EXERCISE 11

Waves, Currents, and Tides

The world's ocean waters are in constant motion via waves, currents, and tides. The immediate cause of each varies; however, the ultimate source of energy is the Sun. Investigating the causes, mechanics, and results of these ocean-water movements will provide a greater understanding of some important systems that operate over 70% of Earth's surface—the world oceans (Figure 11.1).

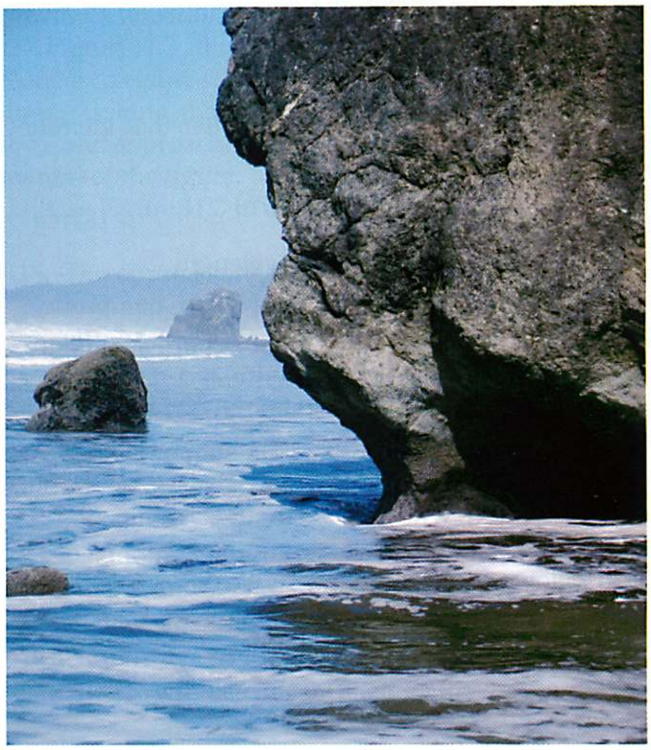

Figure 11.1 Cliff undercut by wave erosion along the Oregon coast. (Photo by E. J. Tarbuck)

Objectives

After you have completed this exercise, you should be able to:

1. Explain how waves and currents are generated in the ocean.
2. Name the parts of a wave and describe the motion of water particles in a deepwater and shallow-water wave.
3. Use a formula to calculate wavelength, wave velocity, and wave period.
4. Explain why waves are refracted and what causes them to break and form surf.
5. Locate each of the major surface ocean currents.
6. List the names and characteristics of the principal deepwater masses.
7. Identify the features of erosion and deposition that occur along shorelines and explain how each is formed.
8. Explain the cause of tides and identify the different types of tides.

Materials

colored pencils hand lens calculator

Materials Supplied by Your Instructor

atlas or world wall map

Terms

wave crest	surface current	estuary
wave trough	Coriolis effect	beach
wave height	density current	spit
wavelength	longshore current	tombolo
wave period	tidal current	baymouth bar
surf zone	emergent coast	diurnal tide
tsunami	wave-cut cliff	semidiurnal tide
refraction	platform	mixed tide
headland	submergent coast	

ty characteristics and general movements of each of the following water masses.

ABW (Antarctic Bottom Water): ____________

____

____

NADW (North Atlantic Deep Water): ________

____

____

AIW (Antarctic Intermediate Water): ________

____

____

MW (Mediterranean Water): ______________

____

____

28. What is the mechanism responsible for causing the very high density of Antarctic Bottom Water?

____

____

Deep-ocean circulation begins in high latitudes where water becomes cold and its salinity increases as sea ice forms. When this surface water becomes dense enough, it sinks and moves throughout the ocean basins in sluggish currents. Oceanographers estimate that after sinking from the surface of the ocean, deep waters will not reappear at the surface for an average of 500 to 2,000 years. A simplified model of deep-ocean circulation is similar to a conveyor belt that travels from the Atlantic Ocean through the Indian and Pacific oceans and back again (Figure 11.6). Use Figure 11.6 to answer questions 29 and 30.

29. What is the name of the cold subsurface water mass forming and sinking in the North Atlantic Ocean?

____

30. Assume that it takes surface water that sinks in the North Atlantic near Greenland 1,000 years to resurface in the Indian Ocean. What would be the approximate velocity of the deep-ocean circulation from the North Atlantic to the Indian Ocean in km/yr and cms/hr?

________________ km(s)/yr

________________ cm(s)/hr

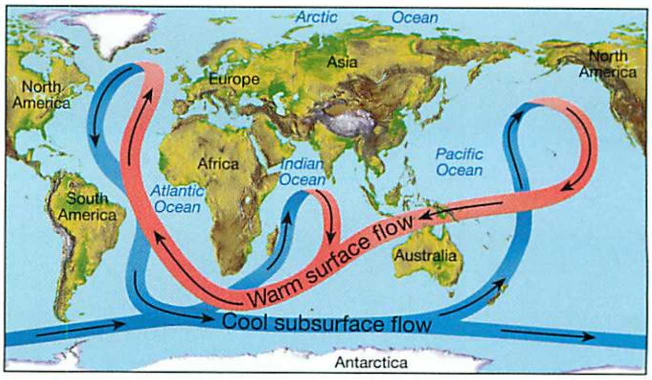

Figure 11.6 Idealized "conveyor belt" model of ocean circulation, which is initiated in the North Atlantic Ocean when warm water transfers its heat to the atmosphere, cools, and sinks below the surface. This water moves southward as a subsurface flow and joins water that encircles Antarctica. From here, this deep water spreads into the Indian and Pacific oceans, where it slowly rises and completes the conveyer as it travels along the surface into the North Atlantic Ocean.

Currents Generated by Waves and Tides

Movements of water that result from waves and tides constitute a third class of currents. Whenever waves or tides push water against a shore, currents form that transport the water along the coast and return it seaward. Two of these currents are longshore currents and tidal currents.

Longshore currents form when waves strike the coast at an angle and the water moves in a zigzag pattern parallel to the shore in the surf zone. These currents transport tremendous amounts of sediment which, when deposited, form many types of coastal features.

Tidal currents, which reverse their direction of flow with each tide, submerge and then expose low-lying coastal zones.

In Figure 11.3 you completed a diagram illustrating wave refraction. Answer questions 31–34 by referring to Figure 11.3.

31. Indicate with arrows the probable directions of the longshore currents.

32. What effect will the small bay have on the longshore current and its transportation of sediment?

____

33. Write the word "deposition" where you would most likely find sediment being deposited by the longshore current.

34. Explain the cause of the sandy beach deposit at the head of the small bay.

____

____

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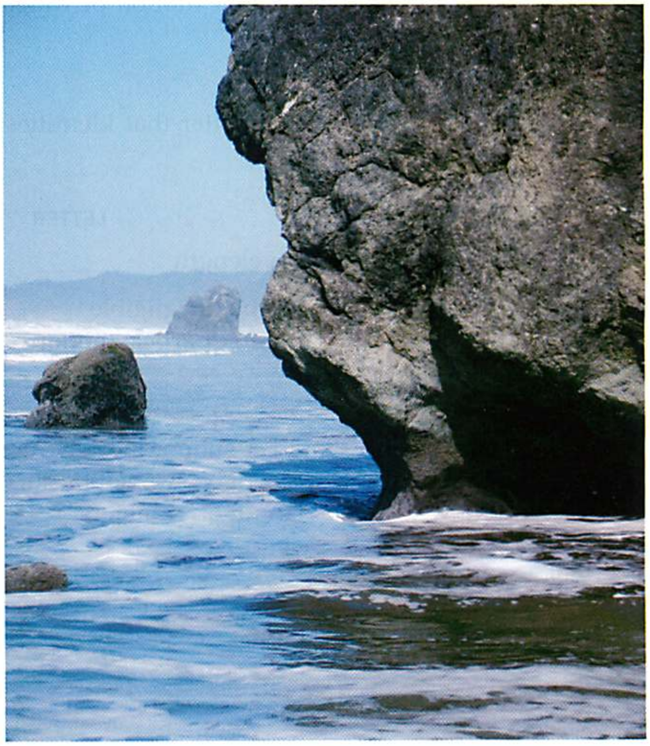

Figure 11.1 Cliff undercut by wave erosion along the Oregon coast. (Photo by E. J. Tarbuck)

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Materials

colored pencils | hand lens | calculator

Materials Supplied by Your Instructor

atlas or world wall map

Terms

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surf zone	emergent coast	diurnal tide
tsunami	wave-cut cliff	semidiurnal tide
refraction	platform	mixed tide
headland	submergent coast	

Waves

Most waves are set in motion when friction with wind begins rotating water particles in circular orbits (Figure 11.2). If you were to watch a ball floating on the surface, you would notice that while the wave form moves forward, the ball, and hence the water, does not. On the surface, as water particles reach the highest point in their circular orbits, a **wave crest** is formed, while particles at their lowest orbital points form **wave troughs**. **Wave height** is the vertical distance between the crest and trough of a wave.

Beneath the surface in deep water the circular orbits of water particles become progressively smaller with depth. At a depth equal to about half the **wavelength** (the horizontal distance separating two successive wave crests), the circular motion of water particles becomes negligible.

1. From Figure 11.2, select the letter that identifies each of the following.

	LETTER		LETTER
wave crest	_____	wavelength	_____
wave trough	_____	depth of negligible water particle motion	
wave height	_____		____________

2. Below what depth would a submarine have to submerge so that it would not be swayed by surface waves with a wavelength of 24 meters?

   Below ________ meters

Wave Mechanics

In deep water, where the depth is greater than half the wavelength, the velocity (V) of a wave depends upon the **wave period** (T) (the time interval between successive wave crests, measured from a stationary point) and the wavelength (L). The mathematical equation that expresses the relation between these variables is velocity = wavelength divided by wave period ($V = L/T$).

As a wave approaches the shore and the depth of water becomes less than half the deepwater wavelength, the ocean bottom begins to interfere with the orbital motion of water particles, and the wave begins to "feel bottom" (Figure 11.2). Interference between the bottom and water particle motion causes changes to occur in the wave. At a depth of water equal to about one-twentieth of the deepwater wavelength [$(\frac{1}{20})L$ or $0.05L$)], the top of the wave begins to fall forward and the wave breaks. In the **surf zone**, where waves are breaking and releasing energy, a significant amount of water is transported toward the shoreline.

3. What are three wind factors that determine the height, length, and period of waves?

   Factor 1: ______________________

   Factor 2: ______________________

   Factor 3: ______________________

Refer to Figure 11.2 to answer questions 4–7.

4. The shape of the orbits of surface water particles in deepwater waves is (circular, elliptical). Near the shore in shallow water, the shapes become (circular, elliptical). Circle your answers.

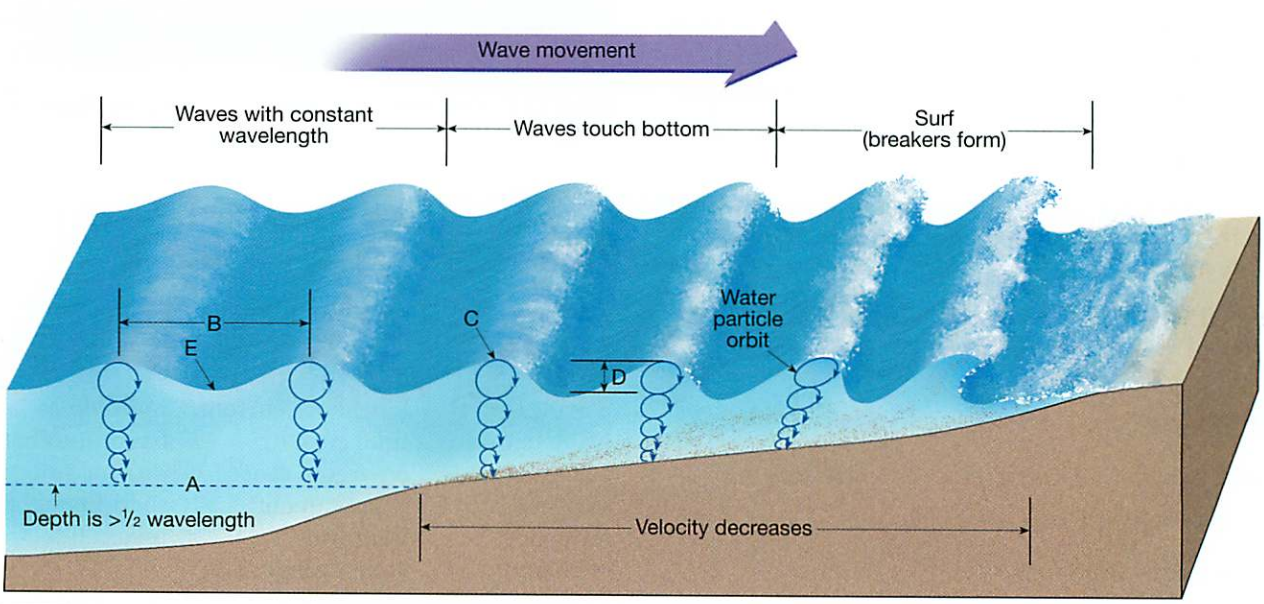

Figure 11.2 Deep- and shallow-water waves.

5. In shallow water, water particles in the wave crest are (ahead of, behind) those at the bottom of the wave.
6. As waves approach the shore in shallow water, their heights (increase, decrease) and the wavelength becomes (longer, shorter).
7. In the surf zone, water particles in the crest of a wave are (falling forward, standing still).
8. What would be the velocity of deepwater waves with a wavelength of 40 meters and a wave period of 6.3 seconds?

$$\text{Velocity} = \frac{\text{wavelength}(L)}{\text{wave period}(T)} = \frac{40 \text{ m}}{6.3 \text{ sec}}$$

$$= \_\_\_\_\_\_\_\_\_\_\_\_ \text{m/sec}$$

9. What would be the wavelength of deepwater waves that have a period of 8 seconds and a velocity of 2 meters/sec? (*Hint:* $V \times T = L$)

   Wavelength(L) = __________ meters

   a. What would be the *wave base* (depth below which water particle motion in the wave ceases) for the waves in question 9?

   Wave base = __________ meters

   b. The waves in question 9 will begin to break at a water depth of about (1, 3, 5) meter(s). Circle your answer.
10. What factor(s) determine the distance between where waves begin to break and the shoreline?

____

11. Imagine that you are standing on the shore considering walking out into the surf zone where the waves are beginning to break, but you cannot swim. You estimate the wavelength of the incoming deepwater waves to be 80 meters. Would it be safe to walk out to where the waves are breaking? Explain how you arrived at your answer.

____

____

12. Along some shorelines, why does the water simply rise and fall rather than forming a surf zone?

____

13. What effect will *breakwaters* (walls of concrete or rock built offshore and parallel to the beach) have on waves?

____

Tsunamis (ocean waves produced by a submarine earthquake, sometimes mistakenly called "tidal waves") can have a wavelength of 125 miles and a wave period of 20 minutes.

14. If a tsunami had a wavelength of 125 miles and a period of 20 minutes, what would be its velocity?

   Velocity = ____________ miles per hour

Wave Refraction

Waves that approach the shore at an angle are **refracted** (bent) because that part of the wave that touches bottom first is slowed down, while the remaining part of the wave continues to move forward. Refraction causes most waves to reach the shore approximately parallel to the shoreline.

Figure 11.3 illustrates a map-view of a **headland** along a coastline with water depths shown by contour lines. Assume that waves, with a wavelength of 80 feet, are approaching the shoreline from the lower margin of the figure.

Use Figure 11.3 to answer questions 15–21.

15. The approaching waves will begin to touch bottom and slow down at a water depth of about (10, 20, 30, 40) feet. Circle your answer.
16. At a water depth of approximately (4, 8, 12, 16) feet, the waves will begin to break.
17. Indicate where the waves will begin to break with a dashed line. Write the words "surf zone" along the line.
18. Beginning with the wave shown, sketch a succession of lines to illustrate the wave refraction that will take place as the waves approach shore.
19. Use arrows to indicate where most of the wave energy will be concentrated as the waves are refracted and impact the shore.
20. Erosion by waves will be most severe (on the headland, in the bay). Circle your answer.
21. What effect will the concentrated energy from wave impact eventually have on the shape of the coastline?

____

____

Currents

Moving masses of water on the surface or within the ocean are called *currents*. The primary generating force for surface currents is wind, whereas deep-ocean circulation is a response to density differences among water masses.

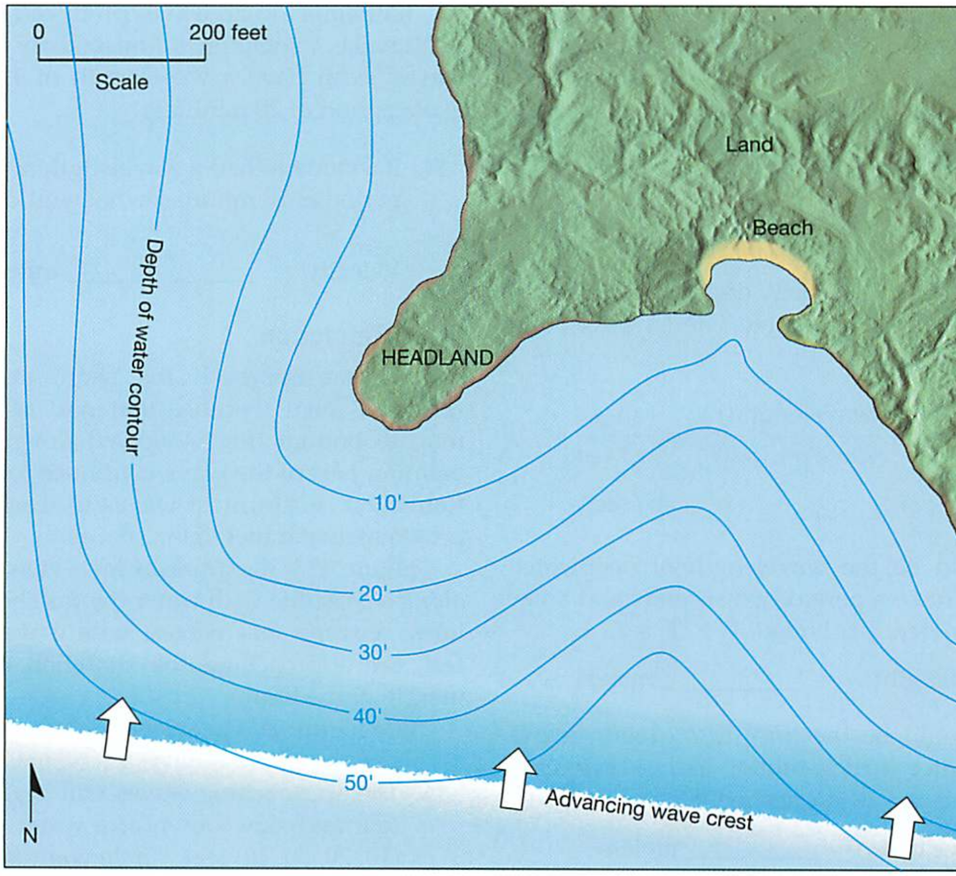

Figure 11.3 Coastline with depth of water contours and an approaching wave.

Surface Currents

Surface currents develop when friction between the moving atmosphere and the water causes the surface layer of the ocean to move as a single, large mass. Once set in motion, surface currents are influenced by the **Coriolis effect**, which deflects the path of the moving water to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. *Warm currents* carry equatorial water toward the poles, while *cold currents* move water from higher latitudes toward the equator.

22. Many surface ocean currents flow with great persistence. On the world map, Figure 11.4, draw arrows representing each of the following principal surface ocean currents. Use an atlas or, if available, a large wall map that depicts surface currents as a reference. *Show warm currents with red arrows and cold currents with blue arrows.* To conserve space on the map, indicate the name of each current by writing the number that has been assigned to it.

PRINCIPAL SURFACE OCEAN CURRENTS

1. Equatorial	4. Canaries	7. Kuro Siwo	10. North Atlantic Drift
2. Gulf Stream	5. Brazil	8. West Wind Drift	11. North Pacific Drift
3. California	6. Benguela	9. Labrador	12. Peruvian

Using Figure 11.4, or a world map of surface ocean currents, answer questions 23–26.

23. Which surface ocean current travels completely around the globe, west to east, without interruption?

____

24. Which surface ocean current flows along the eastern coast of the United States? The current is a (warm, cold) current. Circle your answer.

____

25. What is the name of the surface ocean current located along the western coast of the United States? The current is a (warm, cold) current. Circle your answer.

____

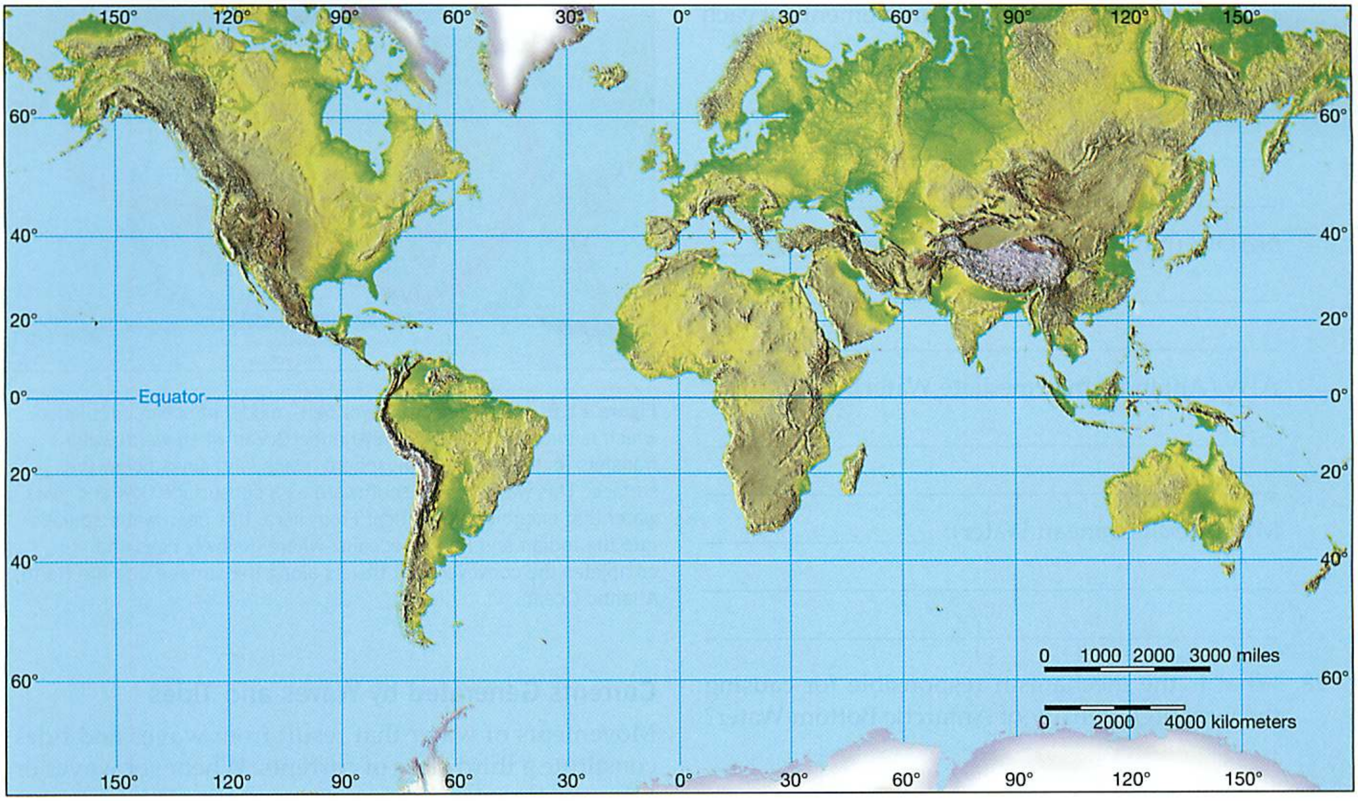

Figure 11.4 World map.

26. The general circulation of the surface currents in the North Atlantic Ocean is (clockwise, counterclockwise). In the South Atlantic, circulation is (clockwise, counterclockwise). Circle your answers.

Density Currents

Density currents result when water of greater density flows under or through water of a lower density. At any given depth, the density of water is influenced by its temperature and salinity—factors that you may have investigated in Exercise 9, "Introduction to Oceanography."

Figure 11.5 is a cross section of the Atlantic Ocean illustrating the deep (thermohaline) circulation. Use the figure to answer questions 27 and 28.

27. After you examine their latitude of origin, describe the probable temperature and/or salini-

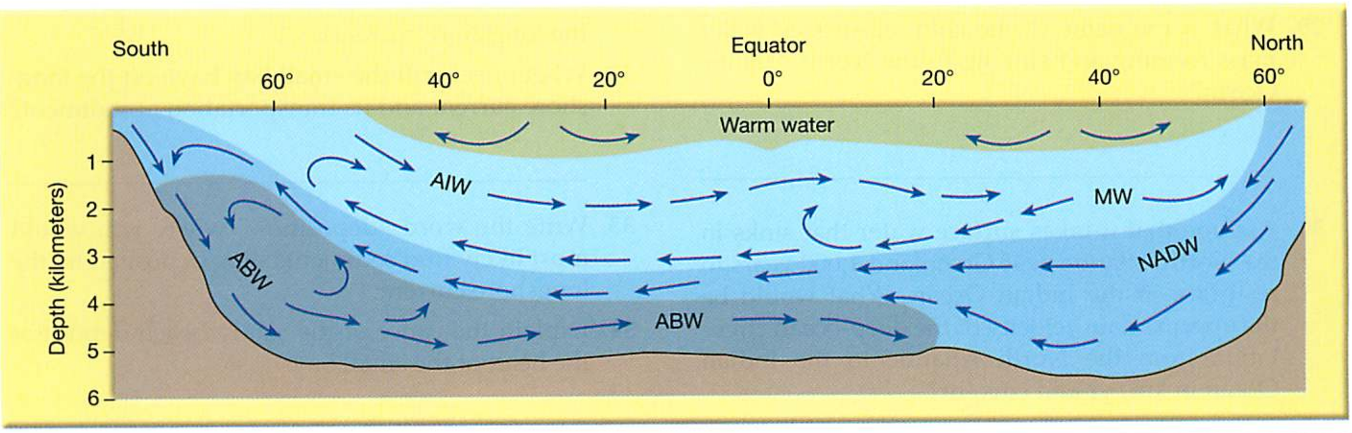

Figure 11.5 Cross section of the deep circulation of the Atlantic Ocean. (After Gerhard Neumann and Willard J. Pierson, Jr., *Principles of Physical Oceanography*, 1966. Reprinted by permission of Gerhard Neumann)

ty characteristics and general movements of each of the following water masses.

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____

____

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____

____

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____

____

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____

____

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____

____

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____

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____________________ km(s)/yr

____________________ cm(s)/hr

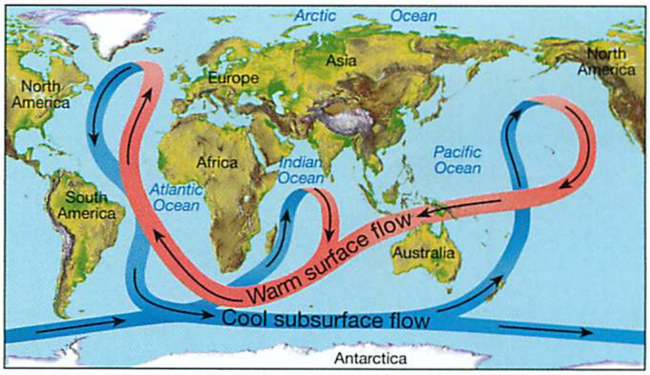

Figure 11.6 Idealized "conveyor belt" model of ocean circulation, which is initiated in the North Atlantic Ocean when warm water transfers its heat to the atmosphere, cools, and sinks below the surface. This water moves southward as a subsurface flow and joins water that encircles Antarctica. From here, this deep water spreads into the Indian and Pacific oceans, where it slowly rises and completes the conveyer as it travels along the surface into the North Atlantic Ocean.

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____

33. Write the word "deposition" where you would most likely find sediment being deposited by the longshore current.

34. Explain the cause of the sandy beach deposit at the head of the small bay.

____

____

Shoreline Features

The nature of shorelines varies considerably from place to place. One way that geologists classify coasts is based upon changes that have occurred with respect to sea level. This very general classification divides coasts into two types, emergent and submergent.

Emergent coasts have been raised above the sea as a result of rising land or falling sea level and are characterized by **wave-cut cliffs** or **platforms**.

Submergent coasts, resulting from a rising sea level or subsiding land, are often irregular due to the fact that many river mouths are flooded and become **estuaries**.

Nevertheless, whether along the rugged New England coast or the steep coastlines of California, the effects of wave erosion and sediment deposition by currents produce many similar features. Some of the more common depositional features include **beaches, spits, tombolos,** and **baymouth bars**.

Features of Emergent and Submergent Coasts

Figure 11.7 illustrates several erosional and depositional features of emergent and submergent coastlines. Using Figure 11.7, complete questions 35–37.

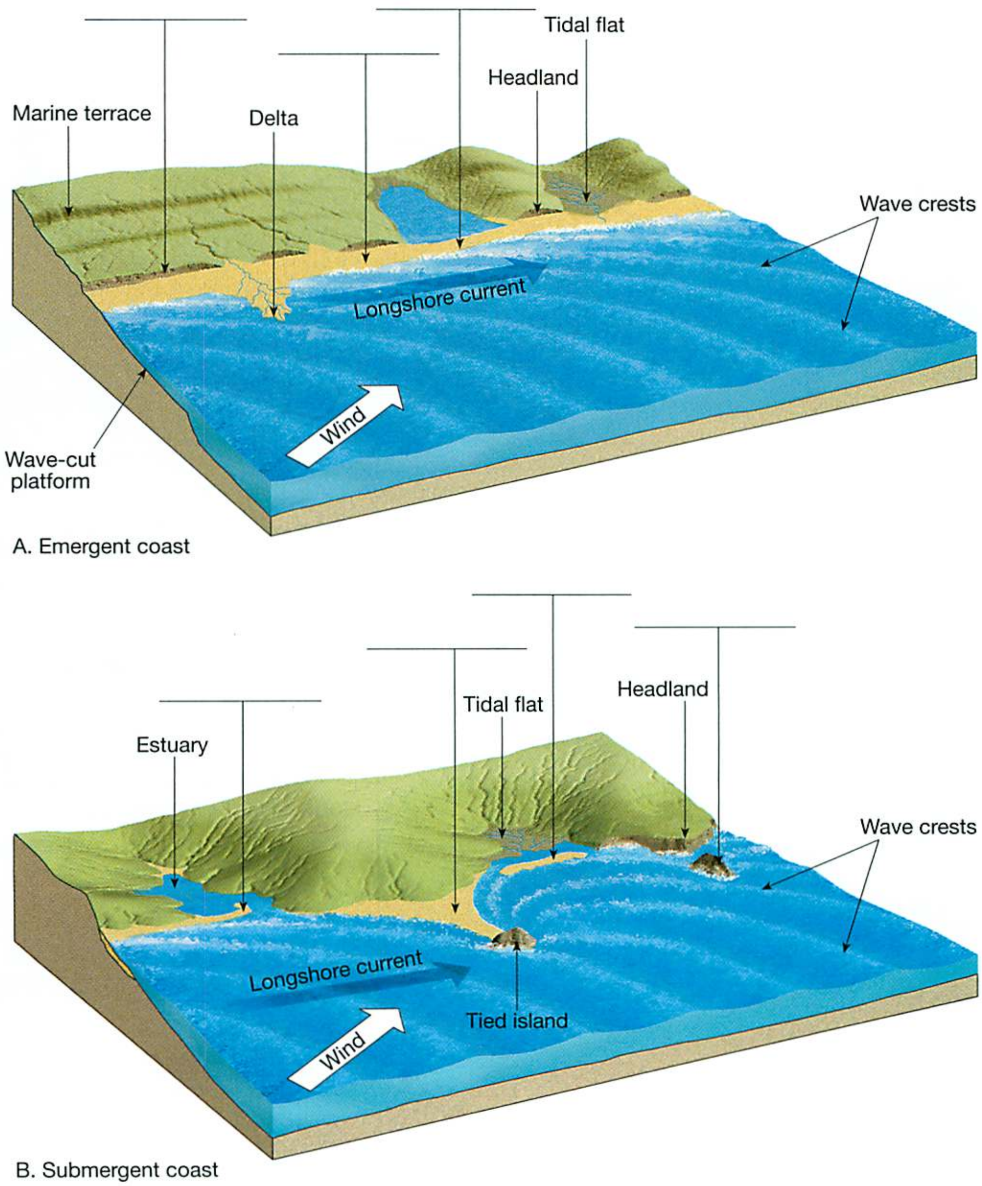

Figure 11.7 Hypothetical illustrations showing general features of **A.** emergent and **B.** submergent coastlines.

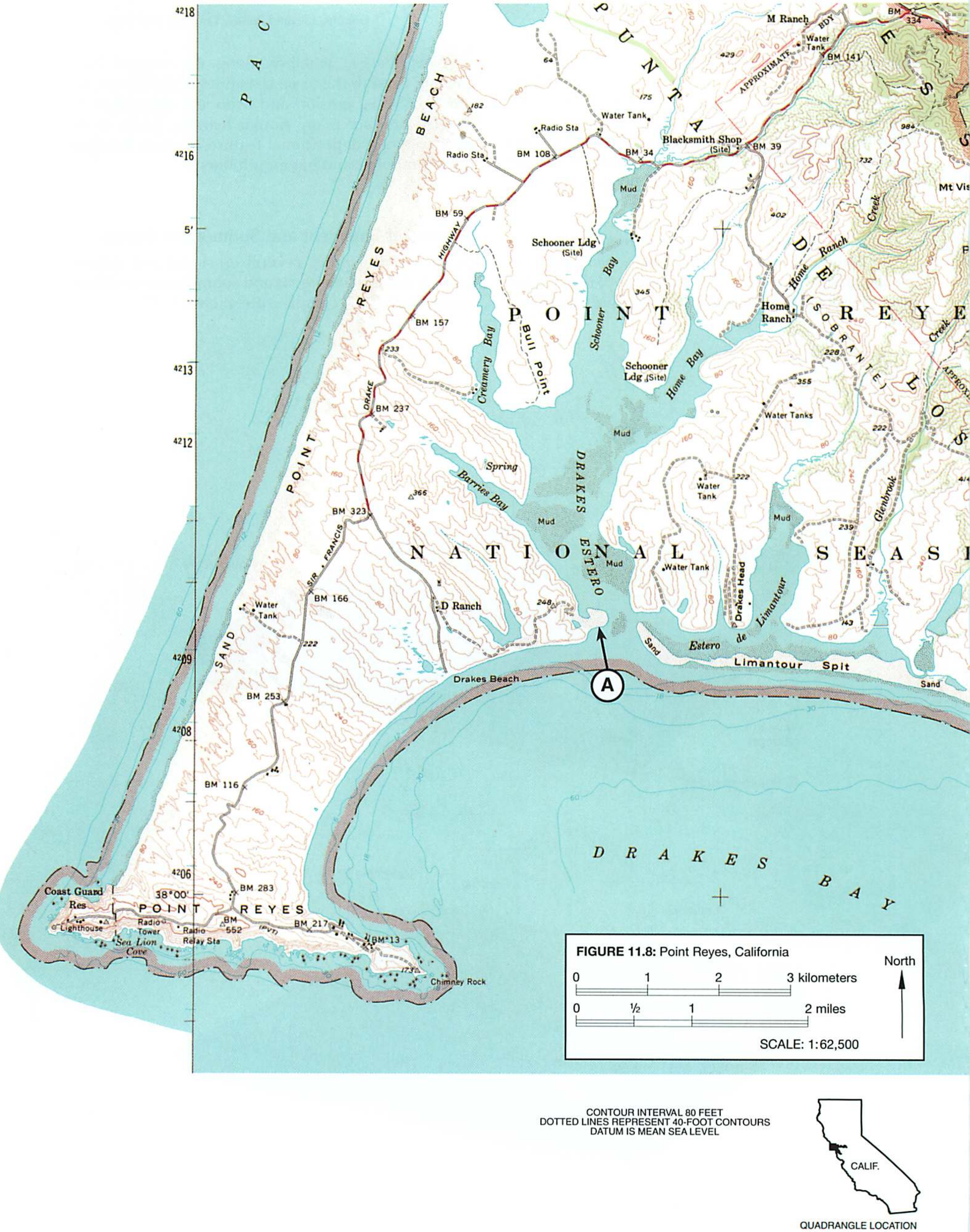

Figure 11.8 Portion of the Point Reyes, California, topographic map. (Map source: United States Department of the Interior, Geological Survey)

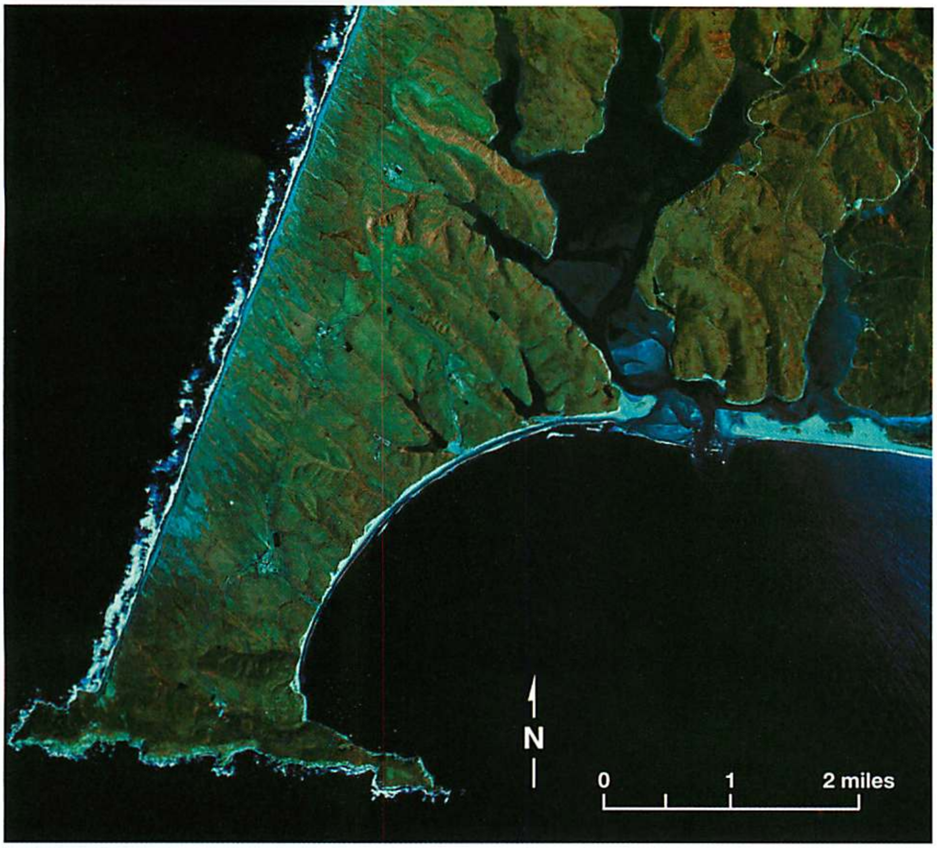

Figure 11.9 High-altitude false-color image of the Point Reyes area north of San Francisco, California. (Courtesy of USDA–ASCS)

35. On Figure 11.7 identify each of the following coastal features by writing their name above the appropriate vertical line.

FEATURES CAUSED BY EROSION	FEATURES PRODUCED BY DEPOSITION	
wave-cut cliff	beach	baymouth bar
sea stack	spit	barrier island
	tombolo	

36. What is the purpose for constructing each of the following artificial features along a coast?

a *groin:* ______________________

a pair of *jetties:* ______________________

37. Draw and label a pair of jetties at the most appropriate location along the emergent coast illustrated in Figure 11.7A.

Identifying Coastal Features on a Topographic Map

Figure 11.8 is a portion of the Point Reyes, California, topographic map. Compare the map with the high-altitude image of the same area in Figure 11.9. Then use Figure 11.8, Figure 11.9, and Figure 11.7 to answer questions 38–44.

38. The features along the shoreline of Drakes Bay suggest that the coast is (emergent, submergent). Circle your answer.

39. Drakes Estero and other bays shown on the map are (estuaries, headlands).

40. Point Reyes, a typical headland, is undergoing severe wave erosion. What type of feature is Chimney Rock and the other rocks located off the shore of Point Reyes? How have they formed?

____

____

41. Several depositional features in Drakes Bay are related to the movement of sediment by longshore currents. The feature labeled A on the map is one of these features, called a (spit, tombolo).

42. Using a large arrow, indicate the direction of the current in the vicinity of Limantour Spit.

43. Assume a groin is constructed by the word "Limantour" on Limantour Spit. On which side of the groin, east or west, will sand accumulate? What will be the effect on the opposite side of the groin?

____

____

44. What is the probable origin of the "U-shaped" lake east of D Ranch?

____

____

Tides

Tides are the cyclical rise and fall of sea level caused by the gravitational attraction of the Moon and, to a lesser extent, by the Sun. Gravitational pull creates a bulge in the ocean on the side of Earth nearest the Moon and on the opposite side of Earth from the Moon. Tides develop as the rotating Earth moves through these bulges causing periods of high and low water. Using tidal information from many sources, tides are classified into three types:

- **Diurnal** (*diurnal* = daily) **tides** are characterized by a single high tide and a single low tide each tidal day.
- **Semidiurnal** (*semi* = twice, *diurnal* = daily) **tides** exhibit two high tides and two low tides each tidal day.
- **Mixed tides** are similar to semidiurnal tides except that they are characterized by large inequalities in high water heights, low water heights, or both (Figure 11.10).

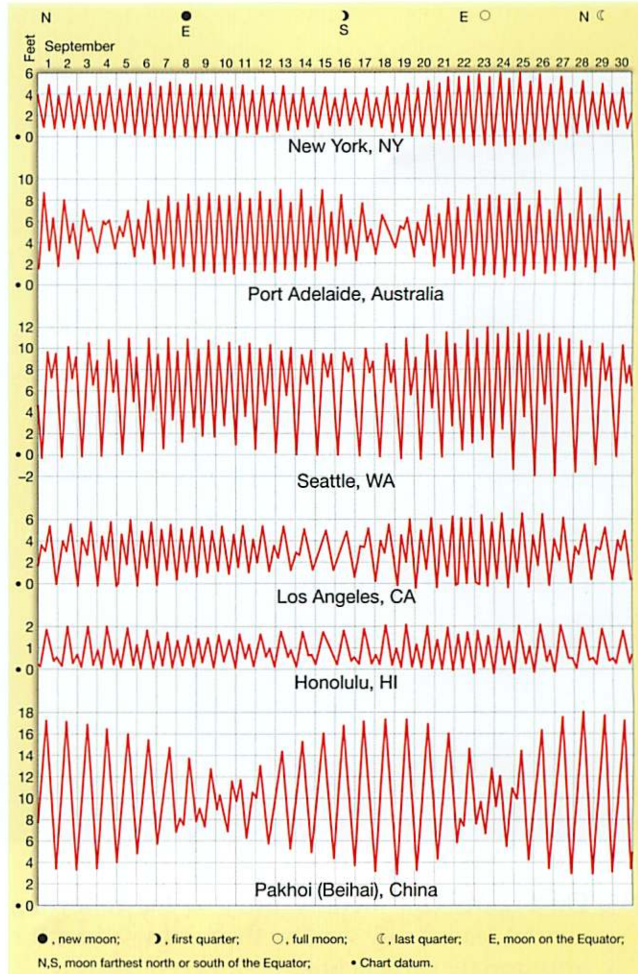

Figure 11.11 Tidal curves for the month of September at various locations. (Source: U.S. Navy Hydrograph Office, *Oceanography*, U.S. Government Printing Office, 1966)

Identifying Types of Tides

Tidal curves for the month of September at several locations are illustrated in Figure 11.11. Use the figure to answer questions 45–47.

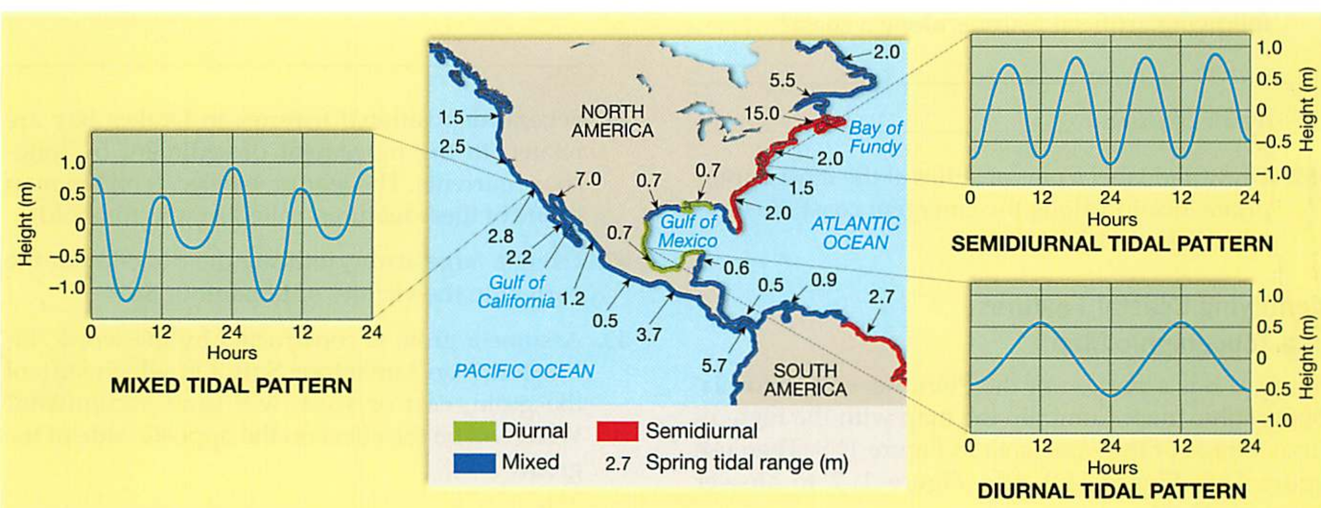

Figure 11.10 Tidal patterns and their occurrence along North and Central American coasts. A diurnal tidal pattern (*lower right*) shows one high and low tide each tidal day. A semidiurnal pattern (*upper right*) shows two highs and lows of approximately equal heights during each tidal day. A mixed tidal pattern (left) shows two highs and lows of unequal heights during each tidal day.

45. Classify each of the tidal curves shown in Figure 11.11 as to the most appropriate type.
Diurnal tides occur at: ____________________

____

Semidiurnal tides: ____________________

____

Mixed tides: ____________________

____

46. Of the locations you classified as having a *mixed* tide, (Port Adelaide, Seattle, Los Angeles) had the greatest inequality between successive low water heights on September 5. Circle your answer.

47. Write a general statement comparing the type of tide that occurs along the Pacific coast of the United States to the type found along the Atlantic coast.

____

____

Tidal Variations

In Figure 11.11, notice that during the month of September, at any given location, the heights of the tides were not constant. Two important factors that influence this variation are (1) the alignment of the Sun, Earth, and Moon, and (2) the distance between Earth and the Moon. Although these two controls are significant, they alone cannot be used to predict the height or time of actual tides at a particular place. Other factors, such as the shape of the coastline and the configuration of ocean basins, are also important. Consequently, tides at various locations respond differently to the tide-producing forces.

Use Figure 11.11 to answer questions 48–53.

48. As shown in Figure 11.11, the *tidal range* (difference in height between high tide and the following low tide) at any one location (changes, remains the same) throughout September. Circle your answer.

The lunar phases for the month are shown at the top of the figure (new moon on the 8th and full moon on the 23rd of the month).

49. What general relation seems to exist between the phases of the Moon and the tidal ranges at New York?

____

____

50. Explain the cause of *spring tides* and *neap tides.* Sketch a diagram showing the relative positions of the Earth, Moon, and Sun, viewed from above, that would cause each situation.

Spring tide

Spring tides: ____________________

____

____

Neap tide

Neap tides: ____________________

____

____

51. On Figure 11.11, label the times of spring tide and times of neap tide for New York.

52. Do the tides at Pakhoi, China, have the same relations to the lunar phases as those that occur at New York? What are some other factors that may be influencing the tides at Pakhoi?

____

____

Table 11.1 Tidal Data for Long Beach, New York, January 2003

TIMES ARE LISTED IN LOCAL STANDARD TIME (LST) — ALL HEIGHTS ARE IN FEET								
DAY	TIME	HEIGHT	TIME	HEIGHT	TIME	HEIGHT	TIME	HEIGHT
1	05:45 A.M.	5.5	12:16 P.M.	−0.7	06:12 P.M.	4.4	—	—
2	12:18 A.M.	−0.5	06:35 A.M.	5.6	01:07 P.M.	−0.8	07:03 P.M.	4.4
3	01:10 A.M.	−0.5	07:23 A.M.	5.5	01:56 P.M.	−0.8	07:53 P.M.	4.4
4	01:59 A.M.	−0.4	08:11 A.M.	5.4	02:42 P.M.	−0.7	08:42 P.M.	4.3
5	02:45 A.M.	−0.2	08:59 A.M.	5.1	03:25 P.M.	−0.5	09:32 P.M.	4.2
6	03:30 A.M.	0.0	09:47 A.M.	4.8	04:07 P.M.	−0.3	10:23 P.M.	4.0
7	04:14 A.M.	0.3	10:35 A.M.	4.6	04:49 P.M.	−0.1	11:12 P.M.	3.9
8	05:01 A.M.	0.6	11:22 A.M.	4.3	05:32 P.M.	0.2	11:59 P.M.	3.9
9	05:54 A.M.	0.8	12:09 P.M.	4.0	06:18 P.M.	0.4	—	—
10	12:45 A.M.	3.9	06:56 A.M.	0.9	12:57 P.M.	3.7	07:10 P.M.	0.5
11	01:31 A.M.	3.9	07:59 A.M.	0.9	01:47 P.M.	3.5	08:02 P.M.	0.5
12	02:19 A.M.	4.0	08:57 A.M.	0.8	02:41 P.M.	3.4	08:53 P.M.	0.5
13	03:10 A.M.	4.1	09:50 A.M.	0.6	03:39 P.M.	3.5	09:41 P.M.	0.4
14	04:02 A.M.	4.3	10:38 A.M.	0.3	04:34 P.M.	3.6	10:28 P.M.	0.2
15	04:51 A.M.	4.6	11:26 A.M.	0.1	05:23 P.M.	3.7	11:15 P.M.	0.1
16	05:36 A.M.	4.8	12:12 P.M.	−0.1	06:08 P.M.	3.9	—	—
17	12:02 A.M.	−0.1	06:17 A.M.	5.0	12:57 P.M.	−0.3	06:51 P.M.	4.1
18	12:49 A.M.	−0.2	06:58 A.M.	5.1	01:40 P.M.	−0.5	07:32 P.M.	4.2
19	01:35 A.M.	−0.4	07:38 A.M.	5.2	02:22 P.M.	−0.6	08:15 P.M.	4.3
20	02:20 A.M.	−0.4	08:21 A.M.	5.2	03:30 P.M.	−0.7	09:01 P.M.	4.4

(Source: Center for Operational Oceanographic Products and Services, National Oceanographic and Atmospheric Association, National Ocean Service.)

At some locations, tidal power is being considered as a means of generating electricity.

53. Suggest two criteria that a bay must meet before its tidal energy can be economically harnessed.

Criterion 1: ______________________________

Criterion 2: ______________________________

Examining Tidal Data

Table 11.1 presents January 2003 tidal data for Long Beach, New York. Accurately plot the data on the graph in Figure 11.12. After you have plotted the data, answer questions 54–58.

54. What type of tide occurs at Long Beach, New York? What fact(s) support your conclusion?

____

____

____

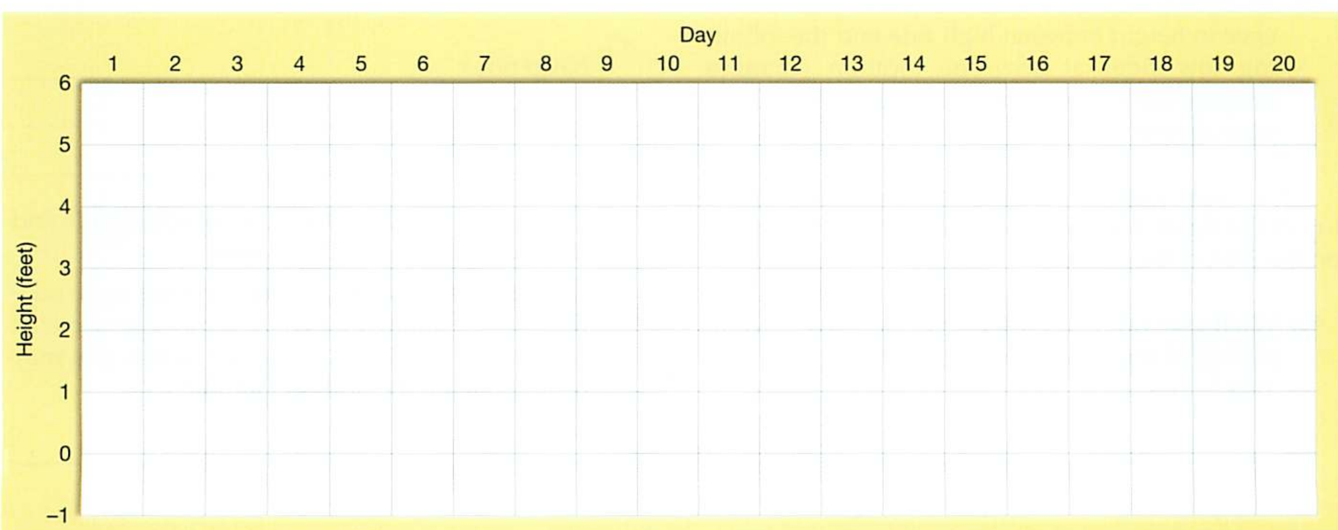

Figure 11.12 Tidal curve for Long Beach, New York

55. The greatest tidal range occurs on day ________, while the smallest range is on day ___________.

56. Selecting from the tidal curves in Figure 11.11, the tides at Long Beach are most like those at:

____

Examine closely the association between the tides shown for the city you selected in question 56 and the phases of the Moon depicted at the top of Figure 11.11.

57. Using Figure 11.11 as a reference, label the most likely lunar phases associated with the tidal curve above the appropriate days on Figure 11.12.

58. Using Table 11.1 and Figure 11.12, assume that at 9:00 A.M. on January 5, a boat was anchored near a beach in 4 feet of water. When the owner returned at 3:30 P.M., the boat was resting on sand. What had happened? Approximately how long did the owner have to wait to sail the boat away from the area?

____

____

____

Waves, Currents, and Tides on the Internet

Continue your exploration of waves and tides by completing the corresponding online activity on the *Applications & Investigations in Earth Science* website at http://prenhall.com/earthsciencelab

Notes and calculations.

Waves, Currents, and Tides

Date Due: ______________________

Name: ______________________

Date: ______________________

Class: ______________________

After you have finished Exercise 11, complete the following questions. You may have to refer to the exercise for assistance or to locate specific answers. Be prepared to submit this summary/report to your instructor at the designated time.

1. On Figure 11.13 sketch a profile view of deep- and shallow-water waves approaching a shore. Label all parts and measurements of a typical wave. Also, illustrate the motion of several water particles at increasing depths in both a deep- and shallow-water wave.

2. What will happen to the shapes of waves as they approach a headland that is surrounded by shallow water?

   ____

3. Describe the formation and appearance of each of the following features:

   Spit: ______________________

   ____

   Stack: ______________________

   ____

   Tombolo: ______________________

   ____

   Estuary: ______________________

   ____

4. Refer to Figure 11.8. What types of coastal features are Point Reyes, Drakes Estero, and Chimney Rock?

   Point Reyes: ______________________

   Drakes Estero: ______________________

   Chimney Rock: ______________________

5. The circulation of the surface currents in the South Atlantic Ocean is (clockwise, counterclockwise). Circle your answer.

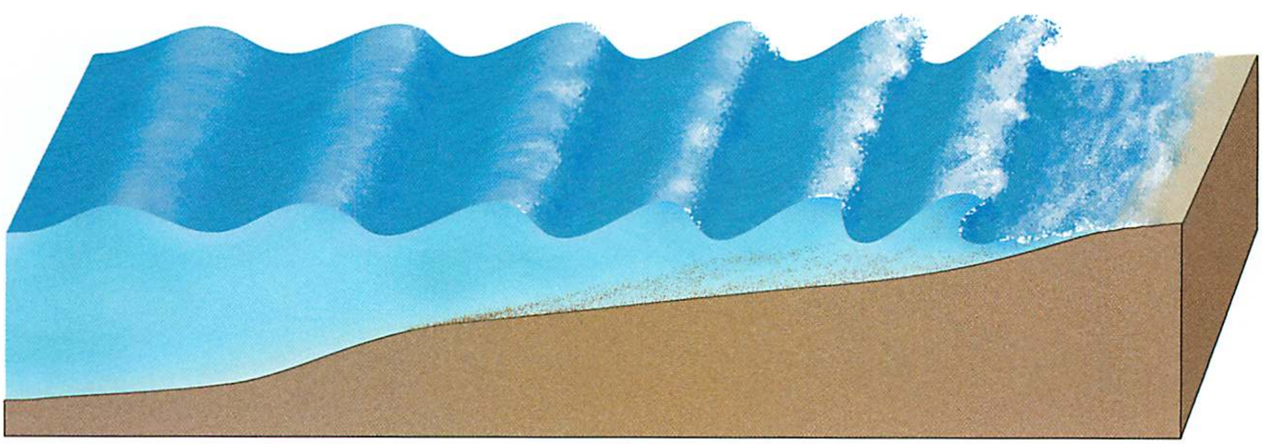

Figure 11.13 Deepwater waves approaching a shallow coast.

6. What are the names of the surface currents that are located along the east and west coasts of the United States? Is each a warm or a cold current?

   East coast: ______________________________

   West coast: ______________________________

7. List the characteristics and describe the movement of the following deep-ocean water masses in the Atlantic Ocean.

   NADW: ______________________________

   ____

   ABW: ______________________________

   ____

8. Spring tides are most likely to occur during which lunar phase(s)?

   ____

9. Which of the tidal curves illustrated in Figure 11.11 exhibits the greatest tidal range?

   ____

10. Refer to Figure 11.11. Of the three types of tides, name the type that occurs at each of the following locations.

    Pakhoi: ______________________________

    Honolulu: ______________________________

    New York: ______________________________

11. Referring to question 54 of the exercise, what type of tide occurs at Long Beach, New York? Describe this type of tide.

    ____

    ____

    ____