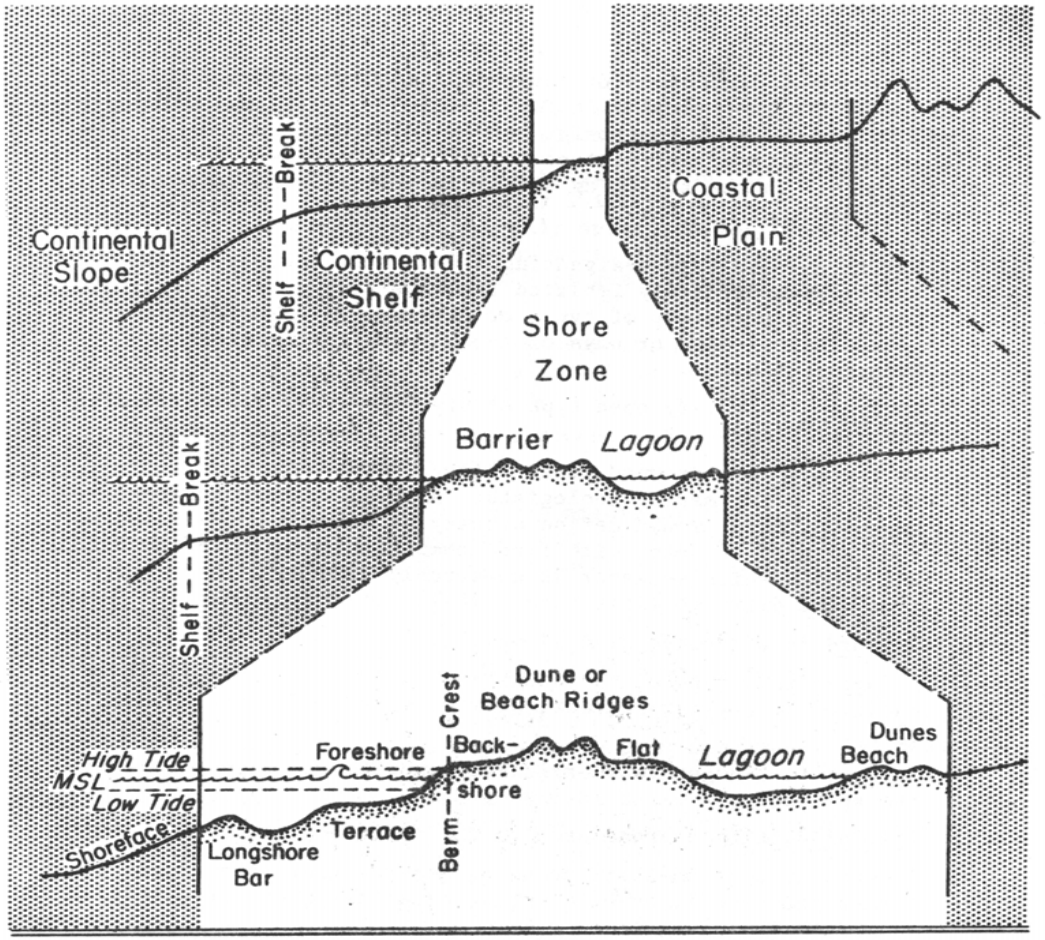
BEACH PROCESSES AND COASTAL ENVIRONMENTS

Beach Reading Material

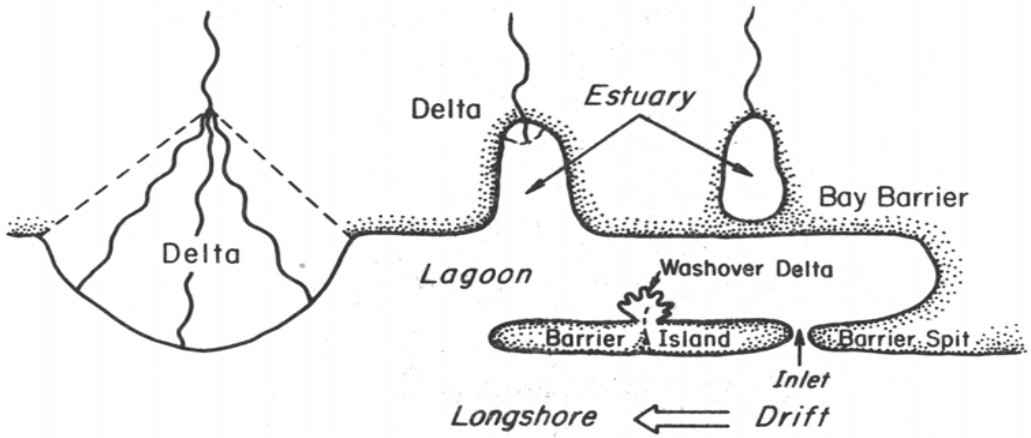
"Inshore oceanography",
Anikouchine and Sternberg
The World Ocean, Prentice-Hall

COASTAL FEATURES

Cross section



Map view



Terminology for Coastal Environment

Beach – extending from MLLW to dunes/cliff

Shoreline – where land and ocean meet

Spit – linear extension of shoreline, due to accumulation of sediment

Barrier – spit or island seaward of land, usually ~parallel to trend of land

Bars and troughs – seabed features in surf zone

Berm – relatively flat region of beach, behind shoreline

Foreshore – seaward sloping surface, located seaward of berm

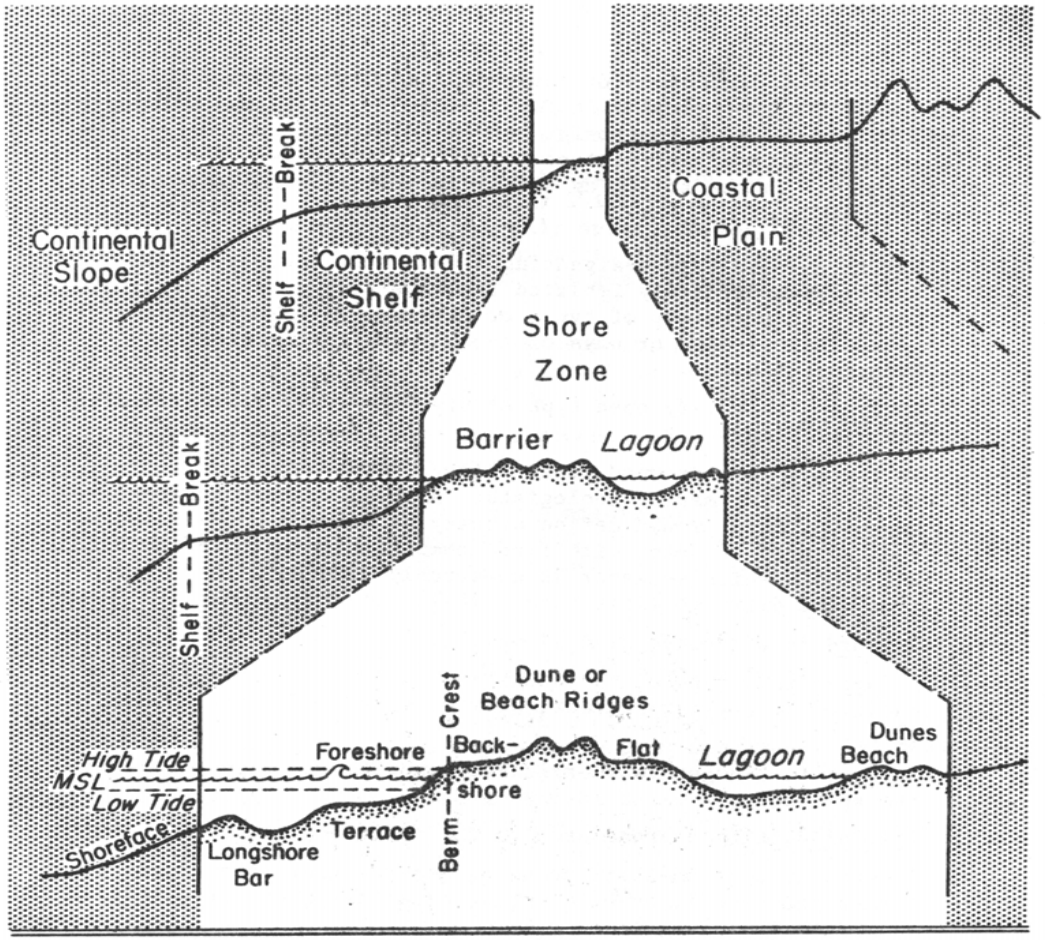
Backshore – berm and dunes

Inlet/washover – means to transport beach sediment landward, due to tides and storms (respectively)

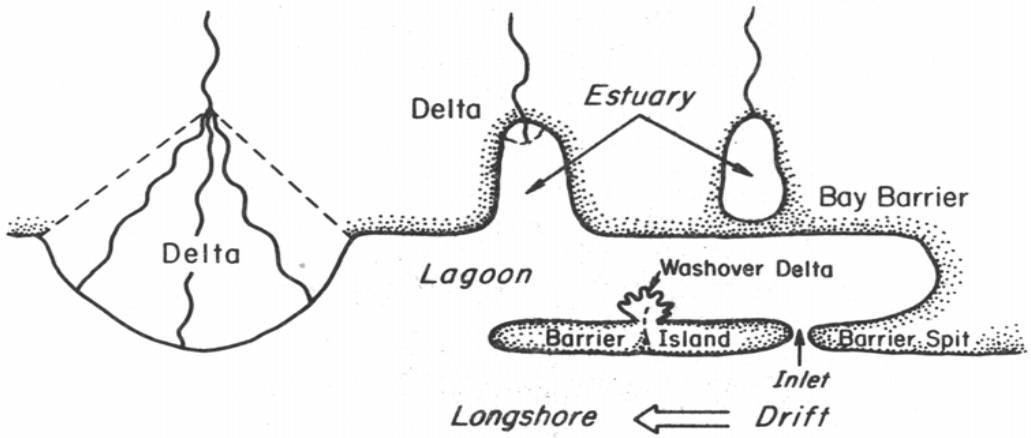
Longshore (littoral) drift or transport – water and sediment movement parallel to beach

COASTAL FEATURES

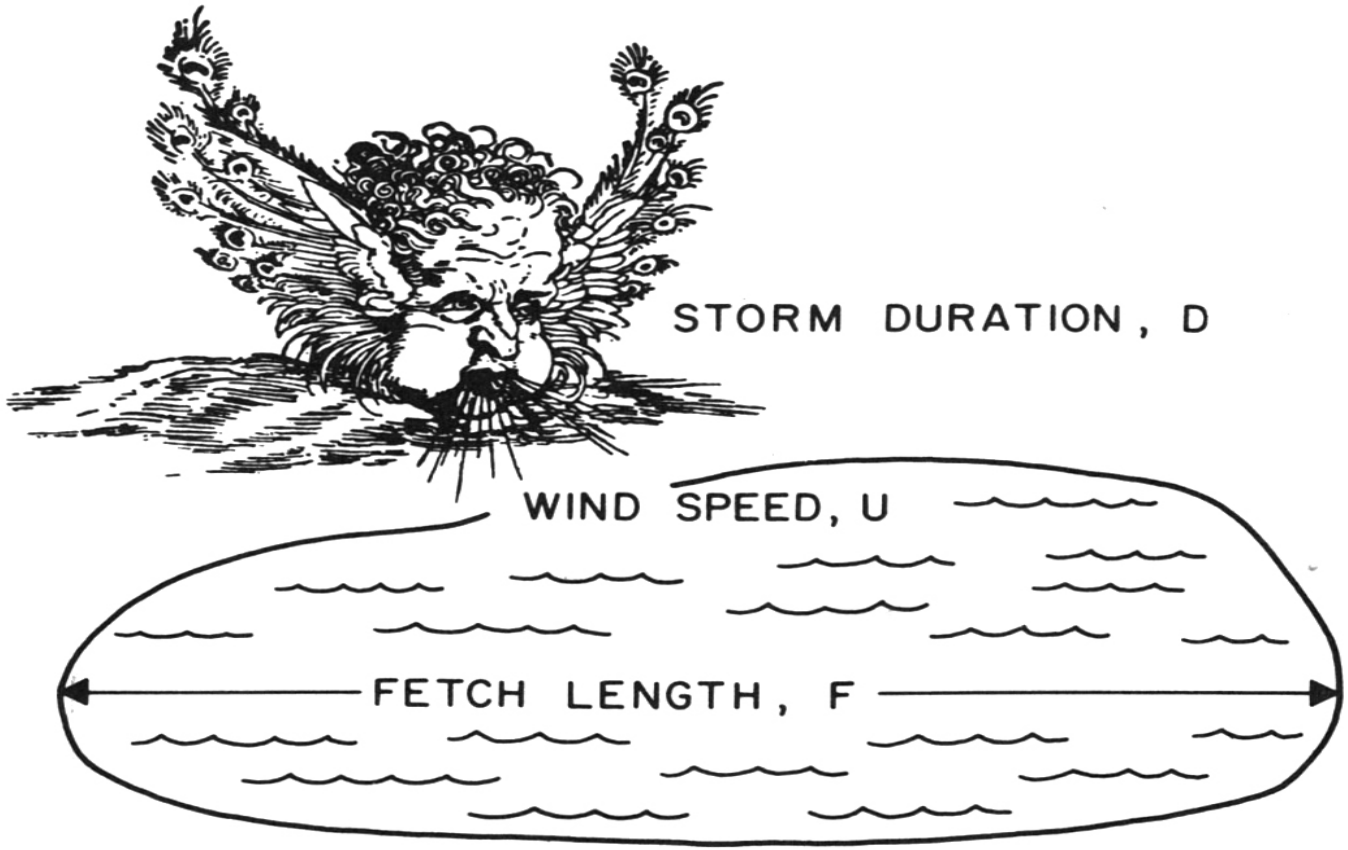
Cross section



Map view



Factors affecting formation of wind waves

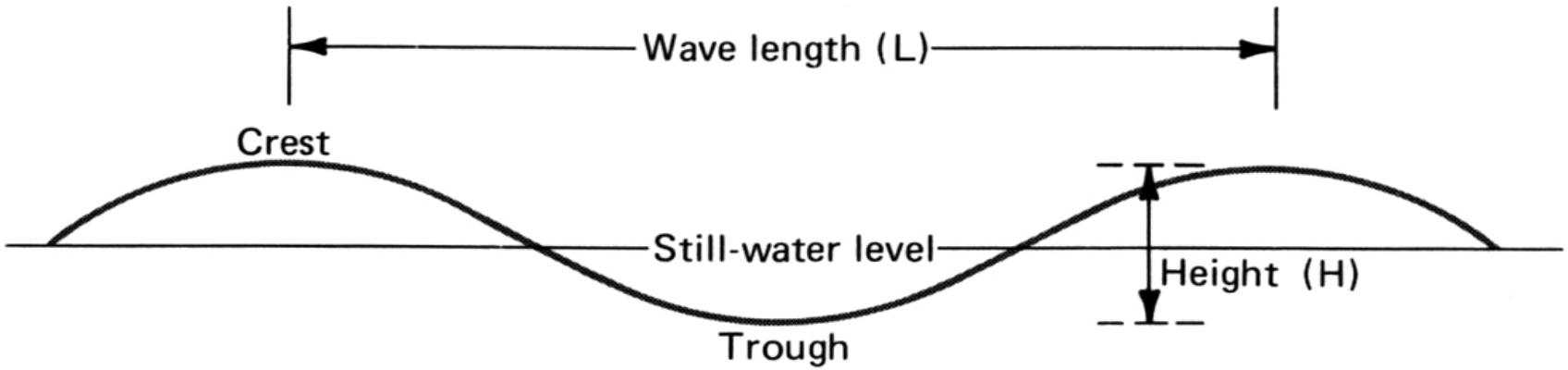


Duration wind blows

Wind speed

Distance over which wind blows (fetch)

Terminology for Describing Waves



T = wave period = time between two wave crests passing a point

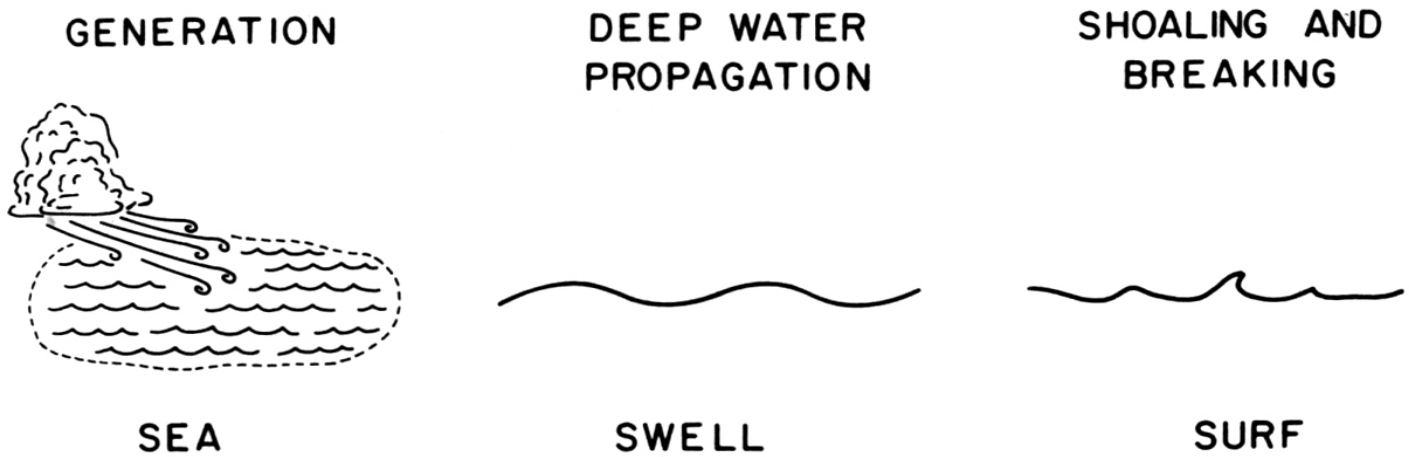
In deep water, wave speed increases with wavelength

Therefore, waves sort themselves as they travel from source area;

waves with large wavelength reach beach first = swell

Changing Wave Character from Source to Surf

Wave shape



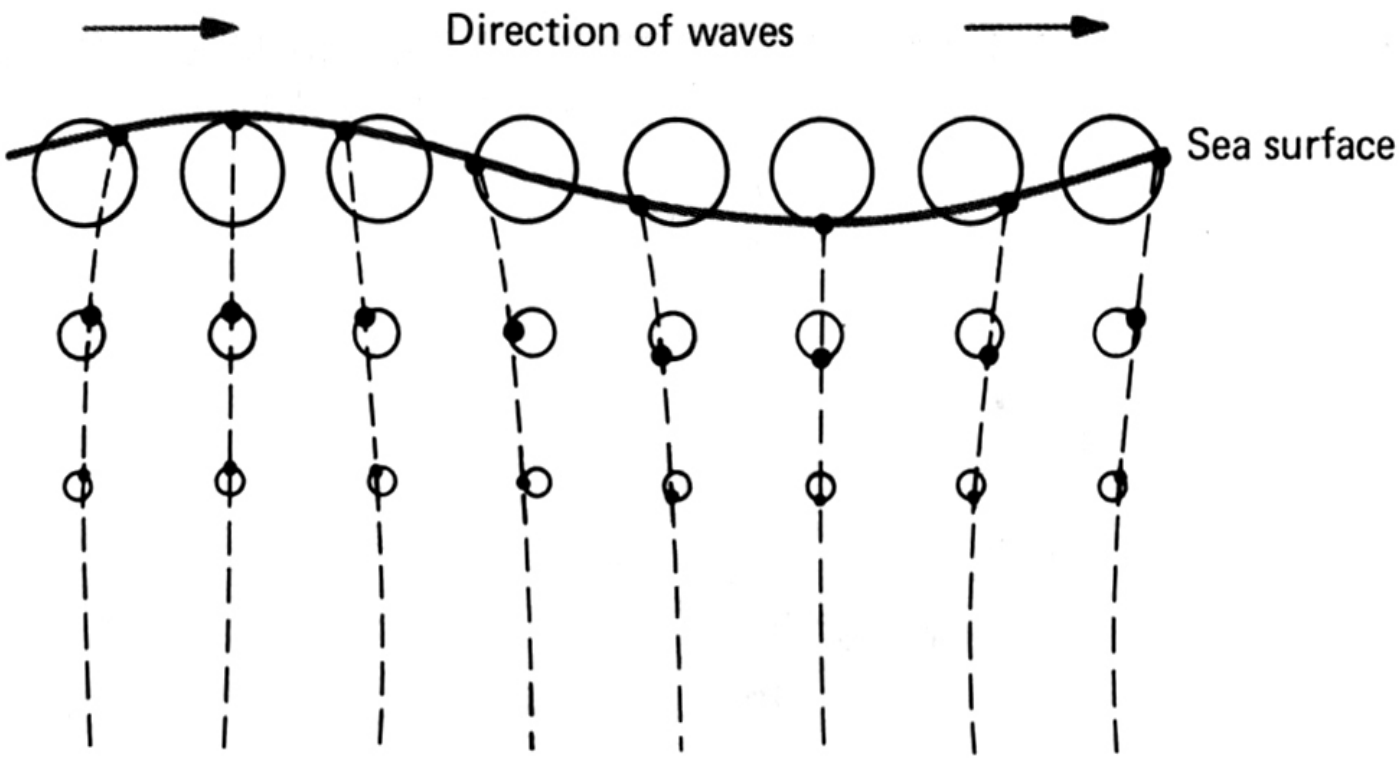
Wave characteristics change with long travel distance, because waves sort themselves

confused sea

single wave shape

pointed wave crest

Waves in deep water



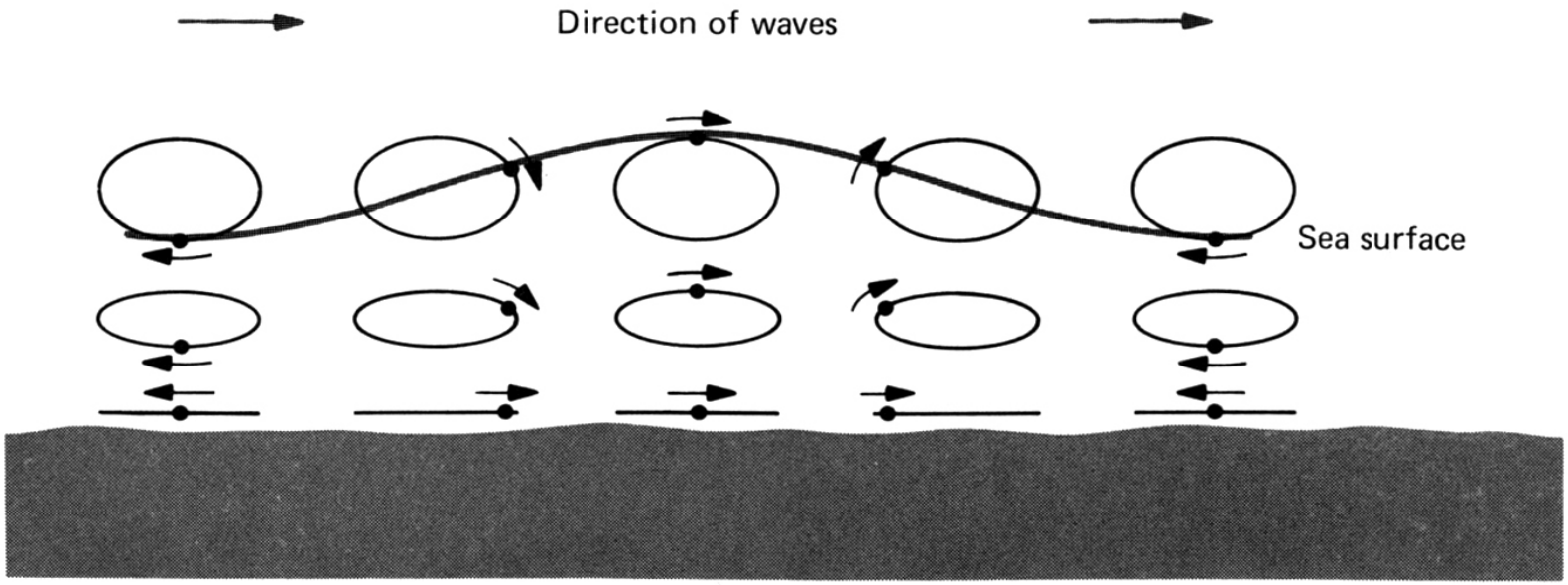
Water molecules move in closed circular orbits

Diameter of orbit decreases with depth below water surface

No motion at a water depth >1/2 wavelength of wave = wave base

Waves in shallow water

(water depth <1/2 wavelength)

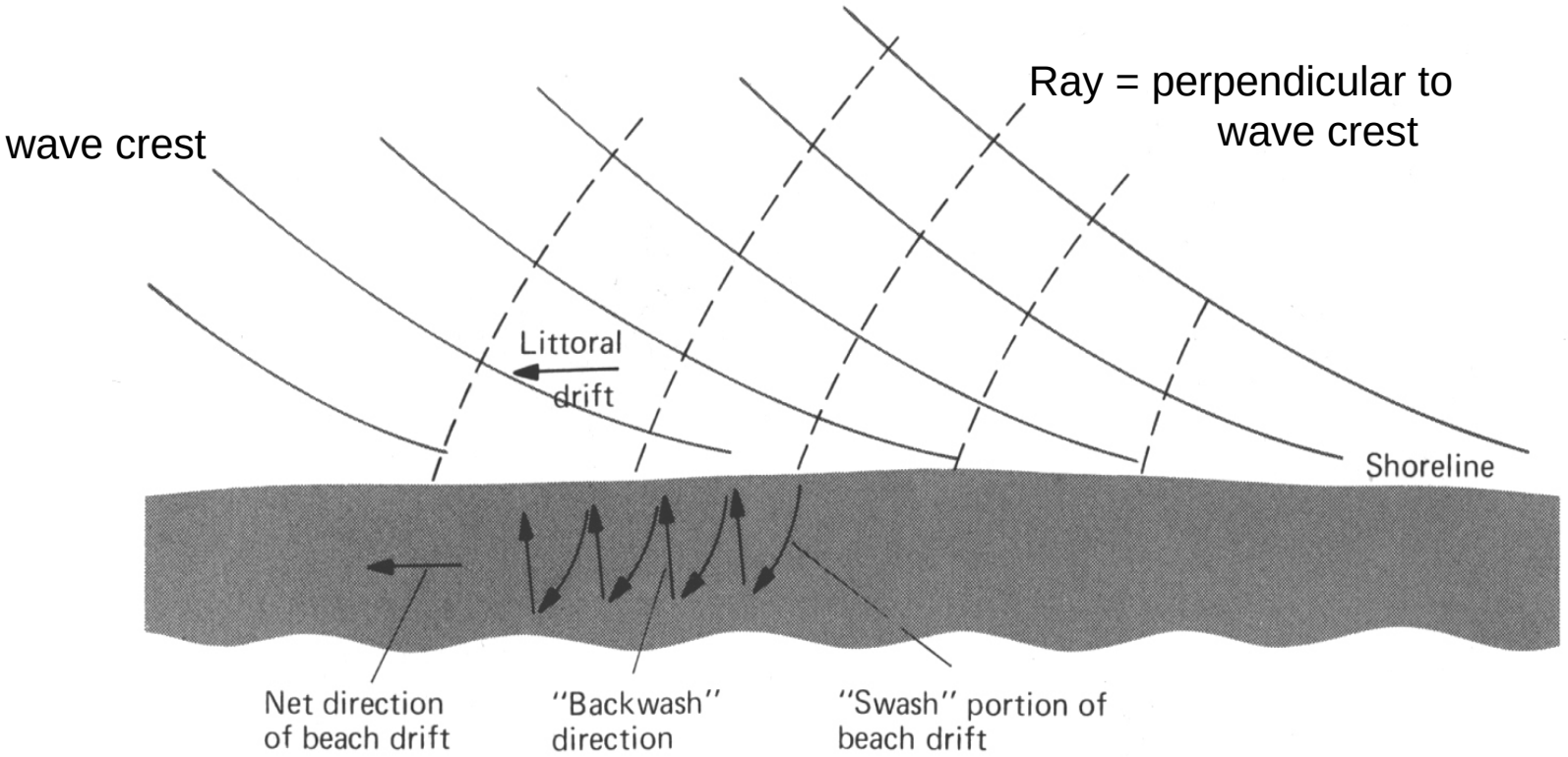


Water molecules move in elliptical orbits

At seabed, water (and sediment) moves back and forth

There is an asymmetry with more transport under crest than trough, causing net movement in the direction of the waves – i.e., toward shore

Waves approaching a straight shoreline

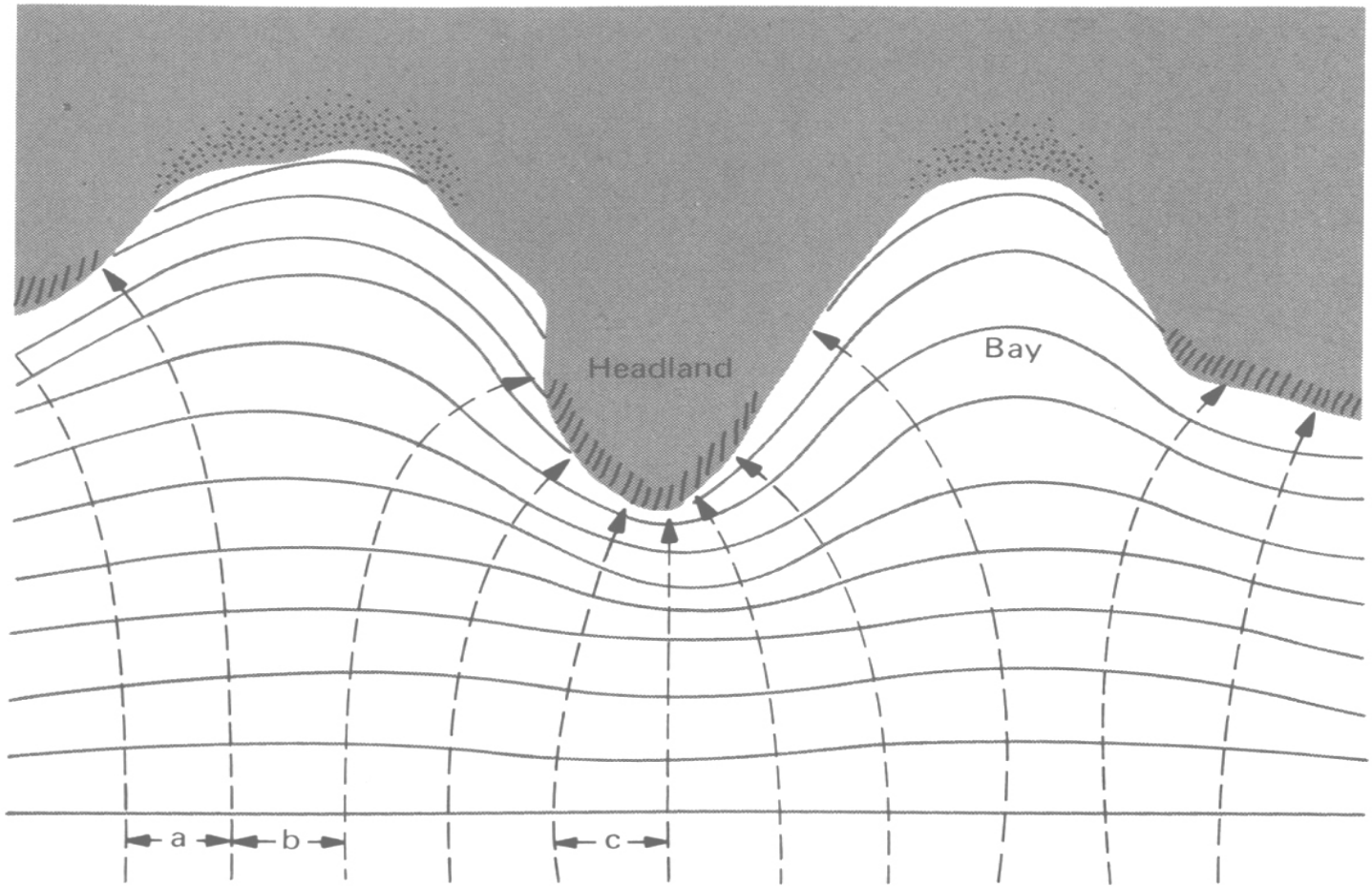


In shallow water, wave speed decreases as water depth decreases

waves travel progressively slower as depth decreases,

therefore crests bend = wave refraction

Waves Approaching an Irregular Shoreline



wave rays = perpendicular to wave crests

paths of rays indicate that waves:

focus energy on headland, eroding it

and defocus energy in embayments, causing sediment deposition

Transitions as waves approach shoreline

1) Waves feel bottom at wave base (1/2 wavelength), ~10-50 meters depth

2) Seabed is eroded, mud moves seaward in suspension, sand moves as bedload back-and-forth with net drift toward shore

3) Wave speed decreases as water depth decreases (wave refraction)

4) Wave height increases, wavelength decreases

5) Crest becomes progressively steeper – ratio of wave height to wave length (H/L) becomes large

6) At H/L ratio > 1/7, wave becomes unstable and breaks = surf

7) Water moves up foreshore as swash, and back down as backwash

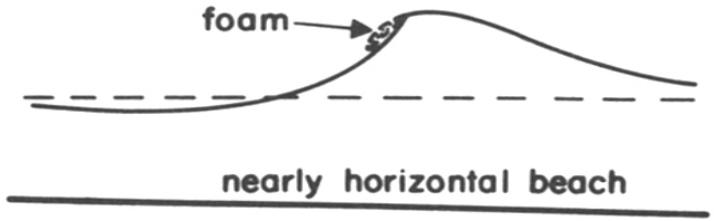
Types of Breaking Waves

Largely dependent on steepness of seabed, which is related to grain size

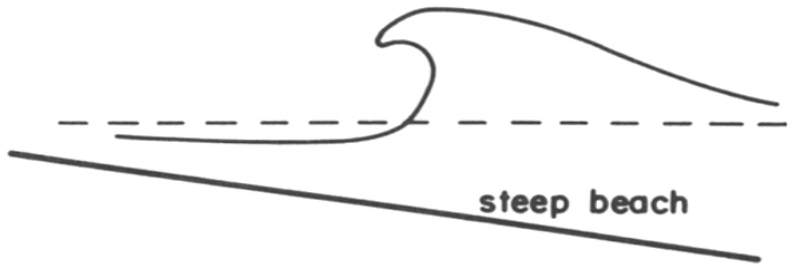
spilling breakers are found on fine sand beaches (e.g., southern Washington coast beaches)

plunging and surging breakers are found on coarse sand and gravel beaches (e.g., northern Washington coast beaches)

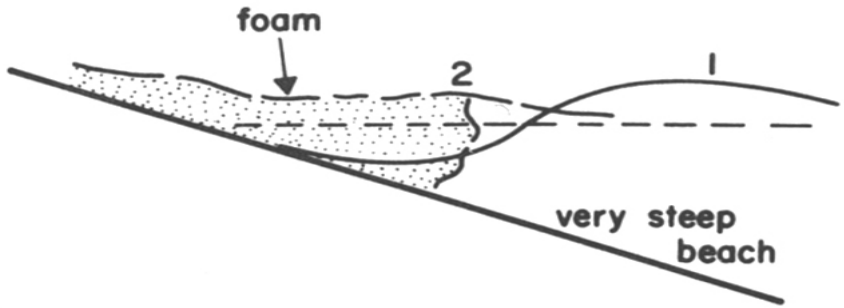
SPILLING BREAKERS



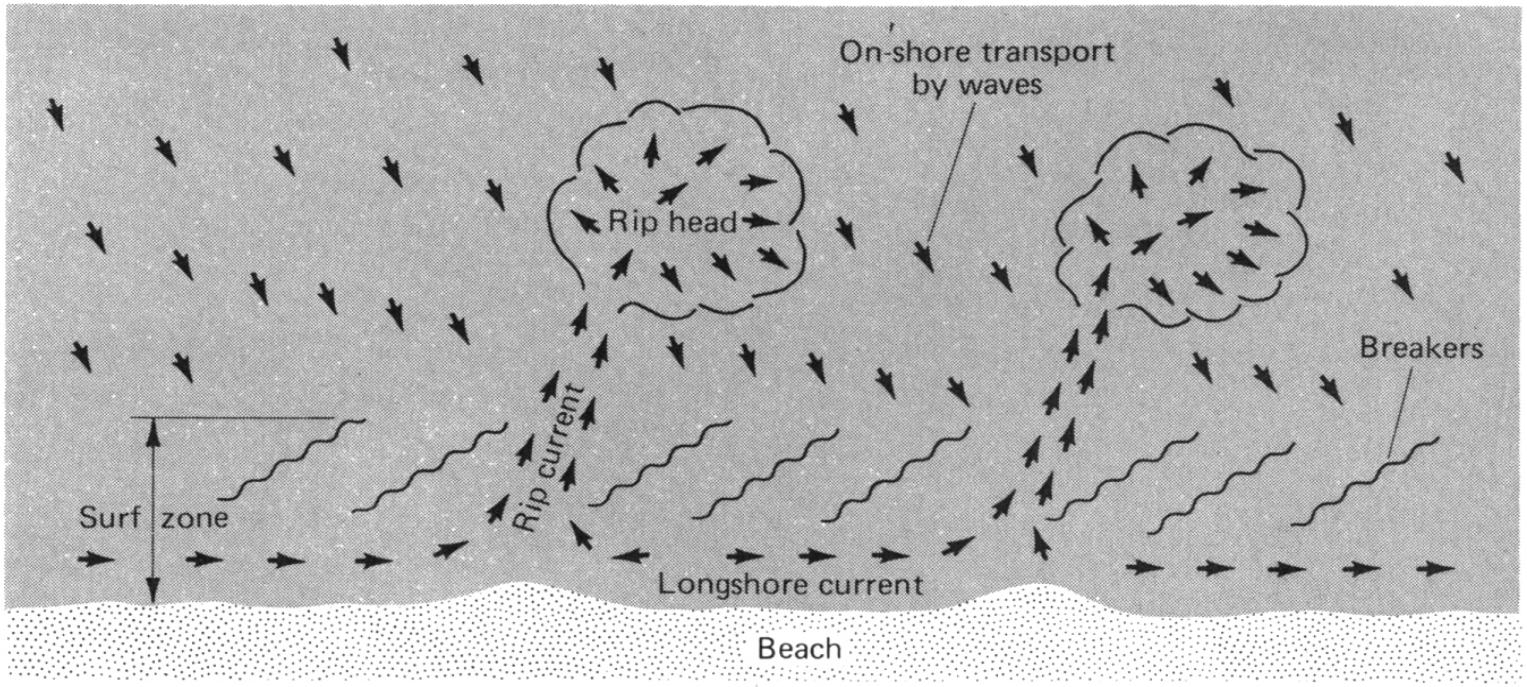
PLUNGING BREAKERS



SURGING BREAKERS



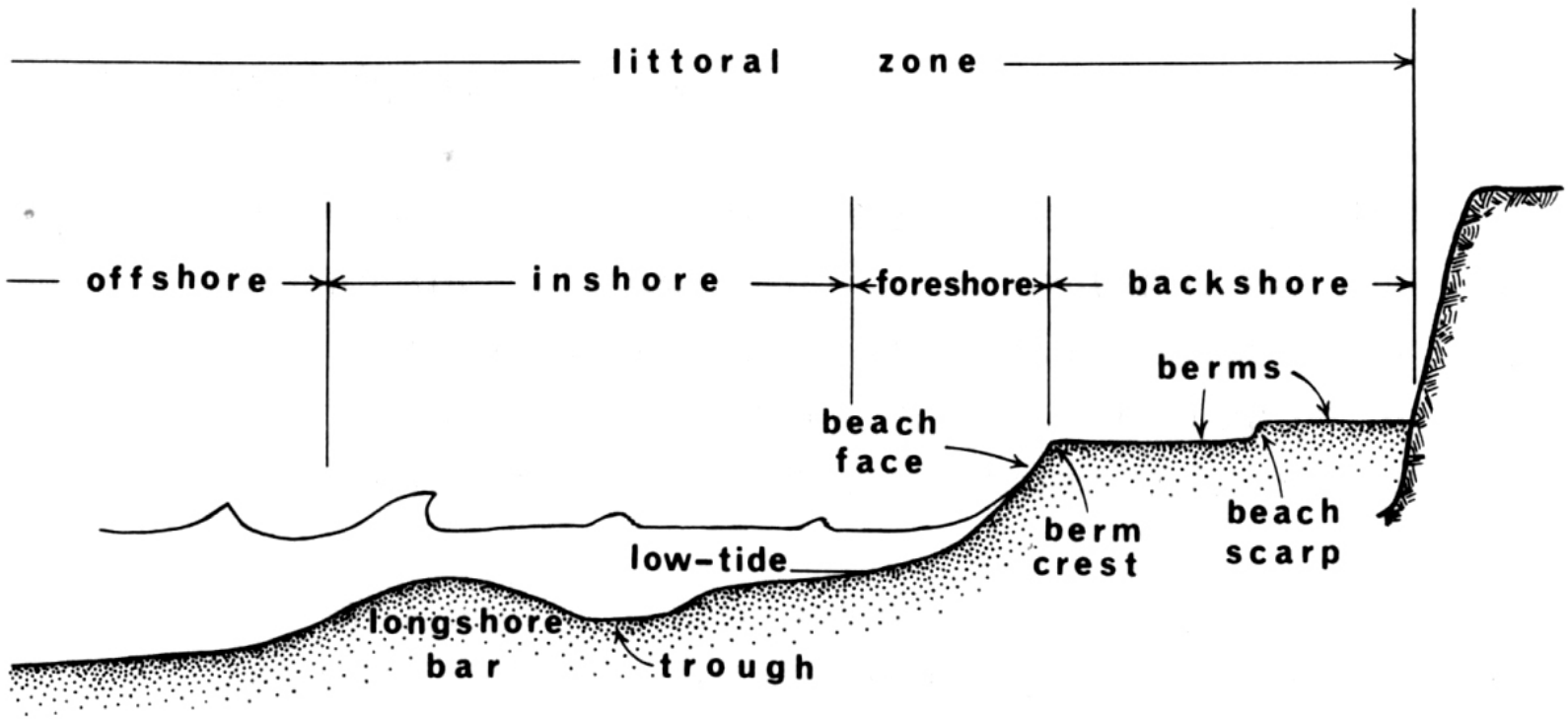
Rip Currents



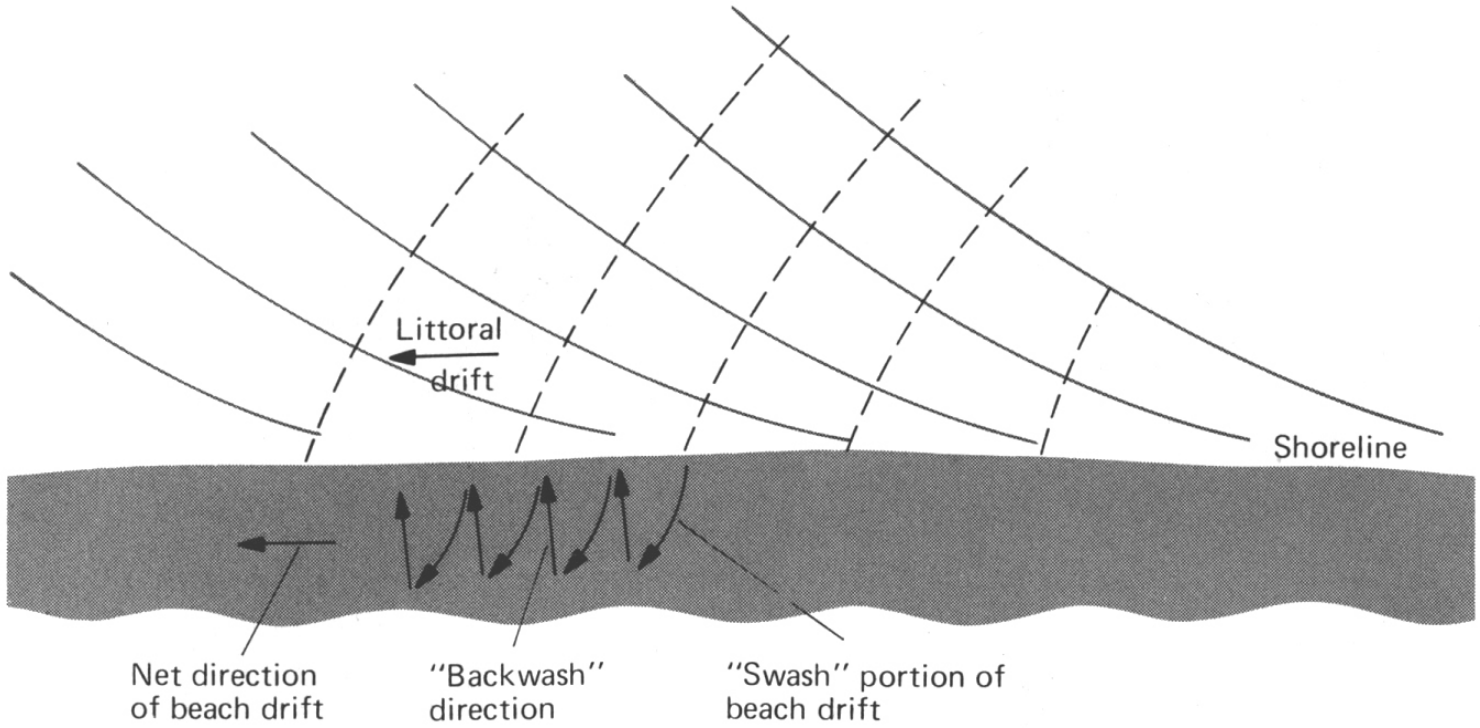
Rip currents are the primary mechanism for returning water through surf zone, and are the most dangerous for swimmers

Also broad, weak flow near seabed = undertow

Beach Terminology



Longshore or Littoral Drift

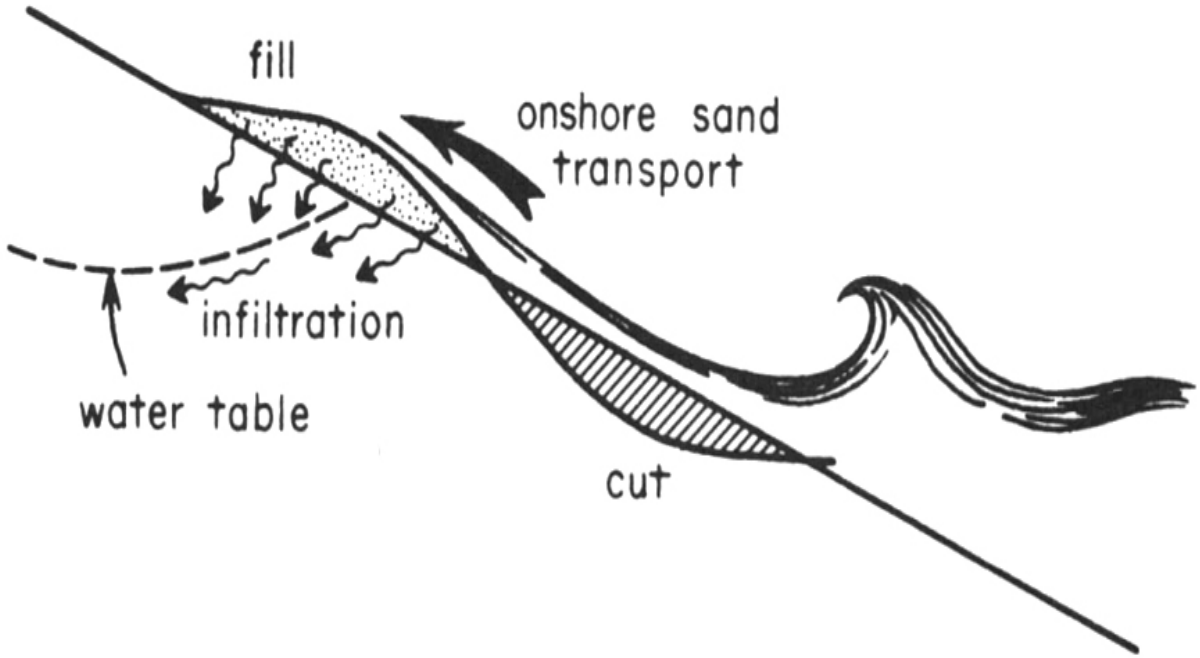


Waves break at angle to shore, which causes swash at angle to shore

Backwash follows gravity down foreshore

Net effect is water and sediment transport along shore

Beach growth during swash and backwash

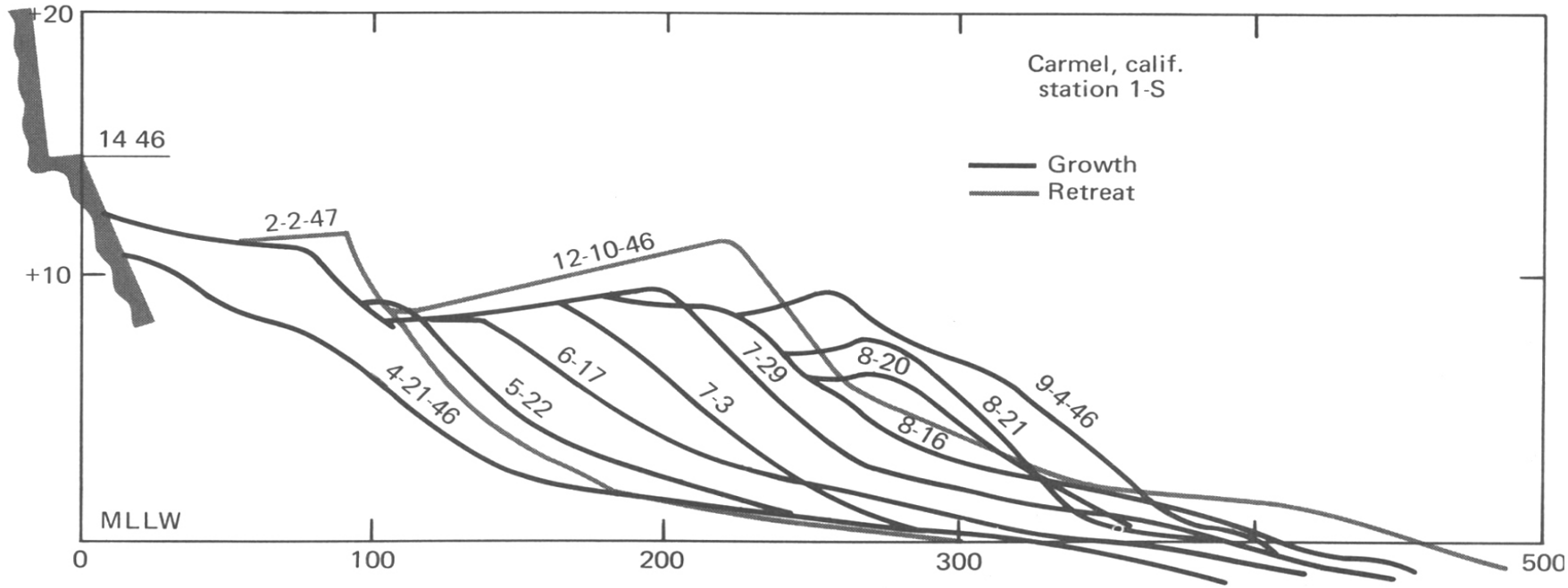


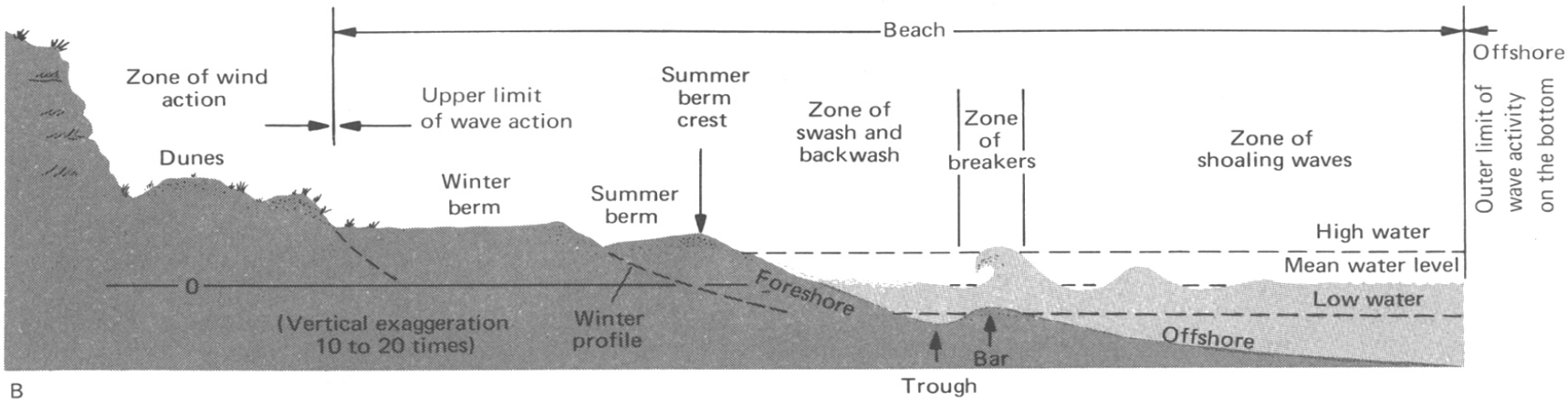
Swash – flow up foreshore after wave breaks
transport all water and much sediment,
but water percolates into permeable beach sand

Backwash - less water and sediment flow with backwash

Therefore, beach builds up to uniform level, creating the berm

Summer Beach Growth





B

Impacts of winter storms

Storms bring strong winds and larger waves

Strong winds push ocean water against coast = storm surge

Larger waves erode beach sediment (i.e., erode fairweather berm)

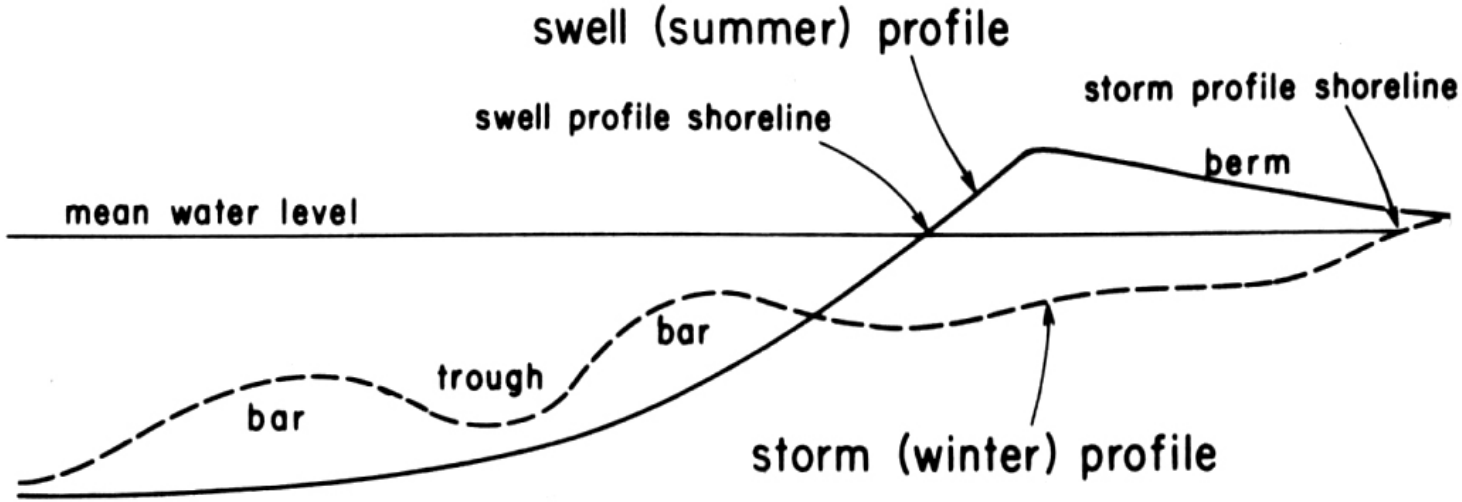
Sediment goes to:

- build bars offshore
- build higher berm (storm berm)
- washes through dunes forming washover deposits

Sediment stored in offshore bars is transported back slowly by waves during fairweather (due to wave crest/trough asymmetry and net drift shoreward)

Processes create cycle of summer/winter beach profiles

Summer/Winter Beach Profiles



Summer: wider berm

little sediment in bars

Winter: summer berm gone; higher berm possible

much sediment in bars

Coastal Barriers

Spits and barrier islands

Common for trailing-edge margins
- gentle gradients
- little tectonic uplift/subsidence

Stretch along most of US Atlantic and Gulf coasts

southern Washington coast
- (protecting Willapa Bay and Grays Harbor)

Landward migration is common today
- due to sea-level rise

Seaward growth can occur near fluvial sediment sources

Formation of spit

Longshore transport is dominant mechanism

Tidal flux in/out of embayment creates inlet

Barrier Islands

Tidal inlets at both ends

Elevation depends on sand supply and winds forming dunes – typically <10 m

Low barrier islands can experience washover during storms

Length of island depends on amount of water that must enter/leave lagoon with tides (= tidal prism)

Formation of Barrier Islands

Spit elongation – Extension of spit becomes too long to allow inlet to transport all water between tides, and a new inlet forms, changing a spit into an island

Bar submergence – Old dune or topographic high is surrounded by water as sea level rises.

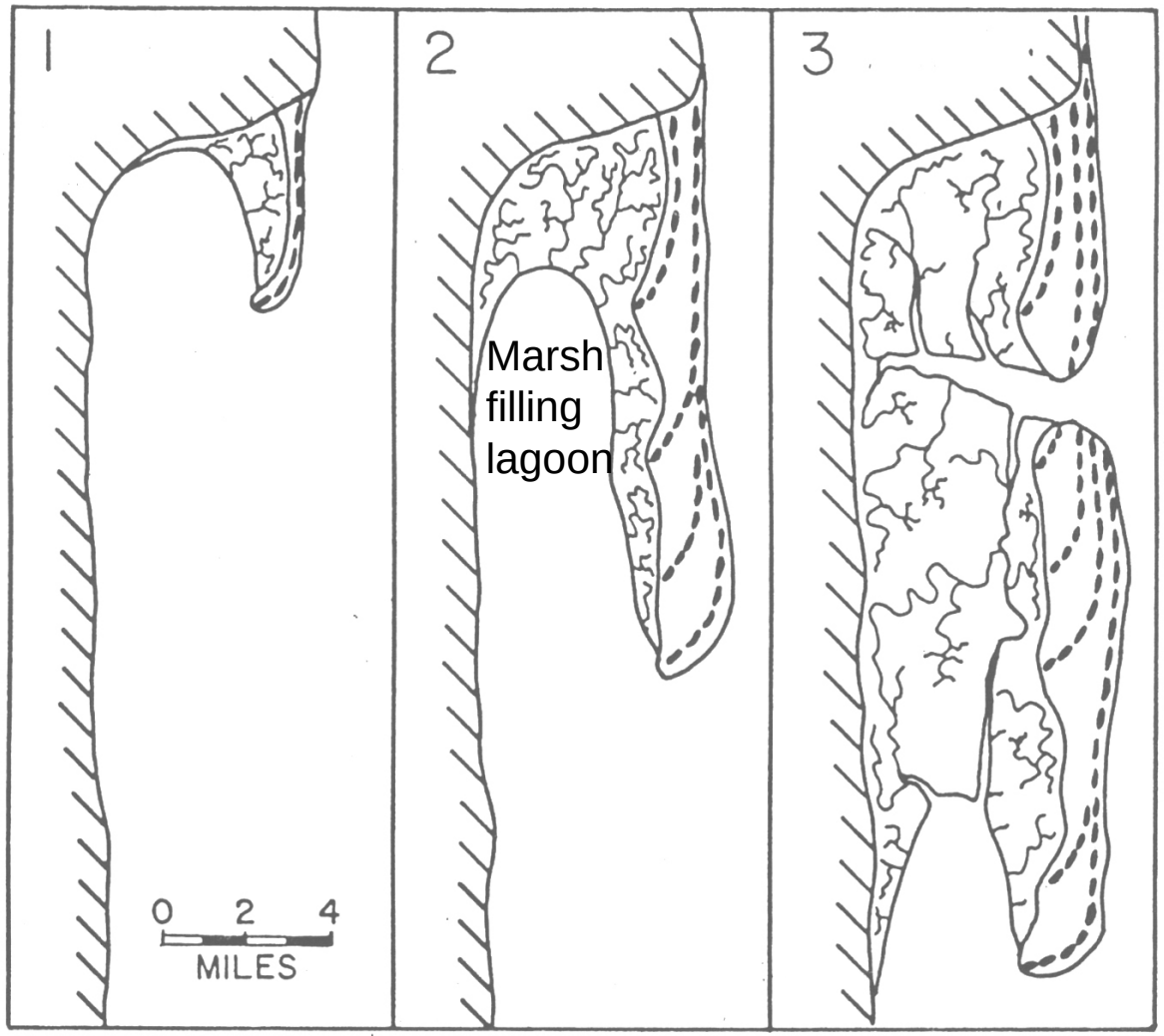
Bar emergence – During strong storm, waves create a large bar offshore, which becomes island when storm surge subsides

Spit Elongation

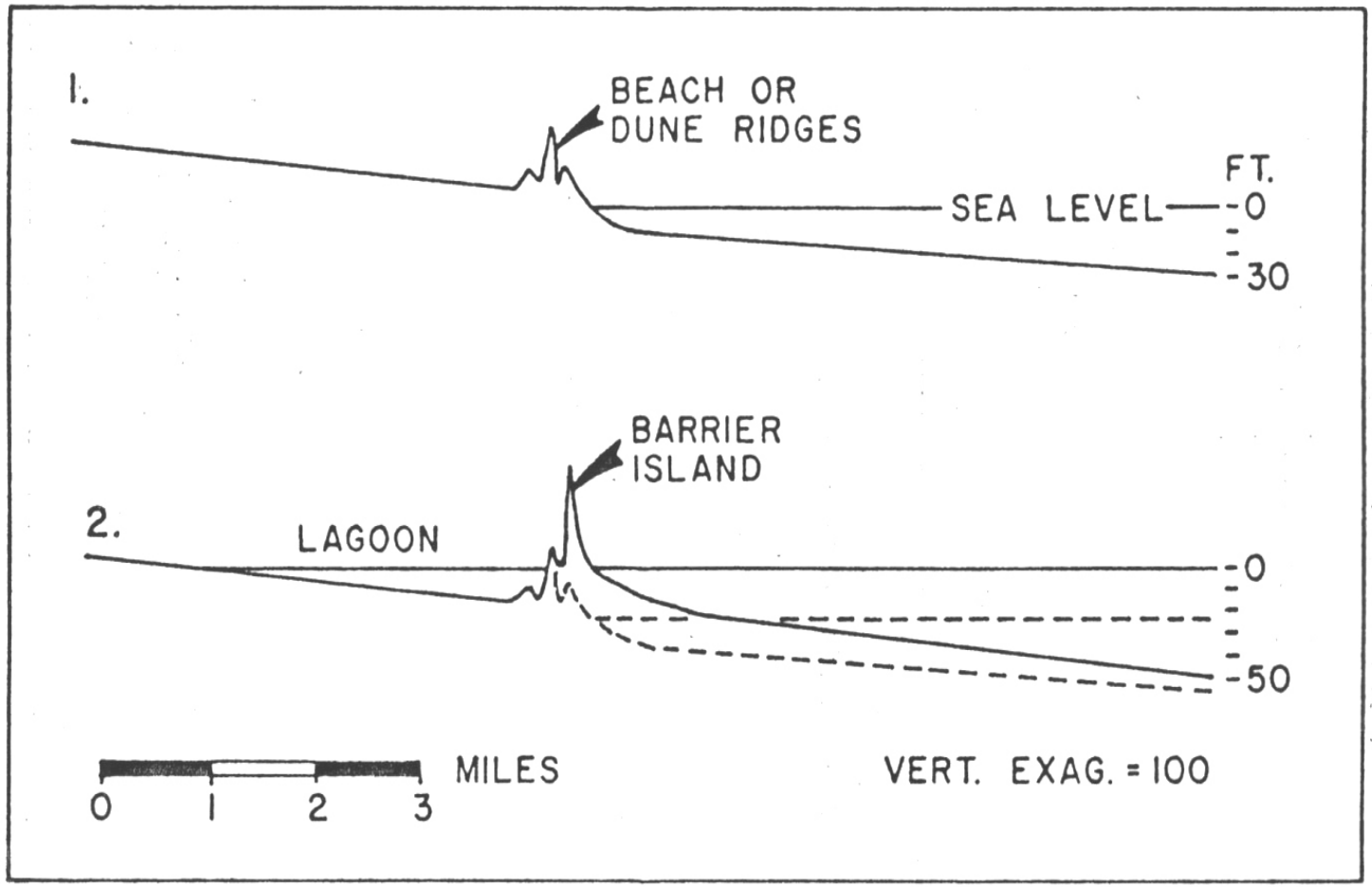
Longshore transport causes spit extension

Flow in and out of lagoon cannot occur entirely with changing tides.

Different water levels on the two sides of spit cause a new inlet to form – usually occurs during storms due to washover disruption and storm surge



Bar submergence



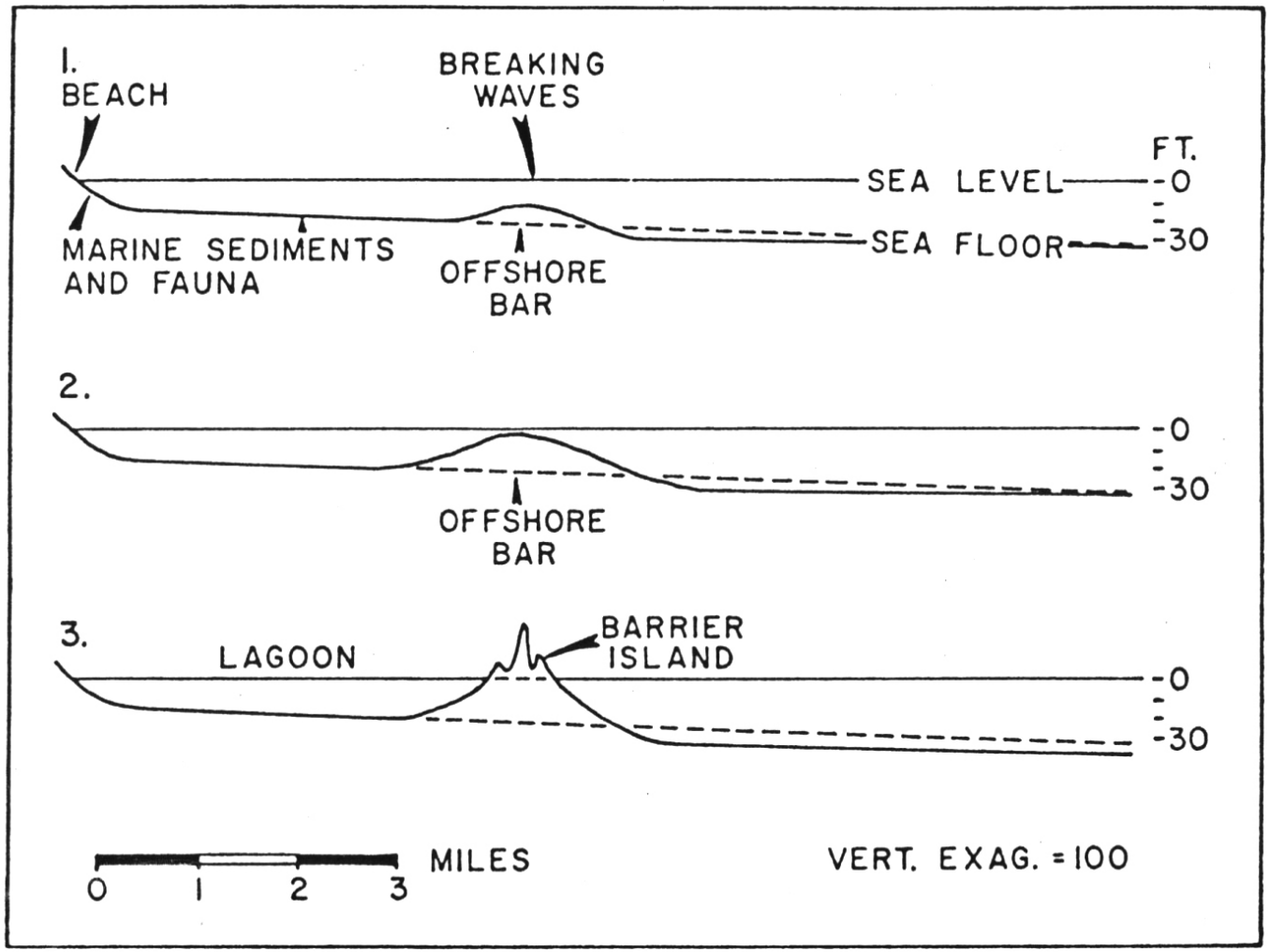
A dune or other topographic high is surrounded by water as sea level rises.

Bar emergence

Large bar forms offshore during storm

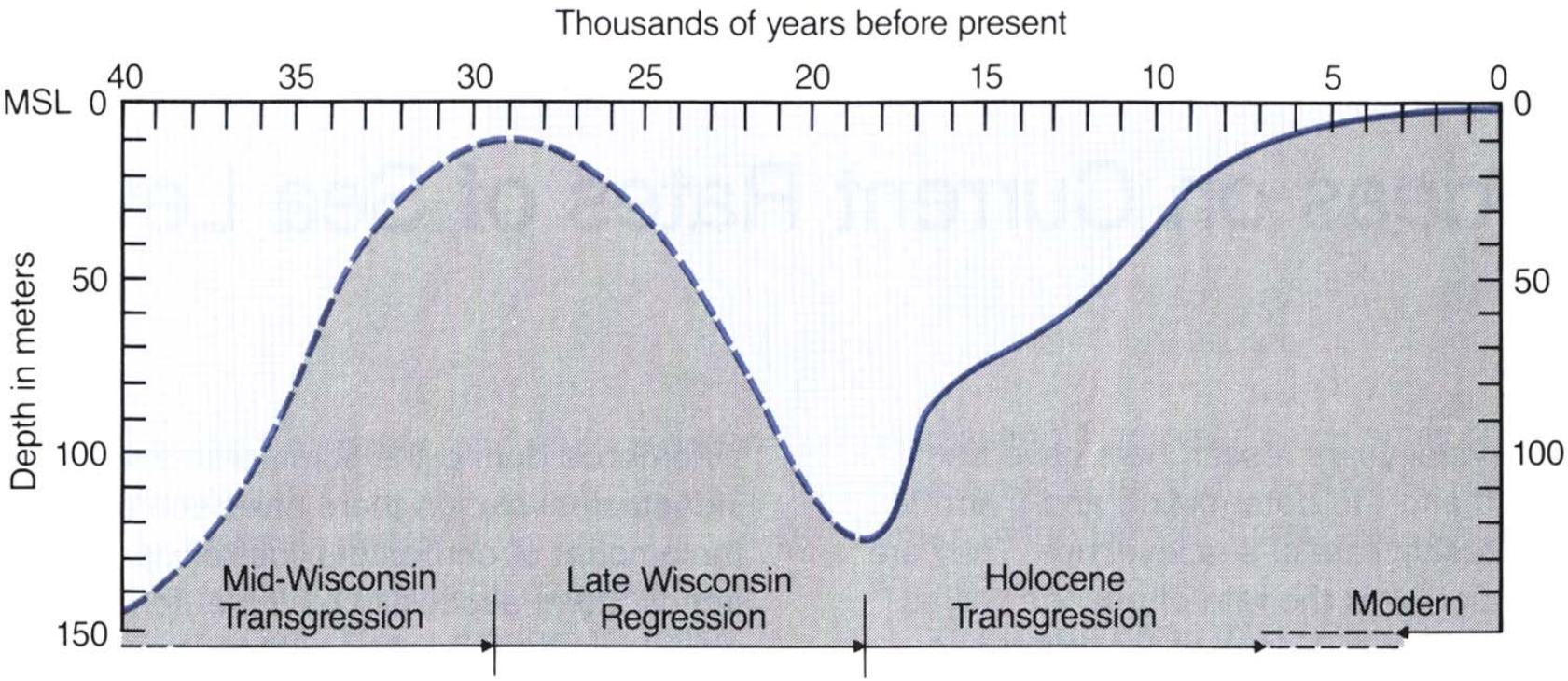
When storm surge subsides, bar is left at or above sea level

Winds create dunes that raise bar above sea level



Sea-Level change

Past 40,000 y



Sea-level rise and migration of barriers

Shorelines migrate in response to:

- sea-level rise
- sediment supply (usually small for barriers, no coastal mountains on trailing-edge margin)
- shoreline erosion (waves, tidal currents, storms)
- tectonic motions (not important for most barriers, on trailing-edge margins tectonics are weak)
- consolidation (not important for most barriers, dominated by sand)

Landward migration found for most barriers

Seaward migration occurs where much sediment supplied (e.g., near rivers)

Mechanisms for landward migration

Must move beach sediment landward:

Wind transport to and through dunes

Washover during large storms

Tidal transport through inlets

Flood-tide delta

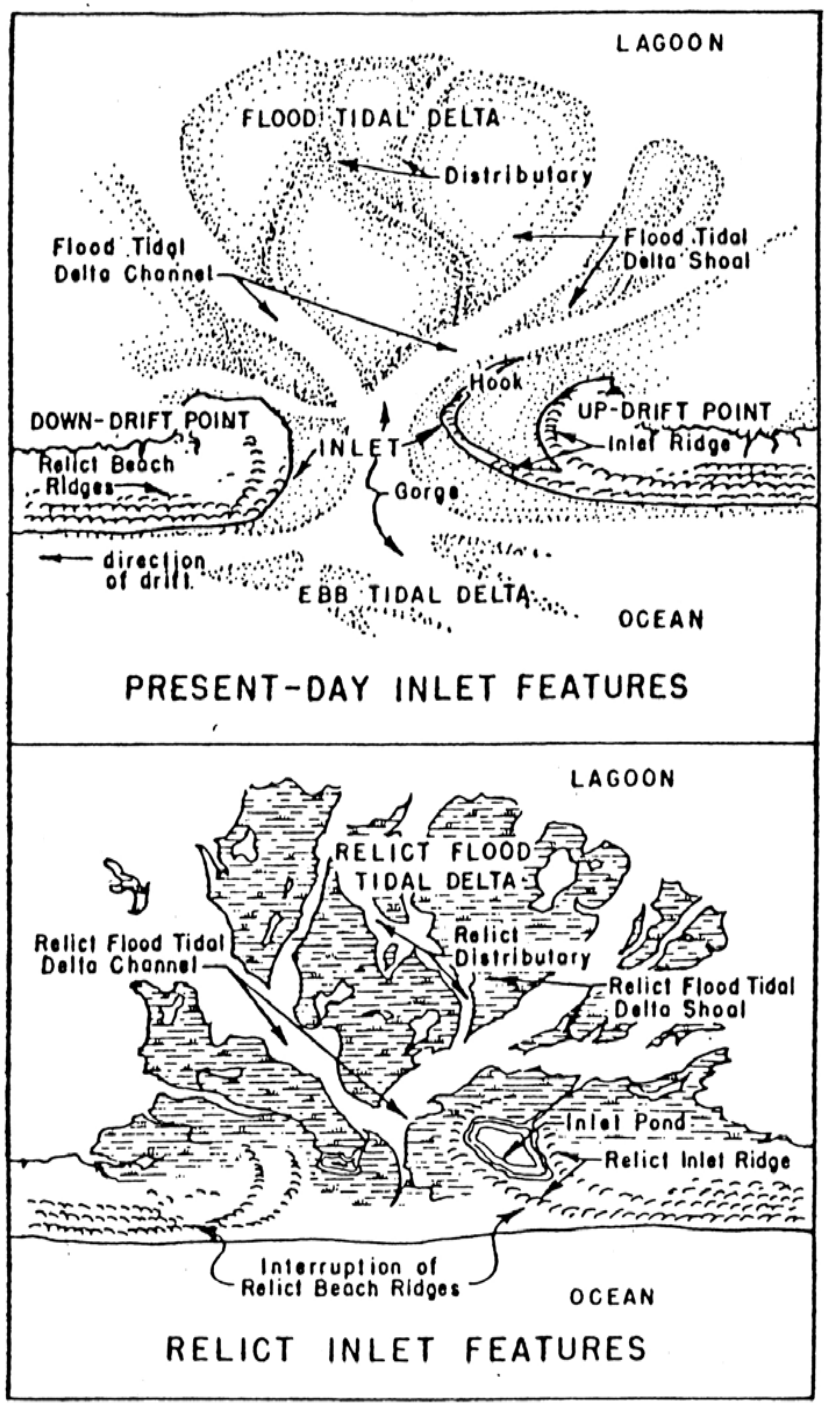
Beach sand carried by longshore transport reaches inlet

If tide is flooding (rising), sand carried into lagoon – where waves are weak

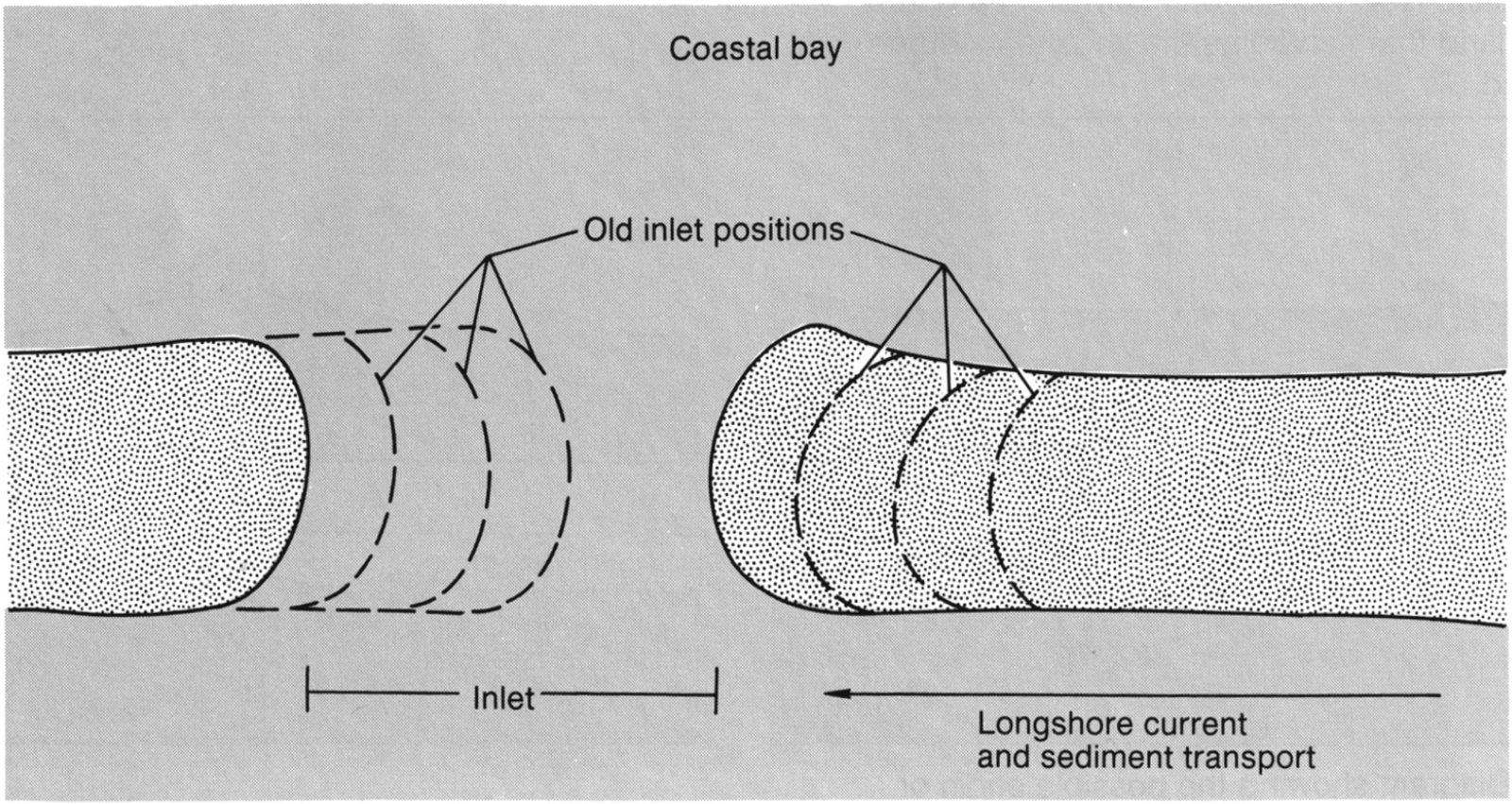
Sand stops moving and forms flood-tide delta, with distributary channels

Some sand reaches inlet during ebb (falling) tide and some sand is transported out of lagoon by ebbing currents. This sediment forms an ebb-tide delta

Ebb-tide deltas are small, due to continued reworking by ocean waves



Inlet Migration

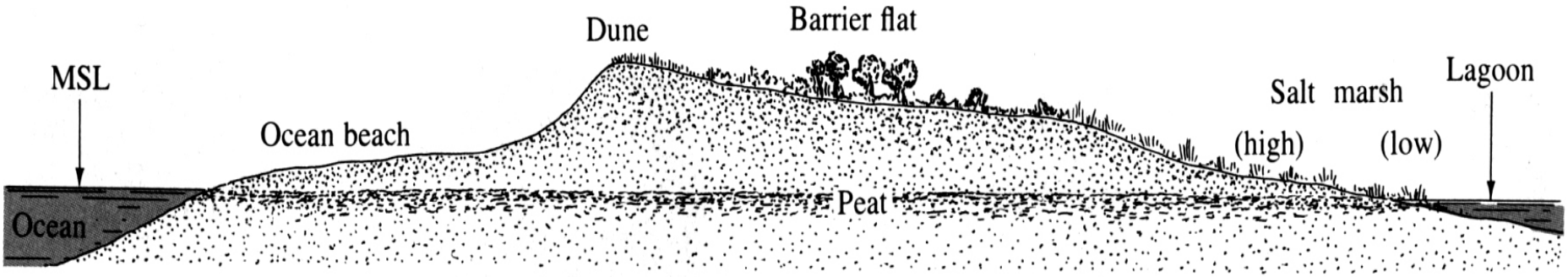


Sand is removed from longshore transport by:
accumulation on upstream side
entrapment in the flood-tide delta

Removal of sand starves the longshore transport system, and causes erosion of the downstream side…

causing the inlet to migrate in direction of longshore transport

Barrier cross section



Natural dunes are not continuous, they have breaks that allow washover sediment to nourish some parts of the barrier flat

Other parts of the flats are protected and develop maritime forests

Tidal flats, salt marshes (temperate) and mangrove forests (tropical) are found near sea level on the lagoon side – contain mud and peat

As barrier migrates landward, mud and peat are buried, and then exhumed on beach