BHARATHIDASAN UNIVERSITY

Tiruchirappalli- 620024
Tamil Nadu, India

Programme : M.Tech., Geological Technology and Geoinformatics

Course Title : Geomorphology and Geodynamics
Course Code : MTIGT0506

Unit-3: Coastal Geomorphology

Dr. J. SARAVANAVEL
Professor, Department of Remote Sensing
Bharathidasan University
Tiurchirappalli, Tamil Nadu
Email : drsaraj@gmail.com, saravanavel@bdu.ac.in

COASTAL GEOMORPHOLOGY

Science dealing with landforms created by marine action/Physical oceanographic processes.

Coast are the areas between low tide and the highest level affected by storm waves

dynamic areas where waves, tides, and marine currents continually modify features

vary from rocky and steep to broad sandy beaches

rising sea level threatens coastal property

Why to study Coastal Geomorphology ?

(i) To understand the genesis of each landform.

(ii) To fabricate the Quaternary geomorphic processes along the coast.

(iii) To understand the ongoing tectonic processes.

(iv) To fabricate the sea level variations in Quaternary period and develop fore casting models.

(v) To understand the flooding pattern & detect flood prone areas / fluvial interfaces.

(vi) To monitor sediment dump pattern.

(vii) To understand back water / creek dynamics.

(viii) To locate placer mineral deposits.

(ix) To locate hydrocarbon locales.

(x) G.W. Targets

(xi) Artificial recharge

(xii) Salt water intrusion

(xiii) Coastal Zone Management

(xiv) For the overall understanding of Land - Ocean interactive processes

COASTAL ZONE

Transition zone where the land meets water. Extends from continental shelf break to the first major change in topography

Shoreline: shifting line of contact between water and land

Coastline: zone in which coastal processes operate or have a strong influence

Dynamic coastal processes

1. Wave action
2. Littoral current Action
3. Rip currents
4. Tide Rips
5. Tides Action
6. Organisms and their Action

Dynamic coastal processes

1. Wave action

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

Wave height determined by

- **wind speed**
- **length of time wind blows**
- **distance wind blows over the water (fetch)**

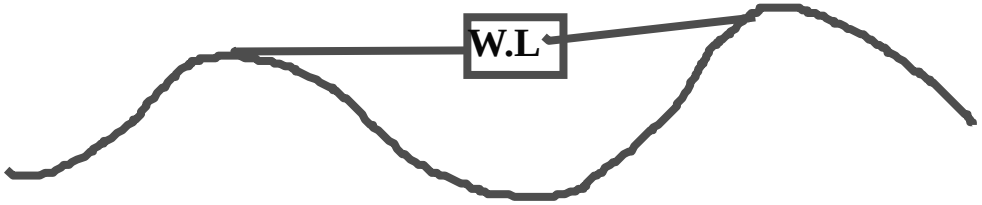
(a) Causes of waves

(1) Earth Tides
(2) Lunar Tides
(3) Sub marine earthquakes
(4) Landslides
(5) Wind
(6) Movement of boat / ships
(7) Tsunamis

(c) Height of waves

➔ Height depends upon the source. (20 to 45 feet)

(d) Wave length of waves



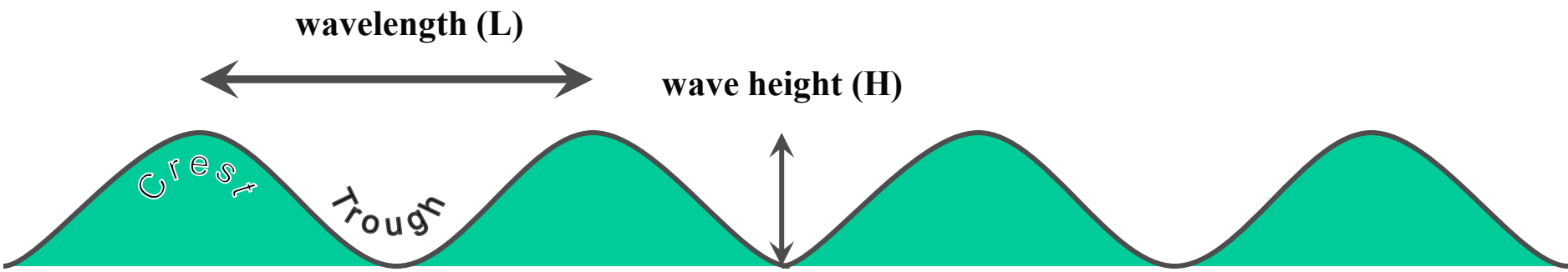
(e) Depth of wave action

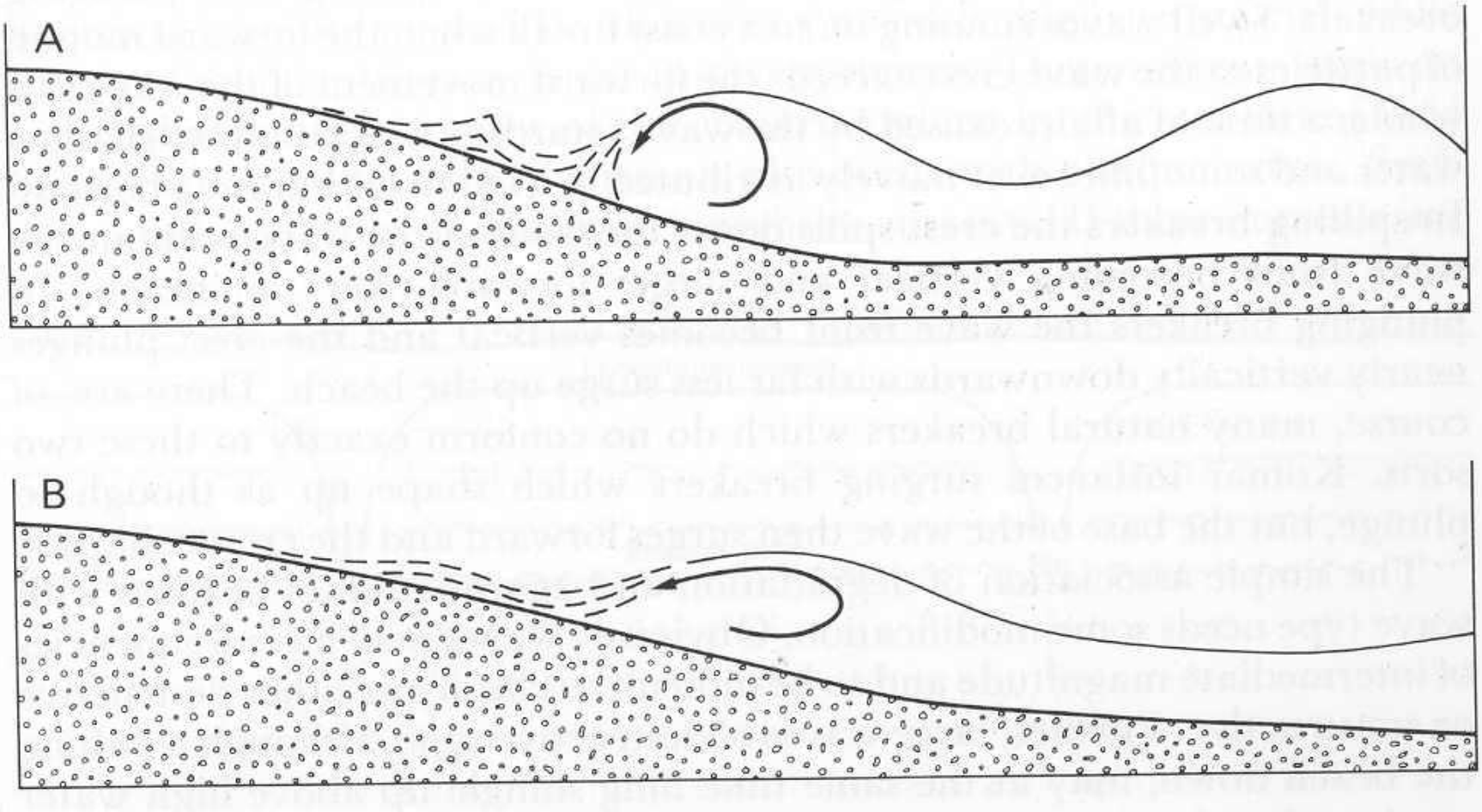
➔ Wave motion decreases rapidly at depth

➔ They carry fine sediments below their surface

Waves in the ocean

- Wave measures:



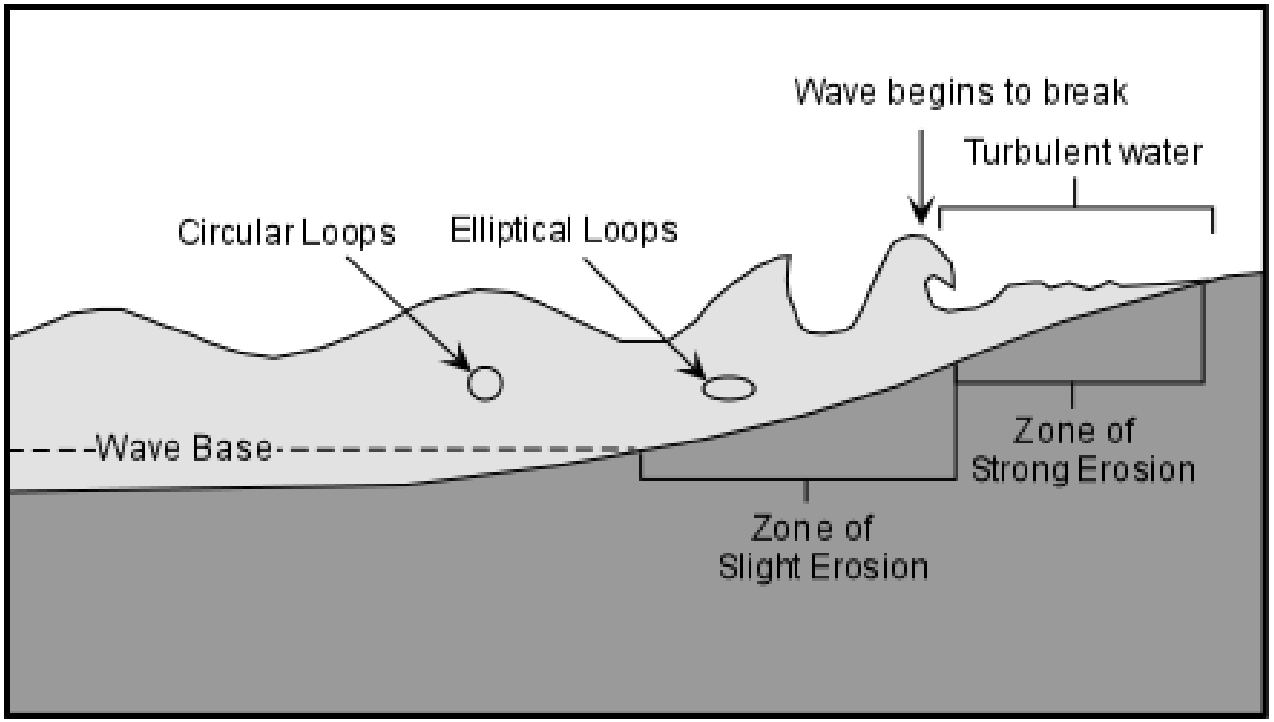

A
B

FORWARD / RETREAT WAVES

(Kayangal Reef)

WAVE MOTION

In Wave motion, there is no horizontal movement of water (only nearer to the shore), only the wave form and energy where transmitted Eg. Wave ripples moving across paddy fields



WAVE MOTION

1. Oscillatory motion

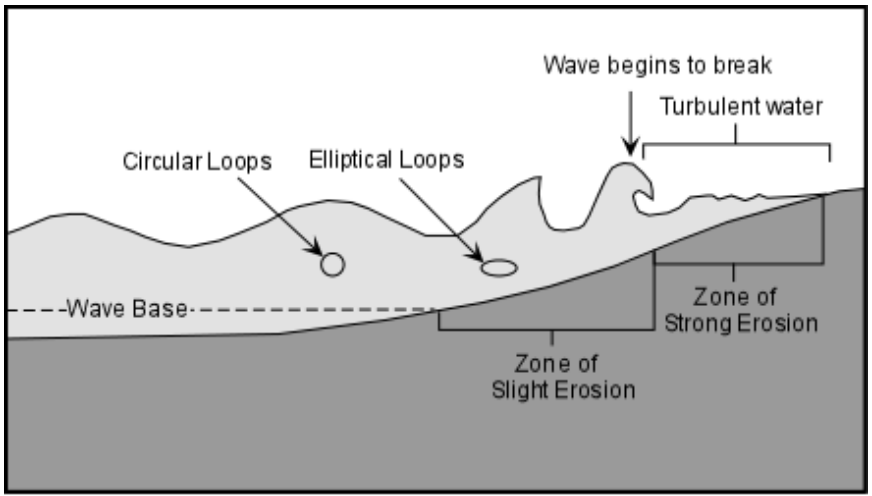
Individual water particle move in circular fashion

They move forward in the crest of the wave and backward in the trough

But during heavy winds the forward motion is accelerated and causes asymmetrical waves

2. Translatory motions

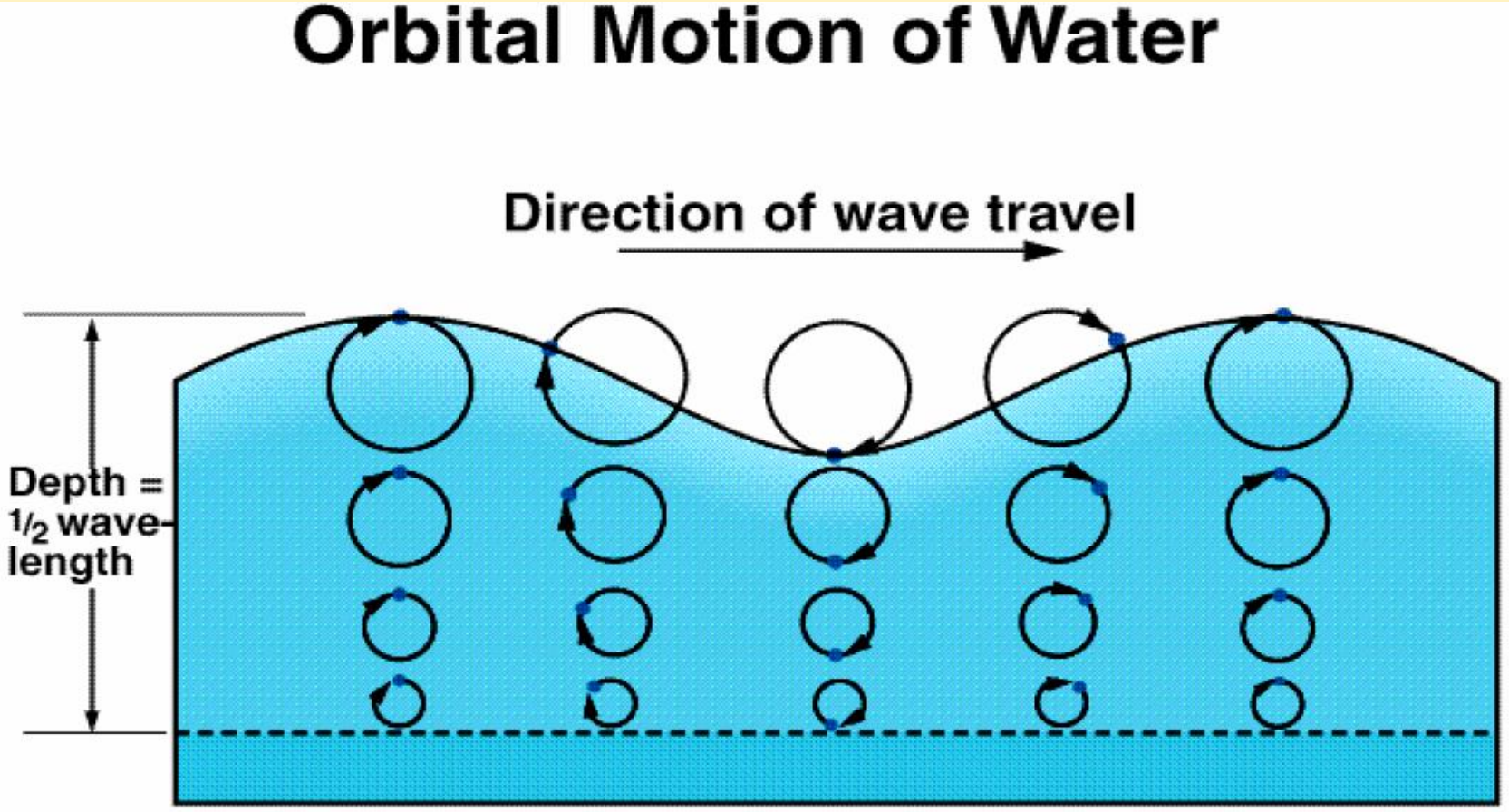
In asymmetrical waves particles will have translatory motion



Waves in the ocean

- How does the water move?

← wave motion



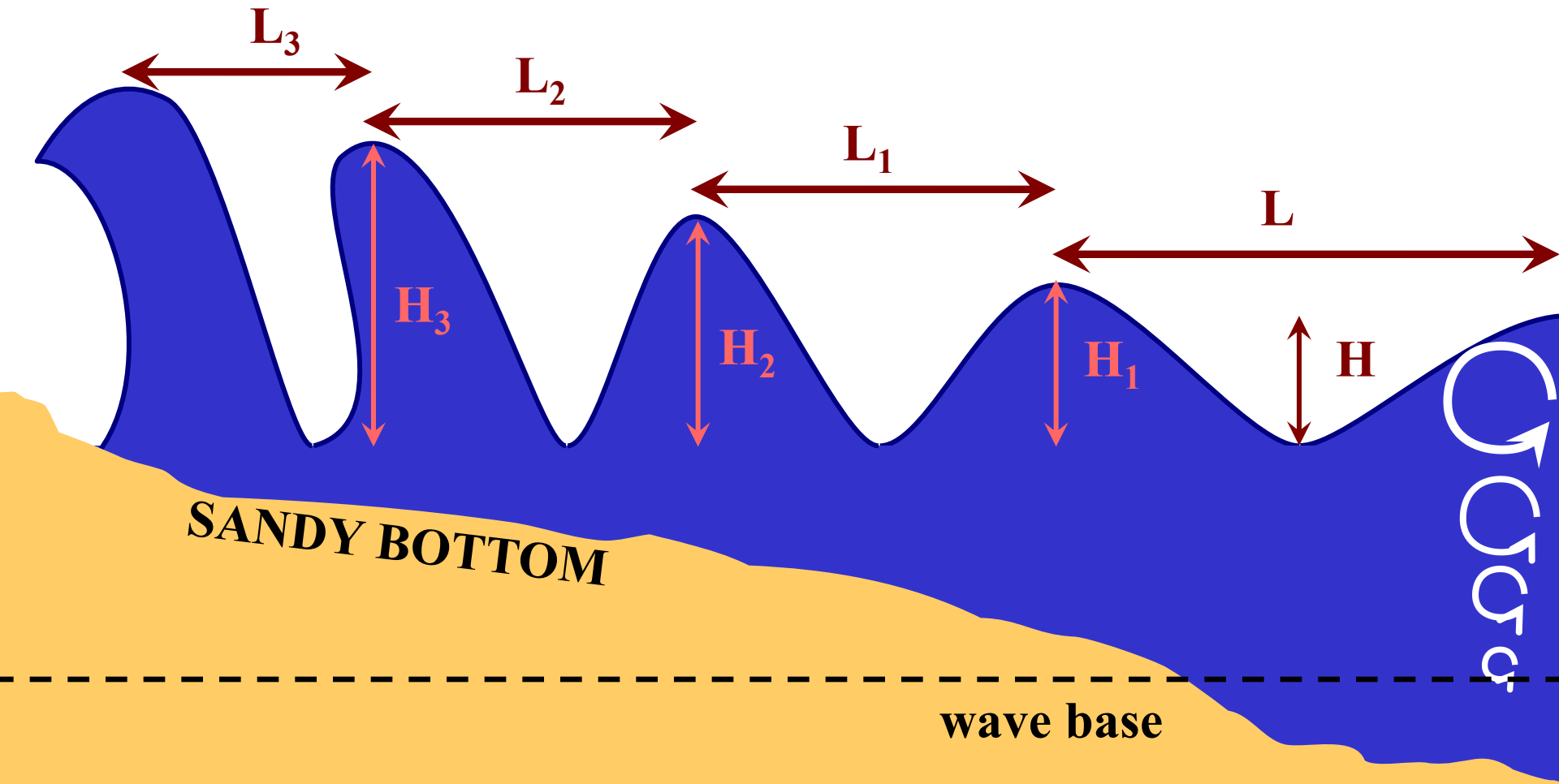
Waves approaching shore

- Wavelength decreases
- Wave height increases
- Speed decreases
- Waves "fall over" (breakers)

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

Waves approaching shore

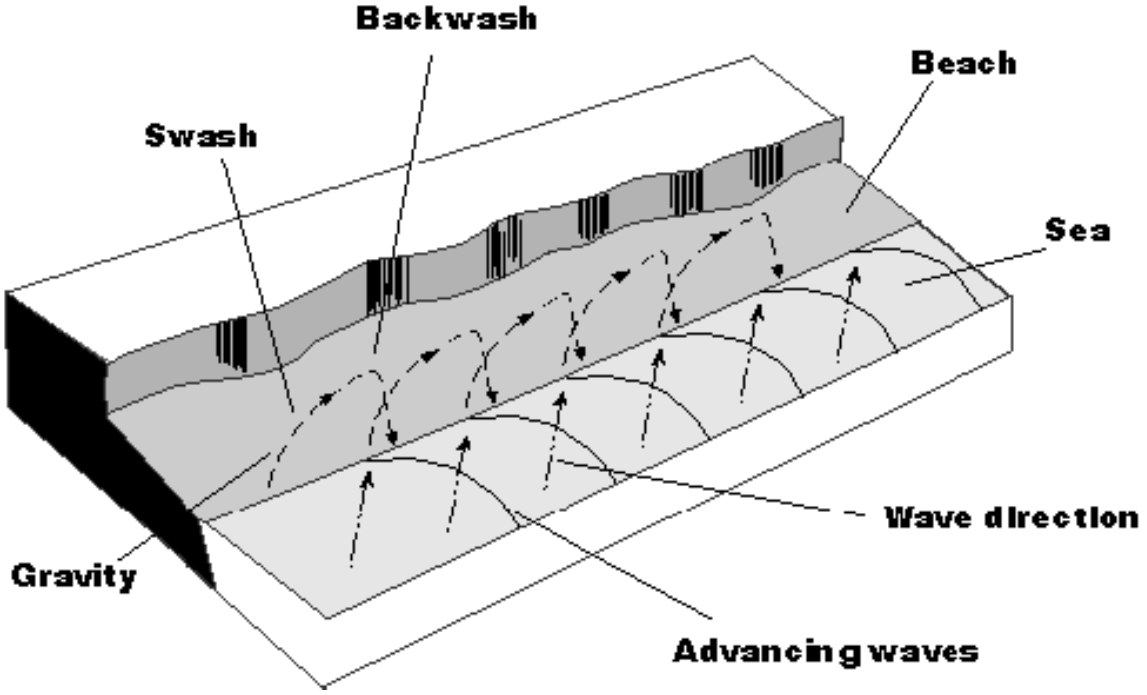


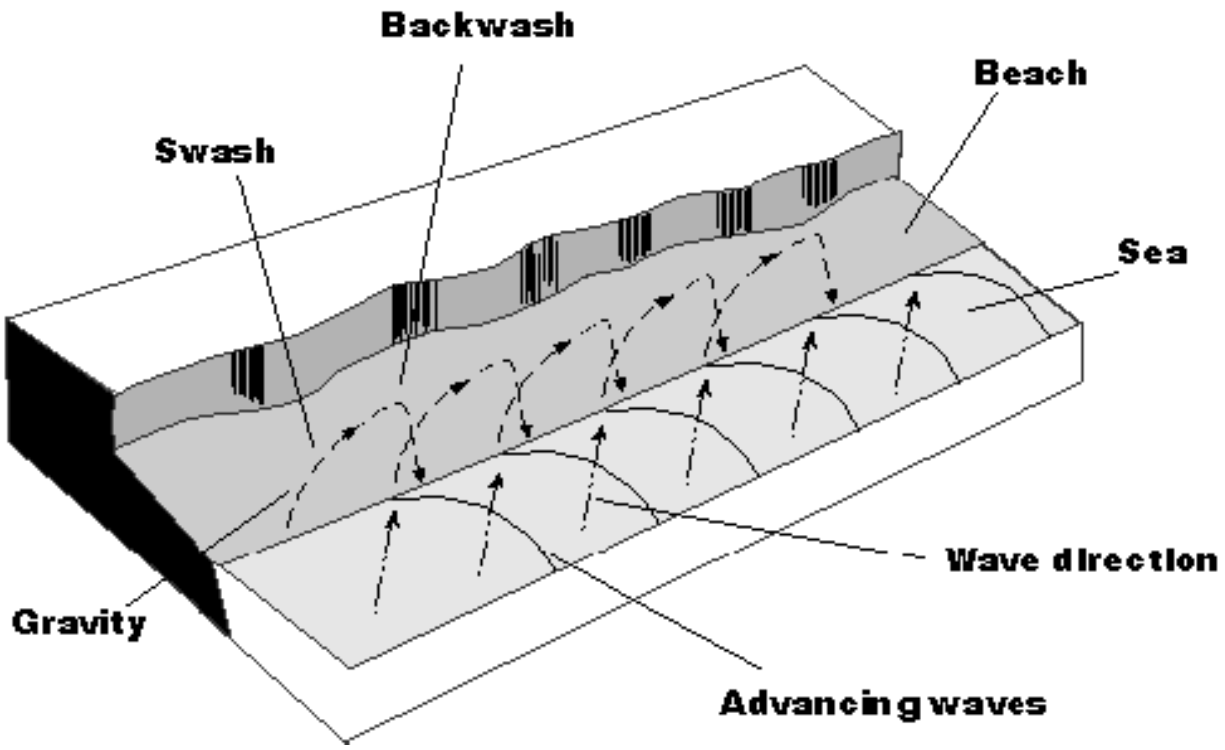
WAVE BRAKES

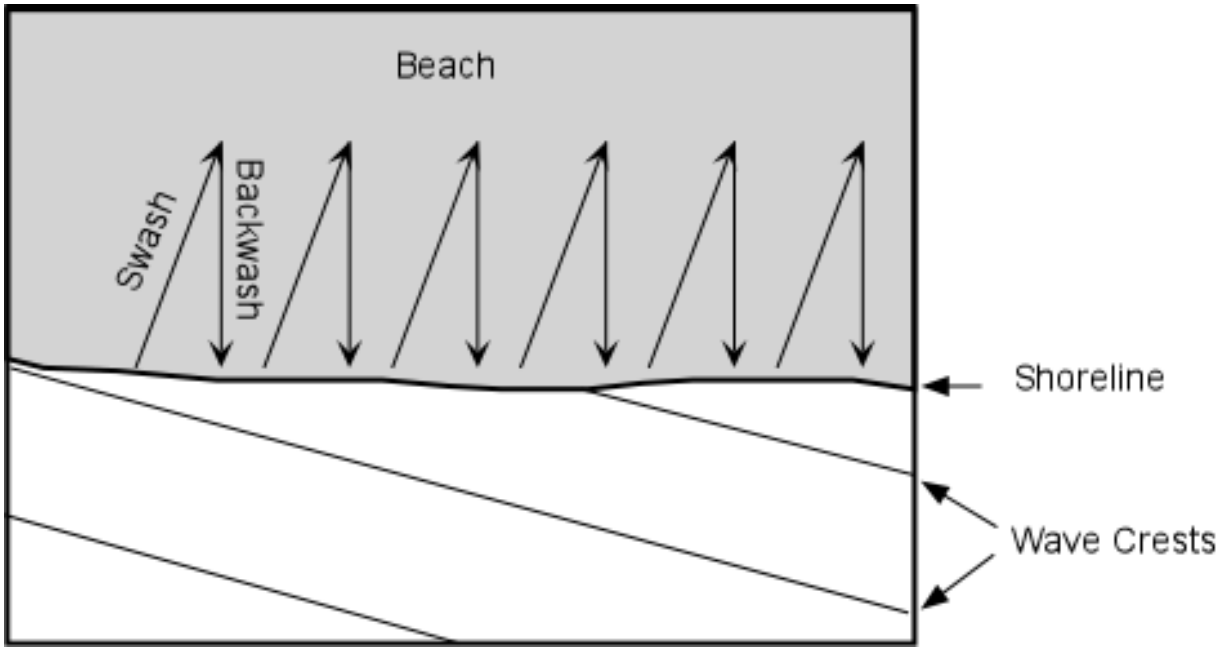
(Crashing Down)

When wave approaching the gently sloping shore the wave length is decreased and wave height is increased. The crest of the wave folds smoothly as the depth of the water is less than one half of the wave length. The falling wave is called as breaker

- ***Swash***: Upward movement of water on to the beach occurs at an certain oblique angle.
- ***Backwash***: Return of water is at right angle to the beach
- ***Beach Drift***: the endless cycle of swash and backwash



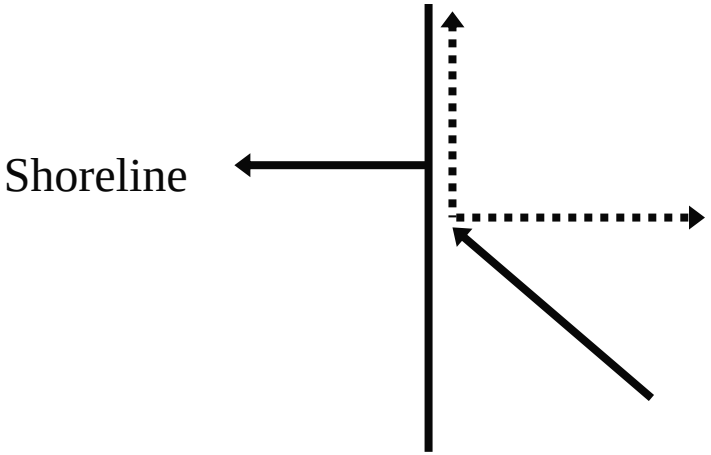

Backwash
Beach
Swash
Sea
Wave direction
Gravity
Advancing waves


Beach
Swash
Backwash
Shoreline
Wave Crests

6.4.2 Littoral current Action

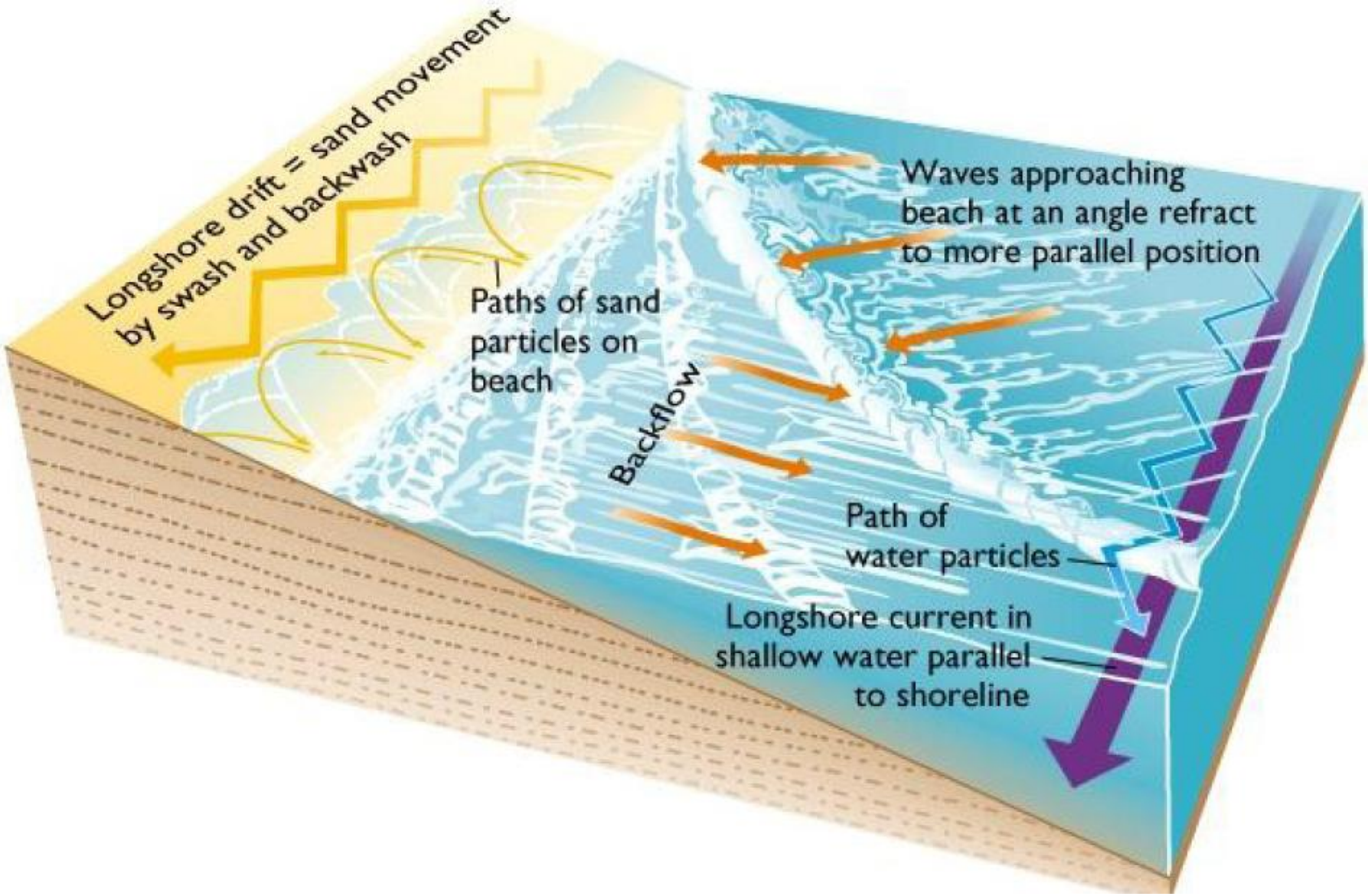
(i) It is a current moving parallel to the coast

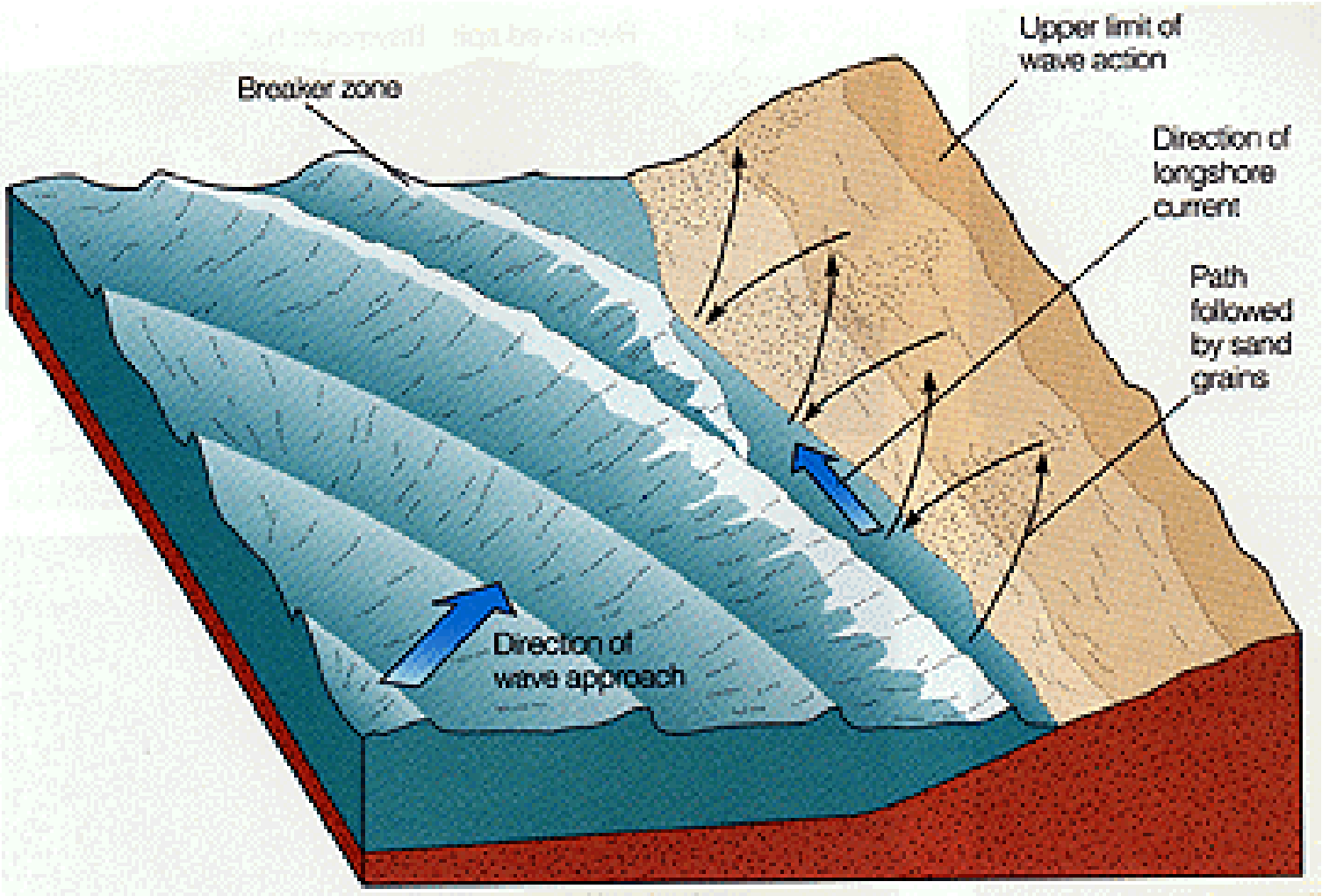
(ii) The tangentially or obliquely hitting waves get resolved into two one parallel to shore another backward. Such parallel current is littoral current.



(iii) * Such Littoral Currents only Cause Severe Coastal Erosion

* Form spits at creek and river mouths

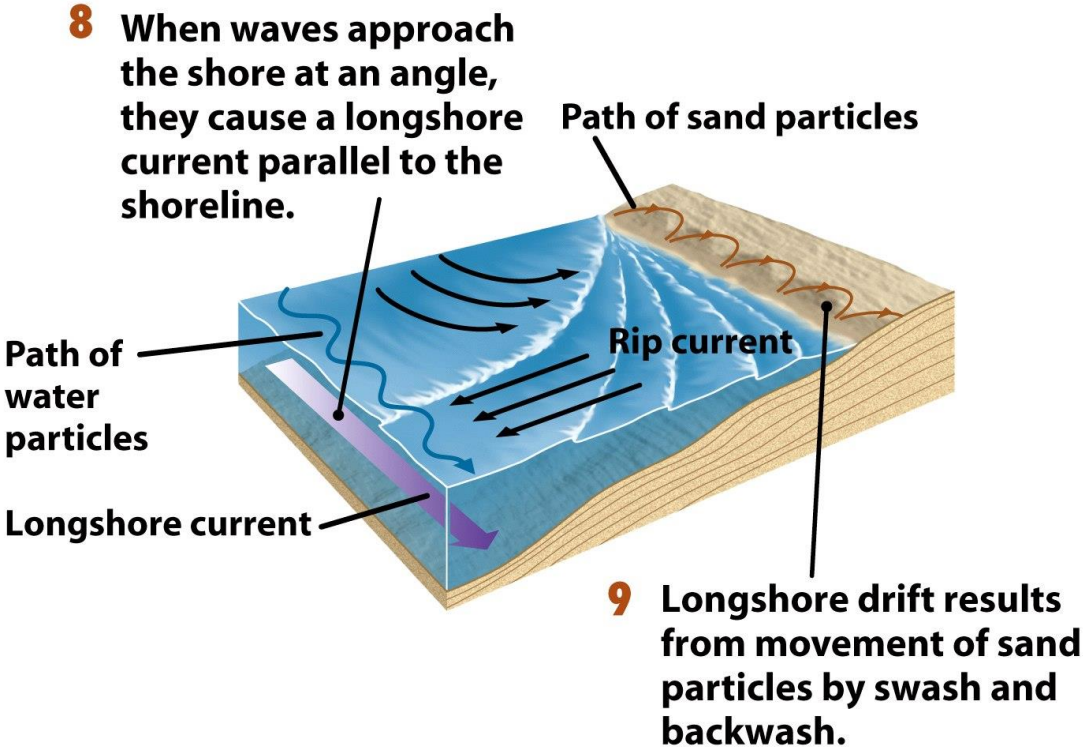

Longshore drift = sand movement by swash and backwash
Paths of sand particles on beach
Backflow
Waves approaching beach at an angle refract to more parallel position
Path of water particles
Longshore current in shallow water parallel to shoreline

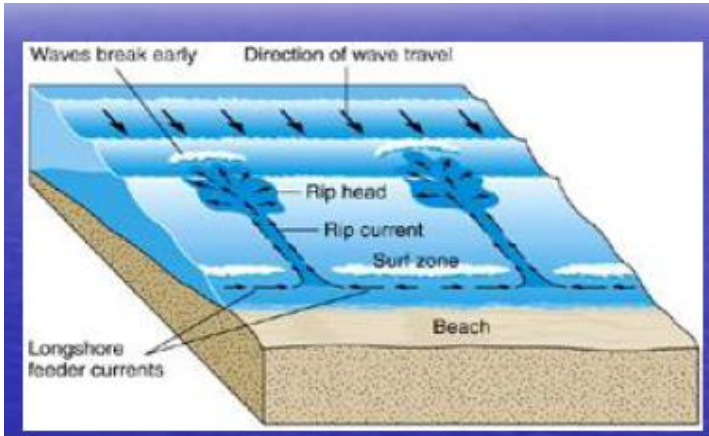

Upper limit of
wave action
Breaker zone
Direction of
longshore
current
Path
followed
by sand
grains
Direction of
wave approach

6.4.3 Rip currents

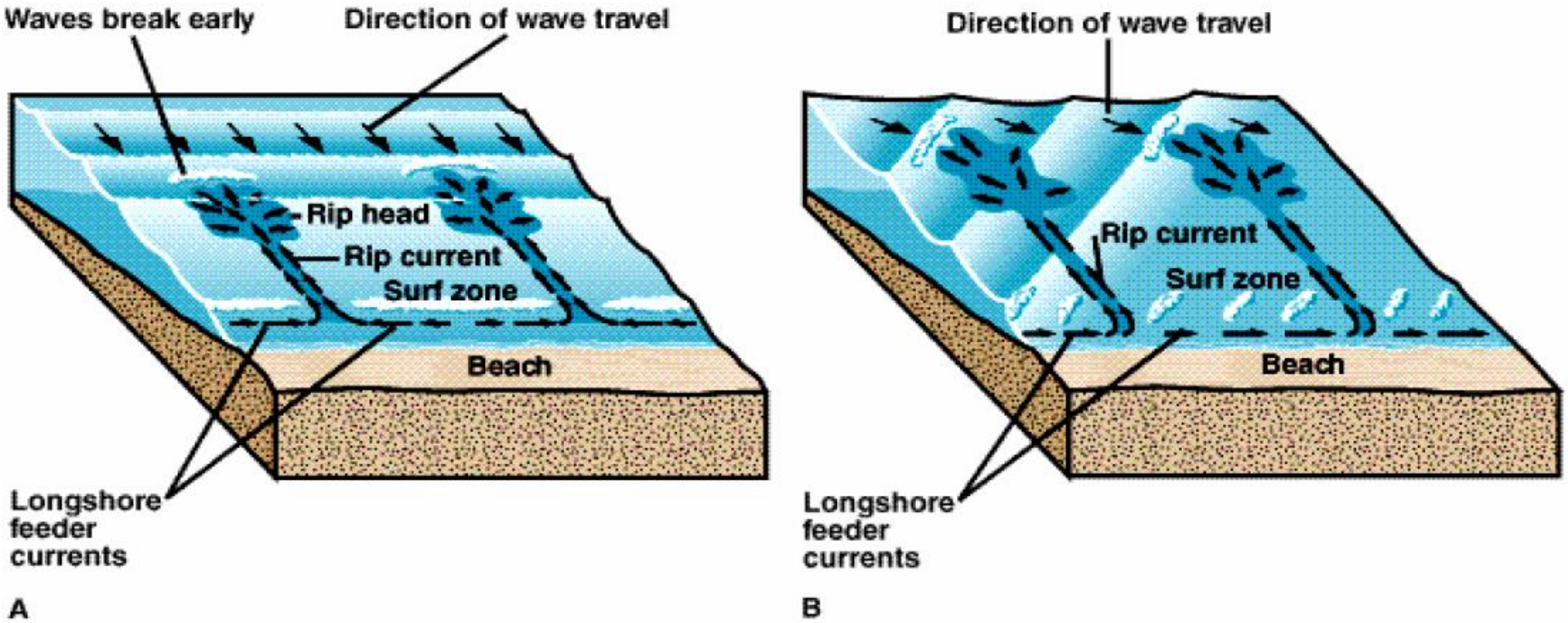
☛ When waves hit the coast and resolved into littoral currents and the seaward drifted currents such seaward drifted currents will be pushed back to the shore by wave

☛ This cause Rip currents





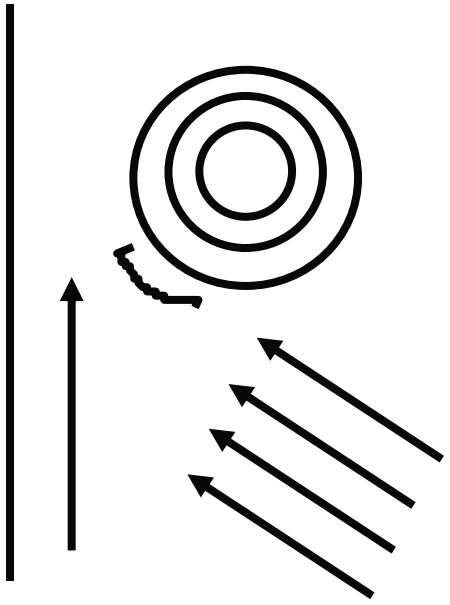
Rip Current Development



CALIFORNIA RIP CURRENT

Tide Rips

The interference between wave front and littoral current will cause eddies. This is called as tide rips.



Tidal currents

Tides are due to the gravitational attraction of Moon and Sun on the Earth

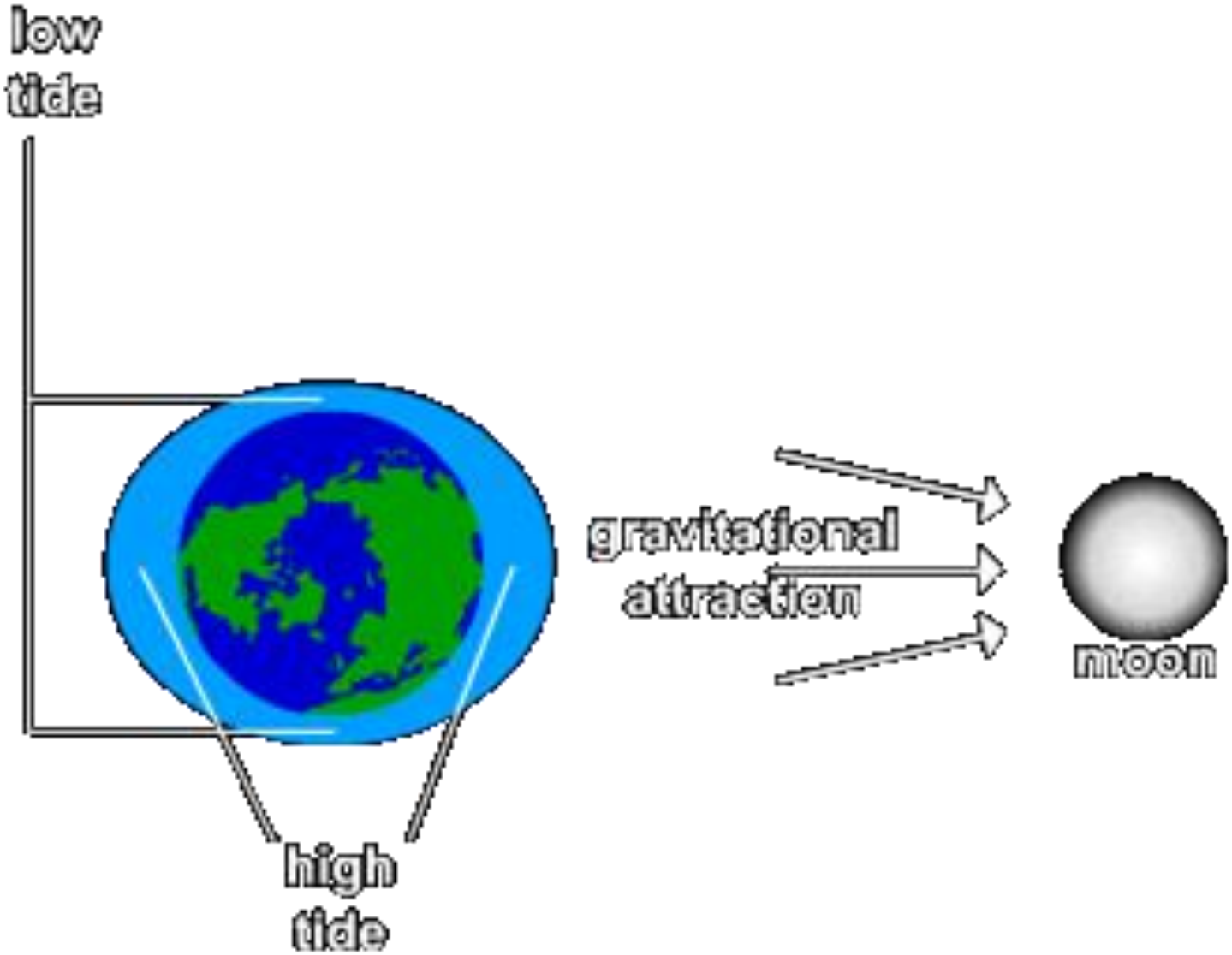
Causes the Earth to bulge toward the moon result in rise and fall of ocean surface

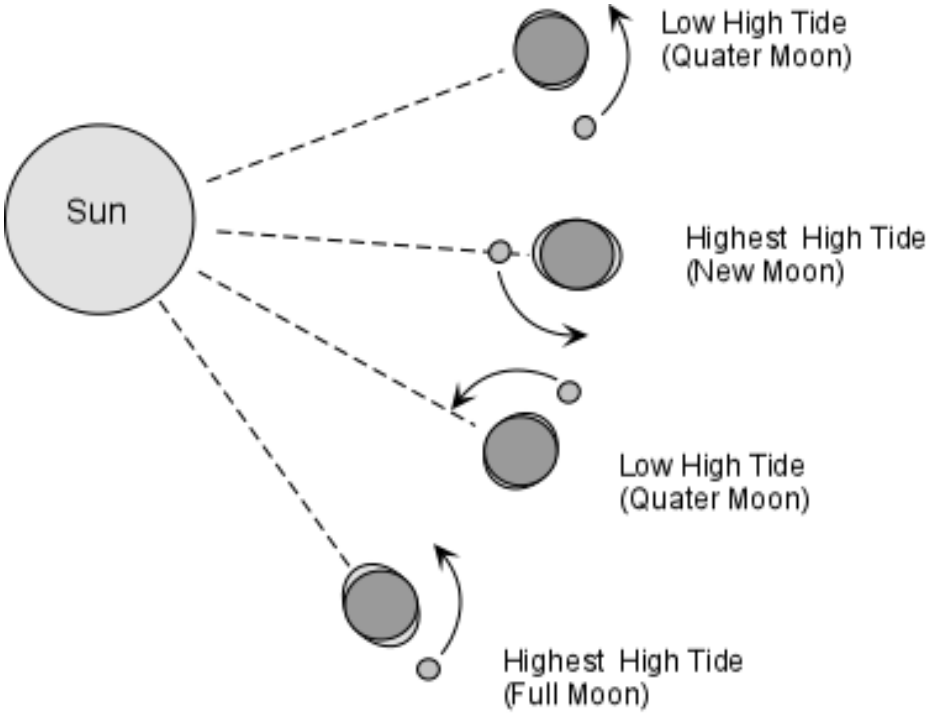
As a result water moves horizontally in the form of currents called as TIDAL CURRENTS

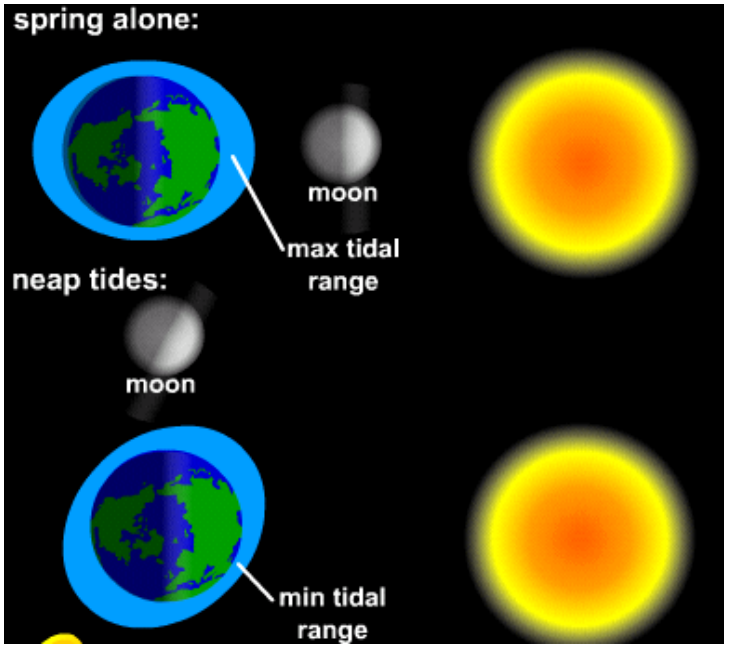
➔ They rise and fall twice a day

➔ Normal height only 1 1/2 feet

➔ But flood tides can move upto 500 k.m/hr and erode upto 300’


low
tide
gravitational
attraction
moon
high
tide





SPRING TIDE: Highest high tides - when the Sun, Moon and Earth are in same line (new Moon & full Moon).

NEAP TIDE: The lowest high tides occur when the Sun and the Moon are not opposed relative to the Earth (quarter Moons)

Organisms And Their Action

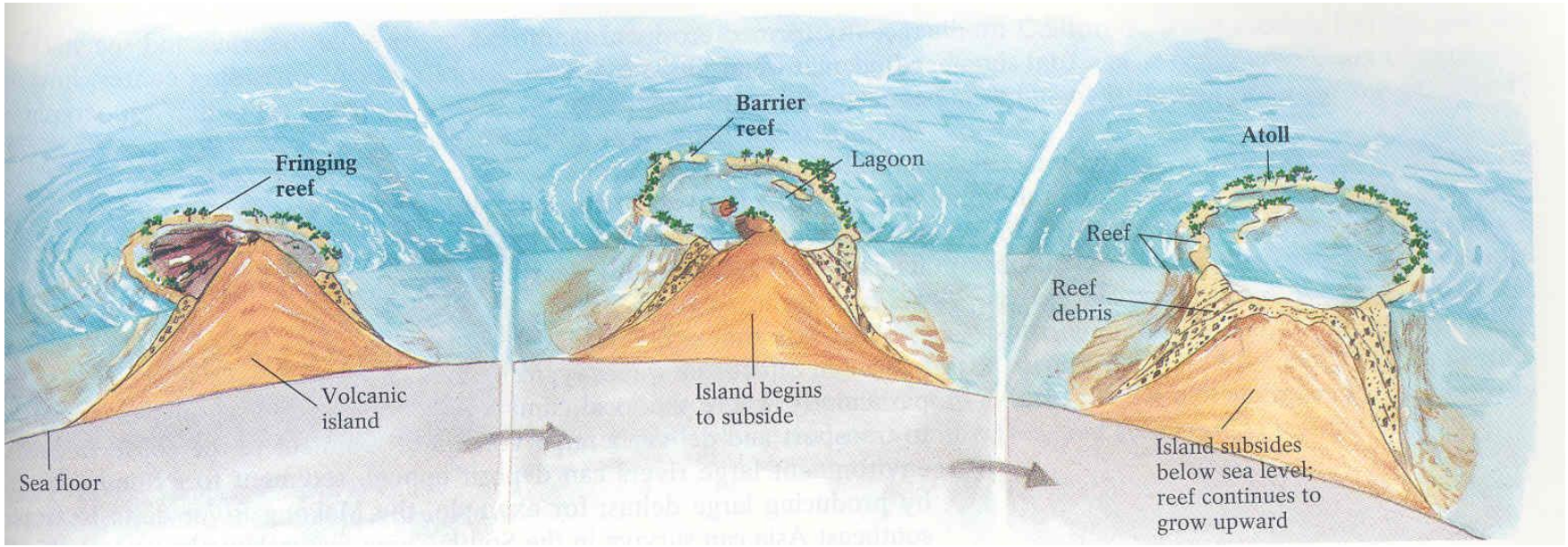
- ➔ Polyps live in 150 - 200’ deep water and when water has more $caco_3$ and the temperature is above 68 degree, these organisms segregate and build reefs which finally grow into Islands

The Evolution of Carbonate (coral) reefs

FRINGING REEFS : adjacent to the volcanic Islands

BARRIER REEFS: Lagoon between Island and Reef

ATOLL: Circular coral reef with central lagoon



SHALLOW SHELF

(Rocks Islands, Palau)

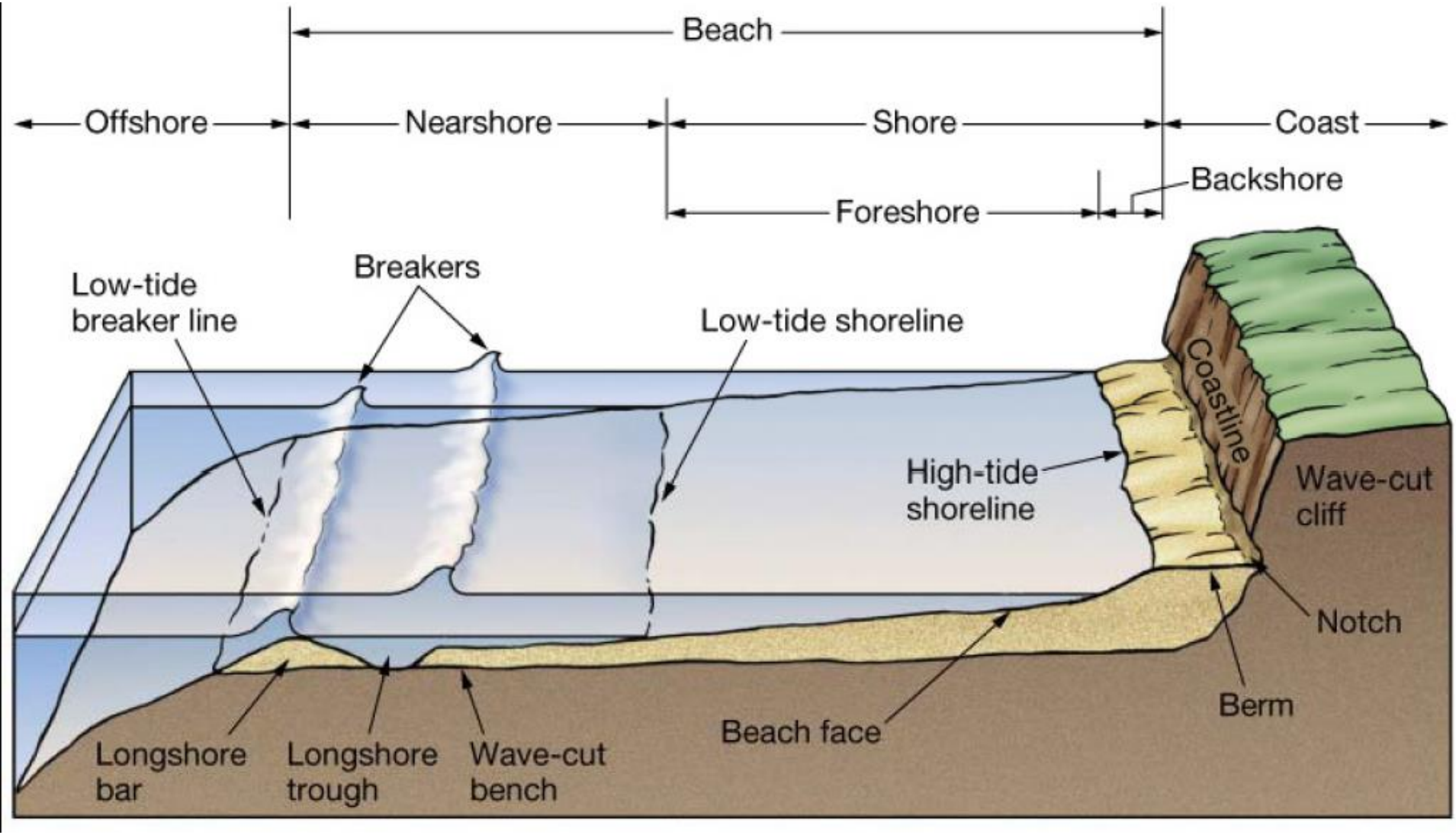
COASTAL ZONE

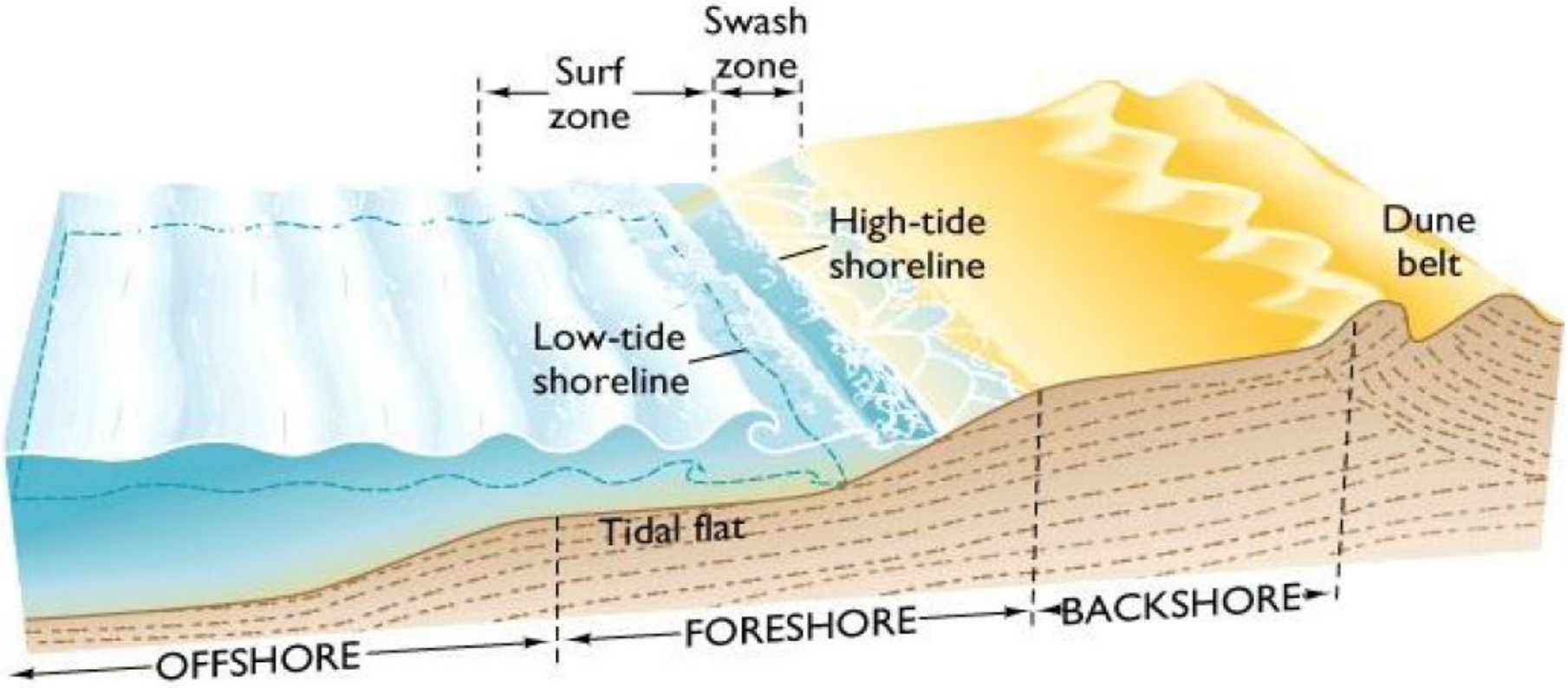
Transition zone where the land meets water

extends from continental shelf break to the first major change in topography

Classified into to four sub units

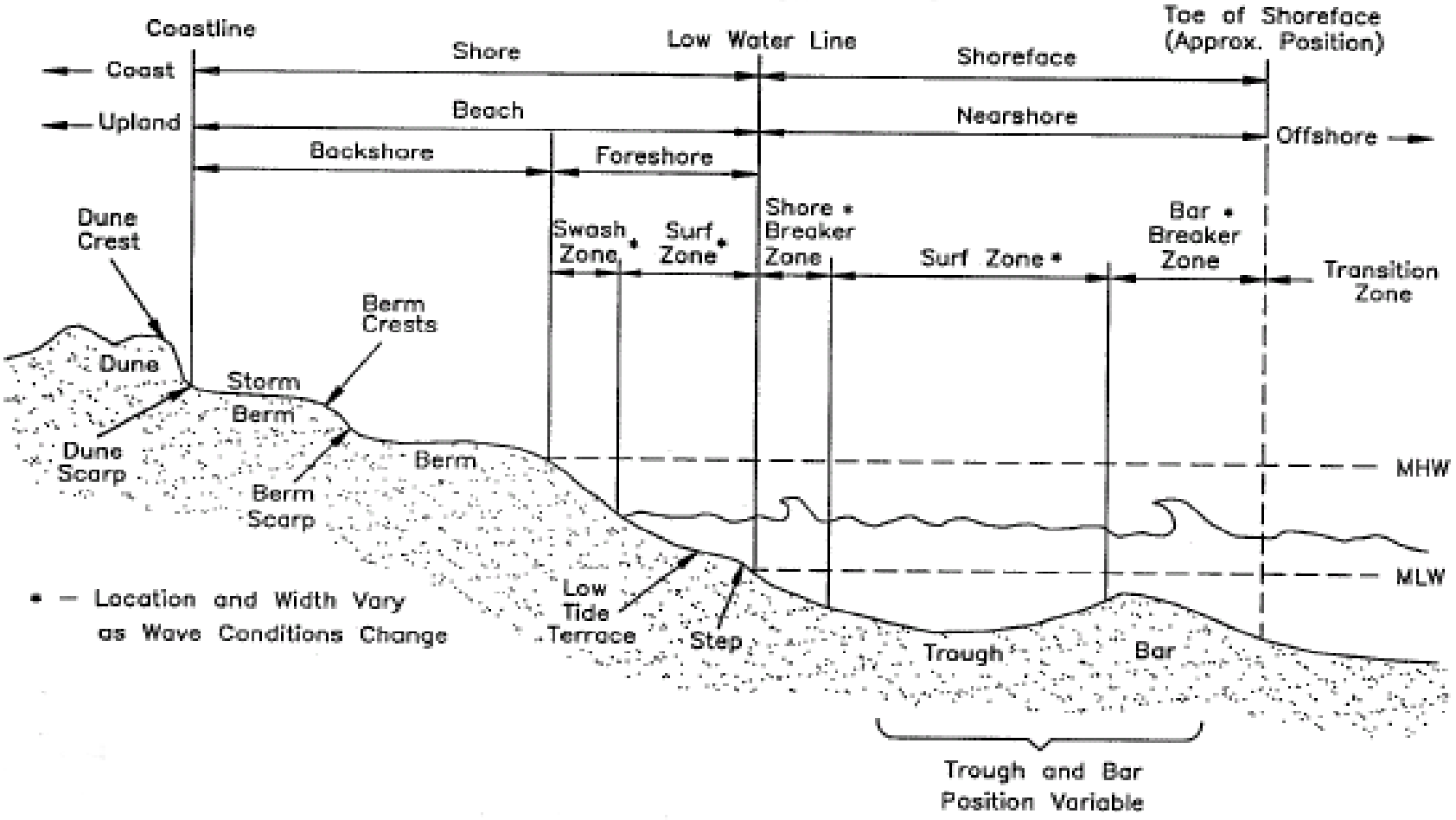
(1) Coast.
(2) Shore.
(3) Near shore
(4) Off shore.


Beach
Offshore
Nearshore
Shore
Coast
Backshore
Foreshore
Low-tide breaker line
Breakers
Low-tide shoreline
Coastline
High-tide shoreline
Wave-cut cliff
Notch
Berm
Beach face
Longshore bar
Longshore trough
Wave-cut bench


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

Coastal regions

- Coast – extends inland from shore as far inland as you can find ocean-related features.
- Coastline – boundary between shore and coast
- Shore – lowest low tide mark to highest storm wave mark (coastline)
  - Berm – above the normal high water mark to the coastline (it's where you put your towel)
  - Foreshore - between low tide mark and normal high tide mark
  - Backshore = berm
  - Shore = foreshore + berm
  - Nearshore – below low tide mark to low tide breaker zone (sub tidal always)
  - Offshore – below low tide breaker zone
- Beach = nearshore + shore


Coastline
Toe of Shoreface
(Approx. Position)
Coast
Shore
Low Water Line
Shoreface
Upland
Beach
Nearshore
Offshore
Backshore
Foreshore
Dune
Crest
Swash
Zone *
Surf
Zone *
Shore *
Breaker
Zone
Surf Zone *
Bar *
Breaker
Zone
Transition
Zone
Berm
Crests
Dune
Storm
Berm
Dune
Scarp
Berm
Berm
Scarp
MHW
MLW
* — Location and Width Vary
as Wave Conditions Change
Low
Tide
Terrace
Step
Trough
Bar
Trough and Bar
Position Variable

CLASSIFICATION OF COASTS

Coasts are highly varied and complex systems. The number and variety of coastal classifications is large and often subject to an author's personal bias or background.

Mostly classifications are based on influencing factor such as geologic history and sea-level changes, tectonic environment, glaciation, sediment supply, wave and tidal regime, biological factor, etc.

Johnson (1919) Classify the coast on the basis of Tectonic and relative sea level changes (eustatic and isostatic).

➔Submergent: Fjord or ria coast (Chesapeake Bay, Martha's Vineyard)

Submerged shoreline formed when water comes in contact with partially submerged land. This type of coast is very irregular. This produces long and narrow bays called estuaries. Due to wave action, sea cliffs, wave cut terrace, sea caves, stacks, beaches, hooks, spits, hooks, etc. are developed

➔**Emergent: Tidal flats and barrier islands**

Emerged shoreline formed when water comes in contact with partially emerged land. This type of coast is regular and flat. Water is shallow to some distance.

➔ **Neutral**

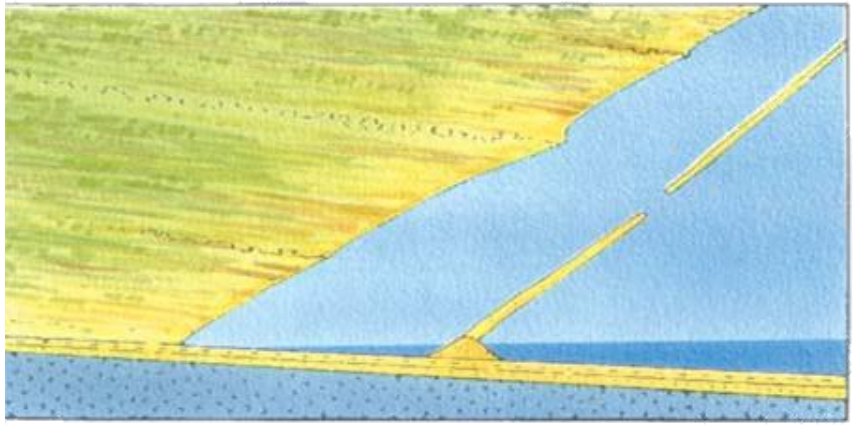
In this types, effects of submergence and emergences of land is not represented (e.g) shoreline produced by sreams (deltas), organic growth (coral reef)

➔**Compound coast**

- **Some emerging coast has the some submergent coastal features**
- **Some submerging coast has the features of an emergent coast landfomrs(e.g. barrier islands)**

Ria coast

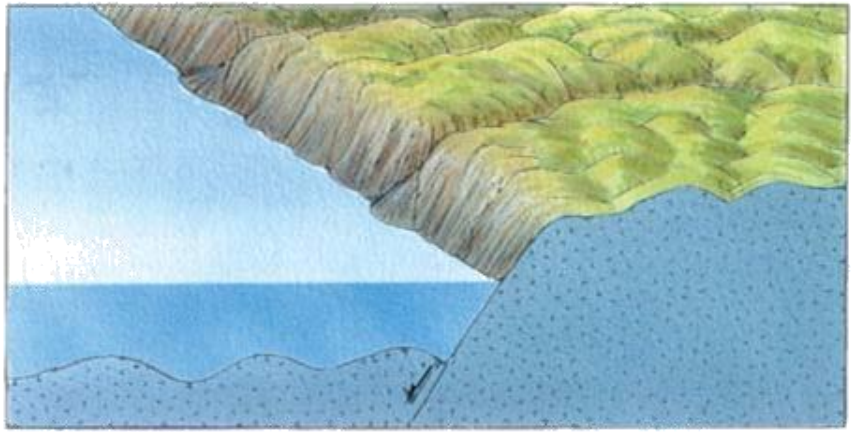
Fiord coast



Barrier-island coast

Delta coast

Volcano coast (*left*) Coral-reef coast (*right*)

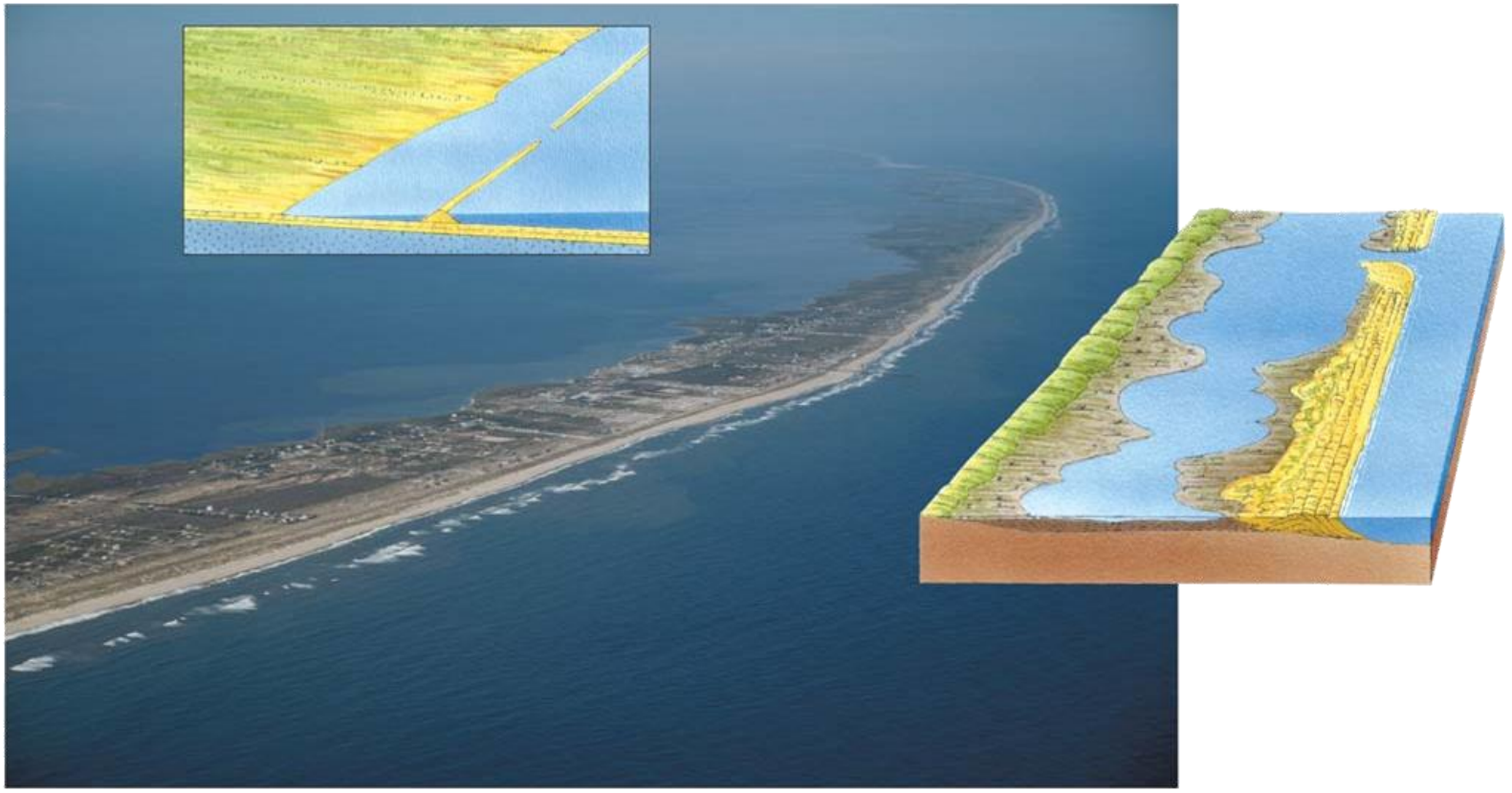


Fault coast

Fiord coast: ocean fills valleys created by glaciers

Barrier-Island Coasts

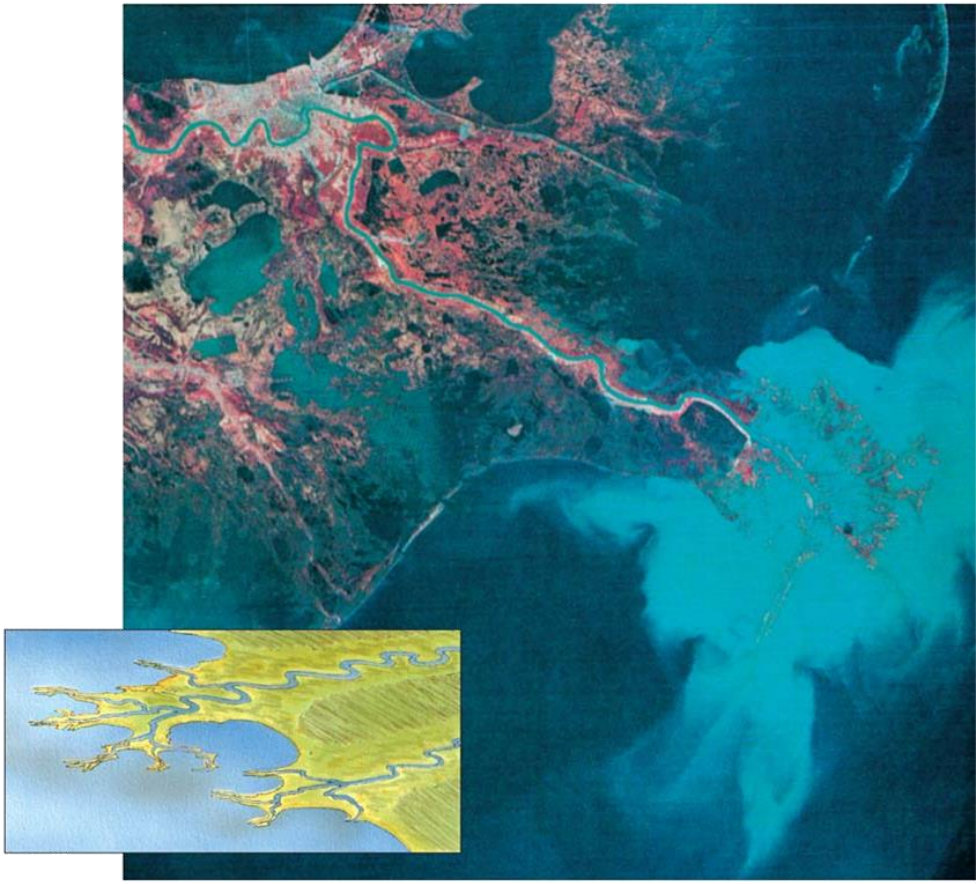
- Barrier island of sand lies a short distance from the coast
- Associated with recently emerged coastal plain
- Ridges of sand built by storm waves
- Behind barrier island is a lagoon
- *Tidal inlet:* gaps in the barrier island through which tide flows



Delta Coasts

Delta: **sediment deposit built by a stream entering a body of standing water**

- **Current of water slows as it enters ocean, and sediment is deposited**
- **River channel divides into *distributaries***
- **Deltas have a variety of shapes**
- **Deltas can grow and shrink rapidly**



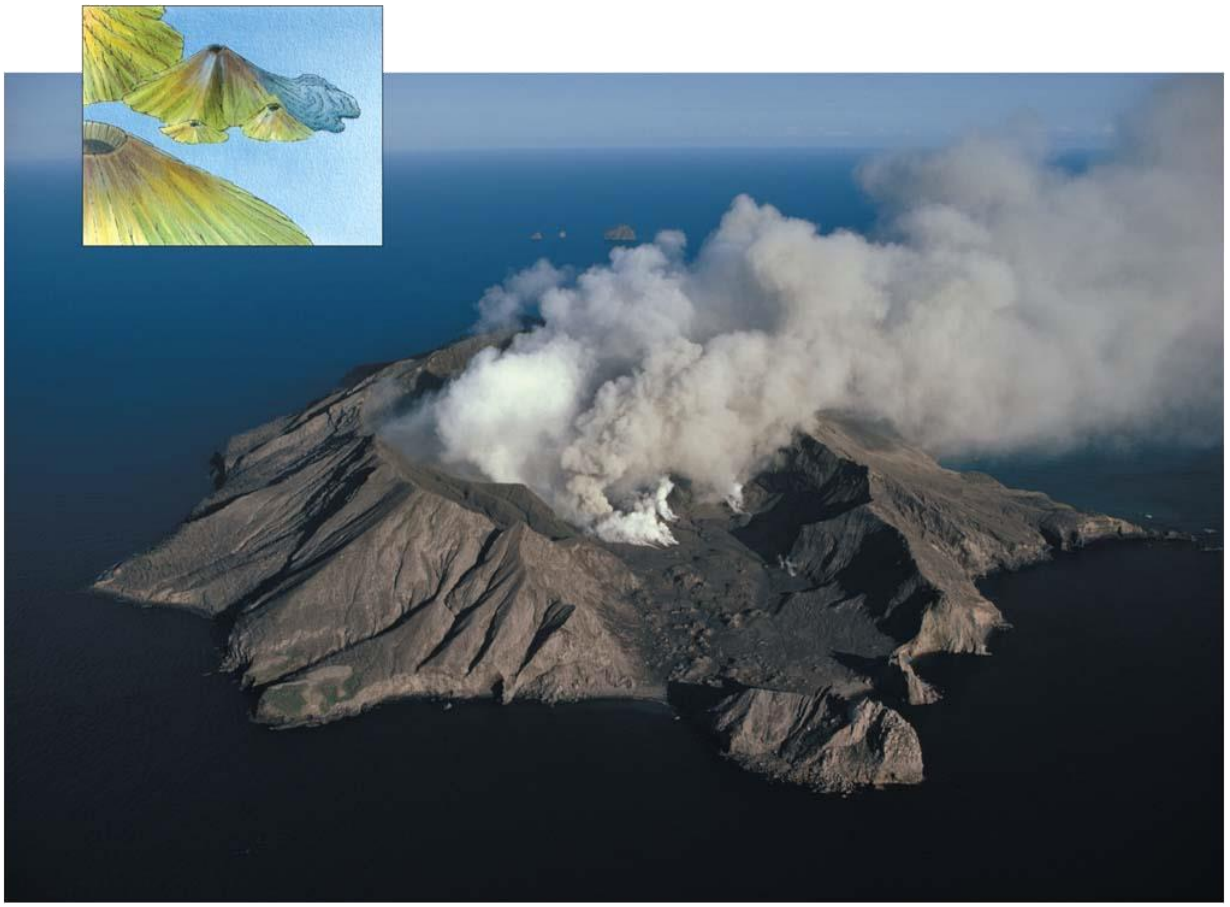
Types of Coastlines

Volcano and Coral-Reef Coasts

Volcano coasts: lava and ash from active volcanoes deposited in ocean

Wave actions erodes the deposits

Forms cliffs and narrow beaches



Types of Coastlines

Volcano and Coral-Reef Coasts

Coral reef: rock-like accumulation of carbonates secreted by corals and algae in shallow water along a marine shoreline

- New land is made by organisms
- Warm tropical and equatorial waters
- Coral needs warm, clean water, good aeration
- Reefs exposed at low tide, covered at high tide

Fringing reefs: reef platforms attached to shore

Barrier reefs: separated from mainland by a lagoon

Atolls: circular reefs enclosing a lagoon; no land inside; most grow on top of old sunken volcanoes

Types of Coastlines

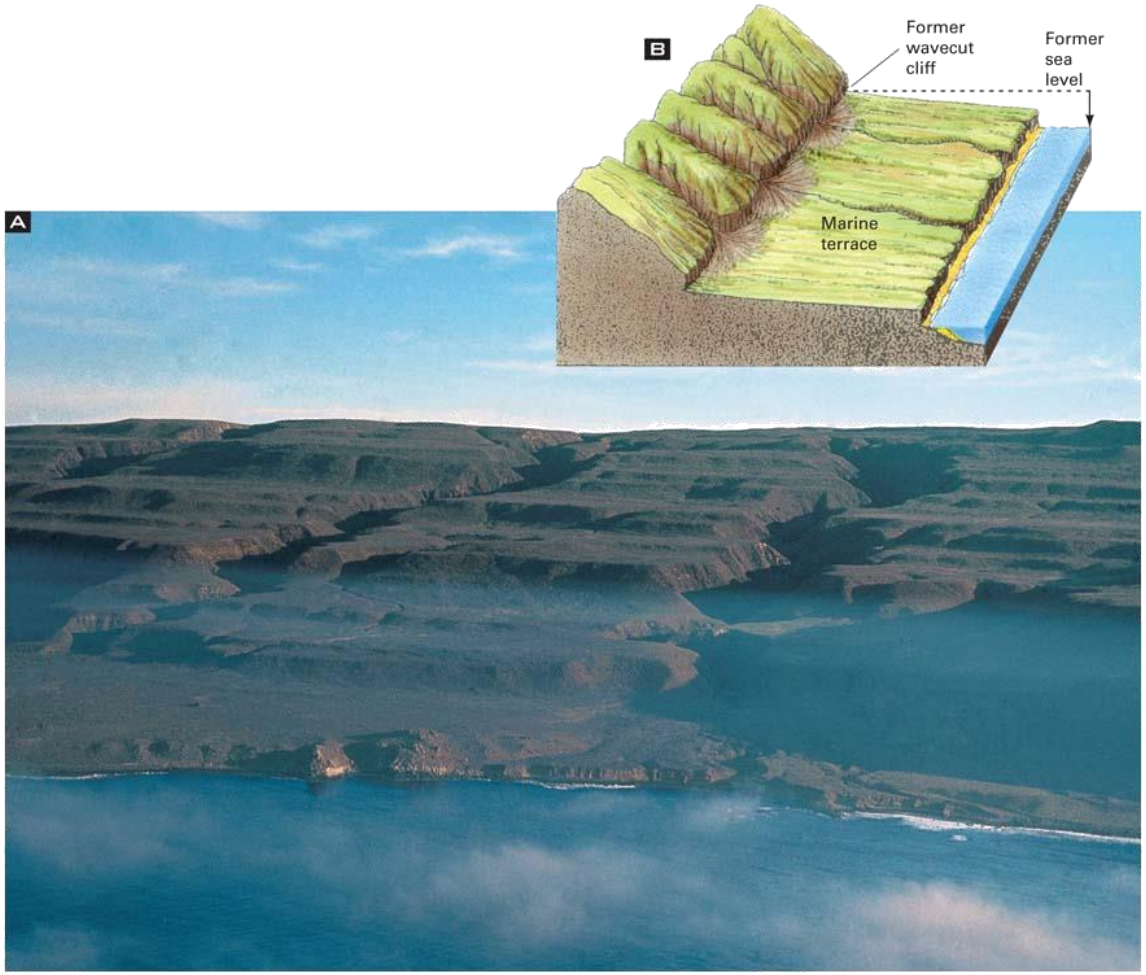
Fault Coast

Faulting can raise cliffs along a coastline

Types of Coastlines

Raised Shorelines and Marine Terraces

Marine terrace: former abrasion platform elevated to become a step-like coastal landform



Classification of the coasts on the basis of marine processes or non marine processes by Shepard (1973)

Primary coast: Unmodified--morphology controlled by non marine processes

Secondary Coasts: Modified by marine processes

Primary coast:

1. Land erosion coasts

➔Drown river valley coast : indented--shape controlled by drainage basin pattern

➔Drowned glaciated coast (e.g. Deep coastal valleys--fiords)

2. Subaerial deposition coasts

- ➔River deposition coasts
- ➔Glacial deposition coasts
- ➔Wind deposition coasts
- ➔Landslide coast
- ➔volcanic coasts
- ➔shaped by diastrophic movements (faulted coasts)

Ice coasts

Secondary Coasts (modified by coastal processes)

➔**Wave erosion coasts**
- ❖**Wave straightened cliffs**
- ❖**Differentially eroded coasts**

➔**Marine deposition coasts**
- ❖**Barrier beach**
- ❖**Barrier island**
- ❖**Barrier spit**

➔**Coasts built by organisms (Coral reef coasts (fringing reef, barrier reef, atoll, etc.)**
- ◆**Fringing Reef- initially surround land, grow seaward**
- ◆**Barrier Reef- separated from coast by a lagoon**
- ◆**Atoll- circular structure from great depth that encloses shallow lagoon**
- ◆**Mangrove coast**

Davies, 1964: Classification based on tidal energy

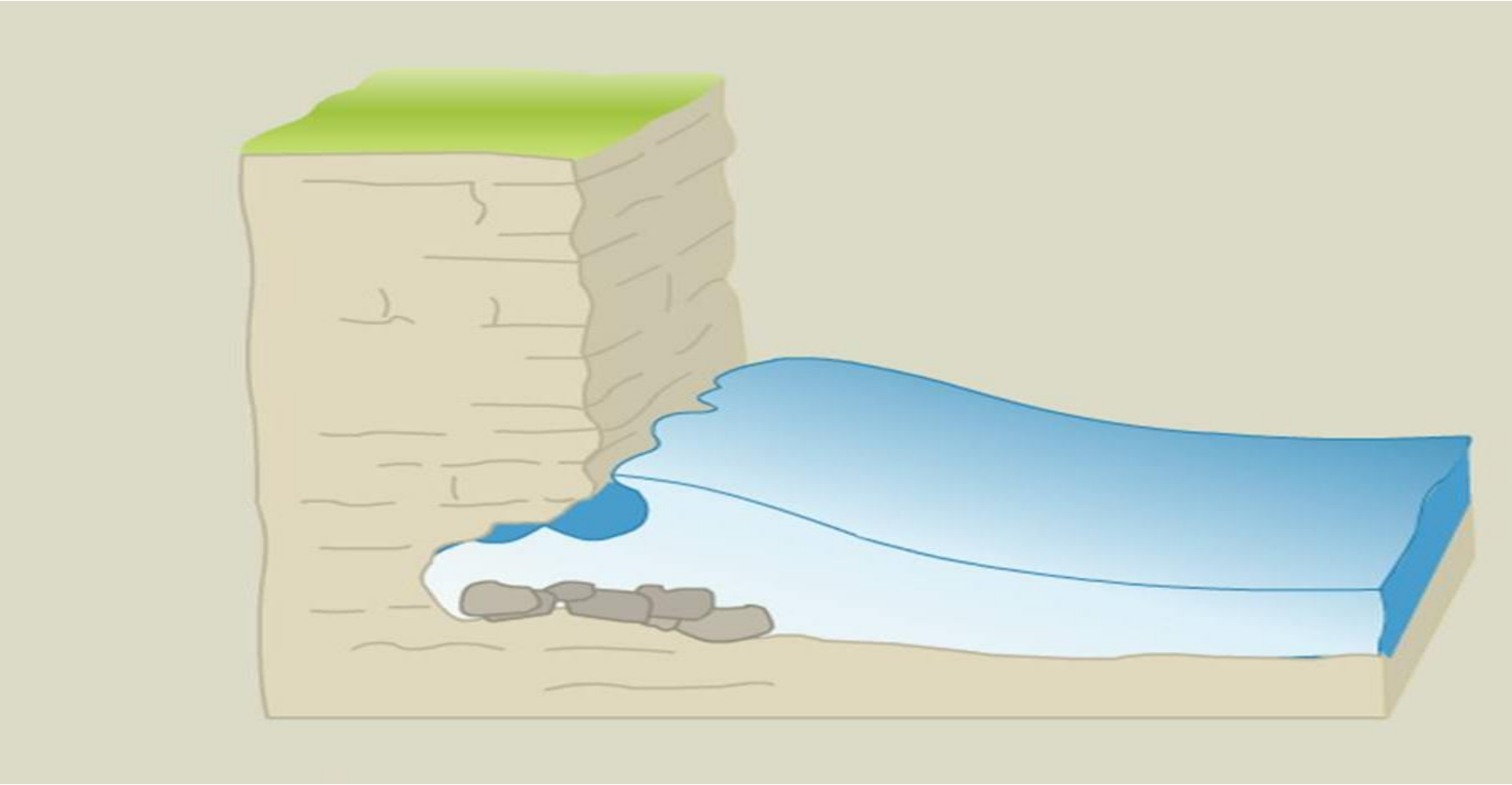
- ➔ Microtidal coasts (tidal range = 0-2 meters)
- ➔ Mesotidal coasts (tidal range = 2-4 meters)
- ➔ Macrotidal coast (tidal range >4 meters)

- ❖ Microtidal = wave dominant
- ❖ Macrotidal = tide dominate
- ❖ Mesotidal = mixed energy

Coastal landforms were formed either by erosional or depositional processes

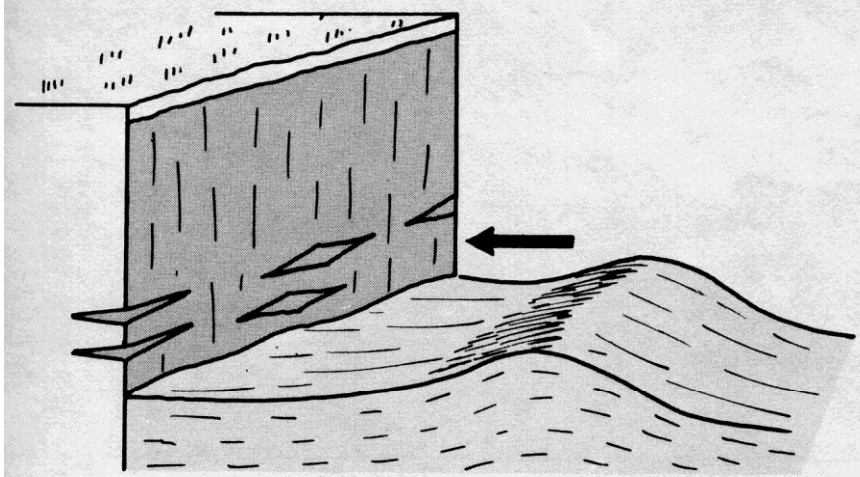
Coastal Landforms can be classified into destructional and constructional landforms

Destructional landforms formed by four main forms of coastal erosion

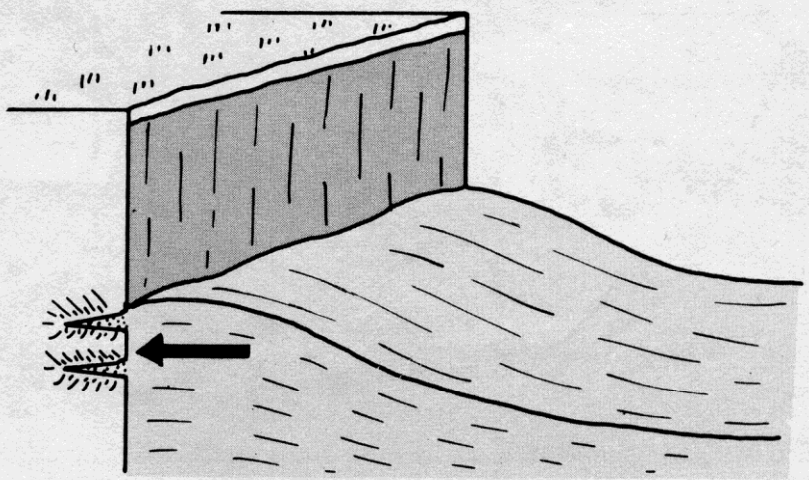


Hydraulic Action, Attrition, Abrasion, Solution

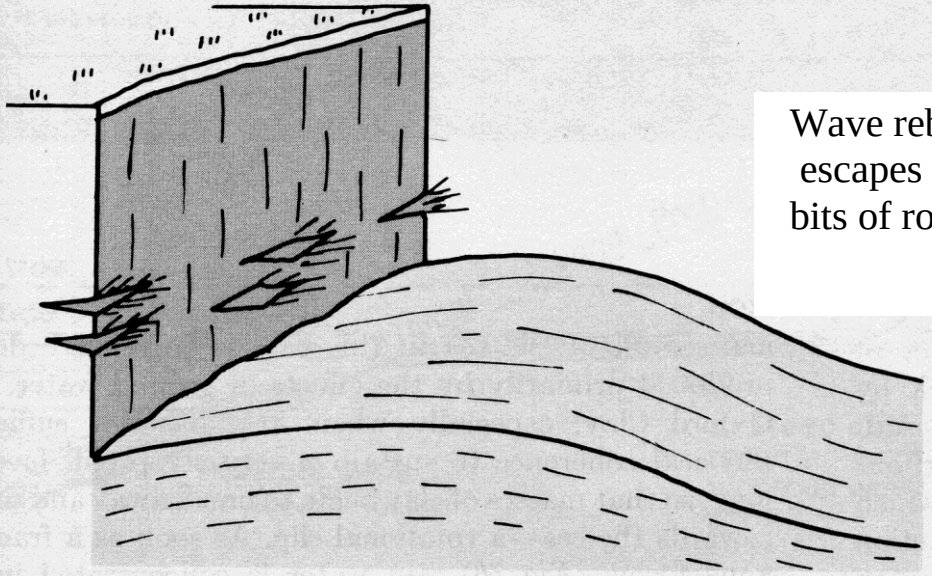
Hydraulic Action



Wave approaches the cliff. Note cracks exaggerated In size



Wave reaches the cliff & the air trapped by the wave is compressed into the crack.



Wave rebounds from the cliff & the compressed air escapes explosively, enlarging the cracks & ripping bits of rock off.

HYDRAULIC ACTION

Abrasion & Attrition (Corrasion)

Abrasion.

- The waves pick up the sediment & hurl it against the cliffs (uses the sediment as ammunition).

Attrition

- As the sediment is hurled against the cliff, bits are chipped off, the sediment gets smaller & rounder.
- Also as sediment roll against each other on a beach.

Corrosion (Solution)

- Salt & other chemicals in sea water attack & dissolve the cliffs.

EROSIONAL LANDFORMS
or
DESTRUCTIONAL LANDFORMS

EROSIONAL LANDFORMS

SEA CLIFF

Coastal highlands due to wave erosion undergo undercutting as a result the overhanging block get collapsed.

WAVE CUT TERRACE

Sea cliff retreats leaving flat platform

SEA CAVES

The underlying weak rocks erode faster that the overlying hard rock resulting cave like morphology

SEA ARCH

Caves may develop from both sides, when unnite develop SEA ARCH

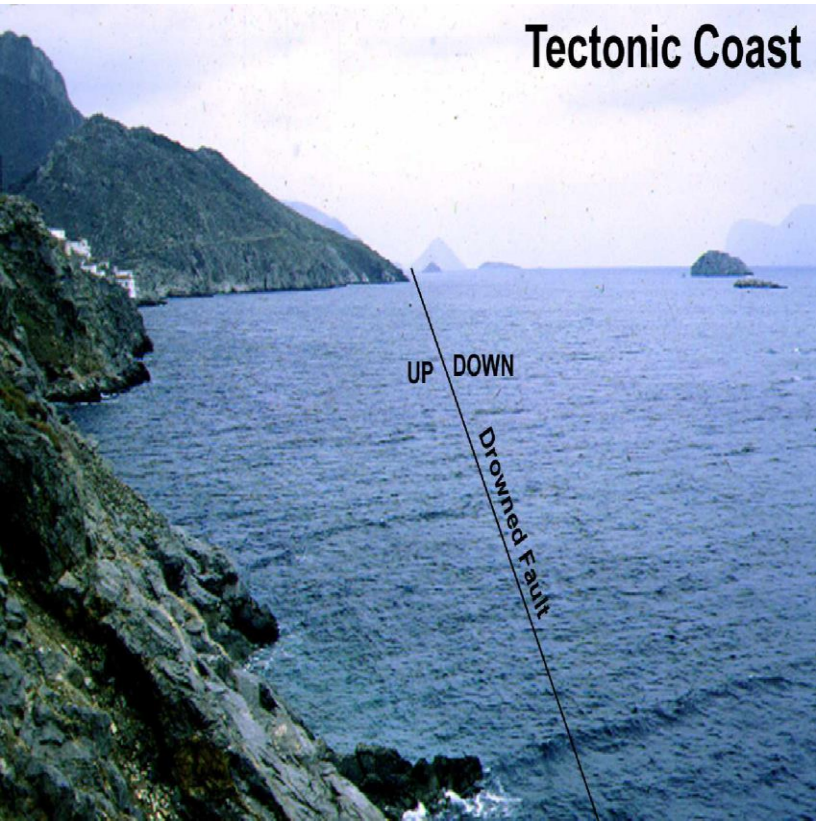
HEADLANDS

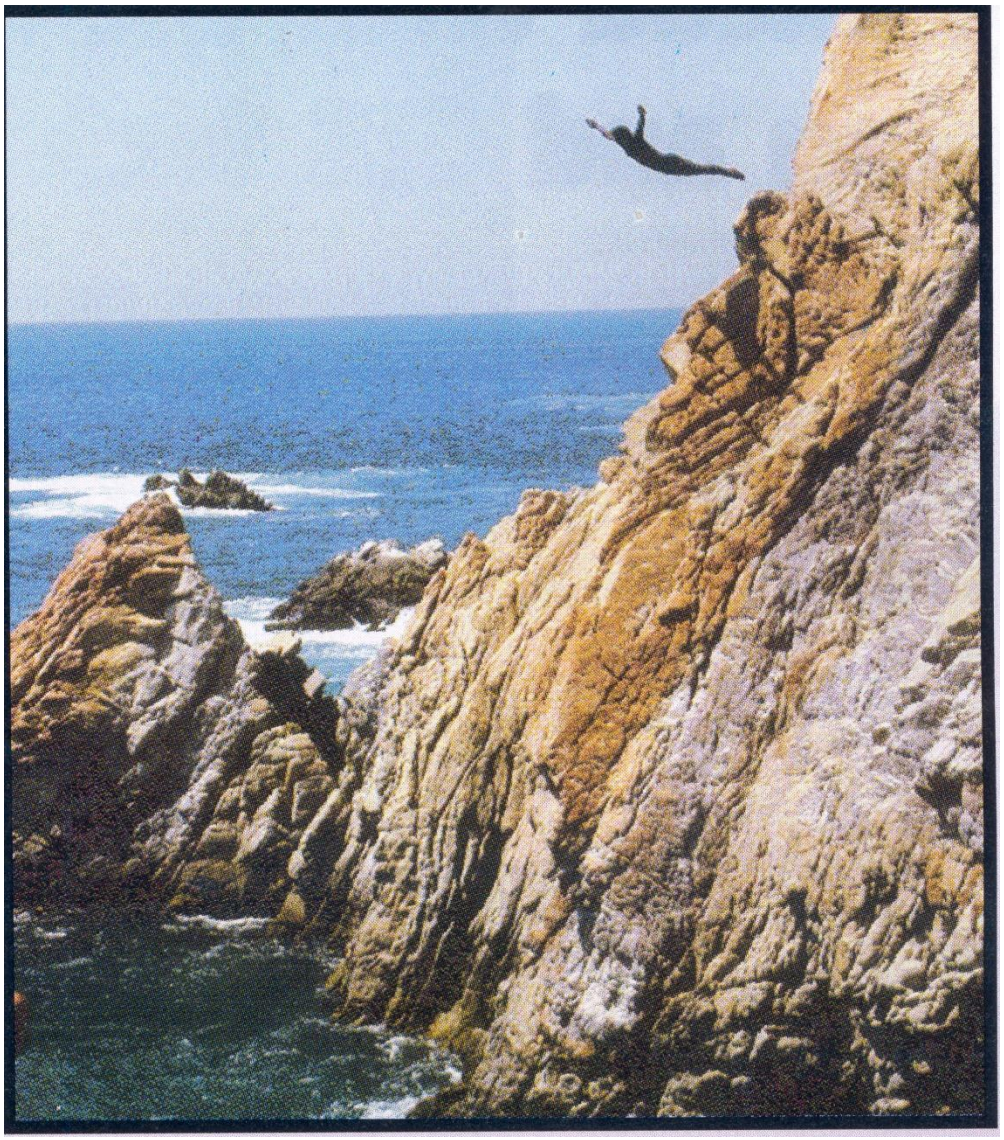
If there is alternate hard rock and weak rock, results in unequal erosion The hard rock extending into the sea is called as HEADLAND

STACKS

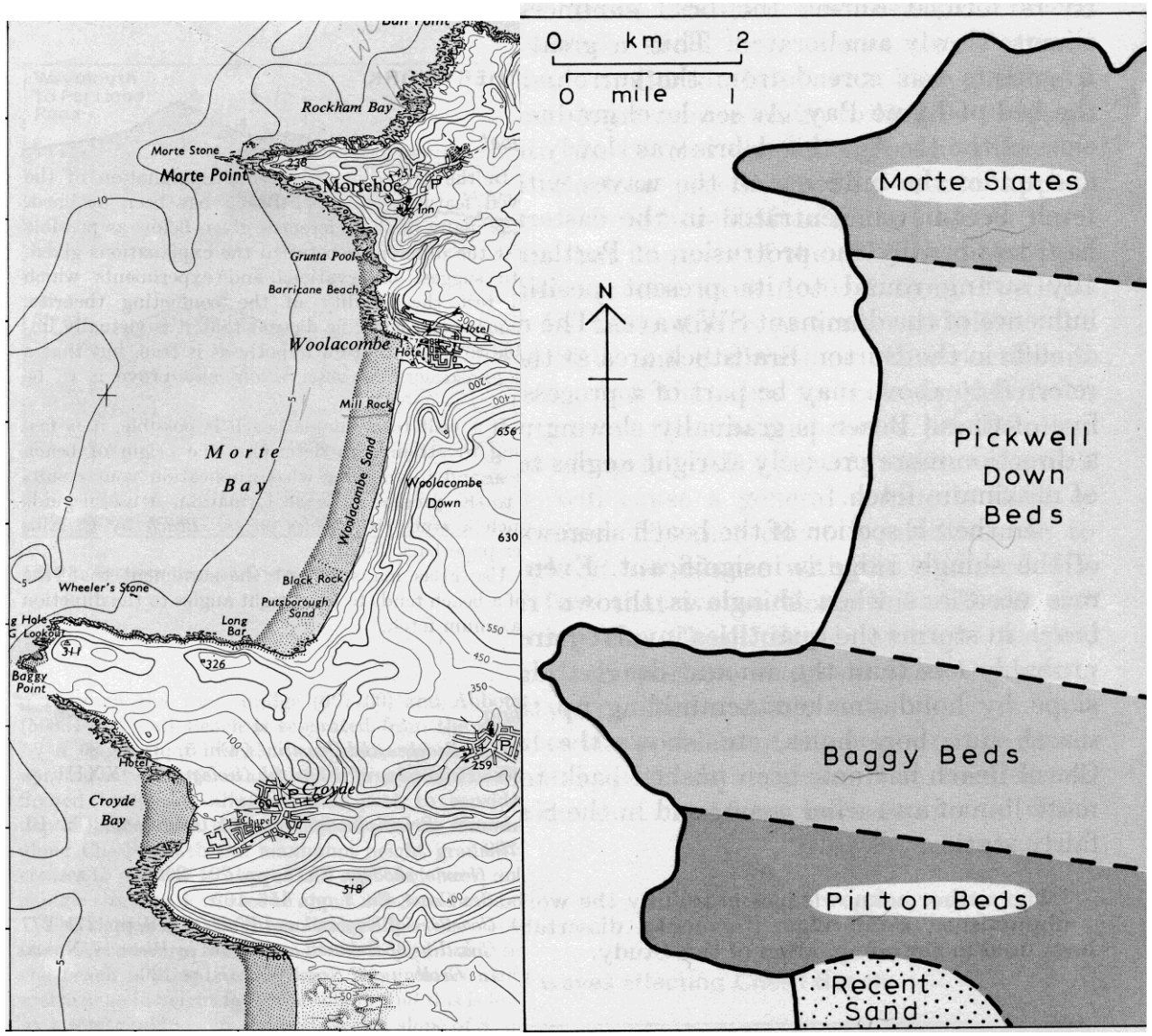
Continuing erosion will develop isolated block of rock called as STACKS

HARD / ROCKY COAST



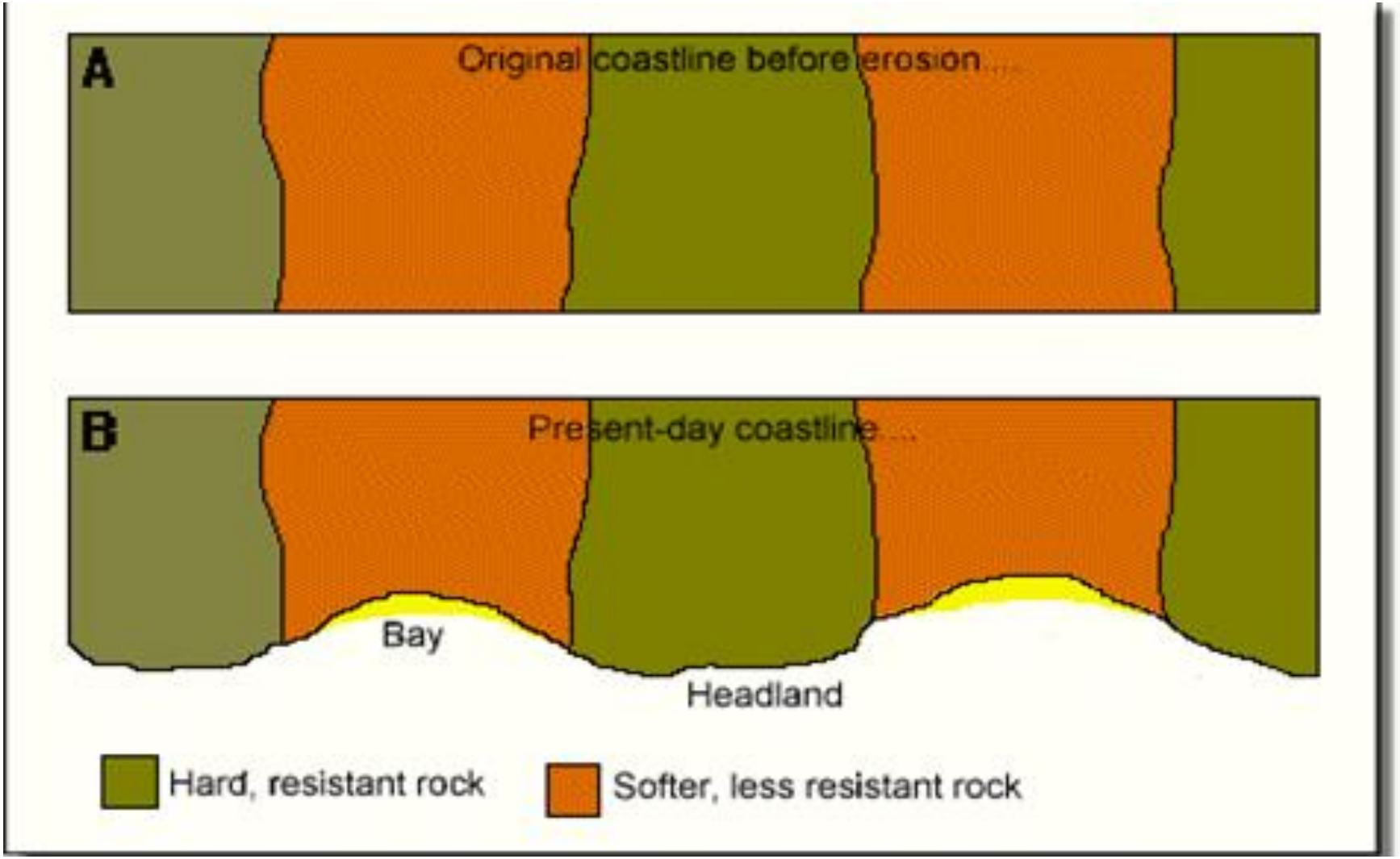


Headland & Bay

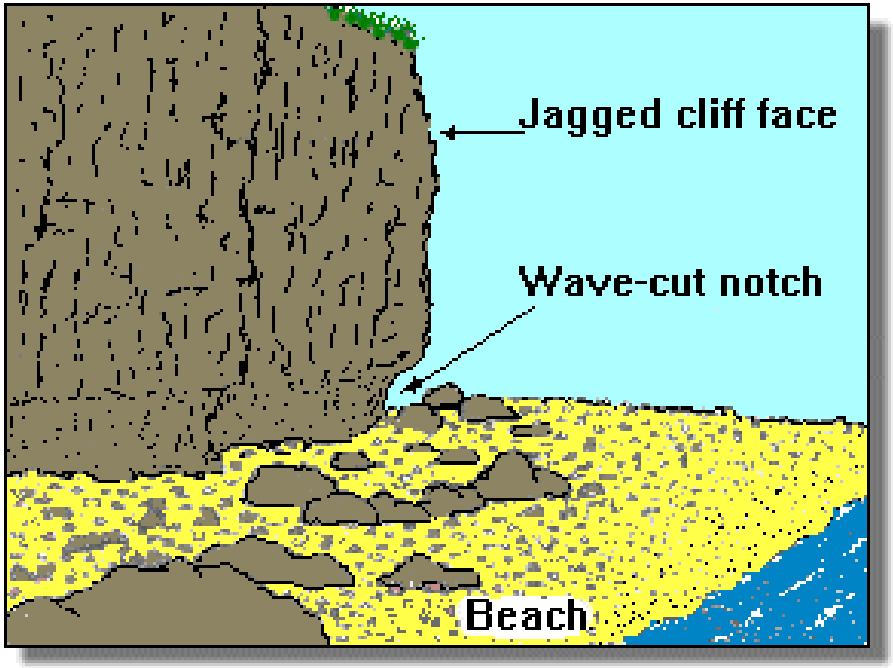


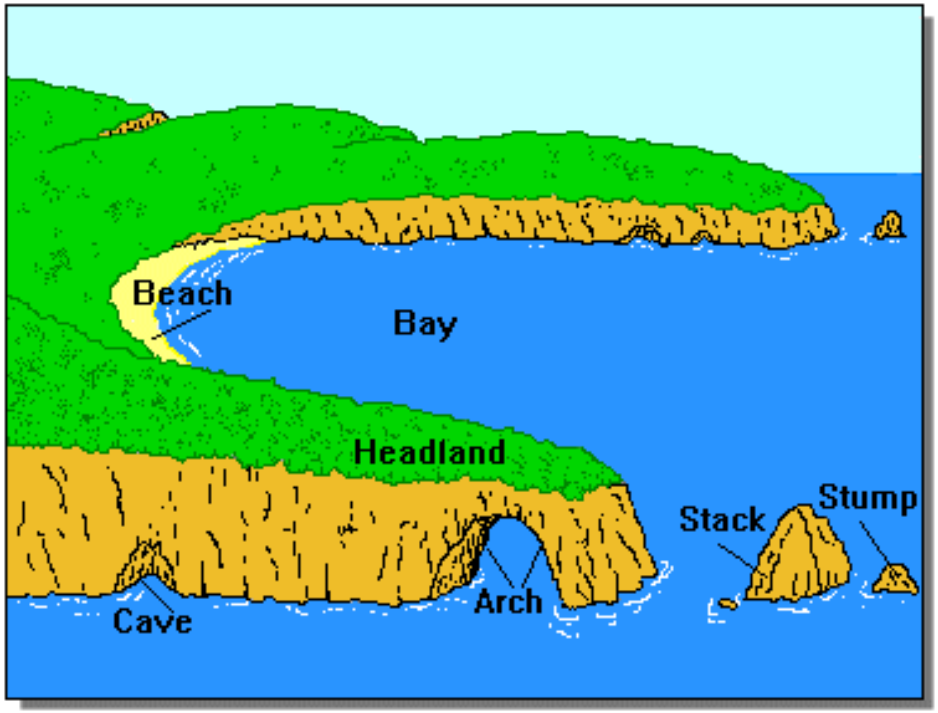
- On a larger scale geological differences influence the whole shape of the coastline, as here in N. Devon.

Headlands & Bays

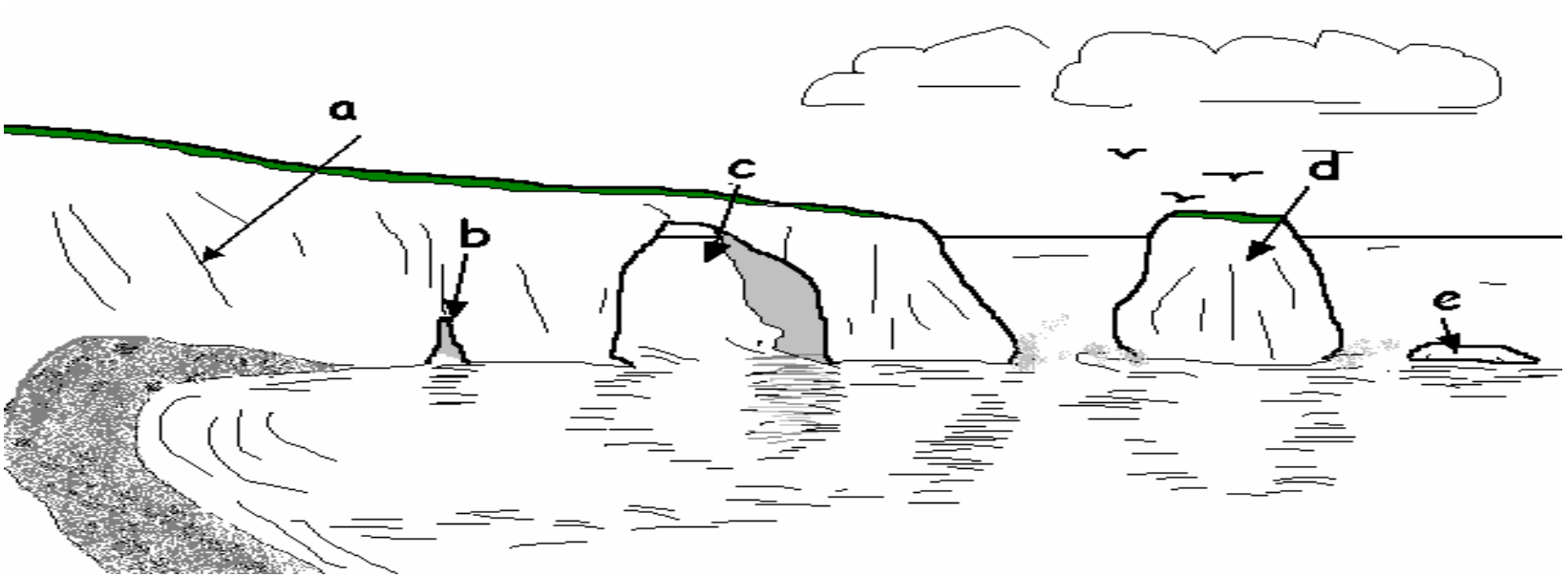


EORDED ROCKY COAST FEATURES

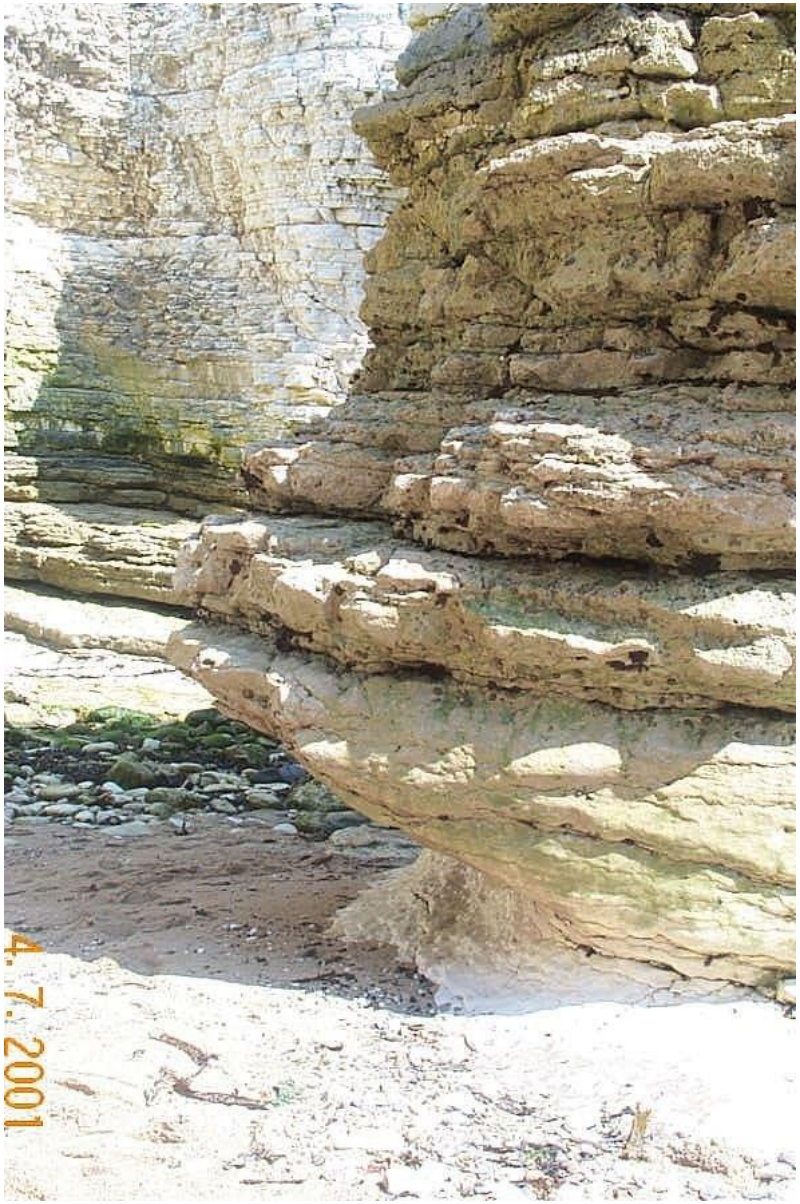




Stages in coastal Development



a) geological weakness (e.g. fault) forming a geo.
b) formation of sea cave by marine erosion.
c) enlargement of cave to form arch.
d) collapse of arch to form stack.
e) removal of stack to create a stump.



- **Wave attack is concentrated at the foot of the cliff.**
- **The waves cut a notch in to the cliff foot**
- **Flamborough Head, North Yorkshire**

Wave Cut Platform

- The cliff above the wave cut notch eventually collapses leaving the cliff further back.
- Repeat this process & a wave cut platform is left at the cliff foot, indicating retreat.

Fairlight Head, E. Sussex

Cliff

- Constant wave attack at the base & leave a steep, near vertical cliff.
- Fairlight head, E. Sussex.

Crack, Inlet or Geo

- Wave attack picks out cracks, joints & weaknesses in the cliff.
- In time these weaknesses are widened, to form inlets or Geos

- Fairlight Head, E. Sussex

Sea Cave

- The inlet is further widened & deepened to form a cave
- Fairlight Head, E. Sussex

Natural Arch

- Eventually the cave deepens enough for it to pass through the headland, or it meets another cave coming the opposite direction.
- London Bridge, Australia

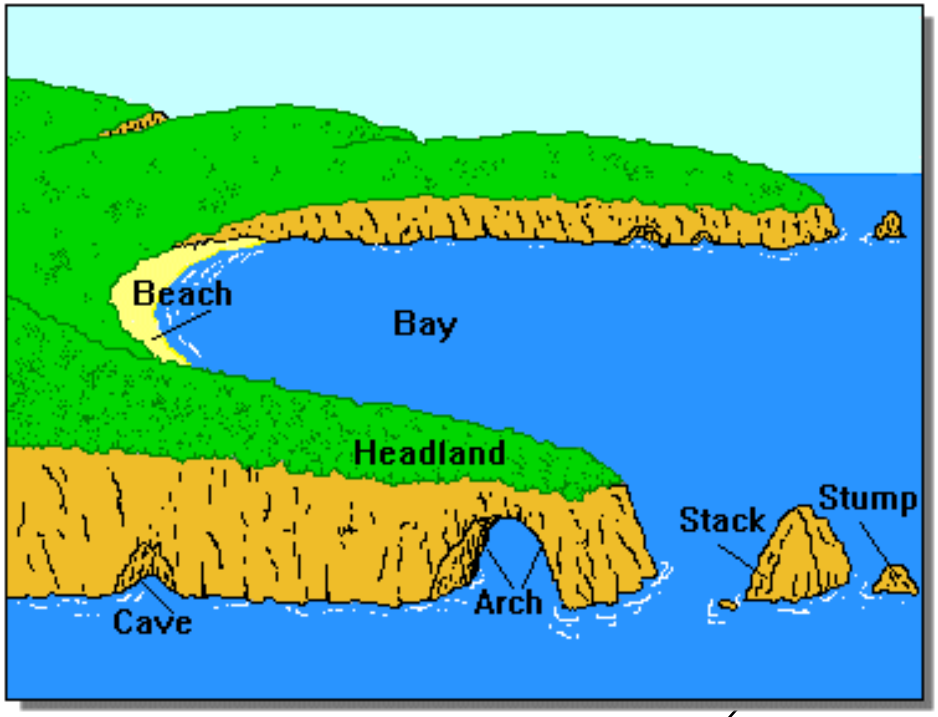
Stack

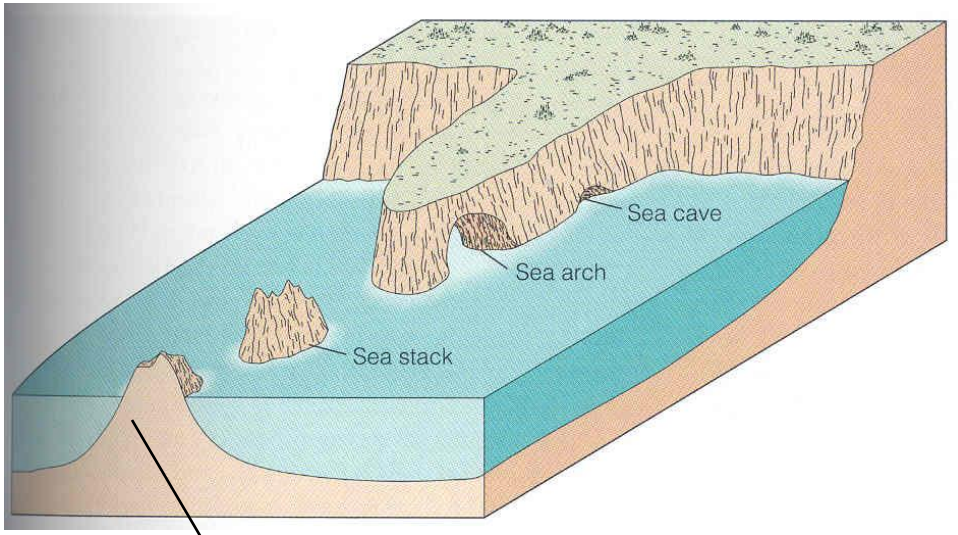
- Continual erosion of the arch causes the roof to become unstable & collapse
- The Twelve Apostles, Australia.

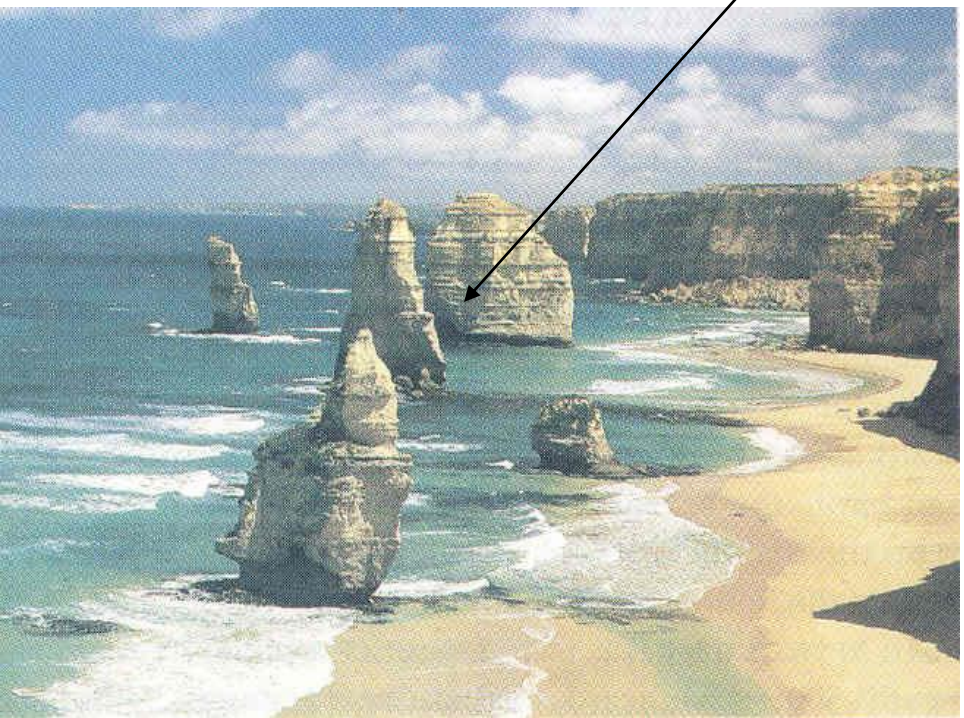
Stump

Continual attack of the stack reduces its height & width & it gradually disappears

Land's End, Cornwall


Beach
Bay
Headland
Stack
Stump
Arch
Cave


Sea cave
Sea arch
Sea stack




Stream
Bay
Headland
Spit
Clifts
Stacks
Stumps
Pacific Ocean

ERODED - SANDY / WETLAND COAST

SANDY / WET LAND COAST

ERODED - SANDY / WETLAND COAST

DEPOSITIONAL LANDFORMS
or
CONSTRUCTIONAL LANDFORMS

1. Beach Ridges
2. Strand Plain Complex
3. Swales
4. Mud Flats / Tidal Flats
    a. Supra Tidal Flats
    b. Inter Tidal Flats
    c. Sub Tidal Flats
5. Creeks
6. Backwaters / Lagoons
7. Salt Flats
8. Beaches

9. Bay Mouth Bars / Spits
10. Protruding Delta
11. Submarine Delta
12. Offshore Islands
13. Shoal
14. Offshore Mud Bank
15. Stabilized Coastal Dunes
16. Migratory Coastal Dunes
17. Coastal Sand Sheets

1. Beach Ridges

- Beach ridges are the long and linear sub parallel swarms of sand ridges occurring parallel to the coast for several kilometers both continuously and discontinuously.

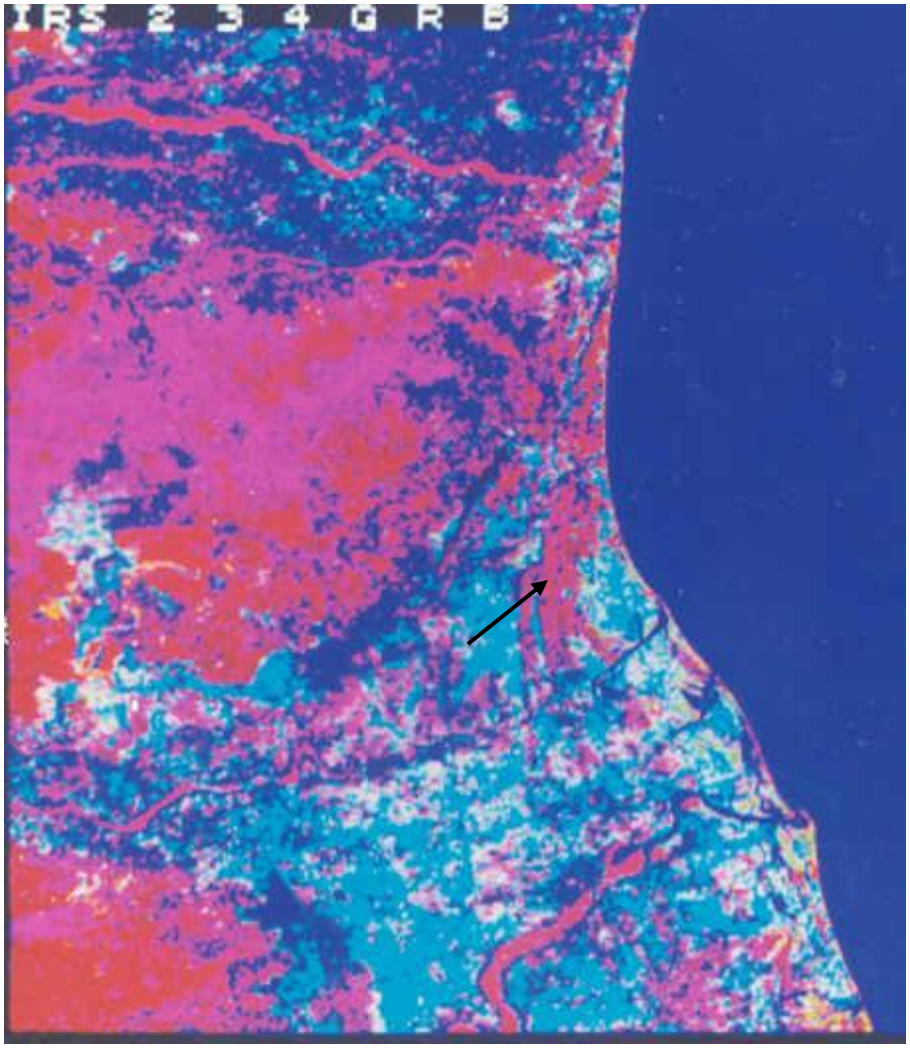
- These represent the ancient shorelines along which the littoral currents and the waves have dumped the sediments and built the beaches.

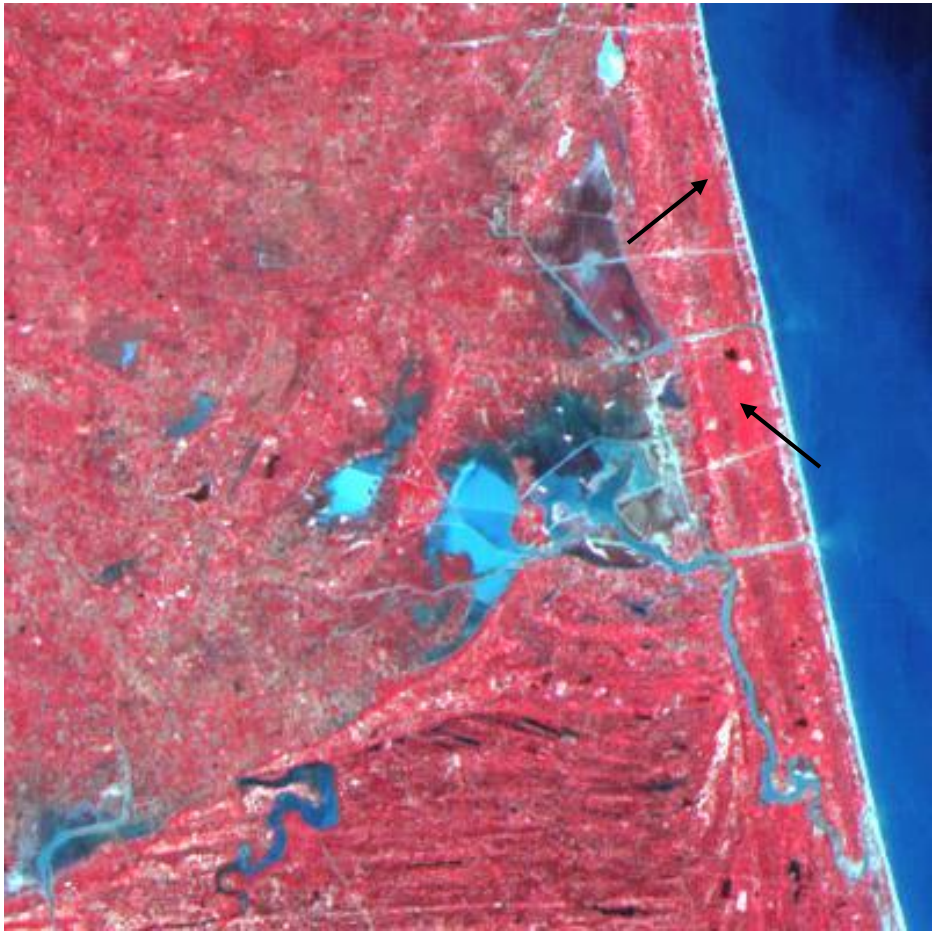
- These have become stabilised as long and linear sand ridges called beach ridges during the process of sea level recession

- These Beach ridges further classified into Palaeo beach ridges (close to landward side) and younger beach ridges (close to seaward side)

STABLISED BEACH RIDGES

BEACH RIDGES





Swales

- **The set of linear depressions sandwiched between the long and linear sand ridges running for several kilometers parallel to the coast are called as swales.**

- **These swales are having 100m to 200m width and at places even more.**

- **These swales have permanent connection with the sea either through the creeks or the streams.**

- **The floor and the banks of the swales are characterized by black clays and mudflats.**

Palaeo Swales

- **sub parallel linear depressions found amidst the long and linear palaeo beach ridges and occurring at a little higher elevation from the MSL are called as palaeo swales.**

- **The clayey sub stratum while indicates its marine origin, the absence of linkage with sea and lack of tidal activities indicate that these would have lost their linkages with the sea in the recent past.**

- **Hence, these are called as palaeo swales.**

Mud Flats / Tidal Flats

- **Fringing the creeks, river mouths, swales, backwaters and near the shore, the mudflats and saltpans are found. These normally occur under the grip of the tidal activities**

- **Extensive land , alternately covered and uncovered by the tide activities consists of unconsolidated sediment (clays, silts and/or sands)**

a. Supra Tidal Flats: Above the MSL

b. Inter Tidal Flats: At MSL level

c. Sub Tidal Flats: Below MSL

SUPRA-INTER-SUB TIDAL FLATS

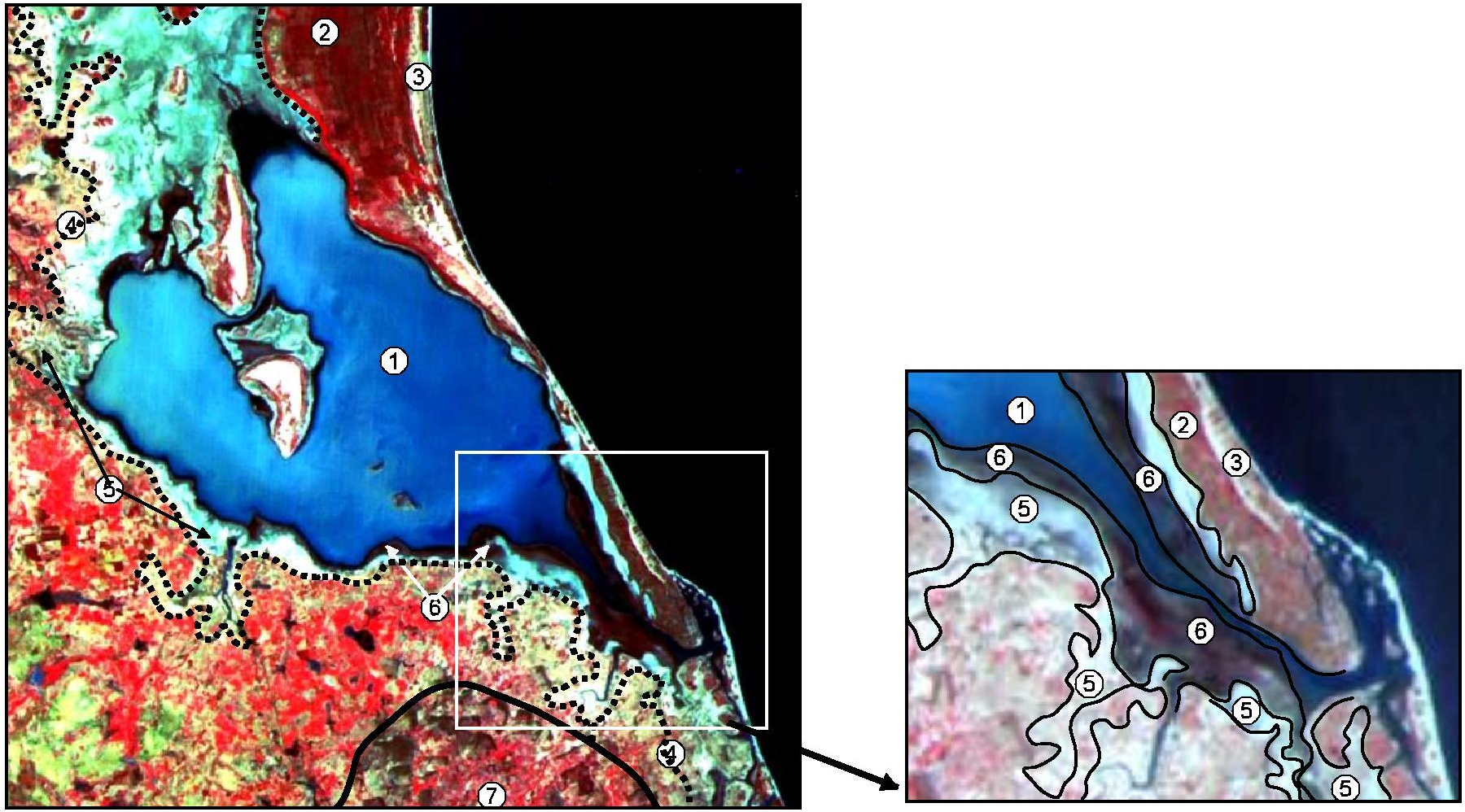
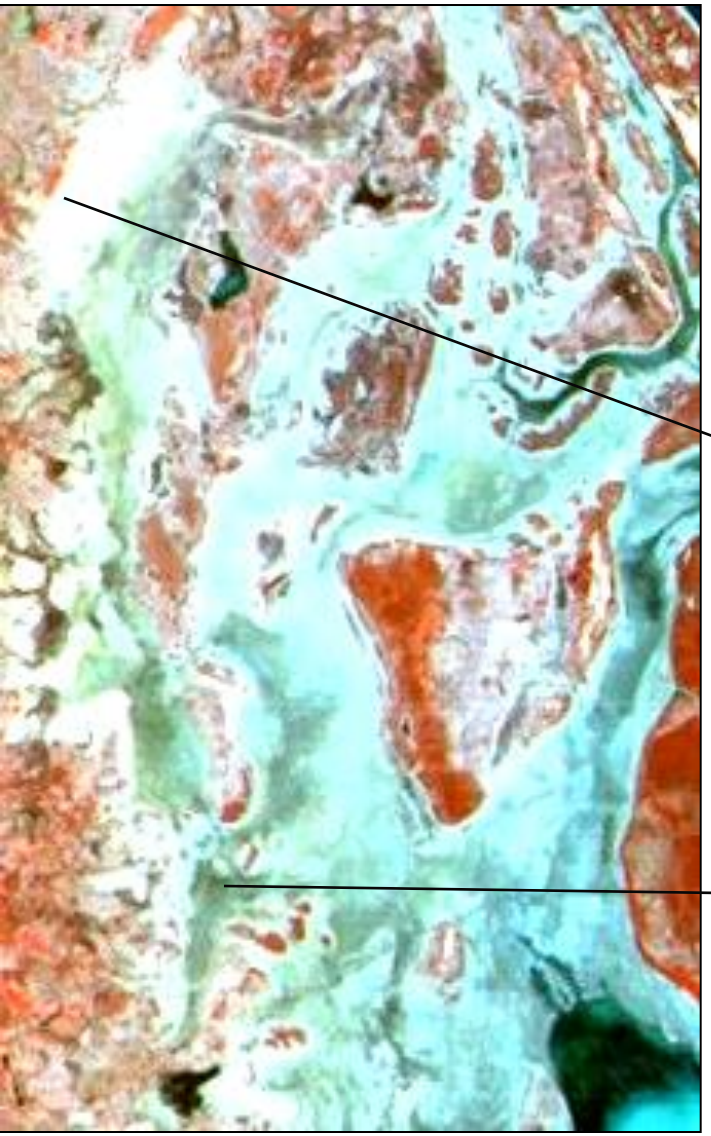


Fig.2 IRS 1B FCC IMAGE SHOWING MORPHOLOGY OF PULICAT BACKWATER & ADJACENT AREA

① Backwater ② Relict Beach Ridges ③ Recent Beach Ridge Complex ④ Older Limit of the Backwater ⑤ Supratidal Flat
⑥ Inter Tidal Flat ⑦ Micro Delta

Mud flats & salt flats



Pulicat lake area

MUD FLAT - GERMANY

Mudflat

TIDAL FLATS / MUD FLATS

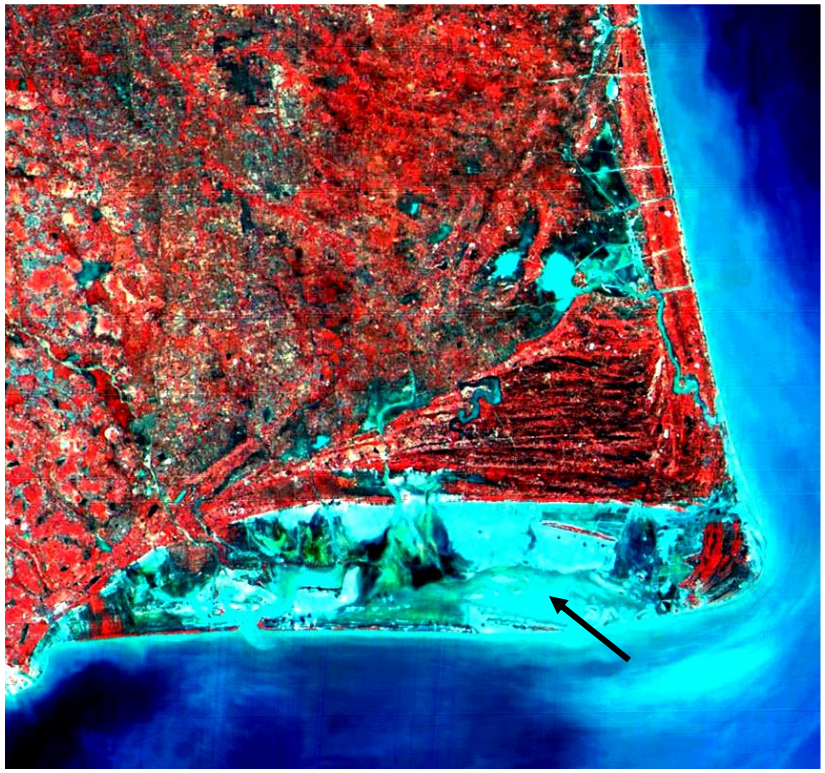
Creeks

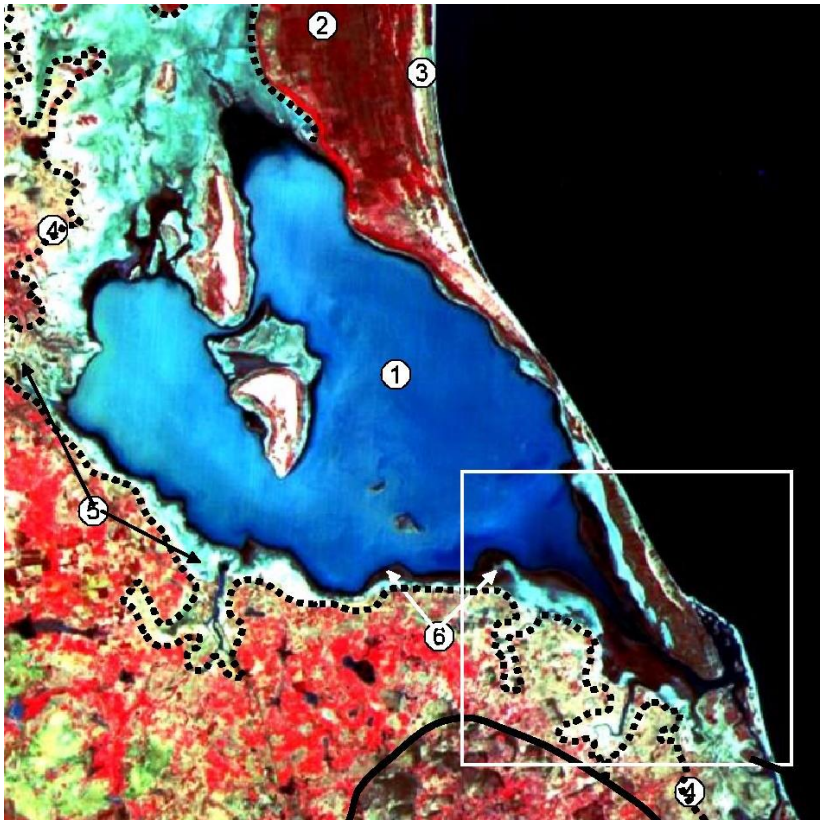
Along the river or stream mouth, fractures, narrow depressions, the tidal water comes and go. This is called the creek

Backwaters / Lagoons

Seawater comes through creeks, swales, fractures and fill the adjoining lowlands areas are called backwater

Water caught up between barrier and shore





Beaches

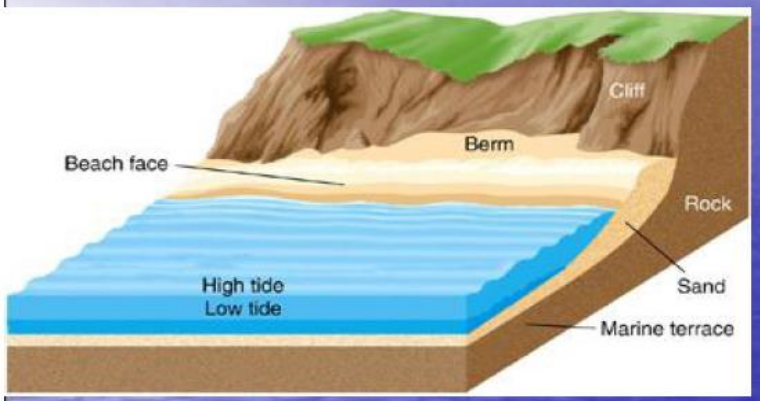
Loose material deposited on the shore by wave action

May be continuous for many miles, or isolated pocket beaches

Unconsolidated sediment extending from a change in topography to low tide mark

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

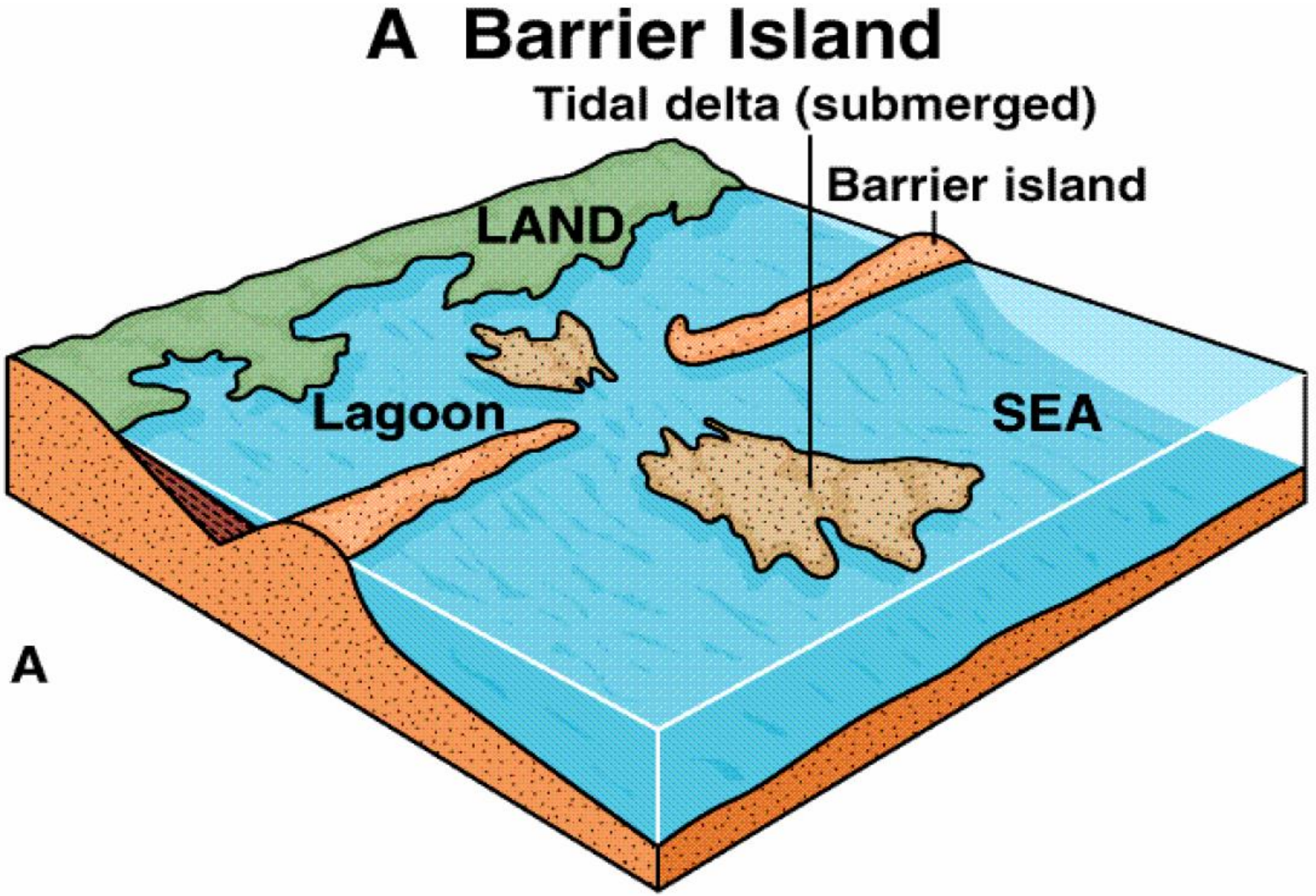


Beaches

Loose material deposited on the shore by wave action

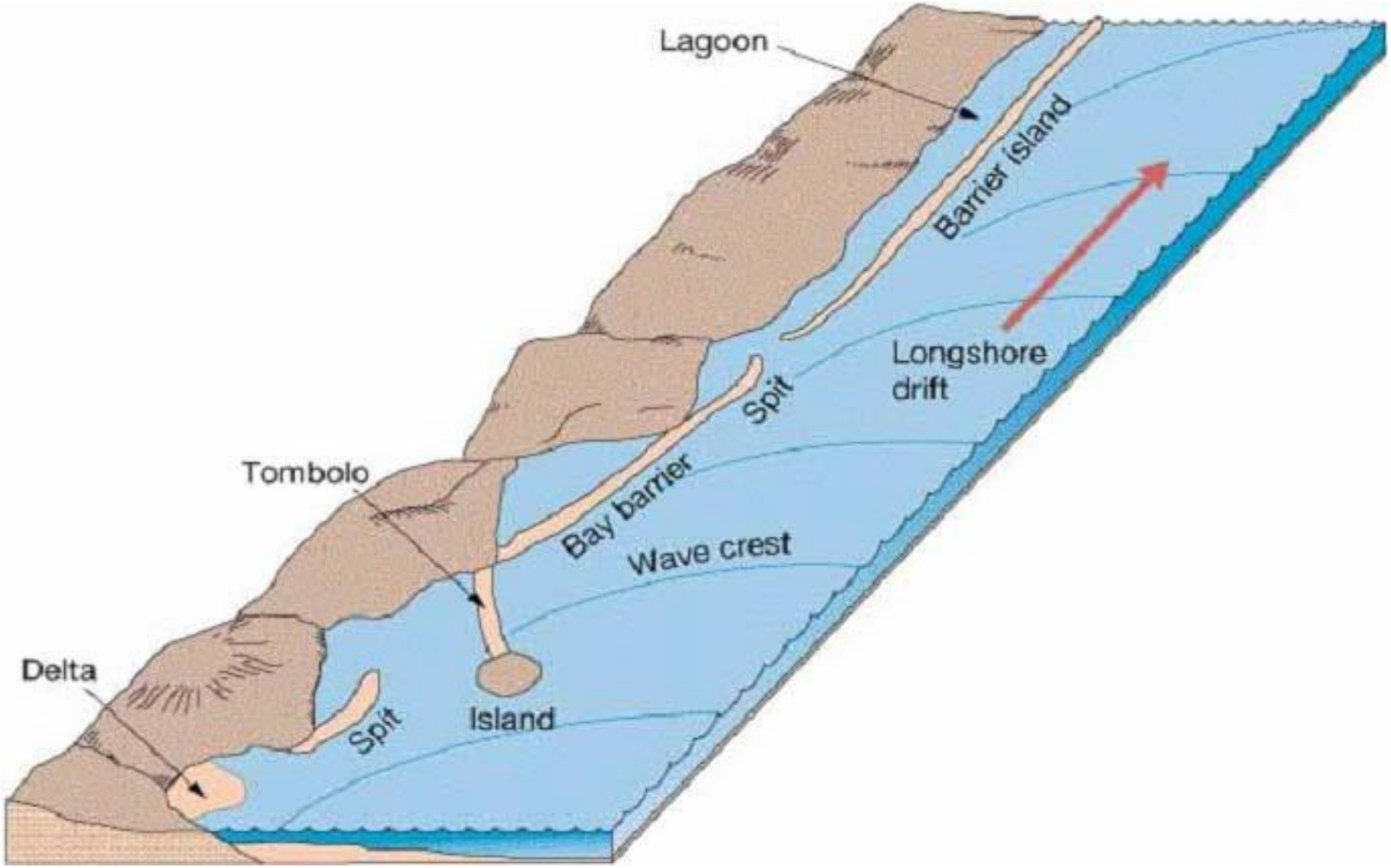
BARRIER BEACH

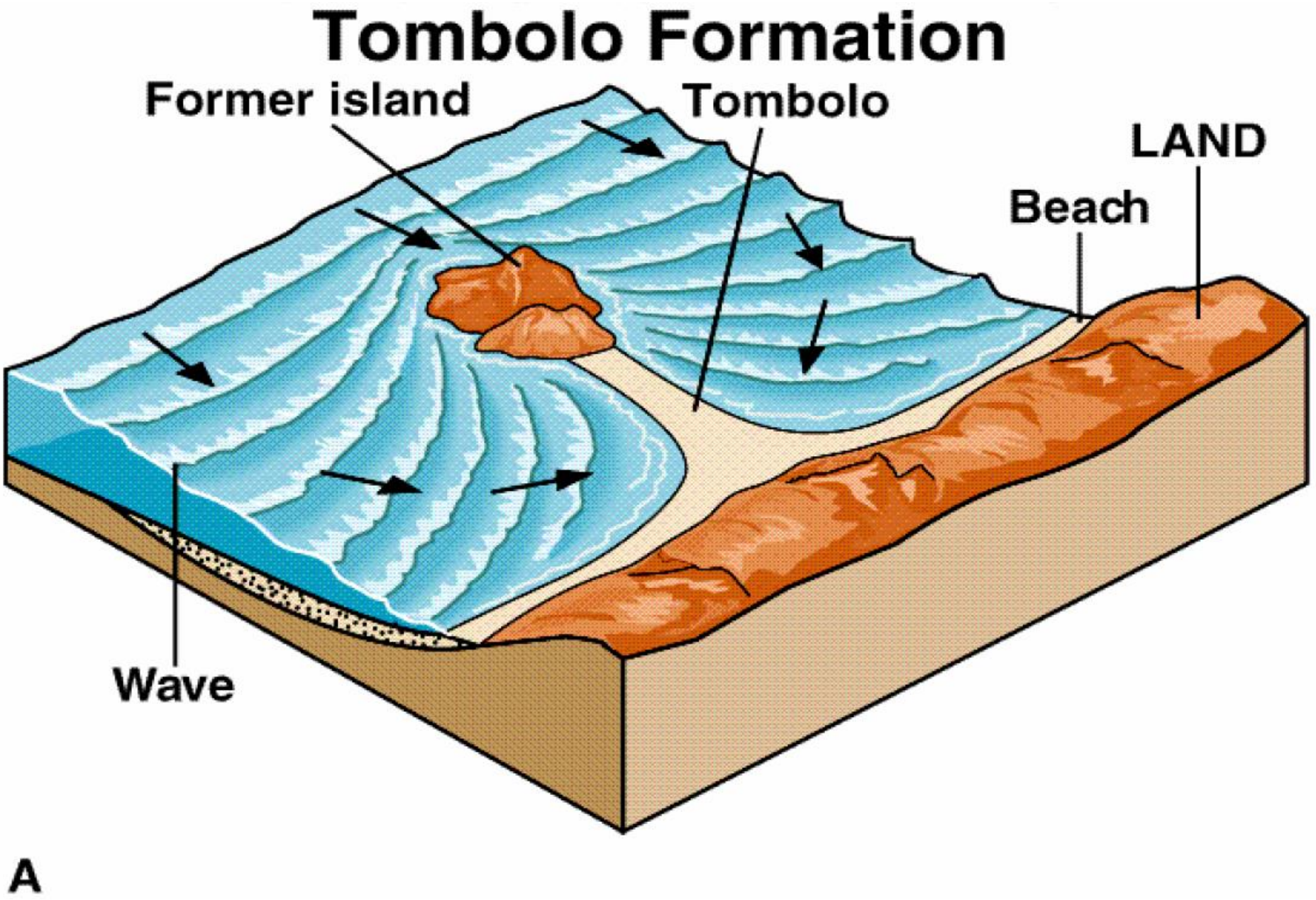
When current and wave deposit material parallel to shore (few meters inside the sea)



B

A Barrier Island


Lagoon
Barrier island
Longshore drift
Spit
Tombolo
Bay barrier
Wave crest
Delta
Spit
Island


Tombolo Formation
Former island
Tombolo
LAND
Beach
Wave
A

Bay Mouth Bars / Spits

Bay Mouth Bar: Sandbar developed at the river mouth or creek mouth parallel to the shore is called Bay mouth bar.
Spit: Growth of sandbar at an angle to the shore or at mouth of an embayment or at faulted segments are called spit HOOK: Curved spit
This indicates that these rivers are dynamically weak, thus facilitating the littoral currents to dump the sediments and build the sandbars at their mouths.

- ➔ **Formed by littoral currents**
- ➔ **Good indicator For palaeo littoral current pattern**

Example. Spits of Tamil Nadu coast
Example. Off shore bars Tirunelveli coast

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

Spit forms when waves and longshore currents transport sediment along beach

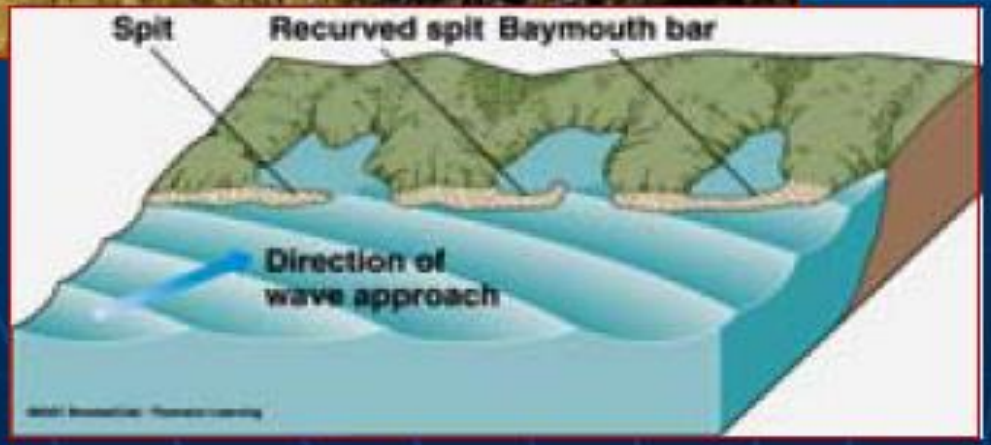
14.05.b7

Spit can grow into baymouth bar

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

3D

Spits and Baymouth Bars



- Spits are fingerlike projections of a beach that form a free end
- Baymouth bars form when spits grow until they close off a bay from open water

Longshore transport, sand bars, and barrier islands

1830–1850 Circle shows

1870–1890 The beach

1910–1930 The southern

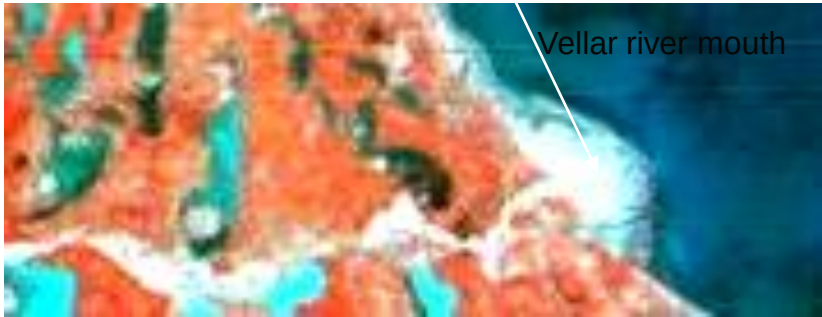
1950–1970 The northern

1987 140-year cycle begins

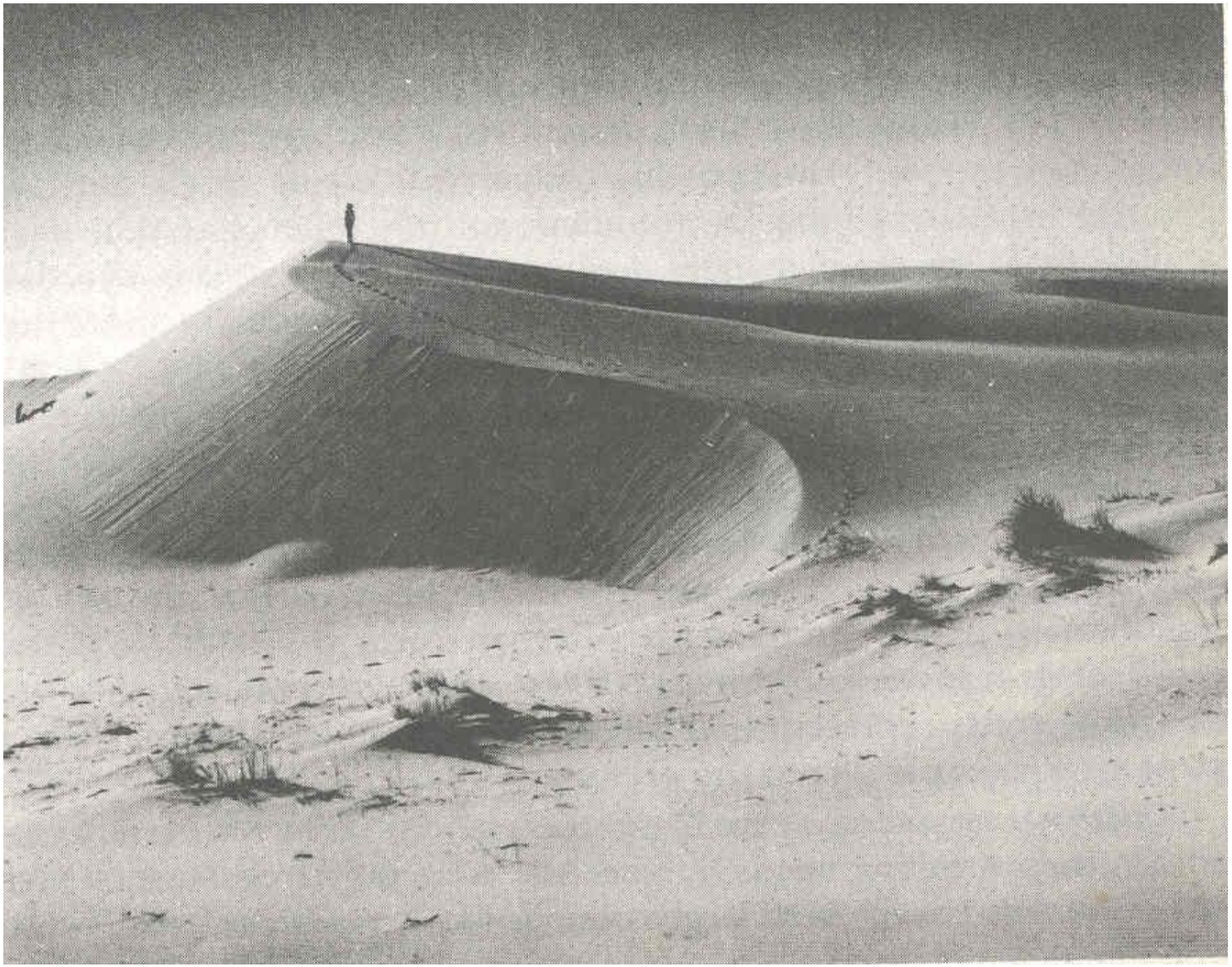
Protruding Delta: Delta Developed at river mouth or at confluencing point is called Protruding delta:

Indicate Excessive soil erosion in catchment

Protruding Delta



COASTAL DUNE - OREGON



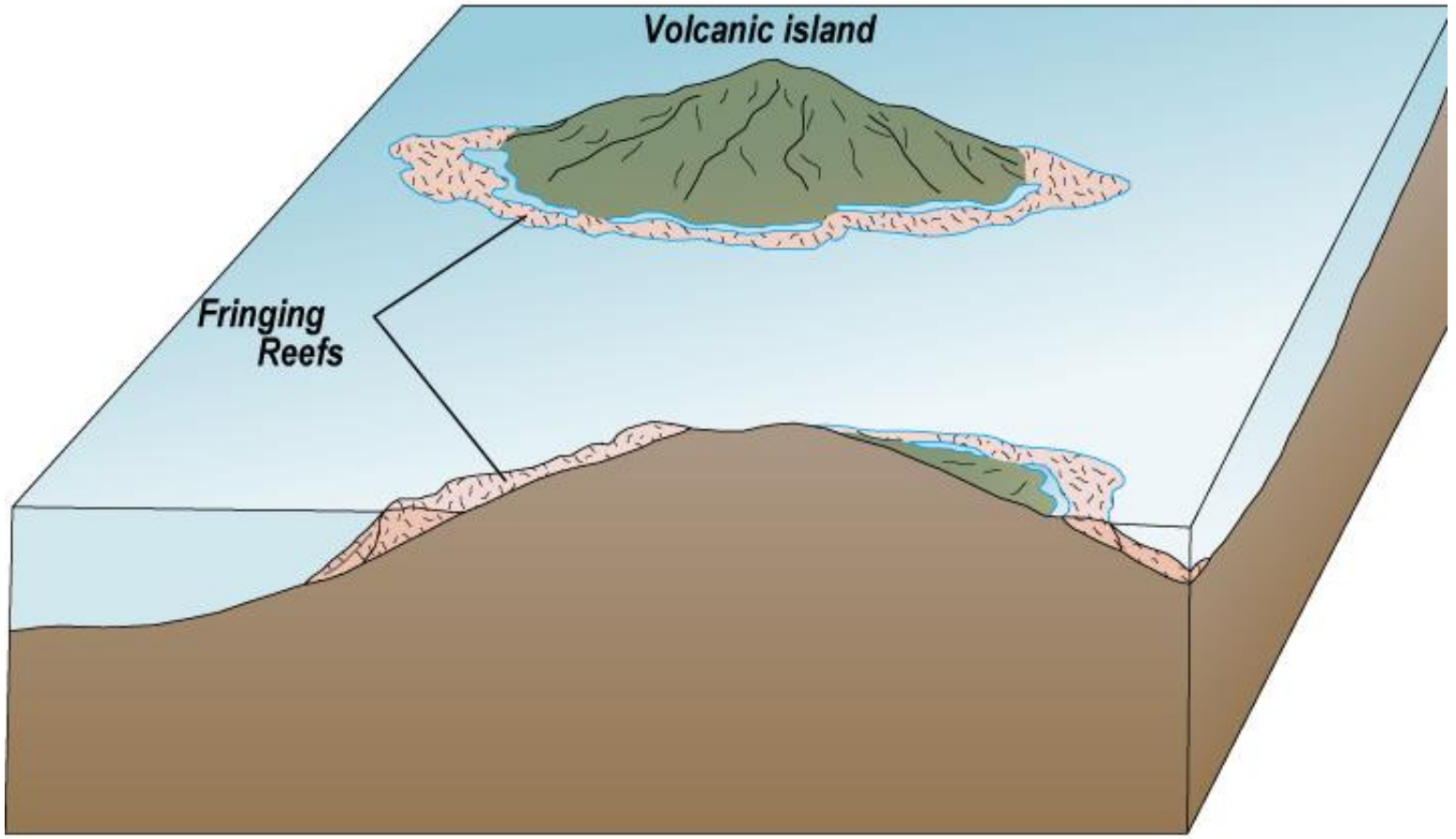
ORGANISMS AND THEIR ACTION

Polyps live in 150 - 200’ deep water and when water has more $caco_3$ and the temperature is above 68 degree, these organisms segregate and build reefs which finally grow into Islands

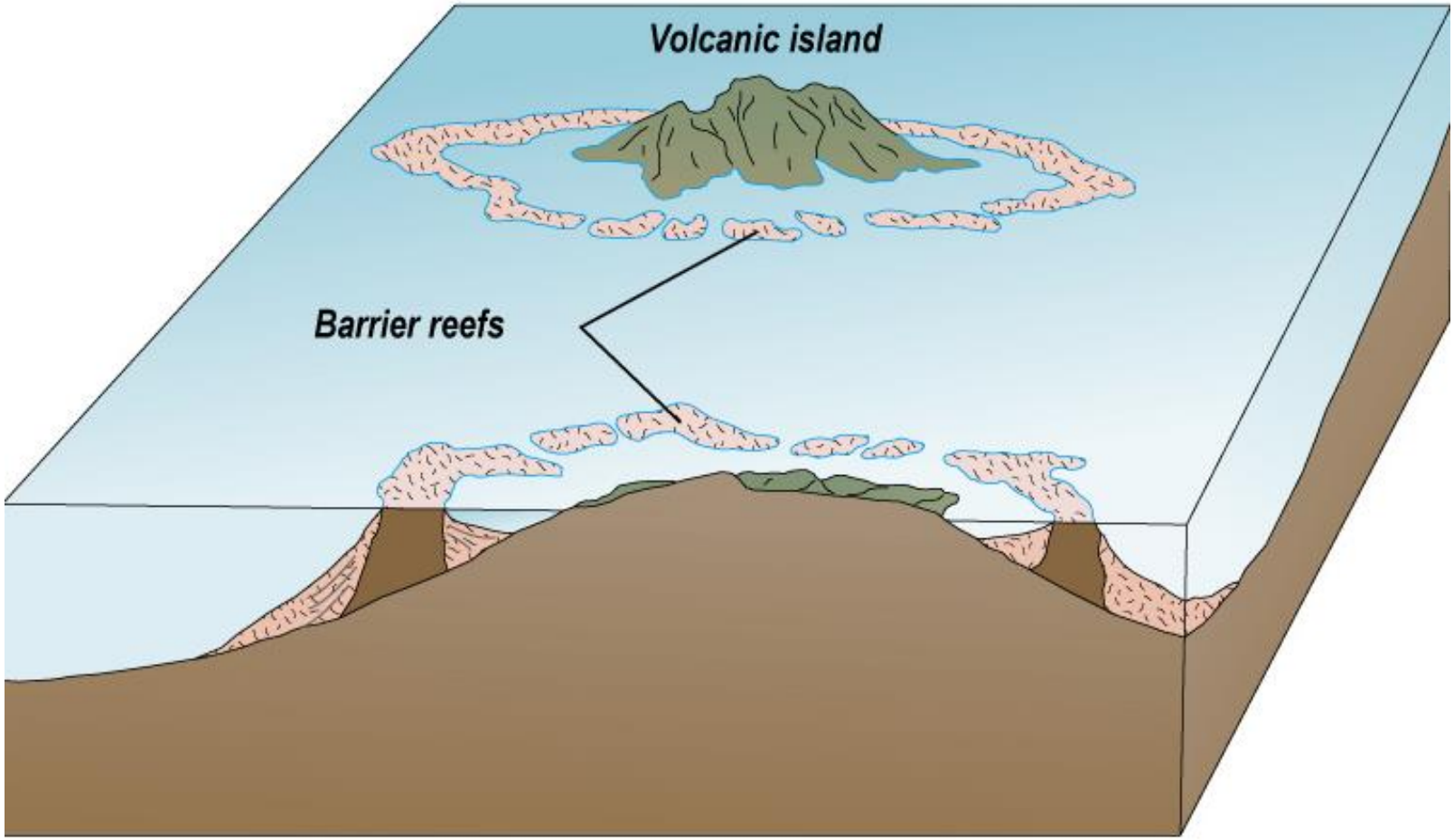
- **Fringing reef**
  - A coral reef built out laterally from the shore, forming a broad bench; slightly below the sea level.
- **Barrier reef**
  - A prominent ridge of coral that roughly parallels the coastline but lies offshore, with the shallow lagoon between the reefs and the coasts.
- **Atoll**
  - Coral reef in the shape of a ring or partial ring that encloses a lagoon that had formally surrounded a volcano, but that volcano has since sunk below surface.

Coral reef

Fringing reef



Barrier reef



Atoll

The Evolution of Carbonate (coral) reefs

FRINGING REEFS : adjacent to the volcanic Islands

BARRIER REEFS: Lagoon between Island and Reef

ATOLL: Circular coral reef with central lagoon