121. What is a swamp? In what ways are swamps associated with lakes? What are peat bogs? Quaking bogs? Climbing bogs? Why are tundras swampy in summer? Where near rivers do swamps occur? Why are swamps common on coastal plains? Give illustrations. What are alkali flats and salines? Playas?

122. What effect have swamps on health? What effect have swamps on agriculture? How may they be made valuable? What fuel is supplied from swamps? What is the origin of coal?

SUGGESTIONS. — (1) Make a valley in clay and pour water into it. It is a stream valley. Place a dam across it and make a miniature lake. What is its shape? Make one or two tributary valleys into which the water rises. What is the shape then? Wash sediment into the lake by sprinkling the sides with a watering pot. Notice the growth of deltas. The lake may even be filled. (2) In a deep jar of water, take the temperature at the top and bottom. Pound up ice and put it into the jar, and when it has all melted, again take the temperature at the top and the bottom. Why has the bottom water this temperature? Continue putting in ice until the temperature at the surface is 36°. What is the temperature at the bottom then? (3) Place a large dish of warm water in a cold room. Does the temperature of the air change as a thermometer is brought near the water? Try the same experiment with a large dish of ice-cold water in a warm room. (4) If your home is near a lake, study it. Can you find out what caused it? Does the outlet stream flow in a deep or shallow valley? Are there any deltas? Where? Any signs of filling by wave action? Are there any swamps? What kinds of plants grow on the shallow lake bottom and shore? (5) Are there any swamps near your home? What is their cause? Is it believed that they are unhealthful? Are any of them partly or wholly drained? How was it done? What effect has the draining had? (6) Make three surfaces of clay: (1) a steep slope, (2) a plain, (3) a plain with vegetation (made by putting pieces of grass in it). Sprinkle with water. Which remains wet longest? Why? Which dries first?

Reference Books. — RUSSELL, *Lakes of North America*, Ginn & Co., Boston, 1895, $1.50; TARR, *Physical Geography of New York State*, Chapter VI, Macmillan Co., N.Y., 1902, $3.50; GILBERT, *Lake Bonneville*, Monograph I, U. S. Geological Survey; *Lake Bonneville*, 2d Annual, U. S. Geological Survey, p. 169; RUSSELL, *Present and Extinct Lakes of Nevada, National Geographical Monographs*, American Book Co., New York, 1895, $2.50; *Lake Lahonton*, 3d Annual, U. S. Geological Survey, p. 195; *Lake Lahonton*, Monograph XI, U. S. Geological Survey; *Mono Lake Region*, 8th Annual, U. S. Geological Survey, p. 267.

CHAPTER X.

THE OCEAN.

123. Importance of the Ocean. — We have already learned (p. 15) that the ocean is in many ways of importance to man. It supplies vapor for rain, and moderates the climate of the lands, it is a source of food and other products that man needs; and it is an important highway of communication between all quarters of the globe.

THE OCEAN BOTTOM.

124. Oceanography.—Oceanography is the study of the ocean, both the surface and the bottom. For carrying on this study there have been numerous exploring expeditions, the most important being that of the British ship *Challenger*, which spent four years in studying the Atlantic, Pacific, Indian, and Southern oceans. Other governments have also sent out ships for this purpose, among them the U. S. Coast Survey steamer *Blake* and the U. S. Fish Commission steamer *Albatross*. One reason for a special study of

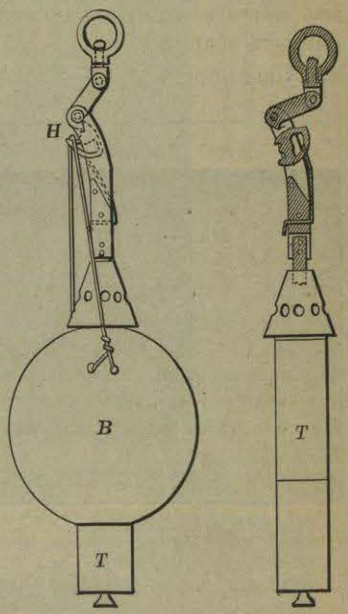

FIG. 310. — Deep-sea sounding apparatus. *B*, cannon ball suspended from hook *H*, which drops when the apparatus strikes the bottom, releasing the ball, as shown in the right-hand figure.

the ocean is to determine its depth and the nature of its bottom in order to discover proper lines for submarine cables. These cables are so important in commerce and war that lines now cross the oceans in various directions.

To determine the depth, use is made of a sounding machine which lowers an iron weight, usually a cannon ball, to the bottom. This heavy weight is not drawn back to the surface, but is automatically released when bottom is struck (Fig. 310).

A sample of the ocean-bottom water is brought up in a metal tube, or water bottle (*T*, Fig. 310), which remains open on the way down, but closes when drawn up. A sample of the ocean-bottom mud clings to soap or tallow placed on the bottom of the water bottle; and the temperature is determined by thermometers attached at various points on the sounding line. These deep-sea thermometers are so made that they record the temperature at the point from which they are drawn up. Thus, by a single sounding, the depth, some of the water, a sample of the bottom, and the temperature of the water at various points are all obtained.

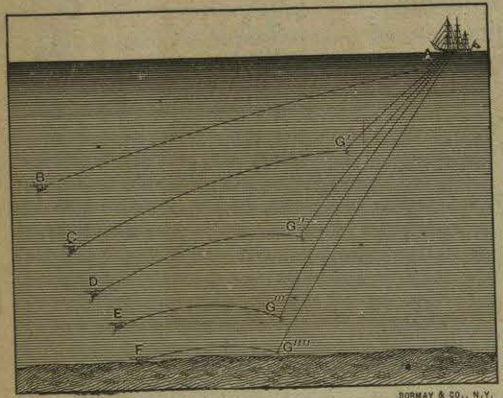

Fig. 311. — Apparatus used by the *Challenger* in dredging. *G* is a weight, and *B*, *C*, *D*, *E*, and *F* represent various positions of the dredge.

Most deep-sea exploring expeditions also make a study of the animal life of the ocean bottom. Specimens of these animals are obtained by means of a deep-sea dredge, or trawl (Fig. 312), which consists of an iron frame several feet in length with a long bag net attached. This is dragged over the ocean bottom (Fig. 311), animals in its path being scooped up by the frame and gathered in the bag. Many weird creatures are thus obtained.

Fig. 313. — The continent of North America and neighboring sea bottoms, showing the continent block; the continental shelf plains; the continental slopes; and the great ocean-bottom plains. In the Pacific are some volcanic cones; and the West Indies are seen to be mountains rising from the sea bottom.

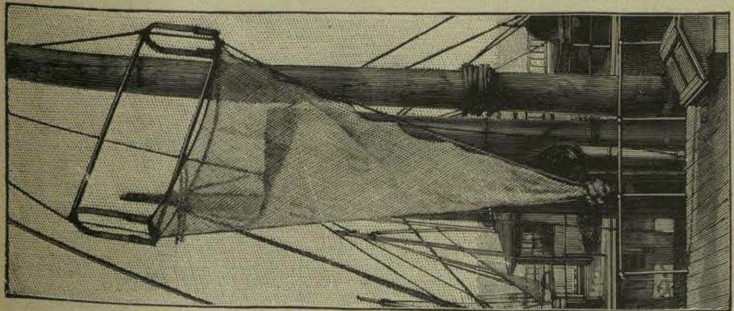

Fig. 312. — Deep-sea trawl used by the U. S. Coast Survey.

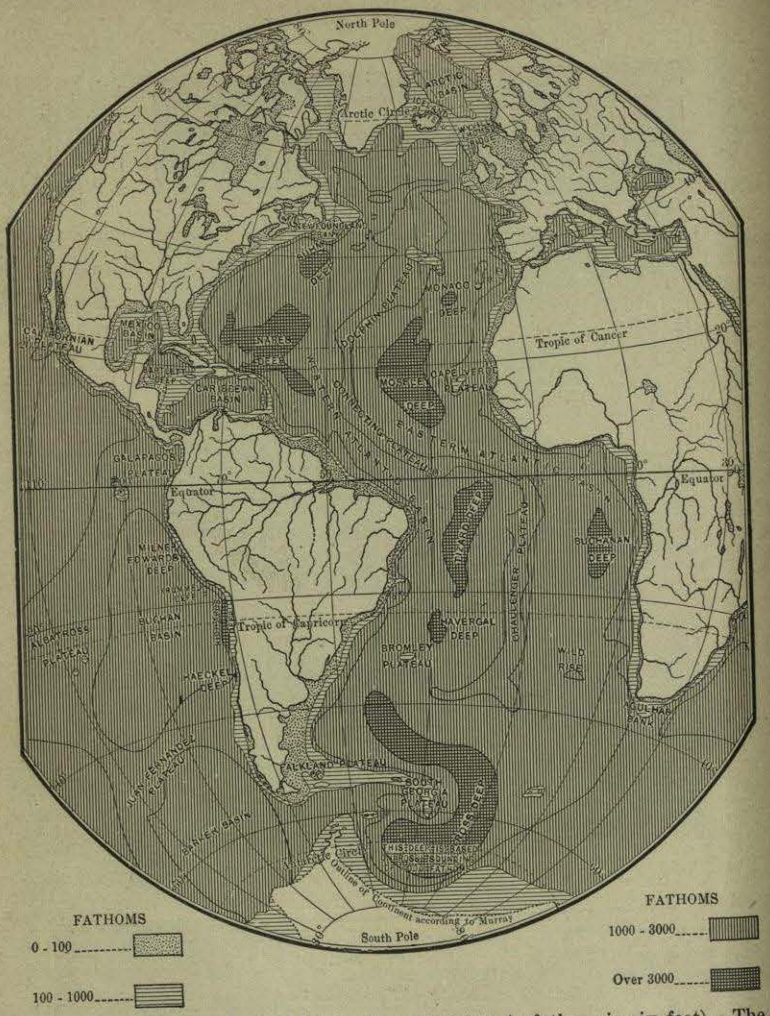

FIG. 314. — The depths of the Atlantic in fathoms (a fathom is six feet). The mid-Atlantic ridge is called Dolphin, Connecting, and Challenger plateaus. Note the continental shelves, dotted.

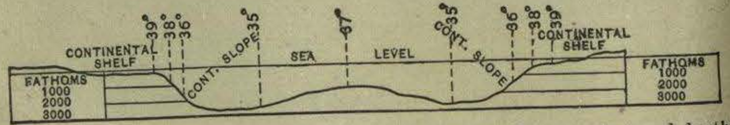

FIG. 315. — Section to show, in diagram, the conditions of temperature and depth in the Atlantic. Ocean depth and width of continental shelf greatly exaggerated. The raised portion in the center represents the mid-Atlantic ridge.

Summary. — *For a study of the ocean, or oceanography, there have been numerous government exploring expeditions, one of whose objects has been to determine the best lines for cables. In the study of the ocean bottom the depth, nature of the water, nature of the bottom, temperature, and kind of animal life are usually determined.*

125. Ocean Basins. — Exploration has shown that the ocean bottoms are mainly vast submarine plains (Figs. 313, 316). Beyond the continental slopes (p. 22) almost the entire ocean floor is a monotonous plain, occupying about two thirds of the earth's surface (Fig. 19). Here and there a portion is sunk below the rest, forming a *deep* (Fig. 314); and here and there volcanic peaks or mountain ridges rise from the ocean floor (Fig. 313), sometimes reaching above the surface. But these elevations and depressions are only exceptions to the general levelness.

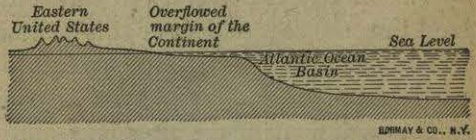

FIG. 316. — Rising of the ocean water over the continental slope overflowing the continent margin or shelf (p. 72).

The Blake deep, not far from Porto Rico, is the deepest known point in the Atlantic Ocean, 27,360 feet (Fig. 313). There are a number of volcanic peaks in the Atlantic, such as the Bermudas, the Azores, the Canaries, Cape Verde Islands, and St. Helena. In the mid-Atlantic there is a low, irregular elevation, or a series of submarine plateaus (Fig. 314), sometimes called the *mid-Atlantic ridge* (Fig. 315). There are deeps on both sides of it. This upraised portion extends the whole length of the Atlantic, usually several thousand feet beneath the surface.

There are hundreds of volcanic peaks in the open Indian and Pacific oceans (Fig. 313), usually in chains along the crests of submarine mountain uplifts, — for example, the Hawaiian chain, and the Ladrone chain, of which Guam is one peak. The deepest known point in any ocean, 31,600 feet, is the Challenger deep, near Guam. The Aldrich deep, near New Zealand, is 30,930 feet; and the Tuscarora deep, east of Japan, 27,930 feet.

Little is known about the Arctic and Southern oceans; but Nansen found a depth of over 12,000 feet in the Arctic, and parts of the Southern Ocean are also known to be very deep.

Summary. — *Beyond the continental slope is a vast expanse of plain, covering about two thirds of the earth's surface. There are occasional deeps sunk below its general level, and volcanic cones and mountain ridges rising above it.*

126. Deposits on the Ocean Bottom. — (A) *Rock Fragments.* — The wind, rain, rivers, and waves drag fragments from the land into the sea. Most of this sediment settles in the quiet water near the coast; but currents drift some of the finer particles out to sea, even to the edge of the continental shelf.

This sediment fills depressions and tends to smooth over the irregularities of the continental shelf; and, by its accumulation, it makes beds of sedimentary rock, coarsest near the coast (p. 32). Remains of ocean animals also accumulate on the bottom and add to the deposit of sediment, being preserved in the rocks as fossils.

FIG. 317. — A magnified sample of globigerina ooze from the ocean bottom.

Summary. — *Near the continents the ocean bottom is covered with layers of rock fragments derived from the land.*

(B) *Ocean-bottom Oozes.* — So little rock waste is dragged far out to sea that the contribution of animal remains exceeds that of rock waste. More than a third of the ocean bottom is covered with an ooze, composed mainly of animal and plant remains. This deposit contains a small

percentage of rock fragments, especially pieces of volcanic ash and pumice that, on becoming water-logged, have settled to the bottom. The ocean-bottom ooze is made partly of organisms that live on the bottom, but mainly of the shells of microscopic organisms that live in vast numbers in the surface waters and, on dying, settle to the bottom.

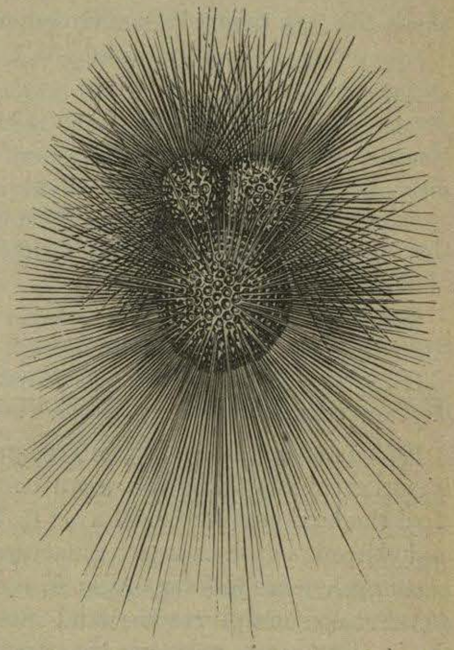

FIG. 318. — A specimen of Globigerina from the surface, greatly magnified.

The ocean-bottom ooze is given different names according to the organisms that are most abundant. Thus a large part of the ocean-bottom deposit is called *globigerina ooze* (Fig. 317), because of the abundance of microscopic Globigerina (Fig. 318). Chalk is a similar ooze deposited on the bottom of ancient seas. There is also *pteropod* and *diatom ooze.* The latter is made of siliceous parts of microscopic diatom plants which thrive especially in the cold waters of the Southern Ocean.

Summary. — *Far from land, where there is little rock waste, the ocean bottom is covered with globigerina and other oozes, made largely of the remains of organisms, mostly microscopic surface forms.*

(C) *Red Clay.* — The shells that sink to make globigerina ooze are composed of carbonate of lime, but contain a very small percentage of other substances, such as iron and silica. In the very deep ocean water (12,000 to 15,000 feet or more), which contains much carbon dioxide, these limy shells are dissolved; but the iron, silica, etc., are not so readily soluble, and they pass on to the bottom forming a clay, colored red by iron oxide. More than a third of the ocean bottom is covered with this red clay, whose rate of deposit must be very slow since it is formed of the very small insoluble portion of shells that are themselves microscopic.

Other facts further prove that the red clay is formed with wonderful slowness. Scattered through it are fragments of pumice, bits of meteoric iron, the teeth of sharks, and the ear bones of whales. There are not many whales or sharks in one place, nor are many meteorites falling. If the red clay were not accumulating very slowly, these objects would be so deeply covered that a small dredge would rarely find any; yet deep-sea dredging often brings them to the surface.

Summary. — *Red clay covers the deeper parts of the ocean bottom; that is, over one third of the entire ocean floor. It is a very slowly forming deposit, made of the insoluble remnants of microscopic shells that have been dissolved in the deep-sea water.*

127. Land and Ocean-bottom Topography. — There are three important reasons why the ocean bottom is far more regular than the land surface (p. 21). (1) While mountain folding and volcanic action cause irregularities both on land and ocean bottom, they are less important in the sea than on the land. (2) Erosion sculptures the land into hills and valleys; but the ocean water protects the bottom from these agents. (3) Sediment washed from the lands, and the settling of organisms to the bottom, tend to smooth the sea floor.

Because of these facts, if a smooth sea-bottom plain is raised into the air, it is soon carved by erosion into a series of hills and valleys; but if an irregular, hilly land is sunk beneath the sea, it is soon smoothed over by a blanket of sediment (p. 72). There is a striking difference between the widespread smoothness of ocean-bottom plains and the pleasing irregularity of the lands.

Summary. — *The ocean bottom is far smoother than the lands because of* (1) *less mountain folding and volcanic action;* (2) *absence of erosion; and* (3) *widespread deposit of sediment.*

THE OCEAN WATER.

128. Surface of the Sea. — Elevations on the land are measured from *sea level*, by which is meant the approach to a spherical form which the water assumes under the pull of gravity (p. 8). The level of the sea is not perfectly in accord with the spherical form of the earth; for the curved water surface is distorted a little by the attraction of the continents, slightly raising its level near the coast. Winds and storms (p. 271) cause local disturbances of sea level; but, as soon as the disturbing cause has passed, gravity draws the water back to its former level.

There are two causes which are slowly operating to change the level of the sea. The less important of these is the deposit of sediment, which tends to slowly raise sea level. It would take long periods of time for this to produce a great effect, for there is a vast amount of water to be raised. Even if all of North America above sea level were put into the Atlantic, the surface of the oceans would not be raised many feet. The second cause for change in level is movement of the ocean bottoms. There is good reason for believing that, during past ages, the ocean basins have been slowly growing deeper. The effect of such a movement would be to gradually withdraw the waters from the lands.

Summary. — *Sea level is slightly disturbed by the attraction of the continents; locally, and for short times, by winds and storms; and very slowly by* (1) *the deposit of sediment in the oceans and* (2) *the sinking of the ocean bottom.*

129. Composition of Sea Water. — Every one is familiar with the saltness of the sea. Probably salt and other mineral substances were held in solution when the oceans first gathered; but certainly some is being added every day. The vapor that rises from the ocean does not remove these mineral substances; but when it falls on the land as rain, it begins to wash more dissolved mineral matter into the sea (p. 51). It would seem, therefore, that the ocean must be growing steadily salter.

About three and a half per cent of ocean water is dissolved mineral matter, more than three quarters of which is common salt. Magnesium chloride and magnesium, calcium, and potassium sulphates are also present; and, in very small quantities, there are many other substances, even including compounds of gold and silver. If all the salt of the oceans could be removed, it would make a layer about 400 feet thick over the earth. In many places where the climate is dry, salt is obtained by evaporating sea water; and many salt beds, like that in central New York, were formed in past ages by the evaporation of the water in arms of the sea, cut off as the Caspian is to-day.

Carbonate of lime, though present in very small quantities, is another important mineral substance in sea water. Many ocean animals, such as corals and shell-fish, use it in the growth of their shells and skeletons. On the death of the animals these have accumulated in beds of limestone which, raised to form land, are now used in building, smelting iron, and making lime.

Some air is mixed with all ocean water, being present even on the ocean bottom, where it is brought by slowly moving currents. A few sea animals, such as the seals and whales, come to the surface to breathe; but the great majority require so little oxygen that they are able to obtain what they need from the air that is mixed with the sea water. Without it most of the ocean animals could not live.

Summary. — *Salt and other mineral substances, including carbonate of lime, of which shells are made, are being constantly washed from the land into the sea. Air mixed with the water supplies the oxygen which makes most of the ocean life possible.*

130. Density and Pressure of Sea Water. — Salt water is heavier, or has a greater density, than fresh water. Calling fresh water 1, the average density of ocean water at the surface is about 1.026. The density is less than the average in the rainy tropical belt, and also near the mouths of great rivers, where a large amount of fresh water is added. It is greater than the average where there is much evaporation, as in the dry trade-wind belt, and in seas inclosed by warm, arid lands, like the Red and Mediterranean seas.

There is an enormous pressure on the bottom of deep oceans. At the depth of a mile every square inch bears a weight of over a ton of water, and the pressure on the bottom of the Aldrich deep is nearly six tons to every square inch. One might expect that so great a weight of water would crush the animals on the ocean bottom; but it produces no more effect on them than does the weight of air (about 15 pounds to the square inch) which our bodies bear.

The reason why this great pressure is not felt is that it affects all parts of the body, both within and without. When deep-sea fishes are brought to the surface, however, and the pressure from outside is reduced, that from within opens cracks in their bodies and often causes their eyes to protrude.

Water, unlike air, is not much compressed, even under the great load that weighs down on the bottom layers. Therefore its density at the bottom does not differ greatly from that at the surface. If it were much compressed, as air is, it might become so dense that objects could not sink through it to the bottom. They would then float around in the dense layers.

Summary. — *Salt water is denser than fresh water; but its density varies somewhat. There is an enormous pressure on the ocean bottom; but, since water is not much compressed under pressure, its density is not greatly increased at the bottom.*

131. Color and Light. — Sunlight illuminates the upper layers of the sea and reaches to the bottom of shallow water. The beautiful blue of the open ocean is partly due to the reflection of the color of the sky, but chiefly to the same cause which makes the sky blue (p. 233). Sunlight is made of waves of many colors, and in their passage through the water they are separated, or scattered, some of them (the indigo and blue) being reflected back, giving the water its color. Near the shore, where there is more sediment, the green waves are reflected, giving the water its green color. The yellow water near the mouth of the Yellow River of China is colored by the mud that the river brings; the color of the Red Sea is due to minute reddish organisms that float in it.

No sunlight penetrates to the bottom of the deep sea, which is darker than the darkest night. Having little use for eyes, many of the deep-sea fish are blind; but others have eyes, and many are brilliantly colored. These eyes and colors are doubtless of use because of the phosphorescent glow, like that of the firefly, which many deep-sea animals emit. Indeed, some of the fish have feelers, phosphorescent on the end, which have been called deep-sea lanterns. Phosphorescence is also emitted by many surface animals, and a boat often leaves behind it a trail of faint phosphorescent light, made by the multitude of animalculæ that its passage has disturbed.

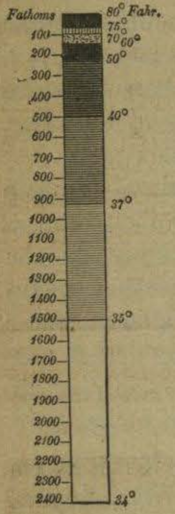

FIG. 319. — Normal descent of ocean temperature at the equator.

Summary. — *The color of the sea is due to the scattering of the waves that compose white light, and the reflection of some of them, such as green, blue, or indigo. No sunlight reaches the ocean bottom, but some of the animals emit a phosphorescent glow.*

132. Temperature of the Oceans. — The surface layers of ocean water are warmed by the sun. Accordingly, while the waters of the frigid zones are nearly at the freezing point of salt water (28° or 29°), tropical waters are warmed to 80° or 85° (Fig. 320). In the inclosed Red Sea, where the

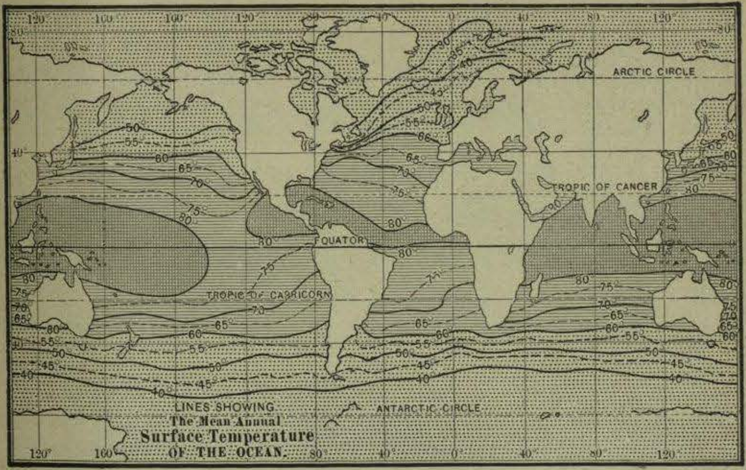

FIG. 320. — Ocean-surface temperature. The effect of the land, and of ocean currents, makes the temperature lines of the northern ocean far more irregular than those in the southern hemisphere. On an outline map of the world make a sketch map similar to this.

FIG. 321. — The advance of waves on a beach, forming surf.

FIG. 322.—A United States government ship (the *Wateree*) stranded on the land in Chile by an earthquake wave in 1869. The surf line is seen one eighth of a mile beyond the farther ship.

FIG. 323.—The bore wave at Moncton, New Brunswick.

entrance of cooler currents is impossible, the temperature may rise to 90° or 95°. Ocean currents greatly influence the temperature of ocean water (p. 194).

Since the sun's rays penetrate only the upper layers of the ocean, deep-sea water is not directly influenced by them. If the surface water is warm, the temperature decreases rapidly in the upper layers, then slowly down to the bottom (Figs. 319, 324). Everywhere, even in the torrid zone, the temperature of the ocean bottom is low (Fig. 325); and about four fifths of the ocean water has a temperature of less than 40°.

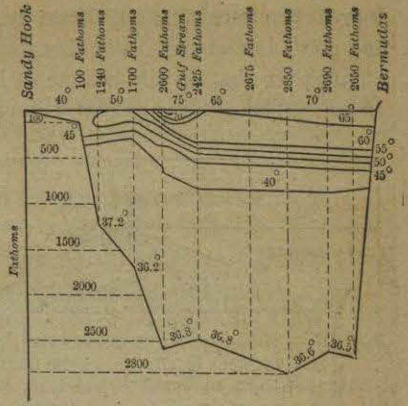

FIG. 324.—Section of the ocean from New York to Bermuda, showing the temperature at various depths.

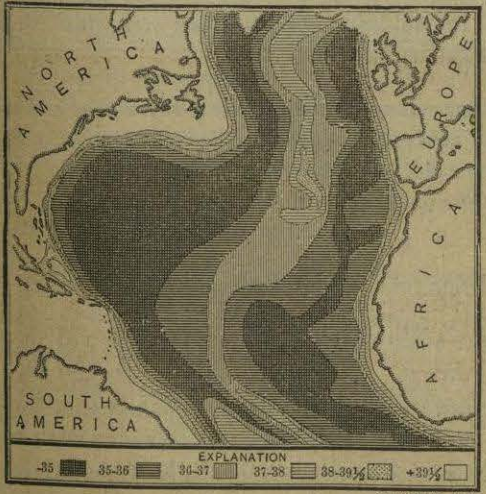

FIG. 325.—Temperature on the bottom of the North Atlantic. The band of higher temperature is on the mid-Atlantic ridge (see Fig. 315).

The explanation of the cold water in the deep sea is that water becomes more dense on cooling, and consequently sinks. While fresh water ceases sinking at 39° (p. 166), salt water continues to increase in density, and, therefore, to sink, almost until its freezing point is reached. For this reason ocean-bottom water is much colder than that on the bottom of lakes; it may, in fact, be as low as 29°. The settling of cold water in the frigid and cold temperate zones starts a slow circulation along the ocean bottom toward the warm belt, where there is a slow rising. It is this circulation which supplies deep-sea animals with the air they need for breathing.

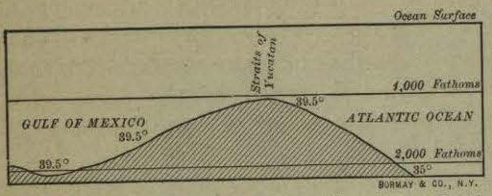

FIG. 326. — The temperature in the Atlantic at a depth of 2000 fathoms is 35°; but in the Gulf of Mexico, at that depth, only 39.5°, which is the temperature at the depth of the barrier (1000 fathoms) over which the water enters the Gulf from the Atlantic.

One of the best proofs of this slow circulation is furnished by such seas as the Gulf of Mexico and the Mediterranean, which are partly shut off from the open ocean. In these seas the decrease in temperature continues down to the level of the barrier, but no lower, because the coldest water that can creep into them is that at the level of the barrier (Fig. 326).

Summary. — *The temperature of the surface water varies with the climate; but settling of cold water, causing a slow circulation, makes the deep sea everywhere cold. Inclosed sea bottoms have the same temperature as that of the open ocean at the level of the barrier.*

MOVEMENTS OF THE OCEAN WATER.

133. Wind Waves. — Blowing on the surface of a dish of water causes small waves. These are similar to the large waves raised on the ocean by the friction of winds that blow over its surface. The water itself does not advance with the wave, but moves up and down, with a slight forward and backward movement. It is the *form* of the wave that advances, as a wave may be made to pass through a rope by shaking it vigorously. Therefore a boat, instead of moving forward, rises and falls as each wave passes under it; but it is also carried forward and backward a little.

Some of the great ocean waves, raised during heavy gales, have a height of from 30 to 50 feet, measured from the top, or *crest*, to the depression, or *trough*, between two waves. Then the sea presents a wild sight, as the great waves come down upon a ship, their crests broken and whitened by the fierce wind. The wind mixes much air with the ocean water in the foam and spray of these white crests, or *whitecaps* (Fig. 341).

Such waves, moving at the rate of 40 or 50 miles an hour, sometimes dash over the decks, carrying all loose objects along, and even tearing away massive wood and iron work. Even great ocean steamers are, at times, forced to change their course to avoid the danger of being upset by the approach of these huge waves from one side. To smaller boats they are very dangerous, and many a fishing schooner (Fig. 341) has been sunk by them.

The use of oil at sea is now common in violent gales. Dropped on the surface, the oil spreads in all directions; and, as the oily surface offers less resistance to wind, the waves are much less broken. There is then less danger of waves coming aboard.

Waves often appear when no wind is blowing, and even when the sea is smooth and glassy. They were formed in some place where the wind was high, and have traveled far beyond their place of origin. Such waves are known as *rollers*, or *ground swell*. Because waves travel so far, no part of the open ocean is ever entirely free from some form of wave or swell.

In shallow water the free movement of waves is interfered with by the bottom, the wave grows higher, its front becomes steeper, and it finally topples over (Fig. 327). Then tons of water are hurled bodily forward as *surf* or *breakers* (Fig. 321), striking the shore with tremendous force.

A current, called the *undertow* (Fig. 327), flows outward along the bottom beneath the incoming breakers. On many wave-beaten coasts the undertow is so strong as to be a source of danger to bathers, who are caught by it and held under water.

Some of the rock fragments that are dislodged from cliffs and ground up on the beaches, are moved offshore in the undertow. Others are pushed along the coast (1) by the breaking of waves which reach the coast diagonally, and (2) by the slow wind-formed surface current (Fig. 327), which moves in the direction the wind is blowing.

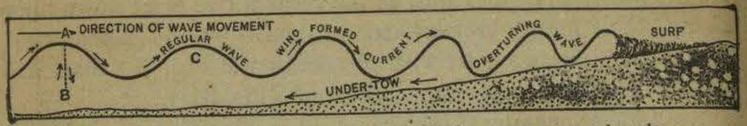

FIG. 327.—Diagram to show approach of a wave upon a beach.

Summary.— *Waves, caused by friction of wind, are a rising and falling of the water, the wave form moving forward, often far beyond the place of origin. They break on the coast with great force, tearing rocks from the cliffs and grinding them on the beaches, moving some of the fragments offshore in the undertow, some along the coast.*

134. Other Waves. — Tap lightly on the bottom of a pan of water, and the water rises in a low dome. An earthquake shock in the ocean produces a similar wave, reaching from the bottom of the sea to the surface. The water may not be raised more than a fraction of an inch, but the disturbance is so deep and affects so much water that, when the wave approaches a neighboring coast, it rises higher and higher. Such a wave may then rise to a height of more than 100 feet, rushing perhaps a mile or more inland, carrying everything before it, and leaving vessels stranded (Fig. 322). Tens of thousands of people have been drowned by a single earthquake wave (p. 119).

Fortunately such waves are not common in many parts of the world, though Japan, the East Indies, and the coast of Chile and Peru are subject to them. The waves travel great distances, some from Asia reaching the California coast; but, so far away, they are too much spread out to be destructive.

The discharge of an iceberg from a glacier (p. 145), or the breaking up of an iceberg as it runs aground, starts a similar

FIG. 328.—High tide near Bourne, Mass.

FIG. 329.—Low tide at same place as above. Describe the difference.