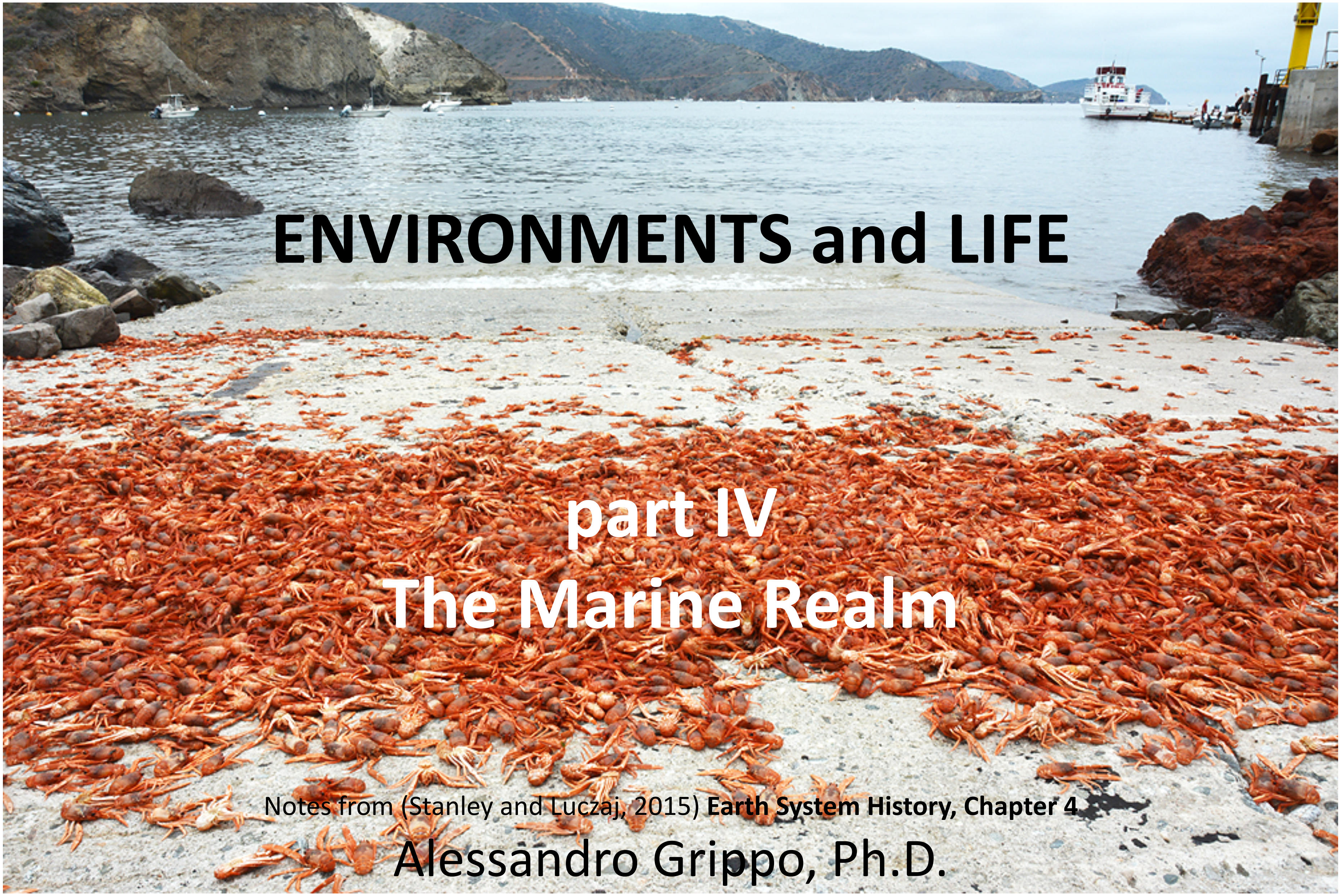


ENVIRONMENTS and LIFE

part IV
The Marine Realm

Notes from (Stanley and Luczaj, 2015) **Earth System History, Chapter 4**

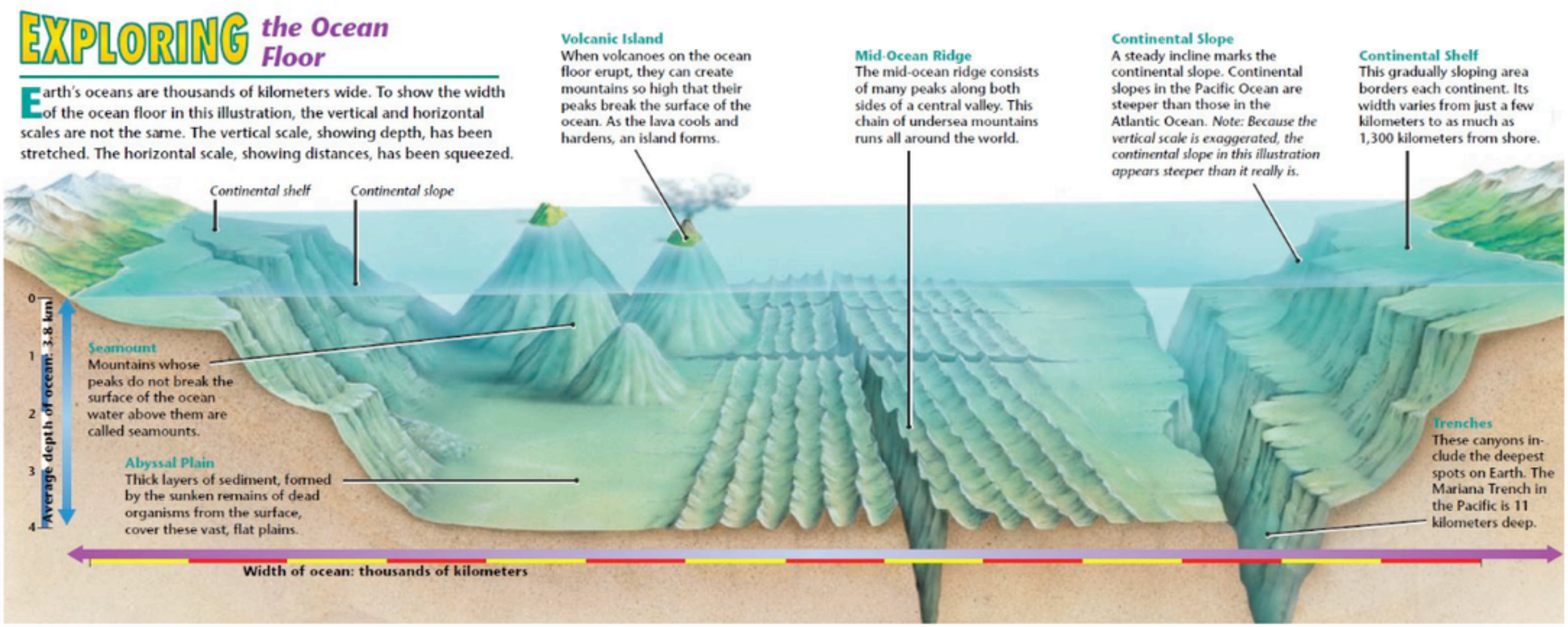
Alessandro Grippo, Ph.D.

Huge amounts of individuals of red crabs *(Pleuroncodes planipes)* washed ashore on the beaches of southern California in 2016

USC Wrigley Institute, Catalina Island

The Marine Realm: introduction

- The ocean floor is a great basin where sediments have accumulated over the course of Earth's history
  - but.. remember about the subduction of the oceanic crust: the Oceanic crust is lost in trenches, and is never older than 200 million years

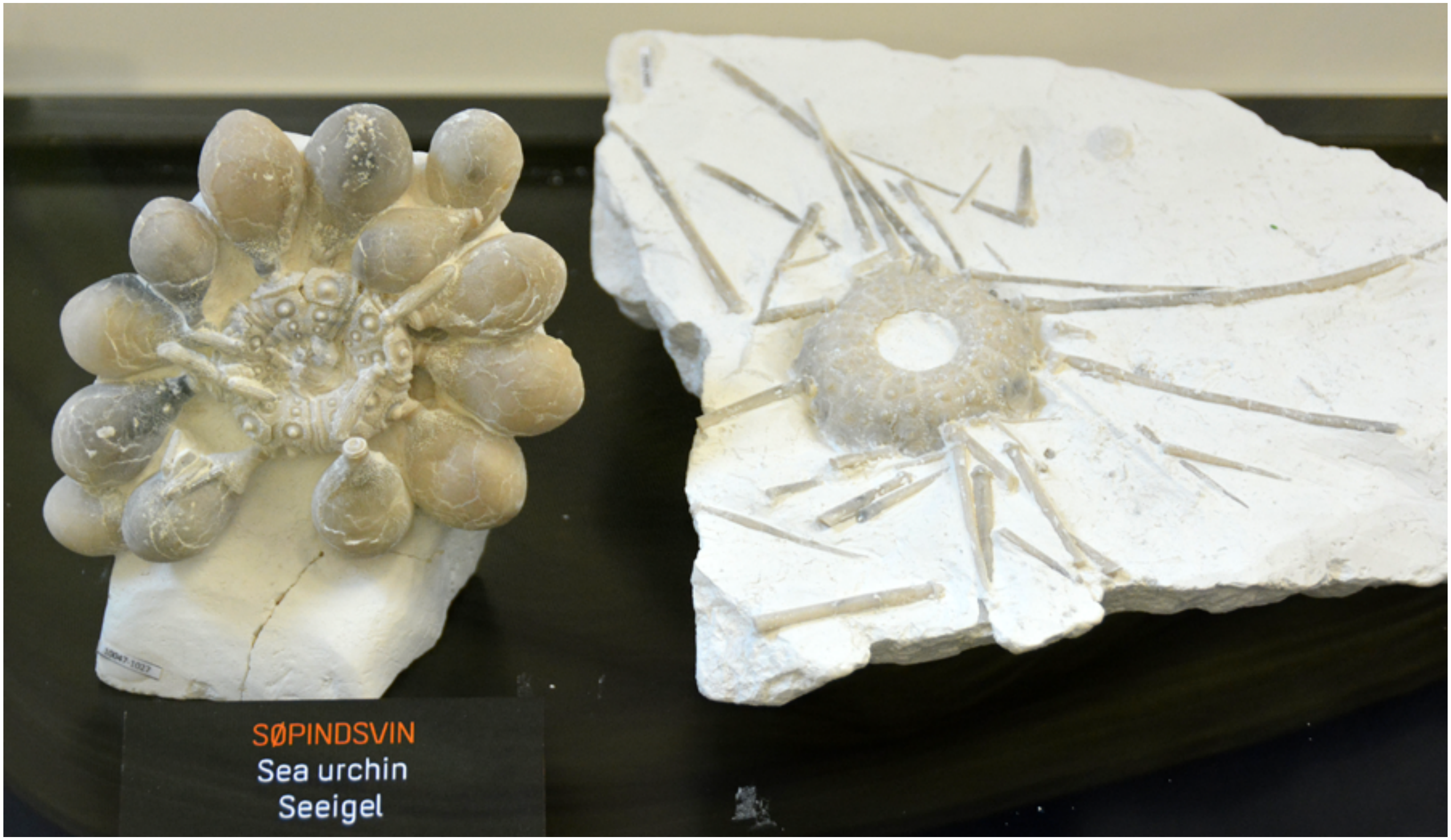


- Many organisms live (and lived) in the ocean
- Many organisms also have readily preserved skeletons
  - Coccoliths & forams, diatoms & radiolarians, for instance

- Land fossil organisms are more susceptible to erosion

- Because of these reasons, **the seafloor** (either shallow or deep) **is where most species in the fossil record have been preserved**

That is, most of Earth's fossils are from marine organisms, that were preserved within ancient seafloors, whether these seafloor rocks are today on land or not



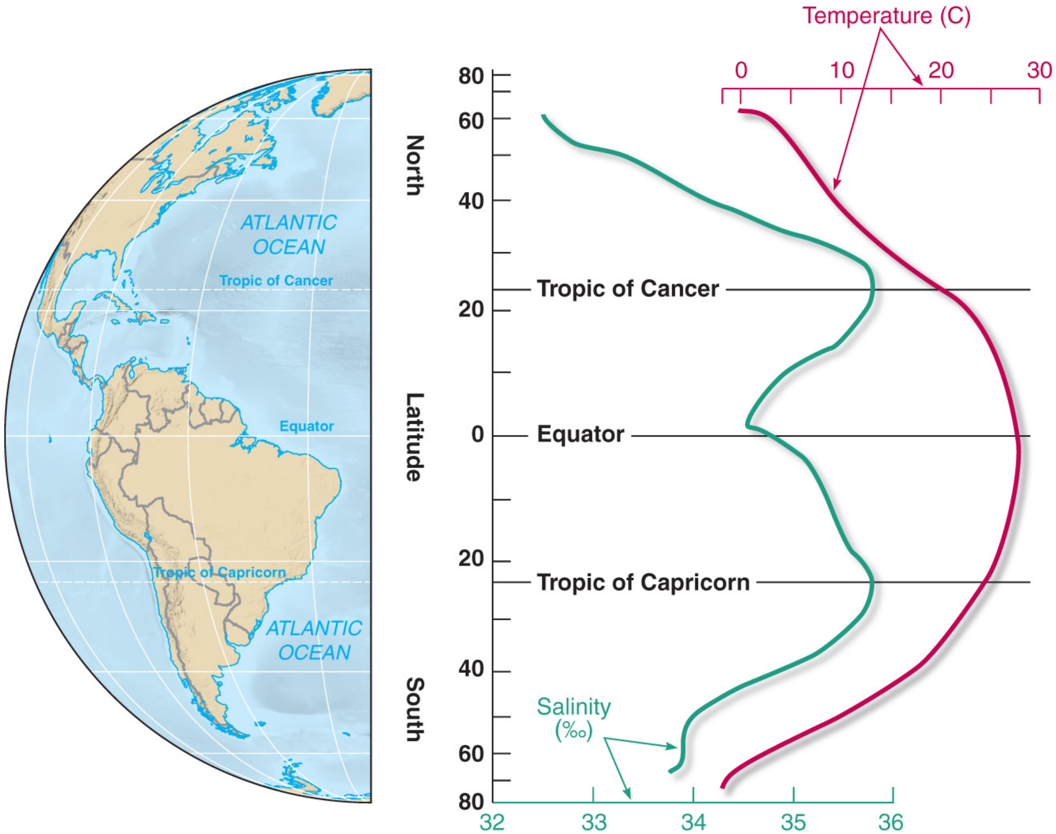
Fossil Sea Urchin from Cretaceous chalk, now exposed on land
Stevns Klimt museum, Højerup, Støre Heddinge, Denmark

- The distribution of marine organisms in the ocean is function of:
  - **Salinity and temperature** in the ocean waters
    - Salinity: amount of salt contained in ocean water
    - Temperature: measure of the average kinetic energy of ocean water
  - Large-scale **movements of ocean water**, similarly to what happens on land for terrestrial species because of atmospheric circulation
    - Ocean currents

Seawater Salinity and Temperature

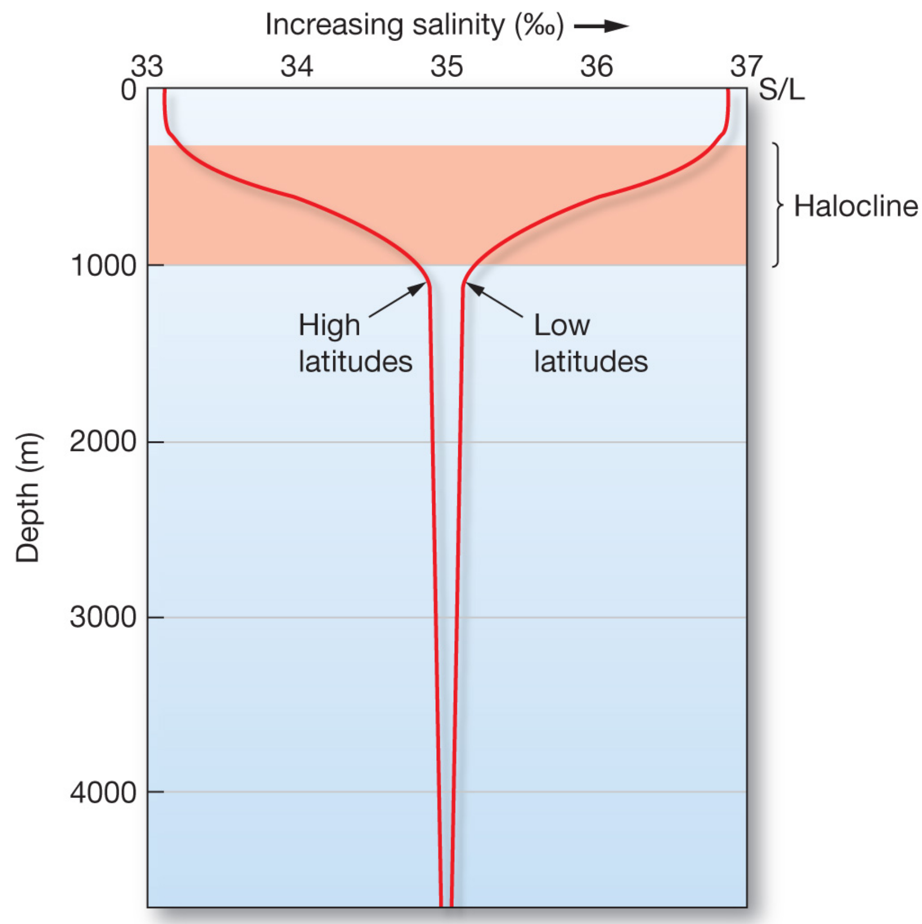
- Surface Salinity Variation

- High latitudes
  - Low salinity
  - Abundant sea ice melting, precipitation, and runoff
- Low latitudes near equator
  - Low salinity
  - High precipitation and runoff
- Mid latitudes
  - High salinity
  - Warm, dry, descending air increases evaporation



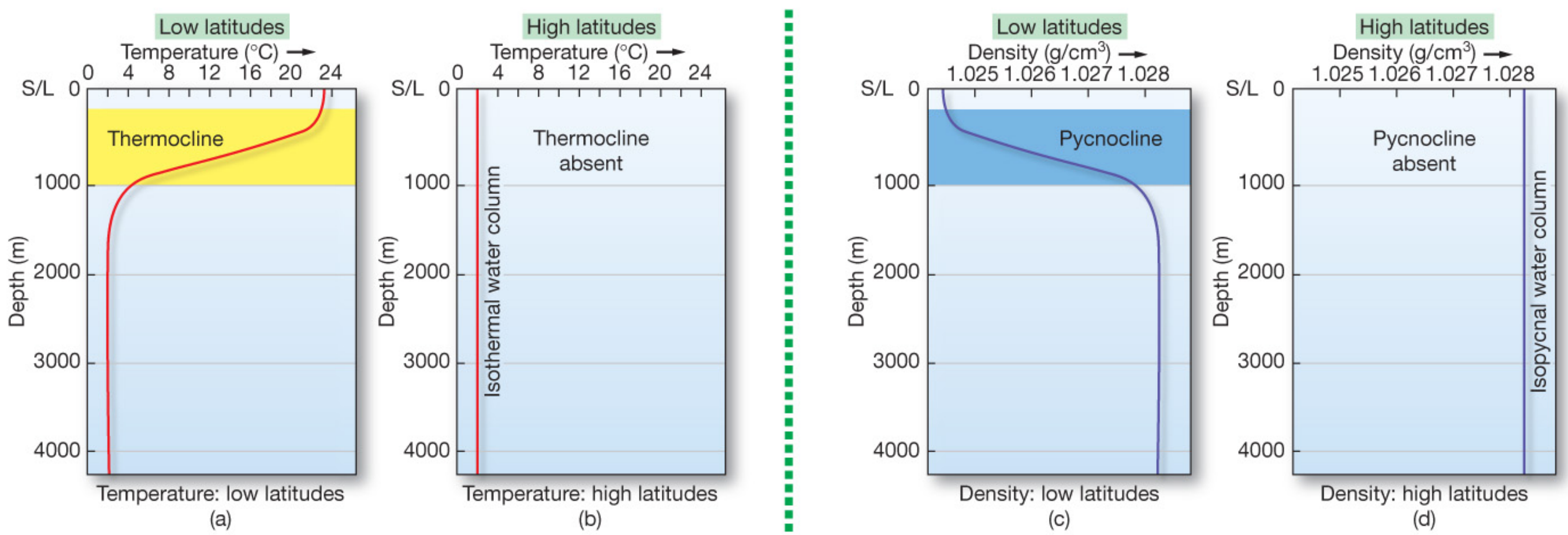
Salinity Variation with Depth

- Low latitudes – salinity decreases with depth
- High latitudes – salinity increases with depth
- Deep ocean salinity fairly consistent globally
- Halocline – separates ocean layers of different salinity



Temperature and Density Variation With Depth

- Pycnocline – abrupt change of density with depth
- Thermocline – abrupt change of temperature with depth



Layered Ocean

Three distinct water masses based on density:

- Mixed surface layer – above thermocline
- Upper water – thermocline and pycnocline
- Deep water – below thermocline to ocean floor
- High latitude oceans – thermocline and pycnocline rarely develop
  - Isothermal
  - Isopycnal

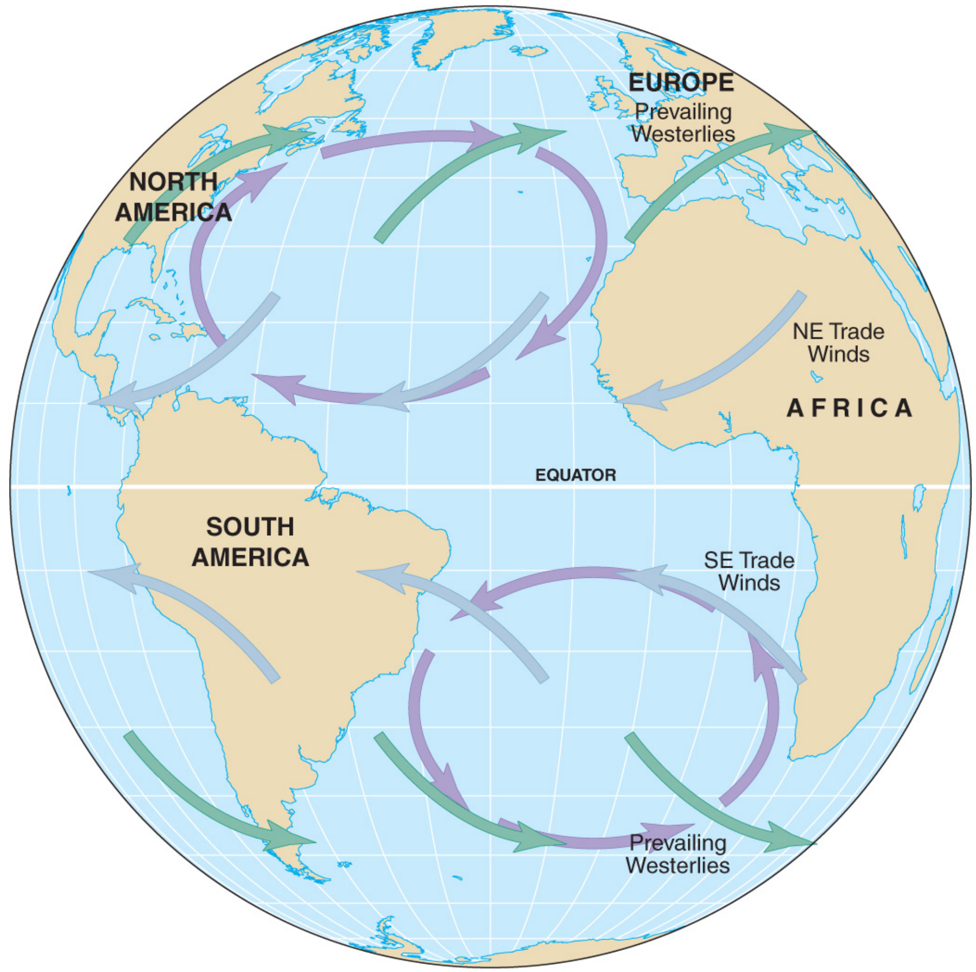
Types of Ocean Currents

- Surface currents
  - Wind-driven
  - Primarily horizontal motion

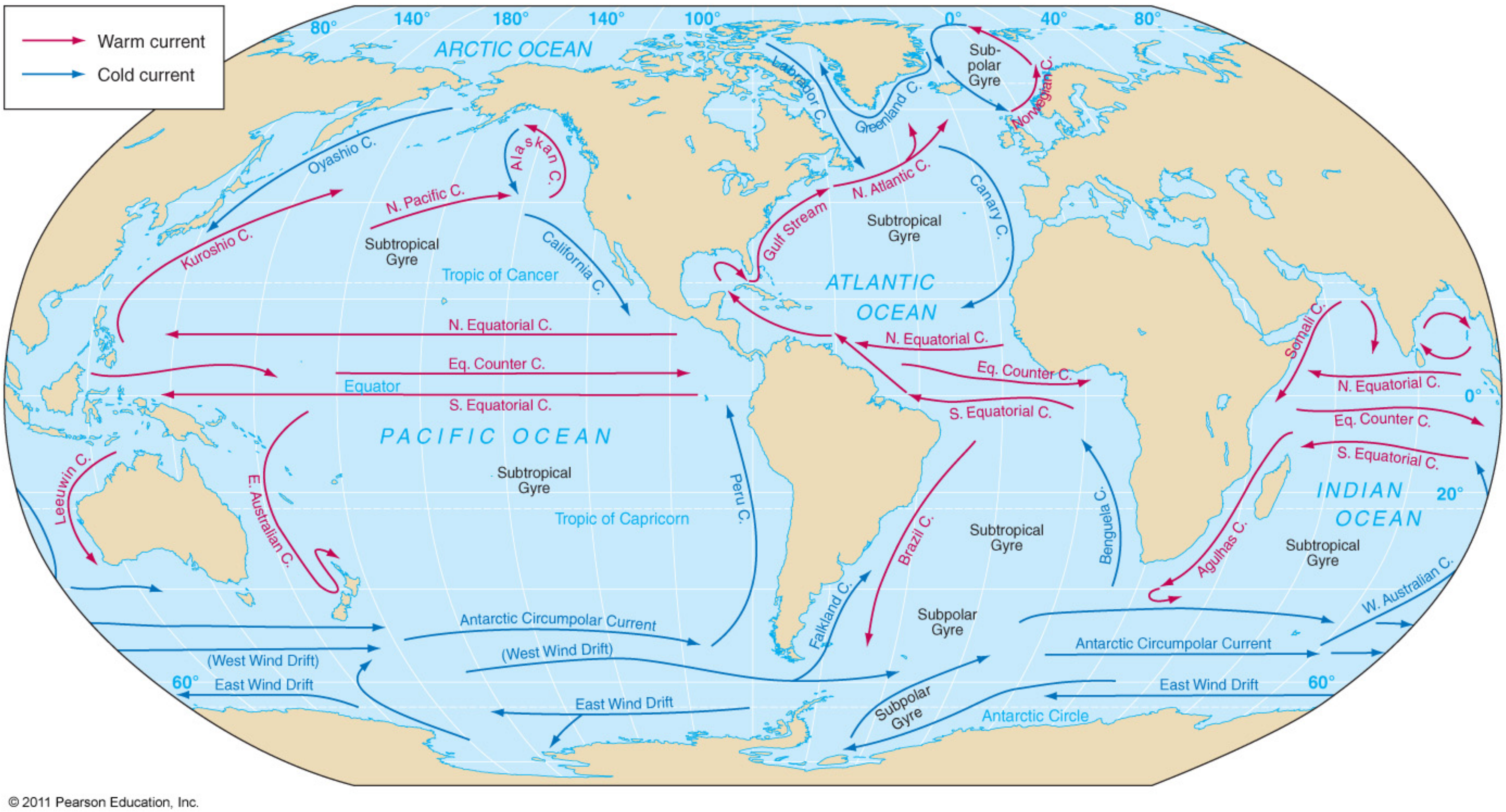
- Deep currents
  - Driven by differences in density caused by differences in temperature and salinity
  - Vertical and horizontal motions

general surface currents patterns

- Only 2% of wind energy is transmitted to ocean
- On a planet without land masses, ocean currents would follow wind belts, creating large, circular loops (**gyres**) of moving water
- On a planet with continents, currents are deflected by land
- Example from the Atlantic Ocean



Subtropical Gyres and Currents

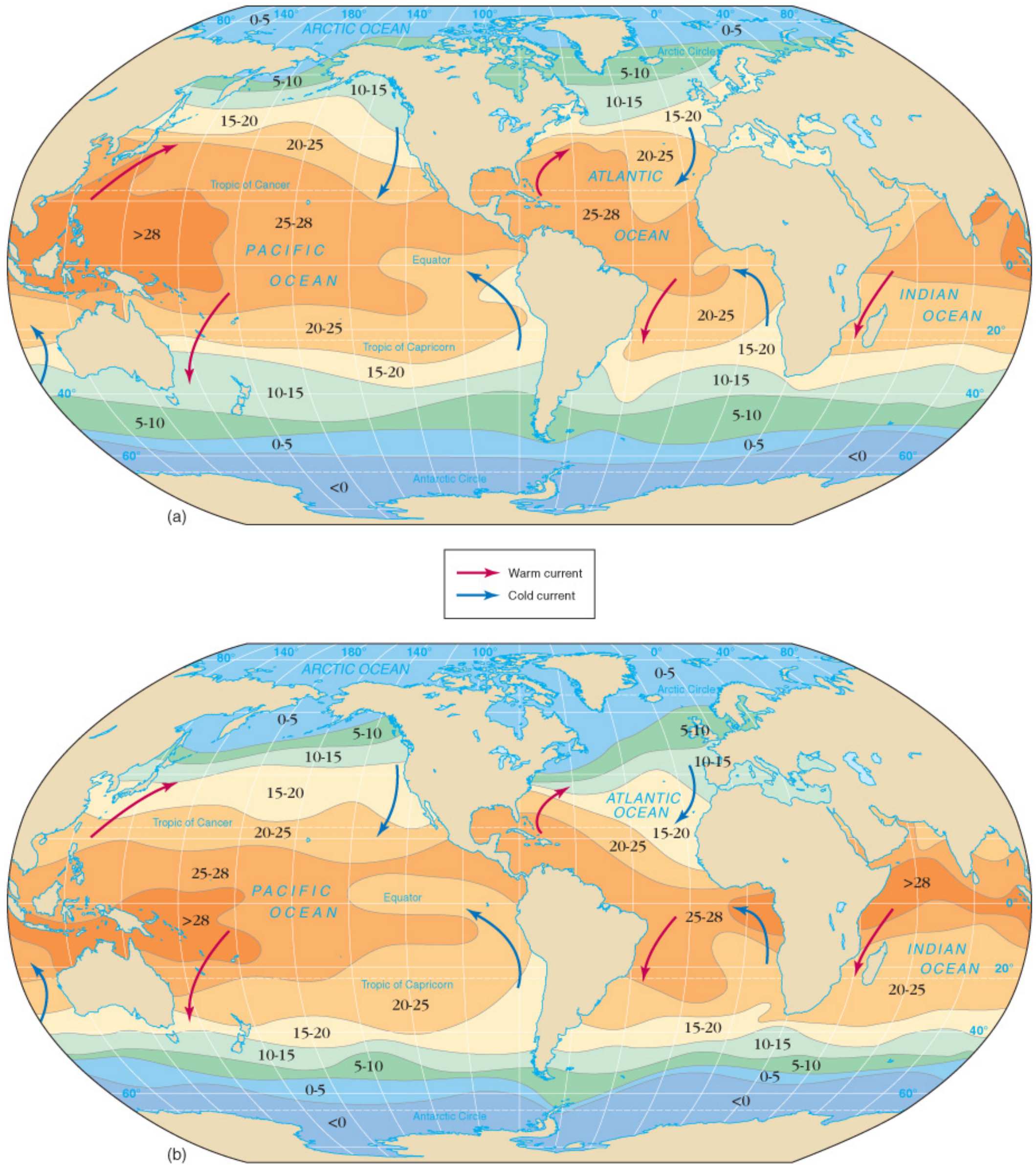


Ocean Currents and Climate

- Warm coastal ocean currents warm the air above. Air absorbs more moisture. Moisture is released when air is cooled
  - Warm, humid air
  - Humid climate on adjoining landmass
    - Florida

- Cool coastal ocean currents cool the air above. Air cannot will acquire moisture when heating up
  - Cool, dry air
  - Dry climate on adjoining landmass
    - California

Ocean Currents and Climate



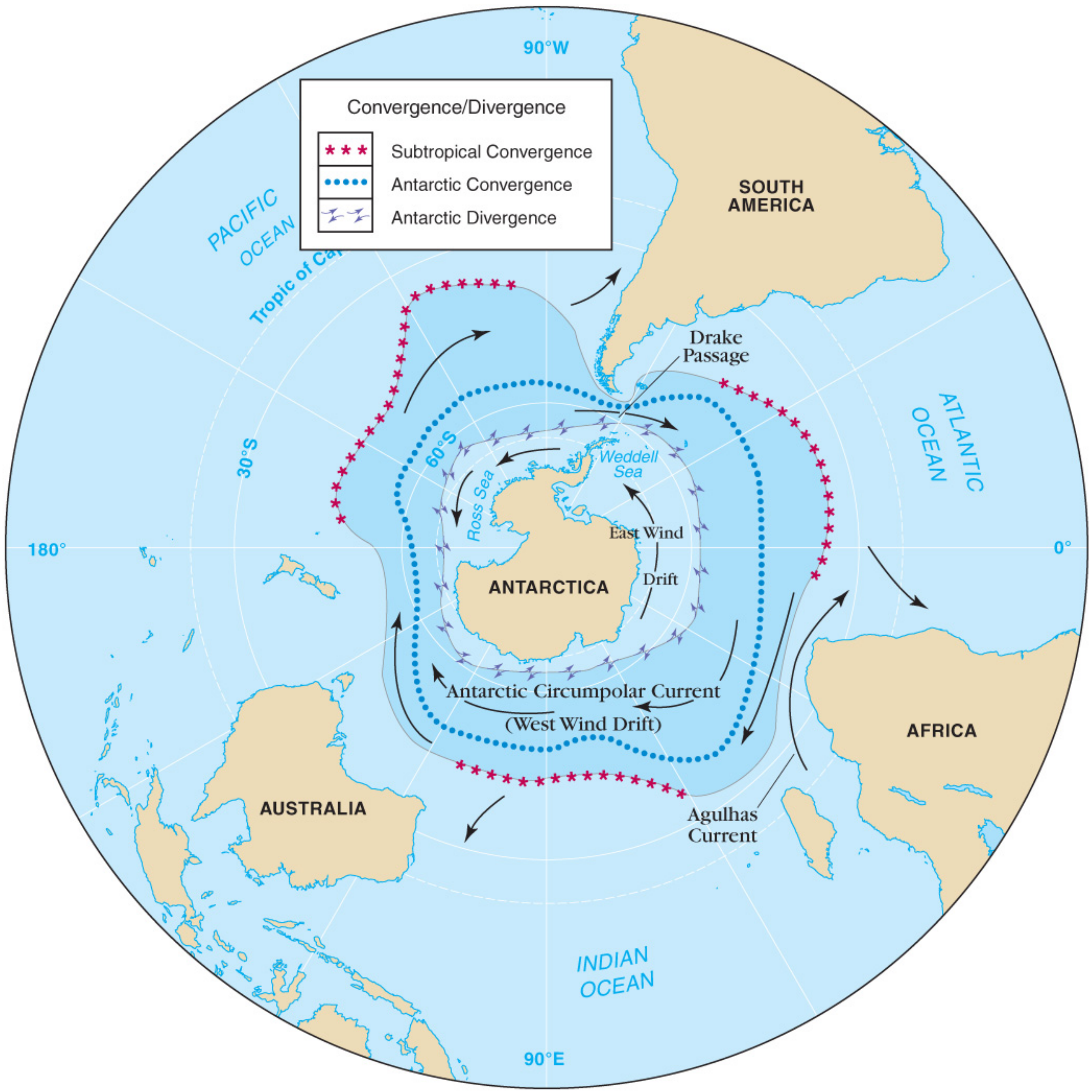
Upwelling and Downwelling

- Upwelling – Vertical movement of cold, nutrient-rich water to surface
  - High biological productivity
- Downwelling – Vertical movement of surface water downward in water column
  - Low productivity, but downwelling carries oxygen to deep waters

- Upwelling and downwelling provide important mixing mechanisms between surface and deep waters

Antarctic Circulation

- Antarctic circulation is dominated by movement of water masses in the southern Atlantic, Indian, and Pacific Oceans, at latitudes south of 50°S
- This is the only area on Earth where ocean currents can flow around the globe unimpeded
- There are two main currents:
  - Antarctic Circumpolar Current (West Wind Drift)
  - East Wind Drift



Convergence/Divergence
Subtropical Convergence
Antarctic Convergence
Antarctic Divergence
90°W
PACIFIC OCEAN
Tropic of Ca
SOUTH AMERICA
Drake Passage
ATLANTIC OCEAN
30°S
60°S
Weddell Sea
Ross Sea
East Wind Drift
180°
0°
ANTARCTICA
Antarctic Circumpolar Current
(West Wind Drift)
AFRICA
AUSTRALIA
Agulhas Current
INDIAN OCEAN
90°E

How Do Deep-Ocean Currents Form?

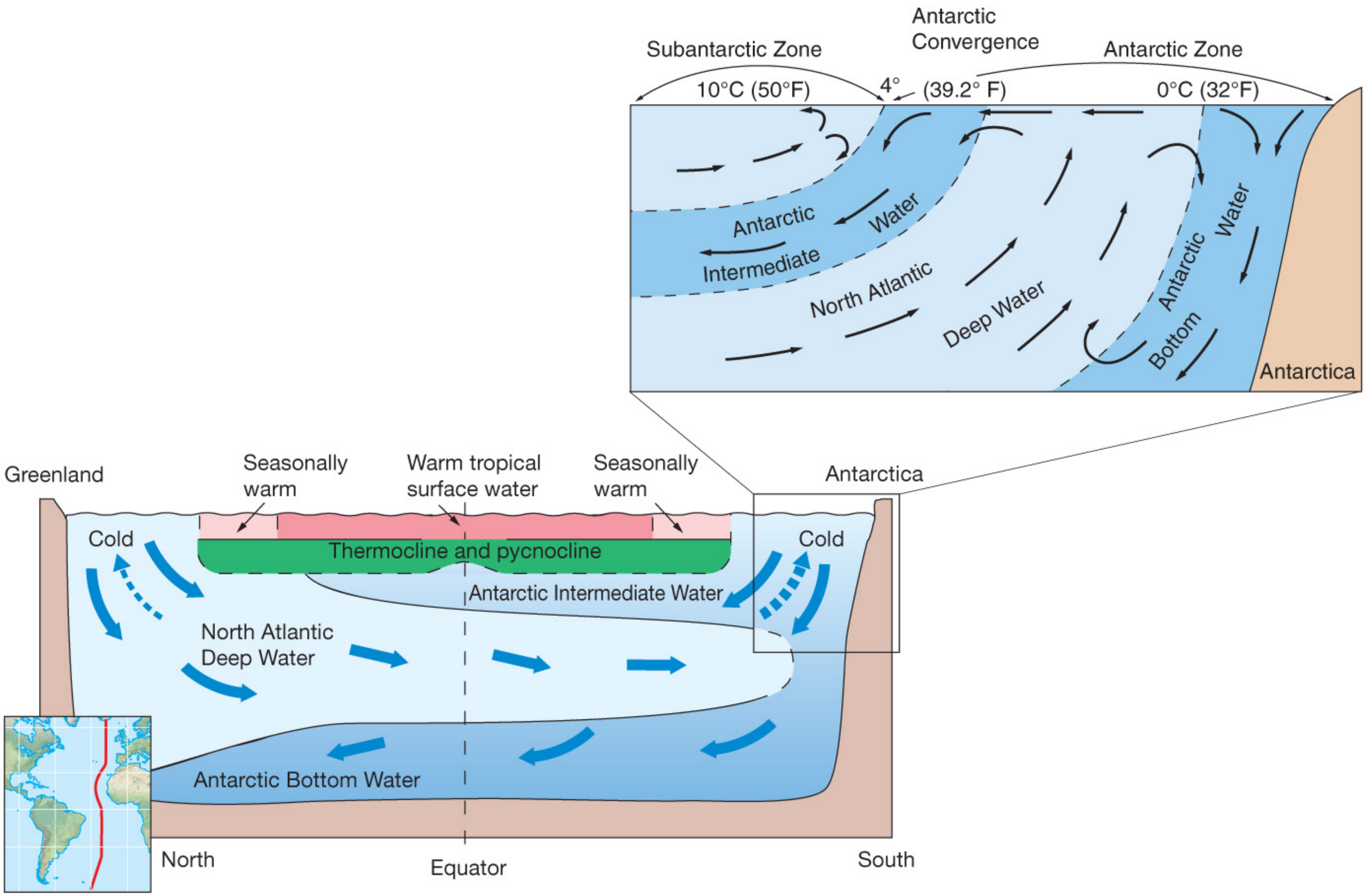
- Occur below the pycnocline
- As a consequence, they effect 90% of ocean waters
- They are created by variations in density of the ocean water
- This circulation system is then called thermohaline (temperature and salinity of ocean waters control their density)
- Thermohaline circulation is very slow: 10 to 20 km/yr

Origin of Thermohaline Circulation

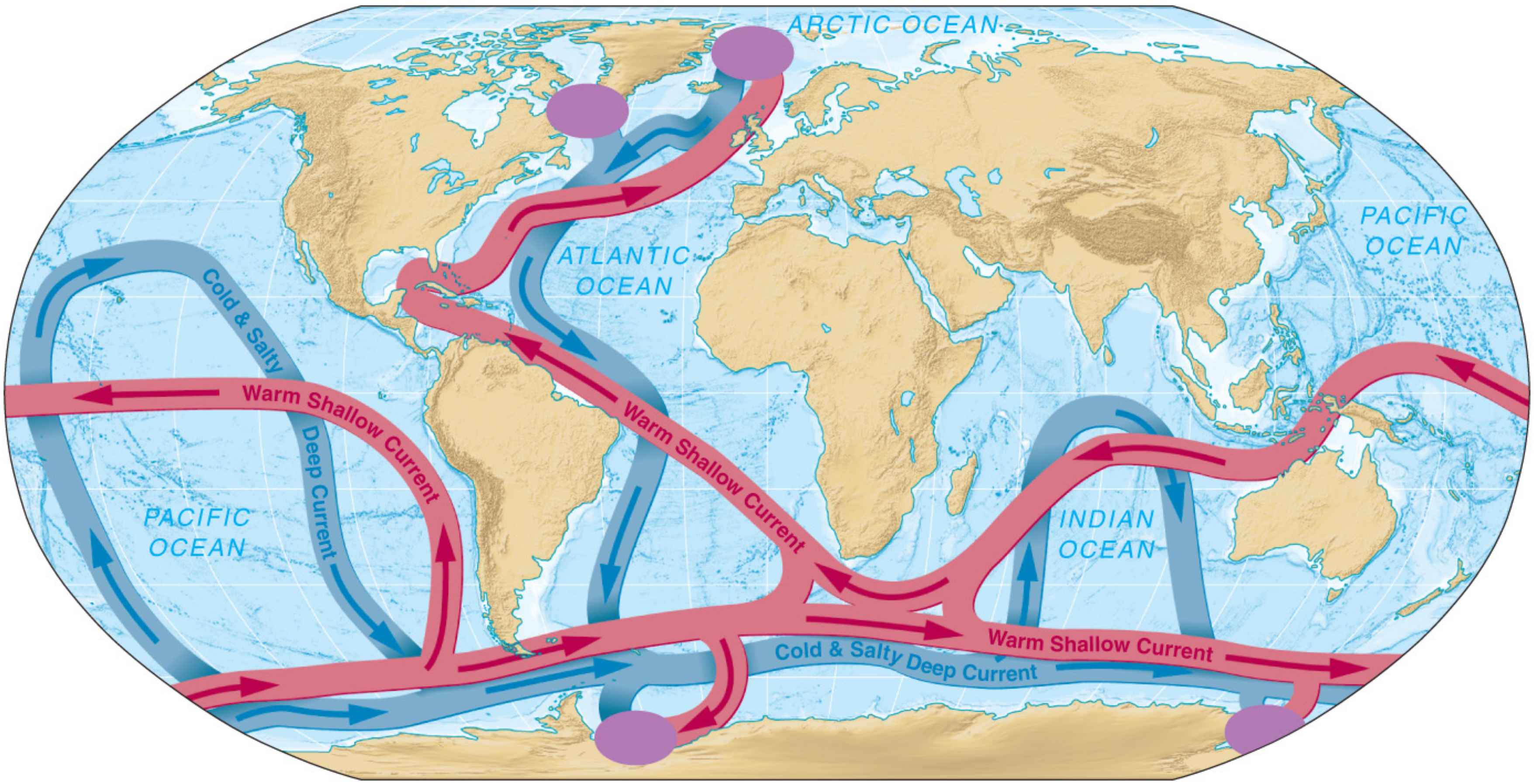
- Originates in high latitude surface ocean
- Cooled, now dense surface water sinks and changes little
- Formation of sea ice increases the salinity, hence the density, of the water left behind, which starts to sink

- Deep-water masses can be identified on a temperature–salinity (T–S) diagram
  - Identifies deep water masses based on temperature, salinity, and resulting density

Thermohaline Circulation



Conveyor Belt Circulation

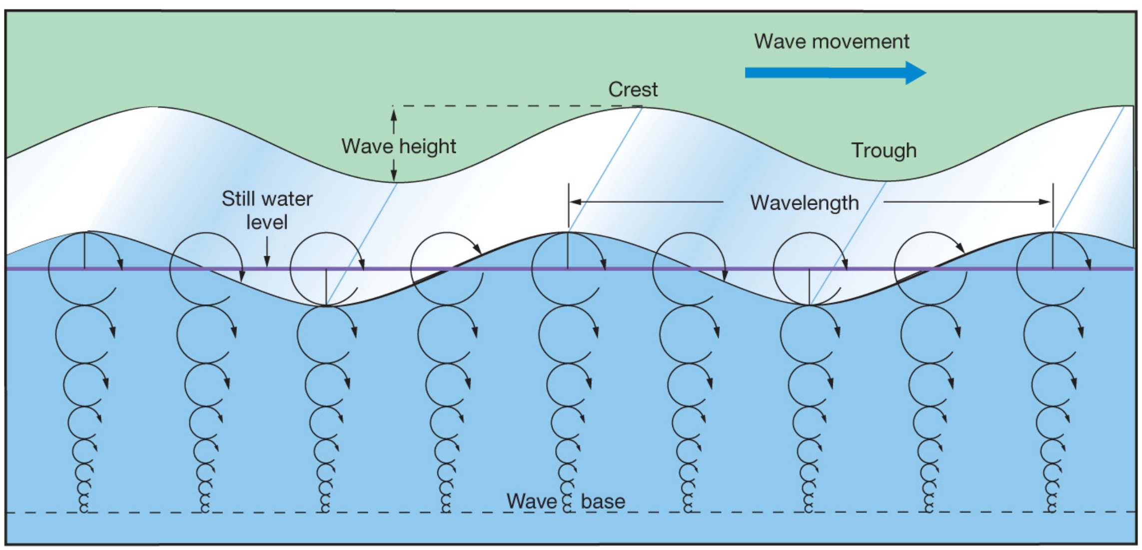


- Dissolved oxygen in deep water
  - Today (icehouse time): abundant life because of presence of O_2 at the ocean bottom
  - Cretaceous (greenhouse time): water could not sink, ocean bottom poorly supplied with O_2
- Conveyor-belt circulation and climate change
  - Plate tectonics changes geography
  - Climate changes affect deep-water circulation

Waves

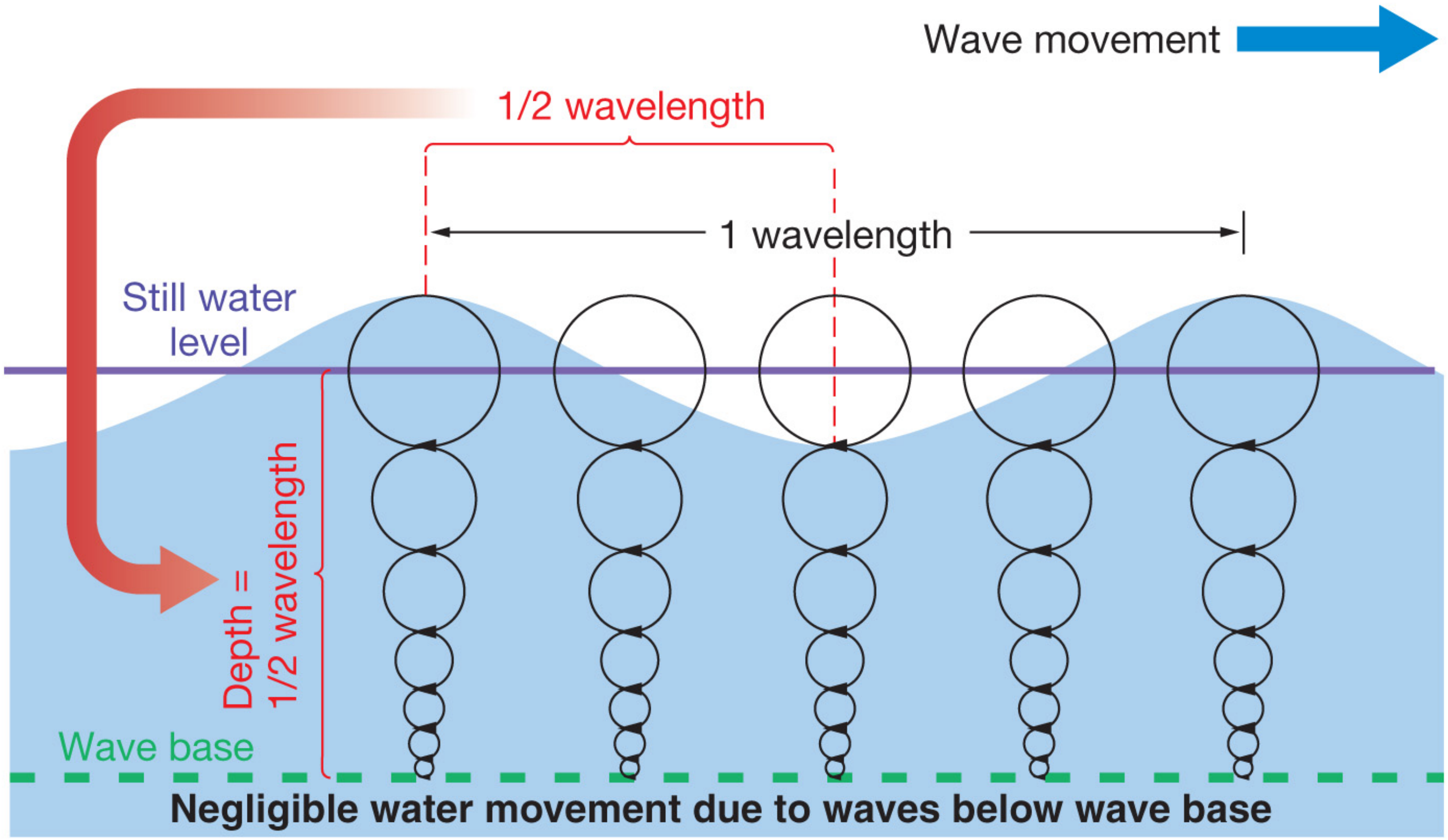
- most waves are generated by winds, during storms
- waves transfer energy across the ocean surface
- all waves begin as a disturbance
- wind blowing across the surface of the ocean generates most ocean waves, which then radiate in all directions
- in general, waves are created by the movement of fluids with different densities

Crest, Trough, Wave Height (H), Wavelength (L), Still Water Level



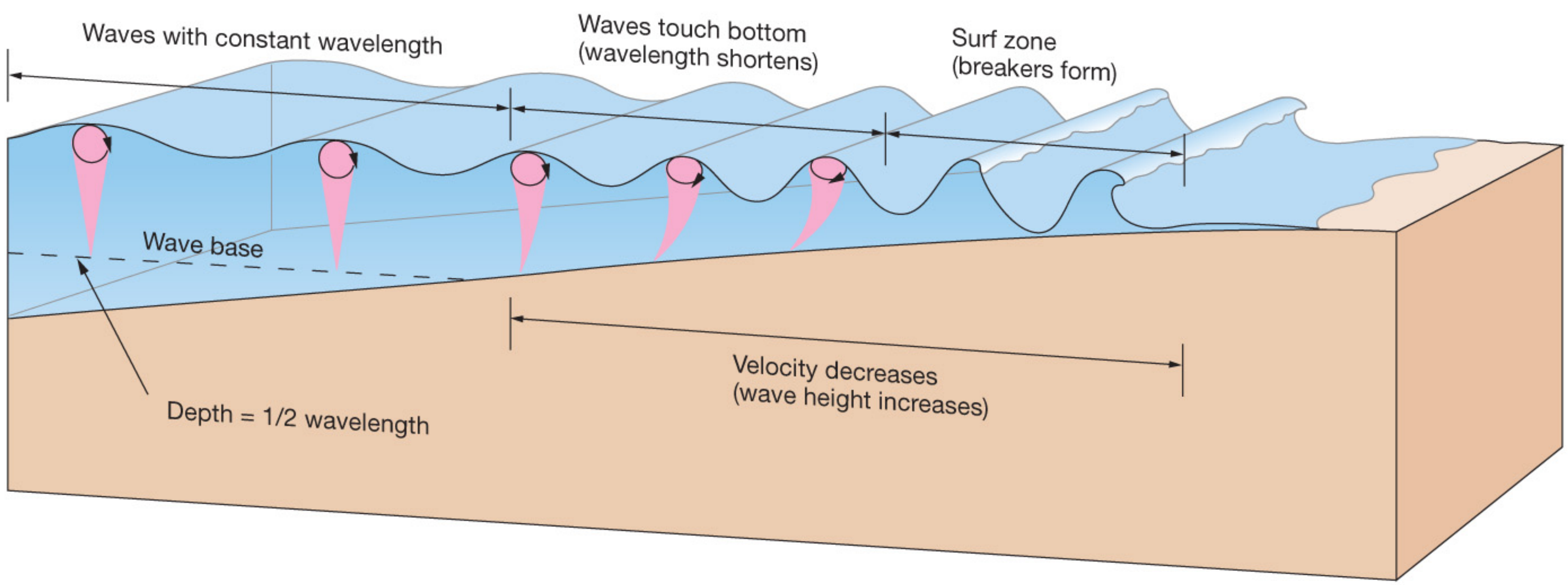
(a) Wave characteristics

- the Diameter of orbital motion decreases with depth
- Wave base = ½ L
- There is hardly any motion below wave base that is caused by wave activity



(b) Calculation of wave base

Waves Approaching Shore



Tides

- Tides are the rhythmic rise and fall of sea level
- Tides are very long and regular shallow-water waves
- Tides are caused by reciprocal gravitational attraction between the Sun, Moon, and Earth

- The Intertidal zone is a coastal area that is alternatively submerged during high tide and exposed to air during low tide (**tidal flats**)
  - Harsh living zone: great variations in temperatures and relatively few species live here

- Landward of this zone is the supratidal zone
  - Even harsher than intertidal zone: dry except when flooded by storms or strong winds enhancing tides

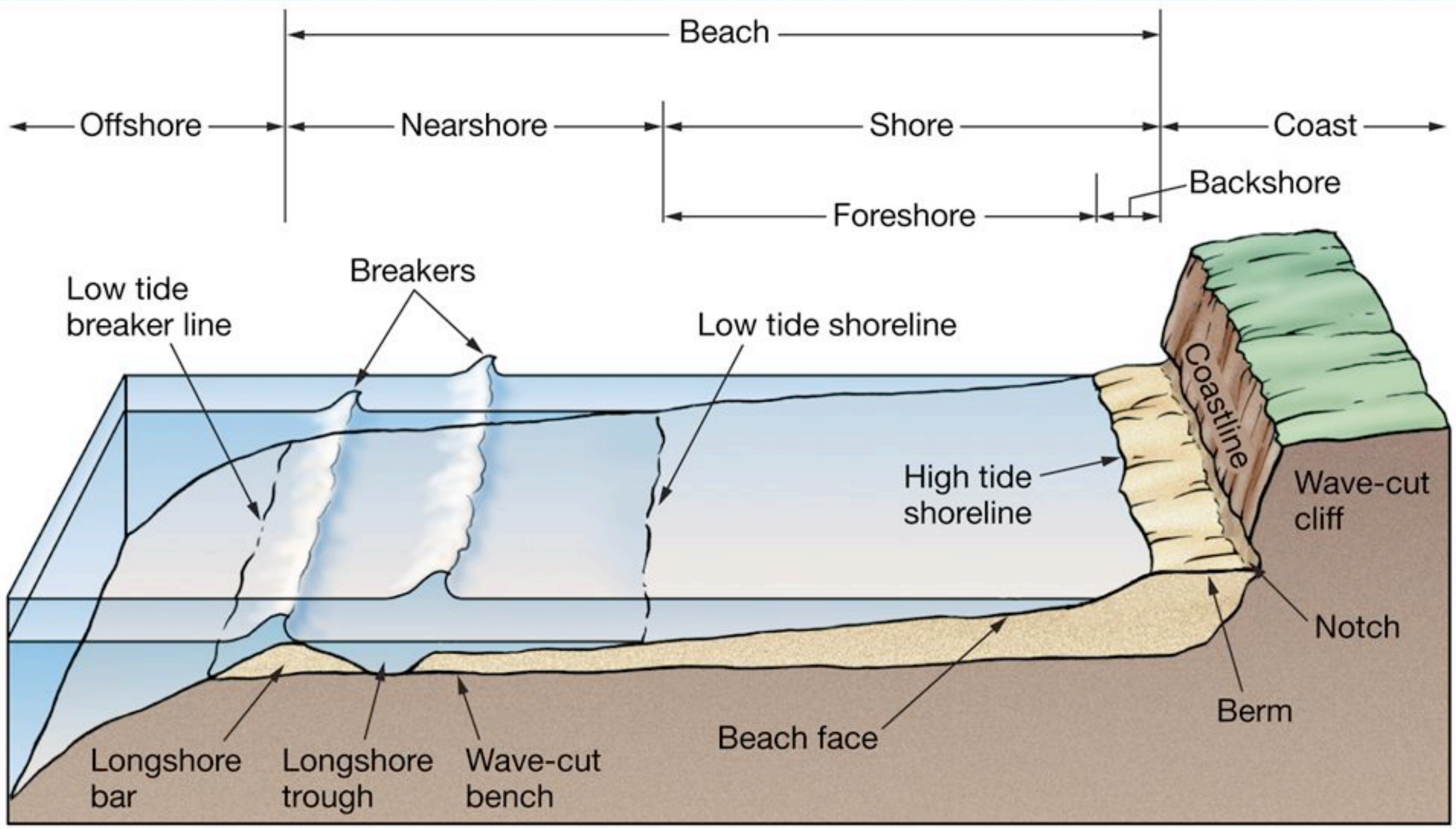

Beach
Offshore
Nearshore
Shore
Coast
Backshore
Foreshore
Breakers
Low tide
breaker line
Low tide shoreline
Coastline
High tide
shoreline
Wave-cut
cliff
Notch
Berm
Beach face
Longshore
bar
Longshore
trough
Wave-cut
bench

Fig. 10-1

Tidal flats on the Pacific Ocean
Vancouver Island
Tofino, British Columbia, Canada

Marine Life varies with depth

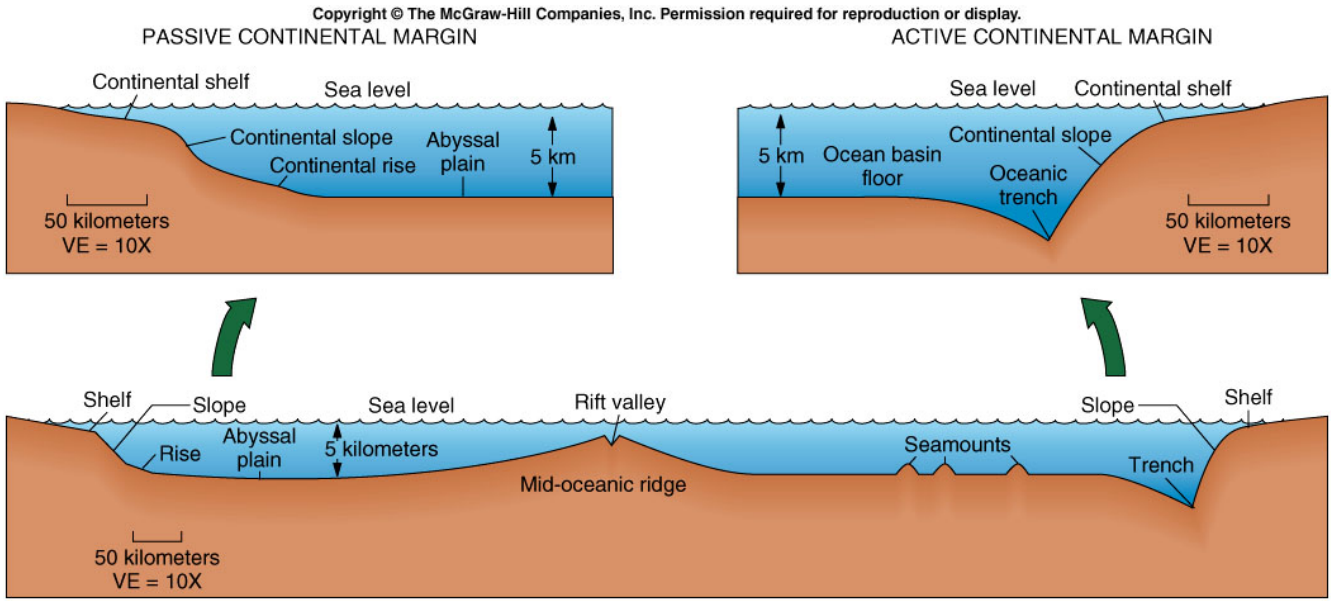
- Ocean depth varies from a watery film in coastal areas to up to 11 km (7 mi) in the Mariana Trench of the southwest Pacific
- Water depth is not important for life, but the restrictions that it imposes are:
  - Light
  - Temperature
  - Water movement

Ocean Floor configuration

A continental margin is where a continent meets the ocean.

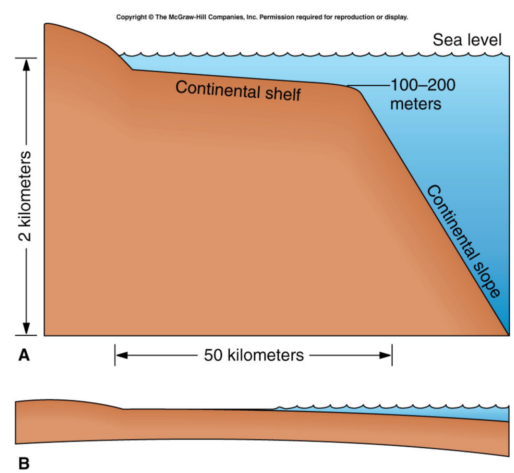
If that coincides with a plate boundary, it is called an **Active Margin** (such as the North American west coast).

If that does not coincide with a plate boundary, it is called a **Passive Margin** (such as the North American east coast)



- Continental Shelf
- Slope
- Continental Rise
- Abyssal Plain

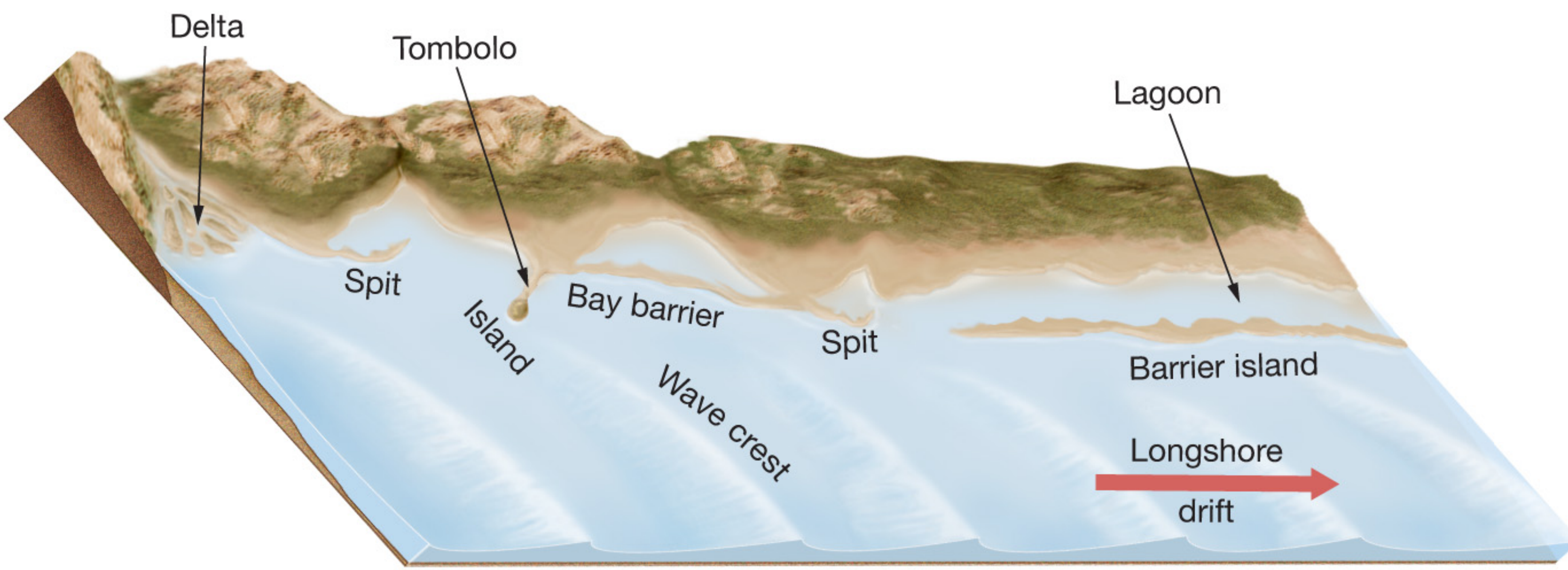
- Mid-Ocean Ridge
- Seamounts
- Trench



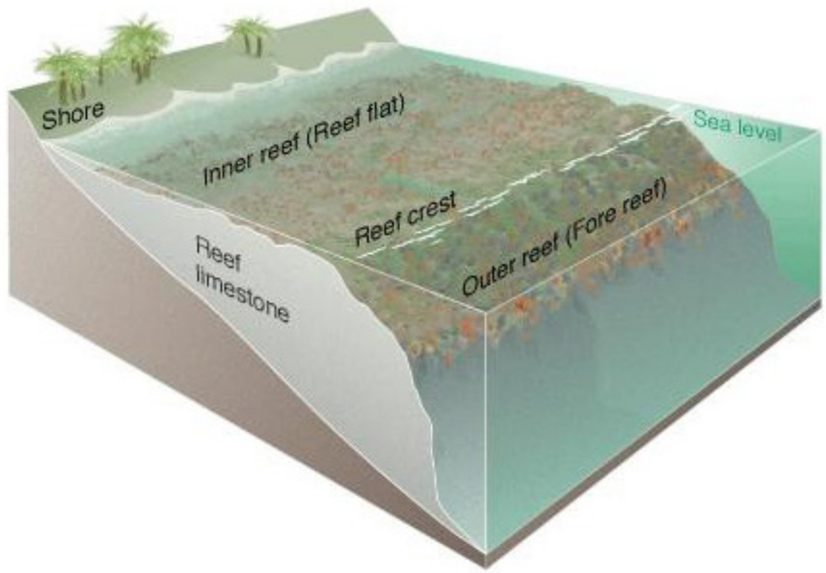
depositional shores

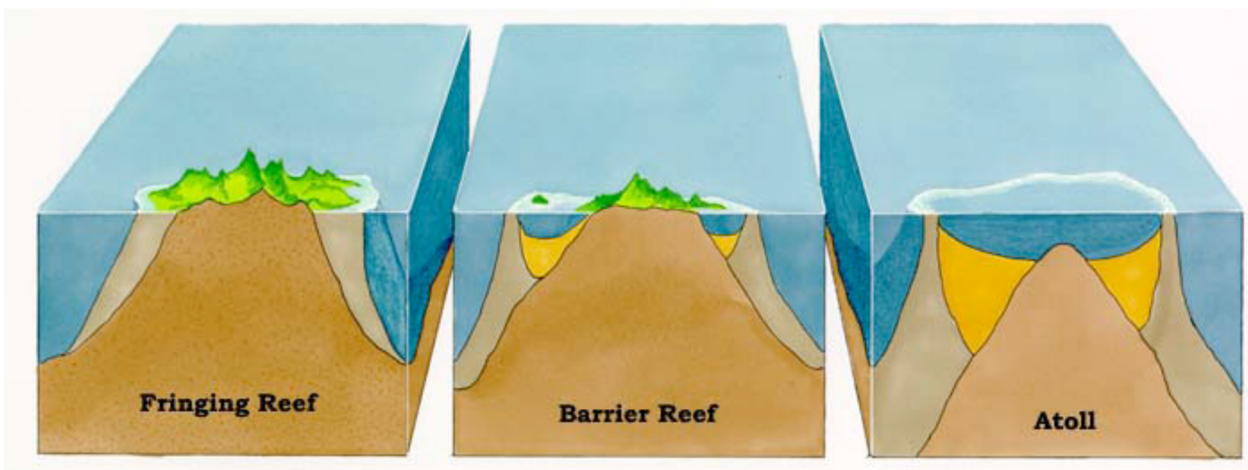
- Sediment (mostly sand) can be:
  - carried to shore by rivers, from erosion of inland rocks
  - produced by coastal erosion
- Waves (longshore currents) distribute sand along the continental margin
- Depositional features
  - deposits of sand moved by a longshore current
    - can be modified by a variety of coastal processes
    - can be partially or wholly separated form the shore itself

- A bay barrier, or bay mouth bar, seals off a lagoon from the ocean
- A Tombolo is a sand bar that connects an island to the mainland
- Barrier islands are offshore sand deposits that parallel the coast
- A spit is attached to mainland at one hand and hooks into a bay



Carbonate margins





erosional shores

- Wave refraction causes:
  - concentration of wave energy around headlands
  - dissipation of wave energy in bays

- As a result, headlands are eroded and bays tend to be filled with sediment

- Waves pound at the base of a headland, undermining its upper portion , which would eventually collapse to form wave cut cliffs

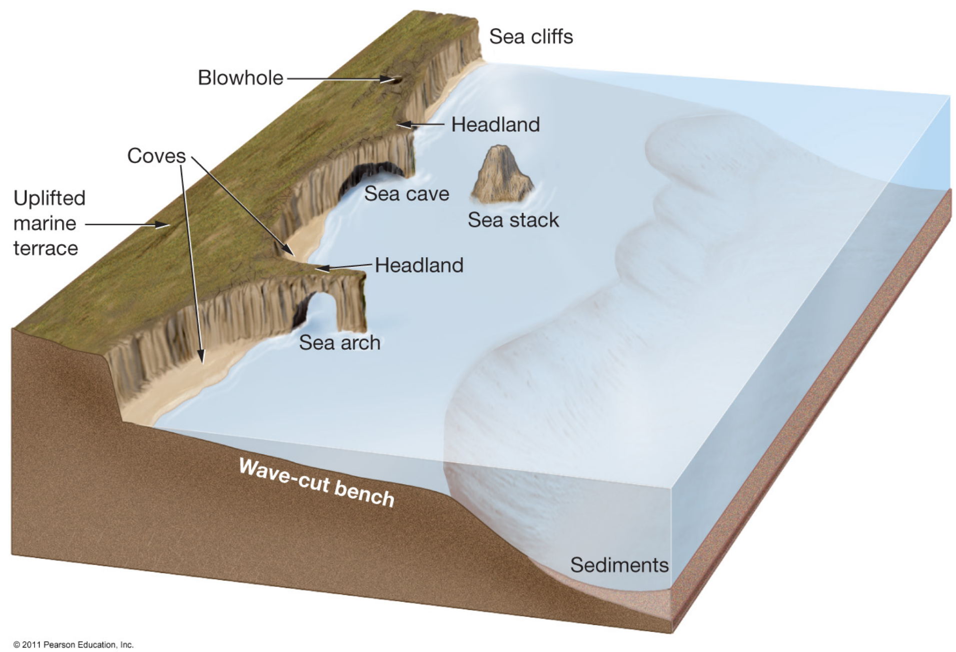
Waves can also carve sea caves at the base of a cliff.

Sea arches form where sea caves in headlands erode all the way through.

Sea stacks form when the tops of sea arches erode away completely.

Waves also erode the wave-cut bench, down to a depth that reflect the average wave-base for the are, forming a flat to gently sloping surface.

Bedrock uplift generates a marine terrace.



Salt Marshes and Mangrove Swamps

These are wetlands: the soil is saturated with water

Salt marshes are found in mid-latitudes, mangrove swamps in tropical areas

Above right: a salt marsh.
Everglades National Park, Dade county, Florida

Below right: a mangrove swamp
Merritt Island National Wildlife Refuge
Cape Canaveral, Florida

Epicontinental Seas

- Epicontinental seas form when a very high sea level spreads over a continents, resulting in extended oceans with very shallow depth
- Today, due to a lower sea level (we are in an icehouse time after all!), epicontinental seas are not well developed

- Life in the ocean is related to water depth
  - Surf vs. intertidal, vs. subtidal (shelf) conditions
  - Photic zone
  - Deep waters
  - Nekton, benthos, plankton

- Life in the ocean is related to water temperature
  - Surface temperatures vs. deep water temperatures
  - Tropical vs. temperate vs. polar temperatures

- Life in the ocean is related to water salinity
  - Brackish, normal and hypersaline waters

Freshwater Environments

- Rivers
  - Water in motion limits planktonic life
- Lakes
  - Huge variety of lakes: Mono Lake vs. the Great Lakes
- Freshwater marshes

- Life in freshwater environments is less diverse, less common, occupies fewer environments and has fewer chances to be preserved as fossils

Ancient lake (terrestrial) fossils: a fish and a leaf
Florissant National Monument
Florissant, Colorado