be studied. Note their force, form, and effects. (7) If by the seashore, the tides should be studied. Observe time of low and high tides for three successive days. These facts may be obtained from an almanac, or better, from the *Tide Tables* published by the U. S. Coast Survey at Washington, the tables for the year, for the Atlantic (15 cents) and Pacific (10 cents) coasts. Observe the time of spring and neap tides. How do they compare with the phases of the moon? What is the range of the tide in each case? Are there any tidal currents near at hand? Are the tides of any importance in your harbor? That is, do they do any harm or good? (8) On cross-section paper, plot a curve to represent the high and low tide for a month (obtaining the facts from the Tide Tables). Let each of twelve students do a different month and then paste them all together. Above the curves indicate each quarter of the moon. Have the students study these to see how closely the phases of the moon coincide with variations in range of the tide. Let the vertical side of each square represent a foot of tidal rise, and the horizontal side, three hours of time. (9) On an outline map of the world sketch the ocean currents from the chart in the book (Fig. 338).

Reference Books. — THOMPSON, *Depths of the Sea*, 2 vols., Macmillan Co., New York, 1873, $7.50; *The Atlantic*, Macmillan & Co., London, 1877 (out of print); AGASSIZ, *Three Cruises of the Blake*, 2 vols., Houghton, Mifflin & Co., Boston, 1888, $8.00; WILD, *Thalassa*, Marcus Ward & Co., London, 1877, 12 shillings; MOSELEY, *Notes by a Naturalist*, Murray, London, 1892, 9 shillings; SIGSBEE, *Deep Sea Sounding and Dredging*, U. S. Coast Survey, Washington, D.C., 1880; TANNER, *Deep Sea Exploration*, p. 1, 1892 Report, U. S. Fish Commission, Washington, D.C.; DARWIN, *The Tides*, Houghton, Mifflin & Co., Boston, 1898, $2.00; *Tide Tables for the Year*, U. S. Coast Survey, Washington, $0.25; PILLSBURY, *The Gulf Stream*, Annual Report, U. S. Coast Survey for 1890, Appendix 10, Washington, D.C.

CHAPTER XI.

SHORE LINES.

142. Importance of Shore Lines. — Some of the busiest centers of human industry are located on or near the seacoast. The great and increasing trade that uses the ocean as a highway converges toward these centers; and to and from them, by river, canal, and railway, there is a steady movement of goods for shipment or for distribution.

So important is the coast line that charts have been made of all parts of it that are reached by the vessels of commerce. Governments maintain bureaus, like the United States Coast Survey, whose duty it is to map the coast, to determine by accurate soundings the depth of water, and to detect and record all changes, such as shifting of channels, which might endanger ships. In addition, our government annually spends large sums of money for the improvement of harbors. This money is used in building breakwaters where no natural harbors exist; in dredging out the sand and mud that waves and currents deposit; and in building jetties and other structures to control the deposits of sediment and keep channels clear.

The approach to the coast, especially in times of storm and fog, is accompanied by so many dangers — from hidden reefs, islands, and projecting headlands — that all civilized nations spend large sums in the effort to lessen these perils. To warn sailors, or to guide them into port, lighthouses are built on exposed points and light-ships anchored on dangerous shoals; and, on the charts, the location and characteristics of these lights are shown. On approaching the coast at night, the first sign of land is the gleam of the lighthouse; and by the color, brilliancy, nature of flashes, or other device, the mariner knows his position. During fogs and stormy weather a fog-horn adds its warning note.

Specially trained pilots are licensed to guide ships into port; and buoys are placed at frequent intervals to mark the channel. Some of the buoys, placed over reefs or near dangerous currents, have bells that are rung, or whistles that are blown, by the rocking of the waves, to warn the sailors of danger. Even with all these precautions vessels far too frequently run ashore. To rescue the shipwrecked, life-saving stations are established at frequent intervals by state and national governments; and in them men with strong life-boats, lines, and other life-saving apparatus are ever ready for the call of distress.

The coast line has become of importance to many people as a vacation resort. In summer, when the interior of the country is hot, the seacoast is cool and pleasant; there are rocky coasts to scramble over, beaches to walk upon, surf to swim in, and boating and fishing to enjoy. Consequently, tens of thousands of people go to the seashore for a part or all of the summer.

Summary. — *The seacoast is the site of some of the busiest centers of human industry. It is so important that it is charted; harbors are built or dredged out; lighthouses, buoys, and other warnings and guides are placed along it; and life-saving stations are established. The seacoast is also an important summer resort.*

143. The Seacoast is ever changing. — Waves and currents are vigorously at work, wearing away the land (Fig. 347) and moving rock fragments to places of deposit; and rivers are ever pouring sediment into the sea. Along some coasts the waves are cutting back the cliffs (Fig. 344) at the rate of one or two feet a year (Fig. 358), as on the outer shore of Cape Cod and Martha's Vineyard. In other places, deposit is building out the coast, especially near river mouths (Fig. 345). Pisa, in the Middle Ages a seaport, is now several miles inland on the delta of the Arno, Leghorn being now the seaport for that region.

Change in level of the land (p. 35), even though slight in amount, produces a difference in the form of the coast.

A slight elevation brings cliffs, beaches, and sea-bottom plains (p. 72) above the reach of the waves; a slight depression, allowing the sea to enter the valleys, entirely alters the outline of the coast. An elevation or depression that in the interior would pass unnoticed, causes such changes in the seacoast that it cannot escape attention.

Since waves are ever at work, since deposits of sediment are always being made, and since the earth's crust is constantly rising or falling, any study of coast lines must be largely concerned with the effects of such changes.

Summary. — *The coast is being cut back by the waves in some places, and built out by deposits in others; and many changes are made by rising or sinking of the land.*

144. Elevated Sea-bottom Coasts. — The uplift of sea bottoms, forming coastal plains (p. 72), produces a low, flat, straight coast line, not generally fitted for dense settlement. Such coasts are found in southern United States, Yucatan, eastern Central America, and Argentina. The land back of the coast is often so level that it is swampy, unhealthful, and unfitted for agriculture.

In tropical lands, as in Central America and Africa, such plains are the seat of deadly malaria. Being made of soft, unconsolidated deposits of clay, sand, and gravel, the soil is often so sterile as to be unsuited to cultivation. Where the soil is fertile and not too damp, however, the level plains make excellent agricultural land; but the lack of good harbors is a handicap to development. Good harbors are rare, chiefly because the contact of the sea with a level plain makes a straight coast with few irregularities.

If a slight sinking occurs, as has been the case in southern United States, the sea enters the valleys, forming bays and harbors; but the harbors are likely to be poor, because the valleys of a coastal plain are shallow. Moreover, the waves and currents, working with loose rock fragments, quickly build sand bars, which skirt the coast, inclosing shallow lagoons, and even extending across the mouths of bays and harbors (Figs. 372, 373). A constant struggle is, therefore, necessary to prevent their entrances from being choked with sand.

Summary. — *Elevated sea-bottom plains are low, level, straight, skirted by sand bars, and have few harbors, and these mostly shallow and poor, even where sinking of the land has admitted the sea to the valleys. Such conditions do not favor dense settlement.*

145. Straight Mountainous Coasts. — The uplift of sea bottoms is sometimes accompanied by mountain folding. This either raises narrow strips of coastal plain, between the mountains and the sea, or else causes the mountains to rise directly out of the sea. Where the mountains rise from the ocean in long chains of folds, they produce a straight and regular coast line.

Such a coast exists in western America, from Oregon to central Chile (Fig. 346). Along this coast there are few harbors, bays, capes, and peninsulas. In many places the mountains rise directly from the sea; elsewhere at the inner margin of a narrow coastal plain (Fig. 117). The sea bottom slopes rapidly, and, in a short distance from the coast, the water is 15,000 or 20,000 feet deep (p. 20).

This coast has been recently elevated, and, in many places, is still rising. Both in 1822 and 1835 a part of the coast of Chile was suddenly raised 2 or 3 feet; and beaches and sea shells on the mountain slopes prove other recent uplifts.

For several reasons, such coasts are not suited to dense populations and high development of industries. (1) There are so few harbors that a place, even though on the shore, may be a long distance from a shipping point. (2) Between the mountains and the sea there is, at best, only a narrow strip of fairly level land, limiting the resources. (3) The mountains act as a barrier to inland communication, few, if any, large streams breaking across them. Peru and Chile have only recently, and at great expense, opened railway communication across the Andes barrier (Fig. 184). The scattered seaports, therefore, have little country tributary to them.

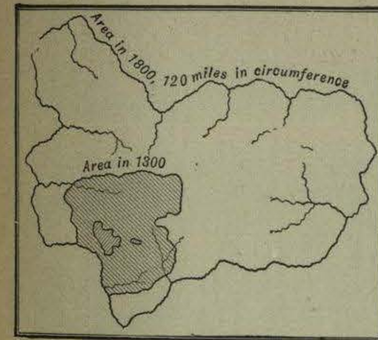

FIG. 344. — Island of Heligoland, in the North Sea. The outer line represents it in the year 800, when its circumference was 120 miles; large shaded area in 1300, circumference reduced by wave erosion to 45 miles; inner shaded area in 1649, circumference only 8 miles.

FIG. 345. — Changes in the coast of a part of Asia Minor, by deposits made chiefly by the river Mæander (from which our word "meander" is derived).

FIG. 346. — The straight, mountainous coast of western South America.

FIG. 347. — An old pump on the coast of Ireland, showing how the waves have cut away the land.

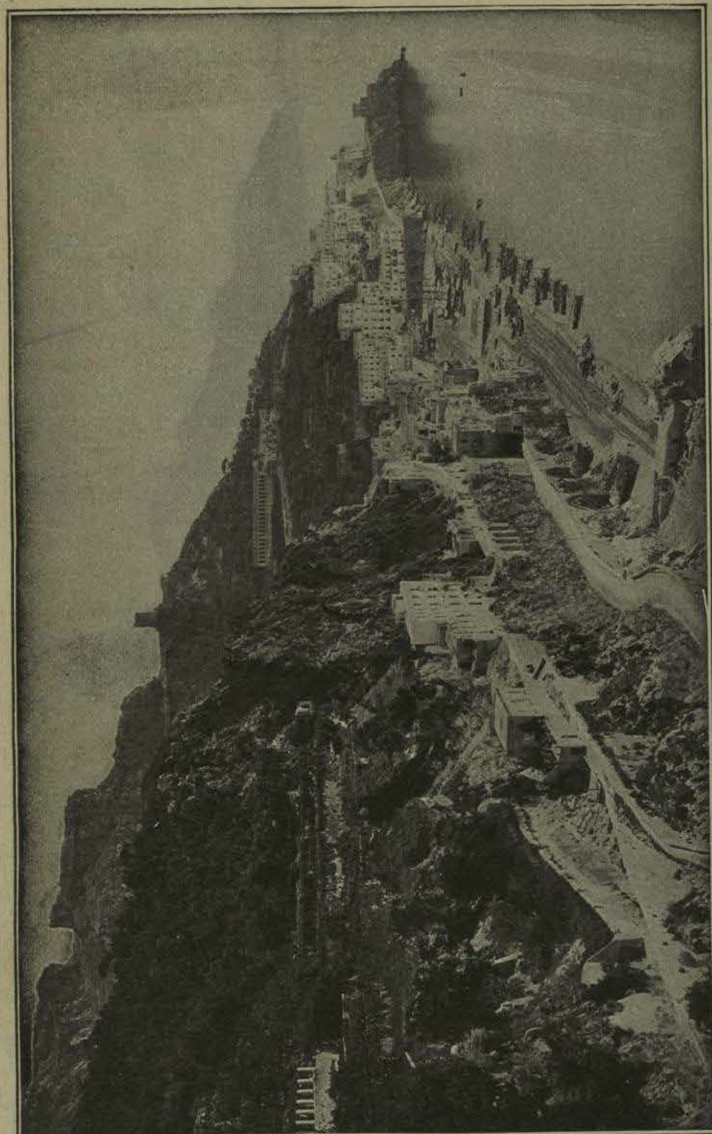

FIG. 348. — The Italian coast near Amalfi, showing the houses clinging to the hillside; the road cut and built on the cliff side, and even tunneling through it; and Amalfi itself built on a small stream delta.

Summary. — *Long chains of mountains, rising from the sea, form straight coasts, as in western America. The scattered harbors, the narrow area of level land, and the mountain barrier render such coasts unsuited to dense settlement or high development of industries.*

146. Irregular Mountainous Coasts. — Mountain growth makes irregular coasts more commonly than straight ones. Irregular coasts result (1) when mountains rise as chains of islands near continents, as in the case of the West Indies, East Indies, Philippines, and Japanese Islands; (2) when the ranges extend out from the mainland as peninsulas, as in the case of Italy, Greece, Alaska, and the Malay Peninsula; and (3) when, between mountain ranges, parts of the crust sink, thus admitting the ocean and forming gulfs or seas, like the Gulf of California and the Mediterranean.

The Mediterranean is a broad, deep depression (over 14,000 feet in depth) between the mountains of Europe and Africa. It is almost cut off from the ocean where the Atlas Mountains of Africa nearly meet the mountains of Spain at the Straits of Gibraltar; it is almost connected with the ocean at the low Isthmus of Suez. Its coast line is very irregular, because there are so many short mountain chains, extending in different directions. These form the peninsulas of Tunis, Italy, Greece, and Asia Minor, besides many smaller projections; and also chains of islands, among which Cyprus, Crete, Sicily, the Balearic Isles, and Corsica and Sardinia are the largest. The mountain chain of Italy, extending through Sicily, and along a submarine ridge to the Tunis peninsula, almost cuts the Mediterranean in two.

Many other large seas, such as the Caribbean Sea, Gulf of Mexico, Japan Sea, China Sea, and Red Sea, are partly inclosed by mountain uplifts. Still smaller seas, bays, and even harbors have been made by the uplift of mountainous islands and peninsulas. Where there has been a later sinking, as in Greece, the entrance of the sea into the mountain valleys has made many small bays and deep harbors.

Irregular, mountainous coasts are better fitted for habitation than straight, mountainous coasts. Communication by land is difficult, and the coast line is often steep and rocky (Fig. 348); but the many harbors, the great length of the irregular coast, and the quiet water of the inclosed seas and bays all encourage navigation. It is largely because of these conditions that navigation early developed in the Mediterranean (p. 377). There are many places that, even to-day, can be reached only by ship; and the coasts, as in western Italy, are often so mountainous that a railway, although close by the sea, must pass through a series of tunnels near together. Wherever there is room for towns or villages, as on the delta of a small stream, the coast is well settled (Fig. 348); and, back of the coast, the settlement is especially dense along river valleys that furnish a pathway to the sea.

Summary. — *Uplift of mountainous islands and peninsulas, and sinking of the land between mountain folds, cause irregular coasts. Such coasts, like the Mediterranean, favor navigation because of the number of harbors, the length of the coast, and the quiet water; but they are frequently steep, rocky, and sparsely settled. Communication between places along them must often be by ship.*

147. Coasts of Drowned Lands. — Sinking of the land drowns a portion of it and makes the coast line irregular (Fig. 349), for the valleys are then transformed to bays, harbors, or estuaries. Sinking of the land has made San Francisco harbor (Fig. 350); it has made Massachusetts Bay, Boston harbor, and the other bays and harbors of New England; and it has drowned the lower Hudson (Fig. 351).

When the hills of a drowned land have been completely submerged, shoals and banks (p. 197) are formed in the sea. When the hills are only partially submerged, islands are formed (Fig. 353), like the British Isles, Newfoundland, and the thousands of islands in northeastern (Fig. 354) and northwestern America. Where there has not been submergence enough to completely surround the land, peninsulas are produced, like Scandinavia, Denmark, Nova Scotia, and innumerable capes and promontories (Fig. 354).

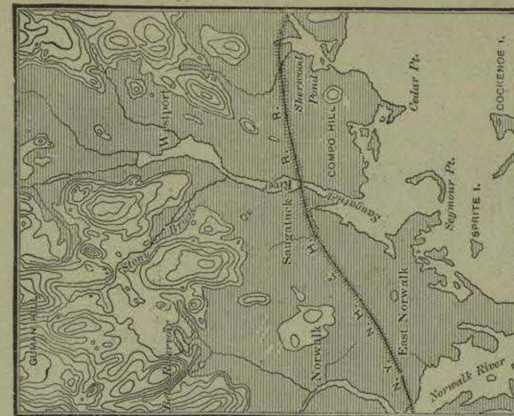

FIG. 349. — The shaded area shows the change in coast outline which would be caused in a part of southern Connecticut if the land should sink 100 feet.

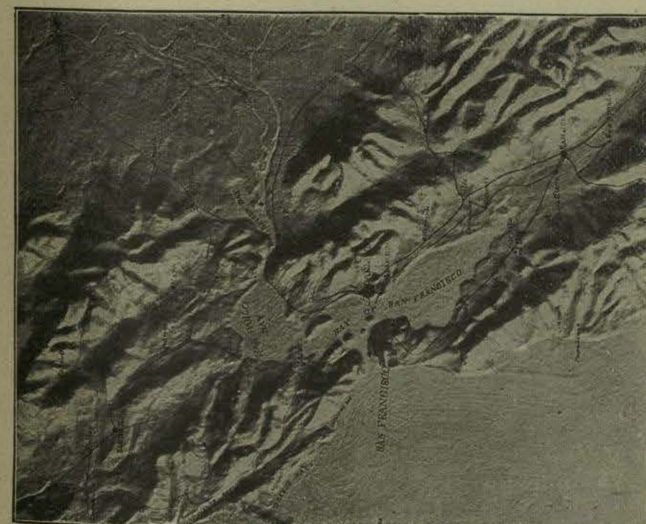

FIG. 350. — The harbor of San Francisco, showing the broad bay and the gap made by the Sacramento River in cutting across the Coast Ranges. Into this, sinking of the land has admitted the sea.

FIG. 351. — The drowned valley of the Hudson, looking north from West Point.

FIG. 352. — A Norwegian fiord.

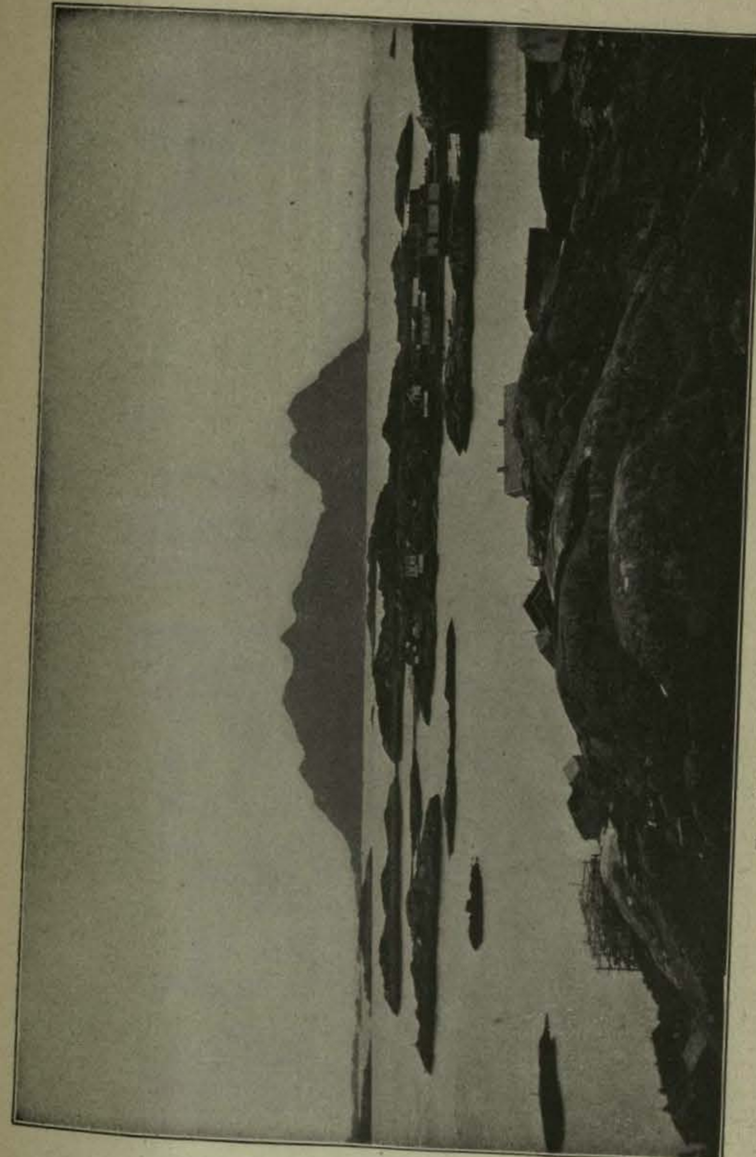

FIG. 353. — The drowned coast of a part of Norway.

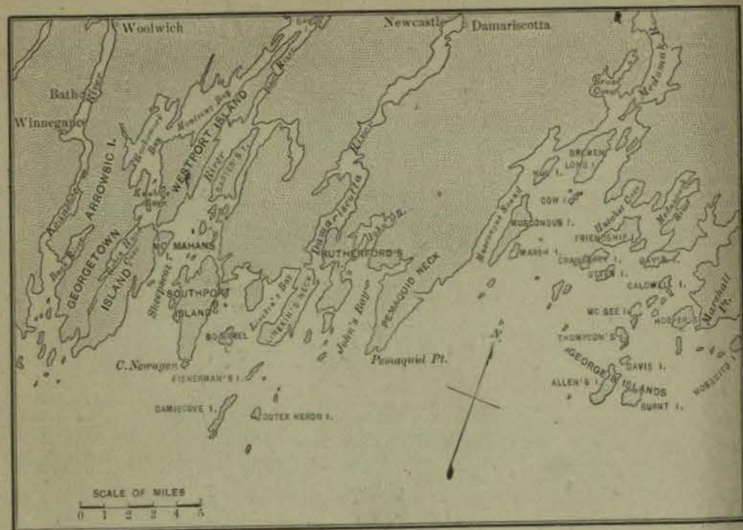

FIG. 354. — A sketch map of a part of the drowned coast of Maine. Measure the distance straight along the coast. Measure it along the greater irregularities.

FIG. 355. — A small bay, or chasm, which the waves have cut in the coast of Cape Ann, north of Boston. Here a narrow dike of trap rock (seen in the middle of the picture) crosses the more resistant granite.

The outline of a sunken coast depends upon the nature of the valleys that existed on the land before it was submerged. Grand fiords, with wonderful scenery, are formed where the sea has entered the deep, steep-sided, mountain valleys of Norway (Figs. 352, 356) and Alaska. These fiord valleys were first cut by streams, then broadened and deepened by glacial erosion. The Hudson is a fiord, and so is the Saguenay in Canada.

FIG. 356. — A Norwegian fiord.

Most fiord coasts, like that of Norway, are too steep and rugged for much settlement. The villages are usually on small deltas, and very often the only communication between them is by water. Such conditions account for the development of that race of hardy sailors, the Norsemen.

The coast south of New York is strikingly different from the rocky coast farther north. This difference is due to the fact that this is a region of soft rock and plains, crossed by broad valleys with gently sloping sides. The entrance of the sea into these has formed broad, shallow bays with gently rising margins, as in Delaware, Chesapeake, and Mobile bays. Along such coasts communication by land is easy and agriculture thrives.

There are several reasons why moderately low, irregular coasts, like those of the Middle States, New England, and England, are favorable to settlement and development. (1) There is an abundance of harbors, — in fact, as in Maine (Fig. 354), often far more than are needed. (2) The irregularity makes a very long coast line for fishing and navigation. (3) There are protected bays and sounds for fishing and navigation. (4) Sinking of the land opens up waterways to the interior. The Columbia, Hudson, and Thames are navigable to ocean ships solely because recent sinking has admitted the sea. Portland, New York, and London could not otherwise be important seaports.

The formation of islands cuts off connection with the mainland and produces very important effects on the inhabitants. Thus Newfoundland is so isolated that its interests are different from those of the Canadian provinces, and it has declined to join the Canadian Confederation. The sinking of the land, which separated Great Britain from Europe at the Strait of Dover, has protected the British from inroads of invaders by land, and has forced the development of navigation and a navy (p. 389).

Summary. — *Sinking of the land forms bays, harbors, and estuaries in valleys, and makes shoals, banks, islands, and peninsulas of hills, thus making the coast irregular. The submergence of mountainous regions forms fiords, and a rugged coast suited to navigation, but not to dense settlement. Regions of soft rock, when drowned, have broad, shallow bays with gently sloping sides, adapted to agriculture. Moderately low, irregular coasts favor development because of the harbors, the favorable conditions for fishing and navigation, and the opening of waterways to the interior. The formation of islands isolates people and greatly influences their history.*

148. Wave and Tide Work. — Waves are constantly battering at the coast line, cutting cliffs where possible and moving the fragments about (p. 186). Some of the sediment is dragged offshore by the undertow and tidal currents; some is drifted along the coast by the waves and the tidal and wind-formed currents. On rocky coasts this shore drift lodges between headlands, forming beaches (Fig. 364); on low, sandy coasts it is built into long sand bars (Fig. 372).

Waves and currents are accomplishing two ends by this work: (1) cutting back the land, (2) straightening the coast. An irregular coast will not long be tolerated by waves and currents; and, were it not for the fact that there are so many movements of the crust, the coast lines of the world would all be straight. When, therefore, we find an

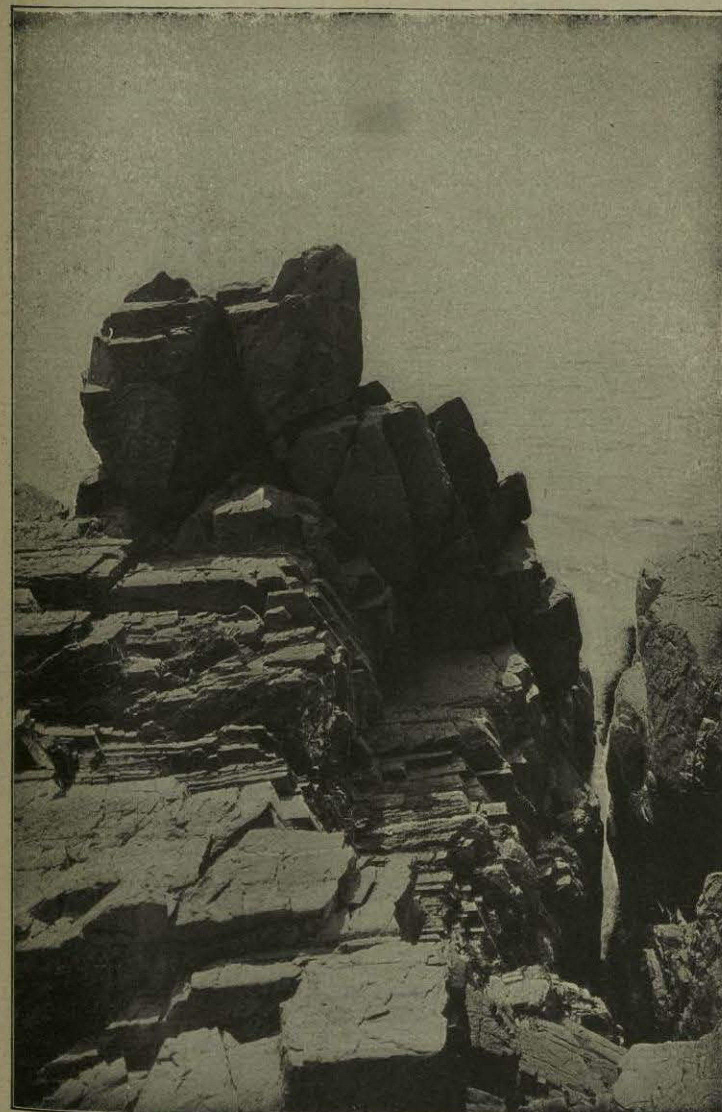

Fig. 357. — A wave-cut chasm in the rocks on the Maine coast.

Fig. 358. — A wave-cut cliff in the clay on the shore of Lake Ontario. This cliff is being cut backward at the rate of about two feet a year; and, by this cutting, trees are undermined and caused to slide down the cliff face.

Fig. 359. — A sea cave which the waves have cut on the Maine coast. The dark area in front is the seaweed mat which the high tide covers.

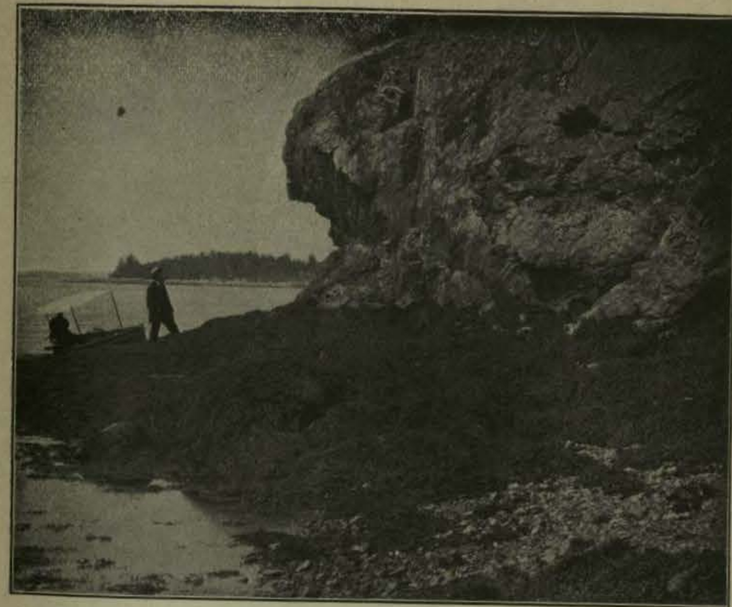

Fig. 360. — A rock cliff on the Maine coast, showing how the waves sometimes undercut, causing the hard rock to overhang. The dark area in the foreground is the seaweed mat, covered at high tide.

Fig. 361. — A cliff in glacial deposit on the Massachusetts coast. The waves have not been able to remove the large bowlders that were in the deposit, and they, therefore, remain as an offshore platform, showing that the land once extended out so far.

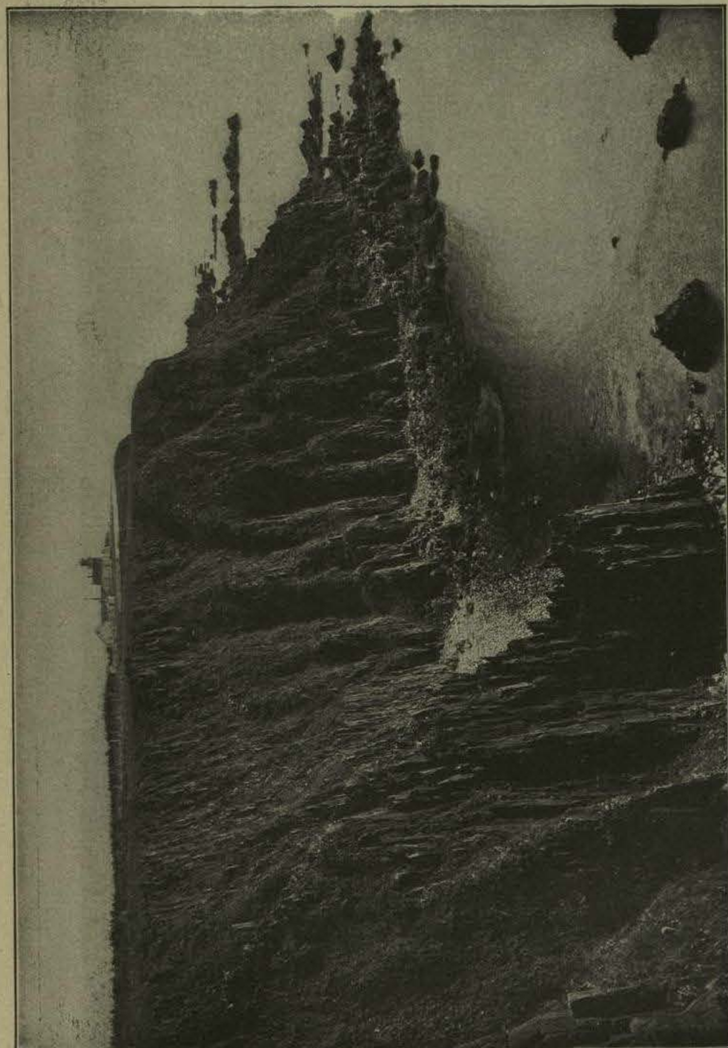

FIG. 362. — A sea cliff on the island of Grand Manan (Bay of Fundy) with a lighthouse on the top. Unconsumed portions of the cliff stand offshore as a platform of reefs. The base of the cliff is skirted with pebbles, with which the waves batter at the cliffs.

irregular coast, we may be certain that the shore has not stood long enough at that level for the waves and currents to straighten it. This work of straightening coast lines is done in two ways — (1) by cutting back the headlands and (2) by closing up and filling the indentations.

Summary. — *Waves and currents are attacking the headlands and moving the fragments either offshore or along the coast, in the latter case building beaches and bars. The result of this work is to straighten the coast.*

149. Sea Cliffs. — Where wave work is vigorous, as on headlands and on exposed island coasts, the waves are sawing into the land (Figs. 344, 347). The zone of most active wave work is almost exactly at the sea level, though the spray may dash to a height of 50 or 100 feet. The advancing breakers hurl against the cliffs tons of water, bearing sand, pebbles, and even bowlders. They act like battering rams, undercutting the cliffs along the surf line (Fig. 360), and thereby undermining the rock so that it falls and keeps the cliff face precipitous.

If made of hard rock, sea cliffs are very steep (Fig. 362), though weathering, aided by the salt spray, usually prevents them from becoming vertical. If made of clay or sand, the cliffs are steeply inclined and constantly sliding down (Figs. 358, 361, 367). On exposed coasts, sea cliffs may rise several hundred feet; but generally they are much lower.

Cliffs in which the rocks have uniform texture may be straight and regular; but if the strata vary, the waves discover the differences and make the shore irregular. Then *chasms* (Figs. 355, 357) and *sea caves* (Fig. 359) are cut in the cliffs along the weaker strata. These irregularities cannot be cut very far back into the land, nor to a very great breadth, because the force of the waves is soon worn out on the sides and bottom. For this reason, waves cannot carve out large bays.

Sea cliffs may be cut back for hundreds of feet, leaving a platform of rock (Figs. 361, 362) which the waves continue to plane down until they no longer break upon it. In the open ocean entire islands have been cut away by waves (Fig. 234), leaving only shoals or reefs. As the cliffs wear back, farms and houses are undermined and caused to tumble into the sea.

Such headlands, with their offshore platforms, are dangerous to navigation; and a vessel wrecked upon the wave-beaten reefs is doomed. There is little hope that the shipwrecked sailors can escape, for there is no landing place on the cliffs, and the waves are ever breaking on the reefs near their base. It is partly for this reason, and partly because of their height, that headland cliffs are commonly selected as the sites of lighthouses (Fig. 362).

Summary. — *The sawing of the waves into the land cuts sea cliffs, leaving offshore platforms as the cliffs are pushed back. Weathering prevents most cliffs from being vertical, but all are steep, even those in sand or clay. Where there are differences in the rocks, chasms, sea caves, and other small irregularities are produced. Headland cliffs and offshore platforms are dangerous to navigation.*

150. Beaches, Hooks, Bars, etc. — Bowlder (Fig. 363) and pebble beaches (Fig. 364) are built of the larger rock fragments, wrested from the cliffs and driven along the coast, till they lodge in bays. Smaller fragments make sand beaches (Fig. 365); and the still finer clay settles in the protected bays, harbors, and estuaries, forming mud banks and flats. Some fine-grained sands form ***quicksands***. In these are numerous particles of mica, which permit the sand grains to slip over one another when wet, so that an object sinks into the sand.

In little pockets between headlands there are often small "pocket" beaches, sometimes called "half moon" beaches, because of their crescentic shape (Figs. 363, 366). Behind them small ponds are often shut in. On exposed coasts these beaches are of bowlders or pebbles; in more protected places, of sand. The beaches serve as mills, in which rock fragments are ground so fine that they can be borne off by the currents and undertow. The rounded form of beach pebbles shows how they are rolled about.

FIG. 363. — A bowlder pocket-beach on the exposed coast of Cape Ann, Mass.

FIG. 364. — A pebble beach on the coast of Cape Ann, Mass. Notice how round the pebbles are. High waves reach clear to the top of the beach.

FIG. 365. — A sand beach, with sand dunes piled upon the landward side by the action of the winds.

FIG. 366.—A crescent beach in a small bay harbor on Santa Catalina Island, Cal. One portion of the cliffs that supply this beach is seen on the right, in the distance. There the waves have not quite consumed the land, but have left a part standing as an island.

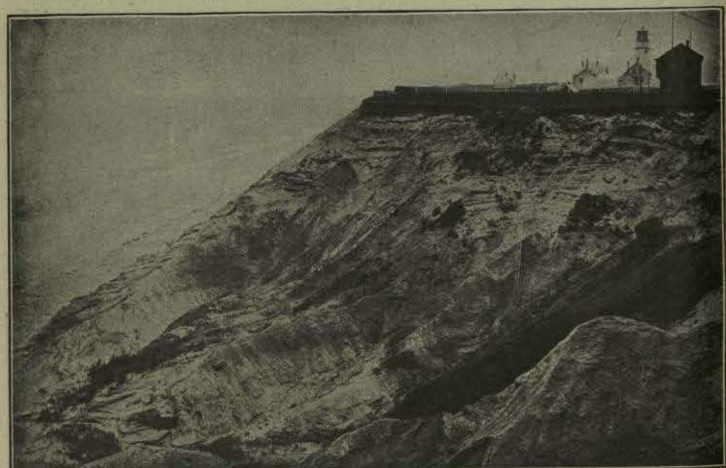

FIG. 367.—Highland Light cliff on the back shore of Cape Cod (Fig. 375). This cliff of loose sand is wearing back so fast that little vegetation is able to find root on its slipping face. It is supplying sand for the waves and currents to drift along the coast and build into sand bars and shoals.

FIG. 368.—A view of the Sandy Hook bar from the Navesink Highlands in New Jersey.

FIG. 369.—A bar joining a small island to the land on the coast of Sicily.

FIG. 370.—A bar at North Fairhaven, N.Y., on the shore of Lake Ontario, partly shutting in a broad bay. The opening is maintained by the outflow of water from the land streams. The pebbles of which this bar is made are supplied from a number of cliffs, of which Fig. 358 is one.