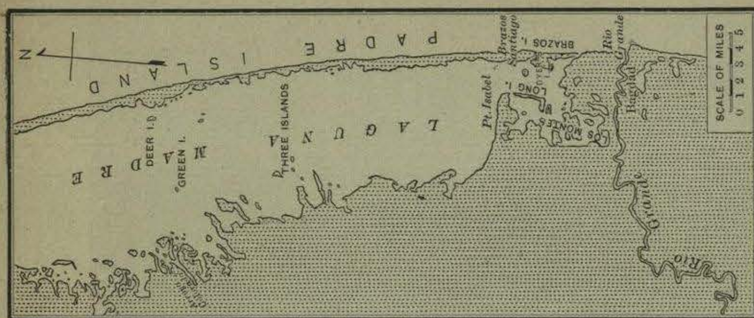

Fig. 371. — Southern part of the long offshore bar which extends northward, from the delta of the Rio Grande, along the Texas coast.

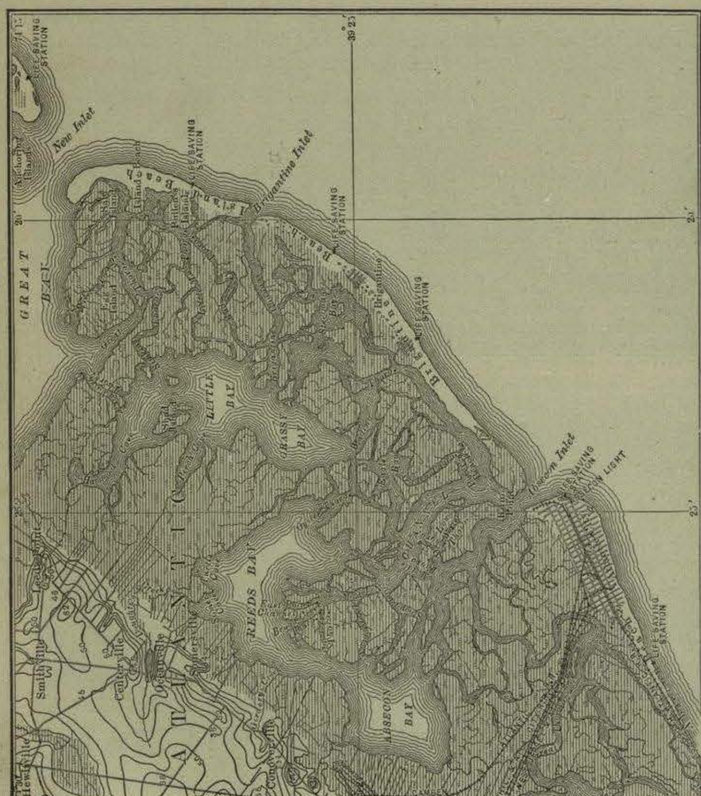

Fig. 372. — Offshore bar on the New Jersey coast. On the mainland, or *old-land*, there is a wave-cut cliff, made before the bar was thrown up (Fig. 387). Now the lagoon between this cliff and the offshore bar, or *new-land*, is being filled with sediment, a part of it being changed to salt marsh. (Atlantic City Sheet, U. S. Geological Survey Topographic Map.)

Some of the rock fragments that are moved along the coast are dropped at the entrance to bays, building bars across them (Fig. 373). If there is much drainage from the land, an opening through the bar will be maintained (Fig. 370); but if not, a bar may completely seal a bay (Fig. 373). A fresh-water pond then gathers behind the bar, slowly draining through it by seepage.

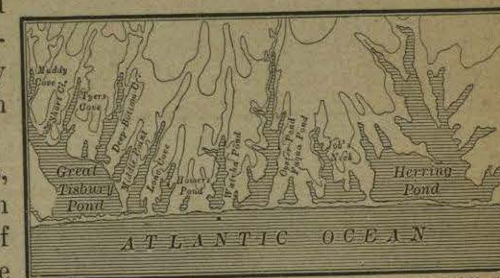

Fig. 373. — A portion of the south shore of Marthas Vineyard, showing how the growth of sand bars may straighten an irregular coast by shutting in the bays and changing them to ponds.

On many coasts, where there is an abundant supply of sand, long bars are built. For example, the waves are vigorously wearing back the high cliffs (Fig. 367) at Highland Light, Cape Cod, and building bars out of the sand (Fig. 375). In the same way Sandy Hook (Fig. 368) has been built of débris worn from the cliffs of the New Jersey shore.

Such bars may be straight, or they may be curved at one end, forming *hooks* (Fig. 374), like Sandy Hook (Fig. 368) and the curved end of Cape Cod (Fig. 375). In some places, often at bends in the shore, waves and currents from opposite directions drive pebbles or sand out into the water, building small points, or *spits*. Bars sometimes form an angle projecting seaward, making a *cusp*, like Capes Hatteras, Fear, Lookout, and Canaveral. Other bars are often built in the lee of islands (Fig. 369).

Summary. — *Rock fragments, drifted along the coast, build beaches in pockets, bars across bays, long bars where large quantities of sand are supplied; also hooks, spits, and cusps. The material varies from bowlders to sand, much of the fine clay going into the bays. The beaches are mills in which rock fragments are ground up.*

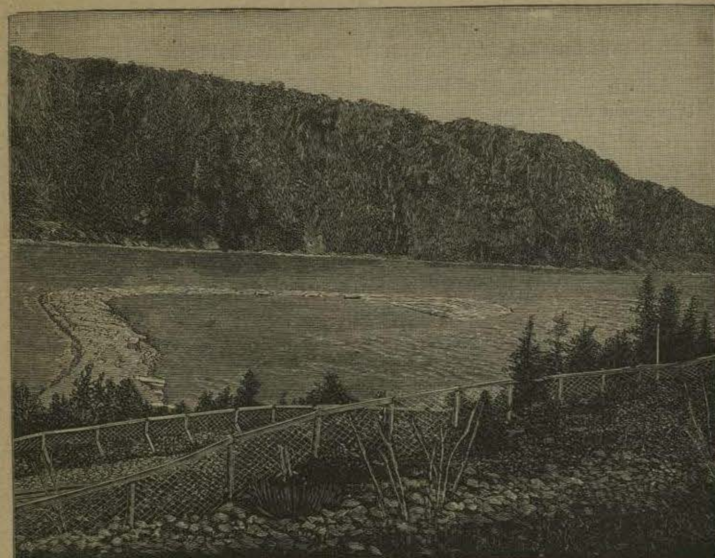

FIG. 374. — A hook in one of the Bras d'Or Lakes (really an arm of the sea) in Cape Breton Island, Nova Scotia. It is made of pebbles driven out into the water by the waves.

151. Offshore Bars. — From New Jersey to the Rio Grande most of the coast is faced by bars at some distance from the mainland, from which they are separated by shallow lagoons (Fig. 372). One of the longest of these bars extends along the Texas coast from the mouth of the Rio Grande (Fig. 371). River water enters the lagoons, some of it seeping through the bar, the remainder escaping through gaps that the outflowing and incoming tide are able to keep open. The movement of sand along the shore constantly threatens to close these channels; and for this reason, where the channels are used as harbor entrances, as at Galveston, it is necessary to build jetties to keep the entrance deep enough for large ships.

Such offshore bars, or *barrier beaches*, are thrown up where waves advance over a shallow bottom of unconsolidated sediment. The shallowness interferes with the onward movement of the waves, and where they commence to break, the sand is pushed up into a ridge or bar. The wind builds the bars still higher, raising sand dunes (Figs. 376, 377), sometimes 100 feet high. The waves gradually consume the sand bars, eating them away on the seaward side and pushing them back toward the land.

Beaches and bars are often useful as places for landing boats (Figs. 348, 366); and for bathing they are resorted to by hundreds of people. Offshore bars are, in addition, habitable, though usually so sterile that they are inhabited only by fishermen, lighthouse keepers, and pleasure seekers. Yet some bars, like the Sea Islands off the Georgia coast (Fig. 376), where the long-fibered Sea Island cotton is raised, are excellent farm land. Here and there, too, because of the absence of other kinds of harbors on such coasts, towns and cities, like Galveston, are built on the sand bars. The destruction at Galveston in 1900 (Fig. 429) proves that cities in such situations are in danger of inundation.

The sand that is drifted about in the building of sand bars often makes dangerous shoals. The shifting sands south of Cape Cod, and those near Sandy Hook, are obstacles to safe navigation; and, on the shoals at the end of Cape Hatteras, many ships have been wrecked.

Summary. — *Where the waves break on shallow sea bottoms the sand is pushed up into ridges, or offshore bars, which are raised still higher by the wind. Such bars, inclosing lagoons, are found along much of the coast from New Jersey to the Rio Grande.*

152. Sand Dunes of the Seacoast. — On beaches, as in deserts (p. 88), there is dry sand, which the wind drifts about, often piling it up in low hills and ridges, or *sand dunes*, along the upper edge of the beach (Fig. 365). Sand dunes are exceedingly irregular (Fig. 377), and their form is ever changing. Between the dune hills are basins, in which, however, there is rarely any water, because the bottom is so porous.

The movement of sand inland, doing much damage, is sometimes made possible by the removal of a forest, which gives full sweep to the wind. The removal of a forest back of Coffin's Beach on Cape Ann, Mass., over a century ago, permitted the sand to move inland and destroy a farm. Dunes in France have moved inland two or three miles, destroying farms and villages to such an extent that the French government has taken up the problem of how to stop their further advance. This is being done by planting trees behind the dunes, and setting out such plants as will grow in the sterile, sandy soil.

A sand-dune region is difficult to cross on account of the loose sand, and of little use to man because the soil is so sterile. But in the Netherlands the sand dunes protect the low plains from submergence. The waves are consuming this coast, having cut it back two miles in historic times. As the waves consume the beach the row of dunes behind the beach is slowly pushed inland.

Summary. — *Along many coasts irregular sand hills, or dunes, are built up by the wind, and their advance inland has in some cases caused the destruction of much property. In the Netherlands the sand dunes act as a barrier, protecting the low plains from the waves.*

153. Salt Marshes. — Sediment deposited in estuaries, in lagoons behind sand bars (Fig. 372), and in other protected arms of the sea, is slowly filling them. Salt-water plants that flourish in these places, such as the eel grass and salt-marsh grasses, aid in the filling. Their aid consists partly in adding their own remains, partly in checking the currents, thus causing them to drop some of the sediment they carry.

In time, the deposit of sediment and plant remains reaches to the level of high tide, forming a salt-marsh plain through which extend channels that the tide occupies (Figs. 372, 378). When, by wash from the land, the plain is built higher than the highest spring tides reach, dry-land plants take the place of the salt-marsh plants. By this process, nature is engaged in reclaiming much land from the sea.

Salt marshes are of little value, though a coarse grass, used as bedding for horses, is cut from them. Where dikes have been

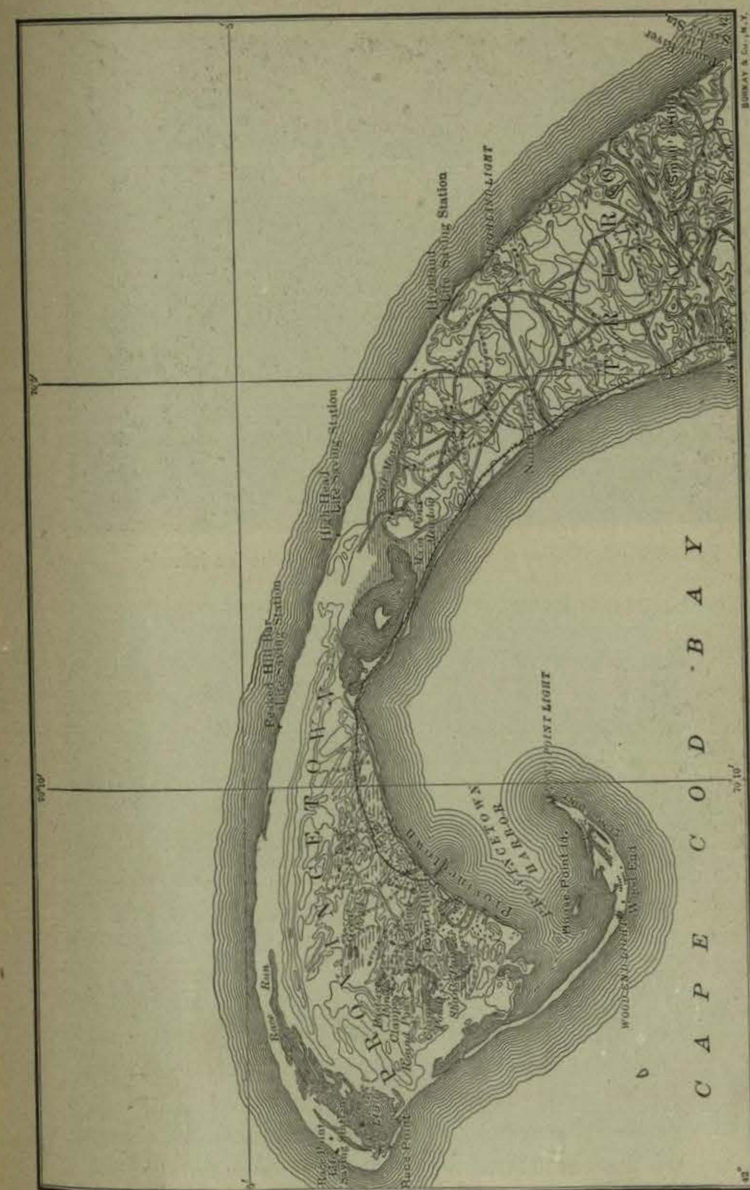

Fig. 375. — Cape Cod, Mass., showing Highland Light cliff (Fig. 367). The base of the cape is terminal moraine; the end, mainly sand dunes and sand bars, the sand having been supplied from the cliffs on the back shore. Long Point is a hook built of sand drifted along the coast. (Provincetown Sheet, U. S. Geological Survey Topographic Map.)

FIG. 376. — A view on the offshore bar of one of the Sea Islands.

FIG. 377. — Sand dunes on the offshore bar of the New Jersey coast. The dune hill in the foreground is protected from removal by a cluster of bushes (bayberries) which have taken root there.

FIG. 378. — A salt marsh plain in an estuary at Cape Ann, Mass. View taken at mid-tide to show the channel-ways filled with water. During high tide the entire plain is submerged beneath the salt water.

FIG. 379. — A mangrove swamp on the Florida coast. Notice the tangle made by the roots of the mangrove, some of them descending from the limbs.

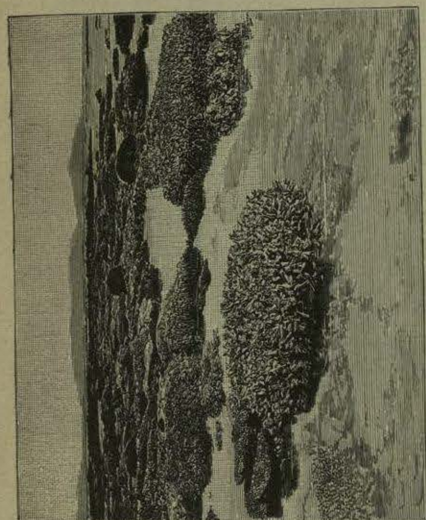

FIG. 380. — Corals on the Great Barrier Reef of Australia.

FIG. 381. — A fringing reef around Vanikoro Island in the Marshall Island group of the Pacific. If this mountain sinks slowly beneath the water, an atoll will be left.

FIG. 382. — One of the Caroline Islands, an atoll in the Pacific.

built to exclude the sea, and the land drained, salt marshes make excellent farm land. Much of the fertile lowland of England, a large part of the Netherlands, and the beautiful Evangeline country of Nova Scotia are diked marsh land. In the United States little has been done to reclaim salt marsh, because we have had enough land without it. But the time cannot be far distant when the extensive salt marshes near New York and Boston will repay diking. Boston is partly built on salt marsh that has been changed to dry land by filling with earth removed from neighboring hills.

Summary. — *In protected bays and lagoons, sediment and the remains of salt-water plants build up salt-marsh plains. In places these have been reclaimed by dikes or by filling.*

154. Mangrove Swamps. — Mangrove trees grow in protected spots on the coasts of warm countries, such as the Philippines, Bermuda Islands, and southern Florida. The mangrove tree (Fig. 379) is firmly anchored by roots that descend from the branches, forming an almost impenetrable jungle, or mangrove swamp.

Summary. — *In warm countries the salt marsh is replaced by the almost impenetrable jungle of the mangrove swamp.*

155. Coral Reefs. — On some warm coasts animal life is so abundant that the shore is made entirely of animal remains. Of these animals, corals are the most important. Reef-building corals thrive only in depths less than 150 feet, where there is little sediment, little fresh water from the land, currents bringing abundant food, and a temperature never below 70°.

Coral is made by lowly animals, of which there are many species, varying in size from almost microscopic to individuals several inches in diameter. Some species live singly, but most unite in colonies, together forming a limy framework (as animals form their bones), which we call coral. Some corals are massive, bowlder-like domes, others, delicately branching, treelike forms. The individuals, or *polyps*, which form the coral, dwell in little cavities that dot its surface. The coral mass is alive on the outside, dead on the inside, and the polyps build their coral homes on foundations laid by former generations.

The polyps can either withdraw into the cavities or extend their branching arms into the water in search of food. To one looking down upon a coral reef, through a box with a glass bottom, the sea floor seems like a garden, with flowers of all colors and many forms; and among the corals are myriads of other animals, some fixed in place, some moving freely about. The abundance and variety of life in such a place is marvelous.

Coral growth is most rapid on the outer side of a reef, where food is most abundant. This causes reefs to grow seaward, and their outward growth is increased by the action of the waves, which break off coral fragments and drag them out to sea. A reef may start close to shore, as a *fringing reef*, and advance so far that it becomes a *barrier reef*. Another way in which a fringing reef may be changed to a barrier reef is by a slow sinking of the land. If the coral grows upward as fast as the land sinks, it will form a reef farther and farther from the sinking land.

There are coral reefs on many coasts, the longest in the world being the Great Barrier Reef (Fig. 380), which for over 1000 miles skirts the northeastern coast of Australia at a distance of 20 to 50 miles. Behind it is a navigable lagoon of quiet, protected water, in which, however, a good pilot is necessary, because of the many coral shoals.

Uplift of the coast adds coral reefs to the land, in the form of terraces, like those in Cuba and other islands. Even in the interior of continents, fossil reefs are found in some of the limestone strata that were deposited in ancient oceans.

Waves and winds often heap the coral fragments above sea level, forming land, as in the Bermuda Islands. The Bermudas, whose base beneath the sea is a volcanic cone, are surrounded by a fringe of coral reefs. Fragments, broken from the reefs by the waves, are ground on the beaches to coral and shell sand, then drifted inland by the winds, forming sand dunes. These are quickly cemented into a soft rock by the deposit of carbonate of lime around the grains. The Bahamas, and many other coral islands, are made in the same manner. The soil of such dunes is far better than the soil of ordinary sand dunes.

Summary. — *In warm, clear water, where there is an abundance of food for fixed animals, corals thrive, building limy skeletons, out of which reefs are made. Fringing reefs are made along the coast, and these may change to barrier reefs either by outward growth or by sinking of the land. The wind often forms dunes of the coral sand drifted from the beaches, thus making land in the sea.*

156. Atolls. — Ring-shaped islands in the open ocean, made of coral fragments, are called *atolls* (Fig. 382). A channel into the interior lagoon is kept open by the incoming and outgoing tides. Atolls are especially common in the South Pacific, and are in some cases several miles in diameter, though rarely rising more than 12 to 15 feet above sea level. They are so low that during hurricanes they are sometimes inundated by the sea. Like the Bermudas, the part above water is made of coral and shell fragments that the waves have thrown on the beach and the wind drifted into low hills.

Few animals have reached these remote islands; but there are numerous plants, including the cocoanut palm. Many atolls are inhabited by man.

Atolls are built on the peaks of extinct volcanoes that rise from the sea bottom. Sometimes they seem to have been built on submerged peaks, the ring shape being due to the faster growth on the outside of the reef, while within the lagoon much of the lime of the coral is removed by solution. In other cases the atolls appear to be due to a slow subsidence of volcanic cones (Fig. 385). According to this explanation there was first a volcanic island surrounded by a fringing reef (Fig. 381); by slow sinking this changed to a barrier reef; finally, when the cone had entirely disappeared, there was a ring-shaped atoll where the cone formerly rose. The sinking of the cone could have been no faster than the upward growth of the reef.

End

Summary. — *Low, ring-shaped coral islands in the open ocean are called atolls. They are built on volcanic cones. In some cases at least, they are caused by a subsidence of the cone at about the same rate as the upward growth of a fringing reef.*

157. Lake Shores. — Most that has been said about sea-coasts applies quite fully to lakes; and illustrations of most shore-line phenomena are found along lake shores. There are headlands, wave-cut cliffs, beaches, bars, sand dunes, islands, promontories, and harbors. There are also elevated and drowned coasts. In fact, from the form alone it is quite impossible to distinguish lake from ocean shores. Figures 358 and 370 are from lake shores.

It is true that tides are absent in all but the largest lakes, and even there are almost unnoticeable; and, because the waves are less violent, the cliffs are usually smaller, resembling those of bays rather than the open ocean; but in great lakes there are some high cliffs.

The effects of life are, however, quite unlike in the two cases. Although swamps are formed in the lagoons and bays of lakes, the plants are very different from those of the salt marsh; and the absence of tide makes the difference between lake and seashore swamps even more marked. In lakes there are no corals, and, consequently, no coral reefs.

Summary. — *Lake and sea-coasts are so alike that, from the form alone, they could not be distinguished. The chief differences are the smaller cliffs, the absence of tides, and the effects of life.*

158. Abandoned Shore Lines. — In many places where lakes have disappeared, cliffs and beaches are now found on the land. For example, very perfect beaches, bars, spits, and cliffs are found near Great Salt Lake, marking the shore line of ancient Lake Bonneville (Fig. 301). Similar shore lines mark the level reached by the glacial lakes in the valleys of the Red River of the North (Fig. 130) and the Great Lakes (p. 150). Such beaches are seen at or near Duluth, Chicago, Cleveland, Rochester, Syracuse, and many other points. They are so much like ocean shore lines

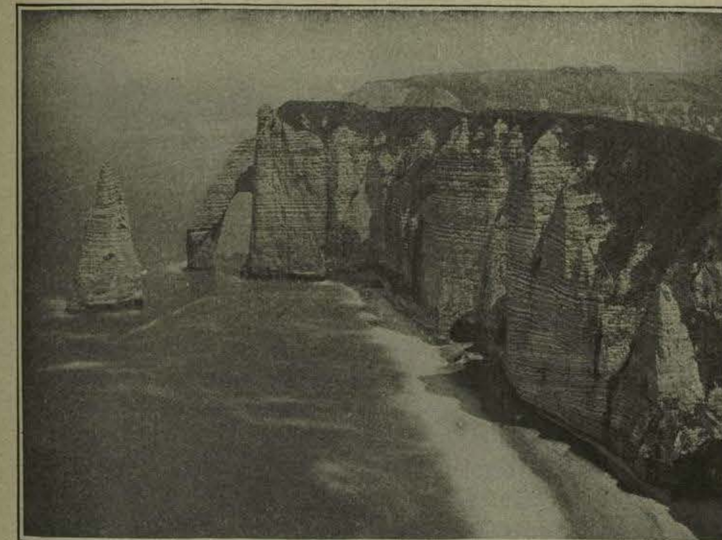

FIG. 383. — A wave-cut cliff on the French coast. In cutting back the land, the waves have left a "stack" island. Another will be formed when the roof of the wave-cut cave falls.

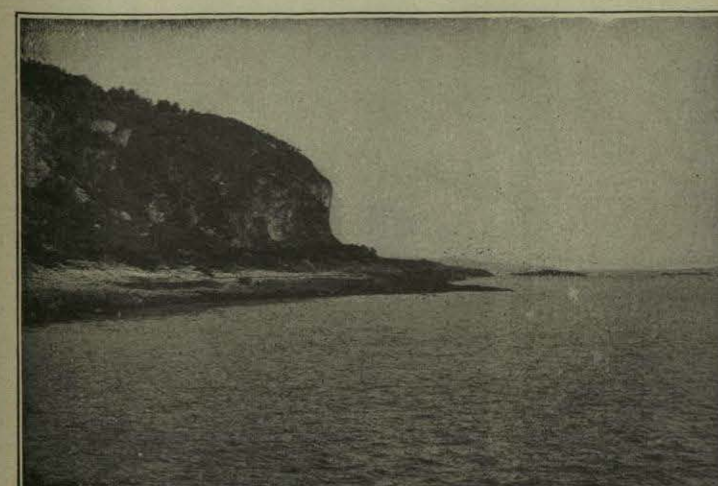

FIG. 384. — Elevated wave-cut cliff on the west coast of southern Scotland. Just beyond this cliff is a sea cave with fields extending up to it.

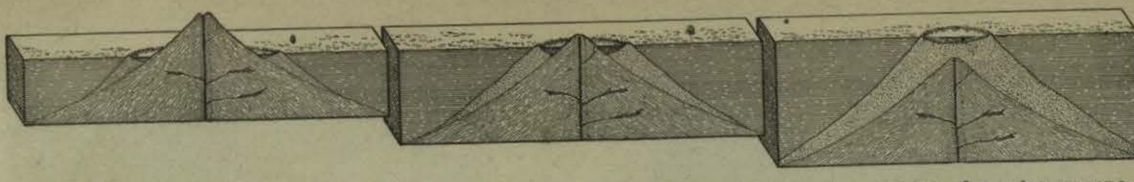

FIG. 385. — Diagram to illustrate the way in which an atoll may be formed by the slow sinking of a volcanic cone.

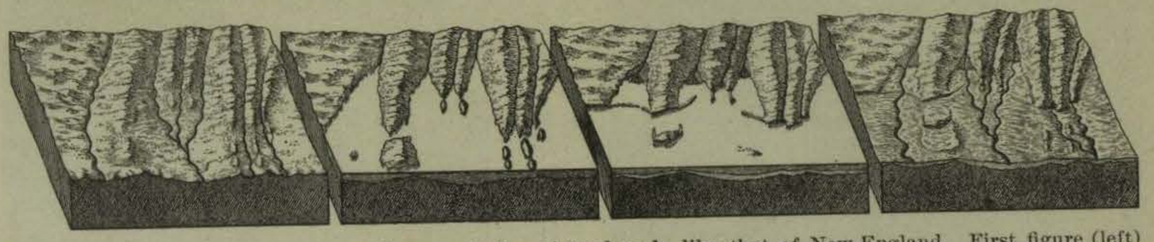

FIG. 386. — To illustrate the changes in a coast line of hard rock, like that of New England. First figure (left) shows a hilly land; second, the same land partly drowned; third, same after cliffs have been cut, bars built, and deltas formed; fourth (right), same elevated. Describe the changes illustrated in these four pictures.

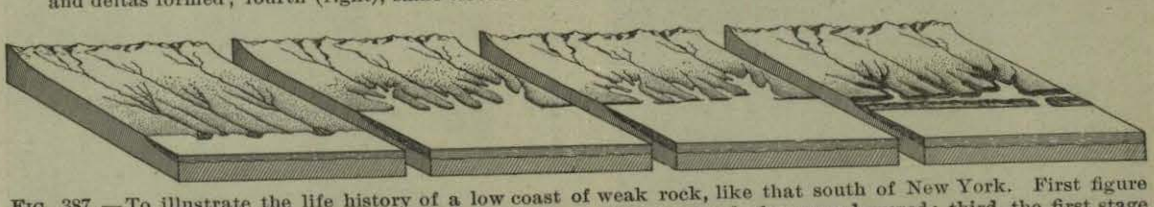

FIG. 387. — To illustrate the life history of a low coast of weak rock, like that south of New York. First figure (left), a sandy coastal plain with streams in shallow valleys; second, the same lowered; third, the first stage of wave work, forming cliffs and short bars (see Fig. 372); fourth, offshore bars have been formed with salt marshes behind, partly filling the lagoons. This is the stage shown in Fig. 372. In a further stage the offshore bar would be pushed back and the waves once more allowed to attack the mainland.

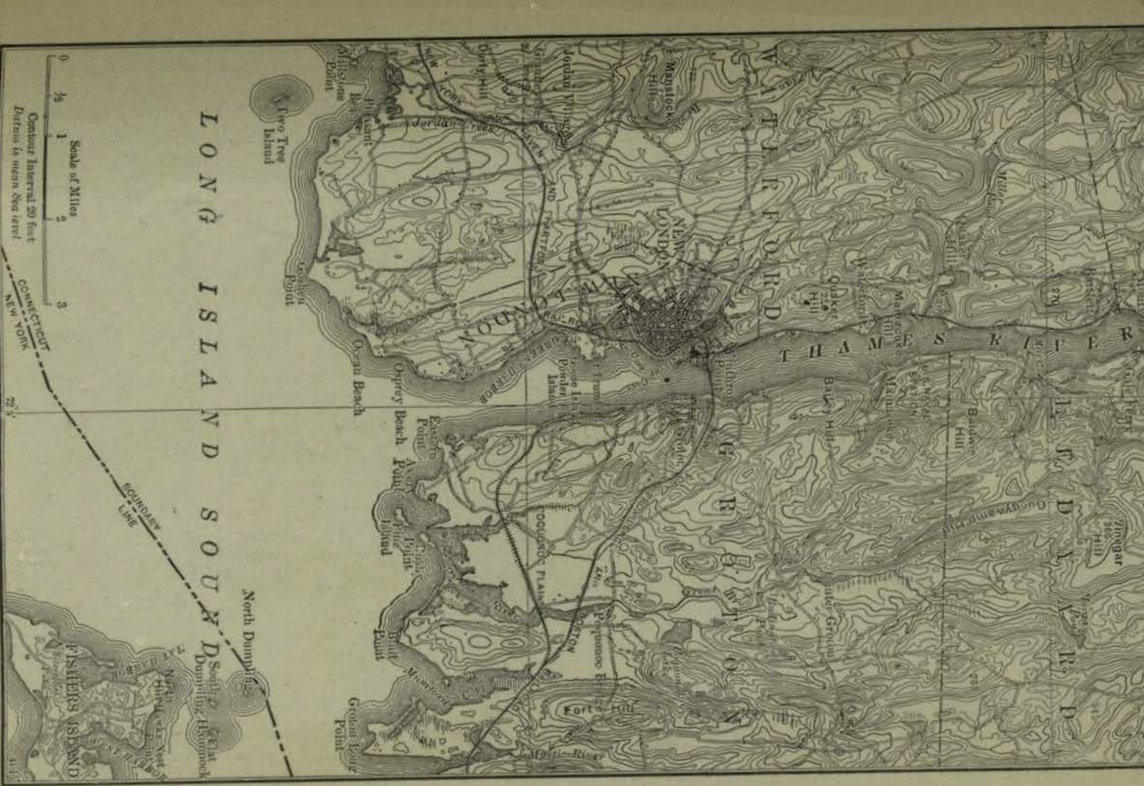

FIG. 388. — The drowned coast of a part of southern New England. Notice the small bays partly or completely shut in by bars. (A part of the United States Geological Survey, New London, Conn., Sheet.)

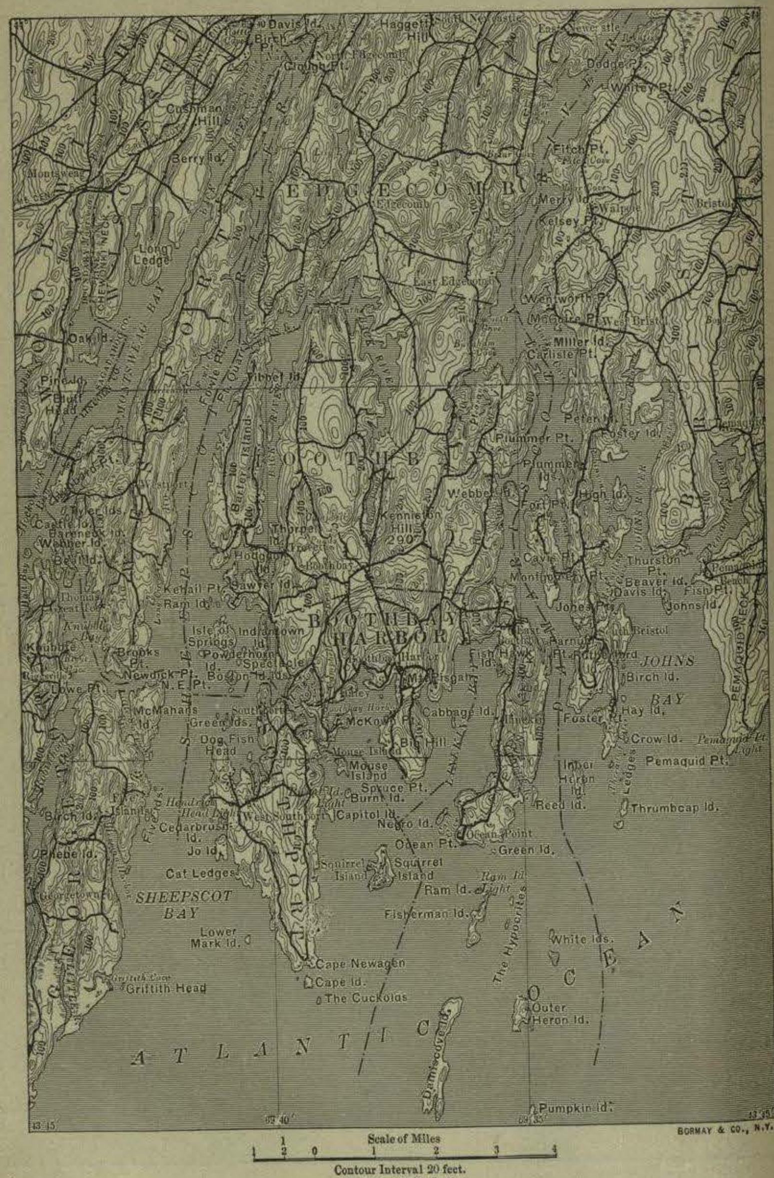

FIG. 389.—The drowned coast of a part of Maine. (United States Geological Survey, Boothbay, Maine, Sheet.)

that for a while they were supposed to have been caused by a sinking of the land, admitting the sea into these valleys.

Elevated sea beaches are found from southern New England to Baffin Land. Near Boston these beaches are from 40 to 60 feet above sea level; in Labrador several hundred feet. There are also elevated beaches in Norway, Scotland, and other parts of northwestern Europe. Here the country back of the elevated shore lines is irregular, rocky, and not well suited to farming; but between the elevated beaches and the present shore is a narrow plain which is good farm land and well settled. It is an elevated sea bottom, from which the waves have partly removed the islands and promontories, and over which sediment has been strewn (Fig. 386). Proof of former wave work at these higher levels is furnished by elevated beaches, marine fossils, islands partly cut away, and cliffs (Fig. 384) with sea caves and chasms.

Summary. — *Shore lines, closely resembling marine shore lines, mark the sites of extinct lakes; and elevated sea beaches are found in northeastern America and northwestern Europe.*

159. Life History of a Coast Line. — Elevations and depressions of the land are so frequent that, before the waves have carried their work very far, some change in level brings new regions within their reach. If a coast were allowed to pass through its life history uninterrupted, the changes would depend on the nature of the rock, the form of the coast, and the force and direction of waves and currents.

We will start with a rocky, irregular, exposed coast, like that of New England, — a typical *young coast line* (Fig. 386). Slowly the headlands are cut back (Figs. 362, 383), some of the materials being moved offshore, some driven along the coast. Of the materials driven alongshore, bars are made, tying islands to the mainland (Fig. 369) and closing the bays (Figs. 370, 373). Sediment slowly fills the bays, transforming them to salt marshes (Fig. 378), then to dry-land plains. This straightened coast is a *mature coast line*. As the waves continue to cut back the headlands, the beaches and bars are also pushed back, and thus the entire coast line retreats.

If the rock is weak, less time is required for this life history; and if at the beginning the coast is not very irregular, less time is required to straighten it. On coasts of loose sand and clay, with gently sloping bottom, cliffs are first cut, then offshore bars are thrown up (Figs. 371, 372, 387). As in the case of other straightened coasts, the waves then gradually push the barrier beaches back toward the land. Coral coasts have a different life history, for they depend on the growth of animals.

Summary. — *Young coasts are irregular; as they advance toward maturity headlands are cut back, bay mouths are closed, and irregularities are filled; then both headlands and beaches are slowly moved backward as the land is consumed. This life history requires a longer time in hard than in soft rock. On gently sloping coasts of soft rock, one of the earliest stages is the building of offshore bars.*

160. Islands and Promontories. — Perhaps the greatest number of islands and promontories are due to sinking of the land (Figs. 349, 352–354, 388, 389), as illustrated by those of northeastern and northwestern America, northwestern Europe, southern South America, and the Grecian coast.

Other islands and promontories are built by mountain growth (pp. 98, 207). Alaska, Lower California, the West Indies, the large peninsulas and islands of the Mediterranean, Madagascar, New Zealand, the East Indies, the Malay Peninsula, the Philippines, the Japanese islands, Korea, and many chains of oceanic islands are of this origin. Many islands in the open ocean are volcanoes (pp. 124, 175); for example, the Azores, Canaries, Madeiras, and Hawaiian Islands.

Atolls and many coral reefs are islands built by animal life, aided by waves and wind (p. 218). These are illustrated by the Bahamas, Bermudas, and the islands off southern Florida, including Key West. Some coral reefs are attached to the land, forming promontories. The formation of barrier beaches (p. 214) is another cause for islands and promontories (Figs. 368, 375), as illustrated along the coast of the United States. Deltas are often promontories; and along their shores are many small islands and promontories that the waves have thrown up (Fig. 105).

Another cause of islands and promontories is the more rapid work of the waves in removing weak strata (p. 211). Small islands thus cut from the mainland are called *stacks* (Figs. 366, 383).

The deposit of bars of sand or pebbles in the protected water behind islands often ties them to the land, changing them to promontories (Fig. 369). The rock of Gibraltar is thus tied to the mainland of Spain (Fig. 390), and a part of the bar is neutral ground between English and Spanish territory. Sometimes an island is tied by two bars, one from each end, inclosing a lagoon between them.

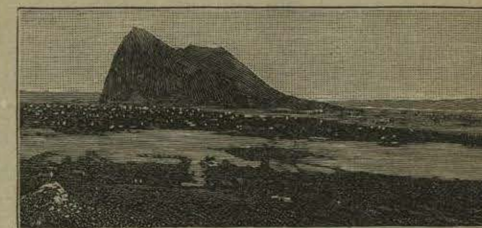

Fig. 390. — The Rock of Gibraltar, from the Spanish coast, showing the bar that joins it to the mainland.

Promontories and islands form irregularities of the coast line, and are usually the boundaries of bays, or other indentations. Therefore, the causes for islands and promontories also explain most of these indentations.

Summary. — *The majority of islands and promontories are caused by sinking of the land. Other causes are mountain growth, volcanic action, coral reef building, the formation of barrier beaches, the growth of deltas, and the irregular cutting by waves. Bars deposited behind islands often change them to promontories. These causes also account for most of the bays and other indentations.*

161. Harbors. — No feature of the seacoast is more important than the harbors, or small indentations of the coast, deep enough for vessels to enter, and protected enough for them to remain safe from wind and wave. By far the greater number of harbors are caused by sinking of the land, admitting the water into the valleys (Figs. 350, 388, 389); but there are many other causes for harbors.

Some, like that of New Orleans, are on large rivers where there has been little or no sinking; others, like that of Naples, occupy bays formed by mountain uplift; and still others, like that of Callao, are merely part of a straight coast where an island serves to cut off the winds and waves. What is the cause for Galveston harbor (p. 214)? There are others of similar origin. The lagoon of an atoll (Fig. 382), and a volcanic crater breached by the sea (Fig. 234), may also form harbors. Among other causes is the work of man; for he has made many harbors, either by dredging shallow tidal rivers, as at Glasgow, or by building breakwaters on harborless coasts.

For a harbor to be useful at the present day, and to become the site of a great city, it must be deep enough to admit large vessels. It was partly because of the shallowness of its harbor that Salem was outstripped by its neighbor Boston; but, of late, even Boston harbor has needed deepening and improvement to admit large modern ships.

To become the site of a great city, a harbor should also have a large area of productive country tributary to it. Baltimore, Philadelphia, New York, and Boston harbors are open to shipment not only from the country round about, but also from the great interior; and New York owes its superiority over the others largely to the fact that it has connection with the interior by water as well as by rail. On the other hand, Castine, Me., has a better harbor than even New York; but it is not connected with an extensive productive country, and consequently has not developed.

Harbors, like many other coast forms, are temporary affairs. If the coast remains at one level, and man does not interfere, bars will grow across harbor mouths and they will be slowly filled with sediment. Both of these processes are in operation, and it is necessary to expend large sums of money to remove the deposits. This is especially true on sandy coasts, where the waves and currents find much loose material to drift about. For this reason

the entrance to New York harbor is through a long, tortuous channel dredged out amid shoals of sand drifted from the sandy shores of Long Island and New Jersey.

Summary. — *A harbor is an indentation of the coast, deep enough for vessels to enter and yet be protected from winds and waves. There are numerous causes for harbors, of which sinking of the land is most important; man also makes harbors by dredging or by building breakwaters. To be the site of a great city, a harbor must be deep enough for large vessels and have an extensive area of productive country tributary to it. Waves and currents are tending to seal up and fill harbors.*

Topical Outline, Questions, and Suggestions.

Topical Outline. — 142. **Importance of Shore Lines.** — Centers of industry; shipping; charts; Coast Survey; harbor improvements; dangers of approach; lighthouses; light-ships; fog-horns; pilots; buoys; life-saving stations; summer resorts.

143. **The Seacoast is ever changing.** — Wave work, — instances; deposit, — instance; effect of elevation; of depression; the ever changing coast.

144. **Elevated Sea-bottom Coasts.** — Nature of coast; illustrations; unhealthfulness; agriculture; harbors; sinking of coast; sand bars.

145. **Straight Mountainous Coasts.** — Effect of uplift; western America, — straight coast, mountains, narrow plain, sea-bottom slopes; recent uplift; settlement, — few harbors, limited resources, mountain barrier.

146. **Irregular Mountainous Coasts.** — Cause of islands; of peninsulas; sinking of crust between ranges; Mediterranean, — cause, entrance, irregular coast; other large seas; small irregularities; sinking of coast; settlement; communication by land; navigation; western Italy.

147. **Coasts of Drowned Lands.** — (*a*) Resulting irregularity: bays and harbors; instances; drowned rivers; shoals and banks; islands; peninsulas. (*b*) Fiord coasts: origin of fiords; instances; settlement. (*c*) Regions of soft rock: effect on coast form; settlement. (*d*) Importance of irregular coasts: harbors; length of coast line; fishing and navigation; interior waterways; instances. (*e*) Islands: isolation; Newfoundland; Great Britain.

148. **Wave and Tide Work.** — Movement of fragments (*a*) offshore, (*b*) alongshore; result; reasons for irregular coasts; straightening coast.

149. **Sea Cliffs.** — Zone of wave work; work of breakers; steepness of cliffs, — hard rock, soft rock, height; chasms; sea caves; limit to wave work; offshore platform; cutting back of land; dangers to navigation.

150. **Beaches, Hooks, Bars, etc.** — Disposition of fragments; quicksands; pocket beaches; grinding of pebbles; bars across bays; bars supplied from sea cliffs; hooks; spits; cusps.

151. **Offshore Bars.** — Instances; lagoons; gaps in bars; closing of gaps; cause of offshore bars; effect of wind; destruction of bars; occupants of bars; cities on bars; shoals.

152. **Sand Dunes of the Seacoast.** — Location; form; effect of removal of forest; instances; encroachment; uselessness; Netherlands.

153. **Salt Marshes.** — Location; aid of plants; channels on marsh; change to dry land; value; diked land; illustrations; United States.

154. **Mangrove Swamps.** — Location; jungle.

155. **Coral Reefs.** — Favoring conditions; differences among corals; polyps; abundant life in a coral reef; growth of reef; fringing reef; barrier reef; two causes for barrier reefs; Great Barrier Reef; elevated reefs; making of land; Bermudas.

156. **Atolls.** — Form; lagoon; size; elevation; cause of elevation; plants, animals, and man; two explanations.

157. **Lake Shores.** — Resemblance to ocean shores; phenomena in common; absence of tides; smaller cliffs; effects of life.

158. **Abandoned Shore Lines.** — Lake shores; instances; resemblance to ocean shore lines; elevated sea shores; instances; characteristics.

159. **Life History of a Coast Line.** — Controlling conditions; young coast; changes in young coast; mature coast; consuming of land; effect of weak rock; offshore bars.

160. **Islands and Promontories.** — Sinking of coast; mountain growth; volcanoes; coral reefs; barrier beaches; deltas; instances of each; wave work; stacks; tied islands; causes of indentations.

161. **Harbors.** — (*a*) Definition. (*b*) Causes: sinking of land; rivers; mountain uplift; islands; lagoons behind barrier beaches; atoll lagoons; crater harbors; work of man. (*c*) Sites of great cities: depth; tributary country; illustrations. (*d*) Sealing up of harbors: bars; filling.

QUESTIONS. — 142. For what is the coast most important? What does the government do to fit it better for commerce? To warn sailors of danger? To protect them? Why is the coast a summer resort?

143. In what different ways is the coast changing?

144. What conditions are unfavorable to the development of elevated sea-bottom coasts? Why are the harbors so poor?

145. What are the results of the rising of long chains of mountains? What is the condition on the coast of western South America? Why are such conditions unfavorable to dense population?

146. How does mountain growth cause irregular coasts? What are the conditions in the Mediterranean? Give other instances of irregular coasts. What is the condition in Greece? Why are such coasts favorable to navigation? Why unfavorable to dense settlement?

147. What results are produced by entrance of the sea into valleys? Give illustrations. What are the results of complete or partial submergence of hills? How do the nature of the rock and the valley form influence the coast outline? What effect has this on settlement? Why are moderately low, irregular coasts favorable to settlement? What effect has sinking of the land on island people? Give illustrations.

148. What work are the waves and currents doing? What effect does this have on irregular coasts? Why are not all coasts regular?

149. How are sea cliffs formed? How do cliffs in hard and soft rocks differ? What effect has variation in strata? What are the results of cutting cliffs back? What effect has this on navigation?

150. What becomes of the rock fragments drifted along the shore? How do the materials vary? What forms are assumed by the beaches and bars thus built?

151. Describe the bars along the Texas coast. How are they formed? Of what importance are barrier beaches?

152. What are the characteristics of sand dunes? What damage do sand dunes accomplish? What is the condition in the Netherlands?

153. Where are salt marshes formed? How? What is the result? Of what importance are salt marshes?

154. What are mangrove swamps? Where are they found?

155. Under what conditions do corals thrive? How is the coral made? How do the polyps live? How do the reefs grow? In what two ways may fringing reefs be made? Describe the Great Barrier Reef. What is the origin of the Bermudas and Bahamas?

156. What are the characteristics of atolls? Where are they found? How are they caused?

157. Compare and contrast lake and sea shores.

158. Give instances of abandoned lake-shore lines. Of elevated sea-shore lines. What is their nature?

159. What causes are there for variation in the life history of a coast line? State the life history of a hard rock, irregular coast. What differences are there where the rock is weak?

160. State the different causes for islands and promontories. Give instances wherever possible. How may an island be changed to a promontory? What are the causes of indentations?

161. What is the cause for most harbors? State other causes for harbors. What two factors are of importance in determining the growth of cities about harbors? Give two instances. Why must money be spent to improve harbors?

SUGGESTIONS. — (1) Take some angular fragments of a soft rock, or brick, and shake them for a few moments in a fruit jar containing water. What causes the water to become muddy? Find out how marbles are rounded. (2) In a shallow pan, mold an irregular land of clay. Carefully pour in water until the land is partly drowned. Study the land forms produced. Blow on the water surface, causing the waves to reach the coast diagonally. Are any bars formed? Any other coast-line features? Study and describe them. Now draw off some of the water to leave the shore line elevated. Describe the new coast line. How does it differ from the former? Cause waves to attack it, and describe the result. By using care, and by making the land of materials varying in hardness, much concerning shore-line phenomena may be simply and easily illustrated. (3) If the school is near the seashore or the shore of a lake, at least one excursion should be made to study shore phenomena. Are there beaches? Where does the material come from? Are there cliffs? What is happening there? Have any portions been recently removed by the waves? Do the bowlders or pebbles show signs of rounding? What is the cause? Where does the finer ground-up material go? Are there any mud flats? What is the source of the material? Ask some fisherman what material covers the bottom offshore. Are there salt marshes? What are their characteristics? Are tidal currents performing any work? (4) If the school is on a sea or lake port, the harbor should be studied; its form; depth (making use of a Coast Survey map); cause; nature of bottom; improvements made; others needed; light-houses; other guides and aids to entrance; source of principal materials received for shipment; of principal imports; places to which these are distributed; reasons for importance of port. If not on a harbor, the nearest large port should be studied in a similar way by means of the Coast Survey or Lake Survey charts (see Appendix J).

Reference Books. — SHALER, *Sea and Land*, Scribner's Sons, New York, 1894, $2.50; TARR, Chapter X, *Physical Geography of New York State*, Macmillan Co., New York, 1902, $3.50; SHALER, *Beaches and Tidal Marshes of the Atlantic Coast*, *National Geographic Monographs*, American Book Co., New York, 1895, $2.50; GILBERT, *Features of Lake Shores*, 5th Annual U. S. Geological Survey, p. 75; SHALER, *Salt Marshes*, 6th Annual U. S. Geological Survey, p. 359; SHALER, *Harbors*, 13th Annual U. S. Geological Survey, p. 99; DARWIN, *Structure and Distribution of Coral Reefs*, Appleton & Co., New York, 1889, $2.00; DANA, *Corals and Coral Islands*, Dodd, Mead & Co., New York, 1895, $5.00.

CHAPTER XII.

THE ATMOSPHERE.

162. Composition of the Air. — (A) *Oxygen, Nitrogen, and Carbon Dioxide.* — Until recently air was believed to be a mixture of two gases, *oxygen* (about 21 per cent) and *nitrogen* (about 79 per cent).[1] Oxyen is of vital importance to animals, for all breathe it; but nitrogen, though used by some plants, is of far less importance. It, however, increases the bulk of the air and dilutes the oxygen. Man probably could not live in an atmosphere of pure oxygen, for it would cause too rapid changes in the tissues of the body.

About 0.04 per cent of the air is carbon dioxide (often called carbonic acid gas), which, in spite of its small quantity, is very important. It is composed of one part of carbon and two of oxygen, and plants have the power of separating them, building the carbon into their tissues.

In the bodies of animals, on the other hand, oxygen unites with carbon by a process of slow combustion, and with each breath carbon dioxide is returned to the air. Fire is a more rapid form of combustion, oxygen combining with the carbon of the wood, coal, oil, etc., and forming carbon dioxide. All forms of combustion, whether rapid or slow, produce heat. In such rapid combustion as fire, sufficient heat is produced to do much work, — for example, the formation of steam, whose energy may be used to run locomotives or

[1] In 1895 a new element, *argon*, was discovered in the atmosphere, and since then several other inert elements have been found in it. They resemble nitrogen so closely that, although they are taken with every breath, they were never before detected.