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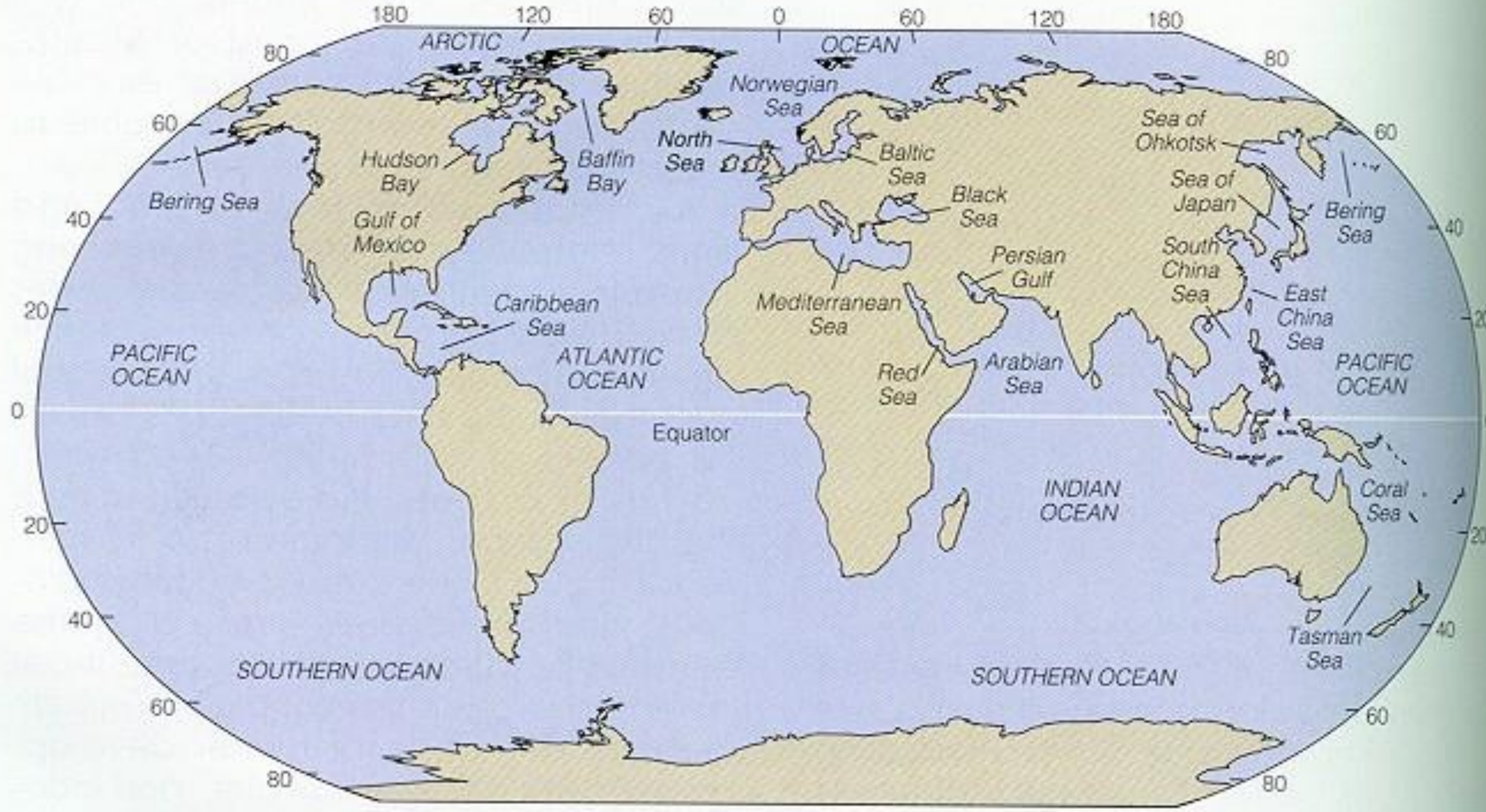


FIGURE 13.1 Major and minor basins of the world ocean.

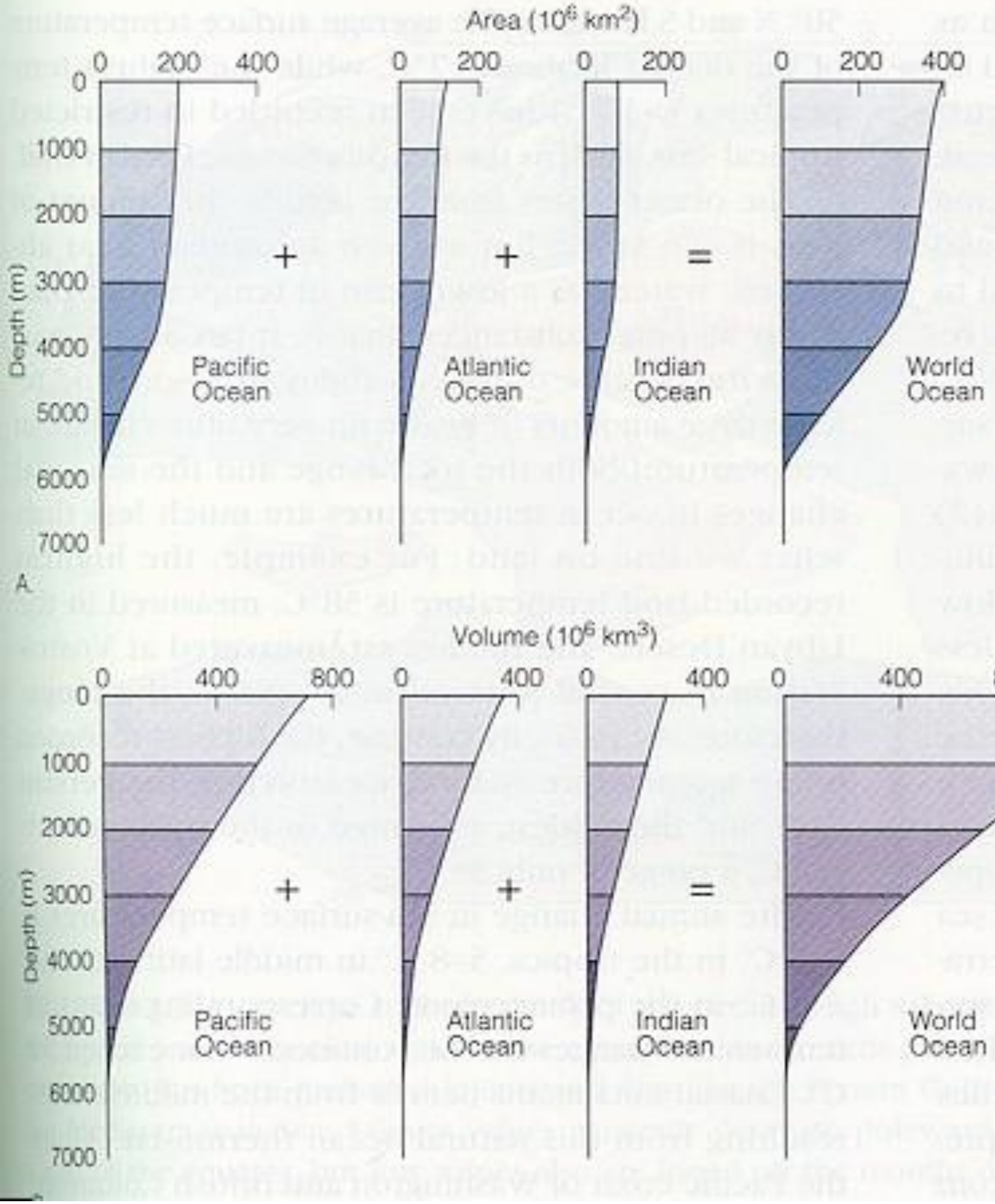
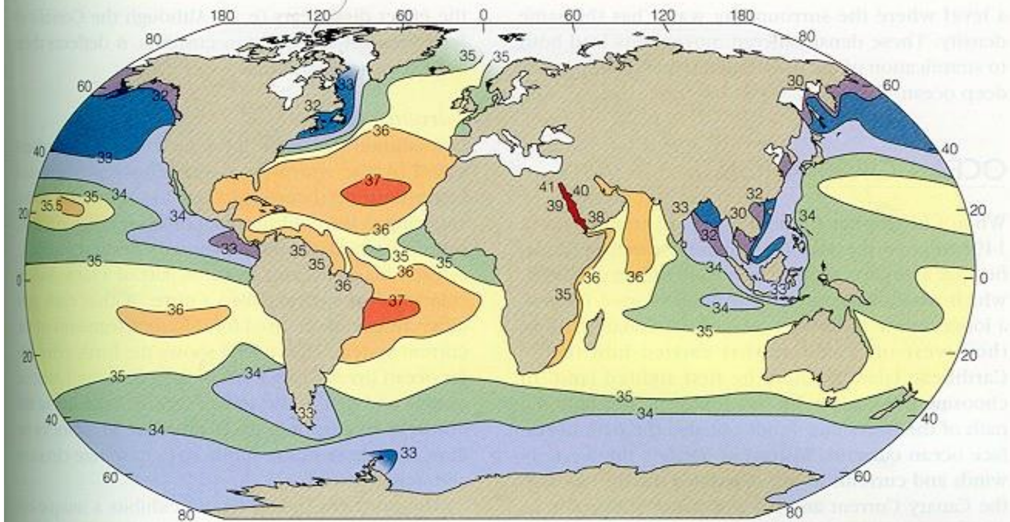
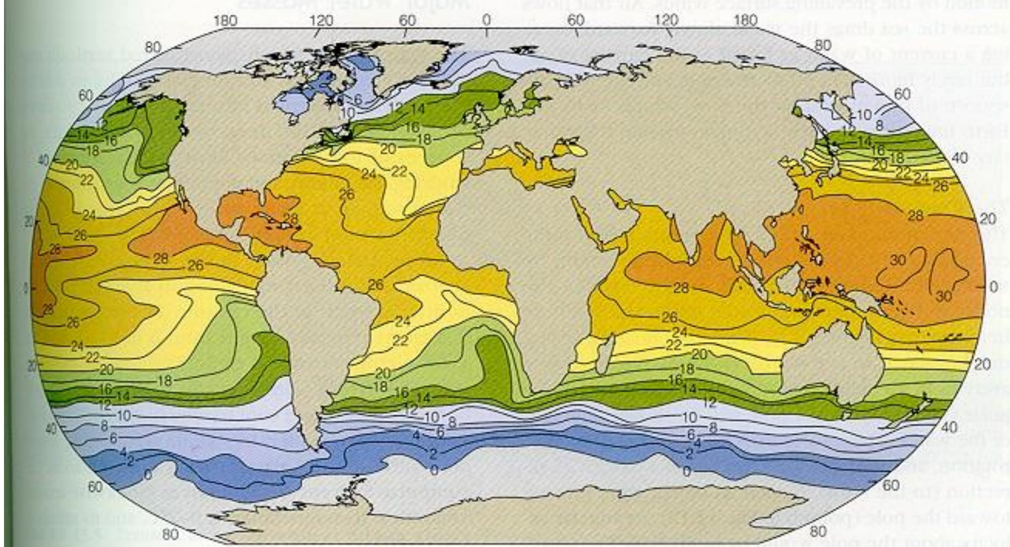


FIGURE 13.2 Area A. and volume B. of the oceans. The Pacific represents nearly half the volume of the oceans, with the Atlantic and Indian oceans being comparable to each other in both size and volume. Although the deepest known place in the oceans lies more than 11,000 m below sea level, nearly all the water lies at a depth of less than 6000 m.



A.

FIGURE 13.3 A. Average surface salinity of the oceans. High salinity values are found in tropical and subtropical waters where evaporation exceeds precipitation. The highest salinity has been measured in enclosed seas like the Persian Gulf, the Red Sea, and the Mediterranean Sea. Salinity values generally decrease poleward, both north and south of the equator, but low values also are found off the mouths of large rivers.



B.

FIGURE 13.3 B. Sea-surface temperatures in the world ocean during August. The warmest temperatures (≥28°C) are found in the tropical Indian and Pacific oceans. Temperatures decrease poleward from this zone, reaching values close to freezing in the north and south polar seas.

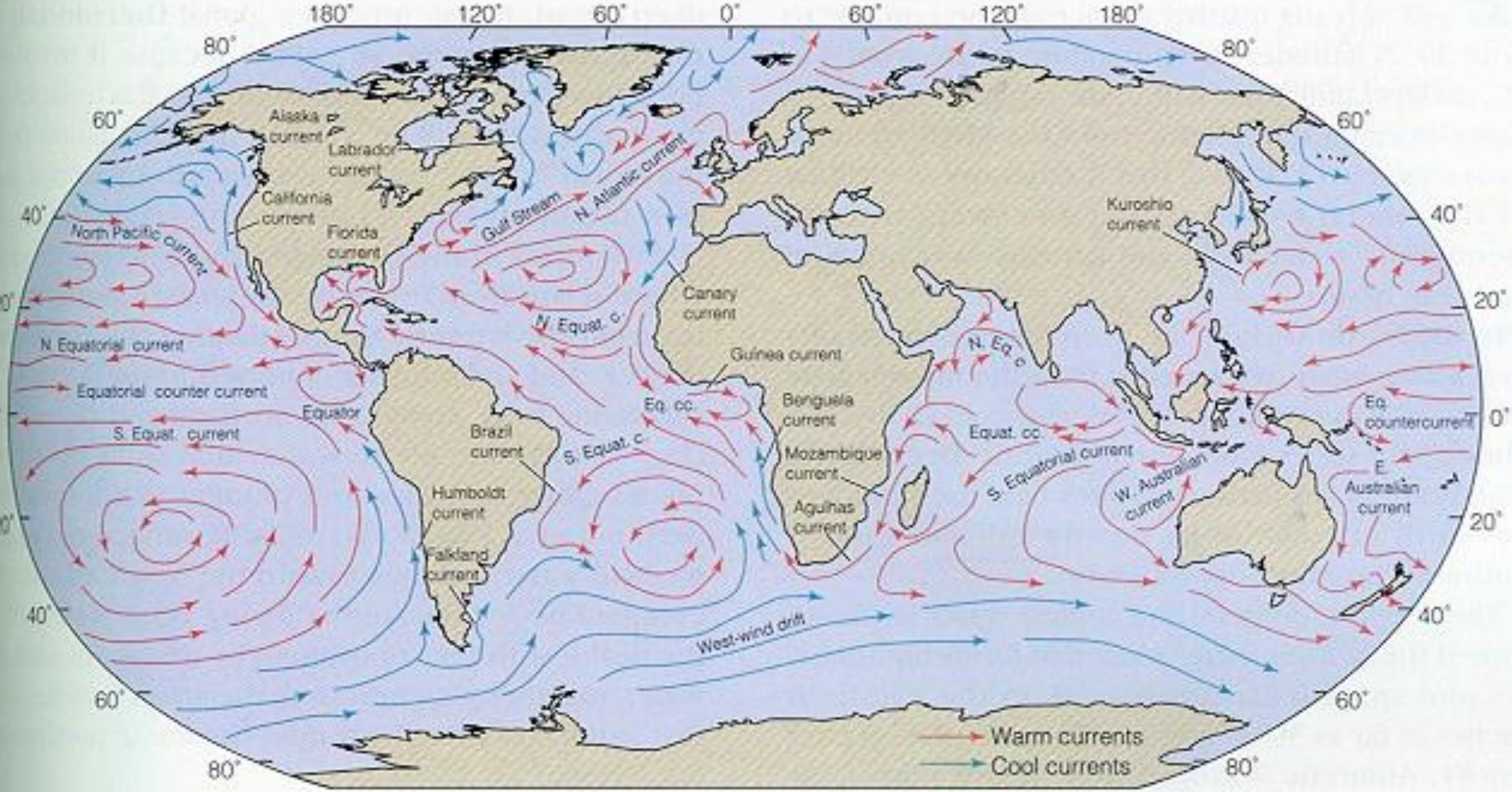


FIGURE 13.4 Surface ocean currents form a distinctive pattern, curving to the right (clockwise) in the northern hemisphere and to the left (counterclockwise) in the southern hemisphere. The westward flow of tropical Atlantic ad Pacific waters is interrupted by continents, which deflect the water poleward. The flow then turns away from the poles and becomes the eastward-moving currents that define the middle-latitude margins of the five great midocean gyres.

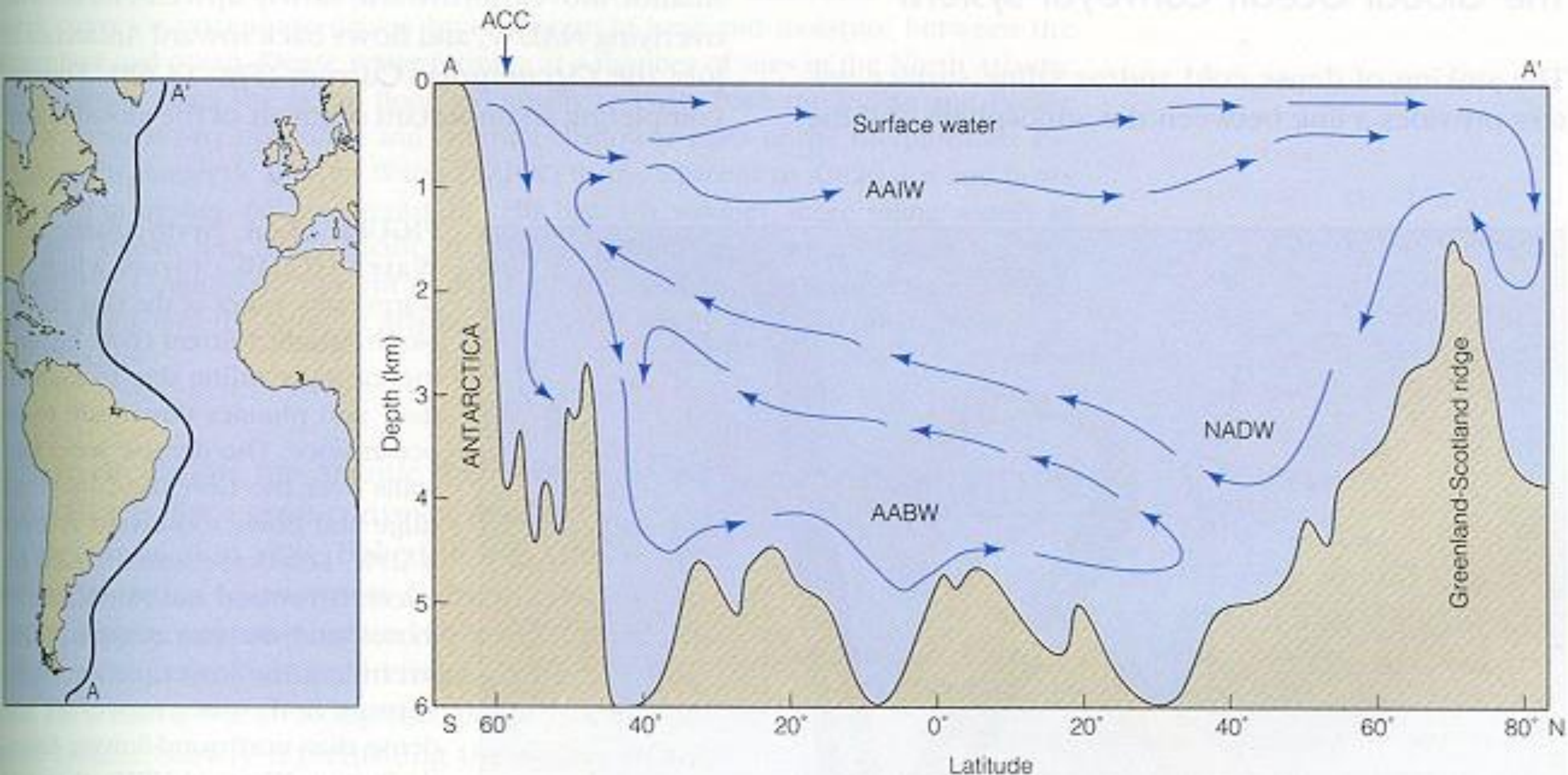
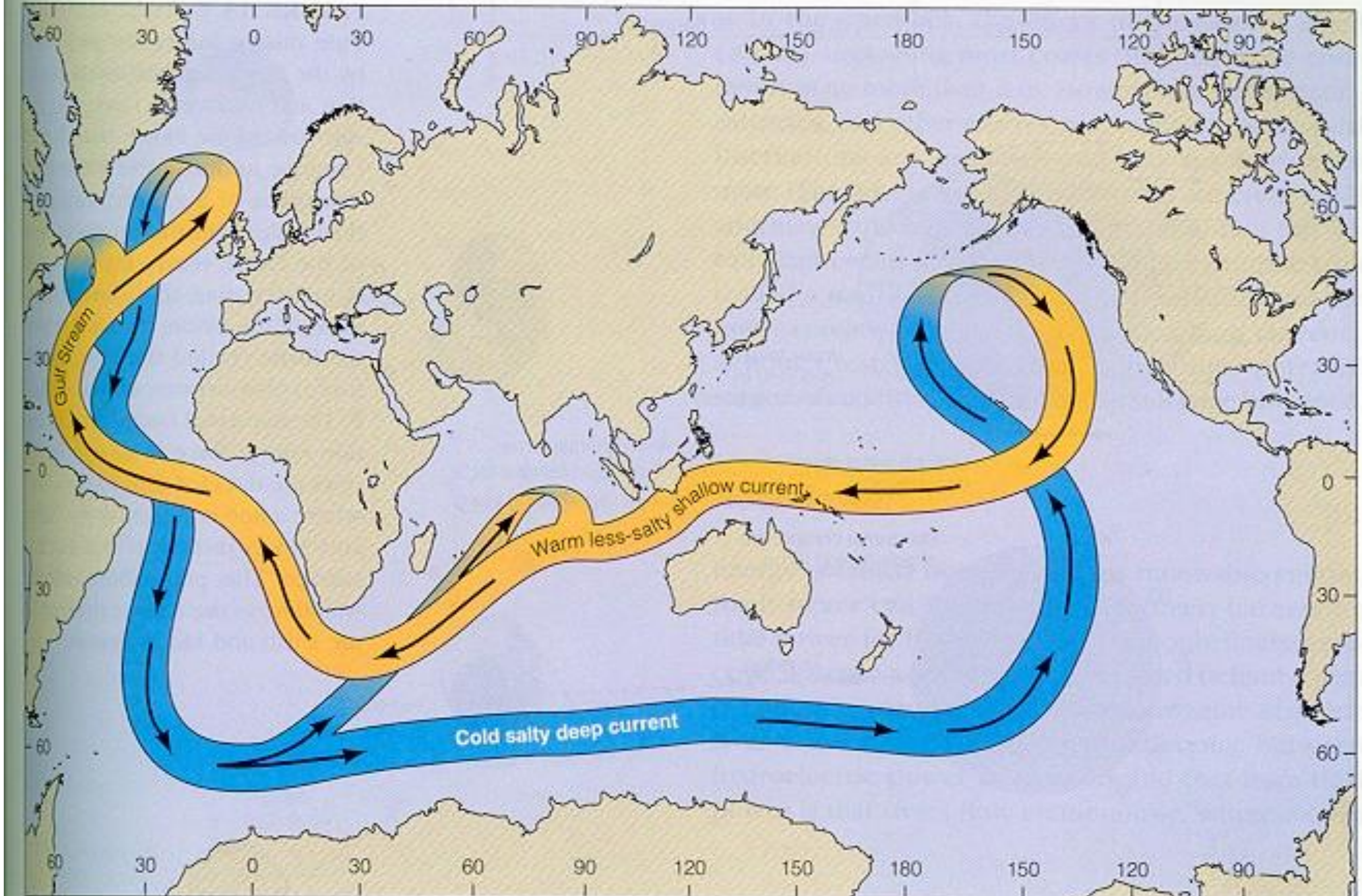


FIGURE 13.5 Transect along the western Atlantic Ocean showing water masses and general circulation pattern. North Atlantic Deep Water (NADW) originates near the surface in the North Atlantic as northward-flowing surface water cools, becomes increasingly saline, and plunges to depths of several km. As NADW moves into the South Atlantic, it rises over denser Antarctic Bottom Water (AABW), which forms adjacent to the Antarctic continent and flows into the north Atlantic as Antarctic Intermediate Water (AAIW) at a mean depth of about 1 km.



B.

FIGURE 13.6B The major thermohaline circulation cells that make up the global ocean conveyor system are driven by exchange of heat and moisture between the atmosphere and ocean. Dense water forming at a number of sites in the North Atlantic spreads slowly along the ocean floor, eventually to enter both the Indian and Pacific oceans before slowly upwelling and entering shallower parts of the thermohaline circulation cells. Antarctic Bottom Water (AABW) forms adjacent to Antarctica and flows northward in fresher, colder circulation cells beneath warmer, more saline waters in the South Atlantic and South Pacific. It also flows along the Southern Ocean beneath the Antarctic Circumpolar Current to enter the southern Indian Ocean. Warm surface waters flowing into the western Atlantic and Pacific basins close the great global thermohaline cells.

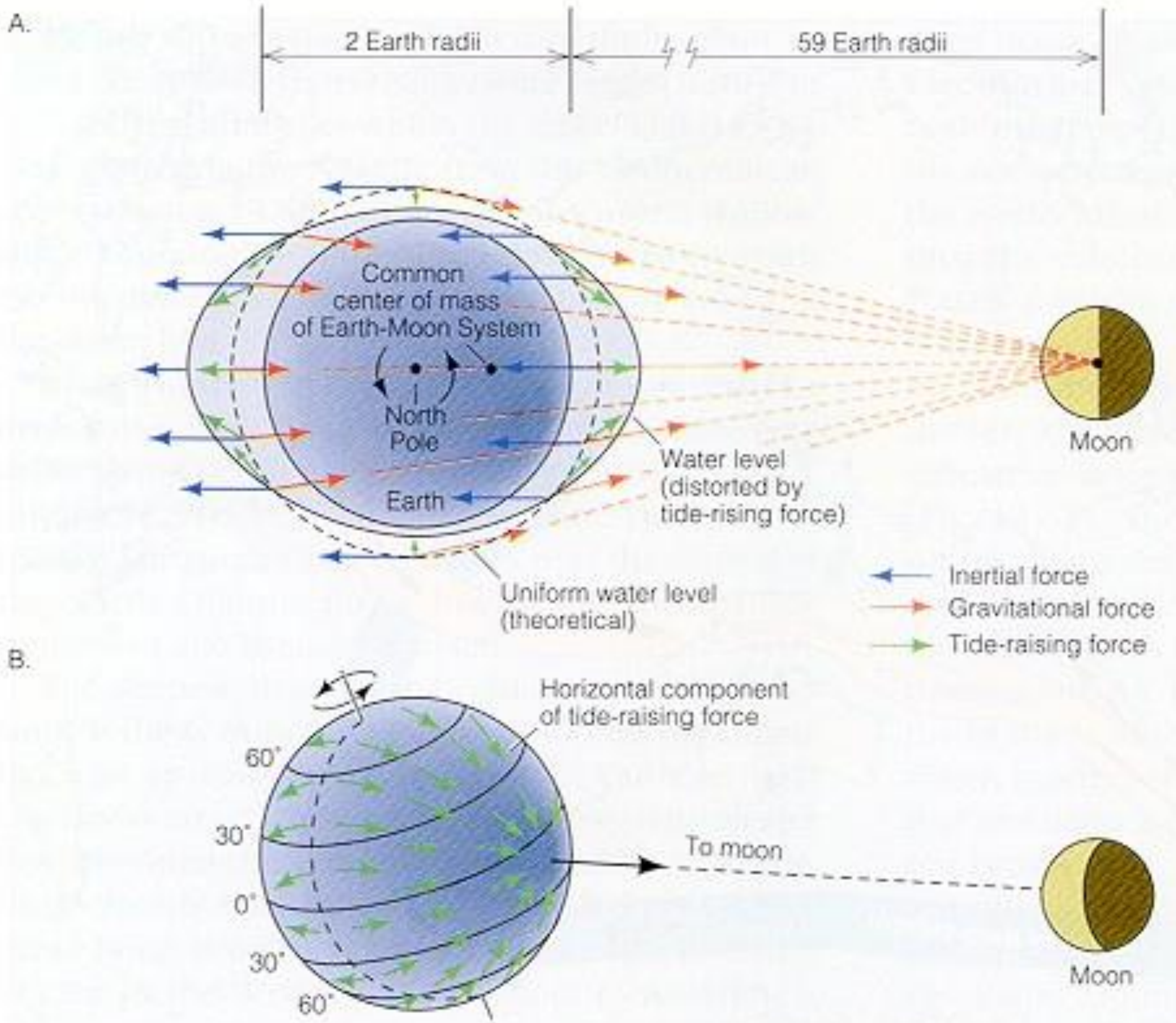


FIGURE 13.7 Tidal forces. A. Tide raising forces are produced by the Moon's gravitational attraction and by inertial force. On the side toward the Moon, both forces combine to distort the water level from that of a sphere, raising a tidal bulge. On the opposite side of the Earth, where inertial force is greater than the gravitational force of the Moon, the excess inertial force (called the tide-raising force) also creates a tidal bulge. B. The horizontal component of the tide raising force is shown by arrows are directed toward the point where a line connecting the Earth and Moon intersects the Earth's surface. This point shifts latitude with time as the relative position of the Earth and Moon change.

A. B.

FIGURE 13.9 The tidal range in the Bay of Fundy, eastern Canada, is one of the largest in the world. A. Coastal harbor of Alma, New Brunswick at high tide. B. Same view at low tide.

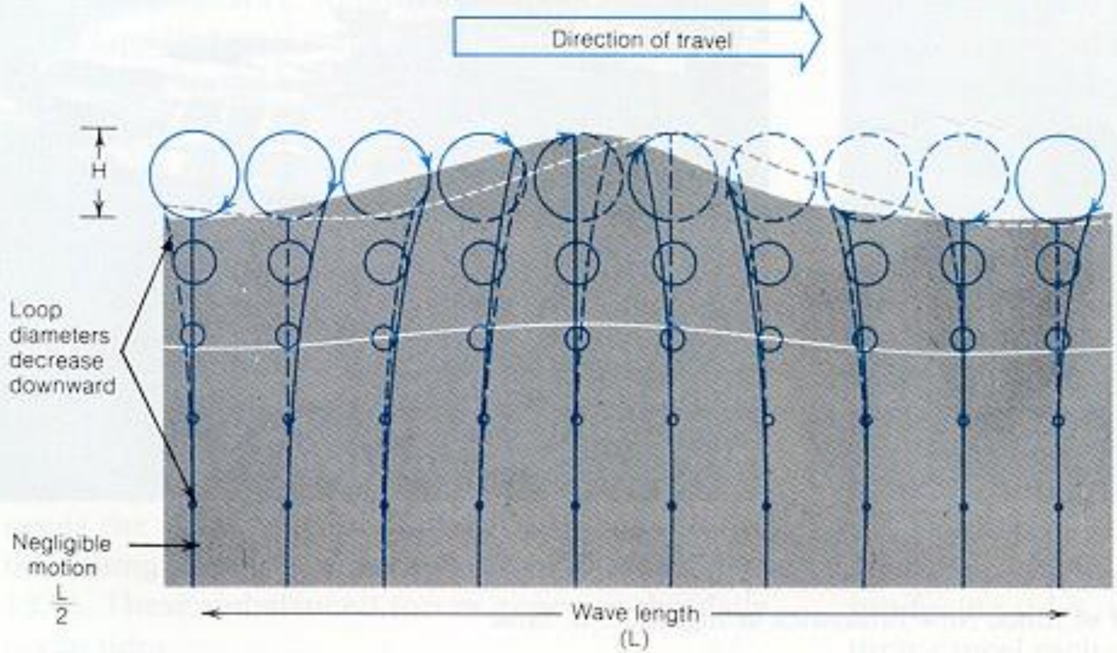


FIGURE 13.10 Looplike motion of water parcels in a wave in deep water. To trace the motion of a water parcel at the surface, follow the arrows in the largest loops from right to left. The resultant motion is the same as watching the wave crest travel from left to right. Parcels of water in smaller loops beneath the surface have corresponding positions, marked by nearly vertical lines. Dashed lines represent waveform and parcel positions one-eighth of a period later.

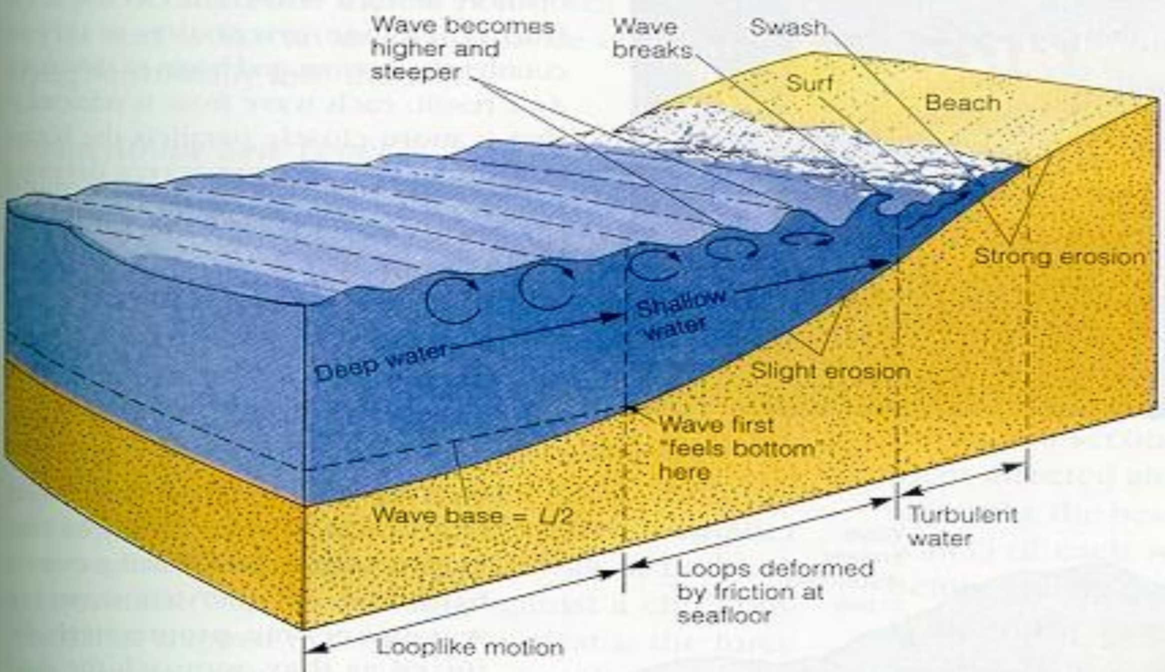


FIGURE 13.11 Waves change form as they travel from deep water through shallow water to shore. In the process, the circular motion of water parcels in deep water changes to elliptical motion as the water shallows and the wave encounters frictional resistance to forward movement. Vertical scale is exaggerated, as is the size of loops relative to the scale of waves. (Compare with Figure 13.10.)

FIGURE 13.12 Waves arriving obliquely onshore along a coast near Oceanside, California, change orientation as they encounter the bottom and begin to slow down. As a result, each wave front is refracted so that it more closely parallels the bottom contours. The arriving waves develop a longshore current that moves from left to right in this view.

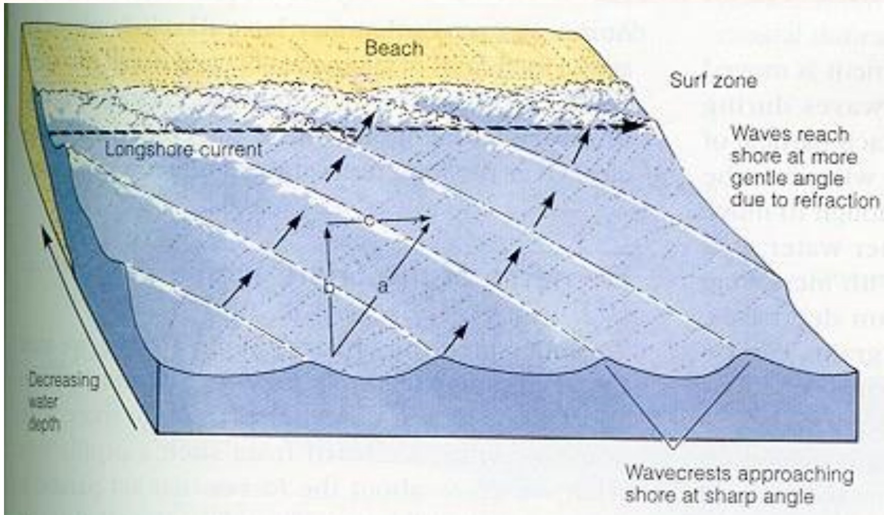


FIGURE 13.14 A longshore current develops offshore as waves approach a beach at an angle and are refracted. The line representing the front of each approaching wave can be resolved into two components: the component oriented perpendicular to the shore (b) produces surf, whereas that oriented parallel to the shore (c) is responsible for the longshore current. Such a current can transport considerable amounts of sediment along the coast.

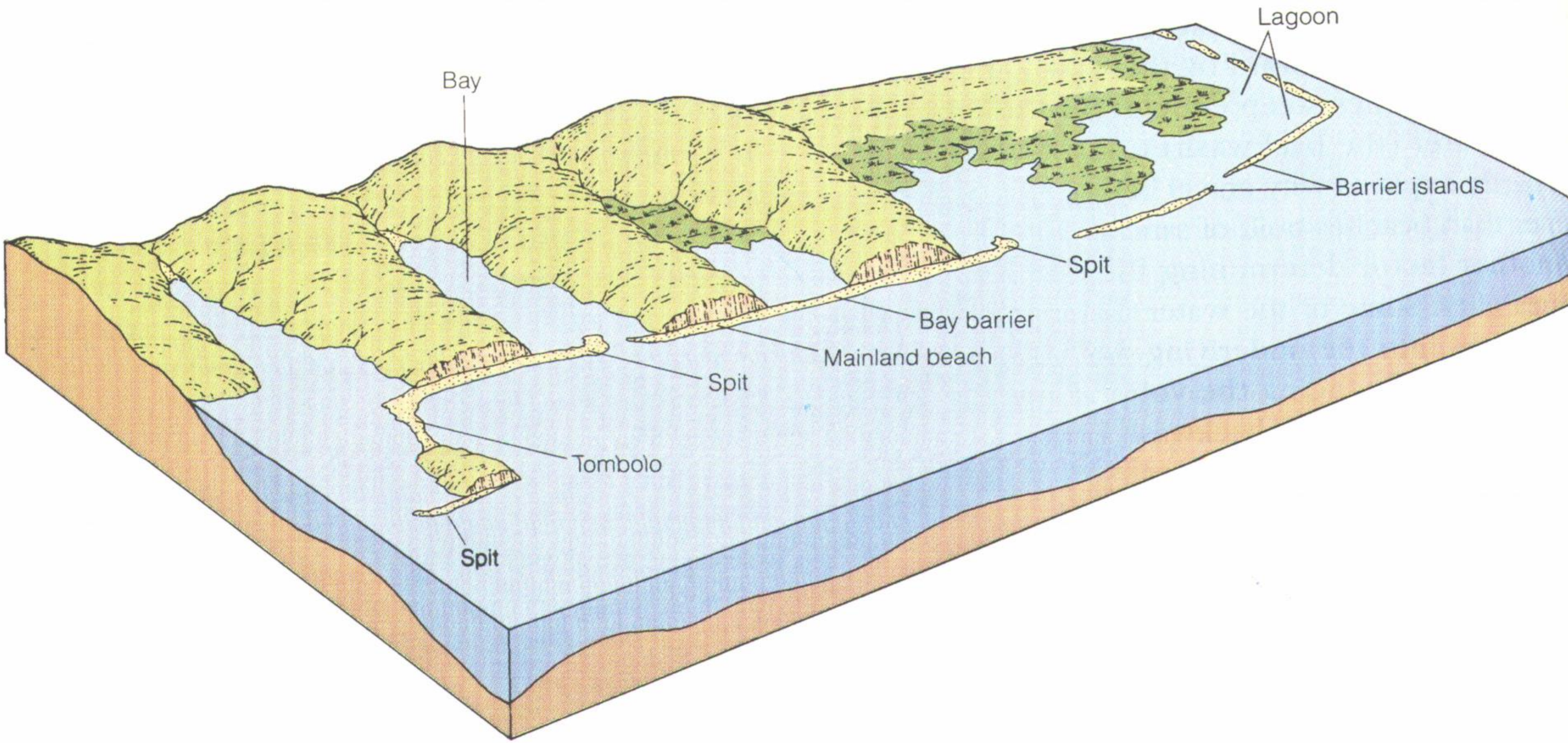


FIGURE 13.22 Some depositional shore features along a stretch of coast. Local direction of beach drift is toward the free end of the spits.

FIGURE 13.23 The long, curved spit of Cape Cod, Massachusetts, has been built by longshore currents that rework glacial deposits forming the peninsula southeast of Cape Cod Bay.

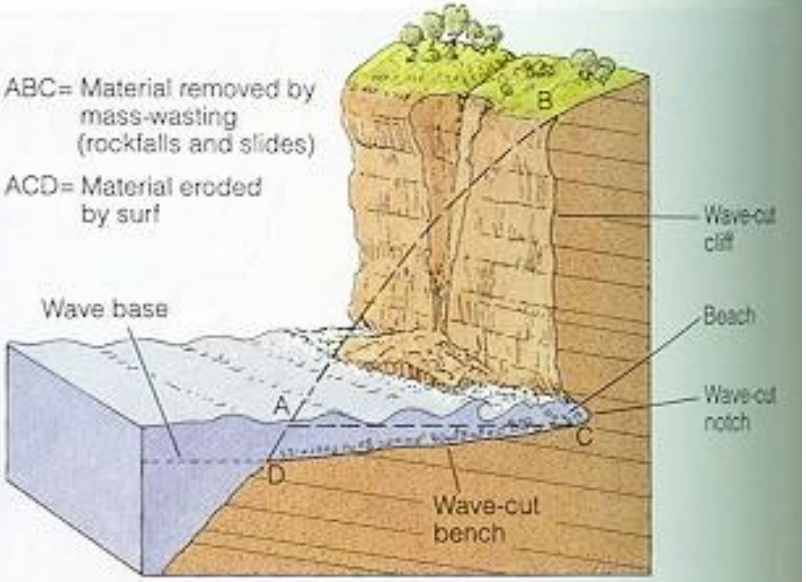


FIGURE 13.18
a cliffed coast.
mines the rock
surf. Note the
mass-wasting (A

FIGURE 13.20 Stack and sea arch along the French shore of the English Channel near Étretat carved in horizontally bedded white chalk. The surf first hollows out a sea cave in the most erodible part of the bedrock. A cave excavated completely through a headland is then transformed into a sea arch. An isolated remnant of the cliff stands as a stack on a wave-cut bench offshore.

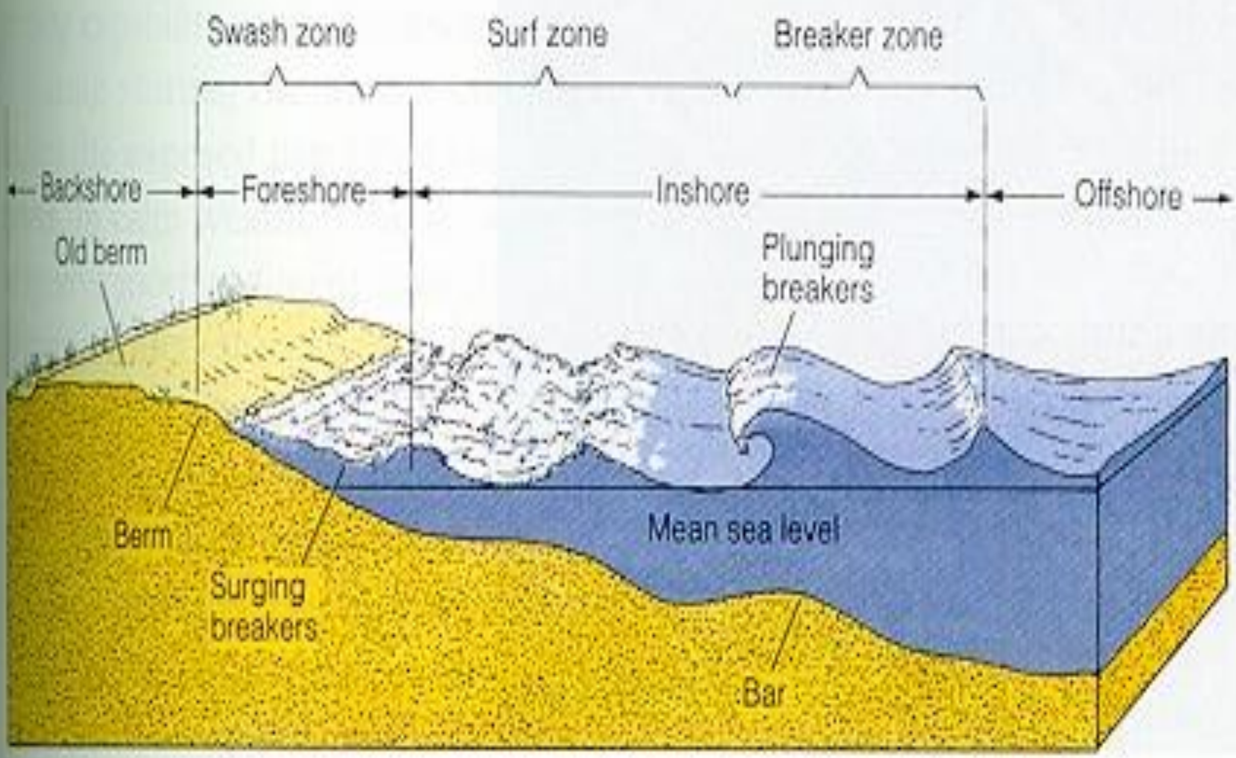


FIGURE 13.17 Section across a beach showing principal elements of the shore profile. Length of profile is about 75 m. Vertical scale is exaggerated.

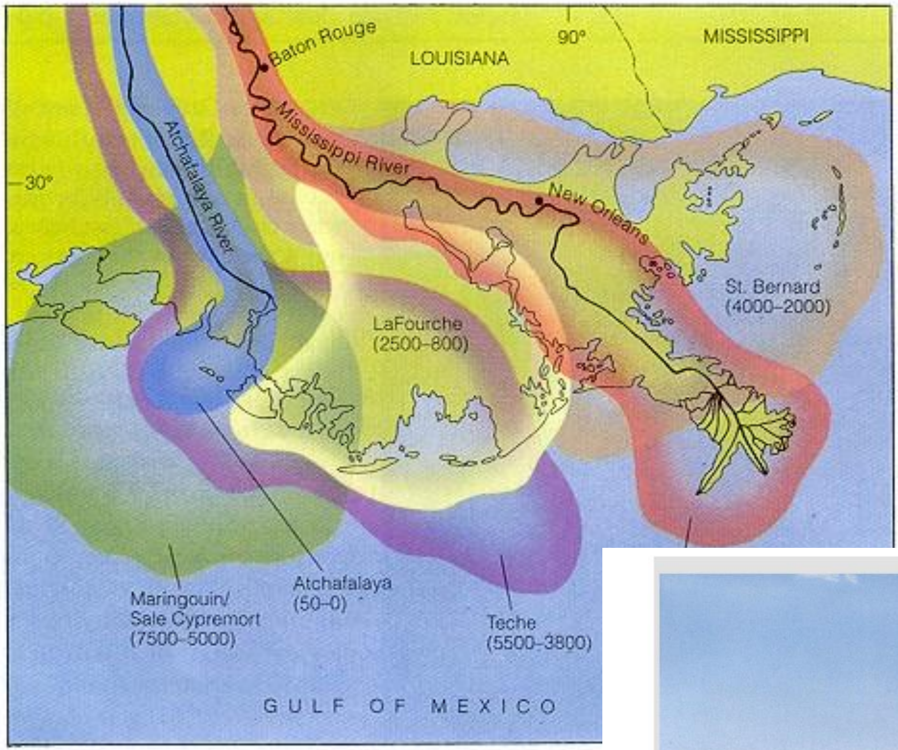
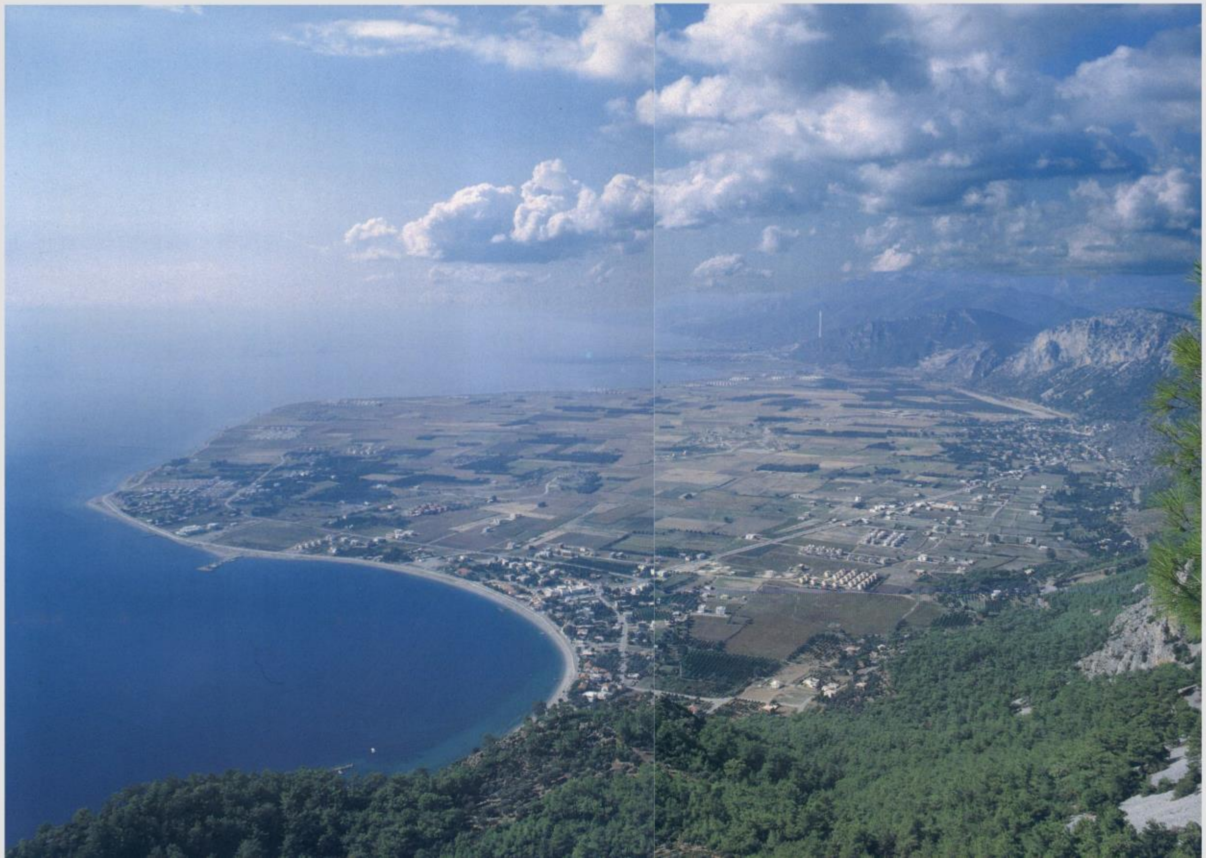
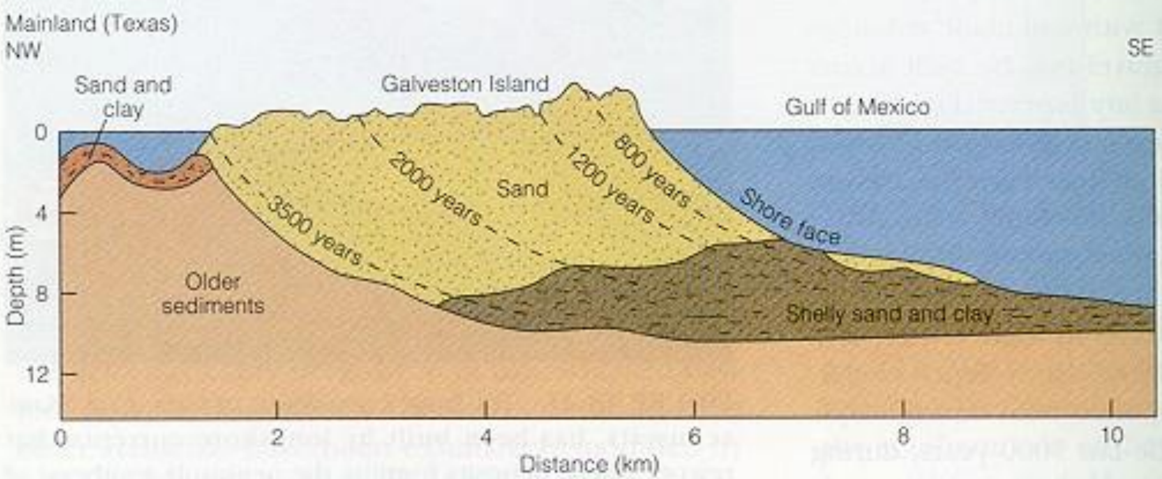


FIGURE 13.21 The Mississippi River has built a series of overlapping subdeltas as it has continually dumped sediment into the Gulf of Mexico. The ages of subdeltas are given in radiocarbon years before the present.



A.



B.

FIGURE 13.24 Barrier islands. A. This sandy barrier island off the coast of Mississippi lies so close to sea level that waves can surge across its surface during large storms, eroding and redistributing the sediment. B. Cross section through Galveston Island, one of a series of barrier islands off the coast of Texas. Dashed lines show the former position of the seaward side of the island, based on radiocarbon dating. Since 3500 years ago, the island has grown southeastward toward the Gulf of Mexico.

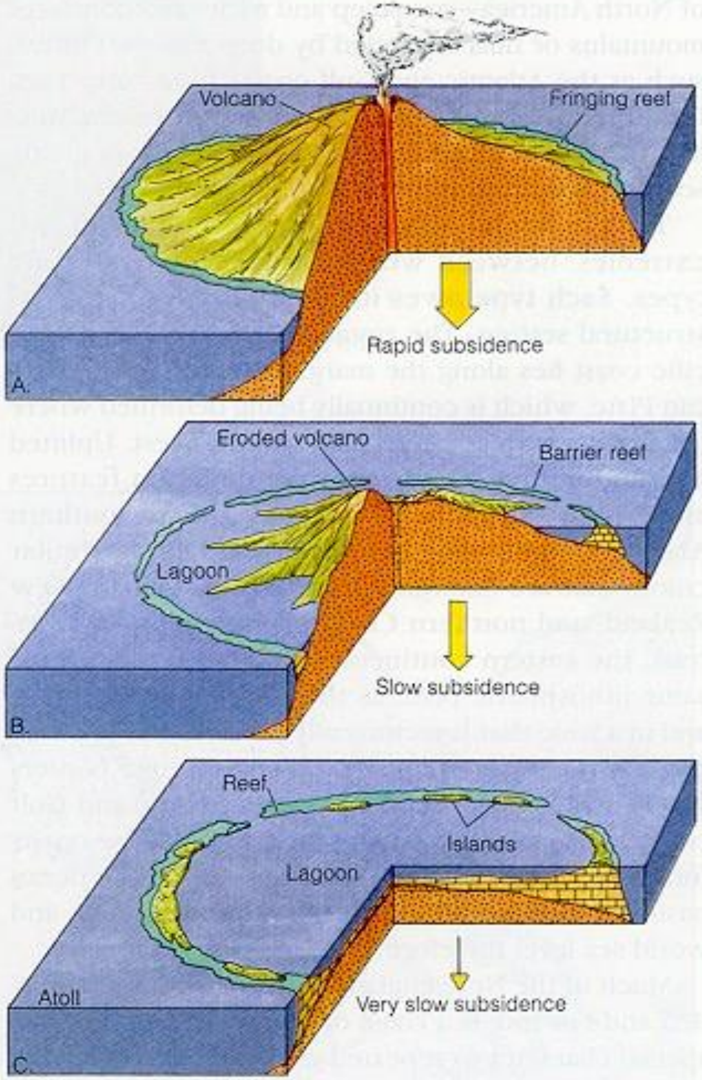


FIGURE 13.26 Evolution of an atoll from a subsiding volcanic island. Rapid extrusion of lava to form an oceanic shield volcano causes the island to subside as the crust is loaded by the volcanic pile. A fringing reef grows upward, keeping pace with submergence, and becomes a barrier reef surrounding the eroding volcano. With continued subsidence and upward reef growth, the last remnants of the volcano disappear beneath sea level and all that remains is an atoll reef surrounding a central lagoon.

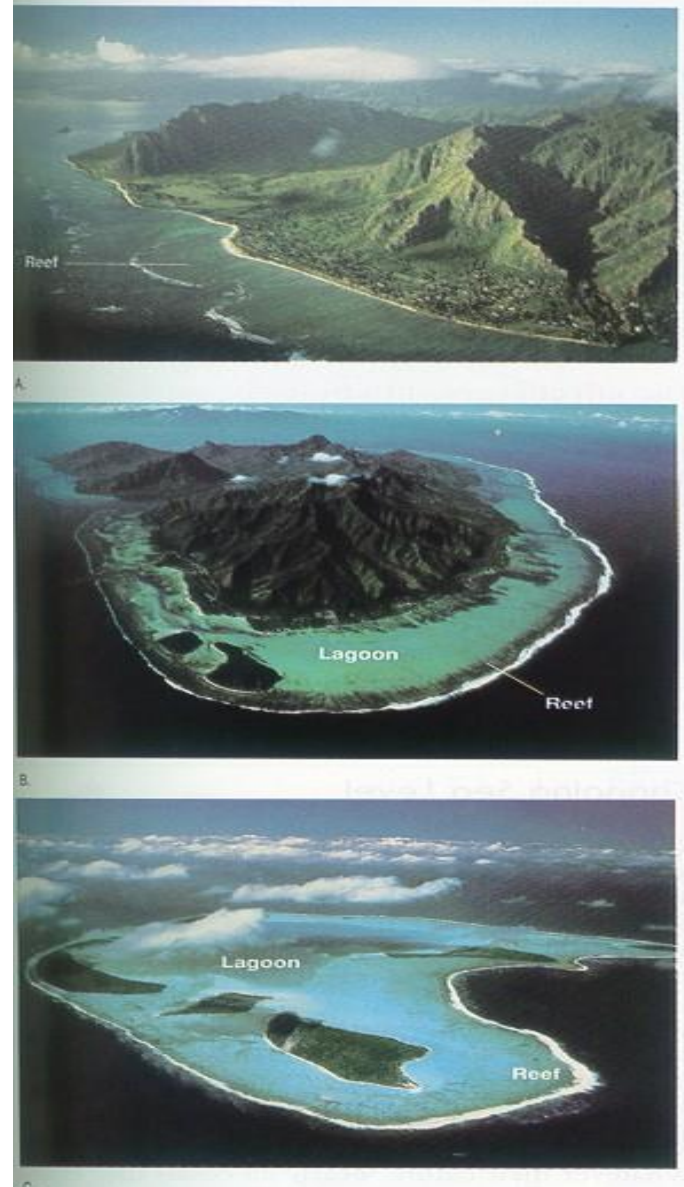
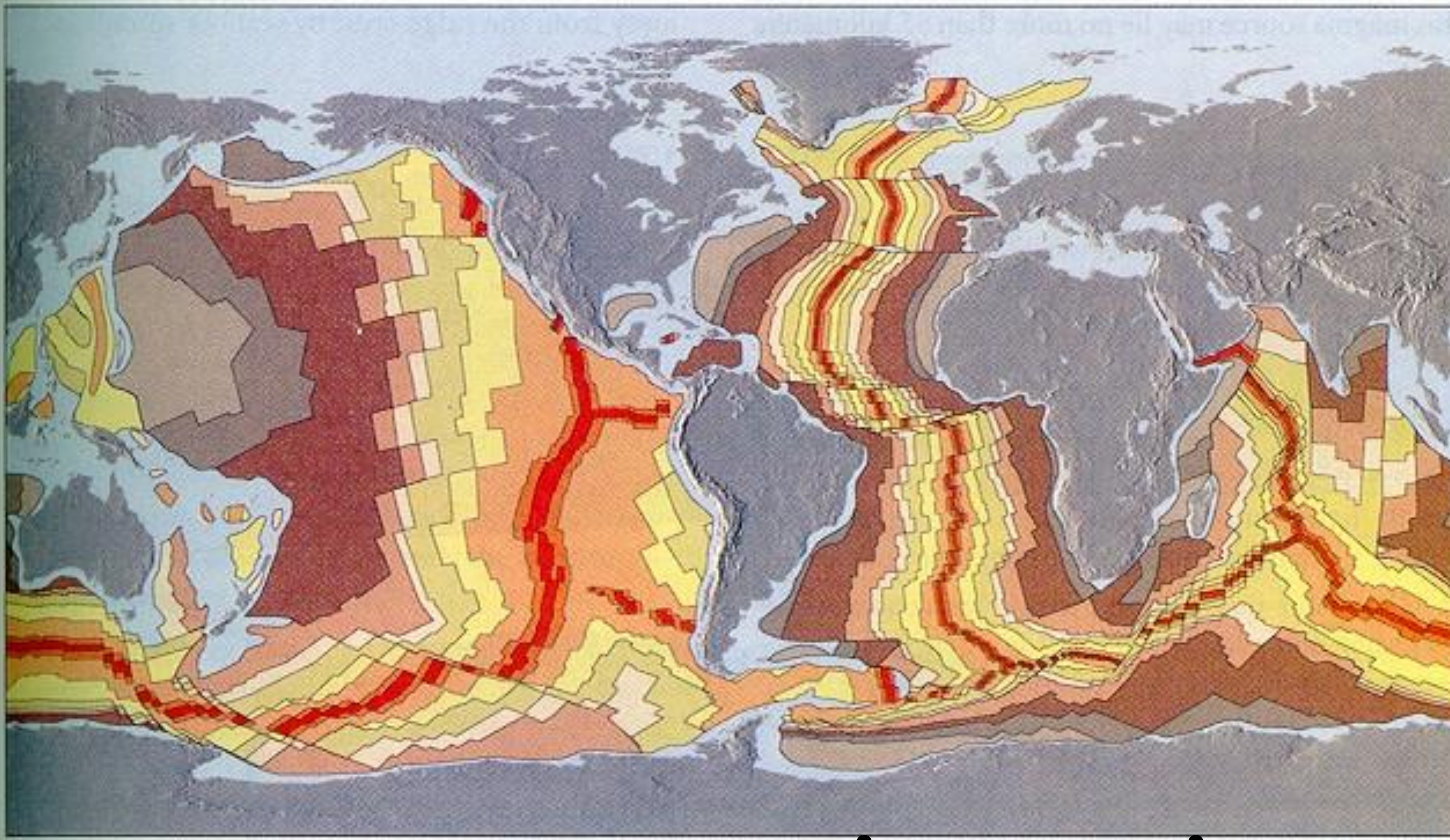


FIGURE 13.25 Chief kinds of tropical coral reefs. A. Fringing reef on the island of Oahu in the Hawaiian Islands. B. Barrier reef enclosing the island of Moorea in the Society Islands. A narrow lagoon separates the high island, which is the eroded remnant of a formerly active volcano, from a shallow reef. C. The reef of a small atoll in the Society Islands is surmounted by low, vegetated sandy islands that lie inside a line of breakers along the reef margin.



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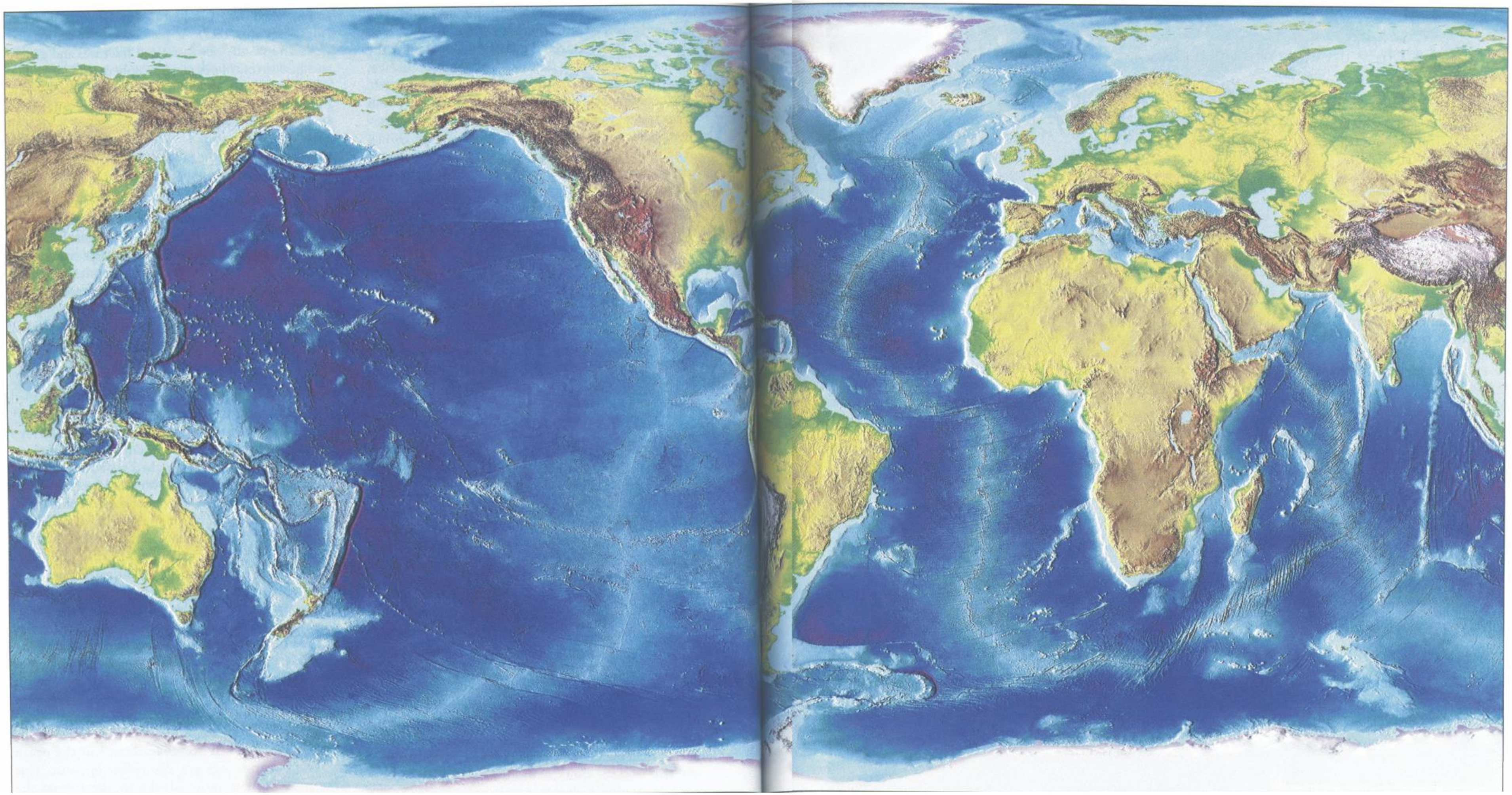


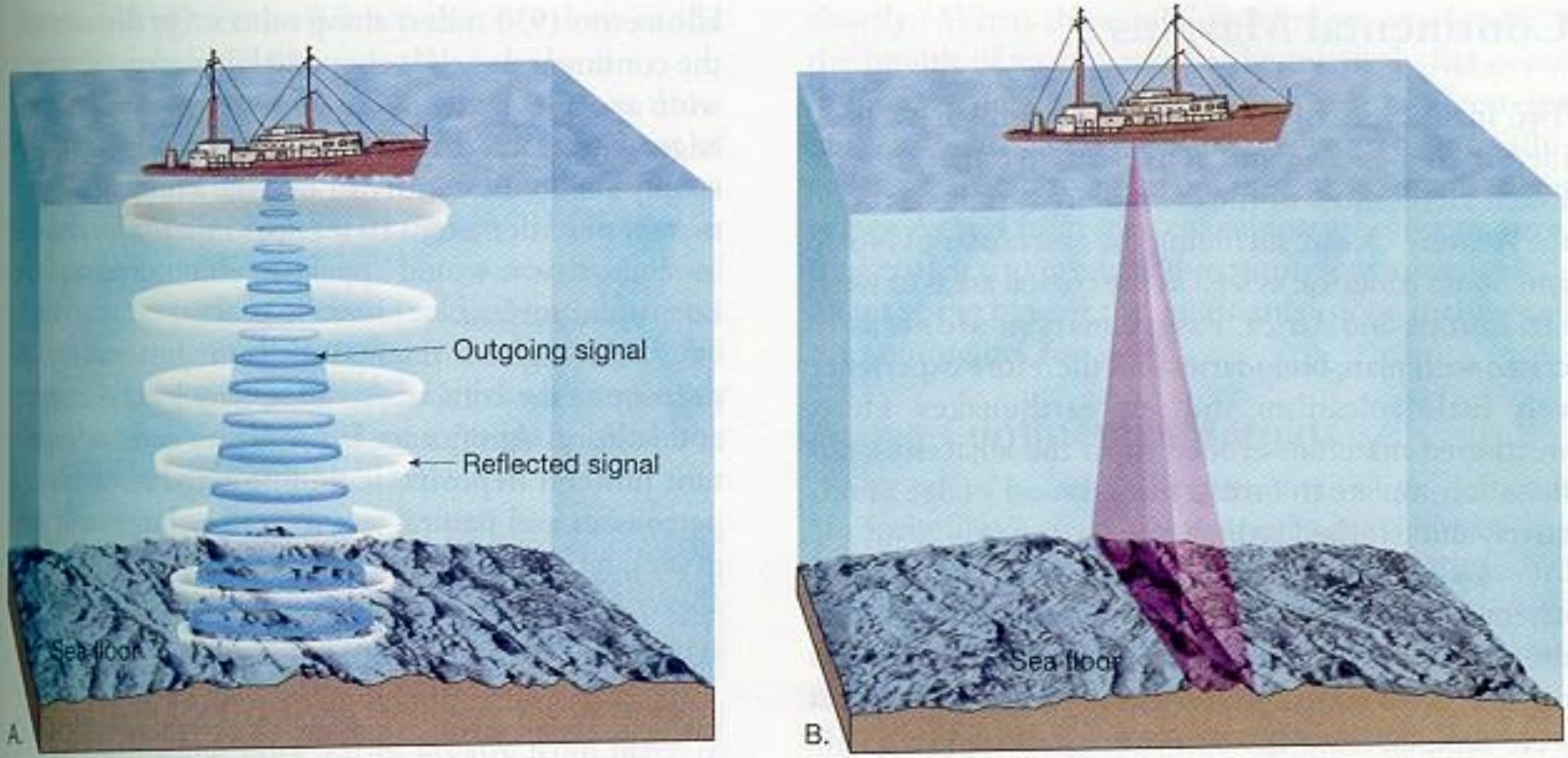


Figure 18.2 Echo sounders. A. An echo sounder determines the water depth by measuring the time interval required for an acoustic wave to travel from a ship to the seafloor and back. The speed of sound in water is 1500 m/sec. Therefore, depth = 1/2 (1500 m/sec × echo travel time). B. Modern multibeam sonar obtains a profile of a narrow swath of seafloor every few seconds.

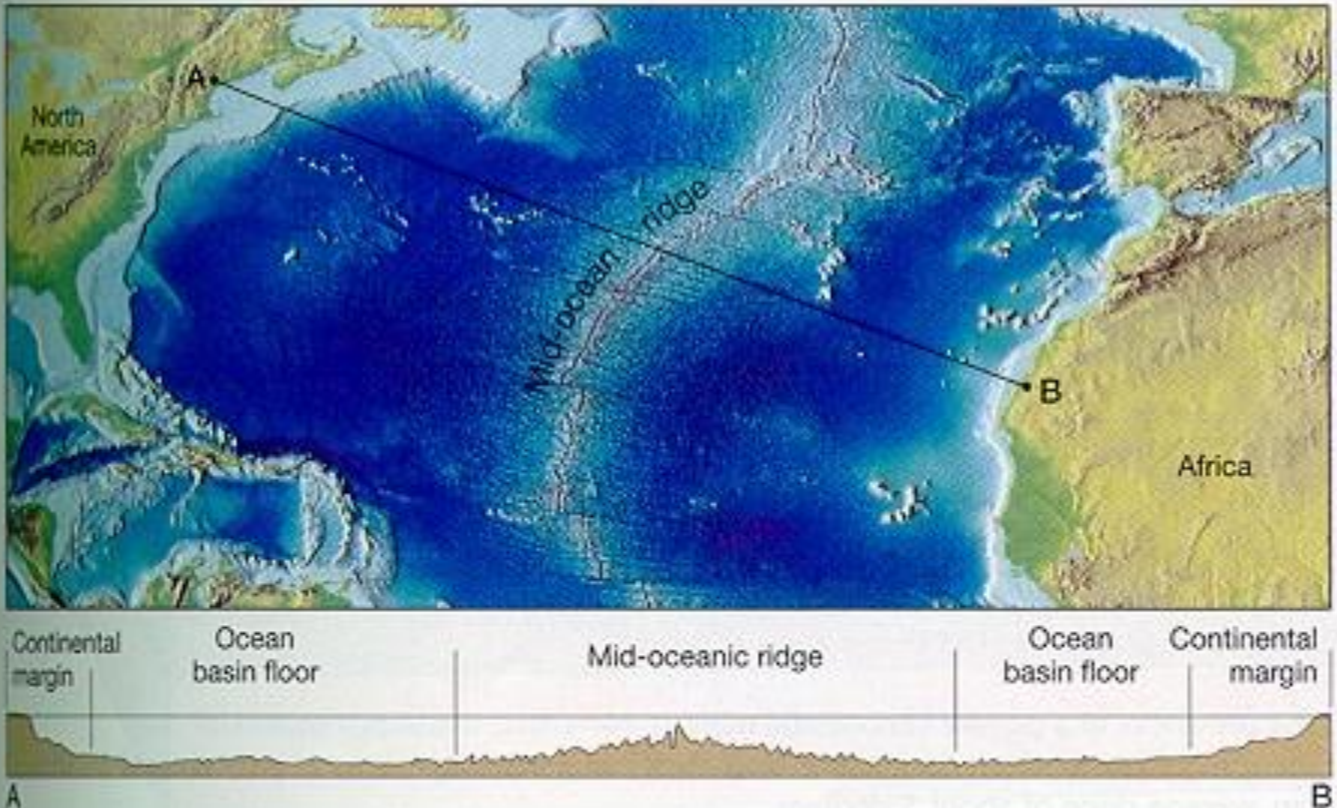


Figure 18.3 Major topographic divisions of the North Atlantic and a profile from New England to the coast of North Africa.

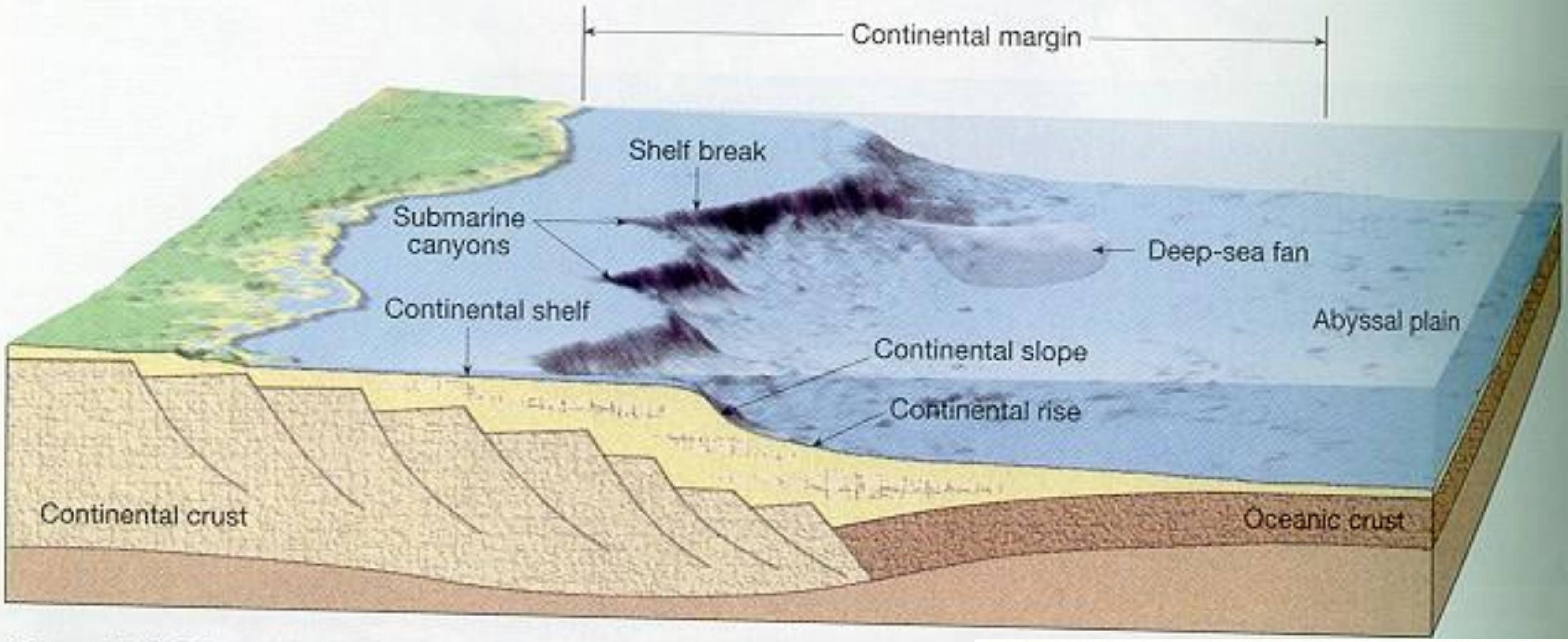
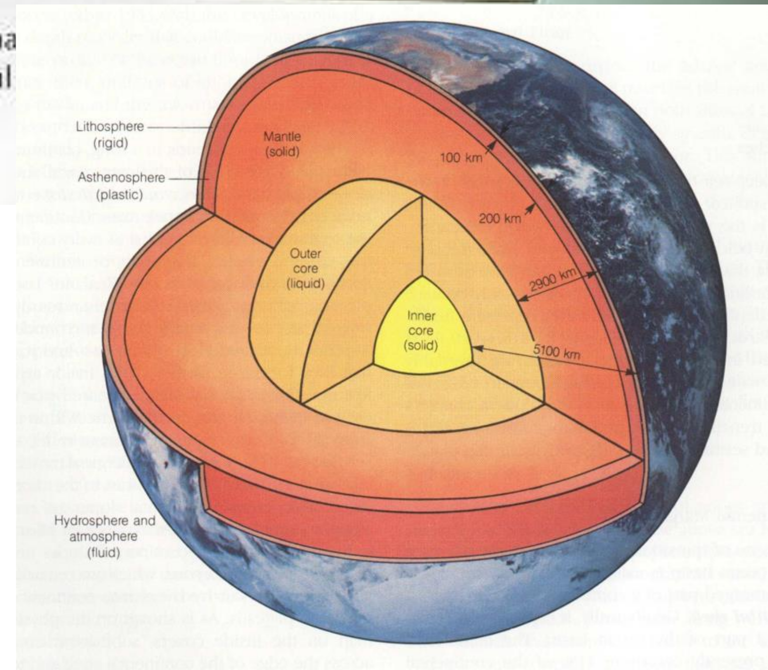


Figure 18.4 Schematic view showing the provinces of a passive continental ma
continental shelf and continental slope are greatly exaggerated. The continental
degree, while the continental slope has an average slope of about 5 degrees.



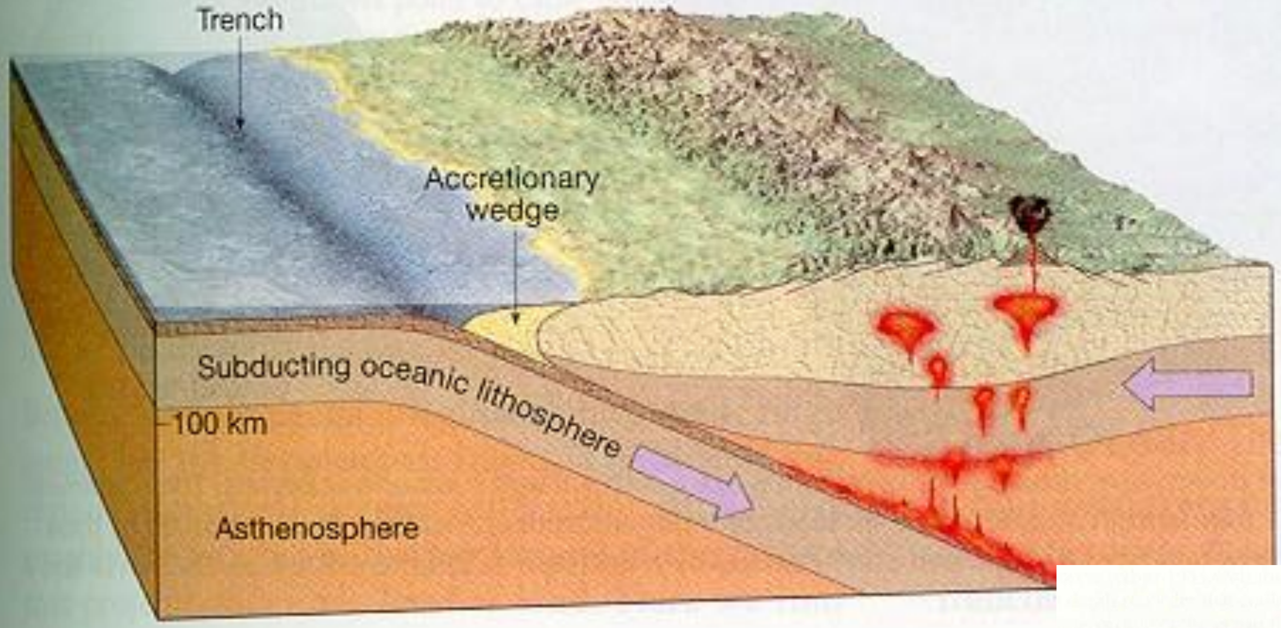
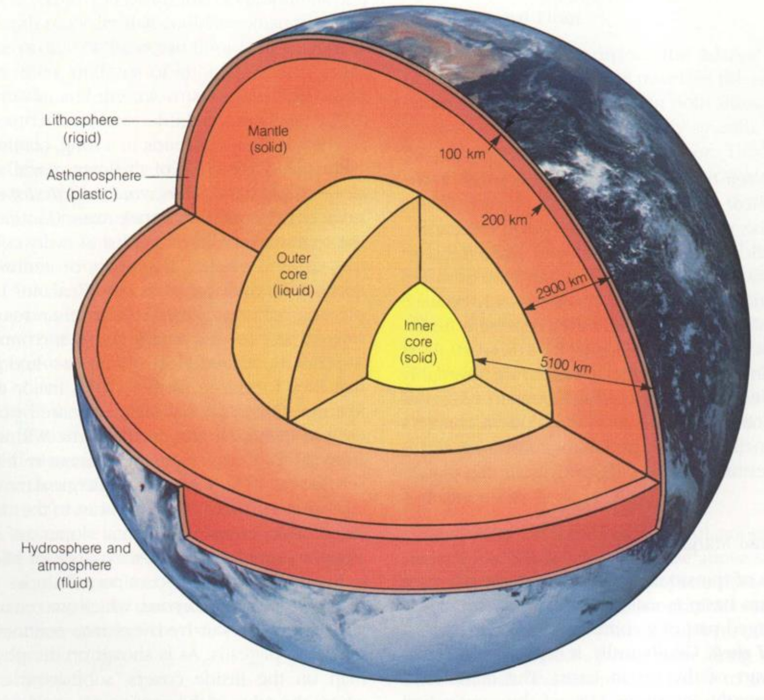


Figure 18.5 Active continental margin. Here sediments from the ocean floor are scraped from the descending plate and added to the continental crust as an



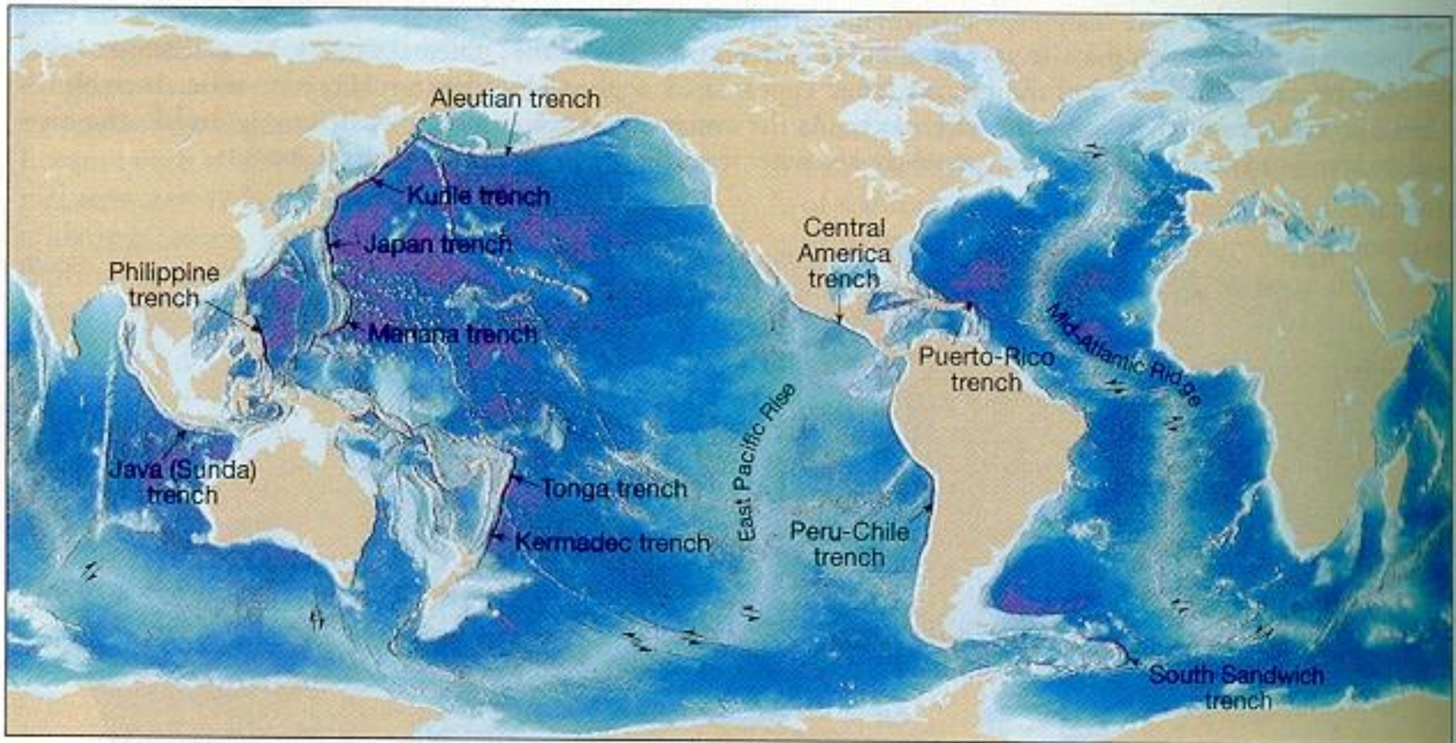


Figure 18.7 Distribution of the world's major oceanic trenches.

Table 18.1 Dimensions of Some Deep-Ocean Trenches

Trench	Depth (kilometers)	Average Width (kilometers)	Length (kilometers)
Aleutian	7.7	50	3700
Japan	8.4	100	800
Java	7.5	80	4500
Kurile–Kamchatka	10.5	120	2200
Mariana	11.0	70	2550
Central America	6.7	40	2800
Peru–Chile	8.1	100	5900
Philippine	10.5	60	1400
Puerto Rico	8.4	120	1550
South Sandwich	8.4	90	1450
Tonga	10.8	55	1400

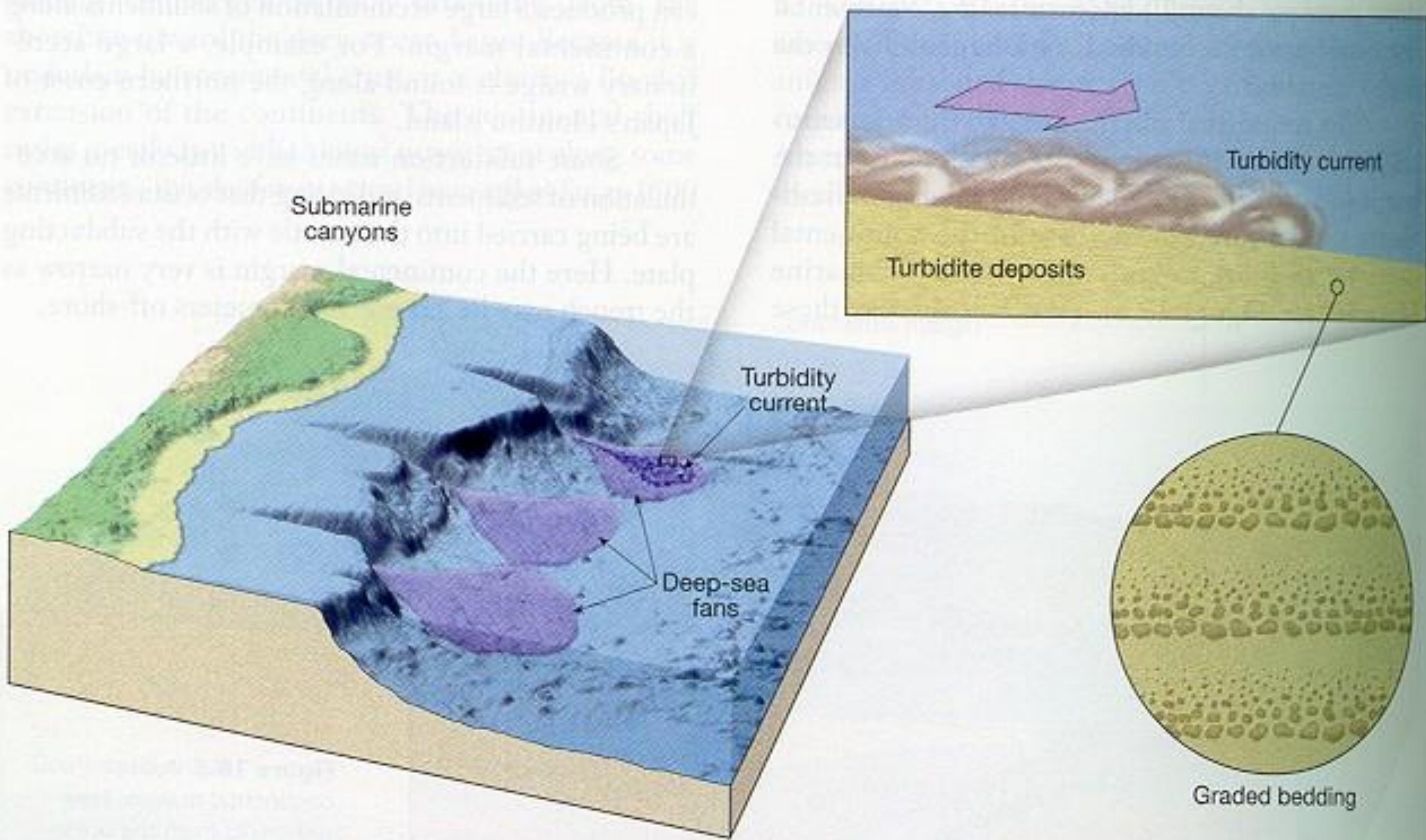


Figure 18.6 Turbidity currents move downslope, eroding the continental margin to enlarge submarine canyons. These sediment-laden density currents eventually lose momentum and deposit their loads of sediment as deep-sea fans. Beds deposited by these currents are called turbidites. Each event produces a single bed characterized by a decrease in sediment size from bottom to top, a feature known as a graded bed.

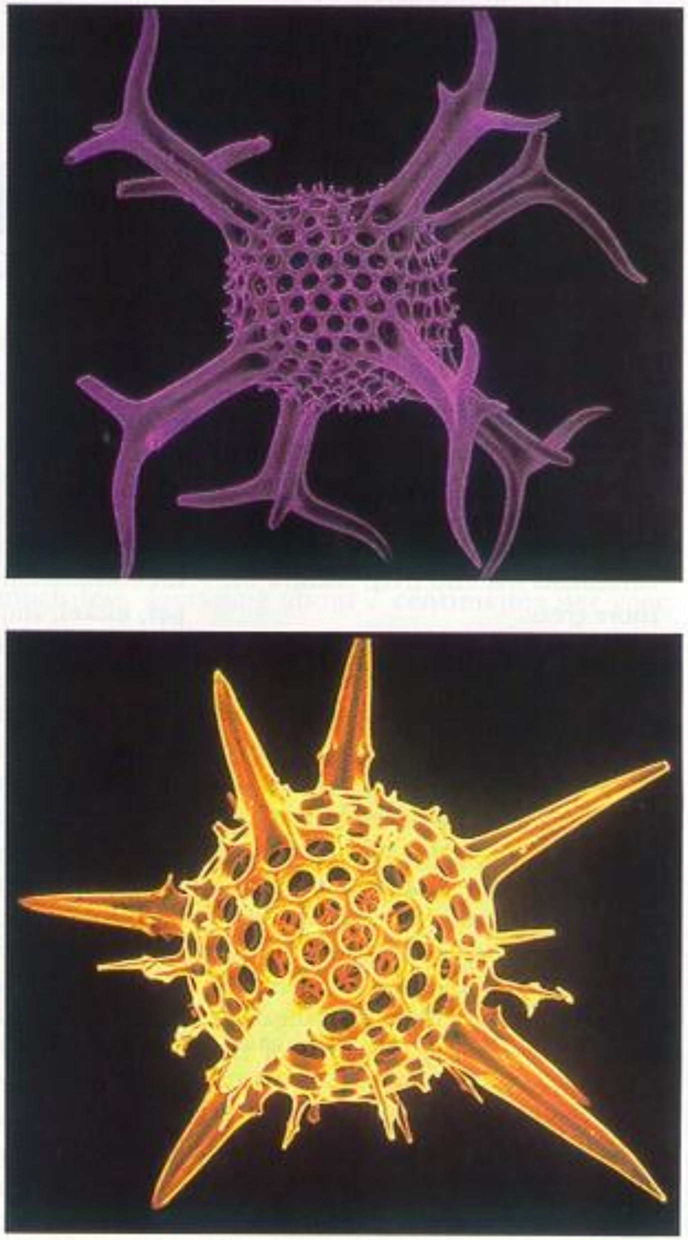


Figure 18.10 Microscopic radiolarian hard parts are examples of biogenous sediments. These photomicrographs have been enlarged hundreds of times. (Photos by Manfred Kage/Peter Arnold, Inc.)

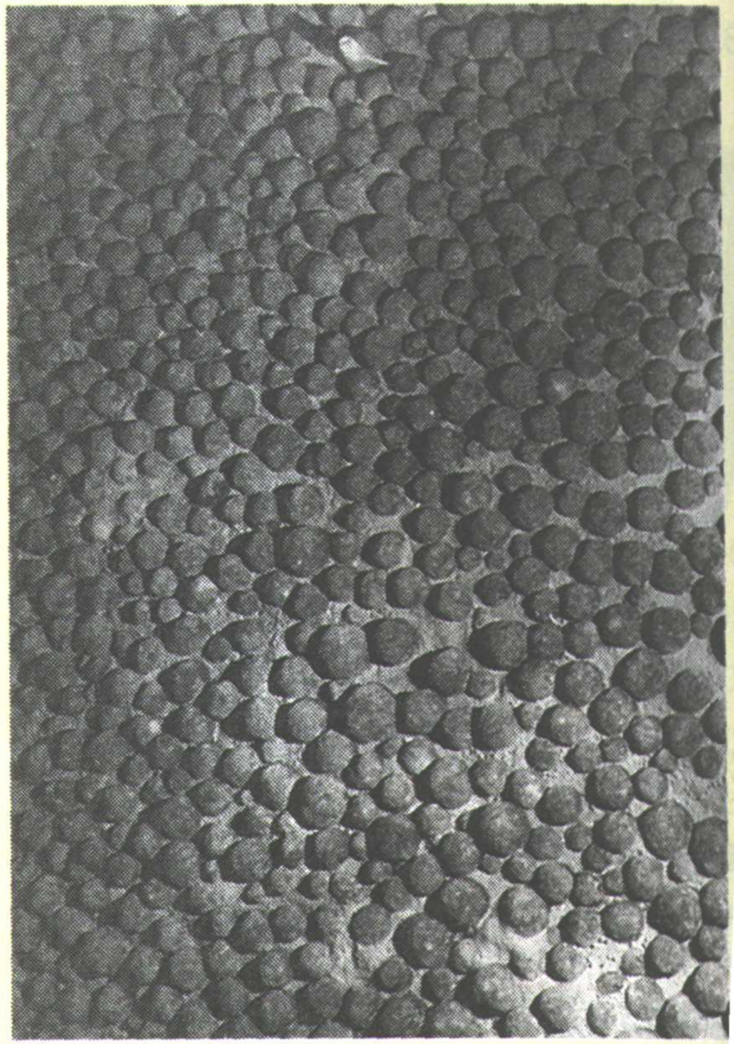
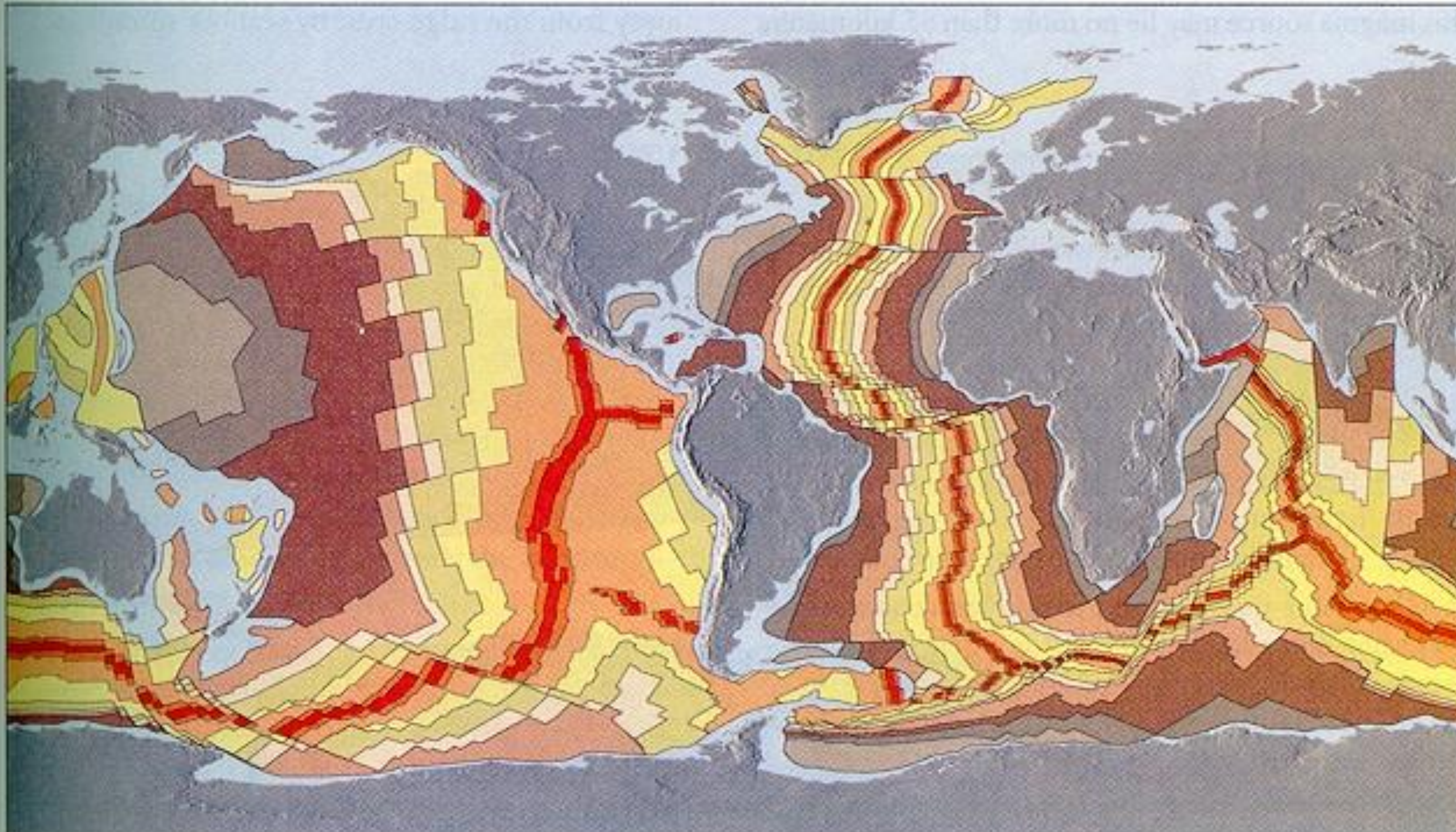


Figure 18.B Manganese nodules on the floor of the Pacific at a depth of more than 5000 meters. (Photo courtesy of Lawrence Sullivan, Lamont-Doherty Earth Observatory)



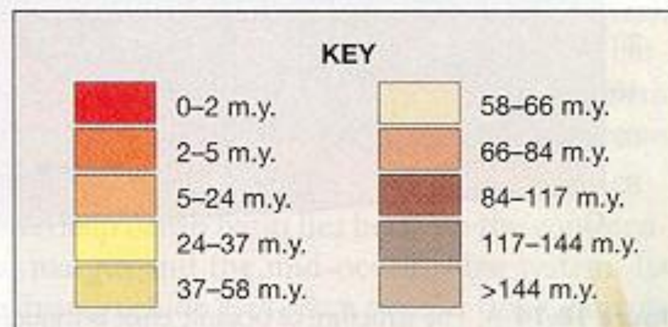


Figure 18.13 The relative age of oceanic crust beneath deep-sea deposits. Notice that the youngest rocks (bright red areas) are found along the oceanic ridge crests and the oldest oceanic crust (brown areas) is located adjacent to the continents and subduction zones in the western Pacific. When you observe the Atlantic Basin, a symmetrical pattern centered on the Mid-Atlantic Ridge crest becomes apparent. This pattern verifies the fact that seafloor spreading generates new oceanic crust equally on both sides of a spreading center. Further, compare the widths of the yellow stripes in the Pacific Basin with those in the South Atlantic. Because these stripes were produced during the same time period, this comparison verifies that the rate of seafloor spreading was faster in the Pacific than in the South Atlantic. (After *The Bedrock Geology of the World*, by R. L. Larson et al. Copyright © by W. H. Freeman)

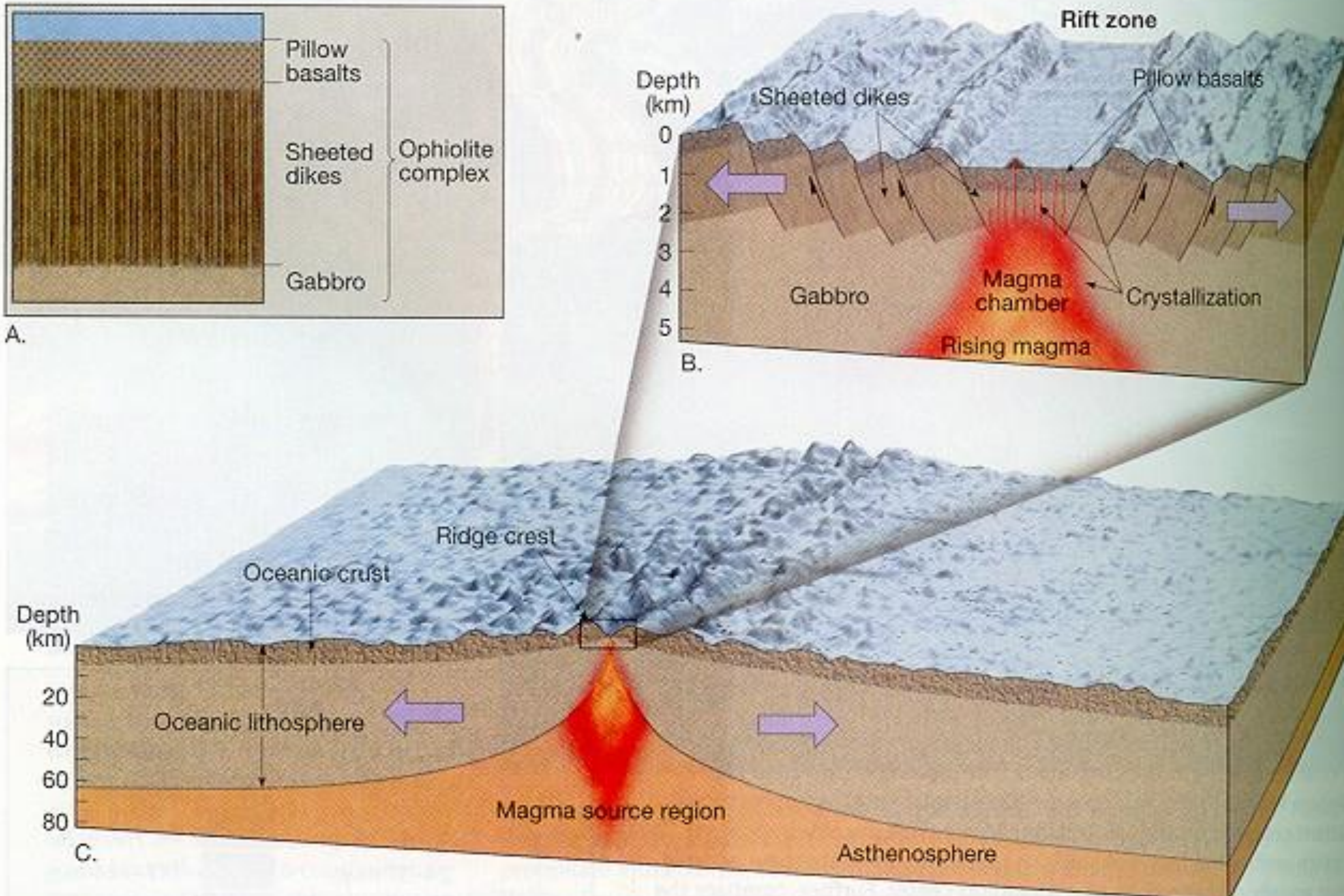


Figure 18.14 **A.** The structure of oceanic crust is thought to be equivalent to the ophiolite complexes that have been discovered elevated above sea level in such places as California and Newfoundland. **B.** The formation of the three units of an ophiolite complex in the rift zone of an oceanic ridge. **C.** Diagram illustrating the site where new ocean crust is generated.

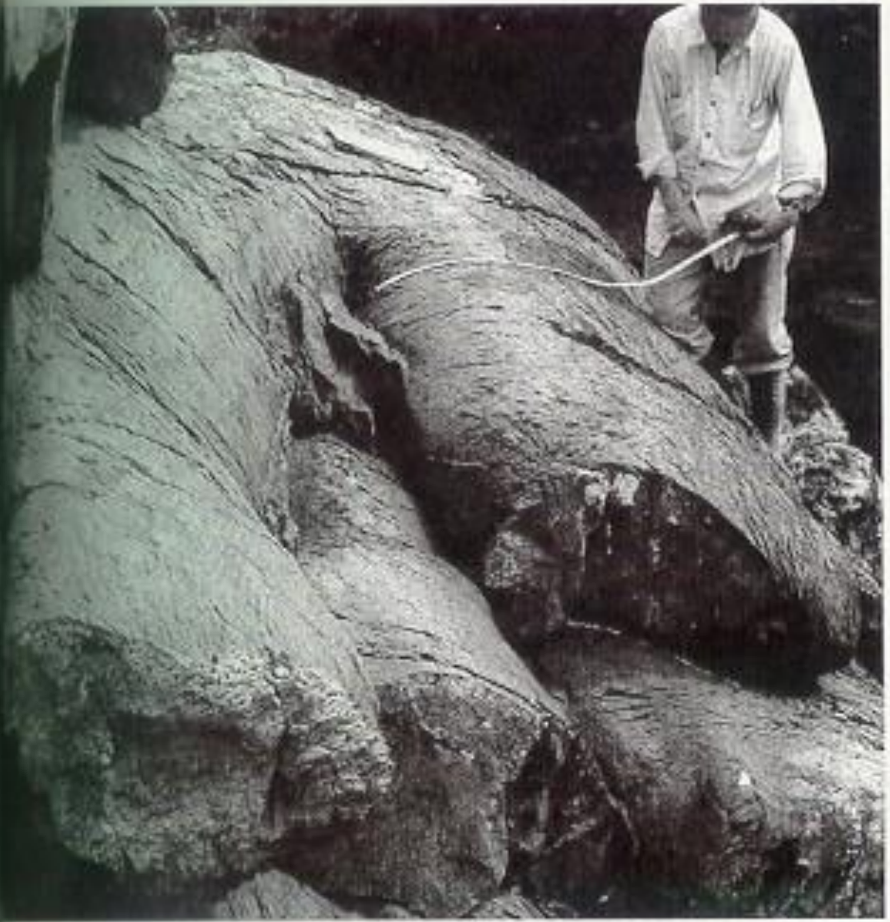


Figure 18.15 Ancient pillow lava at Trinity Bay, Newfoundland. (Photo courtesy of the Geological Survey of Canada, photo no. 152581)

The magma that remains in the subterranean chamber will crystallize at depth to generate thick units of coarse-grained gabbro. This lowest rock unit forms as crystallization takes place along the walls and floor of the magma chamber. In this manner the processes at work along a ridge system generate the entire sequence of rocks found in an ophiolite complex.