Ocean Currents and Climate

There are two type of Ocean Currents:

1. Surface Currents--Surface Circulation

These waters make up about 10% of all the water in the ocean.

These waters are the upper 400 meters of the ocean.

2. Deep Water Currents--Thermohaline Circulation

These waters make up the other 90% of the ocean

These waters move around the ocean basins by density driven forces and gravity.

The density difference is a function of different temperatures and salinity

These deep waters sink into the deep ocean basins at high latitudes where the temperatures are cold enough to cause the density to increase.

Ocean Currents are influenced by two types of forces

1. Primary Forces--start the water moving

The primary forces are:

1. Solar Heating

2. Winds

3. Gravity

4. Coriolis

2. Secondary Forces--influence where the currents flow

1. Surface Circulation

Solar heating cause water to expand. Near the equator the water is about 8 centimeters high than in middle latitudes. This cause a very slight slope and water wants to flow down the slope.

Winds blowing on the surface of the ocean push the water. Friction is the coupling between the wind and the water's surface.

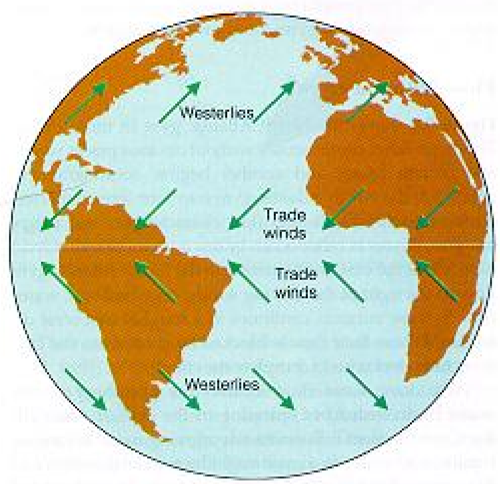


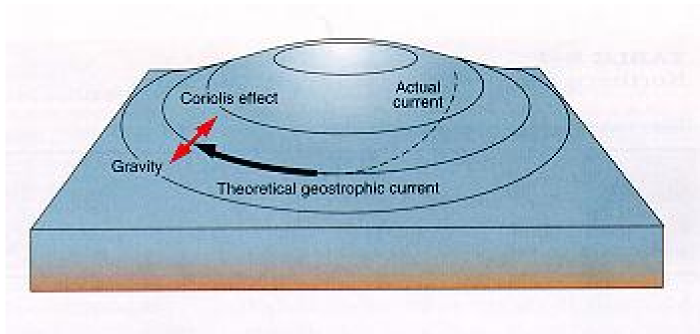
Figure 9.1 Winds, driven by uneven solar heating and Earth's spin, drive the movement of the ocean's surface currents. The prime movers are the powerful westerlies and the persistent trade winds (easterlies).

A wind blowing for 10 hours across the ocean will cause the surface waters to flow at about 2% of the wind speed.

Water will pile up in the direction the wind is blowing.

Gravity will tend to pull the water down the "hill" or pile of water against the pressure gradient.

But the Coriolis Force intervenes and cause the water to move to the right (in the northern hemisphere) around the mound of water.



These large mounds of water and the flow around them are called **Gyres**. The produce large circular currents in all the ocean basins.

Gyres

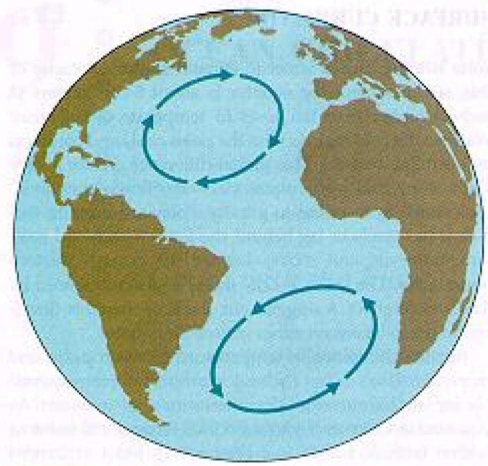


Figure 9.2 A combination of four forces—surface winds, the sun's heat, the Coriolis effect, and gravity—circulates the ocean surface clockwise in the Northern Hemisphere and counterclockwise in the Southern Hemisphere, forming gyres.

North Atlantic Gyre

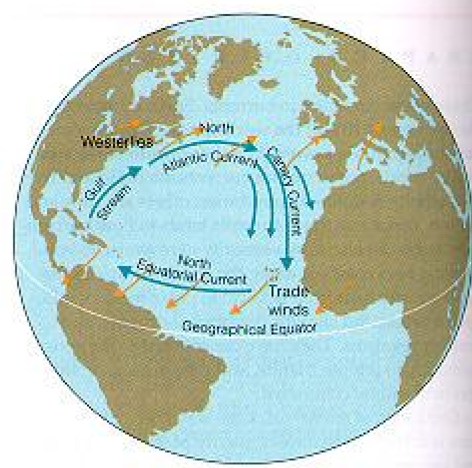


Figure 9.3 The North Atlantic gyre, a series of four interconnected currents with different flow characteristics and temperatures.

Note how the North Atlantic Gyre is separated into four distinct

Currents, The North Equatorial Current, the Gulf Stream, the North Atlantic Current, and the Canary Current.

But why doesn't the water spin towards the center of the ocean? Why does it flow around the hill in this circular motion.

Remember the hill of water-- This hill is formed by the inward push of water through a process call Ekman Transport

Remember the Coriolis Force move objects to the right in the northern hemisphere

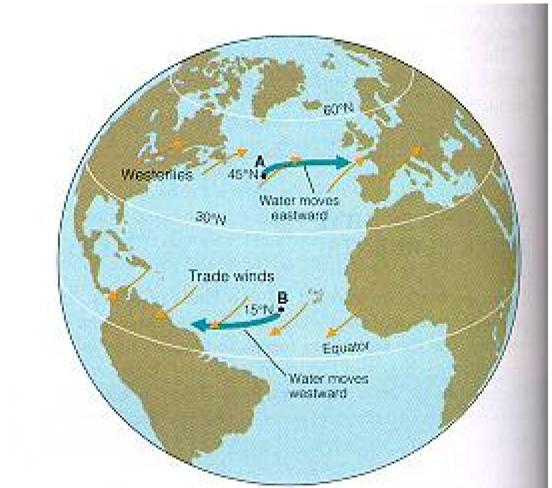
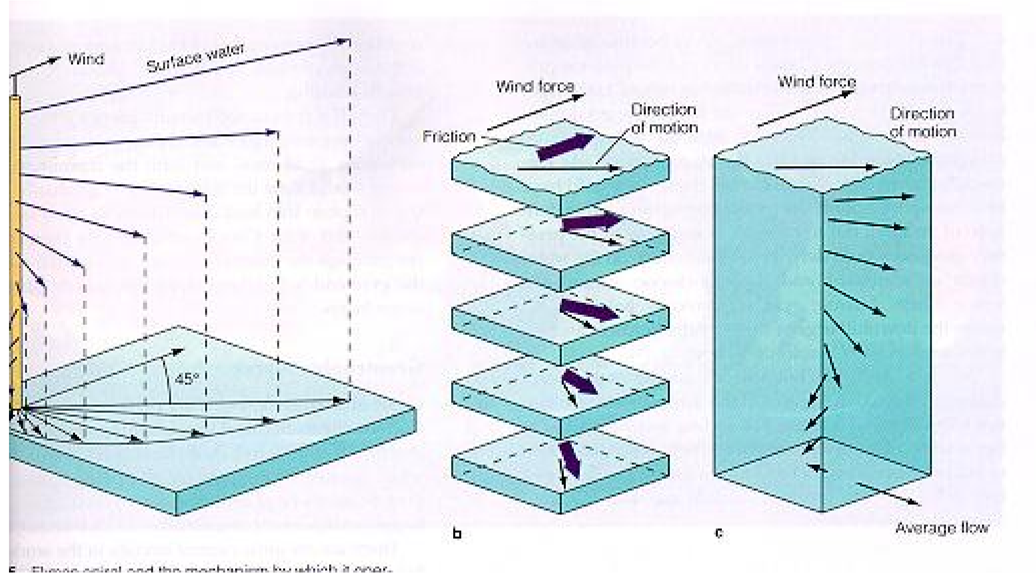


Figure 9.4 Surface water blown by the winds at point A will veer to the right of its initial path and continue eastward. Water at point B veers to the right and continues westward.

Ekman Transport

Wind blowing on the surface of the ocean has the greatest effect on the surface. However, for the lower layers of the ocean to move they must be pushed by the friction between the layers of water above. Consequently, the lower layer moves slower than the layer above. With each successive layer down in the water column the speed is reduce. This leads to the spiral affect seen in the above diagram.



The net movement of water (averaged over the entire upper 330 meters of the ocean) is 90o to the right of the wind direction (in the northern hemisphere).

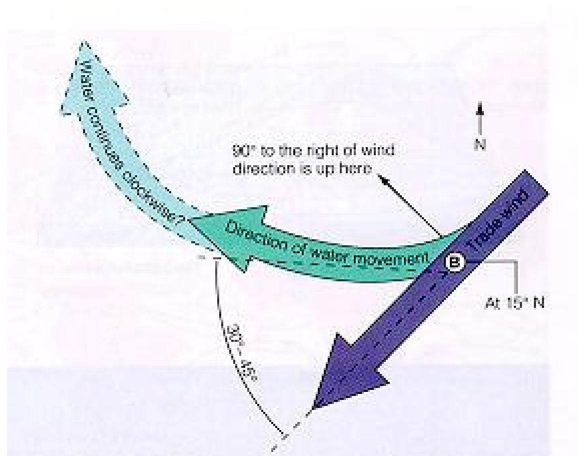
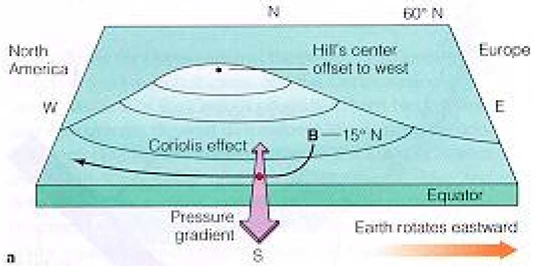
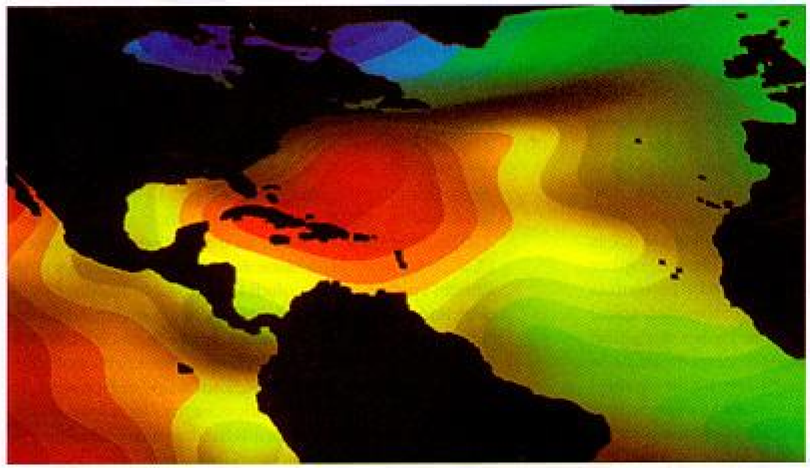


Figure 9.6 The movement of water away from point B in Figure 9.4 is influenced by the rightward tendency of the Coriolis effect and the gravity-powered movement of water down the pressure gradient.

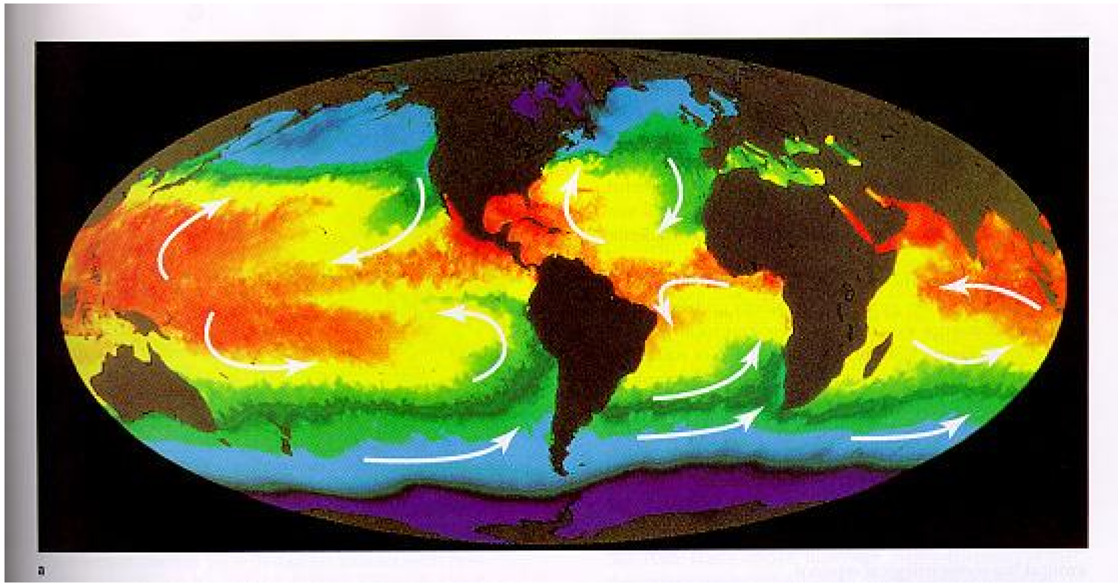
When the water is pushed to the right it forms the hill we described above. So, when water is pushed along by the wind it wants to be turned to the right by the Coriolis force (in the northern hemisphere) but it must fight against gravity (trying to move up the hill of water formed by Ekman transport). A balance is met between the **Coriolis** and the **gravity (pressure gradient force).** This balance produces a balanced flow called a **Geostrophic current.**


N
60° N
North America
Hill's center offset to west
Europe
W
E
Coriolis effect
B
15° N
Equator
Pressure gradient
S
Earth rotates eastward

a



b



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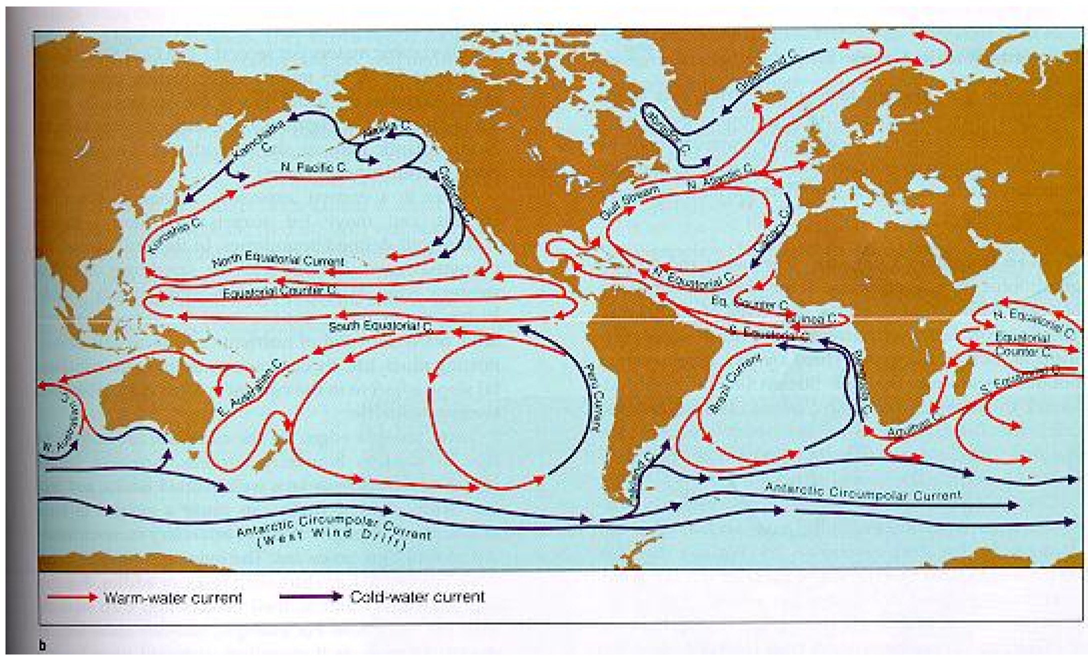


b

Eastern and Western Boundary Currents

Boundary Currents are the major geostrophic currents around the gyre

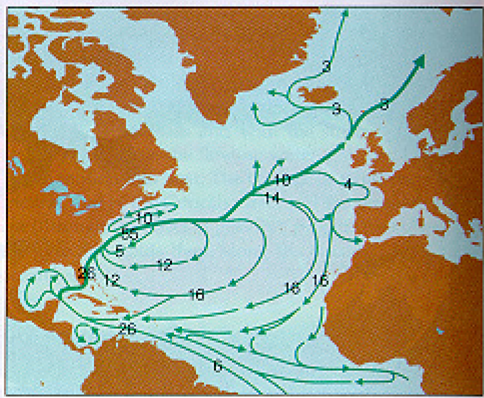
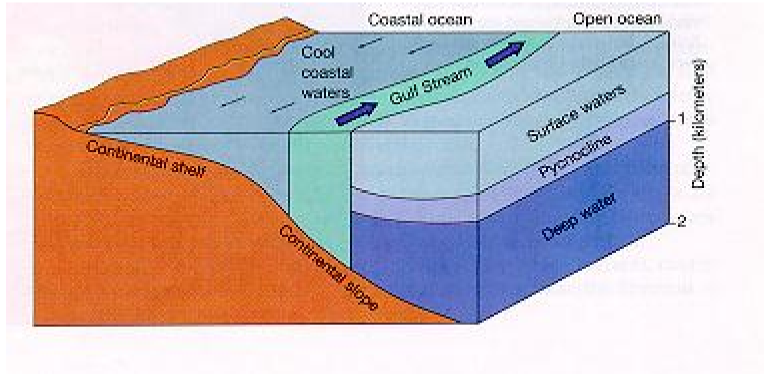


Figure 9.9 The general surface circulation of the North Atlantic. The numbers indicate flow rates in sverdrups (1 sv = 1 million cubic meters of water per second).

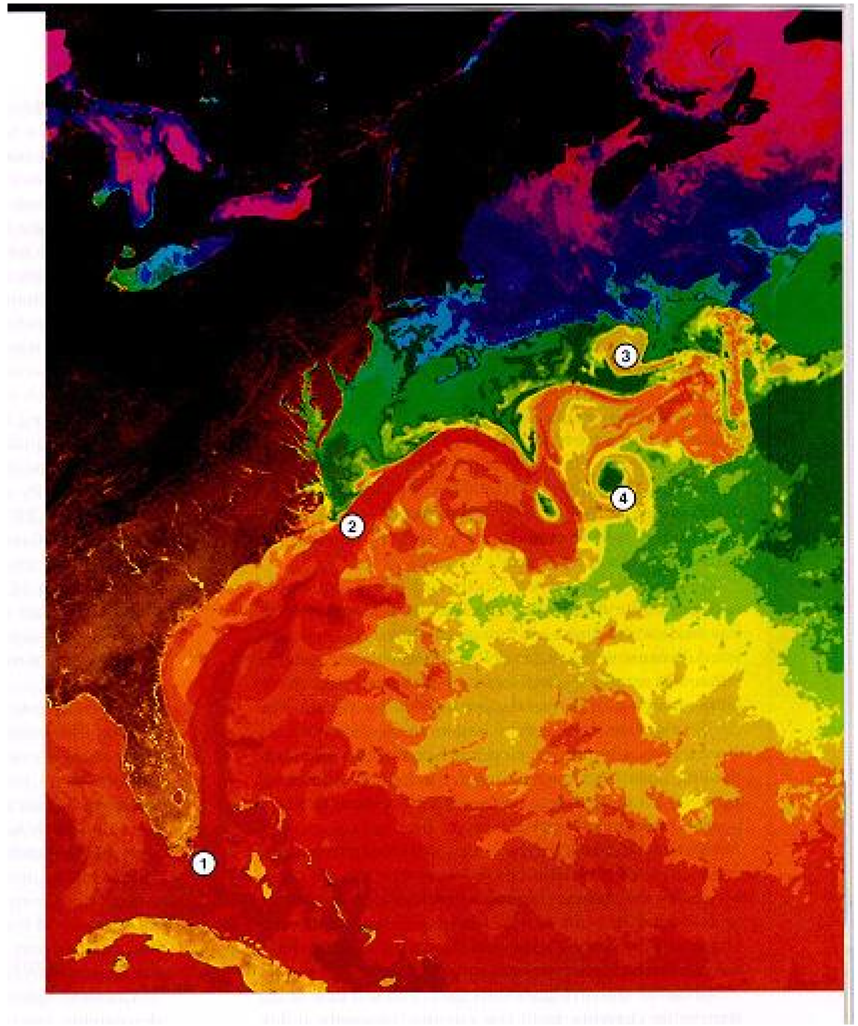
Note the difference is strength (Sv) between the western and eastern boundary currents. This is caused by the effect of the rotating Earth which tends to move the "hill" of water to the western sides of the ocean basins

Table 9.1 Boundary Currents in the Northern Hemisphere

Type of Current (example)	General Features	Speed	Transport (millions of cubic meters per second)	Special Features
Western Boundary Currents Gulf Stream, Kuroshio (Japan) Current	**Warm** Narrow, <100 km. Deep—substantial transport to depths of 2 km.	Swift, hundreds of kilometers per day.	Large, usually 50 sv or greater.	Sharp boundary with coastal circulation system; little or no coastal upwelling; waters tend to be depleted in nutrients, unproductive; waters derived from trade wind belts.
Eastern Boundary Currents California Current, Canary Current	**Cold** Broad, ~1,000 km. Shallow, <500 m.	Slow, tens of kilometers per day.	Small, typically 10–15 sv.	Diffuse boundaries separating from coastal currents; coastal upwelling common; waters derived from mid-latitudes.



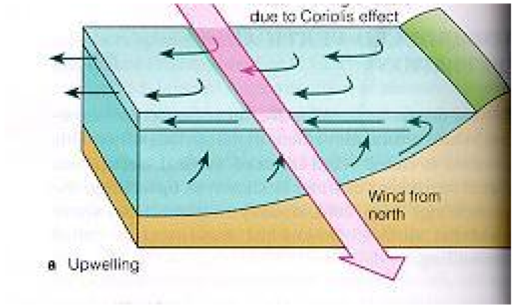
The Gulf Stream is an example of a Western Boundary Current



The effect of winds on the vertical movement of water

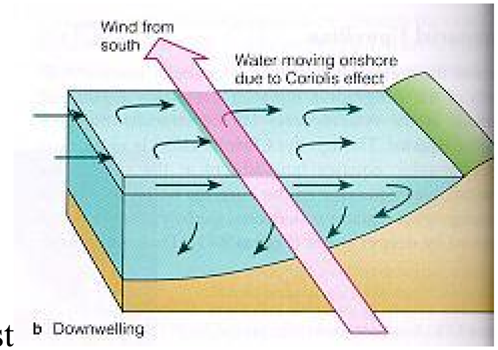
Upwelling along the coast caused by Ekman transport of waters (waters move to the right of the wind).

The waters moved offshore are replaced by waters from below. This brings cold, nutrient rich waters to the surface.

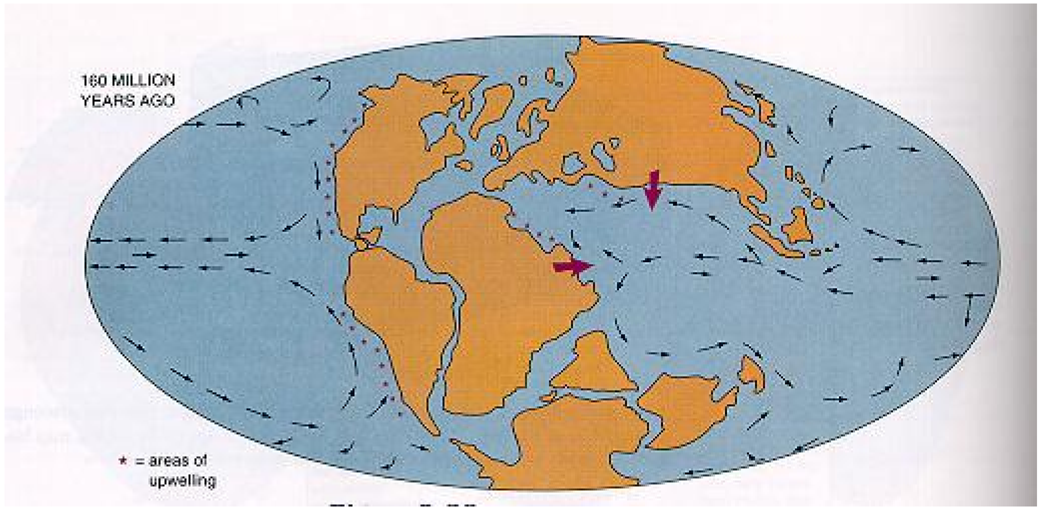


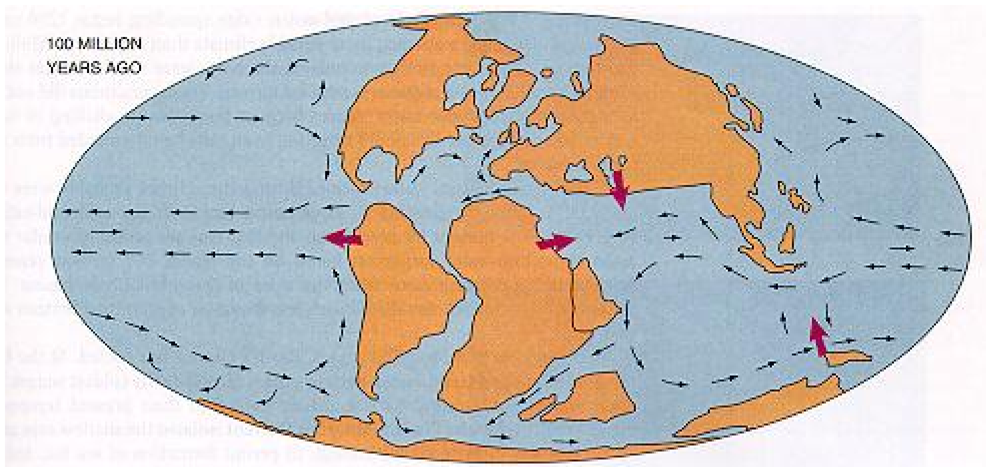
Downwelling caused by Ekman transport onshore (movement of water to the right of the wind direction).

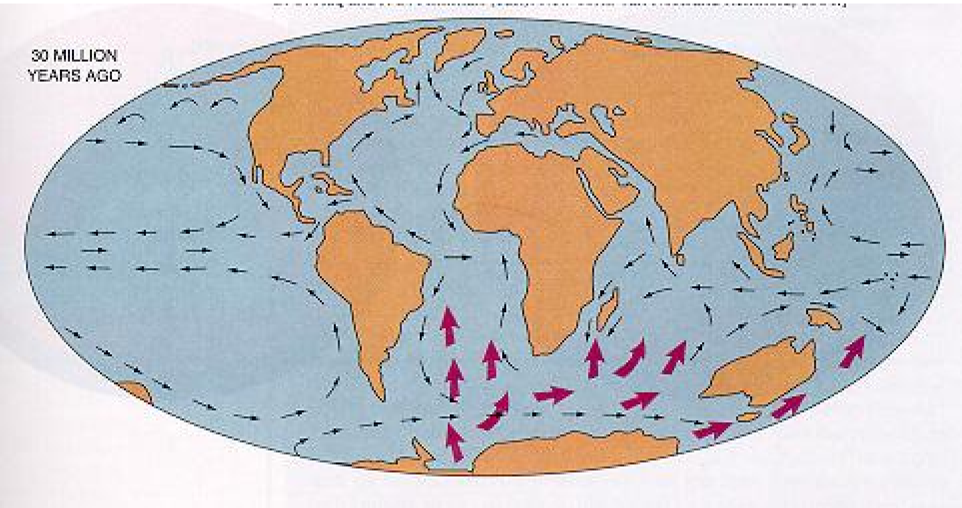
Downwelling along a coast



Ancient Current Systems


160 MILLION
YEARS AGO
* = areas of
upwelling


100 MILLION
YEARS AGO



Deep Water Circulation