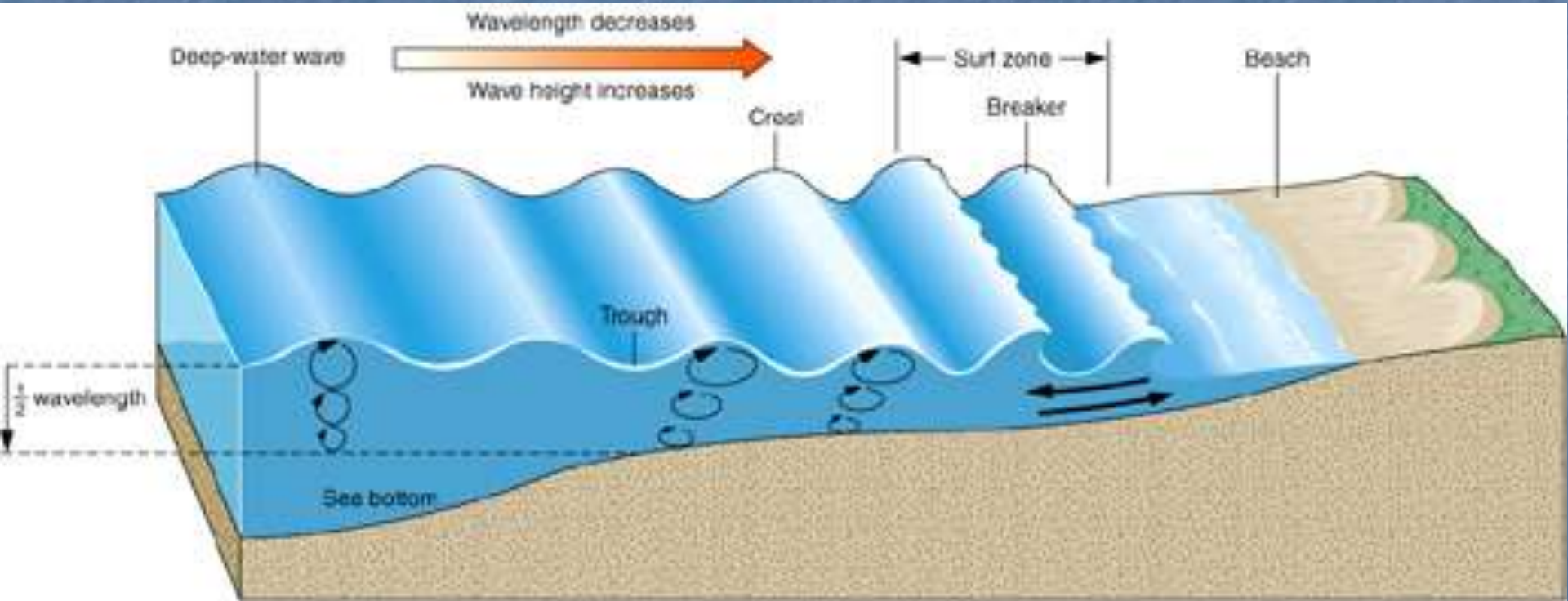
Fig. 14.2, pg. 336

Wavelength and Height



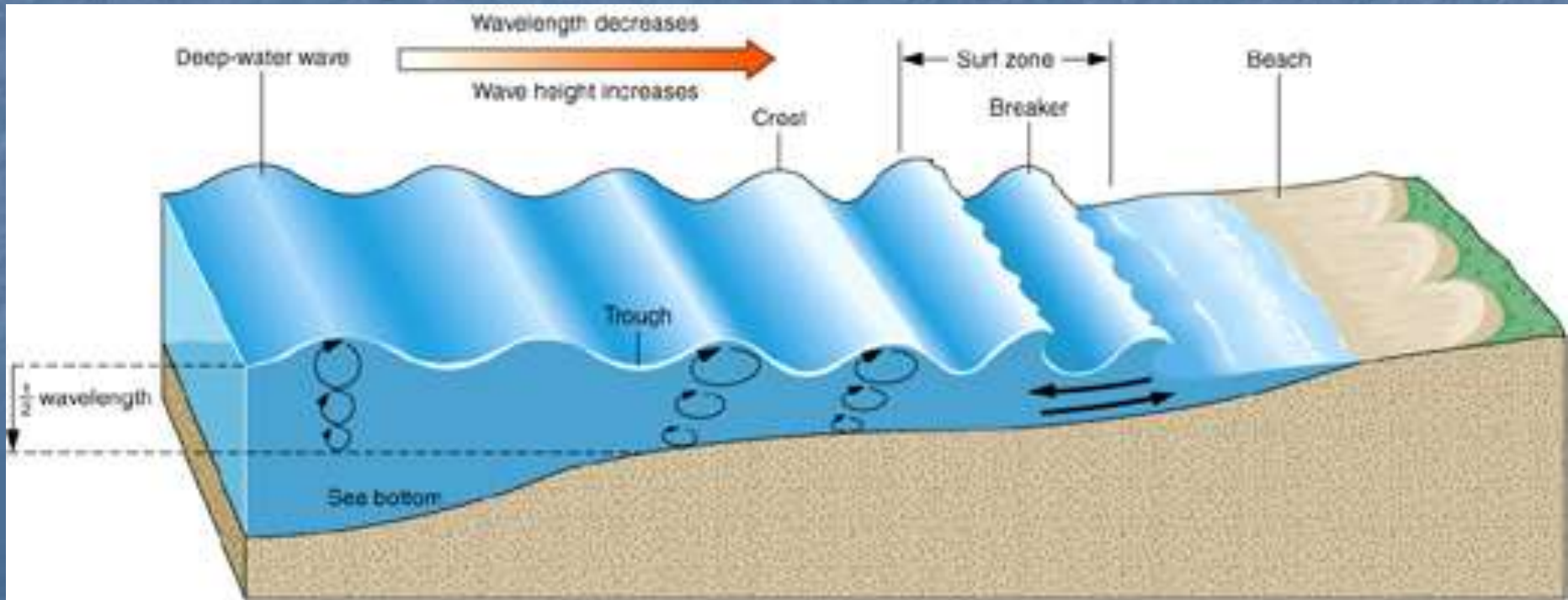
Water Waves

- Movement of water in waves is in a nearly circular path called an *orbit*
- In deep water, *energy advances* with the wave, but the water does not

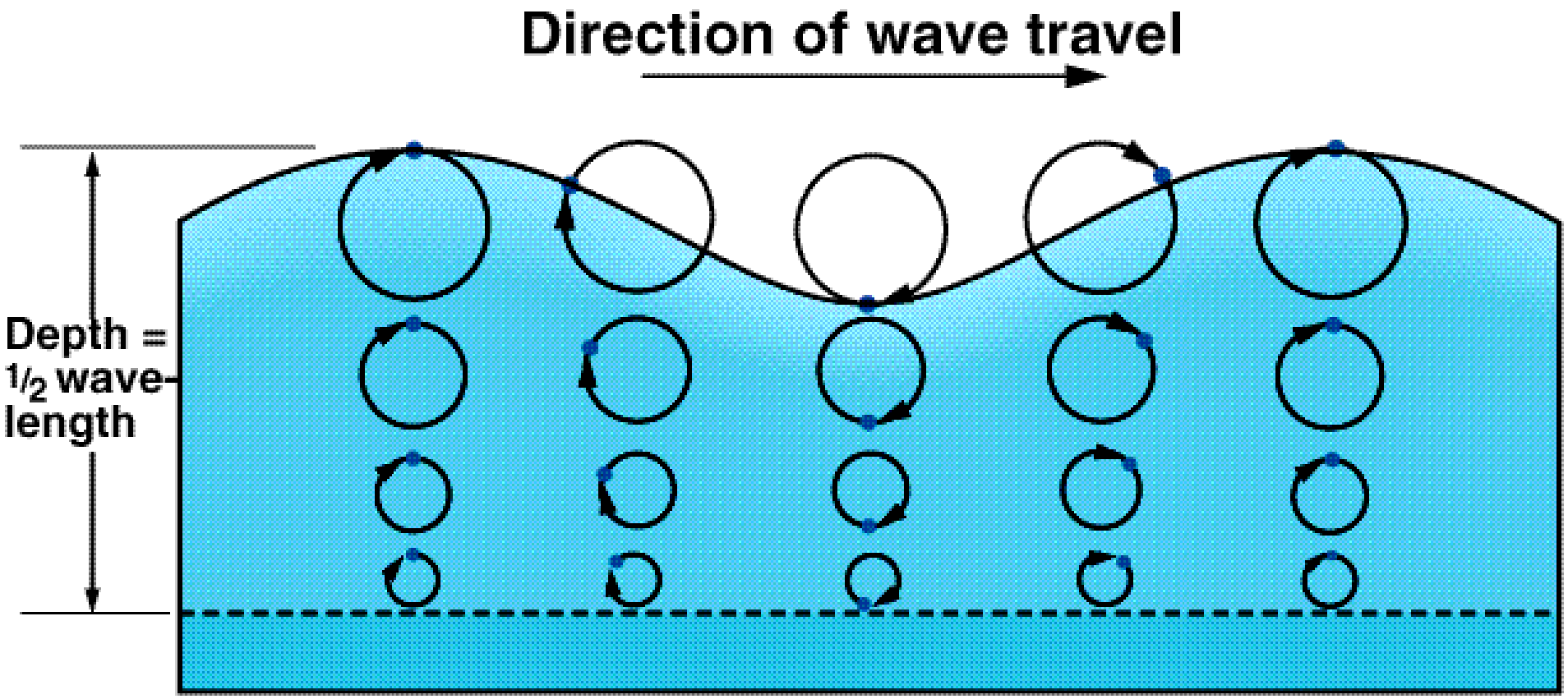


Water Waves

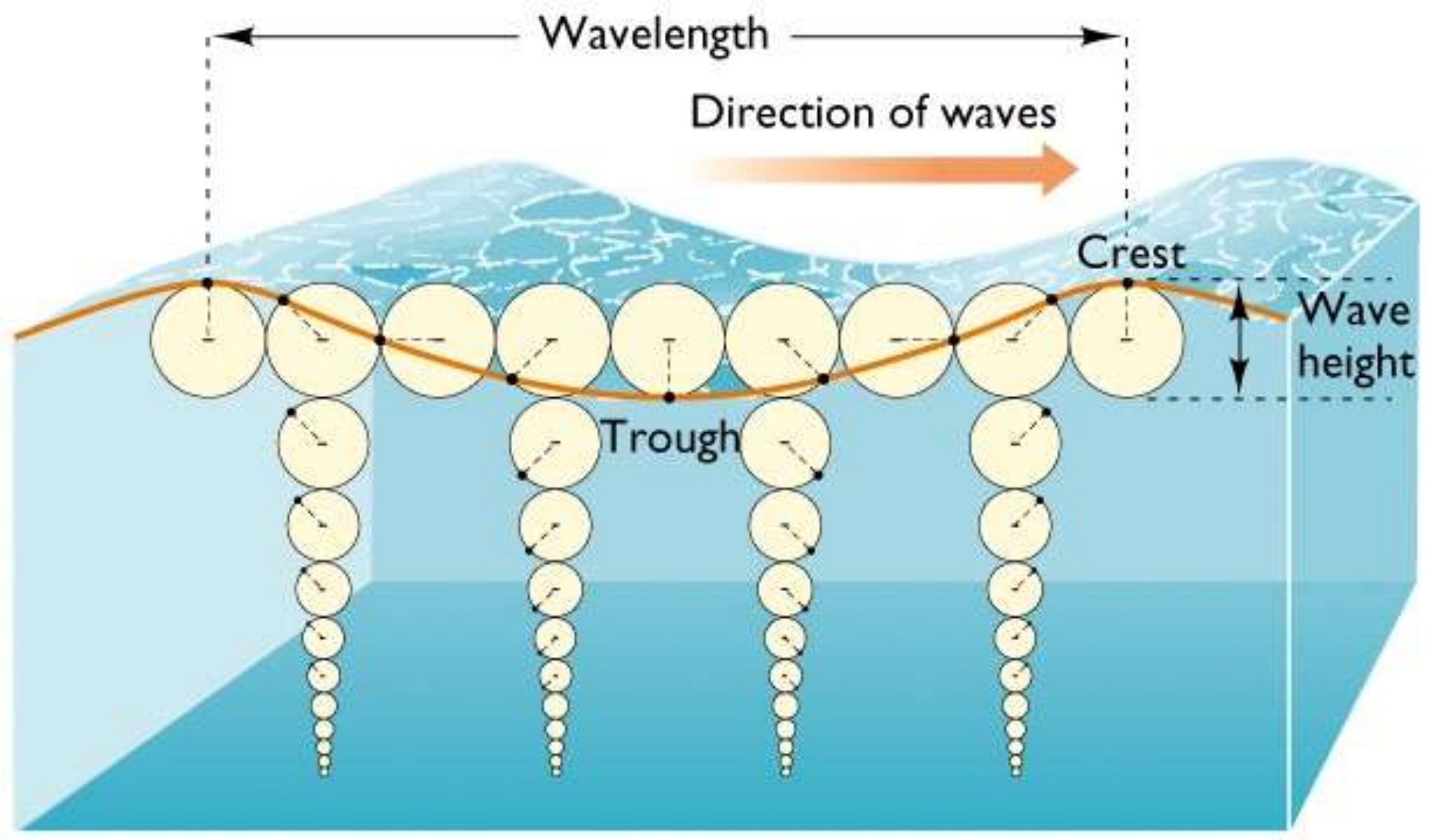
- Orbital motion in waves *decreases with depth* until it is essentially gone at a depth of *half the wavelength*
- As water shallows, orbital motion will eventually impact the sea bottom, causing waves to pile up and *break* (topple forward) in the *surf zone*



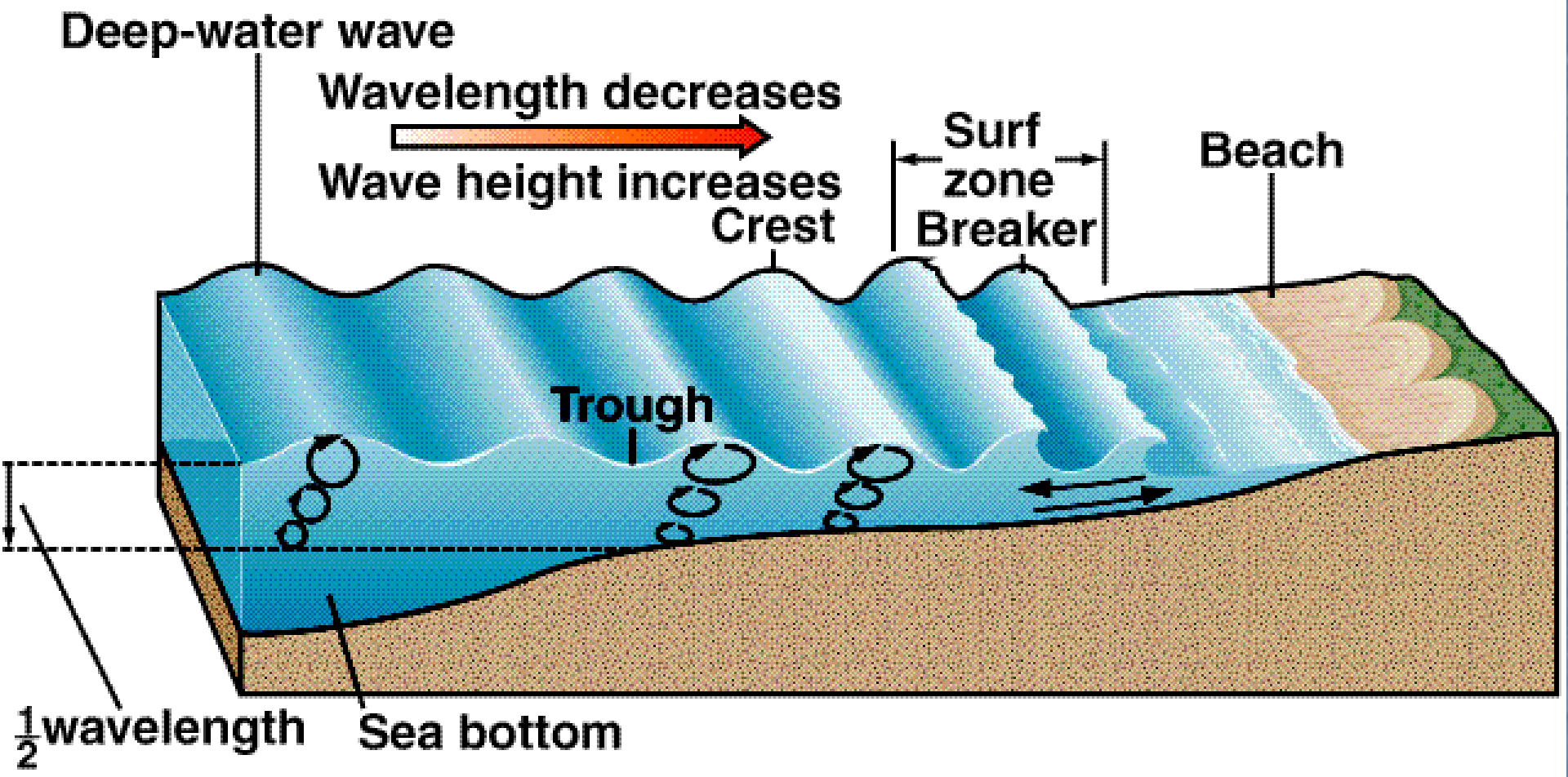
Orbital Motion of Water



Deep Water
Wave motion roughly circular



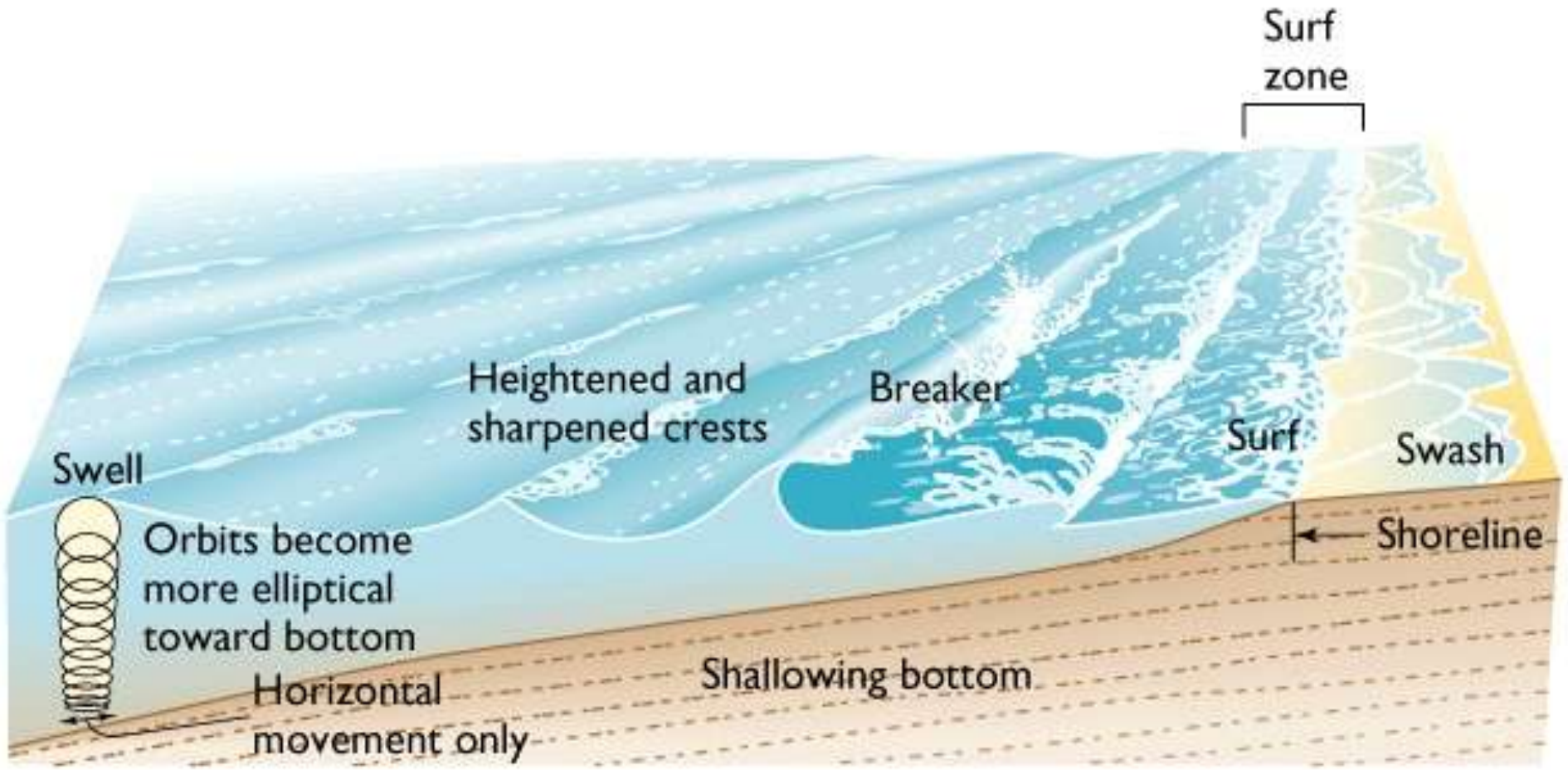
Deep-Water Wave Approaches Shore



Surf Zone — Dynamics of Waves

Elliptical motion, then back-and forth horizontal, moving sediment

Drag on bottom—top comes over=breakers



Waves and Energy Transfer

- Ordinary *ocean waves* are
  - ***not*** tsunamis
  - created by blowing *wind*
- When waves strike coastlines
  - wind *energy is transferred*
    - to beach rocks and sediments
    - erodes coastlines and transports sediments

Near-shore sediment balance

INPUTS

Sediments eroded from backshore cliffs by waves

Sediments eroded from upcurrent beach by longshore drift and current

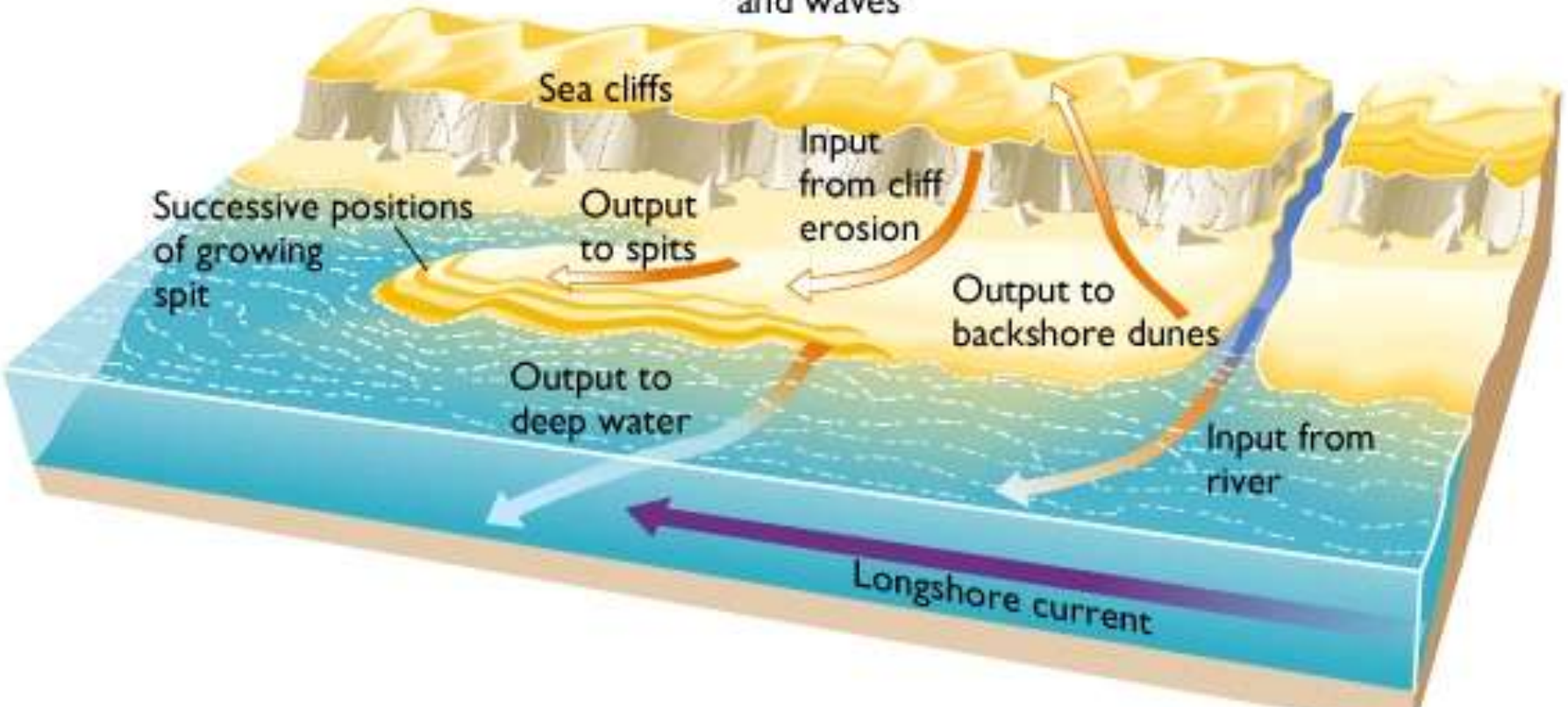
Sediments brought in by rivers

OUTPUTS

Sediments transported to backshore dunes by offshore winds

Sediments transported downcurrent by longshore drift and current

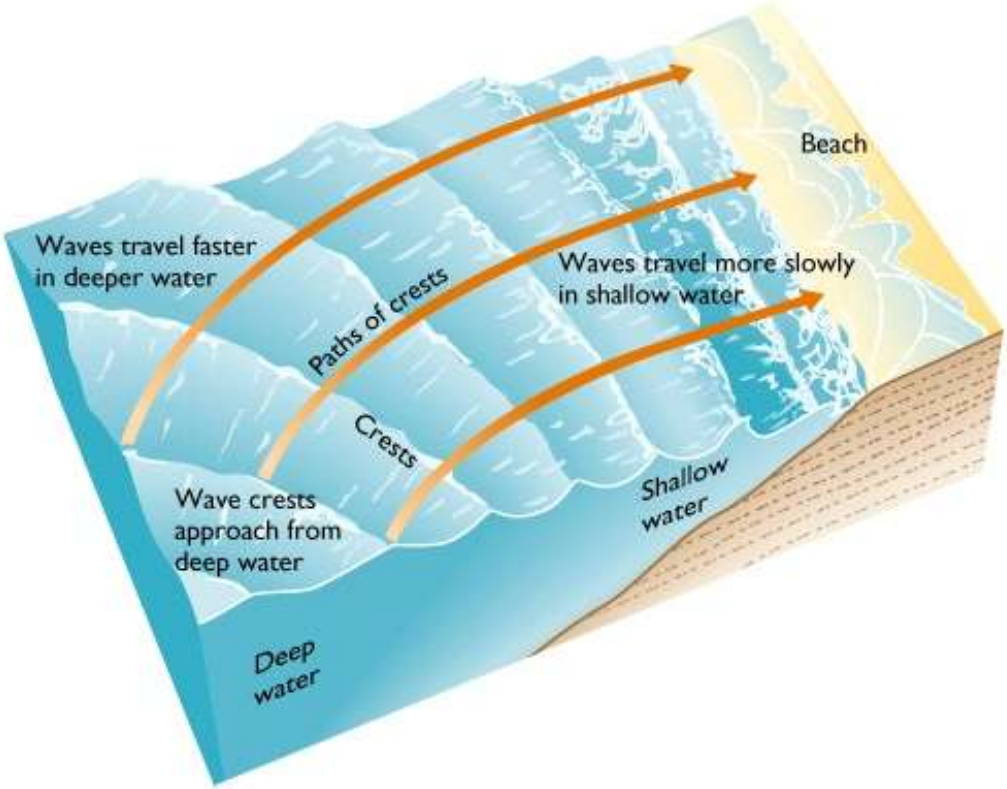
Sediments transported to deep water by tidal currents and waves



Nearshore Circulation

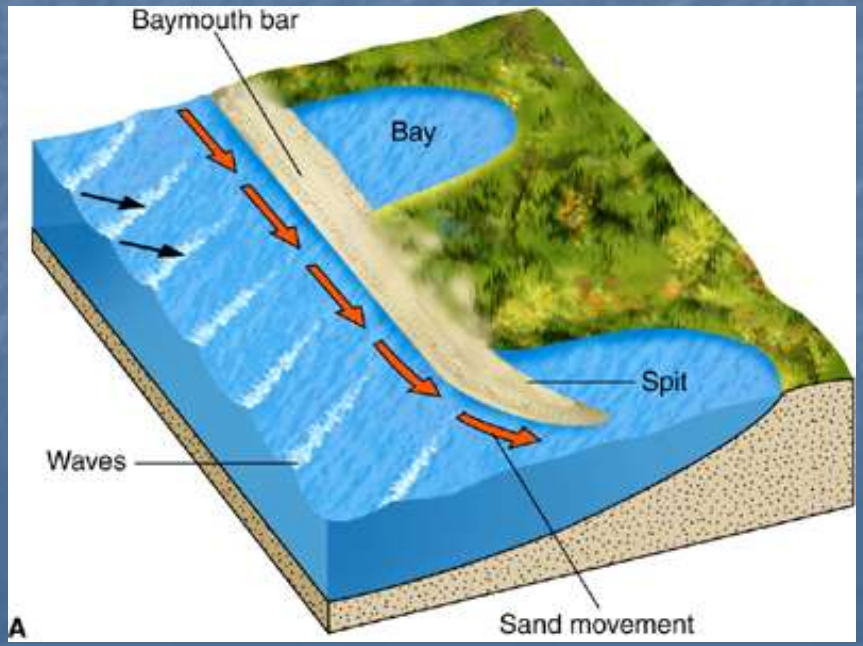
- Wave Refraction
- Longshore Currents
- Rip Currents
- Beaches
  - Beach Face
  - Marine Terrace
    - Wave-built
    - Wave-cut
  - Berm
  - Beach sediment

Waves "bend"
Refract as they approach shore (more head-on)



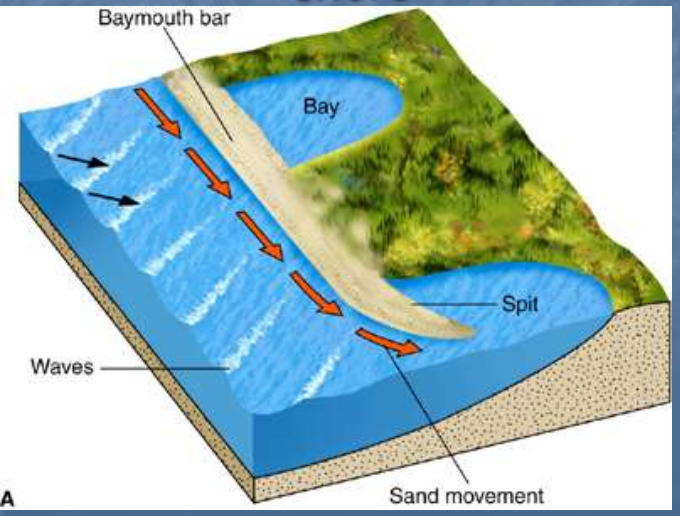
Longshore Drift

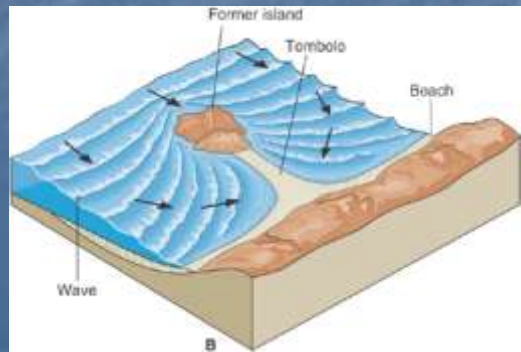
- ***Longshore drift***
  - waves strike shoreline at an angle
  - sediment moves ***parallel to shore***
- **Sediment**
  - some moves as waves wash up on the ***beach face***
  - most transported by ***longshore current*** **in** ***surf zone***



Landforms Longshore Drift

- Sediment "sandbars"
  - ***Spits***
    - build into open water from a point of land
  - ***Baymouth bars***
    - ridges of sediments that cut bays off from the ocean
  - ***Tombolo***
    - bar of sediment linking a former island to the shore

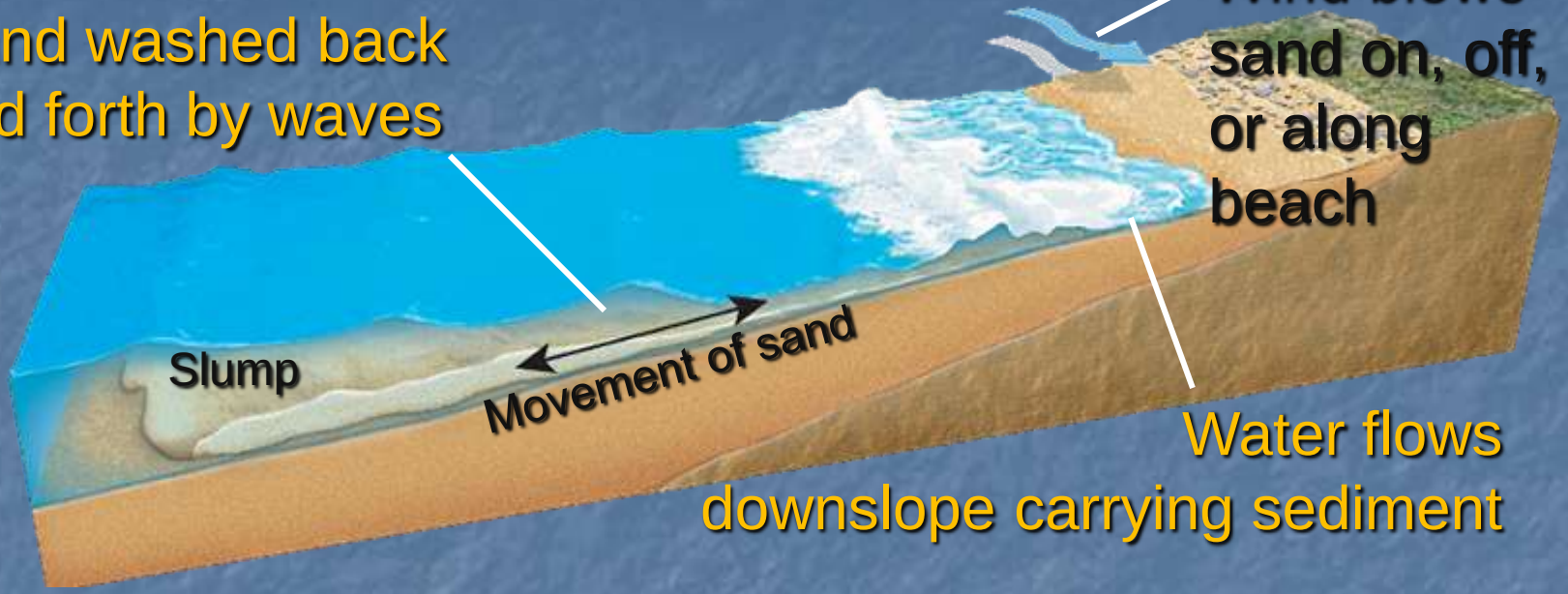




How Sand and Other Sediment get Moved on a Beach

Sand washed back and forth by waves

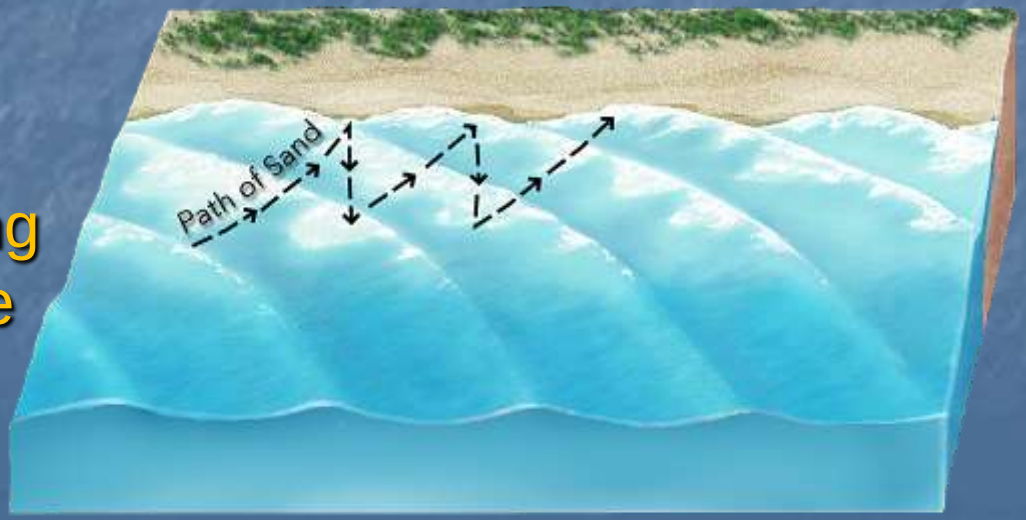
Wind blows sand on, off, or along beach



14.04.c

Water flows downslope carrying sediment

Sediment moves laterally along coast if wave at angle to beach

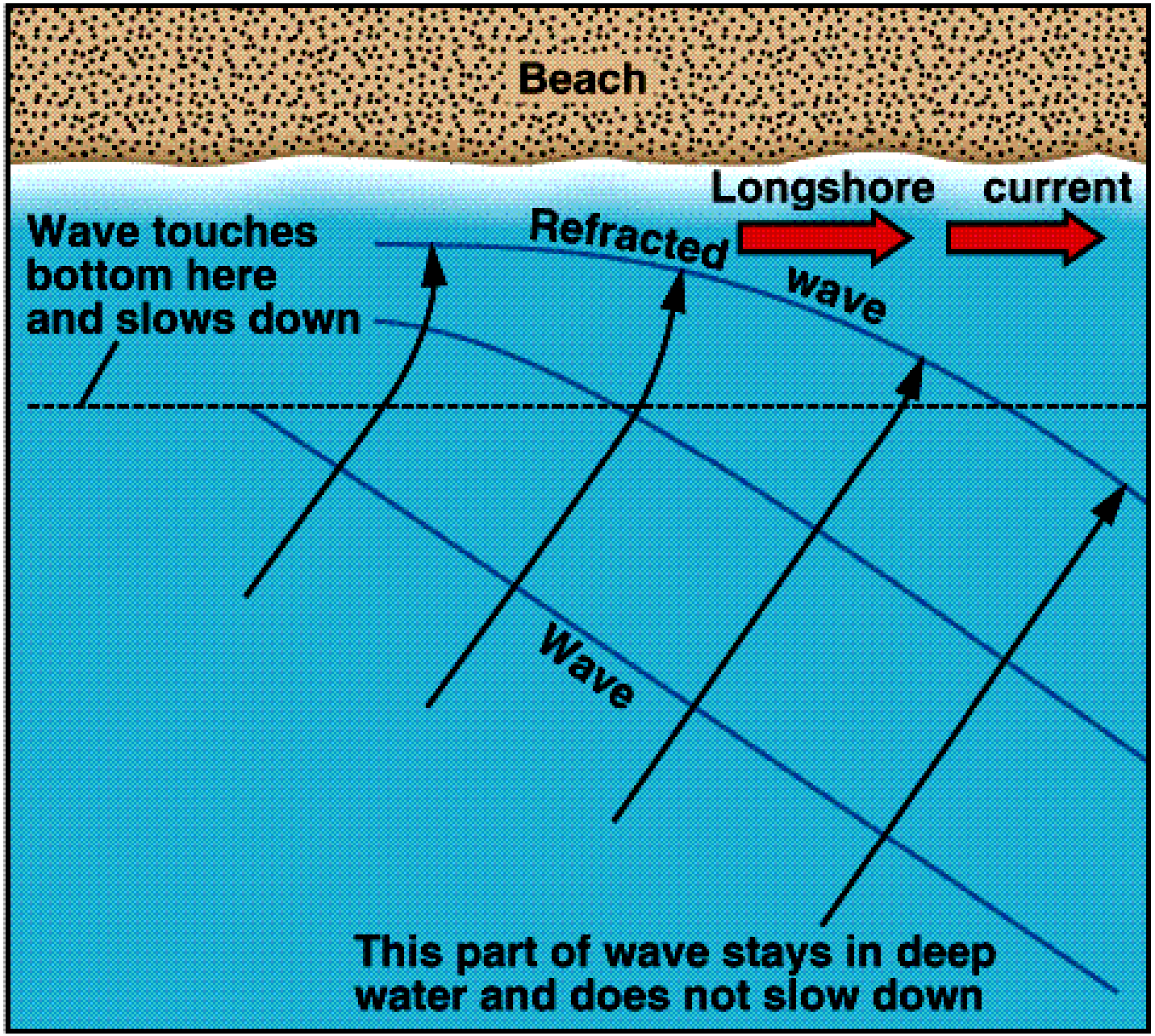


Washes up at angle, but washes directly down slope

Longshore Drift of Sediment

- Longshore Drift
  - Swash/Backwash
- Spit
- Baymouth Bar
- Tombolo
- Human Interference with Sand Drift
  - Jetties
  - Groins
  - Breakwater

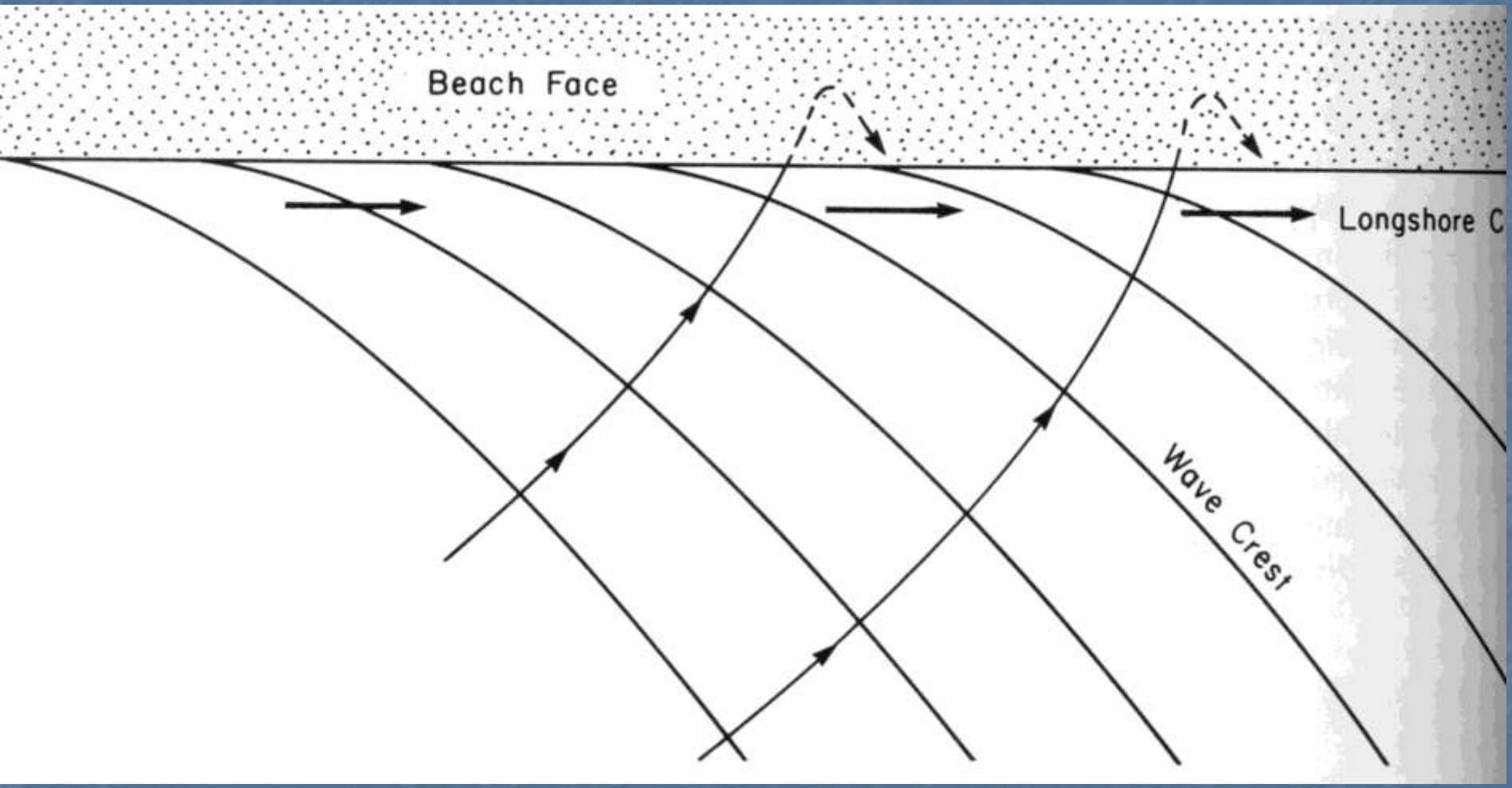
Waves Arriving At Shoreline



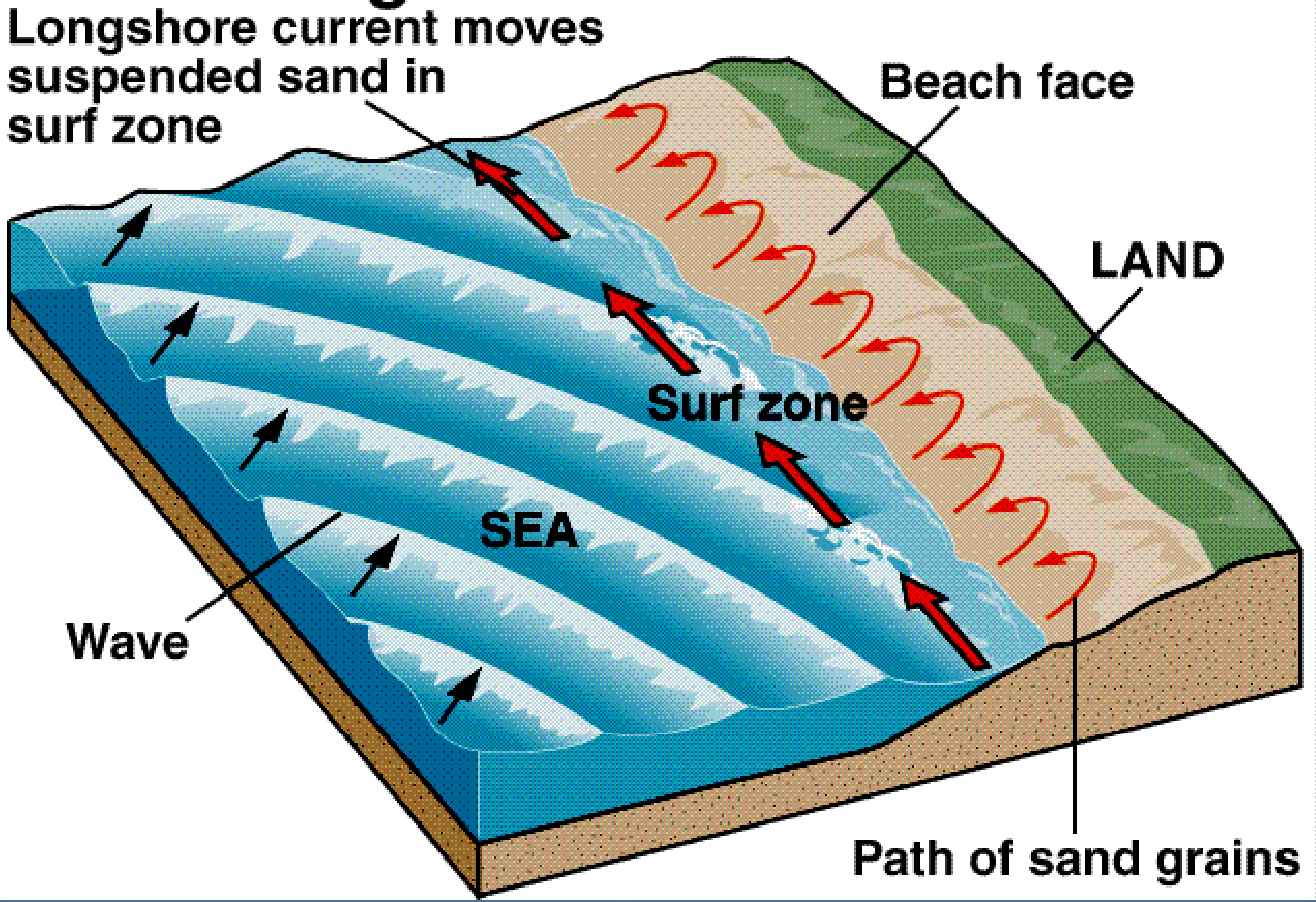
A

Wave Refraction

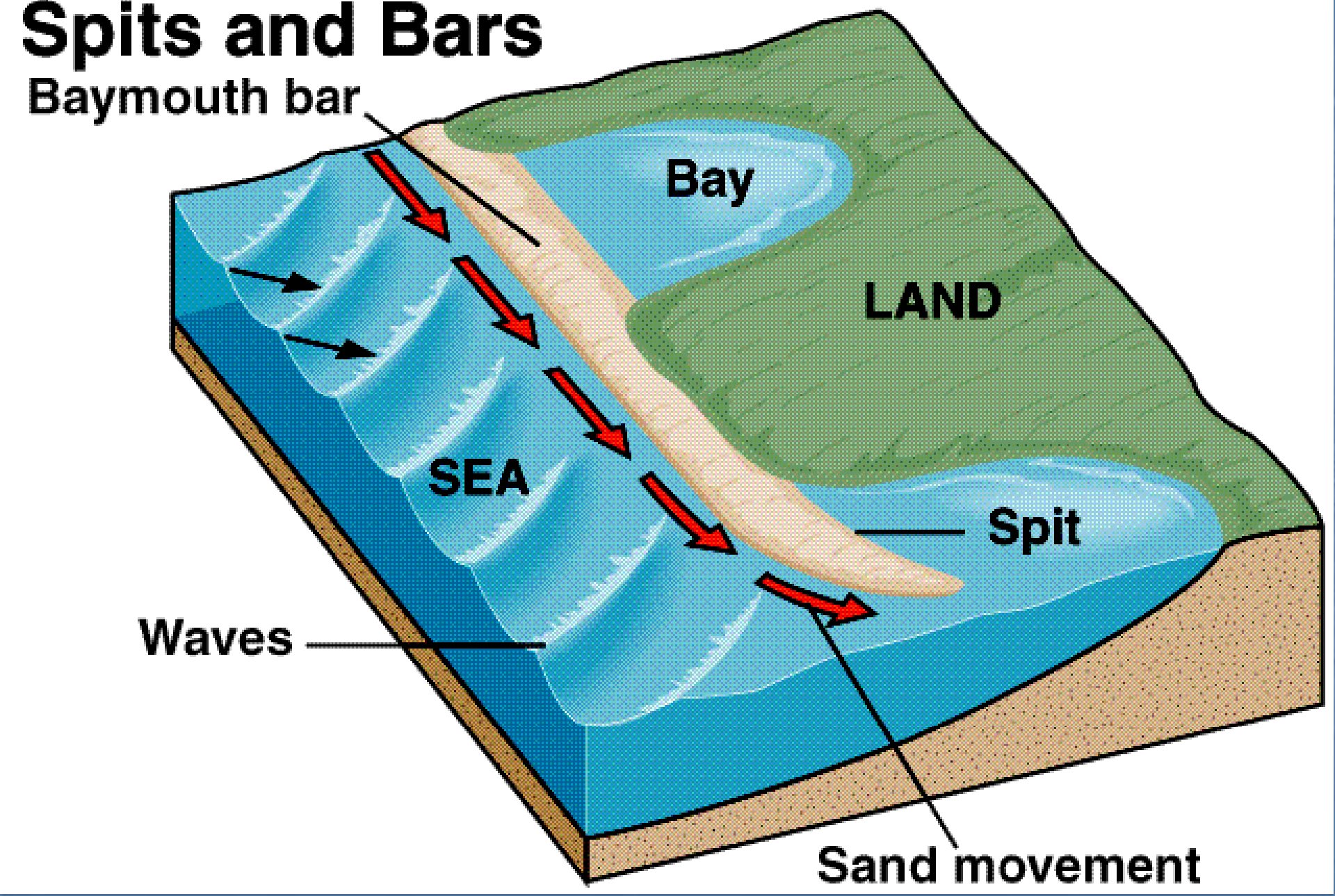
Longshore Drift of Sand Grains



Longshore Drift of Sand



Longshore Drift Forms Spits and Bars



Coasts and Coastal Features

- Drowned Coasts
  - Estuaries
  - Fiords
- Uplifted Coasts (Emergent)
  - Uplifted Marine Terraces
- Coasts Shaped by Organisms
  - Algal Reefs
  - Branching Mangrove Roots

Near-Shore Circulation

- Waves hitting the shoreline at angle
  - bend and change direction
  - become nearly parallel to the shoreline *(**wave refraction**)*
- Refracted waves
  - still impact coast at slight angle
  - push water and sediments
    - parallel to the coastline *(**longshore current**)*

Fig. 14.5-B, pg. 338

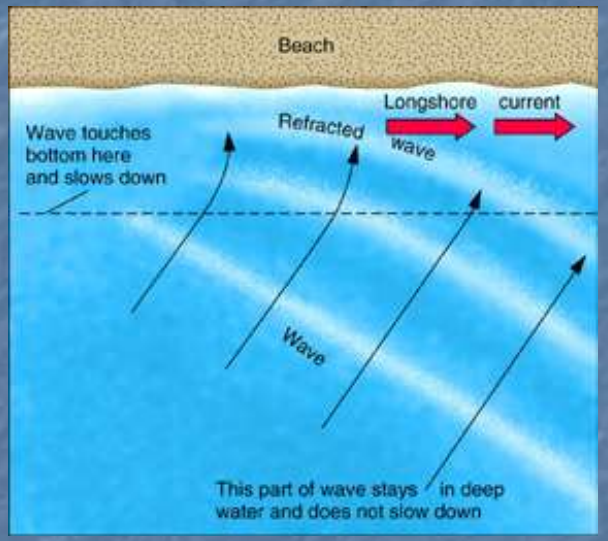
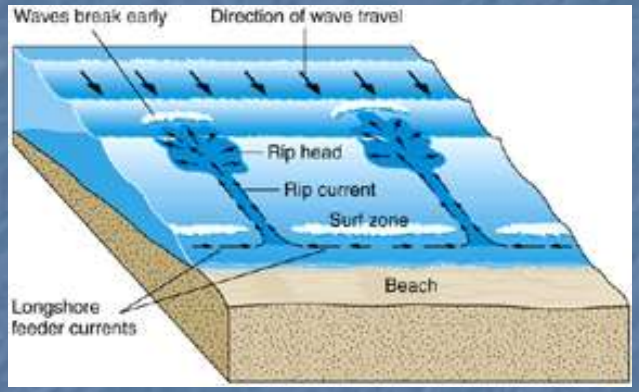


Fig. 14.5-A, pg. 338

Near-Shore Circulation

- Narrow currents that flow straight out to sea through the surf zone are called ***rip currents***
- Rip currents are fed by water in the surf zone, where the backflow of water washed up onto the beach gets localized
  - Rip currents are located where waves in the surf zone are lowered by underwater channels or wave interference patterns
- Rip currents die out quickly with depth and end just outside the surf zone



Near-Shore Circulation

- ***Rip currents***
  - *narrow **out**flows*
  - flow straight back to sea through surf
  - fed by localized surf zone water
  - located where waves in the surf zone are
    - lowered by underwater channels
    - or wave interference patterns
  - die out quickly with depth
  - end just outside the surf zone

Fig. 14.6-A, pg. 339

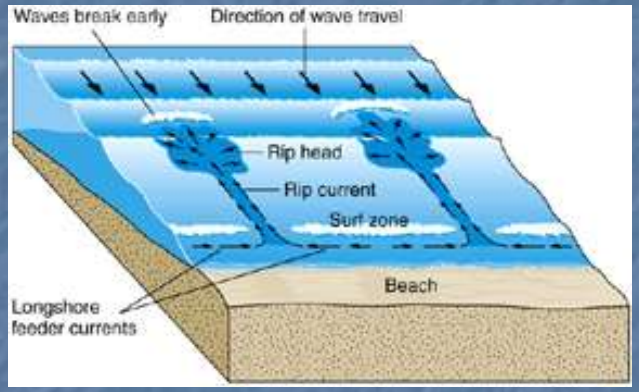
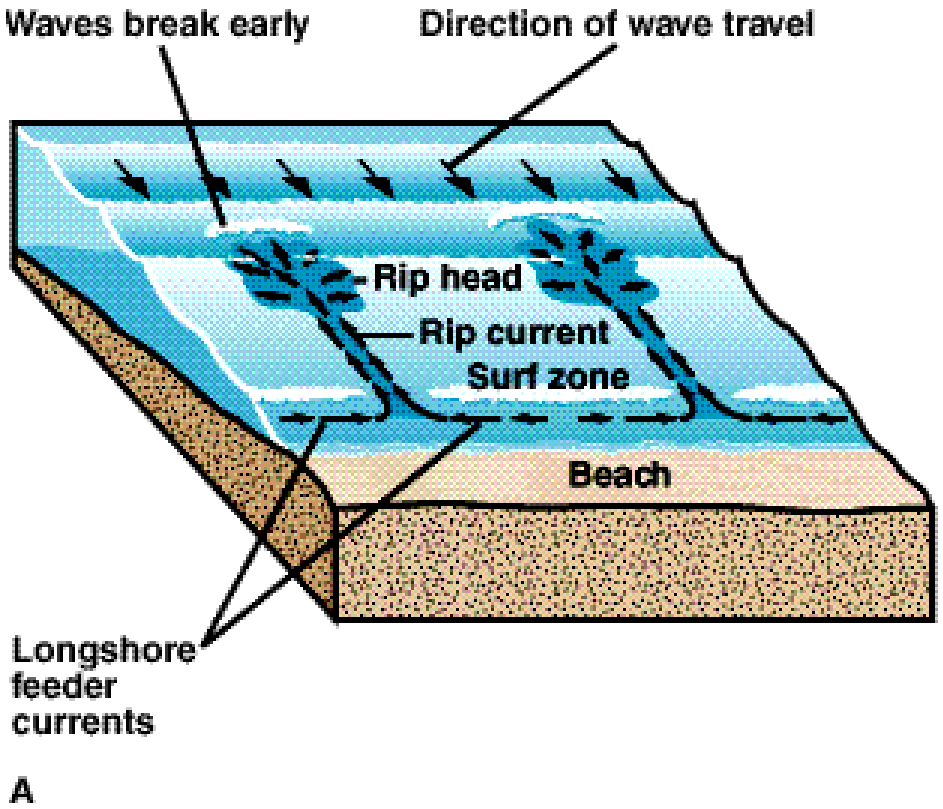
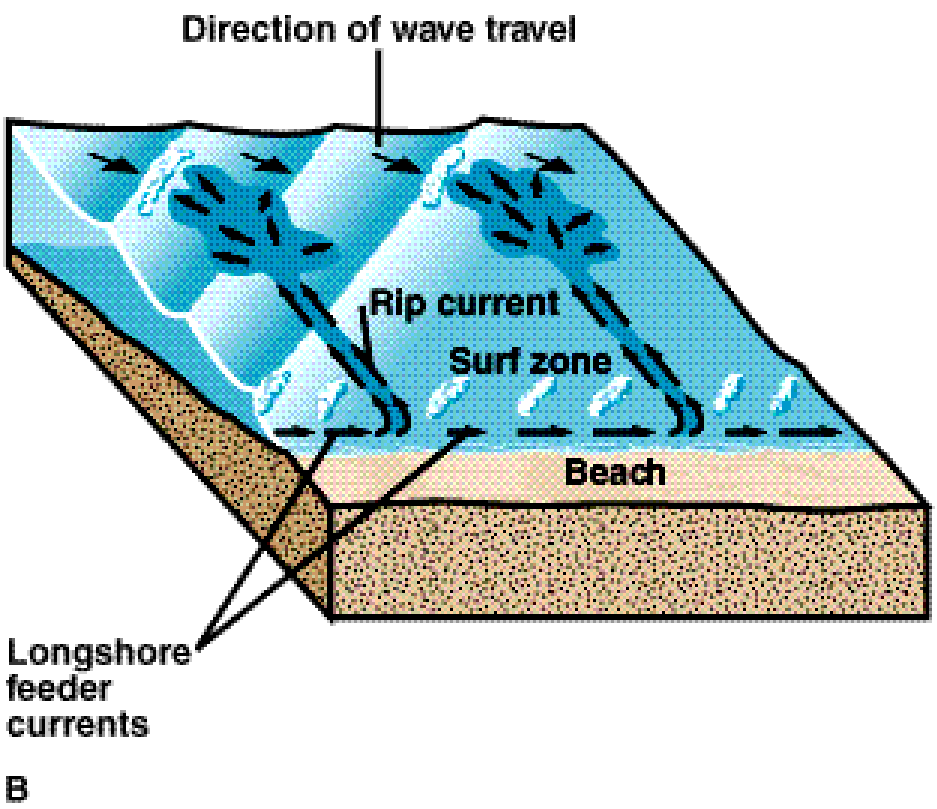


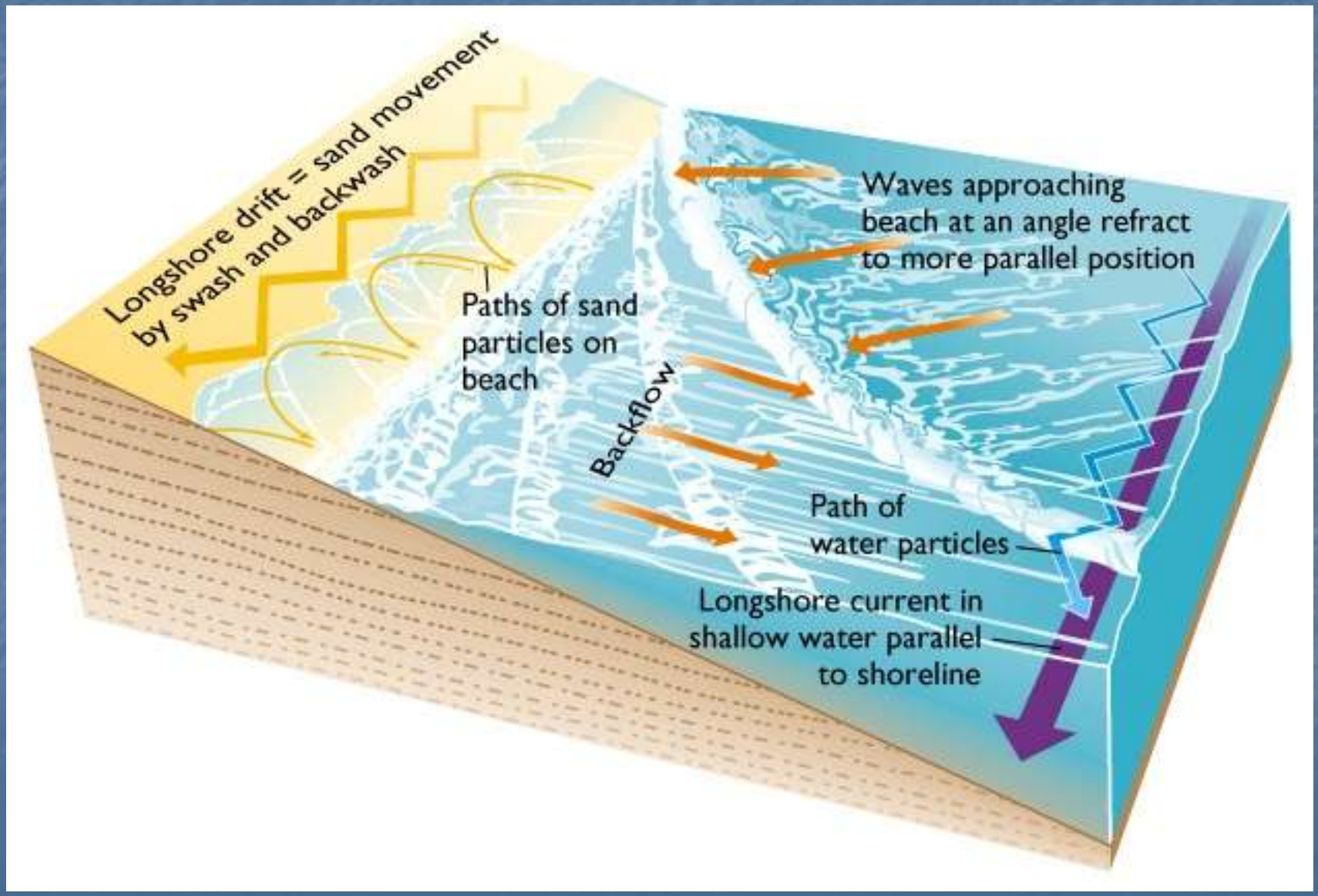
Fig. 14.6-C, pg. 339

Rip Current Development



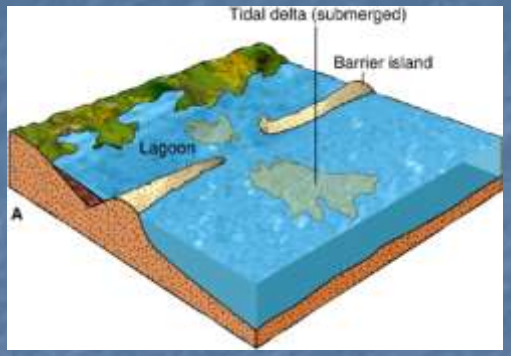


Currents: longshore and rip

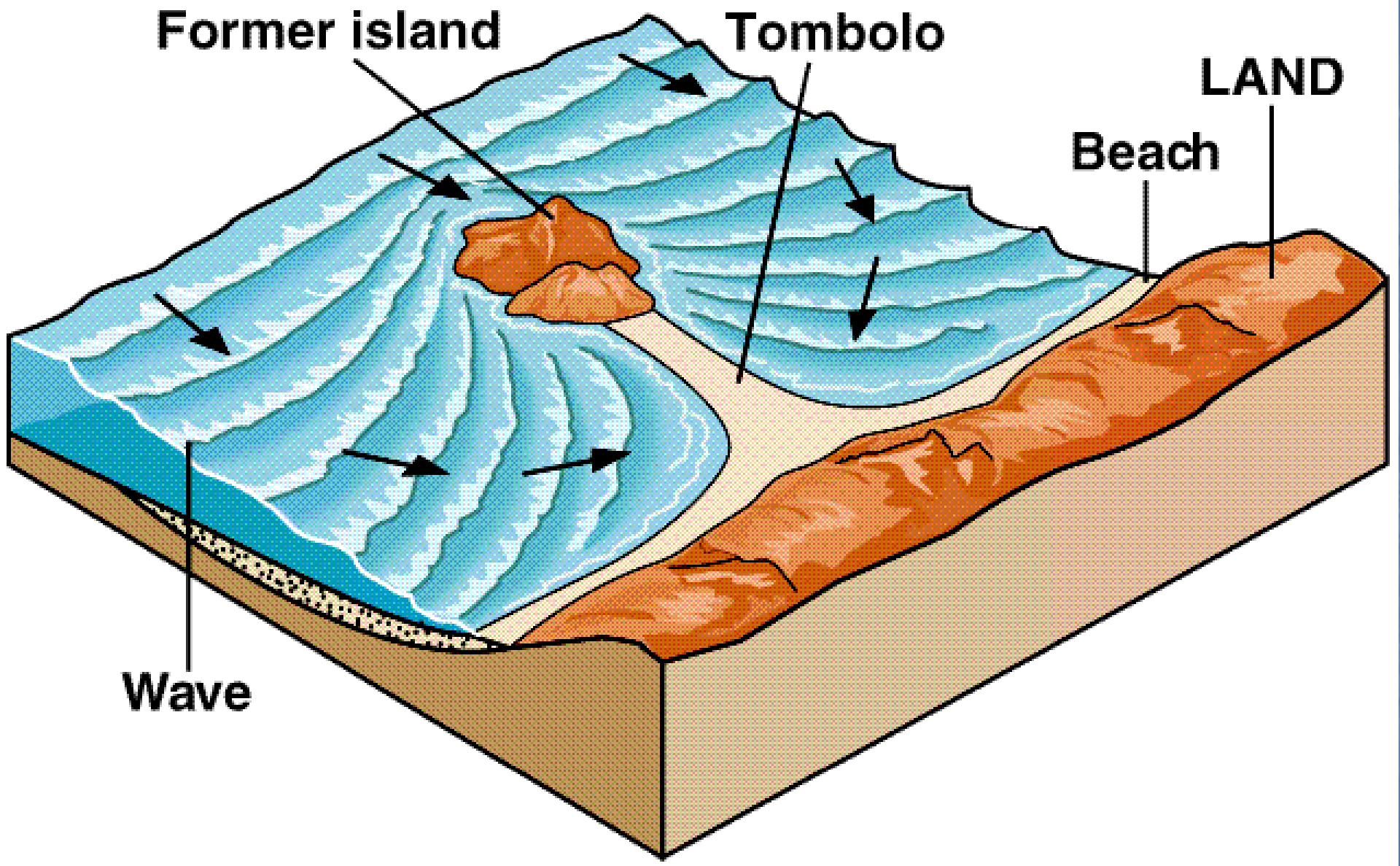


Depositional Coasts

- ***Depositional coasts***
  - have gently sloping plains
  - show only minor erosion
  - shaped by sediment deposition
    - particularly ***longshore drift***
- often associated with ***Barrier islands***
  - are *sand ridges* **parallel to shoreline**
  - ***Lagoons*** separate mainland and barrier islands
  - Barrier islands *dynamic*
    - **rapid** erosion and deposition
    - shape changes during strong storms
    - High human populations lead to *property loss*



Tombolo Formation

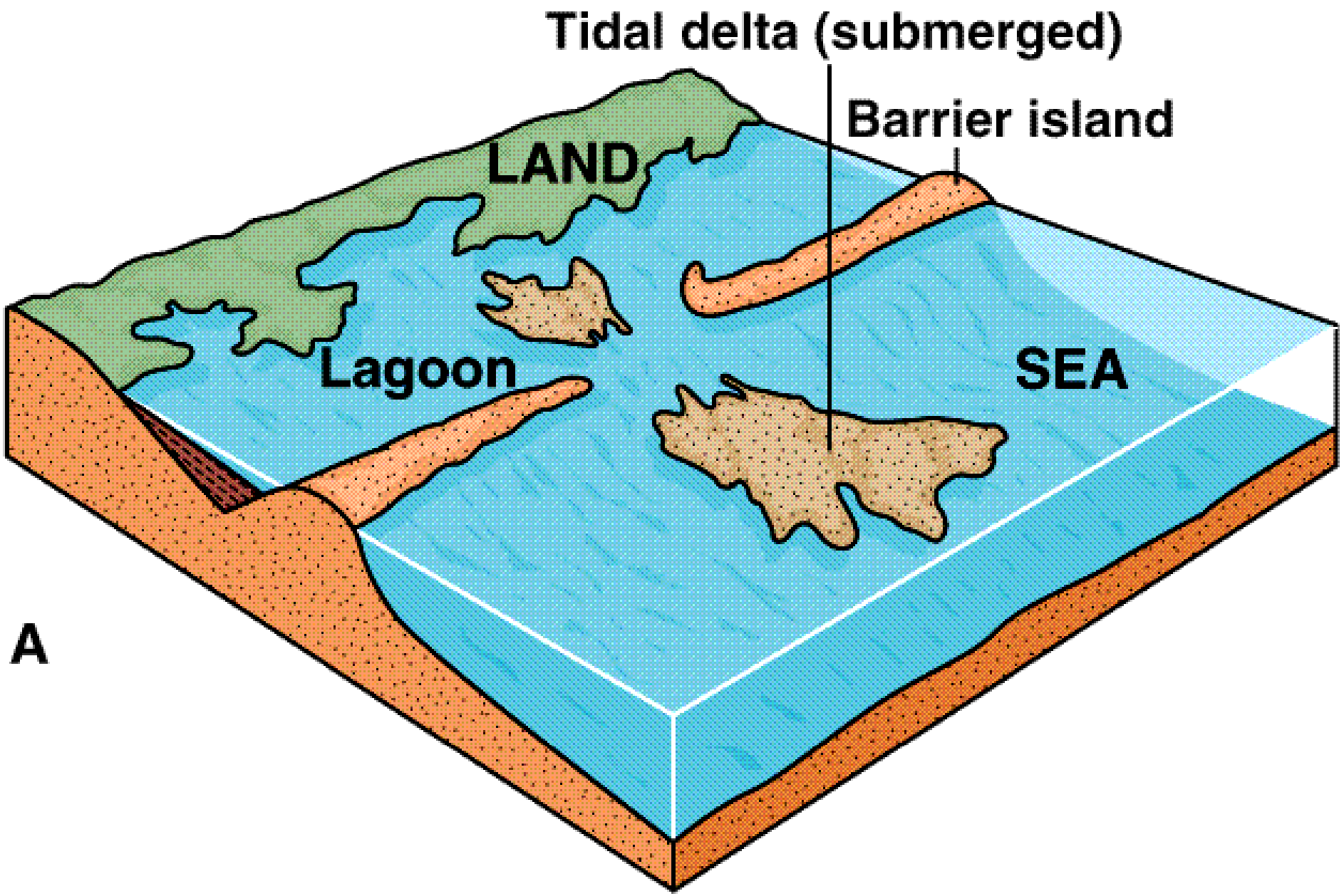


A

Tombolo Near Santa Cruz, CA

B

A Barrier Island

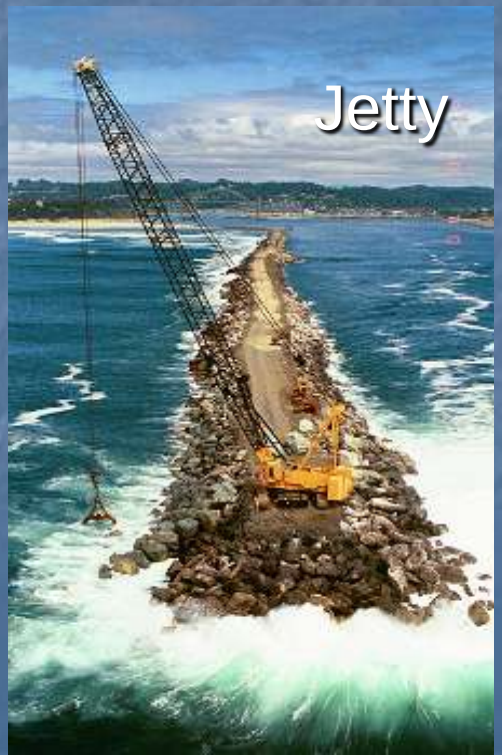


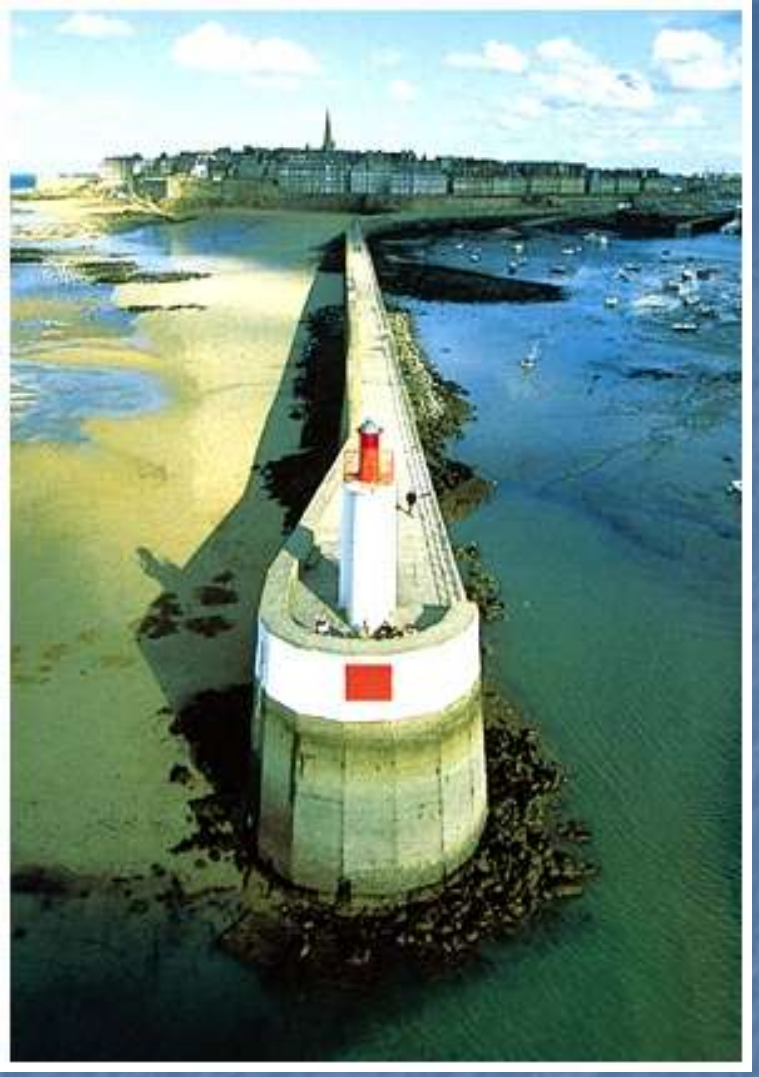
Approaches to Shoreline Problems


Sea wall and riprap


Breakwater


Beach nourishment


Jetty



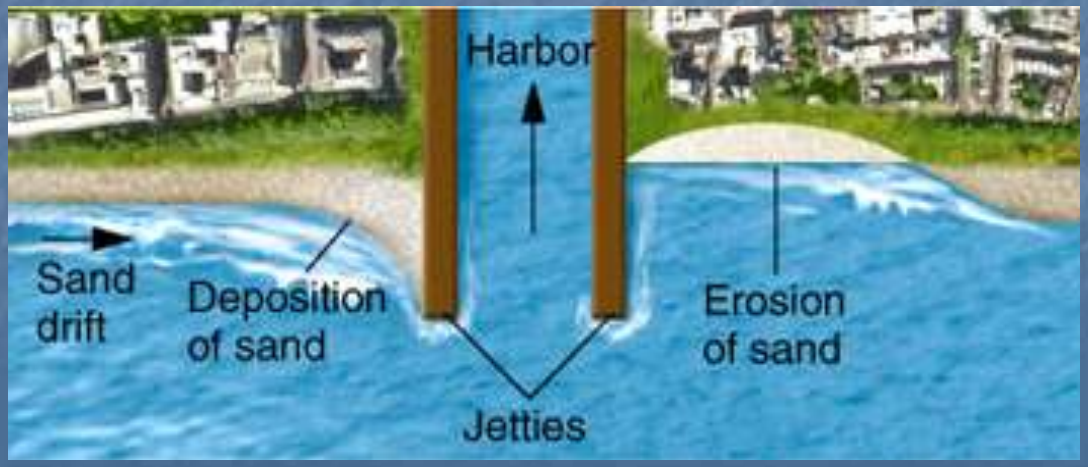
Human impact

Groin

Beach filling

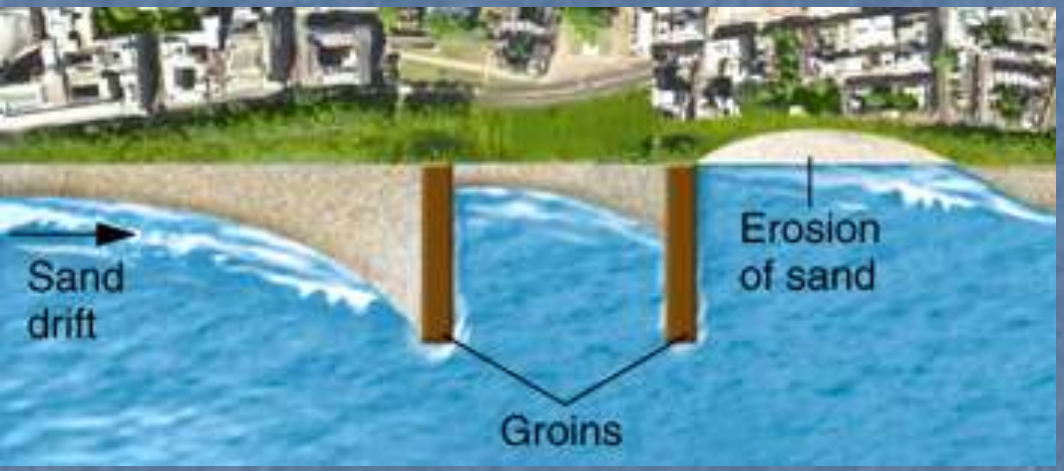
Human Interference with Sand Drift

- Human engineered structures
  - can interrupt sand moving along a beach
  - *Jetties*
    - are rock walls
    - prevent harbor entrances from filling with sand
      - sand piles up at upcurrent jetty
      - downcurrent beaches erode severely

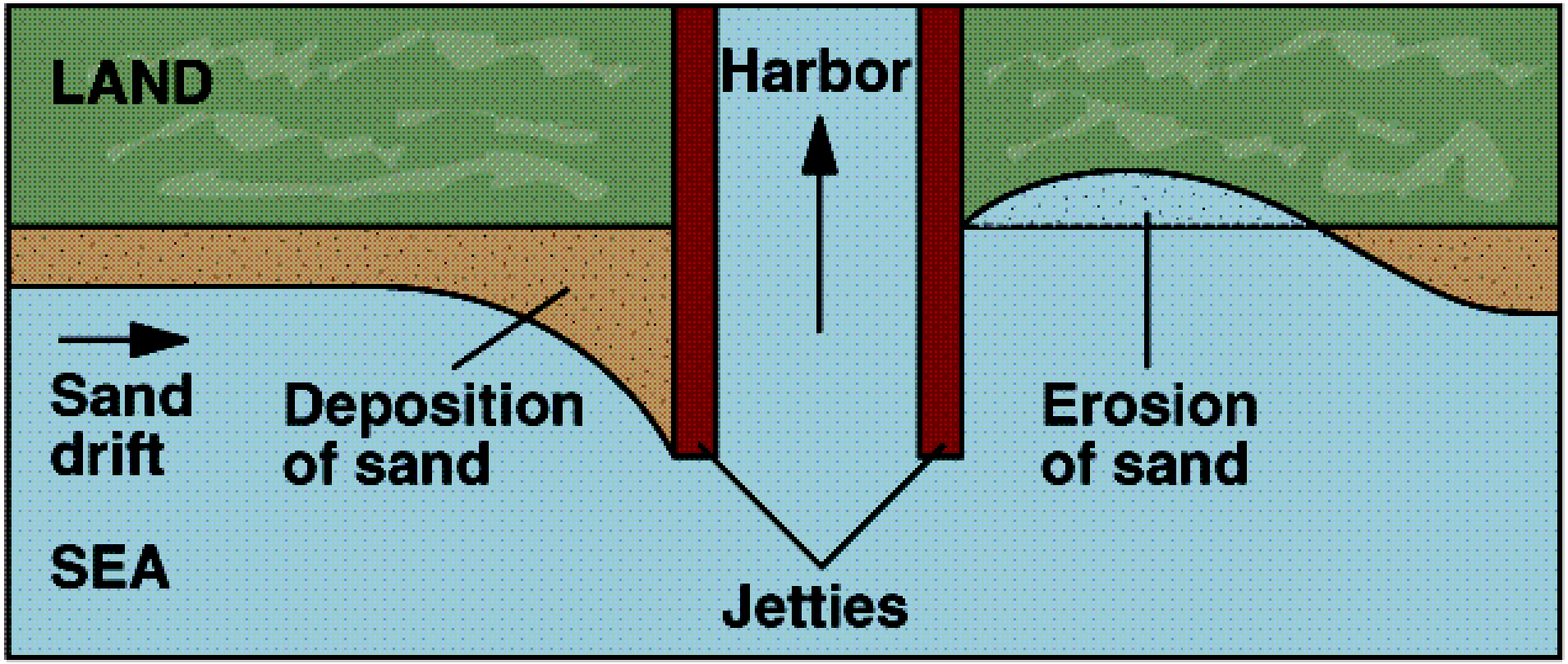


Human Interference with Sand Drift

- Human engineered structures
  - can interrupt sand moving along a beach
  - ***Groins***
    - are short walls ***perpendicular to shore***
    - catches sand - widens beaches
    - downcurrent beaches erode severely

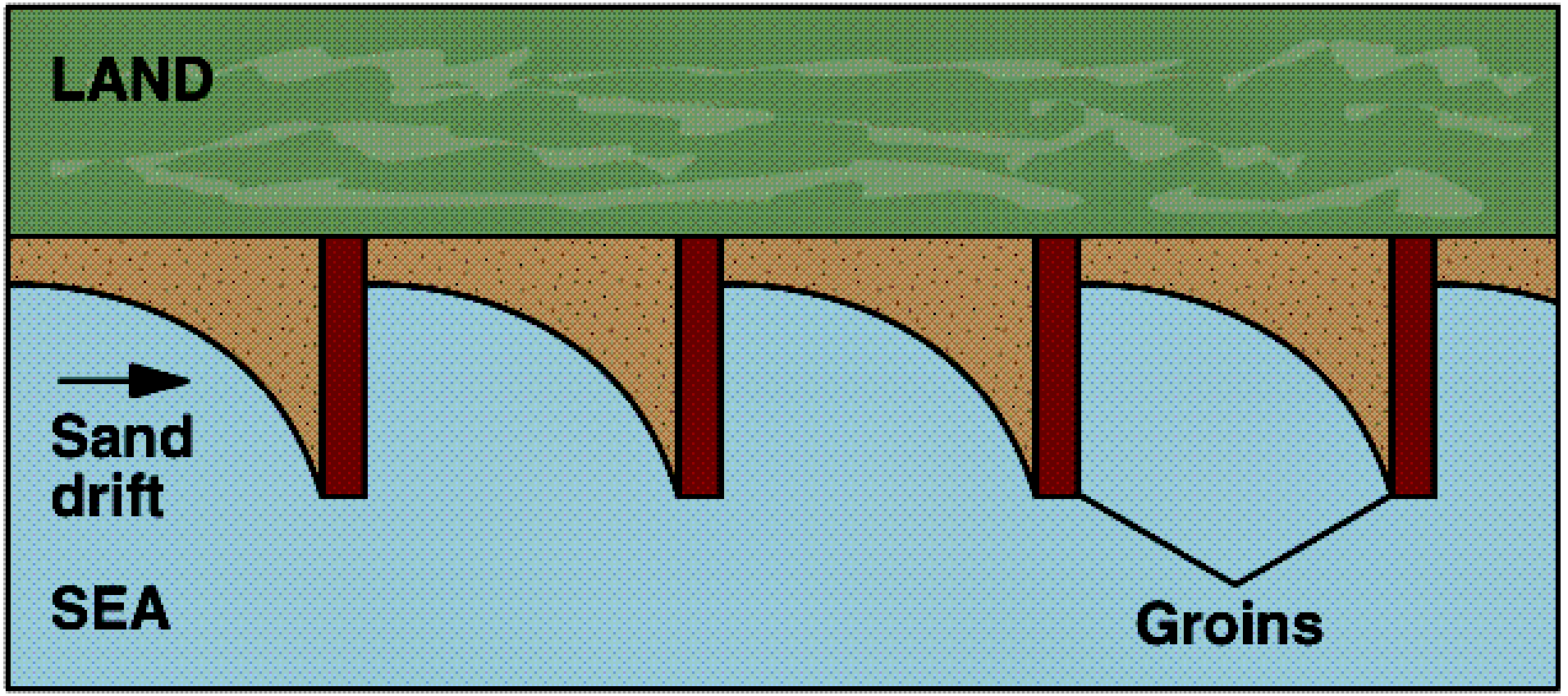


Jetties



A

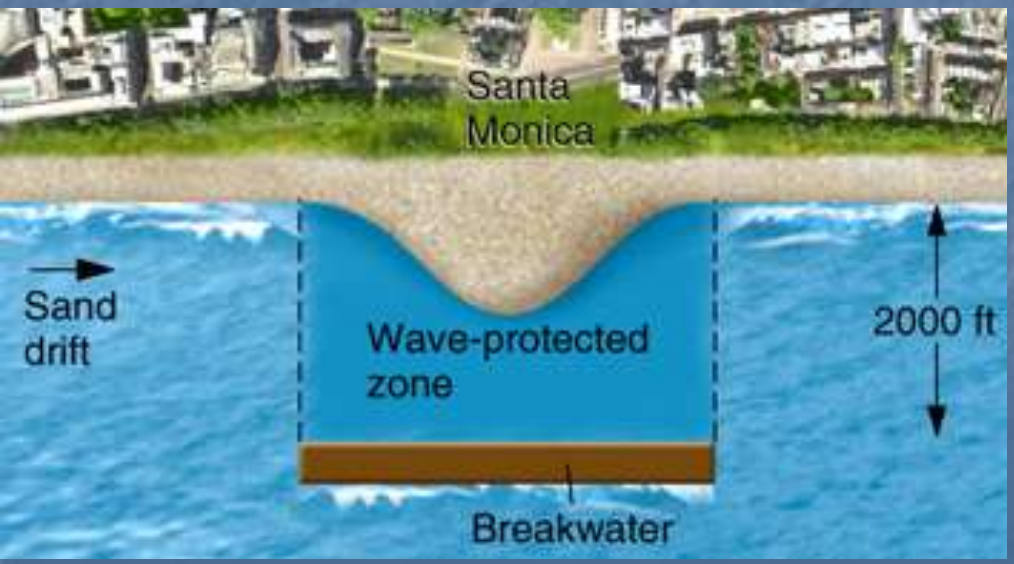
Groins



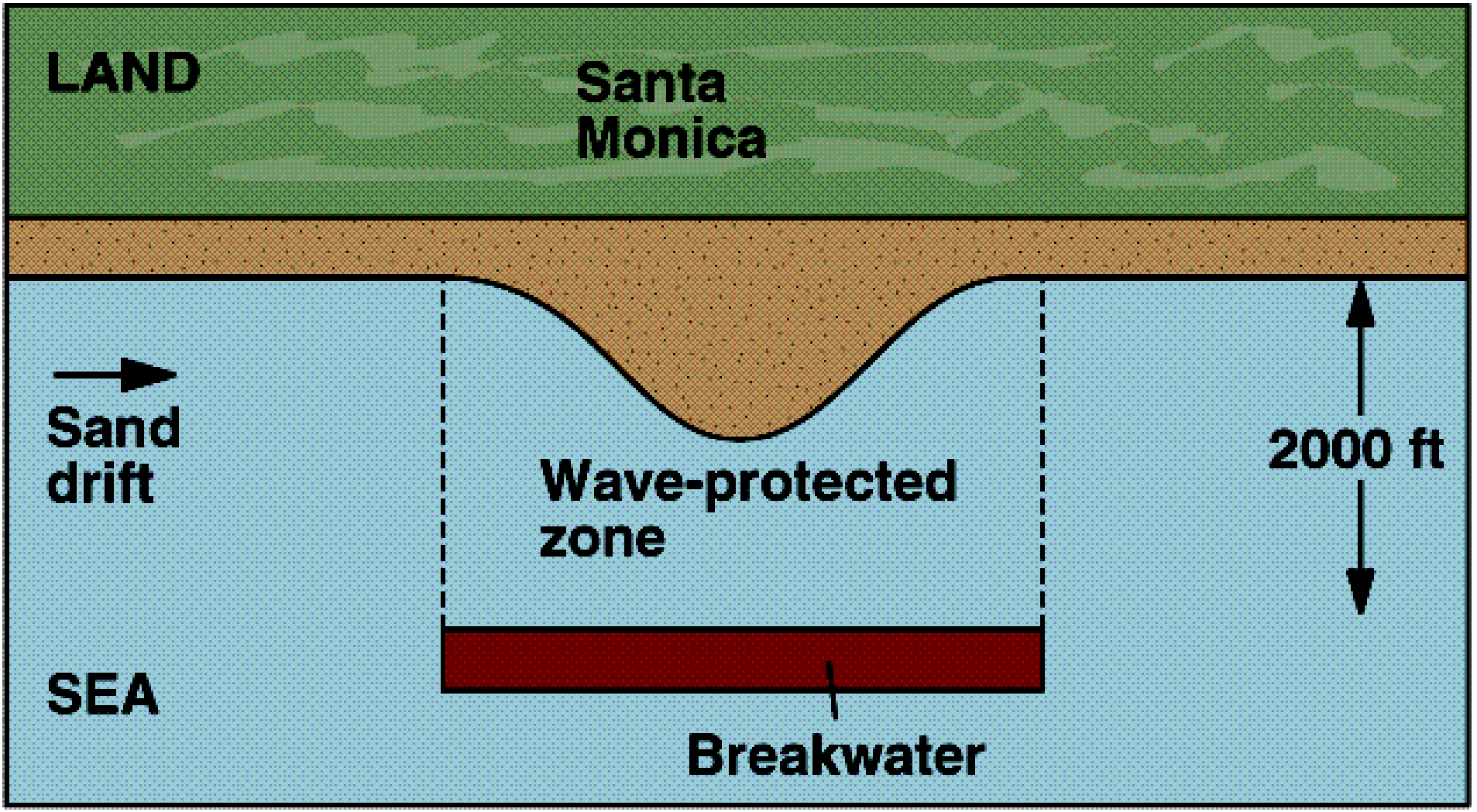
B

Human Interference with Sand Drift

- Human engineered structures
  - ***Breakwaters***
    - offshore structures ***parallel to shore***
    - absorbs force of large breakers
    - provides "quiet" water near shore
      - sand builds up shoreward of the breakwater
      - eventually fills in area of "quiet water"



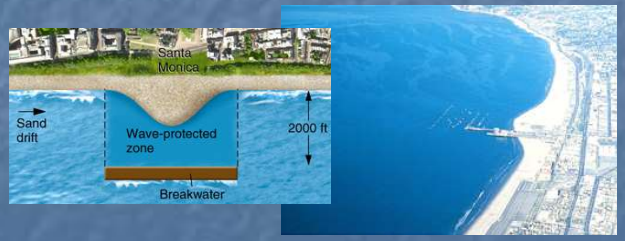
Breakwater



C

Human Interference with Sand Drift

- Human engineered structures can interrupt the flow of sand along a beach
  - ***Jetties*** are rock walls designed to prevent the entrance of a harbor from filling with sand
  - ***Groins*** are short walls perpendicular to shore built to trap sand and widen a beach
  - ***Breakwaters*** are offshore structures, typically parallel to the shoreline, built to absorb the force of large breakers and provide quiet water near shore



Coasts and Coastal Features

- *Coasts*
  - all land near the sea including
    - beach
    - the strip of land inland of beach
  - can be
    - rocky, mountainous and cliffed (Pacific side of N. Am.)
    - broad gentle plains (S. Atlantic side of N. Am.)
- Coastal evolution can be
  - *Erosional*
  - *Depositional*
  - *Drowned*
  - *Emergent*
  - *Organism growth*

Wave Refraction on an Irregular Coast

Coasts and Coastal Features

- Erosional Coasts
  - Headlands
  - Coastal Straightening
  - Sea Cliffs
  - Wave-cut Platform
  - Stacks
  - Arches
- Depositional Coasts
  - Barrier Islands
    - Tidal Deltas
  - Deltas
  - Glacial Deposition

Erosional Coasts

- Wave erosion of headlands creates
  - "Retreating" ***Sea Cliffs***
  - ***Wave-cut Platforms***
  - ***Sea Stacks***
  - ***Arches***
- **Sea walls** built
  - to *slow or redirect* wave energy
  - often hastens erosion of beaches

Fig. 14.15, pg. 346

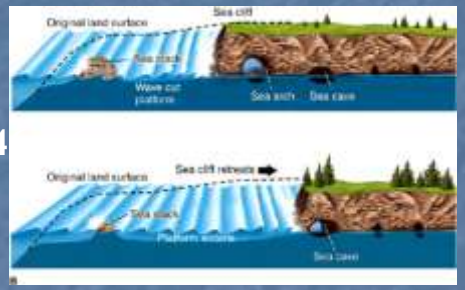


Fig. 14.16, pg. 34

Fig. 14.17, pg. 347

Shoreline Features Carved by Erosion

14.05.a


Sea cliffs


Caves and sea arches


Pinnacles and sea stacks


Wave-cut platforms

Erosional Coasts

- Erosional coasts
  - common where ***bays*** separate rocky ***headlands*** jutting into ocean
  - ***Coastal straightening*** occurs
    - wave ***erosion*** of headlands
    - wave ***deposition*** of sediments in bays

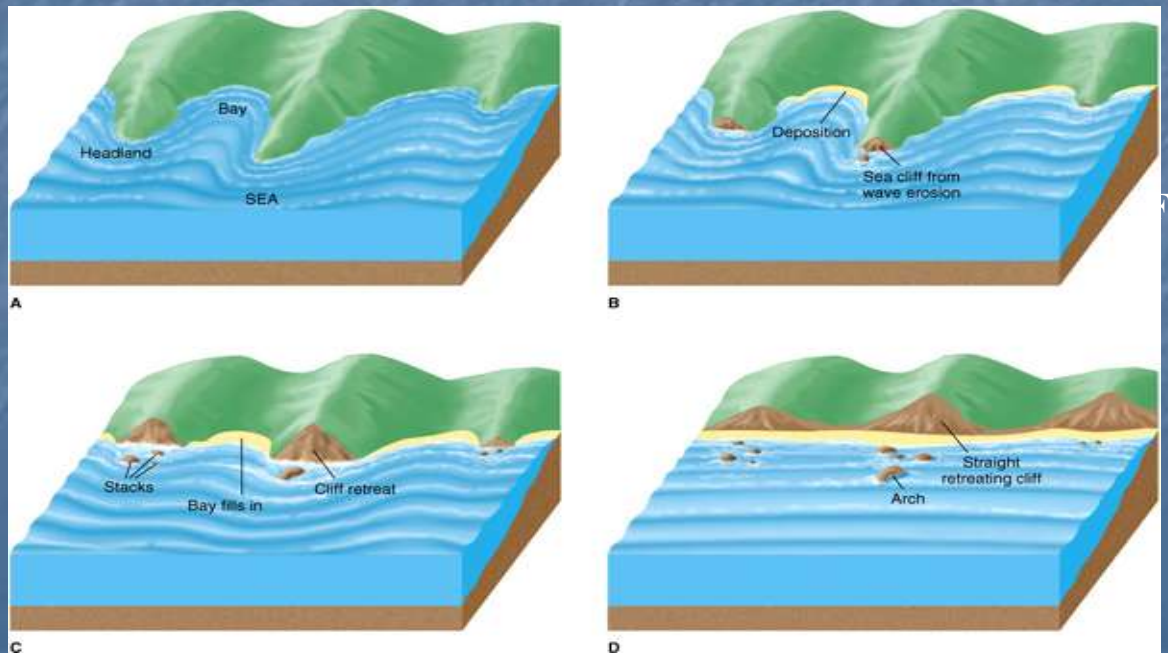


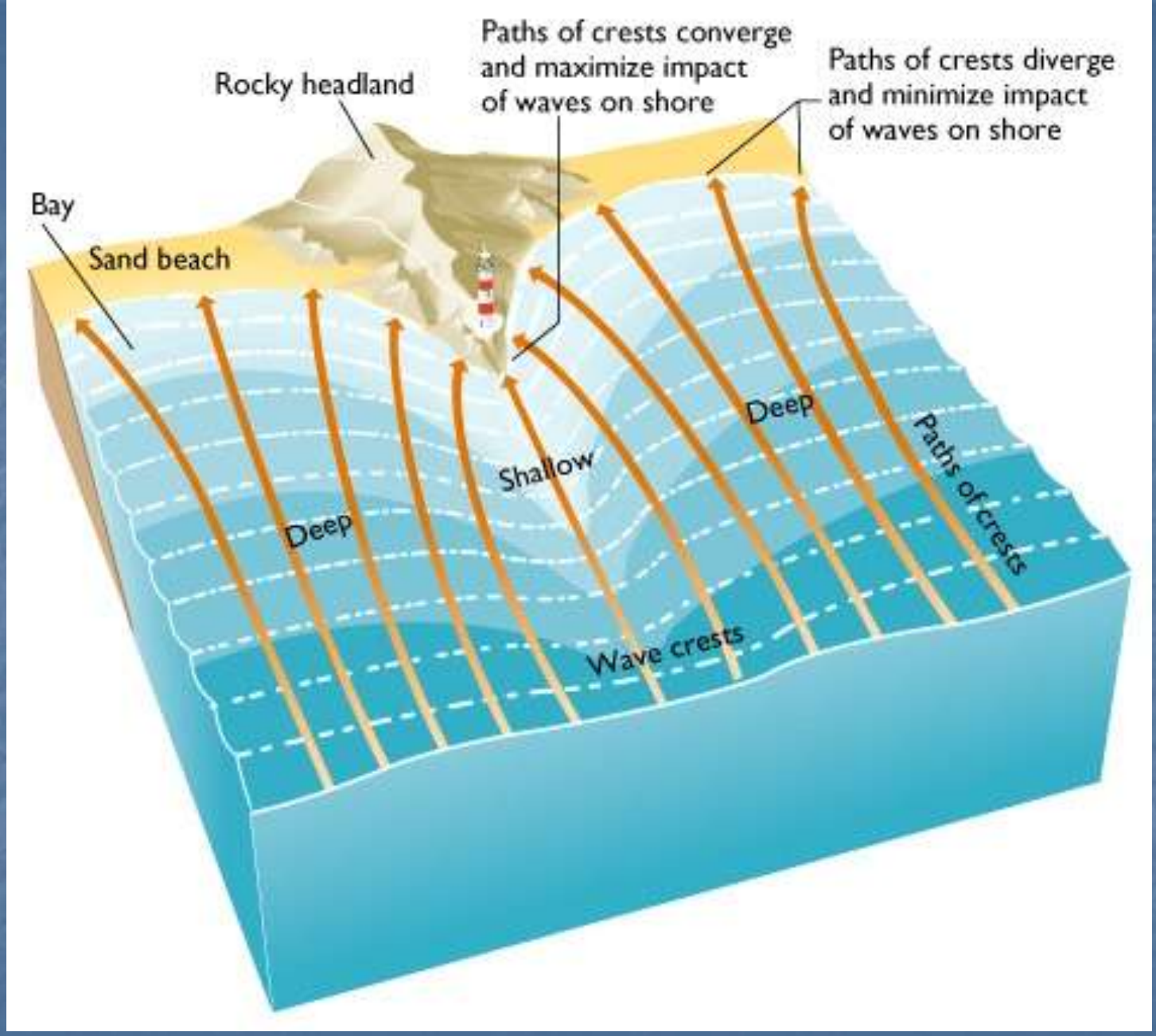
Fig. 14.14-A,-B,-C,-D, pg. 345

Formation of a Sea Cave and Sea Stack

Promontory extends out into the sea

Weak or fractured rock forms cave

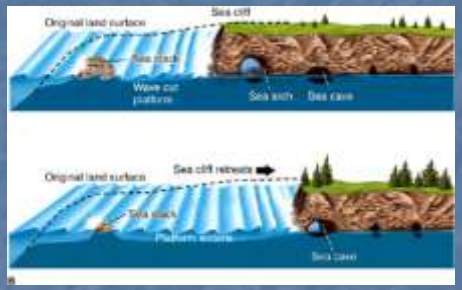
Continued erosion leads to collapsed roof of cave



Focusing energy: Contrast headlands and bays

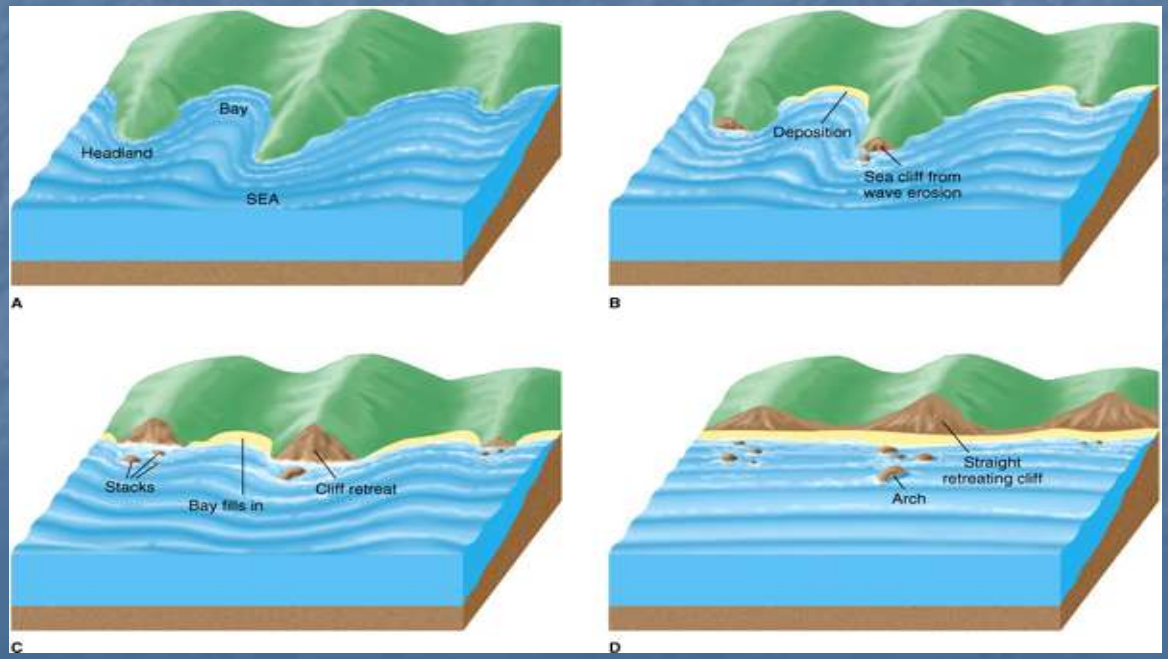
Erosional Coasts

- Wave erosion of headlands will produce ***sea cliffs*** which will retreat with time
  - ***Sea walls*** are sometimes used to protect retreating shorelines, but eventually are undermined by the wave energy they reflect toward their bases
  - Sea walls will also hasten erosion of any sand beach between them and the shoreline
- Other features common to retreating shorelines are ***wave-cut platforms***, ***sea stacks*** **and** ***arches***

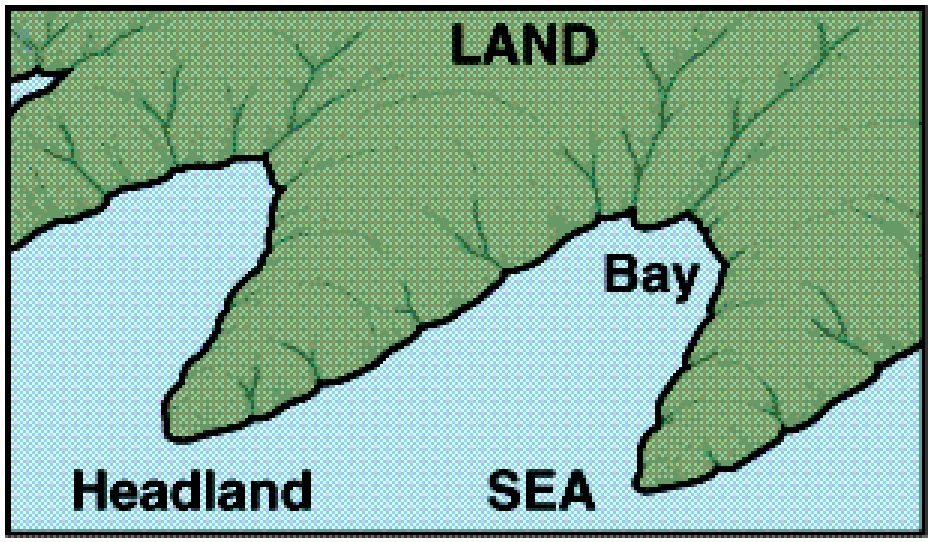


Erosional Coasts

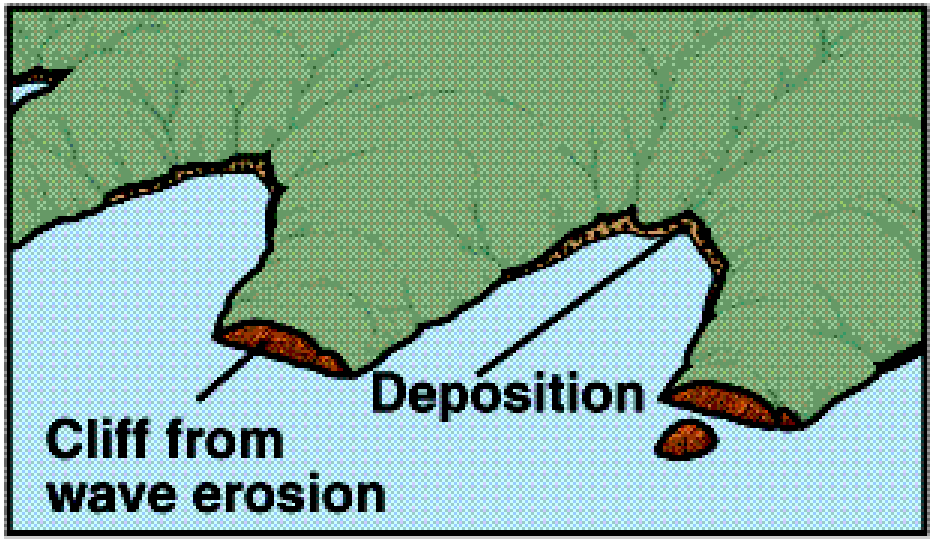
- Erosional coasts are common where *bays* are separated by irregular rocky *headlands* jutting out into the ocean
  - ***Coastal straightening*** will occur, with wave erosion of headlands and wave deposition of sediments in bays



Wave Erosion of Headlands

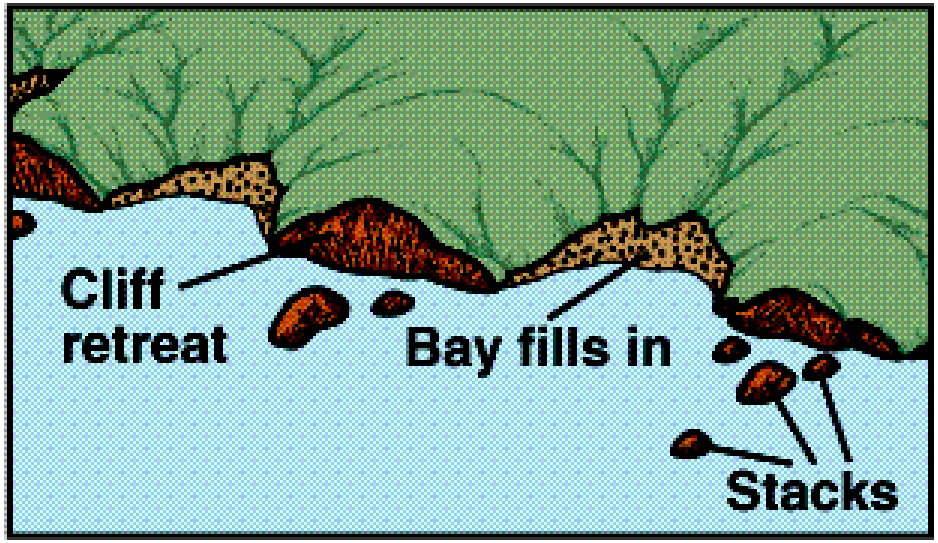


A

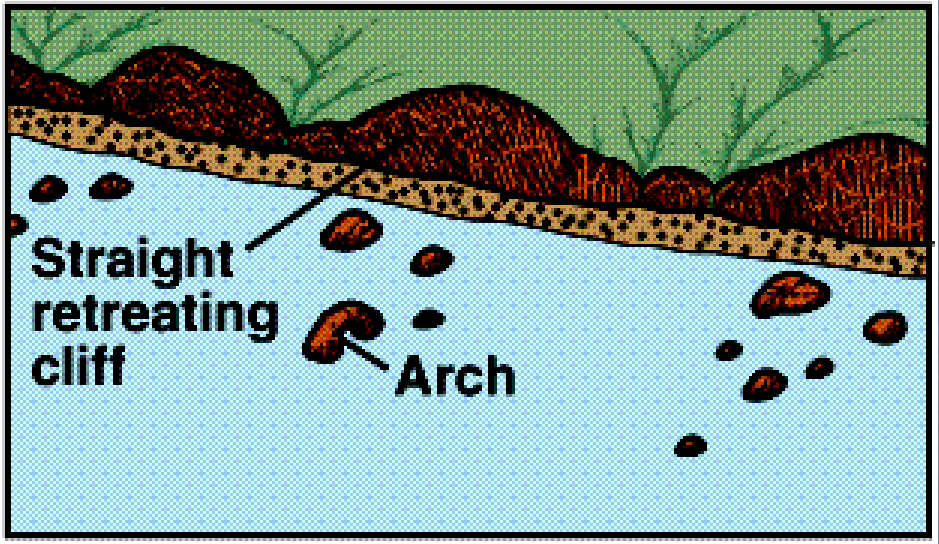


B

Straightening Coastlines



C



D

Erosion from waves

- sea cliffs and wave-cut terraces

Emergent Coasts

Uplifted marine terrace in northern California

- ***Emergent coasts***
  - elevated by deep tectonic forces
  - *uplift more rapidly* than *sea level rise*
- ***Uplifted marine terraces***
  - originally formed offshore from beach
  - exposed along ***active*** tectonic margins
    - California, Oregon

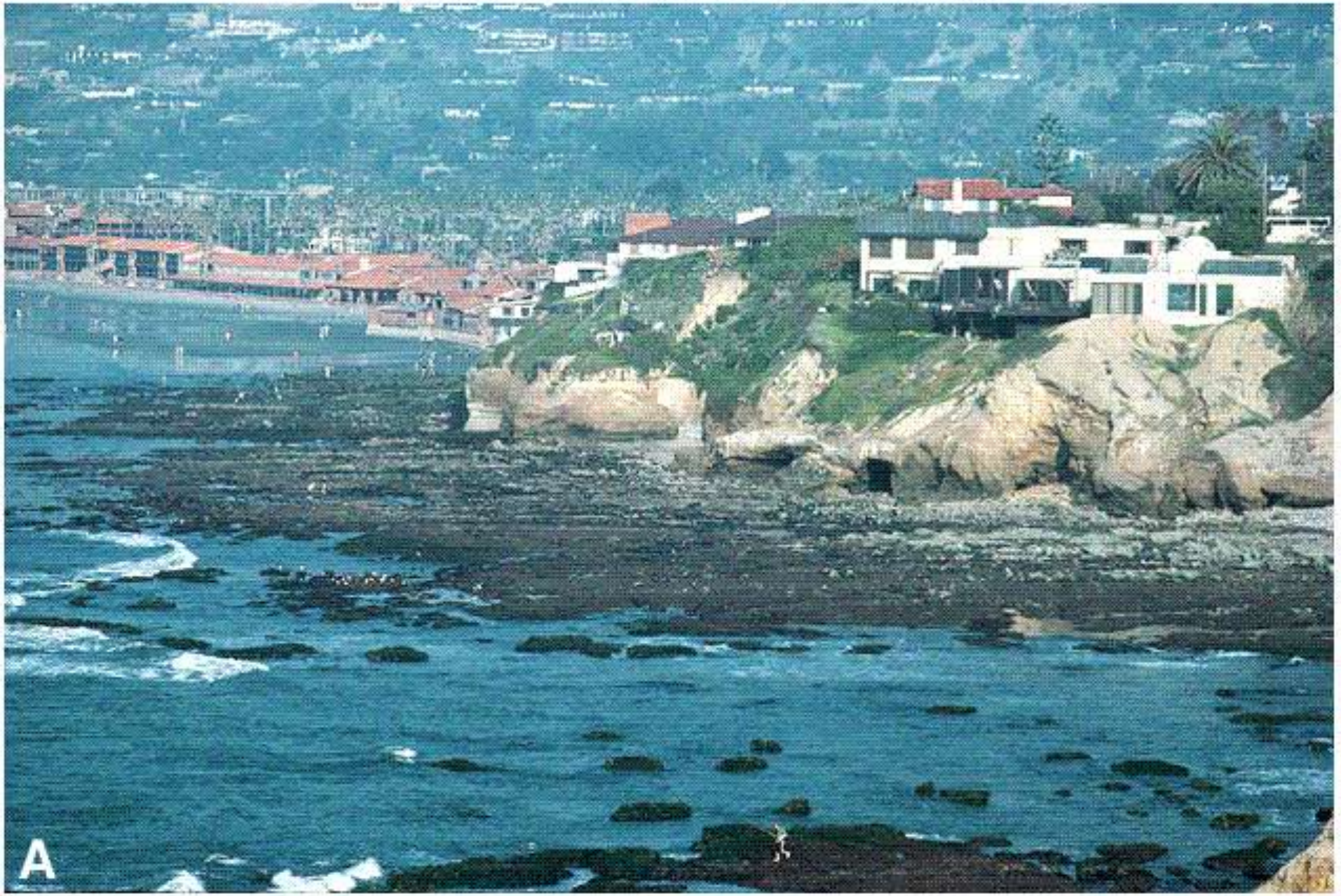
Characteristics of Emergent Coasts

Wave-cut notch above sea level

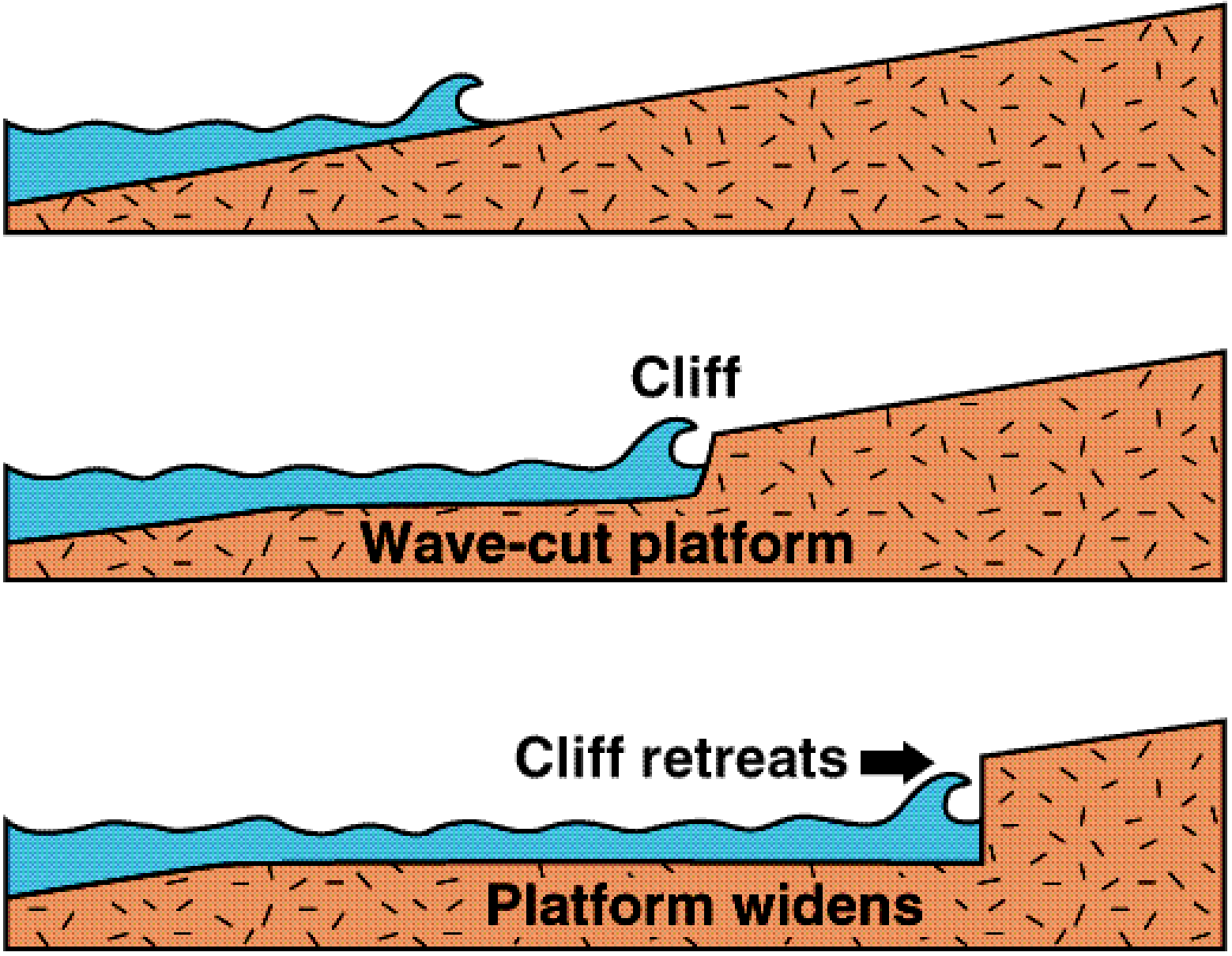
Coral reefs exposed when sea level drops or land uplifted by tectonics

Wave-cut platforms now marine terraces high above sea level

A Wave-Cut Platform



Wave-Cut Platform Widens



B

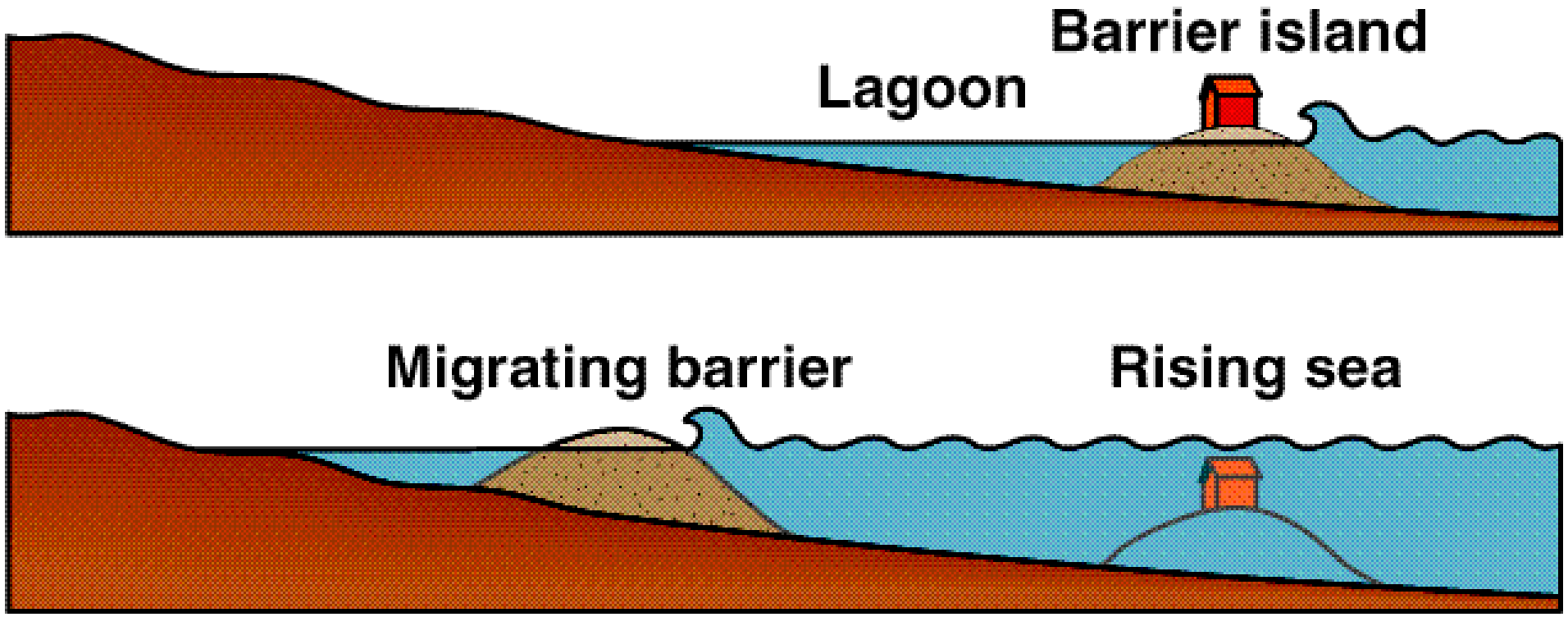
Erosion from waves

- sea cliffs and wave-cut terraces

Tectonic controls — "local"

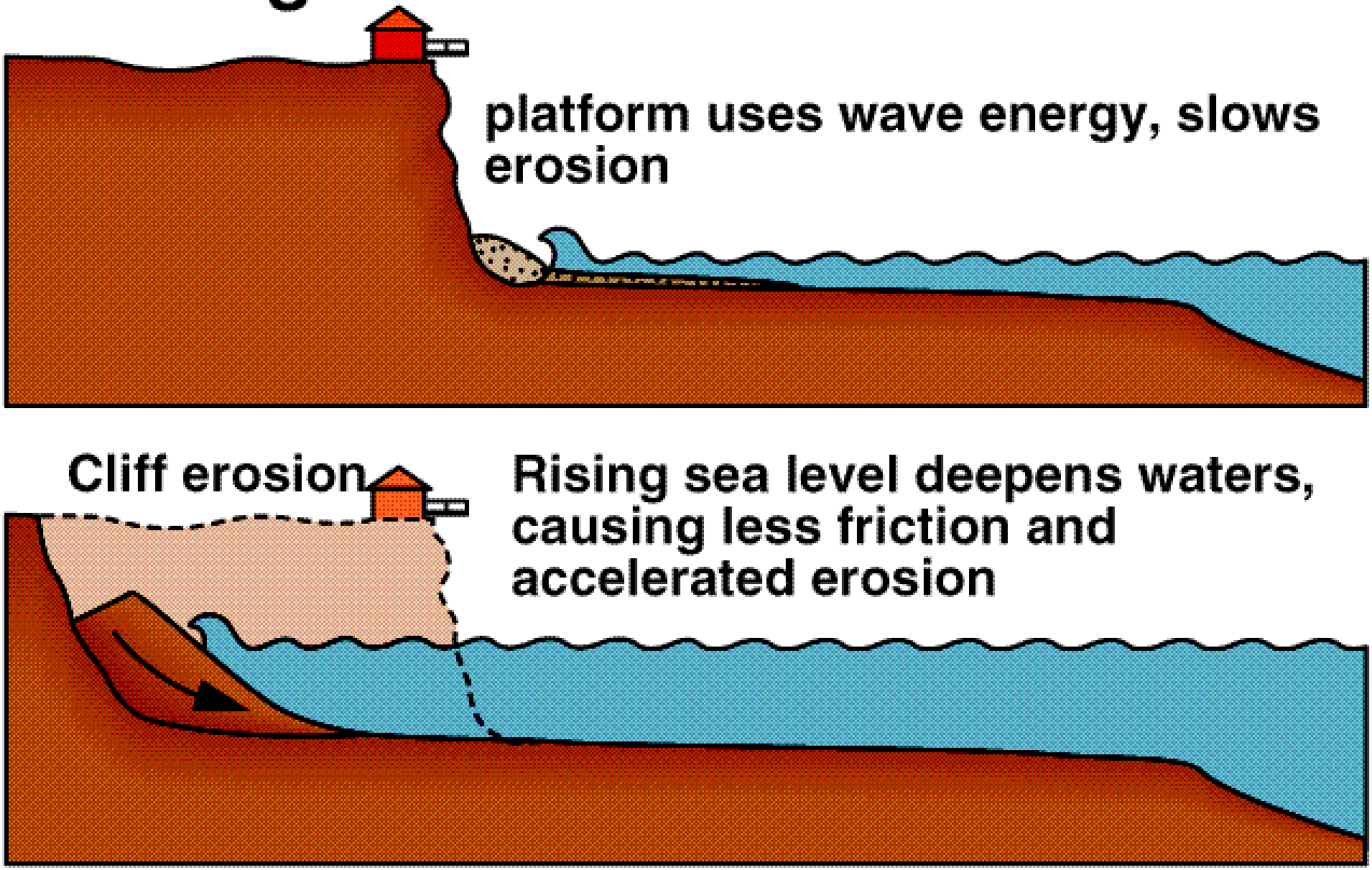
- Uplifted shoreline terrace
- *Why is it exposed?*

Rising Sea Level



A

Rising Sea Level Causes Erosion



B

Erosional coastal landforms

- *Stacks*: Twelve Apostles, Victoria, Australia

- *Wave-cut terraces*: Bolinas Point, California

Emergent Coasts

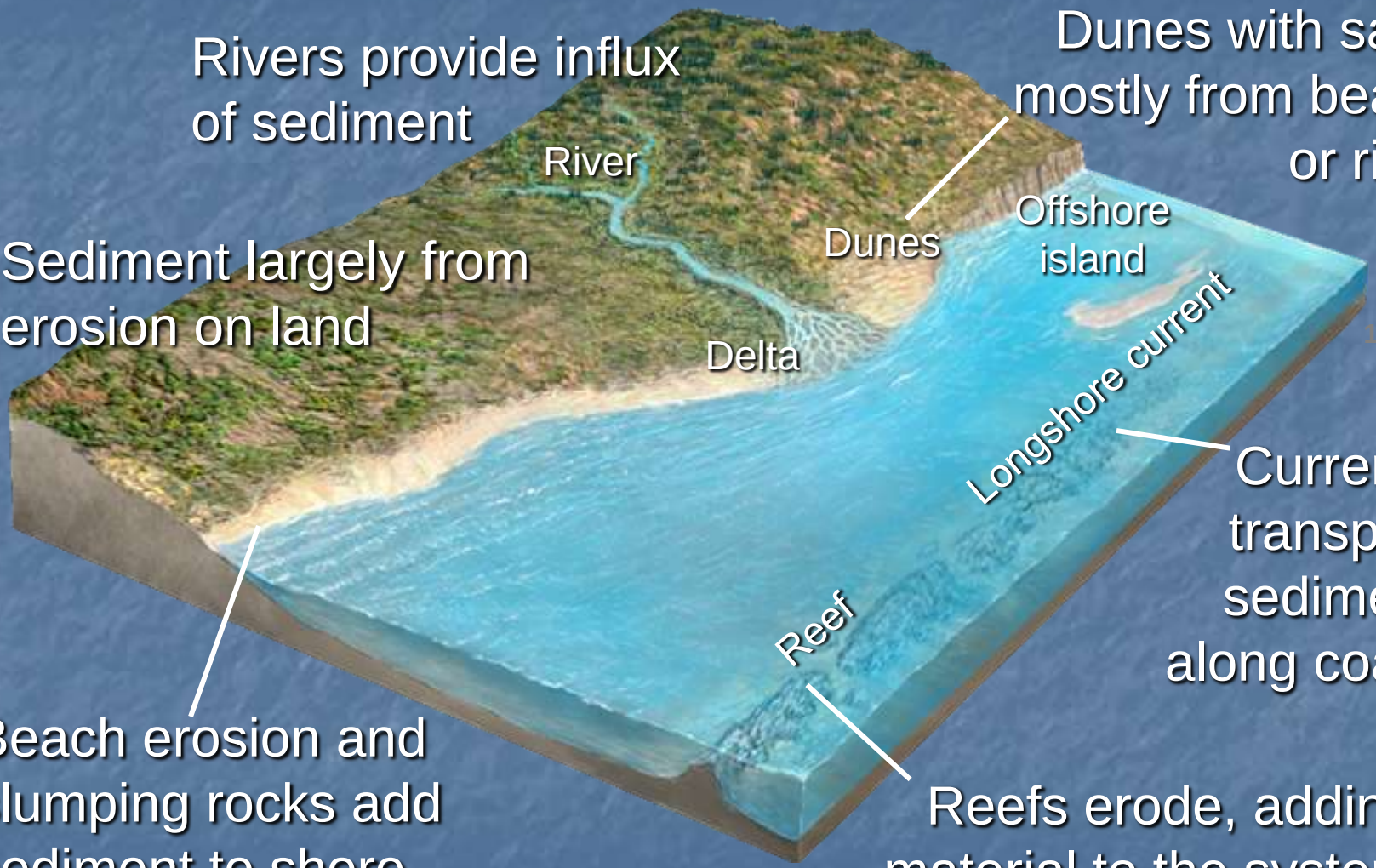
- ***Emergent coasts*** have been elevated by deep-seated tectonic forces
  - Uplift has occurred more rapidly than rise in sea level
  - ***Uplifted marine terraces*** (originally formed just offshore from the beach face) are exposed along the tectonically active western coast of North America

Uplifted marine terrace in northern California

Uplifted Marine Terrace

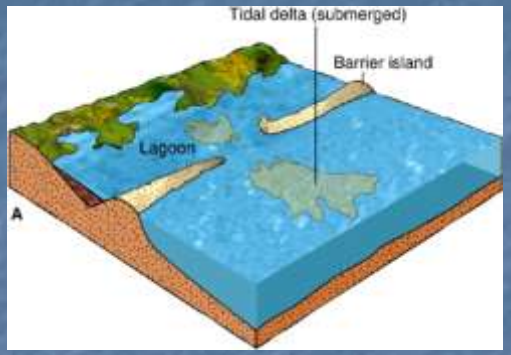
- **Sea cliffs**
  - Creating new land surface, removing fines
- **Marine terraces**
  - Stranded after drop in sea level

Consider what determines whether a shoreline gains or loses sand with time



Depositional Coasts

- *Depositional coasts* typically exhibit gently sloping plains showing few effects of erosion
- Shaped primarily by sediment deposition, particularly by longshore drift
- *Barrier islands*, ridges of sand that parallel the shore, are common on depositional coasts
  - Sea walls will also hasten erosion of any sand beach between them and the shoreline
  - Protected lagoons separate barrier islands from the mainland
  - Barrier islands are *dynamic*, with rapid erosion and deposition in various areas
  - Heavy population on some barrier islands has led to *property loss* from rapid, localized erosion



Shoreline Features Formed by Deposition

Depositional coastal landforms

- Sand bars, barrier spits, barrier islands

Observe the formation of spits, baymouth bars, and barrier islands

Spit forms when waves and longshore currents transport sediment along beach

14.05.b7

Spit can grow into baymouth bar

If sea level rises, spits and bars may become barrier islands

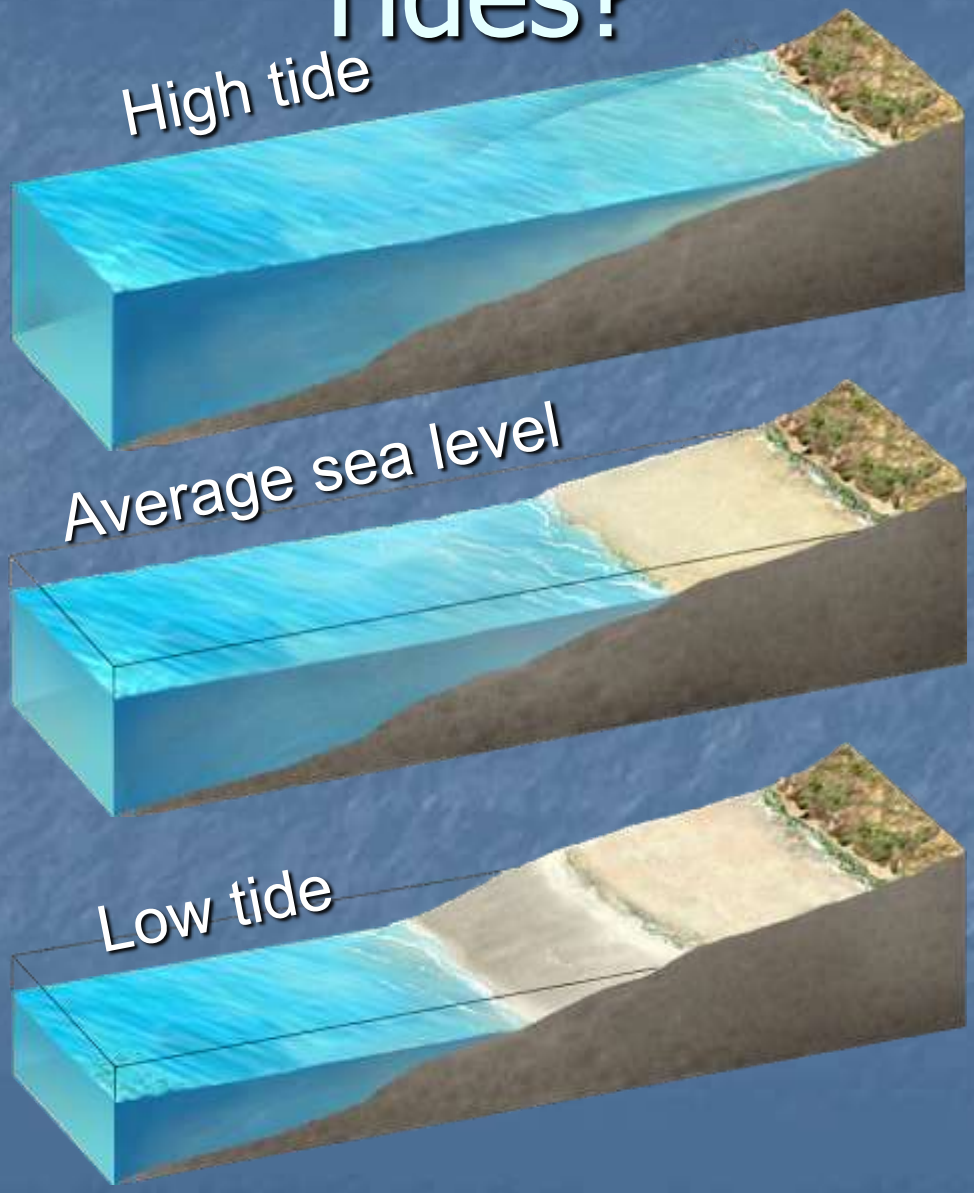
3D

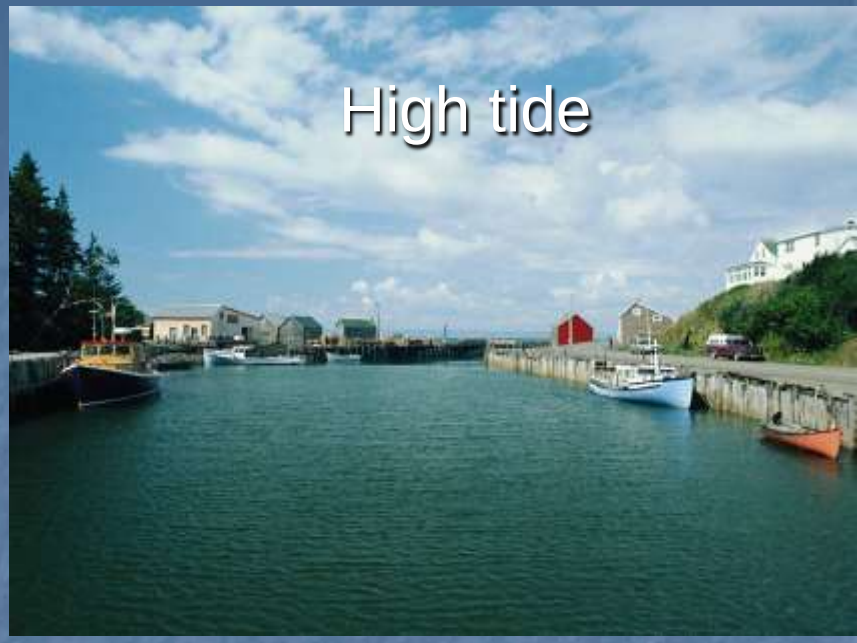
Longshore transport, sand bars, and barrier islands

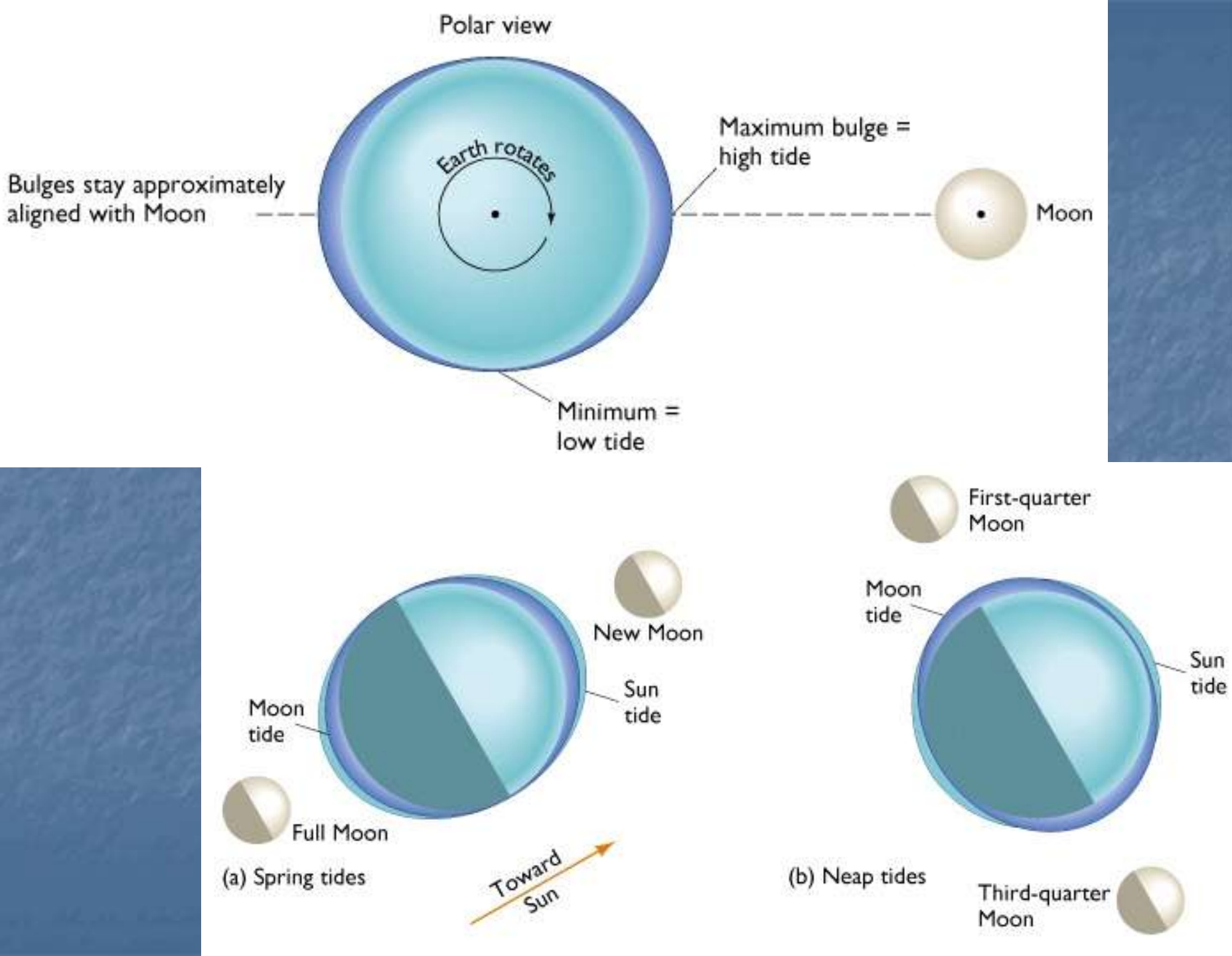
B

A Barrier Island

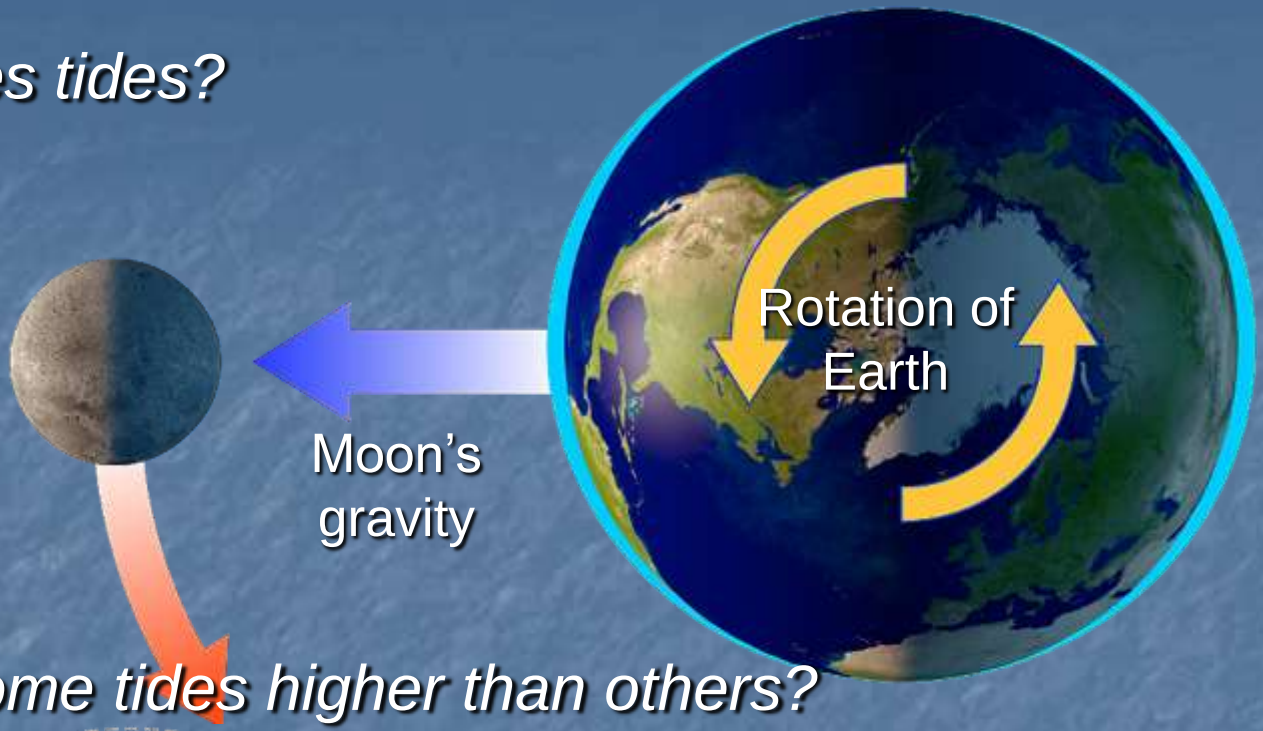
What Are Tides?



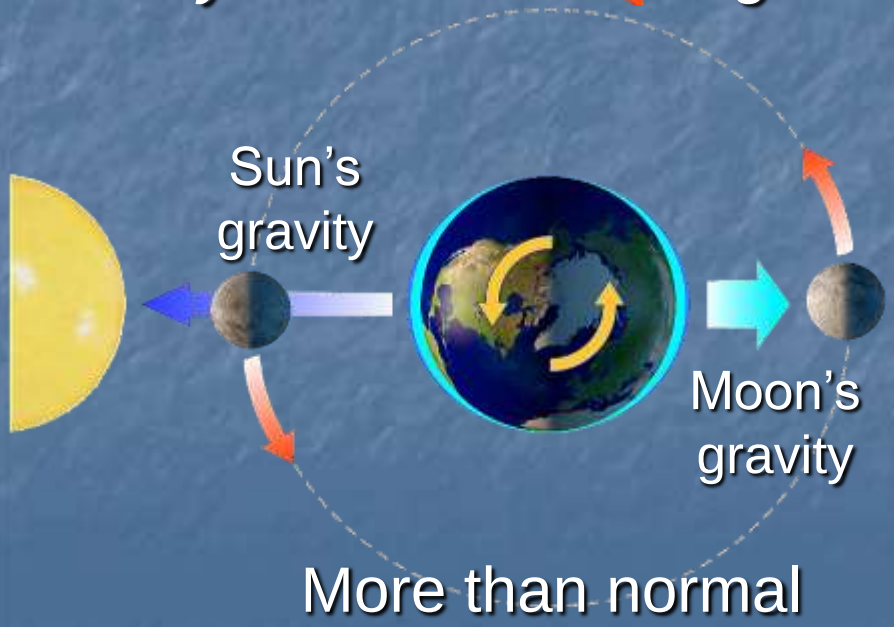


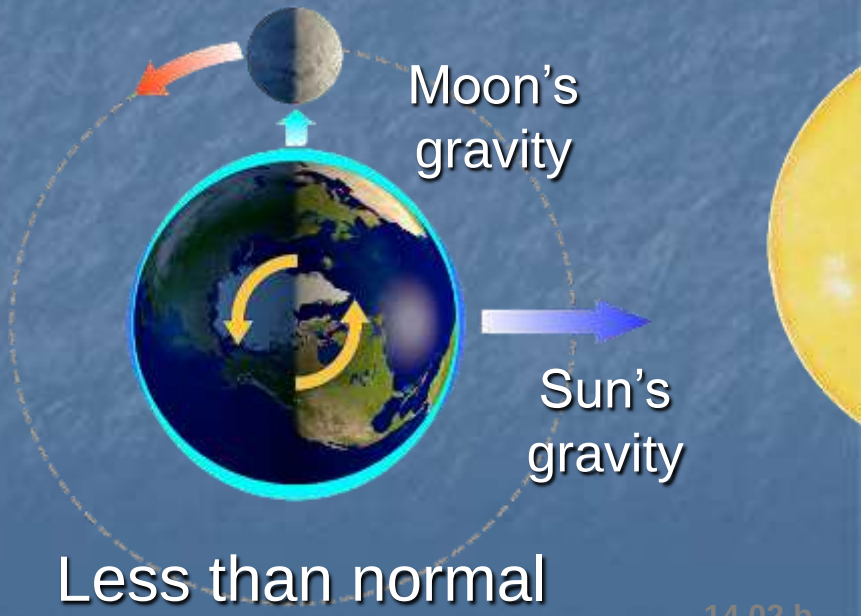

Polar view
Earth rotates
Maximum bulge = high tide
Bulges stay approximately aligned with Moon
Moon
Minimum = low tide
First-quarter Moon
New Moon
Moon tide
Sun tide
Moon tide
Sun tide
Full Moon
(a) Spring tides
Toward Sun
(b) Neap tides
Third-quarter Moon

What causes tides?



Why are some tides higher than others?





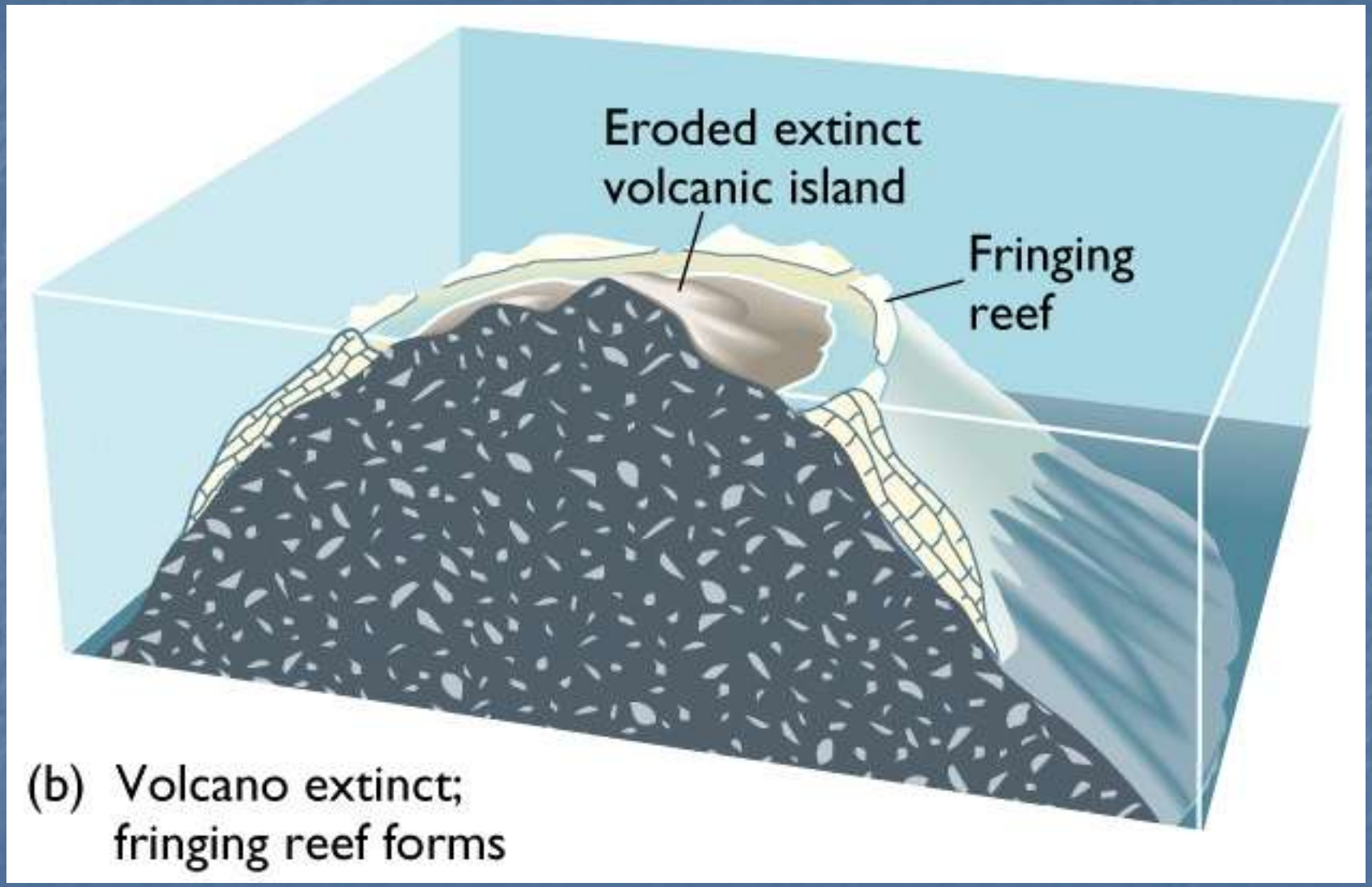
Tide terrace

- Outer ridge is exposed at low tide (sandbar at high tide)
- Rippled tidal flat
- Upper beach

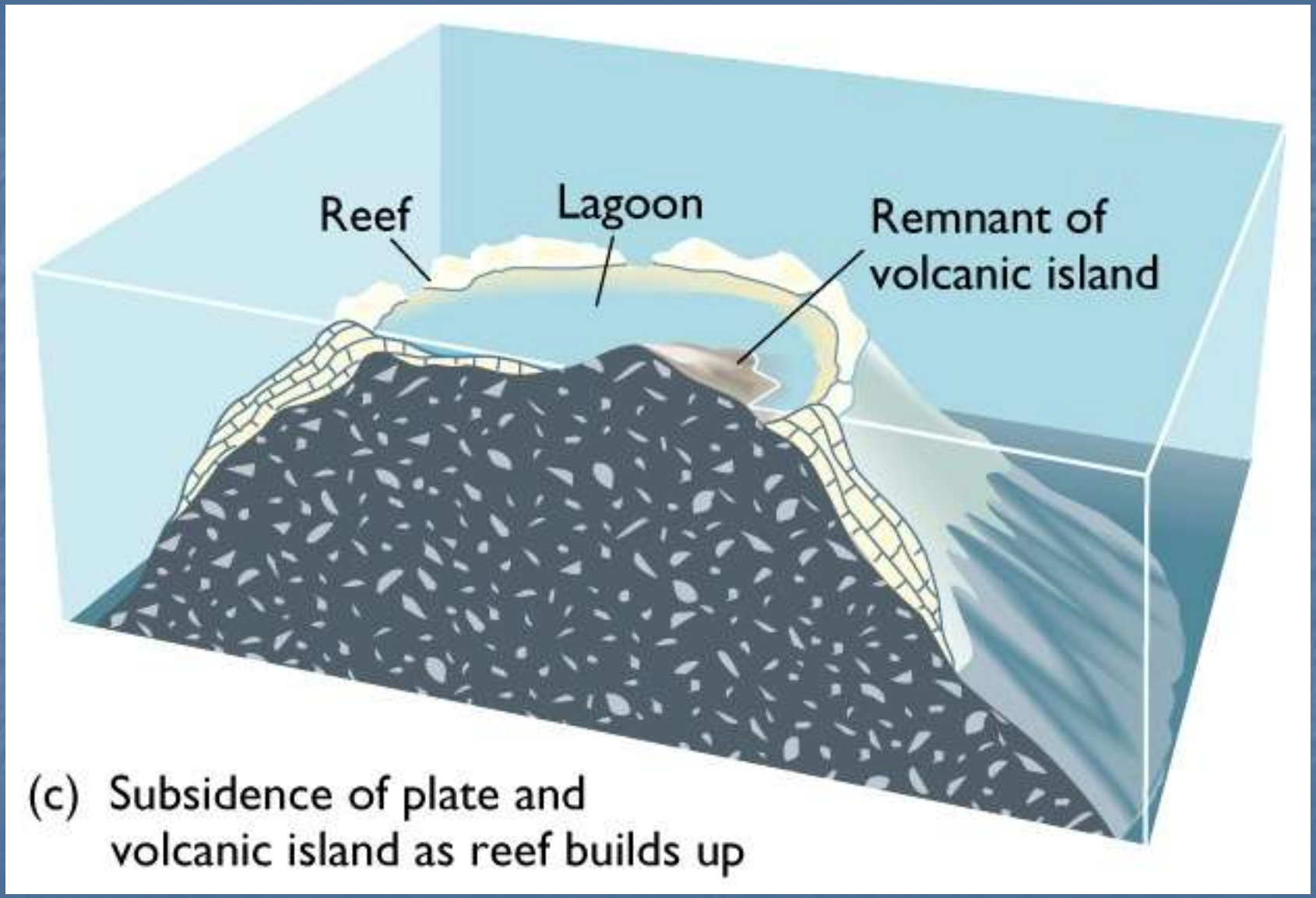
Tectonic controls — "local"

Organism Growth Coastlines

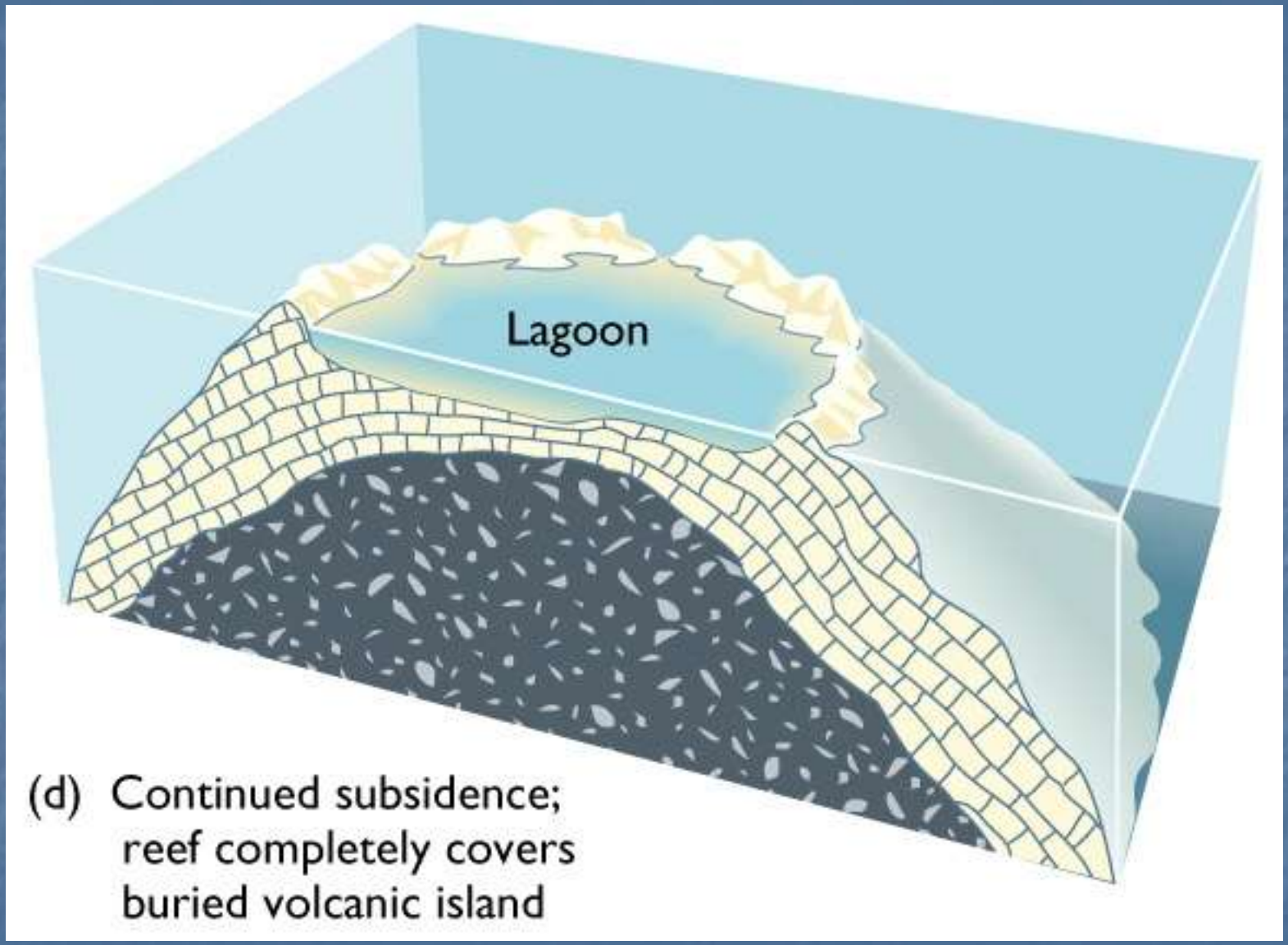
- Coral Reefs
  - ***Fringing Reefs***
    - *broad carbonate platforms attached to shore*
    - are *widest* where wave attack is strongest
  - ***Barrier Reefs***
    - lie *outboard of the mainland*
    - with a lagoon between them
    - usually have narrow gaps cut in them from water movement.
  - ***Atolls***
    - ***circular reefs*** *enclosing a lagoon*
    - often no large landmass inside



(b) Volcano extinct;
fringing reef forms



(c) Subsidence of plate and volcanic island as reef builds up



(d) Continued subsidence;
reef completely covers
buried volcanic island

Drowned Coasts

- *Drowned (submergent) coasts*
  - common today
  - sea level rising (last 15,000 years - end of last Ice Age)
    - levels 400'-500' higher currently
  - ***Estuaries***
    - drowned ***river mouths***
    - very rich in marine life
  - ***Fiords***
    - drowned glacially-cut valleys
- During Ice Ages
  - worldwide continental shelves exposed
  - rivers flowed across shelves - cut valleys

Hazards Along Shorelines

Observe damage from Hurricane Fran in 1996
(numbers show same houses)

14.06.a

Observe damage from Hurricane Katrina in 2005