THE CANYON OF THE COLORADO. (See p. 144.)

PHYSICAL GEOGRAPHY

BY

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PREFACE.

The successful development of Geography, considered as the study of the earth in relation to man, must be founded on Physical Geography, — or Physiography, as it is coming to be called, — the study of man's physical environment. No rational or scientific advance can be made in the former without an appropriate preparation in the latter. The earth's physical features must not only be described, — they must be explained, so that the understanding shall aid the memory in holding them in mind. They must not be presented apart from the manner in which they affect man's ways of living; attention must frequently be drawn to the association of human conditions with the environment by which they have been determined, in order to form the habit of looking at the features of the earth as prime factors in guiding the development of mankind. In brief, physiographic facts should be traced back to their causes and forward to their consequences; and thus the phrase "causes and consequences" comes to serve as a touchstone by which the treatment of the subject may be tested.

It does not, however, seem advisable to make this test absolute in an elementary book, for the causes of certain important facts may be complicated, as is the case with the atmospheric circulation; or unknown, as in the configuration of the continents and in the uplift and depression of the lands; and the consequences of other facts may be indirect or remote, as with the temperature of the deep sea and the configuration of the sea bottoms. Yet in all these cases the facts are so inherently physiographic that they should not be omitted. Nevertheless the test of "causes and consequences" has been, as far as practicable, applied in the preparation of this book.

The subject of Physical Geography, or Physiography, may be naturally divided into four parts: the earth as a globe, the atmosphere, the oceans, and the lands. Extraneous subjects, however interesting or important in themselves, such as the non-geographical elements of astronomy, the principles of physics, and the divisions of geological time, are carefully excluded. When so much space is demanded for the due consideration of strictly physiographic matter, none can be afforded for irrelevant topics. An examination of the book under such index headings as agriculture, animals, forests, plants, etc., will show that the organic environment of man, a large subject in itself, is by no means neglected. It is touched upon because it affords many excellent illustrations of the manner in which the earth's physical features determine the distribution of plants and animals, as well as of man; but the actual distribution of plants and animals, like that of land forms or of nations, is not considered.

Regarding the earth as a globe, it is hoped that the observational exercises suggested in the Appendix may be undertaken even before geometry is studied; for in no other way can so clear an understanding of such topics as the form, size, and rotation of the earth, with their applications in latitude and longitude, be obtained. Observational work of this kind may be much strengthened if it is led up to by simple observations of the stars in earlier years. Attention may be directed to the paragraphs on the origin of the earth's shape, and the consequences of its shape, size, and rotation, as illustrations of the method of treatment above referred to.

The thorough study of the atmosphere demands a knowledge of physics such as cannot be assumed on the part of those for whom this book is intended. For this reason the chapter on the atmosphere is made brief and elementary. It should be supplemented by local observations and by the construction and study of weather maps, as suggested in Appendixes H and I. The atmosphere is of geographical importance chiefly through weather and climate, and these subjects are repeatedly touched upon in later chapters.

The study of the ocean affords less opportunity for observation than the other divisions of the subject, but its relation to climate is of great importance, the monotony of the sea bottom may be effectively presented in contrast with the variety of the lands, and the topics of waves and tides are of much disciplinary value.

The lands have come to be the seat of the highest forms of plant and animal life, as well as the home of man, because of the variety of physical conditions that they afford. It is therefore fitting that the largest part of a book on Physical Geography should be devoted to this part of the subject. Moreover, great progress has been made in explaining the forms of the land during the last half of the nineteenth century, and thus it has now become possible to classify and describe land forms with something of scientific accuracy. But as this method of treatment is to a certain extent novel, it is entered upon with careful choice of simple forms, such as coastal plains, which are susceptible of elementary treatment, and the first examples are presented deliberately. The meaning of the various details of form is thus made so manifest as to establish the expectation that all land forms may, in due order, be rationally explained. At the same time the products characteristic of various land forms, together with the control that they exert over the location of settlements and the distribution of industries, are directly associated with the forms themselves, in order to emphasize their human relations. In addition to the ideal type forms that are frequently introduced, abundant reference is made to actual examples of the types, and practical value is thus given to a treatment that would otherwise be too theoretical. Nearly every place thus mentioned can be located by means of the small regional maps in the text, or upon the maps at the end of the book; the subject is thus made definite and specific.

New technical terms are introduced sparingly. Geological processes, such as deformation and denudation, are presented in as simple a manner as possible; emphasis is always given to the physiographic forms resulting from the processes, and not to the processes themselves. The insertion of a chapter on rivers and valleys in the latter part of the book does not mean that these important topics have not been encountered earlier; they have been mentioned wherever needed in connection with the preceding chapters, but certain features especially associated with rivers are best taken up independently after the more important land forms have been described, and to these Chapter IX is devoted.

The study of the text on land forms should be supplemented as far as possible by appropriate observations in the field. Nearly all schools can make occasional excursions in which some of the activities of the lands (p. 99) and some examples of typical land and water forms may be examined. It is especially desirable that, at such times, comparisons should be made between the locality visited and its representation on the best available large scale map, in order that some real appreciation of the art of map reading may be acquired. After such a beginning the maps referred to in Appendix M will have a greatly increased value as illustrations of typical land forms not accessible in the home district. For the same reason written descriptions of localities visited should be prepared by teacher and students; thus the descriptions of remote localities referred to in Appendix L will gain increased reality. Photographs of scenes familiar on home excursions will give a new value to photographs of distant scenes, especially if both are exhibited by lantern projection.

The opening paragraphs of each chapter are intended to serve as reading lessons rather than as texts for study and recitation. An outline of the subject may be presented in a brief course by omitting more or less of the smaller-type text. The chapters on the Waste of the Lands and the Climatic Control of Land Forms may be omitted in a short course.. The topics discussed in the Appendixes may be entirely disregarded if they seem too difficult for the pupils who are using the book; they will, on the other hand, be found useful extensions of the text for more advanced classes.

The author has had the advantage of association with Mr. W. H. Snyder, master in Science in Worcester (Mass.) Academy, whose experience in teaching has been of much assistance in adapting the text to the needs of secondary schools. The proof-sheets have been examined by Mr. M. Grant Daniell, late principal of Chauncy-Hall School, Boston, Mr. W. C. Moore, instructor in Science in the Salem (Mass.) Normal School, and Mr. H. C. Wood, instructor in Physical Geography in the Cleveland (Ohio) High School, to whom the thanks of the author are due for many valuable suggestions.

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PHYSICAL GEOGRAPHY.

CHAPTER I.

INTRODUCTION.

The Relation of Man to the Earth.

Physical Geography treats of the many kinds of surroundings that man finds in different parts of the world. It describes the various features of the earth that influence the manner in which man lives upon it. Hence it must consider the form of the earth as a whole, the climates of its different parts, the movements of its ocean waters, and the forms of its lands; it must give some account of the rocks and soils that are characteristic of different kinds of land forms, and it must explain the physical agencies that control the distribution of plants and animals. When the more important elements of this great subject are learned, a good understanding may be gained of the way in which climate, land forms, and other features of the earth exercise a control over the habits and customs of mankind.

For example, high temperatures must prevail around the equator of a rotating globe, warmed like the earth by the rays of a hot sun. The warm and moist air of the equatorial belt will frequently be cloudy, and rain will be plentiful. Vegetation will thrive in a region always warm and moist; animal life will be abundant; but the heat and dampness of the climate, the heavy forest growth, and the abundance of animal life make such a region unfavorable to the higher development of man. No people native to the equatorial forests have ever advanced by their own unaided efforts far towards the conditions of civilization.

On the other hand, it will be found that on a globe rotating like the earth a low temperature must prevail in the polar regions where sunshine is weak, and snow will be more common there than rain. As the snow gathers on the polar lands and its under part is compacted into ice, much of the surface will be frozen and barren. Plants cannot flourish in so wintry a region, and land animals cannot be numerous. It is easy to understand that the people inhabiting polar lands must be surrounded by unfavorable conditions, so that they cannot rise above a low condition of life.

The following paragraphs present special illustrations of these principles.

The Dwarfs of the African Forests. — The equatorial belt of Africa is in large part a densely forested wilderness. Tall trees spread their branches aloft, shading the ground all the year with their heavy foliage. Vines and creepers climb the trees and hang from bough to bough in great festoons, and the shady and damp ground is covered by a thick undergrowth of bushes with stems and branches so closely interlaced that it is almost impossible to make one's way through them without cutting a passage. Even the wild animals of the forest go and come by paths that they keep open by frequent passing. Objects near at hand are hidden from sight; the explorer cannot tell what is ahead of him in the gloom of the forest until he is close upon it. Vegetation is here so luxuriant that it is a burden upon the people who live amid its abundant growth.

Some of the savages of this great forest are Dwarfs, from three to four and a half feet in height. They do

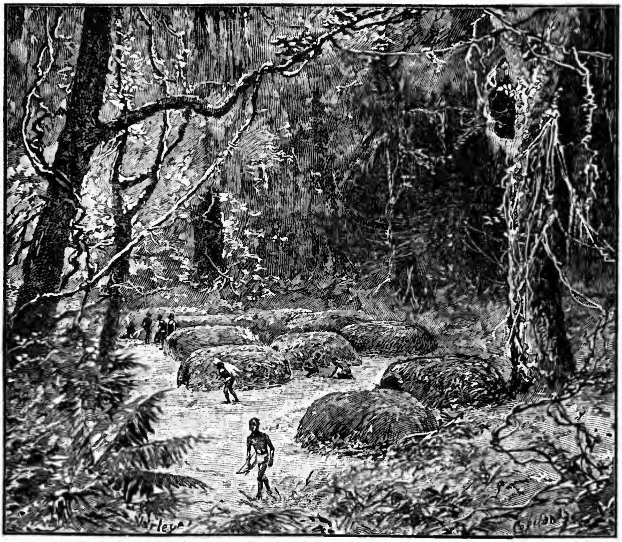

Fig. 1.—Dwarfs in the Equatorial Forest.

not try to make clearings and to cultivate fields, but search out the more open parts of the forest and build their villages where the undergrowth is least dense. They have some trade with other tribes, but live chiefly by hunting wild game, which is generally plentiful and of great variety. Although entirely ignorant of many simple arts practised by the people of more open countries, the Dwarfs are expert in all the ways of forest life. They can travel quickly through the woods, knowing all the paths and open places. They protect their villages from the attacks of neighboring tribes by planting sharpened stakes in all the paths of approach. They dig pitfalls in the narrow forest paths, covering them with sticks and leaves, and in this way capture even the larger wild animals. They prepare a poison from certain plants, and tip their spears and arrows with it; and in spite of their small size, they are formidable enemies.

The Eskimos of Greenland. — How strikingly different are the conditions of life in the cold, desolate regions of Greenland! Most of the land there is covered all the year round with ice and snow — a vast cold desert. A narrow belt along the coast is free from snow in summer, and here live a few tribes of Eskimos; but the ground is so barren that they get little support from it. The only tree-like plants are of stunted growth, seldom over two or three feet high. The herbage consists chiefly of mosses and lichens, which grow for a time in summer when the frozen ground is thawed for a few inches below the surface. A small supply of wood comes from the trunks of trees that are occasionally drifted by ocean currents from warmer regions to Arctic shores; but there is so little of it that many articles which might be made of wood elsewhere are here made from the bones of sea animals.

The Eskimos travel in sleds drawn by dogs over the snow-covered land or the frozen sea. They make slender canoes, called kayaks, which they paddle very skilfully when hunting seals and walruses. Until visited by Europeans and Americans, the Eskimos were as ignorant of the rest of the world as were the African Dwarfs; yet so well have they learned to take every advantage of their frigid surroundings that they survive where men from a more civilized nation, unused to living in so barren a region, might perish.

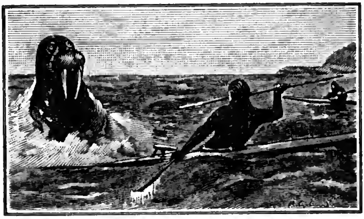

Fig. 2. — Eskimo hunting Walrus.

The Relation of Man to his Surroundings. — These brief accounts of the Dwarfs and the Eskimos show very clearly that, as a rule, the local features of the regions in which they live exercise a strong control over their manner of living. The Eskimos know nothing of forests, pitfalls, and poisoned arrows. The Dwarfs know nothing of snow and ice, sleds, kayaks, and harpoons. But each of these groups of people has become well practised in certain habits and customs that enable them to secure food, shelter, and reasonable safety of life; and these habits and customs are closely related to the surroundings in which they have been acquired.

The further the world is examined, the more general this rule is found to be. Whether we read about the wandering herdsman on the plains of western Siberia, or about the fisherman who sails to the banks of Newfoundland, man is everywhere found making an effort to gain the best advantage from his surroundings. In one region he may be a savage, living in the rudest manner, ignorant of all but the simplest arts, each individual working in about the same way as any other in the search for food and shelter. Here the relation of man's habits to his surroundings is easily understood. In another region he may be one of a civilized nation, where great progress has been made in the arts and sciences, and where each individual gains his livelihood not by working independently, but by doing something that will serve the needs of many other persons besides himself. Here the relation between man's way of living and his surroundings may be very complicated, but it may always be discovered by careful study.

Causes and Consequences.—It is the plan of this book on Physical Geography to explain the cause or origin of the more important kinds of physical features of the earth, and to trace them to their consequences as seen in the conditions of mankind. For example, deep valleys among high mountains will be found to have their origin in the long-continued action of weather and streams. The people who live in such valleys are, in consequence of the enclosure by lofty ridges, comparatively secluded from the rest of the world; hence they generally preserve old-fashioned ways of living, which the people of a more open country have given up for newer ways. Bays are in most cases to be explained as drowned valleys; that is, they result from a slow sinking of the land, by which the waters of the ocean are allowed to advance on the continental borders; the advance is further along the valleys than elsewhere, and thus bays are formed on the coast line. The quiet water of bay heads offers protected harborage to shipping; hence populous commercial cities are often found bordering bay heads. The fine and deep soil of many prairies is the sediment deposited on the bottom of ancient lakes whose waters were long ago drained away; the soil of other prairies has been formed in an even more peculiar manner. Pasturage and food plants thrive in fine soil if the climate is favorable; hence the prairies of the Mississippi valley, in the mid-temperate zone, have come to be occupied by a great agricultural population.

There are numerous features of the world whose causes and consequences are as striking and as important as those just mentioned. Many of them will become familiar to the student of this book. Many others will be found if the student, when travelling over the world in later years, seeks to understand the relation of man to the earth.

CHAPTER II.

THE EARTH AS A GLOBE.

The Relation of the Earth to Other Bodies.

Relation of the Earth to the Sun. — Few of the discoveries ever made by man have been more opposed to his early beliefs than that the earth turns on its axis once a day, and that it moves around the sun once a year; for nothing is more natural than to suppose that the firm earth stands still in the center of the universe, and that all the bodies of the sky turn around it. What is more difficult than really to conceive that we turn "upside down" every day without knowing it, and that we are always rushing along, 18.5 miles a second, or over one and a half million miles a day, on our great annual journey of over 600,000,000 miles around the sun!

The sun, glowing with extreme heat, has the enormous diameter of 866,500 miles. If the earth were placed at the sun's center, and the moon were moving around the earth at its present distance of 240,000 miles, the sun would still reach almost 200,000 miles beyond the moon on all sides. Even at the great distance of 93,000,000 miles, the sun gives abundant heat and light to the earth. So huge a body is a fitting center for the earth to move around.

The stars are distant suns, so exceedingly remote that a ray of light, which travels from the sun to the earth in eight minutes, would be about three and a half years on the journey to us from the nearest star. Many of the stars are believed to be larger than the sun.

Relation of the Earth to Other Planets.— There are a number of other bodies which, like the earth, move around the sun. To the naked eye they look like stars, brighter or fainter, according to their size and their distance from the sun; the telescope shows them to be of globular form. Some of them are smaller, some larger than the earth. Some of them turn on their axes more rapidly than the earth, some much less rapidly. Some of them are nearer to the sun than the earth is and some of them are further away. Some of them move around the sun in a shorter period and some in a longer period than that of the earth's journey. These bodies are called planets. The brightest are called Venus, Mars, Jupiter, and Saturn. It is thus seen that the earth is not a solitary body, unlike all others, but that it occupies an intermediate position in a large family of bodies.

The sun and the planets form a group of bodies called the *solar system*. As the stars resemble the sun in many ways, it is believed that each star may be accompanied by a larger or smaller family of planets; hence the number of earth-like bodies in the universe is probably very large.

Age of the Earth.— It is impossible to say what the age of the earth and the solar system is, but it should be reckoned in millions and millions of years. There is every reason to believe that the sun and the planets existed for an indefinitely long time before the earth was inhabited by plants and animals, and it is well proved that plants and animals lived upon the earth for a vast length of time before man appeared. It seems entirely possible that other planets than the earth may have once been, or may now be, occupied by inhabitants of some kind.

As the solar system has existed for so long a time in the past, it may be expected to endure for an indefinitely long time to come. Even after the sun has lost its heat in the remote future, the planets may continue to wheel around it, cold and lifeless. The part of a planet's existence during which it is inhabitable by life of any kind is probably a relatively small fraction of the whole. It is well that man, whose power over the other occupants of the earth has come to be so great, should sometimes be reminded that the time during which he has been the chief of its inhabitants covers a very small part of its history.

The Shape and Size of the Earth.

Shape of the Earth. — The people of savage races, when they think at all about the shape of the earth, generally believe it to be a great plain, broken by hills and mountains and surrounded by the sea; for that is the appearance of the lands when seen from some high point, with mountains rising to greater heights, lowlands extending to the seashore, and the ocean stretching beyond.

The people of an ignorant race usually regard the place where they dwell as the center of the great earth plain. Of the ocean they know little; its further parts are invisible and mysterious, and its limits are thought to be of a different nature from the safe and solid lands.

Among the earliest observations that led to a knowledge of the true form of the earth are those made by Greek philosophers in the fourth century, B.C. It was noticed that in travelling a few hundred miles north new groups of stars came in sight over the northern horizon, while stars that had been in sight over the southern horizon could no longer be seen. When travelling south, changes of the opposite kind were observed. It was therefore concluded that the surface of the earth must be convex instead of flat, and that the earth as a whole must be a sphere. (See Appendix A.)

Fig. 3. — Eclipse of the Moon, showing the Curved Edge of the Earth's Shadow.

The great philosopher, Aristotle, who flourished about the middle of the fourth century, B.C., said that the earth must be a sphere because when the earth's shadow falls on the moon, causing a lunar eclipse, the edge of the shadow is a curved line. He added that the earth cannot be a very large sphere, for otherwise the change in the position of stars with respect to the horizon would not be so soon evident to one travelling north or south.

The familiar argument for the globular form of the earth, based on the disappearance of the lower part of distant objects at sea, was not mentioned by ancient writers until about the beginning of the Christian era.

Size of the Earth. — The earliest recorded measurement of the size of the earth was made by a Greek philosopher in the third century, B.C., who showed its diameter to be about 8000 miles. (See Appendix B.) The knowledge thus gained by the ancients concerning the shape and size of the earth was afterwards forgotten for many centuries, and was not regained until about the time of Columbus. Since then voyages have been repeatedly made around the earth, and its size has been accurately measured.

About two centuries ago it was discovered that the earth is not a perfect sphere, but is very slightly flattened at the poles. This was explained by Newton as a result of the earth's rotation, and it may be taken as one of the best proofs that the earth, and not the sky, turns round once a day.

The distance from the earth's center to either pole is about thirteen miles less than to the equator. This is so little in a globe nearly 8000 miles in diameter, that if a curve were drawn to show the true polar flattening, the unaided eye could not detect its difference from a circle. The most careful measurements make the distance from center to pole 20,855,121 feet, and to the equator 20,926,062 feet. The average diameter of the globe is 7912 miles.

Origin of the Earth's Shape. — The eruption of hot lavas from volcanoes supports the belief that the inner part of the earth is so hot that the rocks there would yield if they were pressed more in one direction than in another. If the earth ever had an irregular shape, the higher parts would sink down on the yielding interior, and the lower parts would be bulged out until the form became globular and the pressure was everywhere balanced.

Even if the entire earth were as cold as its outer part (commonly called the crust), it could not preserve a very irregular shape, for its inner rocks would not be strong enough to withstand the unequal pressures that would exist beneath the higher and lower parts of its surface.

But even if cold and rigid from surface to center, an irregular form could not endure; for the surface rocks would decay and crumble under the attack of the weather, and the loose rock waste thus formed would be washed from the heights into the hollows. The earth is so old that, whatever shape it may have once had, and however cold and rigid its rocks, it would long ago have been worn nearly smooth and round.

It will be seen in a later chapter that all the higher parts of the lands to-day, plateaus, mountains, and volcanoes, have gained their height late in the earth's history. It may be hundreds of thousands of years since they were formed, but they are nevertheless young in the earth's measure of time. If it had not been for the various forces by which the shape of the earth's crust has been slightly changed, raising plateaus and building mountains here and there, now and then, in its long history, the surface of the earth would be much smoother than it now is.

Consequences of the Size and Shape of the Earth. — The earth is so large that savage peoples, even on the same continent, may remain for centuries in ignorance of each other. Each people comes to have its own way of doing things appropriate to its surroundings. Thus differences of language and customs have originated. But since railroads and steamships have been invented by civilized people in modern times, the earth may be considered a relatively small planet. An active traveller may visit nearly all its larger districts in his adult years.

The civilized nations have become well acquainted with each other. They now maintain an international postal service, by which nearly 200,000 post-offices are placed in communication with each other. The Roman alphabet is used by many nations, although their languages may be different. The use of Arabic numerals is even more extended. The metric system of weights and measures is already widely introduced, and will probably be adopted by all advanced nations in the twentieth century.

Although the entire earth is large, if compared with the size of a single state, the people of many distant countries sell their home products to each other. The products of remote regions are thus exchanged, even from as far as the opposite sides of the earth. The wheat of one country furnishes flour to another. Australian wool and meat are sold in the markets of London. A voyage round the world has come to be regarded as hardly more than a pastime.

Although the lands have many mountains and valleys, the general surface of the continents and oceans does not depart greatly from the form of a smooth globe, as shown

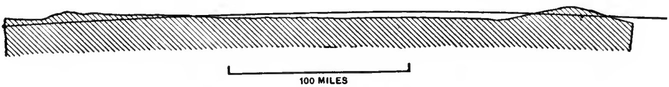

Fig. 4. — Height of Land and Depth of Sea compared to Curvature of Earth's Surface.

in Fig. 4. This is most fortunate, for on a very uneven and irregularly shaped earth long ascents and descents between the higher and lower parts would make travel and transportation enormously difficult and sometimes utterly impossible.

It is the attraction of the earth, or terrestrial gravity, that causes bodies to have weight and to fall when not supported. Recognizing the earth to be a globe, "down" is towards its center, in the direction that bodies are pulled by its attraction; "up" is away from the earth's center, or against the pull of gravity. A level surface, like that of a body of water at rest, is at right angles to up-and-down, or vertical, lines.

The curved surface of the ocean is level, for it is everywhere at right angles to the direction of gravity.

It has been proved by experiment that the stems and trunks of plants grow "up," because the force of gravity acts downward. Even on hillsides trees tend to grow erect, and not square out from the sloping surface. Branches, like those of the spruce, that turn upward when young often droop when old, owing to the long-continued action of gravity.

Many parts of the skeleton of man and animals, as well as many of the muscles of the body, are especially developed to bear the strain that is exerted upon them by the downward weight of the body. The habit of lying down to sleep has been formed partly in order to rest the muscles that are in action while standing.

The Earth's Rotation and its Consequences. — The turning, or rotation, of the earth on its axis from west to east gives us the impression that the sun, moon, and stars move around the earth from east to west. One may gain a false impression of the same kind while looking from the window of a smoothly running train, when it may almost seem as if the landscape moved backward instead of the train forward.

The succession of sunlight and darkness, or day and night, has given man and many animals the habit of working by day and resting by night. The period of the earth's turning furnishes a natural unit of time, easily recognized and counted, and everywhere constant.

Clocks and watches are regulated so as to keep time with the turning of the earth. The hour hand turns once for the average time of daylight and once for the average time of darkness.

The rotation of the earth, causing sunrise and sunset, suggests a natural system of directions even to many savage tribes. The cardinal points, east and west, north and south, are in a general way recognized by most people of the world.

The sun rises through the eastern half of the sky during the morning and sinks through the western half of the sky in the afternoon. Midday is the moment when the sun passes the north and south line that divides the eastern from the western half of the sky. The sun then reaches the greatest height above the horizon; and hence at this moment a vertical rod casts the shortest shadow.

Consequently, a true north line may be determined by noting the direction of the shortest shadow cast by a vertical rod. The north line thus determined would, if followed, lead to the north pole; a line in the opposite direction, to the south pole. All such lines are called meridians, or midday lines. When continued they form circles running around the globe and intersecting at the poles.

Lines drawn at right angles to the meridians run east and west. Such lines form circles parallel to one another, never intersecting; they are therefore called parallels. The parallel that lies midway between the poles is called the equator, because it divides the earth into equal parts, called the northern and southern hemispheres.

A network of meridians and parallels may be in imagination drawn upon the earth's surface so as to divide it in a regular manner with relation to the poles and equator. It is in reference to these lines that directions are accurately defined and the relative positions of various points determined by explorers and surveyors. Thus great advantage is taken of the simple globular form and of the regular rotation of the earth.

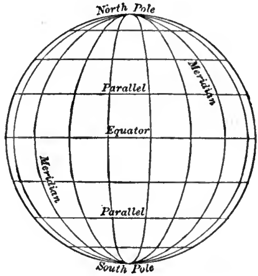

Fig. 5. — Meridians and Parallels.

Land surveys, by which the boundary lines of farms and house lots are marked out, are best made with reference to the local meridian. Navigators constantly have occasion to determine their position with respect to the network of meridians and parallels, in order to avoid islands and headlands and to reach their desired ports. (See Appendix C.)

The boundaries of thinly settled parts of civilized nations and states are often defined by meridians and parallels, as between the western parts of the United States and Canada, as well as between many of the states themselves, and between the various parts of Canada and of Australia.

(Further account of the earth as a globe is given in the Appendixes C, D, E.)

CHAPTER III.

THE ATMOSPHERE.

The Relation of Man to Climate.

The Bedouins of the Sahara. — The uplands and lowlands of a great part of northern Africa receive so little rainfall that their surface is dry and barren, forming the great desert of Sahara. Cultivation of the ground is impossible, except close to the dwindling streams, which

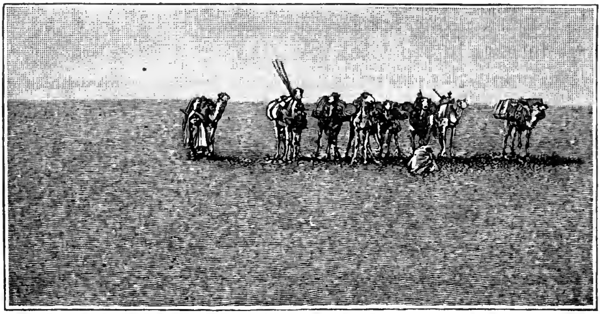

Fig. 6. — Bedouins and Camels on the Sahara.

wither away as they flow from the higher ground where most of the little rain falls. Nearly all the region is uninhabited, — a desolate waste of rock, stones, and sand, — but here and there the under soil in the low ground is moist enough to support a scanty growth of grass, which gives subsistence to the horses and camels of the wandering tribes of Bedouins. These people must frequently move from place to place to avoid starvation; hence they do not build houses, but live in tents that can be easily carried about as they wander from one pasture ground to another. As a result of their wandering habits, they have come to be excellent horsemen and show great endurance in surviving the hardships that they must often suffer. But, on account of being nearly destitute, they have the habit of taking what they want from any passing travellers whom they can plunder. They have thus preserved into modern times a rude manner of life that must have been universal in the early history of mankind, but that has been given up in recent centuries by the people of more advanced nations, among whom theft is now punished as a crime.

One might expect that the Bedouins, on learning something of the rest of the world from the traders of passing caravans, would wish to leave the barren Sahara for more fertile lands. On the contrary, so accustomed are they to a wandering life that they have no desire to change it. They persevere in the miserable conditions of the desert, content with their own ways and disliking the intrusion of strangers. Their manner of living is, like that of the Dwarfs in the equatorial forests and of the Eskimos in Greenland, another example of the great influence that climate exerts on the habits and customs of mankind. Just as the warm and moist climate of the equatorial forest and the frigid climate of Greenland are natural results of the form and rotation of the earth, so the dry climate of the Sahara is a natural result of the movements of the atmosphere on the rotating earth, warmed around the equator by a hot sun.

Climate and Commerce. — The growth and distribution of plants are controlled by temperature and rainfall. Tea, coffee, cane-sugar, cotton, and bananas are the products of plants that flourish best in a warm and rather moist climate. The less intelligent peoples of the cooler and drier parts of the world know nothing about these useful products, and use something else in their place; but the more intelligent peoples of such regions, once having learned how valuable these plant products are, take great trouble to procure them. An important part of commerce is the traffic in articles of food raised in distant parts of the world. Tea is carried overland from China to Russia; a railroad now in construction will soon make this trade more active. Great cargoes of tea are shipped from China and Japan to our Pacific ports, and then sent forward in long freight trains over the mountain passes to the prairies and the eastern states. Steamships run from the West Indies to our Atlantic ports, laden with tropical fruits. The cotton crop of the southern states has been for many years their most valuable product. All of it was formerly, and most of it is still, sent to the mills of Old and New England, where thousands of persons gain a living by spinning thread and weaving cloth; but in recent years some of the crop has been manufactured in southern mills. Many articles of clothing, the sails of ships, and the tents of armies are made from the cotton fiber. New inventions often increase the demand for the cloth and promote the cultivation of the cotton fields, none being more notable than the bicycle, whose rubber tires have a layer of cotton duck. Thus the climate, the commerce, and the industries of the world are intimately associated.

Effects of Weather Changes. — Even temporary weather changes may be of great importance when the ordinary variations of temperature, rainfall, and wind are exceeded. In summer hot winds blowing from the southwest sometimes blight the crops of Kansas and Nebraska. In winter cold winds occasionally sweep down from the northwest and carry freezing temperatures as far as Florida, ruining the orange crop. Unusual drought may injure the growth of wheat, as during the winter and spring of 1898 in California. Excessive rains may flood the lowlands near the greater rivers, as along the lower Mississippi in the spring of 1897, when an area of 13,000 square miles (as much as that of Massachusetts and Connecticut, and more than that of all Belgium) was overflowed, and the destruction of live stock and crops caused losses exceeding $15,000,000. Violent winds may beat down the cornfields in their path, and the loss thus occasioned on a farm may prevent the purchase of better farming machinery for the next year. Storms at sea may help to turn the course of history, as when a gale aided in dispersing the Spanish "Armada" on the British coast in 1588, during the reign of Queen Elizabeth.

The harmful happenings of wind and rain are not to be prevented; but it is possible that the injury they sometimes cause may be lessened when their coming is better foretold, and when protection against their dangers is better planned. The prediction of cold winds by the Weather Bureau often gives farmers and merchants warning in time to guard their property against freezing. Irrigating canals, leading water from streams out upon dry fields, decrease the dangers of droughts; famines are thus averted in the great population of India. Dikes built near the banks of rivers prevent their overflow; the twentieth century may see the Mississippi thus controlled, as the Rhine has been controlled in the nineteenth century. Storms at sea have lost more than half their dangers, partly because sea-going vessels are now much stronger than formerly, partly because the movements of storms are now better known, so that their coming can be foreseen and their greatest fury avoided. An early navigator might have steered his vessel into the midst of a hurricane; the modern sea captain has been taught how to turn to one side of its probable course.

Weather changes are by no means always unfavorable. An early spring, a warm summer, and a sufficient rainfall promote an abundant harvest; and in such a season of plenty the farmer receives a good return for his labor. He is then enabled to carry out improvements in his farm buildings, to clear and plow new fields. Years of prosperity are thus connected with years of good weather, and great as well as small events are influenced by them.

The Atmosphere.

The Atmosphere is a light and transparent mixture of gases known as air. It rests on the lands and seas, forming the outermost part of the earth. Many processes that take place on the surface of the lands and seas result from the action of the atmosphere. The waves and currents of the oceans are caused by the winds; the soil that covers the greater part of the lands results from the decay of the underlying rocks chiefly through the chemical action of moist air. Rainfall, so important in many ways, is entirely supplied by moisture carried from the oceans by the movements of the atmosphere.

The atmosphere far overtops the highest mountains. Meteors, or "falling stars," — small scraps of matter dashing toward the earth from distant space, — sometimes burn at heights of over a hundred miles, showing that some air reaches that great altitude.

Cloud, haze, and dust make the lower air turbid, and often cut off a great part of the sun's rays; but when the atmosphere is clear, even the faint light of stars penetrates its entire depth.

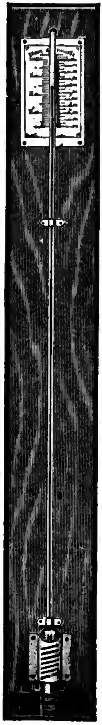

Fig. 7. Barometer.

Pressure of the Atmosphere. — Although the air is invisible, it is attracted by the earth and exerts a pressure on the surface upon which it rests. This pressure is about a ton on a square foot. The pressure on a man's body amounts to several tons; but this is not felt, because the air within the body exerts a corresponding pressure outward. The air is so easily moved that little resistance is noticed when one walks through it, but fast trains on railroads are much impeded by the resistance of the air that they have to push aside.

The pressure of the atmosphere is determined by the barometer, in which the air pressure is balanced by that of a column of mercury about thirty inches high. The ordinary changes of atmospheric pressure, such as accompany changes of weather, are seldom more than a fifteenth of the total pressure. If a barometer is carried up a mountain, leaving much of the atmosphere beneath it, the pressure of the overlying atmosphere is found to be much reduced. An ascent of a thousand feet causes a lowering of about an inch in the barometric column. Even the slight loss of pressure caused by going from the ground floor to the top of a building is easily recognized with a good instrument.

Although very light, the air supports the flight of birds and insects. The wind drives sailing vessels and windmills; it carries about myriads of germs and pollen grains, as well as particles of mineral dust. In dry regions, where the land is not covered with vegetation, the shape of the surface is changed by the long-continued action of the wind in drifting sand and dust from place to place.

Air is extremely elastic, changing its volume with every change of pressure. Its lower part is compressed by the weight of the overlying part, so that a cubic foot of air at sea level weighs about 0.075 pound, while at three miles above sea level its weight is only about half as much; and at an altitude of a hundred miles the air must be almost imperceptible.

Men and animals living on high plateaus have become accustomed to the rarity of the air around them. There are villages on the plateau of Tibet where the density of the air is little more than two-thirds that at sea level. Mountain climbing above altitudes of 20,000 feet is almost impossible from the difficulty of breathing the thin upper air.

It is by slight wave-like movements in the air that sound is transmitted. So easily is the air disturbed that a locust (cicada) may set hundreds of tons of air vibrating perceptibly to our nerves of hearing. When the volcano Krakatoa, between Java and Sumatra, exploded in August, 1883, sounds were heard for 3000 miles, and atmospheric waves, detected by slight changes of pressure in barometers, passed three times round the earth.

Composition of Air. — Air consists of a uniform mixture of gases, in which a small and variable quantity of water vapor is usually present. The gases are nitrogen, about four-fifths; oxygen, about one-fifth; argon, carbonic acid, krypton, and some others, each a hundredth or less.

Nitrogen is found in much larger share in the air than in all the rest of the earth, but it does not seem to be actively useful. Argon and krypton, recently discovered, are at present known only in the atmosphere.

Water vapor, originally supplied by evaporation from the oceans, is the source of rainfall and the supply of all streams. The air feels damp or dry according to the amount of water vapor that it contains. When damp in hot weather, the air is sultry and uncomfortable; when damp in cold weather, it is chilly and disagreeable. The same temperatures would be much more easily borne if the air were dry.

All plants and animals take in air and use some of its oxygen to combine with part of their substance in a very slow combustion, which produces a slight amount of heat but no fire. Thus all forms of life, animal and vegetable, gain the energy with which they are enabled to perform their life work.

Plants do much less work and use much less oxygen than animals. The process of taking in a portion of air and giving out the unused part along with the products of the slow internal combustion (water vapor and carbonic acid) is called respiration, or breathing. It continues day and night. The organs of respiration differ greatly in different forms of life, but the process is much alike in all.

Fire is the result of an active combination of some combustible substance with the oxygen of the atmosphere. The heat thus developed may convert water into steam, and the expansive force of the steam may be used to drive engines and many kinds of machinery.

Carbonic acid, although a small part of the atmosphere, is of great importance as the chief food of plants. It is taken in by the green cells and decomposed under the action of sunlight, part of it (carbon) being retained to unite with the sap and form the tissue of the plant, part (oxygen) being given out again.

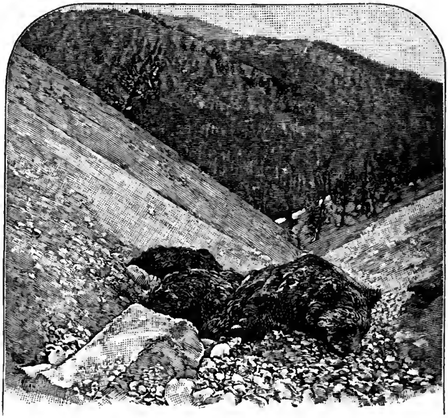

Fig. 8. — Grizzly Bears suffocated in Death Gulch, Yellowstone Park.

Carbonic acid is suffocating if present in much larger quantity than usual. It is given forth from the ground in certain parts of the world, as in Death gulch, Yellowstone Park. Grizzly bears often lose their lives in this ravine.

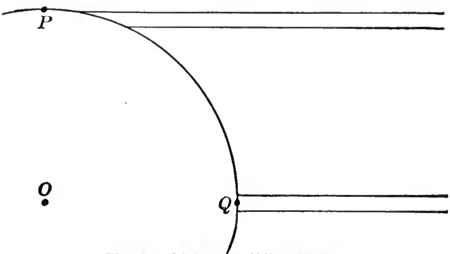

Fig. 9. — Direct and Oblique Rays.

Temperature of the Atmosphere. — The temperature of the land and sea surface and of the lower atmosphere is controlled by the sun's rays. Hence higher temperatures must prevail around the equatorial belt, where the sun shines more directly upon the earth's surface; and areas of low temperature must be found around the poles, where the sun's rays are oblique, as shown in Fig. 9. Belts of stronger, medium, and weaker sunshine are thus defined, which are known as the torrid, temperate, and frigid zones. (See Appendix F.) Fortunately the cold or frigid areas around the poles occupy a relatively small part of the world.

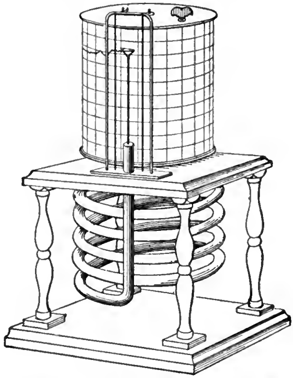

Fig. 10. — The Comey Self-Recording Thermometer.

The temperature of the air may be measured by a thermometer suspended so as to be protected from direct sunshine and from rain or snow. If placed outside of a window, the thermometer should be on the north side of the building, and where warm air escaping from windows beneath cannot affect it. Some thermometers are arranged so as to give a continuous temperature record in a curve drawn on a sheet of paper; such instruments are called thermographs, one pattern being shown in Fig. 10.

The temperature of the air is not much affected by the direct action of the sun's rays; it is controlled largely by the temperature of the land or sea surface on which the air rests. Zones of high and low temperature are therefore found in the lower atmosphere from the equator to the poles, but the upper atmosphere is everywhere cold. At the height of ten or more miles, the air above the equator is probably but little warmer than that over the poles.

Temperature Charts. — The distribution of the average temperatures for the year is shown on the chart of the world, Fig. 11. A line drawn near the earth's equator, through the middle of the belt of greatest heat, is called

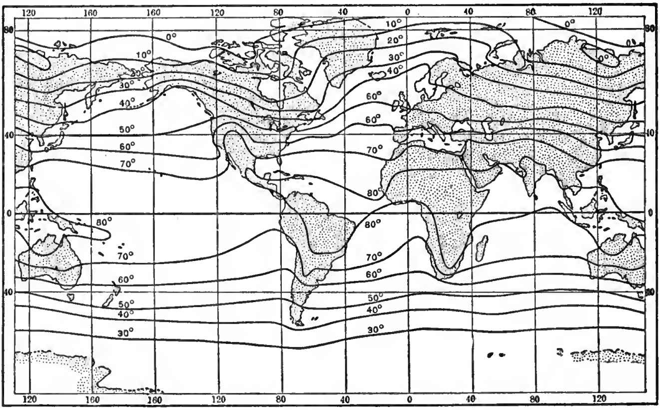

Fig. 11. — Chart of Mean Annual Temperatures.

the heat equator, the average temperature of which is about 80°. From the heat equator the temperature decreases toward each pole at the rate of about a degree of the Fahrenheit thermometer scale to a degree of latitude.

The distribution of temperature on charts, such as Fig. 11, is indicated by lines drawn through places having the same temperature, and separating regions of higher and lower temperature. Fig. 12 gives the degrees of temperature prevailing over the middle and eastern United States on a certain morning. The broken line is drawn so as to separate all places having higher temperatures than 40° from those having lower temperatures. Similar lines may be drawn for temperatures of 10°, 20°, 30°, 50°, and 60°. Such lines are called isothermal (equal temperature) lines, or *isotherms*.

Circulation of the Atmosphere. — Cold air from the polar regions, being heavier than the warm lower air of the torrid zone, continually tends to creep under it; and the warm air thus lifted up tends to overflow towards the poles. A permanent interchanging movement, or circulation, is thus established in the atmosphere between the warmer and colder parts of the earth. On account of the earth's rotation, the air currents, or winds, do not flow directly north and south, but are turned somewhat to the east or west. (See Appendix G.)

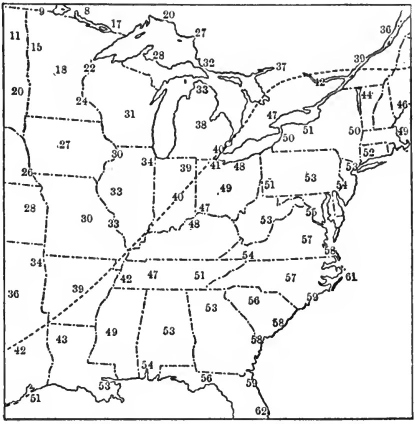

Fig. 12. — Illustration of an Isothermal Line.

A circulation will be established by opening a door between two rooms, one warm and the other cold. The cold air will creep into the lower part of the warm room, while the warm air will spread into the upper part of the cold room. The movement may be shown by the drift of smoke from a smouldering match. If the cold air is warmed as it enters the warm room, and the warm air cooled as it enters the cold room, the circulation will continue indefinitely.

Planetary Winds. — The most important members of the atmospheric circulation on our planet may be briefly described as follows. The trade winds blow from about latitude 28° N. and S. obliquely towards the equator, in the northern hemisphere from the northeast, in the southern from the southeast.[1] The prevailing westerly winds blow from a westerly source, but with a slight inclination towards the pole, over the greater part of the temperate zones. The polar winds, occupying relatively small areas around each pole, are little known. Belts of light, variable winds and frequent calms lie between the several belts of steadier winds. All these are members of what may be called the *planetary circulation.*

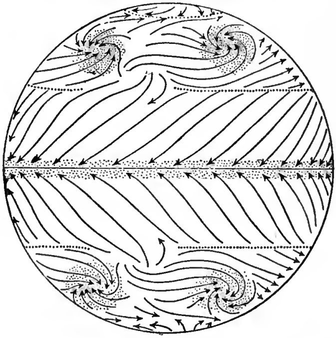

Fig. 13. — The Planetary Circulation of the Atmosphere.

The *trade winds* are so called from the constancy with which they follow a steady or "trade" course. Their velocity is from ten to thirty miles an hour. They give fair weather, seldom interrupted by storms, and generally dry unless a mountain range rises across their path. Lowlands over which they blow are made desert by the drying action of their warm air. The African Sahara and the central Australian deserts are thus explained.

[1] Winds are named from the point of the compass from which they blow.

When sailing vessels enter the trade-wind belt, they may count upon making good headway. If sailing with the winds, extra sails are often rigged out on the ends of the yards, and thus aided by a broadened stretch of canvas, the vessels speed along day and night.

Where the trade winds encounter mountain ranges, they are forced to ascend the side on which they approach. As they rise the air expands, cools, and becomes cloudy and rainy. The eastern slope of the Andes about the headwaters of the Amazon, the mountains along the east coast of Brazil under the southeast trades, and the eastern slopes of the highlands of Mexico and Central America under the northeast trades, thus receive a good amount of rainfall (80 to 100 inches a year). All these mountain slopes bear heavy forests. (See Appendix H.)

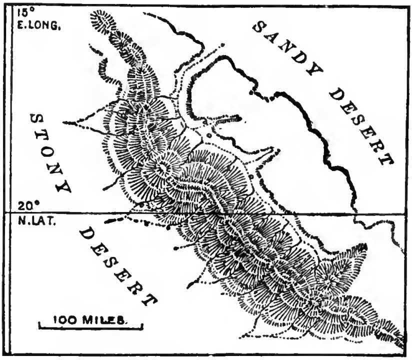

Fig. 14. — Wet-Weather Streams of the Tarso Mountains, Sahara.

The further slope of the mountains, where the winds descend, is relatively dry and barren, as on the western side of the Peruvian Andes.

Even in the Sahara the few mountains that interrupt the general surface receive a sufficient rainfall to permit tree growth; but the streams supplied on the mountain sides wither away after descending to the desert below.

The *prevailing westerlies* are much less regular than the trades. They may weaken to less than ten miles an hour, or strengthen to gales of sixty miles an hour. They often shift from their general course to take part in irregular movements, indicated in the temperate latitudes of Fig. 13. It is chiefly to these great whirl-like movements that the frequent changes of weather in temperate latitudes are due.

The lands under the westerly winds are generally well watered, especially on bold coasts east of the oceans. Abundant rainfall is received on the mountainous Pacific slopes of North and South America in middle latitudes, but the opposite slopes are comparatively dry. In these latitudes the western slope of the mountains is heavily forested, while the eastern slope has an open tree growth, or none. The distribution of forests over the great American mountain system thus gives striking illustration of the relation of timber supply to winds and rainfall.

The belt of calms and light breezes in the neighborhood of the equator, between the inflowing trade winds, is called the *doldrums*, or equatorial calm belt. It is prevailingly cloudy; rain falls every day or two, especially in the late afternoon or night. The lands are heavily forested under this warm and moist belt, and agriculture is difficult from the very luxuriance of vegetation.

Sailing vessels bound across the equator are frequently becalmed for several days in the doldrums. They must then take advantage of every light breeze to push onward and reach the trade winds beyond. The dull sky, the sultry air, and the glassy sea make the delay all the more vexatious.

The rain of the doldrums results from the slow ascent of the warm air supplied by the inflowing trade winds. The lower air is raised to greater and greater height by the inflow of more air beneath from both sides; it expands as it rises, cools as it expands, becomes cloudy as it cools, and thus gives forth plentiful rain. Violent thunderstorms are frequently formed in the great cloud masses of the calm belt.

An ill-defined belt of light breezes and occasional calms, known as the *horse latitudes*, or tropical calm belt, lies in each hemisphere between the trades and the prevailing westerlies. Here the weather is generally fair and dry.

The lower winds blow obliquely away from this belt on both sides, and air must descend from aloft to supply their currents. As the air slowly settles down, it is compressed by the weight of that which rolls in on top of it; as it is compressed, it is warmed; and as it is warmed, any clouds that it may have contained are dissolved; hence clear, fair weather is prevalent in this belt.

Storms of the Westerly Winds. — The irregular winds by which the prevailing westerlies are so often interrupted sometimes have an inward, sometimes an outward, *spiralling movement*, as in Fig. 15. They are like great, slow-turning whirls, 500 to 1000 miles in diameter. When blowing outward, the winds are light and the weather is fair. When blowing inward, the weather is cloudy and wet, and the winds may gain a stormy strength, 50 to 80 miles an hour on land, and sometimes over 100 miles an hour at sea.

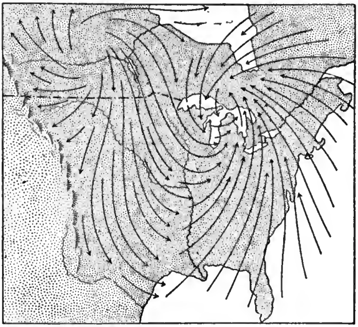

Fig. 15. — Spiral Wind Courses.

Both classes of whirls travel 500 to 1000 miles a day in an easterly direction, with the general drift of the atmosphere in temperate latitudes. They may strengthen and increase in area for a time, then weaken and fade away; their duration being from a few days to two or three weeks, and their distance of travel from 5000 to 15,000 miles.

The great whirls in the westerly winds are well shown on the daily weather maps published by the U. S. Weather Bureau, from which Figs. 26 to 29 are reduced. The direction in which the whirls turn in the northern hemisphere is opposite to that in the southern.

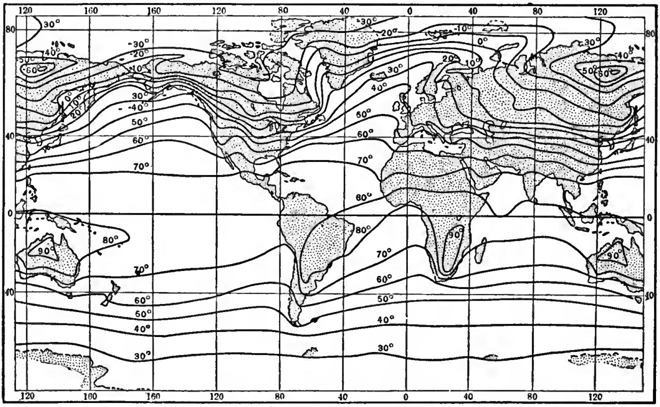

Fig. 16. — Isotherms for January.

The pressure of the atmosphere is less than usual about the central part of the inward whirls, and greater than usual in the outward whirls. Hence they are often called low-pressure and high-pressure areas. They have also been named cyclonic and anticyclonic areas from the curving movement of their winds.

The small and very destructive whirling storms, commonly called *cyclones* in the United States, are better named *tornadoes*. Their winds probably reach a velocity of 200 miles an hour. They should not be confused with the large, slow-whirling cyclonic areas here described.

Change of Seasons. — The earth moves around the sun once a year. For six months in each year (March 20 to September 22, or September 22 to March 20), one hemisphere receives a greater amount of sunshine than the other; it may then be called the summer hemisphere, while the other is called the winter hemisphere. (See Appendix F.)

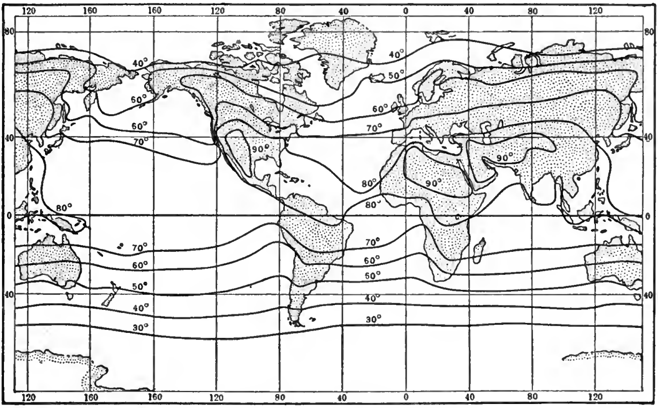

Fig. 17. — Isotherms for July.

During the summer half-year the heat equator moves a moderate distance from the geographic equator into the summer hemisphere, the high temperatures of the torrid zone advance towards middle latitudes, and the rigor of polar cold is lessened. In the winter half-year the polar cold is extreme, low temperatures advance over the middle latitudes, and the heat on the border of the torrid zone is tempered.

In both hemispheres the succession of higher and lower temperatures during the year produces the change of seasons. The winter months in the northern hemisphere are December, January, and February (these being the summer months of the southern hemisphere); the spring months are March, April, and May; the summer months, June, July, and August; the autumn or fall months, September, October, and November.

The change of temperature with the seasons is much less marked in the torrid zone than nearer the poles. In the temperate zone the summer half-year is the time of plant growth, and is therefore the season of greater activity in all industries immediately connected with agriculture.

One of the most interesting consequences of the advance of summer temperatures into higher latitudes is the passage of migratory birds, familiar to every lover of outdoor nature. The approach of winter is accompanied by the return of the birds to warmer latitudes.

Terrestrial Winds. — The strength of the planetary winds and the boundaries of their belts vary with the seasons, as shown in Fig. 18. Thus modified, the winds may be called terrestrial, as belonging to the earth rather than to planets in general. In the winter hemisphere the difference of temperature between equator and pole is strengthened, and the velocity of the winds is therefore increased. This is especially true of the prevailing westerlies, where winter is the stormy season. The trade winds show a less distinct seasonal change of strength.

The tropical calms move toward the equator in winter and toward the pole in summer (*ST*, Fig. 18). Any country over which the calms migrate will have the westerlies and their storms in winter, and the drying trades in summer.

This is the case with southern California, central Chile, and the Mediterranean countries of southern Europe and northern Africa. These countries are said to have a *subtropical* climate.

As countries in the subtropical belts are dry in the growing season, agriculture generally requires the aid of irrigation (watering the fields by canals led from streams or reservoirs). The same is true of regions traversed by winds that have just crossed a mountain range, as in the western interior of the United States.

The calms and rains of the doldrums migrate north and south with the heat equator. The regions of rainfall thus controlled form the *subequatorial* belts (*SQ*, Fig. 18).

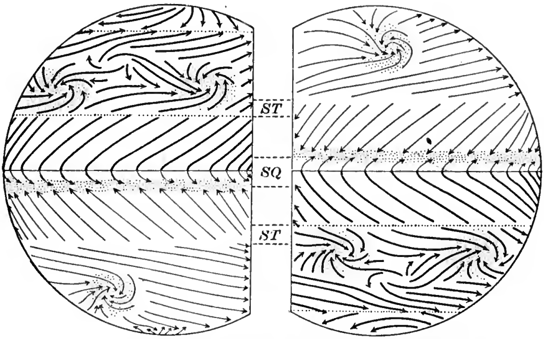

Fig. 18. — Diagrams of Terrestrial Winds for January and July.

The plains of the Orinoco in Venezuela receive a plentiful rainfall in July and August, but in December and January they are relatively dry. In the wet season cattle find abundant pasture on the uplands; in the dry season they are driven into the valleys. On the plains between the headwaters of the Amazon and Parana, the months of wet and dry seasons are reversed from those of Venezuela (Figs. 19 and 20).

The Sudan, between the Sahara and the equatorial forests of Africa, is a region of summer rains, with open tree growth or grassy plains. The western Sahara, between the reach of the subtropical (winter) rains on the north and the subequatorial (summer) rains on the south, gives no important river to the Atlantic along a thousand miles of coast line. The rise of the Nile in Egypt from June to September results from the northward advance of the equatorial rains over the upper part of its basin, as in Fig. 20.

Another remarkable result of the migration of the doldrum

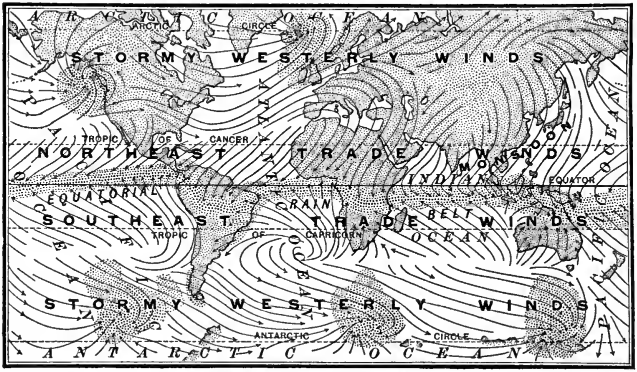

Fig. 19. — Winds of January.

belt is seen in the change in the direction of the trade winds when they cross the geographic equator on the way to the heat equator (Figs. 18 to 20). The northeast trade is extended into a northwest wind in the southern summer, the southeast trade into a southwest wind in the northern summer. Thus on both sides of the equator, in the narrow subequatorial belts where this relation appears, the winds alternately blow from opposite directions as the seasons change. Winds of this kind are called *monsoons.*

Tropical Hurricanes. — Thunderstorms are of frequent occurrence in the doldrums over the oceans. When the doldrum belt migrates to its furthest distance from the equator, north or south, larger storms with whirling winds, known as hurricanes or tropical cyclones, are occasionally developed, as if from overgrown thunderstorms.

After being started in the doldrums, hurricanes travel along a curved path near the western border of the ocean, and in a week or two reach the temperate zone, increasing in size, but generally decreasing in violence as they advance.

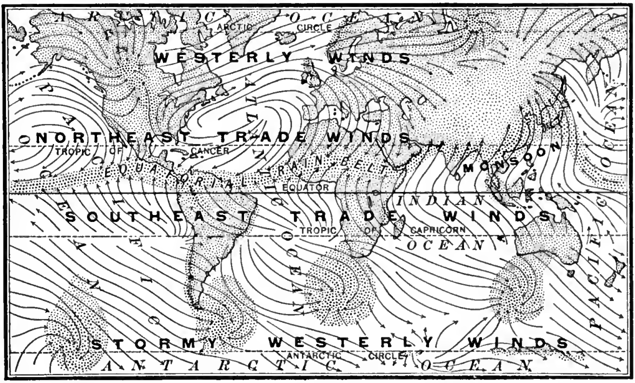

Fig. 20. — Winds of July.

Formerly great destruction was wrought on vessels at sea by these storms; but now that the season of occurrence (late summer), the usual path, and the behavior of the winds of hurricanes have been learned, and now that vessels are built larger and stronger, losses at sea are much less serious than they were a century ago.

When hurricane winds blow over islands in the torrid ocean, they may cause much damage to vessels in the harbors by driving them ashore; and to settlements by destroying their plantations. Cocoanut palms may thus be stripped of their great leaves, after which they require a number of years of growth before again bearing the fruit of which so many uses are made.

Irregular Development of the Terrestrial Winds. — The irregular arrangement of land and water prevents the regular development of the terrestrial wind system, and gives rise to certain changes in wind direction over each ocean and continent.

The heat equator generally stands north of the geographic equator over the Pacific ocean, especially over its middle and eastern parts. (This is chiefly because more cold water is brought towards the equator by ocean currents from the south than from the north.) During the northern summer a southwest monsoon is imperfectly developed within the northern

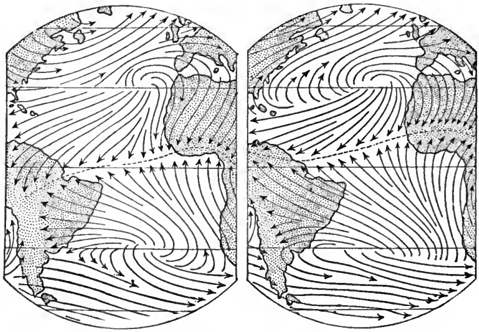

Fig. 21. — Winds of the Atlantic Ocean in January and July.

subequatorial belt of the Pacific; during the southern summer a northwest monsoon makes its appearance only in the western part of the southern belt (Fig. 19).

In the Atlantic also the heat equator is prevailingly north of the geographic equator. (This is for the same reason as in the Pacific.) The southeast trade wind is extended into the northern subequatorial belt during the northern summer; but the northeast trade wind does not reach the corresponding southern belt during the southern summer.

The continents lie somewhat across the paths of the terrestrial winds, and interfere with their regular flow. Hence branch winds connect the trades and the westerlies, and great wind eddies blow more or less distinctly around each ocean basin, especially in the summer hemisphere, as in Figs. 19 to 21.

The North Atlantic wind eddy is so distinct that the Pyrenees and Atlas mountains are more rainy on their northern than on their southern slopes. On the Pacific west of North and South America the eddying winds blow towards the equator across the subtropical belts.

Annual Range of Temperature. — The air over the lands is warmer in summer and colder in winter than that over the oceans in the same latitudes. Places in the interior of continents, therefore, have a much stronger change of seasons than those on continental borders or on islands.

The difference between the average temperatures of the warmest and coldest months is shown in Fig. 22. It is generally less than 10° over the torrid oceans, and less than 20° over most of the temperate oceans. On land the range is stronger. Central Australia and the interior of the Sahara have a range of over 30°. Over most of the United States the range reaches 30° to 60°; over a belt of land from Hudson bay into Alaska the range is more than 80°. Over the greater part of Europe-Asia the range exceeds 40°; and in northeastern Siberia it exceeds 100°.

In regions of the greatest range the winters are so cold that the ground is frozen to a depth of 100 feet or more. In winter ice is so hard that the runner of a skate does not hold upon it; wood is too hard to be chopped with the axe. In summer thawing reaches only a few feet below the surface.

As the air over the continents is alternately warmer and colder than that over the surrounding oceans, the winds

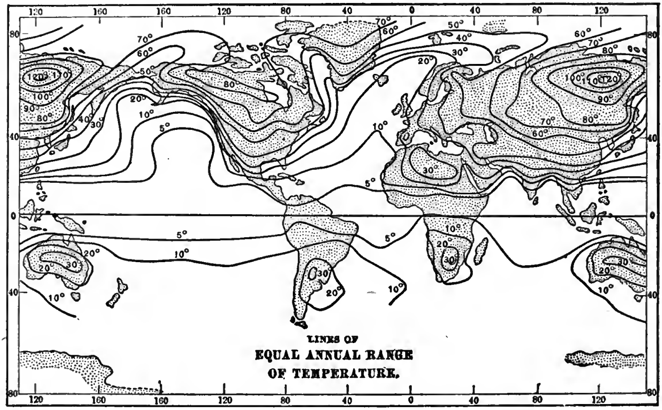

Fig. 22. — Chart of Equal Annual Range of Temperature.

tend to blow inward towards continental centers in summer, and outward from them in winter. The terrestrial circulation is much complicated by this tendency.

In winter, when the winds tend outward from land to sea, the far inland regions have much dry and clear weather; in summer, when winds blow inward, the lands have a greater share of clouds and rain.

The summer inflow from sea to land strengthens the wind eddies on the western side of the oceans. For example, in July and August a prevailing southerly wind blows from the Gulf of Mexico up the Mississippi valley, increasing the rainfall of the region that it reaches. In winter the outflow from the continent tends to counteract the eddy; at that season the winds of the Mississippi valley are prevailingly from a northern source, and the rainfall is light.

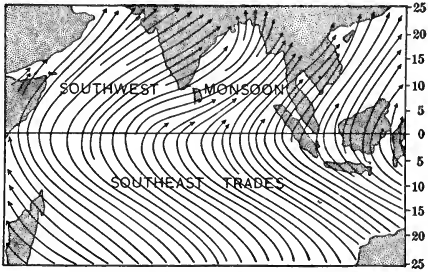

Fig. 23. — Monsoons of Northern Summer.

Southern and eastern Asia exhibit these features on a large scale. In summer the winds blow obliquely towards the continent from the Indian and Pacific oceans, giving a heavy rainfall on the more mountainous slopes. In winter the winds blow obliquely outward from the continents, and the lands are then relatively dry. These changing winds are known as the Asiatic monsoons.

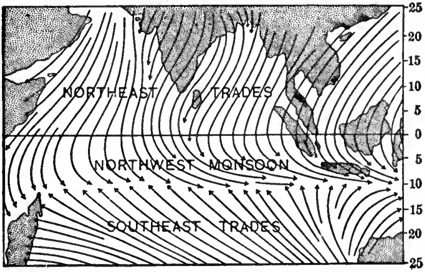

Fig. 24. — Monsoons of Southern Summer.

The monsoons of the Indian ocean are the most remarkable of the world. In the northern summer (Fig. 23) they seem to be a great extension of the southeast trades, turned into a southwest wind after crossing the equator, and becoming somewhat irregular in direction on reaching the lands. In the southern summer (Fig. 24) the northeast trade wind not only occupies its usual belt, but appears to be extended across the equator into the southern hemisphere, where it is turned to a northwest wind. The primitive sailing vessels of the Indian ocean in earlier centuries, poorly adapted for sailing against the wind, made voyages only as the monsoons favored their courses,—going outward from India to Africa in one half-year, and returning in the next.

The east coast of the Malay peninsula is beaten by heavy surf under the northeast monsoon, and then the native fishermen stay ashore. But under the southwest monsoon, an off-shore wind, the water is comparatively smooth, and large fleets of fishing boats put out to sea with their palm-leaf sails.

Winds on Land. — The winds are not so strong or so regular on the uneven lands as on the level seas. In valleys the winds are much influenced by the direction of the enclosing slopes. Hence observers in a rugged country may often recognize the general direction of the winds better by watching the drift of the clouds than by noting the position of their wind vanes.

The air over the lands is cooler and heavier than that over the sea at night, but warmer and lighter by day. Hence the wind tends to blow alternately off and on shore on many coasts, such winds being known as *land and sea breezes.*

On the coasts in the torrid zone the sea breeze is welcome, as it tempers the excessive heat of the day on land. The same is true of summer weather in the temperate zone. On the coast of Peru the fishermen sail off shore in the morning with the land breeze, and return in the afternoon with the sea breeze.

Daytime winds. — In fair, warm weather the lower air lying on the land becomes unduly heated by day, as compared to the overlying air. Overturnings are thus produced, and the faster-moving currents from aloft are brought down to the surface. Hence on land the winds of daytime are commonly stronger than those of the night. This is prevailingly the case through the year on torrid lands; it is characteristic of summer weather in the temperate zone, but is less noticed in winter. At sea no such daily change in the strength of the wind occurs.

Rainfall. — Rain, snow, hail, and sleet are all included under the general term rainfall. The explanation already given of the winds has shown how closely the amount and season of rainfall are connected with the circulation of the atmosphere. It is largely in this way that the prevailing winds are important in controlling the distribution of vegetation, and thus of population.

Snow is formed when the moisture of the air is condensed at temperatures below the freezing point (32°). Rain occurs when the moisture of the atmosphere is condensed into drops at temperatures above the freezing point, or when the snowflakes of lofty clouds descend into the warmer lower atmosphere, where they melt before reaching the ground. Sleet is half-melted snow. Hail occurs chiefly in summer, when the ascending air currents of lofty thunderstorms carry raindrops so far upward that they are frozen before they fall. (See Appendix H.)

The amount of rain is determined by measuring the depth of water that is collected in a vessel having vertical sides, called a rain gauge. Snow should be melted before it is measured. An annual total of 18, 20, or more inches is necessary for agriculture, as over the great prairie region of the Mississippi and Ohio valleys from the 95th meridian eastward. If the annual amount is between 18 and 10 inches, agriculture requires irrigation, as on a large part of the Great Plains east of the Rocky mountains, and over large areas in the basins of Utah and Nevada; but scattered grass sufficient for cattle ranges may grow in such regions. If the annual total is under 12 or 10 inches, there will not be water enough for irrigation, unless it is supplied by a large river that rises in a moister climate, as in parts of Arizona and southeastern California.

The distribution of rainfall over the world, represented in Fig. 25, shows that the greater amounts occur in the subequatorial belts, and on mountain slopes ascended by

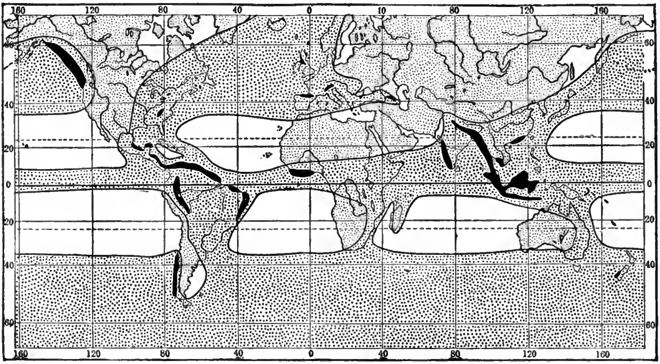

Fig. 25. — Chart of Annual Rainfall.
Dark shading, heavy rainfall (over 100 inches); medium shading, moderate rainfall; light shading and blank, light rainfall (generally under 20 inches).

the trade winds or the prevailing westerlies. The dry and desert regions of the world are either lowlands of the trade-wind belt, like the Sahara and central Australia, or continental interiors crossed by the westerly winds. The greater part of western Europe and of eastern North America are fortunate in receiving a plentiful but not excessive rainfall.

The heaviest rainfall in the world occurs on the southern slopes of the Himalaya, north of the Bay of Bengal. Here the rainfall of a single year would measure 35 or 40 feet in depth, and much more than half of this amount falls during the summer half-year when the southerly monsoon is blowing. On the bold southwest coast of India an annual fall of over 30 feet has been measured.

In the polar regions the annual snowfall, melted, would seldom exceed 15 inches of water, and would frequently be less than 10. This is because the cooling of cold air does not condense much moisture from it. In the torrid zone the equatorial rains are heavier, because the cooling of warm air produces an abundant condensation of moisture.

Dew and Frost. — Dew is a deposit of moisture on the ground, or on loose objects like leaves and sticks lying on the ground. It is formed when the ground becomes cool enough at night to chill the air near it so as to change some of the water vapor that it contains into the liquid form.

The temperature at which dew begins to be formed is called the *dew point.* It may be determined by experiment as follows: half fill a tin cup with water whose temperature is about like that of the air. Then slowly pour in ice-water, stirring it with a thermometer. When the outer surface of the cup is clouded by a deposit of moisture, the temperature of the water gives a close indication of the dew point.

When moisture is condensed upon the ground at temperatures below the freezing point, it forms frost. Thus frost on the ground corresponds to snow in the air, and dew corresponds to rain.

Dew and frost are in part supplied from water vapor in the air that lies near the ground, in part by vapor that rises through the soil from its deeper and moister parts. In the daytime the vapor from the soil escapes into the warm air;

but at night, when the ground is colder at the surface than beneath, the rising vapor is condensed. Dewdrops found on the blades of grass and on the living leaves of plants close to the ground are in large part supplied by the water that the plants bring up from the ground through the roots. In the daytime the moisture evaporates from the leaves, but at night it may collect upon them in drops.

Dew and frost are formed more abundantly on clear and calm nights than on cloudy and windy nights; for under the latter conditions the ground is not much cooled, while under the former conditions it may cool at night to a temperature 30° or 50° below that which it had under noonday sunshine.

Weather Changes. — The term weather includes all the atmospheric conditions that an observer may feel or see, — hot or cold, clear or cloudy, dry or wet, windy or calm.

In the torrid zone the weather is marked by regular changes from day to night; the changes are small at sea and greater on land, and they are seldom interrupted by storms. In the summer of temperate latitudes the same is largely true, although hot and cold periods give variety to the regular succession of day-and-night changes. In winter the weather of temperate latitudes is largely controlled by the passage of cyclonic and anticyclonic areas, which are then numerous and large, and the control by the change from day to night is relatively indistinct.

In frigid latitudes the change of weather from day to night is always weak compared to the changes caused by the passage of the great atmospheric whirls.

A comparison of the changes of local weather with the atmospheric conditions shown on the official United States weather maps discloses many problems of interest. (See Appendix I.) The summer season of the central and eastern United States offers many examples of southerly winds, under whose influence the weather becomes warmer day after day, sometimes reaching an oppressive degree of heat. At the same time the day-and-night control is distinct, giving higher temperature, stronger wind, and greater cloudiness under the action of the sun than in darkness. Then, as the distribution of pressure is altered by the eastward drifting of cyclonic and anticyclonic areas, the wind changes to northwest, and the temperature falls for a few days to a moderate degree.

In winter the irregular weather changes are stronger and more frequent than in summer. They may overcome the regular day-and-night changes. A mild spell of southerly winds with cloudy weather near a cyclonic center may be quickly followed by a change to northwest winds and clearing weather, accompanied by a rapid fall of temperature to a low degree, this fall being known as a *cold wave.*

The coldest winter weather usually occurs during periods of light winds or calms, under the influence of the central part of an anticyclonic area. The sky is then very clear, and the ground and the lower air are reduced to extremely low temperatures by cooling through the long quiet night.

The changes of weather caused by the passage of a succession of high and low pressure areas over the central and eastern part of the United States are illustrated in Figs. 26 to 29 for four successive days. (See Appendix I.)

At first the central area of low pressure, with rain and

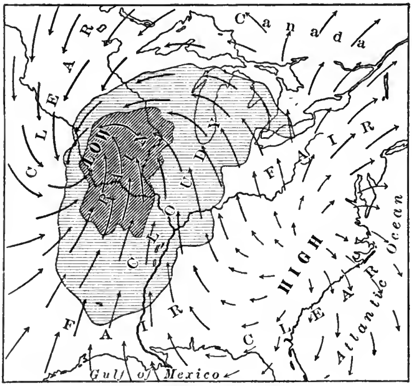

Fig. 26. — Weather Map (first day).

whirling winds, lies in western Iowa and Missouri, while clear or fair weather prevails over the Atlantic slope around an area of high pressure with outflowing winds.

A day later the rainy area has reached the southern Great Lakes; clouds are spreading eastward as far as New England, while clear weather with northwest winds is extending from the Great Plains towards the Mississippi.

On the third day the rainy area that at first lay over Iowa has reached the lower Great Lakes and the northeastern states; a great extent of country in the Mississippi valley and the southern states has clear and fair weather around a center of high pressure in western Tennessee, while a new area of clouds appears on the western plains.

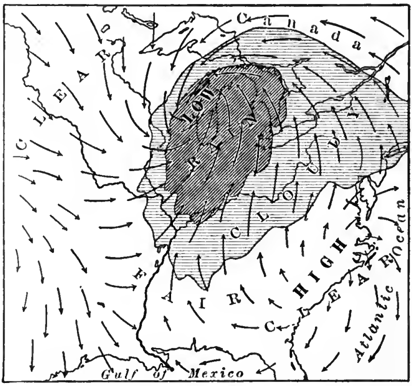

Fig. 27. — Weather Map (second day).

On the fourth day the first cloudy area has nearly disappeared in the northeast, and the second, with its central low pressure, whirling winds, and rainy area, is approaching the lower Mississippi; the region of clear and fair weather stretches from Minnesota to Florida, with a center of high pressure in North Carolina.

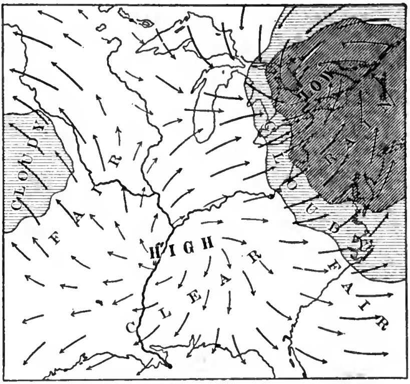

Fig. 28. — Weather Map (third day).

The succession of weather changes produced at any one place, as Washington or St. Louis, by the eastward passage of these areas of high and low pressure may be inferred from the diagrams.

Changes of weather in the Mississippi and Ohio valleys are favored by the great extent of open plains from the Gulf of Mexico to the Arctic. The winds of cyclonic and anticyclonic areas are thus allowed free passage from regions that, especially in winter, have very different temperatures.

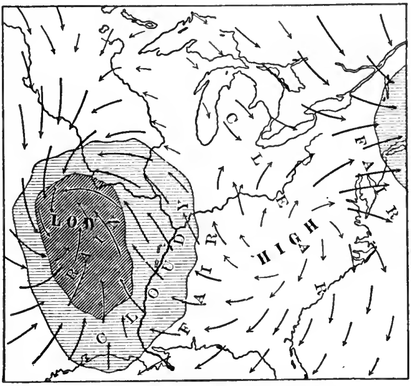

Fig. 29. — Weather Map (fourth day).

In western Europe weather changes are not so strong or so frequent as in the central and eastern United States, but they are of the same general order. The European cold wave does not come from the northwest, where the Atlantic is tempered by the extension of the Gulf Stream, but from the continental area on the northeast.

Weather predictions, as published by the Weather Bureau, are based on maps like those of the preceding figures, but much larger and more detailed; observations for the maps are gathered by telegraph from all parts of the country.

Under such conditions as those of Fig. 29, continued fair weather would be predicted for the Atlantic states, warmer weather with increasing cloudiness and rain for the Ohio valley and southern states, and clearing weather with lower temperature for the southwest.

Climate. — The general succession of weather changes through the year, averaged for many years, constitutes the climate of a region. The five zones into which the earth is commonly divided need further subdivision in order to correspond to the many well-marked types of climate in different lands and seas.

The trade-wind belt at sea has the simplest climate in the world, with small daily and yearly changes of temperature. The steady wind and fair weather of almost any day gives a fair example of the year. Lowlands under the regular trade winds suffer greater daily and yearly changes of temperature, with light rainfall.

The subequatorial belt has distinct seasonal changes, as the clouds and rains of the heat equator move away and give place to the dry trade winds. On or near the geographic equator certain places have two wet and two dry seasons in a year; for the heat equator crosses them twice, and between its visits they are occupied first by the northeast and then by the southeast trade winds.

The subtropical belts have a distinct variation of temperature between the warmer and colder parts of the year; in summer they have the mild and regular climate of the trade winds; in winter the more irregular and stormy climate of the westerly winds.

The south temperate zone is mostly an oceanic belt. The changes of air temperature with the seasons are small, because the water surface warms and cools so little in summer and winter. Its winds are more stormy in winter, less stormy in summer; never very hot or extremely cold, but for the most part chill, damp, and blustering. Islands near 50° S. are hardly habitable, not that the winters are too severe, although cloudy and wet, but that the summers are too inclement.

The north temperate zone contains large areas of land and water, and the climates of its various parts are therefore very unlike. The parallel of 50° N. crosses regions whose climates are so different that they would hardly have been placed under a single zone had they been studied before being named.

Beginning in the moderate climate of the North Atlantic, the parallel of 50° N. enters the favorable climate of middle Europe, where the last thousand years have witnessed the greatest human progress in the arts and sciences that the world has ever known. It crosses the broad deserts of central Asia, where the scattered population is held down in barbarism chiefly by severe and unfavorable climatic conditions.

The broad North Pacific has a climate as moderate as that of the North Atlantic. Passing the tempered and moist climate of the coast belt of British Columbia, and crossing the snowy mountain ranges beyond, the severe interior climate of middle Canada is reached, with extremes of temperature, summer and winter, only less than those of inner Asia. As far as habitability is concerned, the middle north temperate zone contains climatic differences almost as great as those found in passing from the equator to the pole.

Relation of Climate and Vegetation. — The plants that so generally cover the surface of the lands grow by taking food from the air and the soil. Full-grown plants produce seeds, most of which fail for one reason or another to grow; but the others, germinating at a less or greater distance from their source, give rise to a new generation of plants, which produce seeds in their turn. In this way all kinds of plants might in time be distributed all over the world, if certain barriers did not oppose their progress.

Young plants growing from heavy seeds, like nuts, spread away slowly from the parent plant. Plants growing from light seeds, especially from such as are carried by the wind, like those of the dandelion, the thistle, and the fireweed, are very rapidly diffused.

Oceans and mountain ranges are the chief visible barriers to the diffusion of plants, but these are not so important as the invisible barriers of climate. Seeds might be carried by winds or birds across an arm of the sea or over a mountain range; and if the climate is fitting at the end of their journey the seeds would grow and the plants would take possession of the new home offered them. But, however actively seeds are distributed, plants cannot invade a region whose climate is unfit for their growth.

Plants like palm trees, that flourish in the torrid zone, spread into lands in higher latitudes on both sides of the equator until they reach regions where the summers are too cool for their growth. Plants like corn and wheat, that occupy the temperate zones, are limited to belts on whose polar side the summer is too brief and cool, and on whose equatorial side the summer is too hot for their wider extension.

Plants that need a plentiful rainfall cannot spread into those regions in which the winds fail to supply rain, even if the temperature is fitting. Thus corn, which grows so luxuriantly in the Ohio and middle Mississippi valleys, cannot be raised on the dry western plains without the aid of irrigation. On the other hand, many kinds of thorny cactus plants are found on the dry plains, but they cannot invade the moister regions further east.

Relation of Climate and Animals. — Land animals, like plants, tend to spread over all parts of the earth to which they have access; the limits of their distribution are controlled partly by climate and partly by food supply, which in turn depends on climate. Like plants, animals are limited on the polar side of their range chiefly by insufficient heat in summer, and on the equatorial side by excessive heat in summer. Within the belt thus defined by the values of summer temperatures the distribution of animals is largely controlled by food supply.

Animals subsist either on animal or on vegetable food; but flesh-eating animals, like the lion, often devour plant-eating animals, like the antelope; and thus in the end all animals depend for food directly or indirectly on plants, and the distribution of plants has already been shown to depend on climate.

The study of climate is therefore not only of importance in itself, but also from the control that it exerts over the distribution of plants and animals, and thus indirectly over the distribution and occupations of mankind.

Climate and Man. — Those parts of the torrid zone that have a moist climate support a luxuriant plant growth and contain a great variety of animals; but they are not favorable to the development of the civilized races of man. In dry deserts and in the polar regions it is so difficult to gain a living that human progress is hindered. As a result of the generally small land areas of the south temperate zone the great ocean preserves a uniformly inclement climate, under whose depressing influences man finds little opportunity for development.

In those parts of the spacious north temperate lands, where the climate is neither too dry nor too severe, there is the great advantage of a winter that is cold enough to require the storage of food, and of a summer that is warm enough to provide the food to be stored. There can be little doubt that the habits of industry and thrift here made necessary, but not too difficult, have been of great importance in bringing civilization out of savagery.

CHAPTER IV.

THE OCEAN.

The Exploration of the Ocean.

Man's conquest of the ocean is one of his greatest triumphs. With wonderful daring and skill he has ventured to trust himself on the perilous waters. Undismayed by dangers and losses, he has persevered

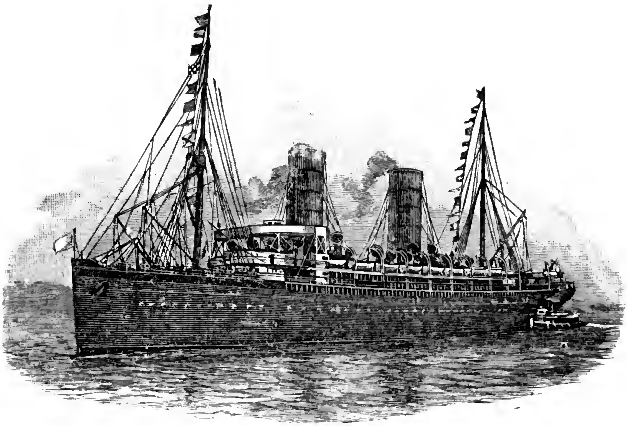

Fig. 30. — An Ocean Steamship.

through centuries of effort, invention, and discovery, and now he travels almost as safely by sea as by land. He no longer relies upon the wind or oar to propel him, but with metal hull and tireless engines he defies the storms and uses the pathless ocean as a natural highway in spite of its great perils. To-day the iron steamship, a product of many highly developed arts, crosses the trackless seas so surely and quickly that the people of nations on the opposite sides of an ocean are coming to feel almost like neighbors. The length of a trip between the United States and Europe is so well timed that the date of arrival at its end is almost as regular as the date of sailing at its beginning.

The thoughtful traveller reflects on the many lines of human progress that have led to the possibility of his voyage. How little was it imagined when iron was first smelted from its ore, thousands of years ago, that the heavy metal would one day be used to build the safest kind of ships! When the ancient Greeks watched the movements of the sun and stars, and studied the properties of angles and circles, how little did they realize that from such beginnings the navigator would some day learn to guide himself across the broad seas! Even as lately as when the steam engine was invented, little more than a century ago, no one supposed that steamships would so generally take the place of sailing vessels as they now do.

Although a dweller on the lands, man has sailed over nearly all parts of the oceans. The narratives of exploring voyages, like that of Darwin's "Voyage around the World," present many volumes of entertaining and instructive reading. The shores of continents and islands have been carefully surveyed and mapped. Soundings have been taken in the shallower waters near the lands, to discover any hidden reefs that might endanger passing vessels. Sea captains on voyages in all parts of the world have faithfully observed the direction and strength of the winds, so that advantage might be taken of them to shorten the voyages of sailing vessels. The currents of the ocean have been charted, so that they should not drift a vessel unawares out of its course. Tides have been measured at many ports, so that the time of high water may be calculated in advance; the master of a vessel may now learn from his tide tables at what hour of any day he will find high water on approaching the shallow entrance of a harbor. Even the depths of mid-ocean have been measured, and the bottom has been found a safe ground on which to lay submarine cables. As a result of this brave progress, commerce has been greatly developed between distant parts of the world.

The Physical Features of the Ocean.

Form of the Ocean. — The ocean is a sheet of salt water, clear and blue, covering about three-quarters of the earth's surface to an average depth of about two miles. It lies in broad depressions between the continental masses, its shallow edges lapping over the land margins.

A vast water area, comprising the Pacific and Antarctic oceans, covers nearly half the globe. Its surface is broken only by Australia, the Antarctic lands, and many small islands. A short Indian arm extends from this great oceanic area into the space between Africa and Australia; and a long, relatively narrow Atlantic arm runs between the Old and New Worlds, ending in the gulf-like Arctic Ocean around the North Pole.

The outline and distribution of the ocean should be studied on a globe. It may then be seen that the surface of a hemisphere whose pole is near New Zealand is nearly all water;

while the opposite hemisphere contains all the large land areas, except Australia, the Antarctic lands, and the extremity of South America. It is not a little curious to note that near the pole of the land hemisphere stands the greatest city of the world, the capital of the empire whose colonies are more widely spread than those of any other nation.

The Ocean as a Highway. — The lands are widely separated by the oceans, and navigation of the "high seas"

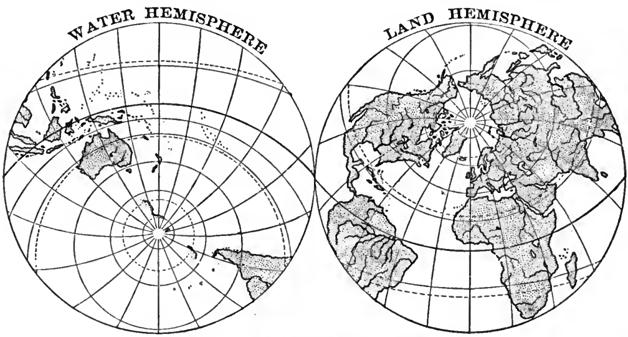

Fig. 31. — Land and Water Hemispheres.

requires great skill and is fraught with many dangers. But the oceans are a ready-made highway, where movement is easy and open to all comers, and the winds furnish free motive power to sailing vessels. Hence transportation in ocean-going vessels is very economical. Before railroads were invented, the two sides of the North Atlantic were in more active communication by sea than the two sides of any continent overland. Since railroads have been extensively built, inland transportation has greatly increased; but a great part of international commerce is still carried on across the oceans.

Exploration of the Ocean. — The earlier exploration of the ocean discovered its continental shore lines and its islands. Exploration in the latter part of the nineteenth century has penetrated its depths and reached its bottom.

Soundings are now made with much accuracy, even to depths of four miles or more. Fine steel wire is used for a line; the sinker is a heavy iron ball that is automatically detached

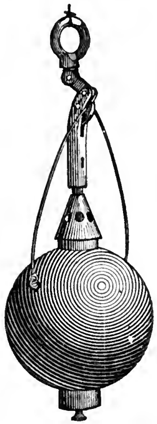

Fig. 32. — Sounding Instrument and Water Bottle.

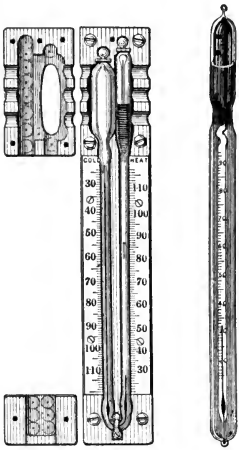

Fig. 33. — Deep-Sea Thermometers.

on touching the bottom; then the wire is rapidly reeled in by steam power. A sounding of 3000 fathoms (one fathom equals six feet) can be completed in about an hour.

The temperature of the deep water is taken by self-registering thermometers. They must be protected by an outer glass tube against the tremendous pressure of the deep water. Samples of water are obtained from various depths by the use of brass tubes, called "water bottles," sent down open, but automatically closed when reeling in begins.

Specimens of the ocean bottom are gathered by dredges; wire rope is needed to haul up the ton or more of material that they take in while dragged on the sea floor at depths of one, two, or even three miles. Nets are sometimes attached to the rope for the chance of catching animals at different depths. The best nets are closed while sinking and rising, being opened only while trolling at the greatest depth that they reach.

Fig. 34. — Dredge.

Ocean Depths. — Soundings have shown that the ocean basins are comparatively steep-sided and flat-floored. The greatest depth yet found is 5155 fathoms (30,930 feet) in the South Pacific, near the Fiji islands. Another place of great depth in the Pacific, over 4600 fathoms, lies northeast of Japan.

The deepest sounding yet made in the Atlantic is 4561 fathoms, in a local depression about 100 miles north of Puerto Rico, West Indies. The Atlantic is generally less deep along its middle (1500 to 2000 fathoms) than on either side (2500 to 3000 fathoms), the shallower middle part being sometimes called a "ridge" or "swell."

Composition and Density. — The mineral substances dissolved in ocean water constitute about three per cent of its weight; their presence makes it heavier than pure water in the proportion of 1.026 to 1.000. Although water is easily moved, it is very little reduced in volume even when compressed by great forces. Hence, in spite of the great pressure of the upper layers of the ocean on those beneath, the ocean is of nearly uniform density from top to bottom. Anything that is heavy enough to sink at the top will sink all the way to the bottom.

The ocean contains a great variety of substances in solution, for it has received everything that streams have dissolved and carried from the lands for ages past. Common salt makes three-quarters of the dissolved substances. An important but much less plentiful dissolved substance is limestone, of which many sea animals make their shells or skeletons.

A small quantity of atmospheric gases is found dissolved in sea water, even in its deepest parts. It is upon the oxygen thus supplied that fish and most other marine animals depend for "breathing"; but whales and other mammals living in the ocean come to the surface for air.

Ocean Temperatures. — The surface layers of the ocean vary in temperature with latitude, reaching about 80° around the equator, and being reduced to 30° or 28° in the polar regions. The great body of the deep ocean is cold in all latitudes; its temperature is about 30° in high latitudes and 35° or 40° in the torrid zone.

When exploring vessels dredge in torrid oceans, the sediments brought up from the bottom have a temperature near freezing, strangely in contrast with that of the objects on shipboard under a hot sun.

The sun's rays have small effect on ocean water at depths below 100 or 150 fathoms. At greater depths the ocean must be nearly dark, with hardly perceptible difference between day and night, or between winter and summer.

The temperature at any point in the great body of the deep ocean is nearly constant.

In Fig. 35 depth is measured downward, and temperature horizontally. Curve *ABC* shows the change of temperature with depth in the torrid oceans; *DEF*, in the temperate oceans; and *GHJ* in the frigid oceans. Below 400 fathoms the curves are all much alike.

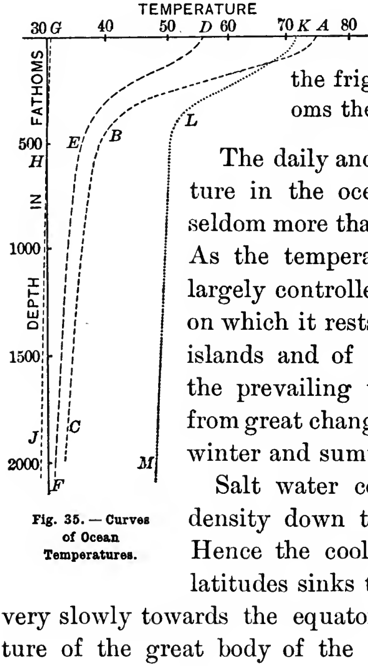

Fig. 35. — Curves of Ocean Temperatures.

The daily and annual range of temperature in the ocean surface is very small, seldom more than 3° and 15°, respectively. As the temperature of the lower air is largely controlled by that of the surface on which it rests, the climate of mid-ocean islands and of continental borders where the prevailing winds blow ashore is free from great changes of temperature between winter and summer.

Salt water contracts and increases in density down to its freezing point, 28°. Hence the cooled surface water of high latitudes sinks to great depths and creeps very slowly towards the equator; thus the low temperature of the great body of the ocean is accounted for.

A movement in the deep waters is also proved by the presence of dissolved oxygen in specimens of water brought up in "water bottles" from great depths. The oxygen is gained from the atmosphere, and as the animals of the deep sea use it in "breathing," the supply would long ago have been exhausted had it not been renewed. (See Appendix K.)

Fresh water is unlike salt water in being densest at 39°. On being warmed or cooled from this temperature it expands and becomes lighter. Hence in winter, when all the water of a lake has been cooled to 39°, further cooling affects only the surface water, which then soon freezes.

Ice in the Ocean. — The ice formed from salt water expands a little as it freezes, and therefore floats. The ice

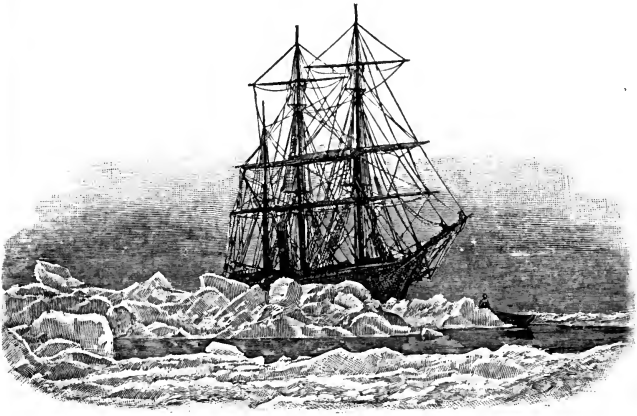

Fig. 36. — A Vessel beset by Pack Ice.

thus formed in the polar oceans is known as *floe ice;* it may reach a thickness of from 3 to 7 feet in a single winter.

Great fields of floe ice drift with the winds and currents. They may thus be torn apart or crushed together. When two floes collide, *pack ice* of very irregular surface is formed; it may reach a thickness of over 100 feet.

In the return of Greely's expedition to the Arctic regions in 1883, his boats were frequently in danger of being crushed when ice fields drifted together, closing the water passage he had been following.

Smooth floe ice is easily crossed on sleds. The Eskimos make winter journeys upon it. Where packed, it may be impassable. It was on account of the roughness of ridged pack ice that Nansen had to turn back from his "dash for the pole," in latitude 86° 13′ N., longitude 96° E., on April 8, 1895.

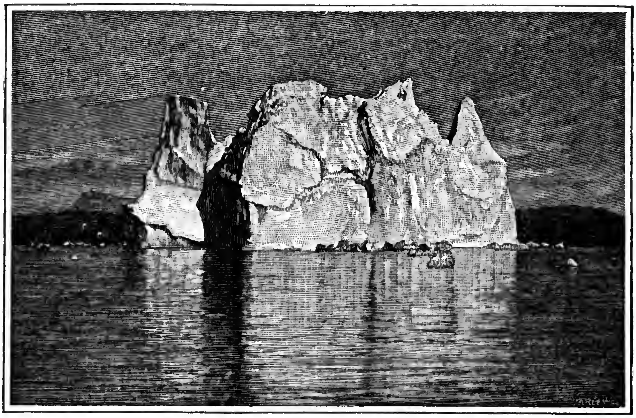

Fig. 37. — An Iceberg.

When two large fields of pack ice drift together, a vessel between them would be crushed, unless of great strength, and shaped so as to escape by rising. Nansen's vessel, the "Fram," was especially constructed to withstand great pressure, and so survived the dangers to which it was exposed.

Icebergs in the North Atlantic are fragments of glaciers formed on Arctic lands, chiefly Greenland; they are of fresh water. The tabular icebergs of the Antarctic ocean are fragments of a heavy sheet of ice that is believed to rest upon land or upon a shallow ocean bottom around the south pole. Some of these ice blocks measure a mile or more on a side, and 1200 to 1500 feet in thickness. The height of icebergs above the sea is about one-sixth or one-seventh of their depth below the surface.

Collision with an iceberg is one of the dreaded dangers of navigation in high latitudes. In the southern oceans drifting icebergs reach latitude 50°, or even 40°. In the North Atlantic they reach latitude 45° southeast of Newfoundland, but they are absent from the northwestern coast of Europe even in latitude 70°, on account of the warm water there prevailing. They are wanting in the North Pacific, except in the bays of the Alaskan coast.

The Ocean Bottom. — The greater part of the deep ocean bottom is a comparatively even plain of soft ooze [1] of similar composition and form over great areas. The plain rises and falls gently in broad swells, and is not varied by hills and valleys of uneven form. Its smoothness is due to the slow but long-continued gain of material chiefly from the surface and in small part from the shores.

No mountain ranges with sharp peaks and ridges separated by deep passes and valleys have yet been discovered on the open ocean floor far from the continents. But Cuba and some of the neighboring islands in the West Indies seem to be the crests of a mountain range, whose western extension forms submarine ridges in the northern Caribbean, dividing it into a number of deep basins, and connecting the islands with Central America.

Volcanic and coral islands are the most abrupt forms of the deep ocean. Volcanic cones sometimes rise above the ocean surface, forming lofty mountains, as in the Hawaiian islands; sometimes they are known only by soundings.

[1] Fine-textured deep-sea deposits of animal origin are called ooze; if derived from the wash of the lands, they are called muds.

The calcareous (limy) ooze which covers a large part of the ocean floor consists of the minute shells, more or less decayed, of simple animal forms that live at or near the surface. One of these, highly magnified, is shown in Fig. 38. In greater depths than 3000 fathoms the ooze is commonly replaced by a reddish clay, which is believed to be a very

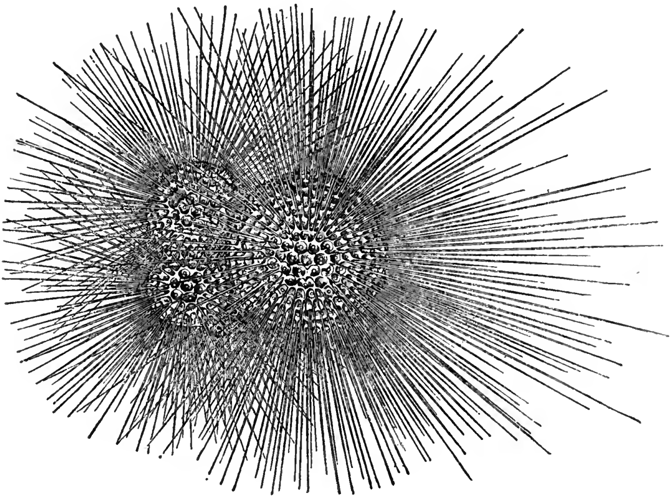

Fig. 38. — Globigerina (magnified 100 times).

slowly accumulating deposit of insoluble substances that remain after the calcareous material of the minute shells is dissolved in the deep-sea water.

"The monotony, dreariness, and desolation of the deeper parts of this submarine scenery can scarcely be realized. The most barren terrestrial districts must seem diversified when compared with the vast expanse of ooze which covers the deeper parts of the ocean."

Mediterraneans. — Besides the open oceans thus far considered, there are several deep seas, more or less separated from the oceans by land barriers. The most important of these is the classic Mediterranean (the sea "in the middle of the lands"), averaging nearly as deep as the great oceans, but connected with the Atlantic only by the narrow and shallow strait of Gibraltar.

Other similar mediterranean seas are the Caribbean and the Mexican (deep central part of the Gulf of Mexico). The former has many inlets from the Atlantic between the various islands of its eastern rim; it is divided into

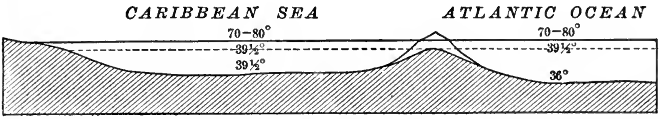

Fig. 39. — Temperatures of the Caribbean Sea.

several deep compartments by ranges of the West Indian submarine mountain range. The latter is a single basin.

Several mediterraneans of moderate size are found east of Asia. The Japan, China, Sulu, Banda, and Celebes seas are the most important; they are imperfectly enclosed from the Pacific by island chains.

The deep water of mediterraneans is warmer than that of the adjacent oceans, as shown in Fig. 35, *KLM*. The temperature of the Caribbean sea is 39½° at great depths, as in Fig. 39, this being the temperature of the adjacent Atlantic at the depth from which the water in the Caribbean is supplied; for the deepest connecting channel, east of Puerto Rico, has a temperature of 39½° at its bottom, 900 fathoms. The deep Atlantic is several degrees colder.

The Mediterranean has a constant temperature of 55° from a depth of about 250 fathoms to the bottom (over 2000 fathoms), this being somewhat colder than the adjacent Atlantic at the depth of the shallow entrance near the strait of Gibraltar.[1] In winter the northern Mediterranean is of uniform temperature from top to bottom; hence it is believed that this sea repeats the condition of the oceans in accumulating in its greatest depths the coldest water that is supplied at the surface.

Continental Shelves. — The ocean often overlaps the borders of the continental masses in a comparatively shallow belt of water, at whose outer edge the depth is com-

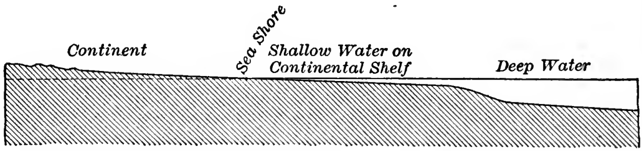

Fig. 40. — Section of Continental Shelf.

monly about 100 fathoms; thence it rapidly sinks to the deep ocean floor. These shallow bottoms are known as continental shelves. The water on the shelf is often greenish from fine suspended sediment, unlike the clear deep blue water of the open ocean and the yellowish water opposite the mouths of great rivers, such as the Amazon and the Hoangho.

The gravel, sand, and clay washed from the lands are more or less moved about by waves, currents, and tides on the continental shelves. Thus they are slowly ground finer and finer, and their finest particles are gradually moved outward to deeper water. They are seldom found

[1] The water in the strait is over 400 fathoms deep; a less depth is found a short distance westward.

in dredgings over 200 miles from shore; for the most part they are carried a less distance. In the course of ages the sediments thus accumulating may form successive layers or strata hundreds of feet thick, including many shells and other relics of marine life.

The lowland borders of continents are often built of layers of sand and clay frequently containing marine fossils; thus suggesting that a former sea bottom has there been raised to a land surface.

A well-defined continental shelf, from 50 to 100 or more miles in width, stretches along the eastern side of North America from Newfoundland to Florida, and thence around the Gulf of Mexico. The British Isles stand upon a continental shelf that borders mid-western Europe. The Malayan and Australian islands surmount broad shelves between Asia and Australia, separated by a belt of deeper water.

Continental shelves are of great importance as the chief fishing grounds of the world. The European ports around the North sea send out hundreds of fishing vessels to its shallow waters. The rich fishing grounds of the Newfoundland banks attracted many fishermen from the Old World over three centuries ago.

Waves. — When the wind blows over the sea, the water gains an undulating motion, forming waves that advance with the movement of the wind. Although the wave form moves forward, the water only oscillates up and down, to and fro, with little progressive motion. The stronger the wind, the higher the crests and the lower the troughs of the waves; and the greater their length or distance from crest to crest, the deeper their disturbance extends beneath the surface, and the faster their progressive motion.

Great waves formed in the open ocean by gales and hurricanes are often called *seas*. Their height from trough to crest reaches 30 or 40, but seldom exceeds 50 feet. Their length varies from 300 to 1500 feet or more, and their velocity from 20 to 60 miles an hour. The interval between the passage of successive crests, or the period of the wave, is seldom more than 10 seconds.

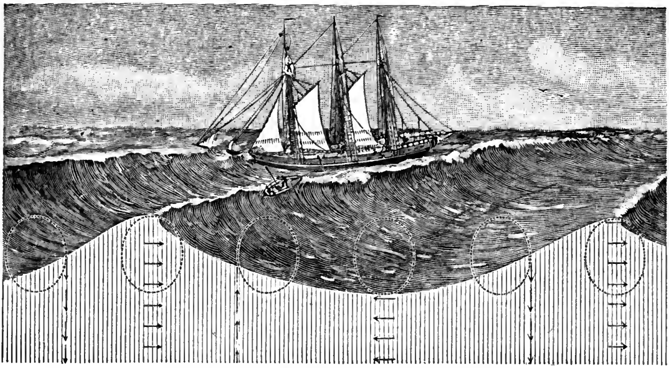

Fig. 41. — Orbital Movement of Water in Waves.

The water particles in waves move forward in the crest (Fig. 41), downward on the back, backward in the trough, and upward in the front of the next wave. Hence each particle moves around a curved path every time that a wave passes by; the movement of the wave being constantly in one direction, while the water particles rise and fall, advance and retreat, at a much less speed.

The waving of a field of grain under the wind may be taken as an illustration to show the relation of the curved-path movement of the particles to the forward progress of the waves. The independence of wave and water movement may be seen on a river surface when the wind is blowing up stream; or at the mouth of a harbor when the wind is blowing on shore while the tide is running out.

It is fortunate that only the shape of great waves has a rapid forward movement, while the water oscillates at a moderate rate. If the water moved forward with the waves, vessels would be swept thousands of miles from their courses and thrown violently on the shores; the ocean would not be navigable.

In the construction of ocean steamers and war vessels it is important that the period in which they naturally roll (like the period of a swinging pendulum) shall be longer than that of any waves they are likely to meet; for if the two periods agreed, the repeated action of the waves might make the vessel roll more and more until it capsized.

A small quantity of oil poured on the sea spreads rapidly and reduces the violence of the waves in a storm. A gale ordinarily forms ripples and small waves on the backs of greater waves, and causes the crests of great seas to curl over, so that they would break with destructive strength on the deck of a vessel. At such a time a film of oil decreases the catch of the wind on the water and prevents the large waves from curling and breaking.

Many accounts of the use of oil in storms have been published by the United States Hydrographic Office, Washington. They show that, when a vessel is headed towards the wind ("hove to") and heavy seas come on board over the bow, a little oil allowed to drip from a bag will spread even towards the wind, forming a smooth surface or "slick"; and the waves entering the slick will decrease in height and cease breaking over the deck.

When a vessel is running with the wind, heavy seas sometimes come aboard over the stern; but if a little oil is allowed to drip overboard, the slick spreads out like a fan across the wake, and the great seas are rounded off as they run into it, so that the vessel rides them without difficulty.

Great waves, travelling 20 to 60 miles an hour, soon run out of the storm that forms them and swing far across the ocean, preserving their length and velocity, but diminishing in height. In this reduced form a wave is called a swell.

In calm weather the ocean surface may be smooth and glassy, but not absolutely level and quiet; for it is never free from the slow heaving and sinking of fading swells from distant storms. A vessel becalmed in the doldrums always swings idly to and fro as the swell rolls by.

When the swell runs into shoaling water near land, its velocity decreases; its crest rises, and its trough sinks, thus making its height greater; the front becomes steeper than the back; and on reaching a sloping shore the crest curls forward and dashes upon the beach, forming surf or breakers.

The surf is like a mill in which rocks, gravel, and sand on the shore are ground finer and finer. During storms surf exerts an enormous force capable of moving blocks of rock 10 or more feet in diameter.

Exposed coasts may be beaten by a heavy surf while the neighboring sea is unruffled by the wind. The surf is then derived from a broad swell, which comes from the great waves of a storm that may be 1000 or more miles away.

The great hurricane of Sept. 3–12, 1889, while on its way from the West Indies to the Carolina coast, produced a destructive surf on the coast of New Jersey while the storm area was still a thousand miles distant. At St. Helena, a lonesome island in the South Atlantic, boats from vessels at anchor in the harbor frequently cannot reach the shore in

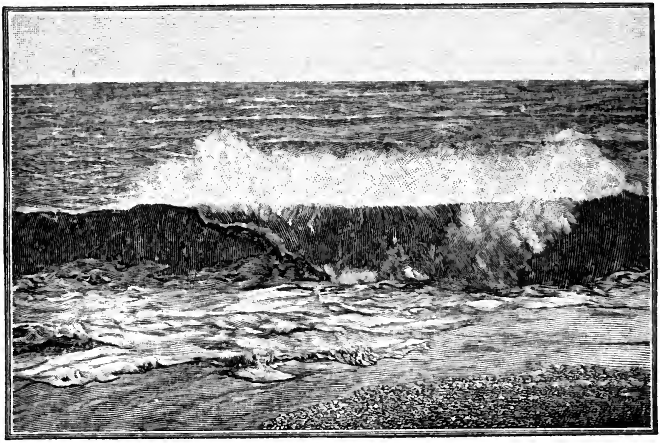

Fig. 42. — Surf.

fair weather on account of the "rollers," or heavy surf, on the beach. The swell that produces this surf is believed to come from storms in temperate latitudes of the North Atlantic.

Earthquake Waves. — When an earthquake, caused by some disturbance in the earth's crust, occurs beneath the sea, the whole body of the ocean above it is moved slightly, and the movement then spreads away on all sides in long, low waves that travel with great speed. When nearing the shore, the speed and length of the wave are decreased, but the height is greatly increased. The wave may then rush far in on a lowland coast, causing great destruction.

The tremendous explosive eruption on the volcanic island Krakatoa, between Java and Sumatra, in August, 1883, produced waves that spread far around the world. Their average velocity of progression was nearly 400 miles an hour. On distant coasts their rise and fall was slight; but on coasts near Krakatoa the waves rushed upon the land with a height of from 50 to 80 feet, flooding the lowlands, sweeping away many villages, and drowning thousands of the inhabitants. A large vessel was carried a mile and a half inland and stranded 30 feet above sea level.

An earthquake in the North Pacific produced a destructive wave, 10 to 50 or more feet high, on the coast of northern Japan in the evening of June 15, 1896. The coast was laid waste for 175 miles. The few persons who saw the wave and survived it reported that the sea first drew back about a quarter of a mile, and then came rushing in like a black wall, gleaming with phosphorescent light and overwhelming the shore. On the open coast the sea became quiet in a few minutes after the wave broke; but in bays the water surged and swirled for half an hour. The outline of the shore was changed in many places; many villages were destroyed, and thousands of acres of arable land were laid waste. Thousands of fishing boats were crushed or carried away; 27,000 persons lost their lives, and 60,000 survivors were left homeless.

It is thought that earthquake waves are sometimes produced by great masses of fine sediments sliding down the slopes of continental shelves. In Japan many earthquakes are ascribed to this cause. Telegraph cables lying on such slopes are especially subject to injury; when raised for repairs, they are found torn, as if violently dragged with the sliding sediments.

Ocean Currents. — The upper waters of the ocean, to a depth of 50 or 100 fathoms, move slowly in the general direction of the prevalent winds, thus forming currents that circulate about the great oceanic areas. The outline diagram of ocean currents (Fig. 43) shows that each of

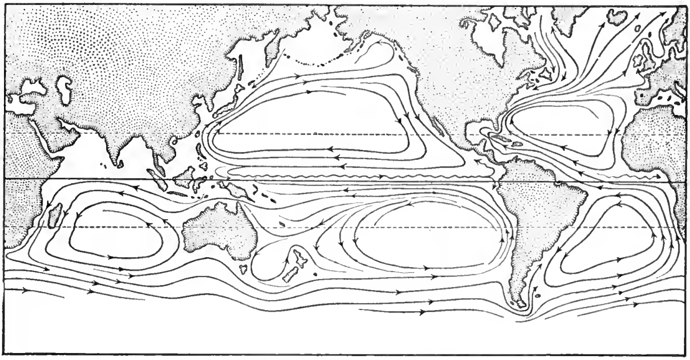

Fig. 43. — Chart of Ocean Currents.

the great oceans possesses a great eddy-like current that moves slowly around it, leaving the central waters relatively quiet.

If an observer stood in the center of an oceanic eddy in the northern hemisphere, the currents would pass around him from left to right; in the southern hemisphere, from right to left.

The eddying currents are the chief natural basis for subdividing the great oceanic area into the six oceans; the North and South Pacific, the North and South Atlantic, and the Indian oceans, each having its own great eddy; while the Antarctic ocean has a great eddy around the south pole, joining the eddies of the three southern oceans. The Arctic also has a current about the pole, joining that of the North

Atlantic, somewhat like the two loops of a figure 8; but the Arctic should be classified as a large sea or gulf, rather than as an ocean.

A current that advances slowly in a broad and shallow sheet at a rate of 10 or 15 miles a day, like that which crosses the middle North Atlantic, should be called a *drift*. A current that flows rapidly in a comparatively narrow passage, with a velocity of 50 or more miles a day, like that issuing from the Gulf of Mexico through the strait of Florida, should be called a *stream*.

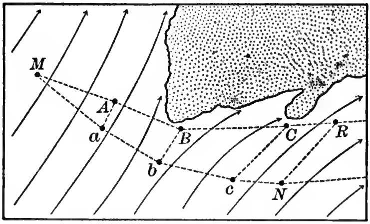

Fig. 44. — Displacement of a Vessel by Currents.

It is important that the masters of vessels should be acquainted with the movements of ocean currents. In cloudy and foggy weather, when observations of the sun cannot be made to determine latitude and longitude, a vessel might be drifted out of its expected course if no allowance were made for the movement of the waters. Thus if, intending to follow the course *MabcN* (Fig. 44), a vessel were drifted to the course *MABCR*, it would pass dangerously near the headlands at *B*

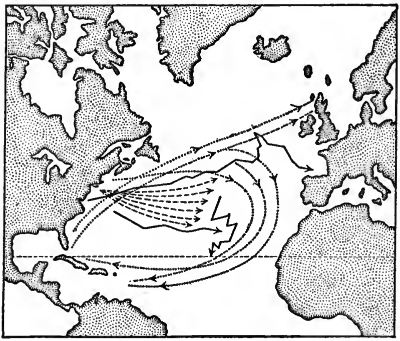

Fig. 45. — Drift of Floating Objects by Currents.

and *C*, and might even run ashore. Wrecks on the southwest coast of Ireland have not infrequently been due to this cause.

The drift of abandoned wrecks, whose positions are noted by passing vessels, gives indications of the movements of currents. The angular lines in Fig. 45 show the drift of several wrecks. The broken lines indicate the drift of many logs from a great timber raft that was abandoned in a storm while on the way from the Canadian Provinces to New York, December, 1887.

Thousands of bottles have been thrown into the sea, with record of the time and place where they have been set adrift, and request that the finder shall report the time and place of their discovery, afloat or ashore. The dotted lines of Fig. 45 give a few inferred "bottle tracks."

In Nansen's famous attempt to reach the north pole he sailed eastward along the northern coast of Asia and turned northward into a region of ice fields, where his vessel was caught between two floes. He then drifted with the ice, expecting that the Arctic current would carry him past the pole towards Greenland. Had he gone further east before turning north, a closer approach to the pole might have been made.

The remarkable correspondence between the course of the oceanic eddies (Fig. 43) and the course of the prevailing winds over the oceans, as shown in the charts, Figs. 19 and 20, points to the winds as the cause of the currents. Like the circulation of the atmosphere, the eddying of the upper waters of the oceans must be regarded as a characteristic habit of a globe having large oceans, a mobile atmosphere, and a warm equatorial zone.

The belief that the winds cause the currents is confirmed by the way in which the surface drift of the waters may be for a time brushed to one side of its usual course, or even reversed, during a storm.

The currents of the Indian ocean, with its gulfs on the north of the equator, show an extraordinary variation in direction, following the change in the blowing of the monsoons. During the northern summer, when the southwest monsoon is developed north of the equator (Fig. 23), the waters under it have a general eastward motion, as in Fig. 46. During the southern summer, when the northwest monsoon is developed south of the equator (Fig. 24), the waters under it also move eastward, while on the north of the equator the currents run in a general westerly direction under the northeast monsoon of that region, as in Fig. 47.

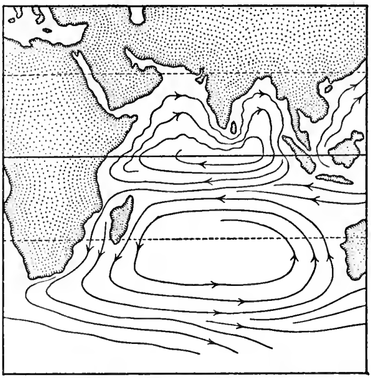

Fig. 46. — Currents of the Indian Ocean in July.

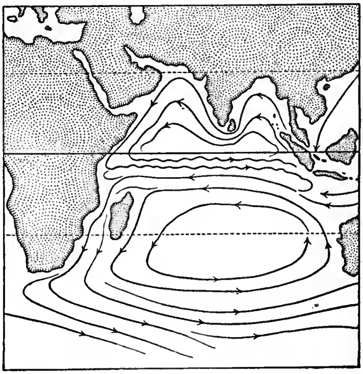

Fig. 47. — Currents of the Indian Ocean in January.

East-flowing currents of this kind near the equator are called counter currents, because they move in a direction opposite to that of the equatorial members of the great eddies.

The several parts of the various eddies may receive special names. Those parts which run westward, near and about parallel to the equator, are called the equatorial currents. The eastern part of the South Pacific eddy is called the Humboldt, or Peruvian, current; it brings a great body of cool water from far southern latitudes, and keeps the temperature about the Galapagos islands (west of Peru) so low that coral reefs, such as abound in the equatorial Pacific further west, are not found on their shores.

The name Gulf Stream, in the Atlantic, should be properly limited to the narrow, deep, and rapid current which issues from the Gulf of Mexico with a velocity of 80 or 90 miles a day; but it is popularly extended far northeast over the broad, shallow, and slow-moving drift on the northern side of the North Atlantic eddy, and even along its branch, past Norway. This extension of the current is not a stream at all, and it includes much water that passed outside of the West Indies and not through the Gulf of Mexico.

Sailing vessels should take advantage of winds and currents in shaping their courses. If bound from the United States to far South American ports, they should cross the equator well to the eastward, so as to avoid being carried backward by a strong current past the Guiana coast, where the winds may fail in the doldrums. A ship sailing from an Atlantic port to Australia should round Cape of Good Hope and take advantage of favorable winds and currents in the southern Indian Ocean about latitude 50°. On the homeward voyage favoring winds and currents would be found in the same latitude of the South Pacific, towards Cape Horn.

Currents and Temperatures. — Certain ocean currents carry warm water poleward; others carry cold water equatorward, thus causing an irregular arrangement of sea-surface temperatures. The eddying winds over the several oceans and the bordering continents cause similar irregularities in atmospheric temperatures. In a general way the eddying of the waters and winds narrows the warm belts on the eastern side of the torrid oceans, and widens the temperate belts on the eastern side of the oceans in middle latitudes.

The effect of currents and winds in disturbing the even arrangement of temperatures is much less distinct in the southern hemisphere, where only one continent extends over 50° from the equator, than in the northern hemisphere, where the continents almost enclose the polar sides of the oceans. The eastern drift of the far southern surface waters (forming the Antarctic circumpolar eddy) is little interrupted, and the temperature belts follow close along the parallels of latitude.

The temperature belts of the North Atlantic are more disarranged than those of any other ocean. This is because of the shape of its shores. It gains a large branch current from the South Atlantic, thus giving it an undue amount of warm water in the neighborhood of the West Indies; a great branch of its eastward drift turns northeast, past the British Isles and Norway; and a cold current, returning from the Arctic regions, flows past Labrador and Newfoundland. The belt of temperate climate (Fig. 48) is broadly spread over the western coast of the Old World between latitudes 30° and 60°. The same

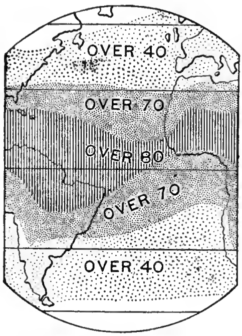

Fig. 48. — Temperatures on the Atlantic.

climatic belt is compressed between latitudes 30° and 45° on the eastern coast of North America.

Florida and Nova Scotia differ as much in mean annual temperature as Morocco and Norway. Labrador is a bleak, desolate region very thinly inhabited, while England, in the same latitude on the opposite side of the Atlantic, has a mild climate and a dense population. The chilling northeast wind of New England is part of a cyclonic whirl, supplied by air that has been lying over the cold Labrador current.

Tides. — Regular movements of the ocean, rising and falling on the shores twice in a little more than a day, are called tides. In the open ocean tides are not perceived; in many bays the tidal change of level, or range,

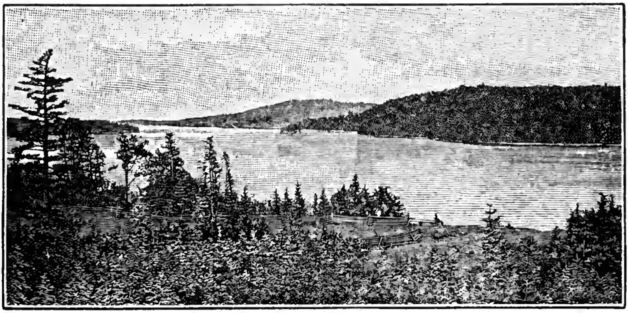

Fig. 49. — High Tide.

reaches 10, 20, or more feet. The change of level is accompanied by currents — flood tide running in from the open ocean, ebb tide running out again. A brief period of quiet or slack water occurs when flood changes to ebb, or ebb to flood.

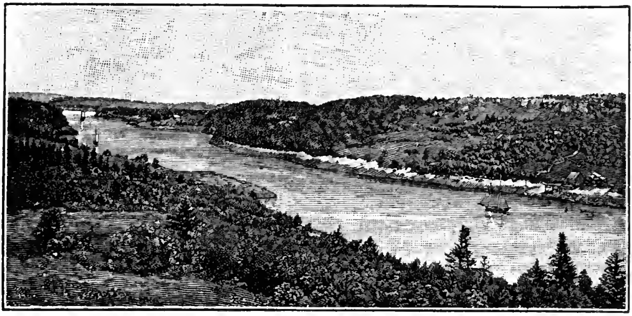

Fig. 50. — Low Tide.

The following table and diagram (Fig. 51) give the time of high and low water and the direction and velocity of flood and ebb currents for several stations in a large bay, which lead to a number of important conclusions, as follows: —

The interval or period between the times of successive high tides is constant at all stations, being 12 hours 26 minutes.

The range of the tide increases from the entrance towards the head of the bay, and then diminishes up the tidal river or estuary further inland.

The rise and fall are of equal duration at outlying stations, low tide occurring at mid-interval between high tides; but near the head of the bay the rise is more rapid than the fall,

Station.	High Water.	Rise.	Current.	Slack Water.	Low Water.	Fall.	Current.	Slack Water.	High Water.	Rise.
	h.m.			h.m.	h.m.			h.m.	h.m.	
A	0.05	2 ft.	1 m.	3.10	6.20	2 ft.	1 m.	9.25	12.30	2 ft.
B	2.10	3	2	5.15	8.25	3	2	11.25	14.35	3
C	2.55	3	2	6.10	9.10	3	2	12.20	15.20	3
D	4.25	4	2	8.05	11.50	4	2	14.20	16.50	4
E	8.30	5	3	12.35	16.40	5	3	18.50	20.55	5
F	15.05	6	3	19.30	0.00	6	3	1.45	3.30	6
G	22.20	6	3	3.10	7.55	6	3	9.20	10.45	6
J	4.00	4	2	8.20	12.45	4	2	14.35	16.25	4

and low tide occurs nearer the following than the preceding high tide.

Dotted lines are drawn in Fig. 51 to indicate the inferred position of high tide in the bay at the even hours. The advance of high tide is then seen to be about 50 miles an hour in the deeper water off-shore, but only 10 miles or less in the shallow water near the bay head.

The flood and ebb currents run past the outlying stations (*A, B*) for some time before and after high water. At the head of a little bay, like *L*, slack water occurs at high and low tide; flood currents run while the tide rises, and ebb currents while it falls.

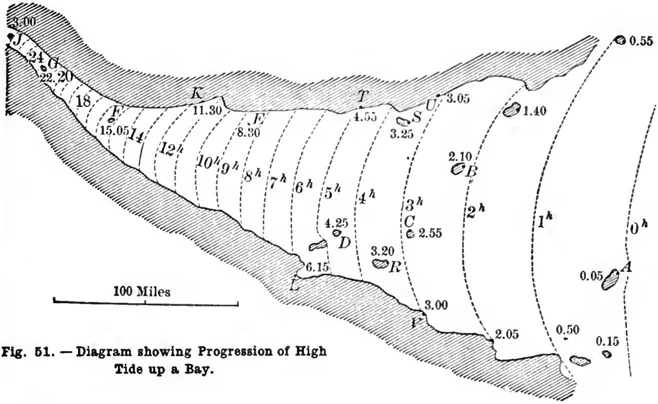

Fig. 51. — Diagram showing Progression of High Tide up a Bay.

When high water occurs in the entrance to the bay, the high waters of two preceding tides are near the head of the bay, as shown in section in Fig. 52. Many actual examples illustrating these phenomena may be found in the Charts and the Tide Tables published by the U. S. Coast Survey.

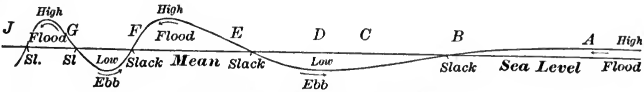

Fig. 52. — Diagram of Tide Waves.

It appears from the foregoing that tides resemble waves in many ways. High tide is the crest of the long, flat tidal wave; low tide is the trough. Tidal currents correspond to the curved-path movements of water in ordinary waves. The change in the range, velocity, and form of the tide, as it advances up a bay, may be compared to the change in the behavior of the ocean swell as it runs ashore.

Cause of the Tides. — The regular arrival of wave-like tides on all ocean shores leads to the belief that the whole ocean must be undulating. The tide waves in the open ocean must have a less range and a greater velocity than the tide waves near shore; but the period must everywhere be 12 hours 26 minutes. The undulation of the oceans must be caused by some disturbing force that acts in the same period as that of the tides.

The apparent daily movement of the moon carries it from one side of the earth to an opposite position in 12 hours 26 minutes; and this fact suggests that the moon is the cause of the tides. The power of the moon to produce the tides can be reasonably explained as a result of the attraction that it exerts on the earth and the oceans.

It was known to the ancient inhabitants of Great Britain in the time of Julius Cæsar, almost 2000 years ago, that there was some relation between the moon and the tides; but Newton, the great English mathematician and astronomer, first gave about two centuries ago a clear explanation of the process by which the moon can produce tides. (See Appendix J.)

Tides are beneficial in maintaining a circulation in bays and harbors where the waters might otherwise be almost stagnant. At high water a harbor will admit vessels of a larger size than could enter if the ocean level did not change; but at low water the harbor may be inaccessible except to much smaller vessels.

In funnel-shaped bays or estuaries the tidal range becomes large, and flood and ebb currents are very strong, making navigation difficult or even dangerous. The tidal range

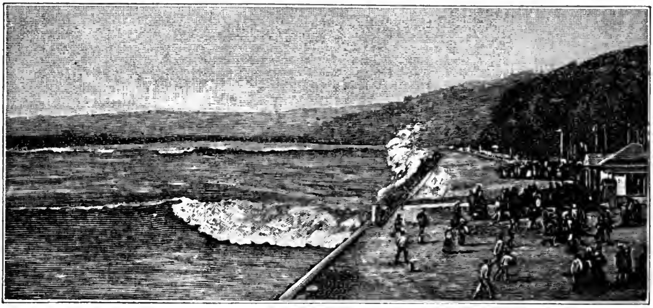

Fig. 53. — The Tidal Wave or Bore in the Seine.

sometimes exceeds 50 feet at the head of the Bay of Fundy and of the Bristol channel; here the flood current rushes in like foaming surf. The estuary of the Seine in France has a similar surf-like tide, shown in Fig. 53. Such surf-like tides are called *bores.*

Many curious tidal phenomena are found on shore lines of different forms. At New York a high tide entering from the harbor reaches the rocky narrows of Hell Gate when a low tide arrives through Long Island sound; and six hours later a low tide from the harbor meets a high tide from the sound. Thus a rapid current is caused to flow back and forth in the narrow passage, which was dangerous to vessels until the channel was widened by blasting away its reefs. A current of this kind is sometimes called a tidal race.

Faint tides are observable in large lakes. In Lake Michigan at Chicago, and in Lake Superior at Duluth, the strongest tides have a range of about three inches, but they are usually masked by an irregular rise and fall of the water due to on-shore and off-shore winds.

Life in the Ocean. — The surface layers of the open ocean possess a considerable variety of animal life, from large mammals like whales to minute organisms (Fig. 38) whose tiny shells are so plentifully strewn over the ocean floor. The former occur in moderate numbers; the latter are countless. The distribution of surface life is determined chiefly by differences of temperature from the torrid to the frigid zones. Those forms which swim or are drifted freely by the currents are found over vast areas.

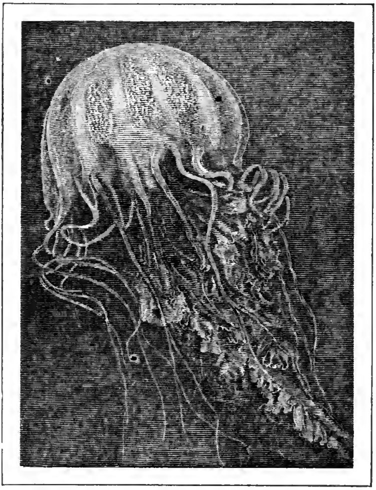

Fig. 54. — A Floating Jellyfish.

In fair weather the surface waters are sometimes alive with minute, jelly-like forms. In the warmer seas the phosphorescent light which these simple organisms produce when disturbed, as in rippling waves or in the wake of a vessel, makes the water glow at night.

The relatively quiet water about the central part of the great surface eddies generally contains a considerable quantity of floating seaweed, or *sargassum;* hence these central areas are called *sargasso seas.* The *sargassum* is believed to be derived from shallow marginal waters, where it grows on

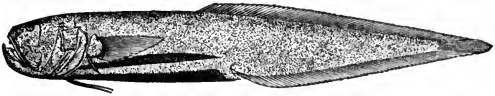

Fig. 55. — Deep-Sea Fish. × ½.

the bottom. A great variety of small animals live on the floating weed, and a certain kind of fish uses it as a "nest" for its eggs.

The deep ocean floors have no plants. They are inhabited by a considerable variety of animals, such as fish, crabs, shellfish, starfish, etc.; but the forms of life are here much less varied and less numerous than in the shallower waters near the shore.

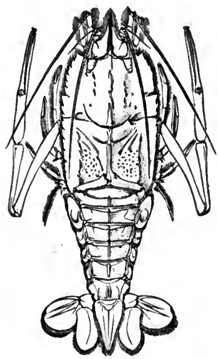

Fig. 56. — Deep-Sea Crustacean. × ½.

The animals of the deep sea live under enormous pressure, even several tons to a square inch. But just as land animals have air within their bodies, and thus withstand the pressure of the atmosphere, so sea animals are permeated by fluids, and thus unconsciously support the heavy pressure of the ocean.

While many deep-sea animals are blind, it is curious that some have well-developed eyes, and are ornamented by colors in elaborate patterns. Hence there must be some light in the ocean abysses. It may be supplied by phosphorescent animals, of which there are many kinds in the deep sea.

The intermediate depths of the ocean, between the upper part and the bottom, are prevailingly without life — a great desert space, cold, quiet, and monotonous.

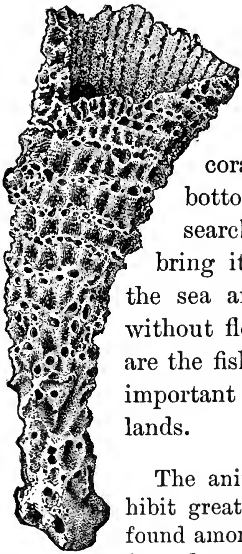

Fig. 57. Deep-Sea Sponge. × ½.

The shallow waters of the ocean margin teem with plants and animals. Many animals, such as sponges, corals, and barnacles, are fixed to the bottom; they need not move about in search for food, because the moving waters bring it to them. Nearly all the plants of the sea are of a comparatively simple kind, without flowers or seeds. The shallow waters are the fishing grounds of the sea, and furnish important supplies of food to the neighboring lands.

The animals of the shallow sea margins exhibit greater variety from place to place than is found among those of the open surface or of the deep floor. A notable peculiarity of the shallow waters in the polar regions is an abundance of seaweeds similar to those of low latitudes; while the plants that grow on Arctic lands, chiefly mosses and lichens, are very unlike the land plants of warmer latitudes.

CHAPTER V.

THE LANDS.

The Changes of the Lands.

The form of the lands varies greatly from place to place. Here we find endless variety, in contrast with the wonderful uniformity prevailing in the oceans. As a result of this variety, the conditions of life are very different for people on broad plains far inland, in deep valleys among lofty mountains, near harbors of the seacoast, or on lonely islands in mid-ocean. The people of a savage tribe, living in any one of these homes and knowing little or nothing of the rest of the world, might contentedly remain ignorant of the way in which the forms of the land around them were produced. The people of a civilized nation, learning much about all parts of the world from explorers and travellers, and perceiving that the way in which the people of different nations live is largely controlled by their geographical surroundings, naturally inquire about the origin of highlands and lowlands, of mountains and valleys.

During the nineteenth century, land forms have been studied attentively and much has been learned about their origin. The most important general result of this study is that the forms of the land as we now see them are found to be the effect of slow changes continued for thousands and thousands of years. It is at first difficult to realize that the crust of the earth, seemingly so solid, nevertheless slowly rises or falls, now revealing the bottom of a shallow ocean border as a land surface, now submerging a low continental border beneath the sea; but there can be no question that such movements have repeatedly taken place, and that they are even now in slow progress. It is hard to believe that deep valleys have been worn between high mountain ridges by nothing more than the long-continued action of rills and streams such as are still at work; but the attentive observer must notice that active streams wear their channels, and remove the waste of the land that is washed from the enclosing valley slopes; and great results must follow from these processes if they are long continued. The more the world is studied, the more certain it becomes that changes of these kinds are ordinary, not extraordinary, events in the history of the earth.

The time required for all these changes can hardly be calculated; it must be vast beyond comprehension. All the centuries of human history are only long enough to discover small changes in land forms. The lowlands that guided the migrations of the early races of men across the continents, and the mountains that stood in their way, are lowlands and mountains still; yet in the history of the earth lowlands have over and over again been slowly uplifted to mountain height, and mountains have repeatedly been very slowly worn down to lowlands. Such changes in the expression of the face of the earth must have required periods of many million years, compared to which man's life on the earth is but a brief interval. But only when the forms of the land are recognized as the result of long changes can the lands be properly understood as the home of man.

Physical Features of the Lands.

Area of the Lands. — The globular earth is uneven enough to raise somewhat more than a quarter of its surface slightly above the oceans in broad land areas, called continents. The continents, covered only by the atmosphere, present many contrasts to the deep sea floors covered by the oceans; and these contrasts have for long ages been of the greatest importance in determining the geographical conditions of animal and vegetable life on the globe, as they have in recent ages determined the geographical conditions of man.

The area of the globe is about 197,000,000 square miles. The lands occupy somewhat more than 50,000,000 square miles; their total area remains uncertain until the polar regions are fully explored. Six-sevenths of the land area are in the land hemisphere, where the ocean occupies little more than half the surface. The lands in the water hemisphere occupy only about one-fifteenth of the surface.

The greatest islands are near the continents, as in the archipelago north of North America, the West Indies, Newfoundland, the British Isles, and the Malayan-Australasian archipelago. Most of these islands stand upon continental shelves, and are separated from the continents only by shallow water. The numerous oceanic islands, distant from continents, are of small total area (about 40,000 square miles).

The five continents differ greatly in size, arrangement of parts, and degree of separation. It is not possible in the present state of knowledge to give a precise definition of a continent, other than to say that it is a large area of land.

Asia and Europe form a single continent, often called Eurasia; but on account of their great extent, and still more because of their great differences with regard to human history, it is convenient to regard each of them as a "grand division" of land.

Height of the Lands. — The highest mountain peaks, 25,000 to 29,000 feet, do not rise above sea level so much as the greatest ocean depths sink below it, and the average elevation of the lands (2400 feet = 735 meters) is much less than the average depth of the oceans.

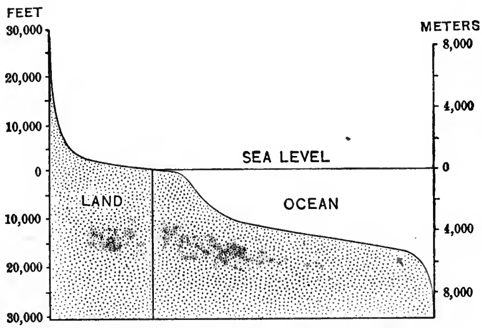

Fig. 58. — Height of Land and Depth of the Sea.

Fig. 58 exhibits the share of high and low land, and of deep and shallow ocean, the whole area of the earth being measured by the breadth of the figure. It is thus seen that most of the land surface is but little above sea level, while most of the sea floor lies deep below the sea surface.

Continental Outline. — Africa and South America are similar in having simple outlines, with few large bays, peninsulas, and outlying islands. North America and

Eurasia are alike in having irregular outlines, with many large bays and peninsulas, and with numerous outlying islands. Europe is rich in arms of the sea entering far into the land, like the North, Baltic, and Adriatic seas.

Continents are generally broader in the north than in the south. This is distinctly seen in South America, North America, and Africa. Land arms are more frequently directed southward than northward, as in Florida and Lower California, and in many peninsulas from Spain to Farther India.

The grouping of the continents is very irregular and follows no known law. The lands occupy an irregular belt stretching from Cape Horn to Cape of Good Hope, broad across the middle of the continents, narrow at their ends, broken at Bering Strait, and with a half-submerged arm reaching out to Australia.

The earth as a whole, being of globular form, may be treated as a body of regular shape, its different parts from equator to poles being marked off by a simple system of parallels and meridians. The atmosphere, covering the entire earth, may be for the most part treated in belts, the members of the wind system and other climatic features being arranged nearly parallel to the equator, but made somewhat irregular by the interference of the continents.

The ocean, covering the greater part of the earth, exhibits a well-marked system of surface movements that are roughly symmetrical on both sides of the equator. The lands are so irregularly distributed and so uneven in surface that no simple system can be found in their arrangement.

Changes of Continental Outline. — The form of the lands and the outline of their shores seem at first sight to be unchangeable. But the more the world is studied, the more certain it becomes that slow changes are going on in the shape of the earth's crust, and that the outline of the continents is subject to change as the continental masses very slowly rise or sink. Thus in the course of long ages the geography of the world may be greatly altered.

Slight movements of elevation or depression, such as have often happened in the earth's long history, may slowly drown a lowland on a continental border, or gradually reveal a part of a continental shelf as a plain bordering higher land. These movements are so slow that they are hardly perceptible in the course of a century; but when continued for hundreds of centuries they cause changes of great importance in the geography of the lands.

It has been discovered that a large part of North America had a land existence at an early stage in the earth's history, uncounted millions of years ago, and that it was afterwards submerged; for wide-spread rock layers formed of bedded sediments and containing fossils of sea animals are found overlying and burying an ancient land surface with hills and valleys. In still later times the continent has suffered many small changes of altitude, sometimes sinking so that a sea of moderate depth overspread its borders, sometimes rising again so that the land extended beyond the present shore line, but in a general way retaining its ancient outline.

The same may be said of a considerable part of Eurasia, and of certain parts of other continents. Hence it is coming to be believed that, on the whole, continents are elevations in the earth's crust that have for long ages stood higher than the deep ocean floors.

Changes in continental outline are so slow that they have seldom been detected by direct observation; but this is chiefly because delicate observations of shore lines have been made only within the last century or two.

If the ancients had been as attentive to geographical as to astronomical problems, it can hardly be doubted that many distinct changes in the level of the land and in the position of shore lines would have been found between the time of ancient Greece and to-day.

Observations in the last hundred years or more give reason to believe that the coasts of Massachusetts and New Jersey have sunk (one or two feet a century), and that much of the coast of Sweden has risen (maximum, three feet a century). The coast of the Netherlands is sinking a foot a century, and its fields near the shore, 15 to 20 feet below the sea level, are diked to keep the water off. Many geographical proofs of change of level will be given in later pages.

The globular form and regular rotation of the earth as a whole seem to be permanent features of our planet. The belt-like arrangement of the winds seems to be as enduring as the shining of the sun. The eddying of the oceans must be affected by the outline of the continents; yet as long as the sun shines, the earth rotates, and the winds blow, the eddies must turn regularly to the right or left, according to their hemisphere. But the outline of the lands is subject to many changes that seem to be without system.

There will always be doldrums around the equator, and westerly winds in temperate latitudes. There will always be a current entering the torrid zone on the eastern side of the oceans. But in other ages Asia and Europe may have been or may come to be separated by the submergence of the plains from the Black sea to the Arctic; and Asia and Australia may be united by the elevation of the sea floor between them. Hence, although the continents seem to be the most permanent features of the earth's surface, they may be long outlived by the systematic movements of the ocean currents and the winds.

Variety of Land Surface. — The surface of the continents possesses great variety of form and composition, in strong contrast to the monotony of the broad sea floors. Rocks and soils, as well as mountains, valleys, and plains, differ from place to place. Peaks and ridges of resistant rocks, slopes and valleys underlaid with weak rocks and covered with soils of gravel, sand, and clay; these and many other differences give great variety to the lands.

Mountain ranges are characteristic of the continents rather than of the sea floors, where plains of vast extent prevail. But mountain ranges occasionally rise from the sea bottom, showing their crests above the surface, as in the West Indies. Submerged ranges may yet be discovered by soundings among the island groups of the Pacific.

The continental shelves overlapped by some of the oceans have something of the variety of the lands from which they receive washings of gravel, sand, and clay. Volcanoes and their lavas are among the few features possessed in common by the deep sea and the dry lands.

Climate of the Lands. — The conditions of the land surface vary greatly under different conditions of weather and climate. Heavy rains are followed by clear sky; strong winds by light winds or calms. A bare desert surface in the torrid zone may be heated at noon above 150°, and may cool nearly to freezing the next night. In the frigid zone the frozen soil may thaw and warm at the surface during summer, but it will be intensely frozen again, even to 80° below zero, the next winter.

Variations of temperature, so distinct at the land surface, rapidly decrease under ground. At a depth of 4 or 5 feet daily changes are hardly perceptible; at a depth of 20 or 30 feet there is but little variation from the mean temperature of the year (about 80° in the torrid zone, near zero in far northern lands).

In northeastern Siberia, where the ground is frozen to a depth of 300 to 500 feet, grass and bushes grow when the soil thaws for a few feet in summer; but large trees are wanting. The mammoth, an animal resembling a hairy elephant, but no longer found living, has sometimes been preserved in the frozen beds of sand and gravel that border some of the Siberian rivers, where it was buried at the time of river floods centuries ago.

On descending beneath the land surface, as in deep mines, the crust of the earth is found to be about 1° warmer for every 60 feet of descent; but this rate varies in different regions. Hot springs, geysers, and volcanoes all indicate the occurrence of high temperatures deep under ground; hence it is believed that the great body of the earth beneath its cool outer part or crust is glowing hot, and less rigid than if it were cold. In spite of the great store of heat within, the temperature of the surface is hardly affected by that of the interior, but depends almost wholly on sunshine.

Activities of the Lands. — In nothing do the continents differ more strikingly from the sea floors than in the activity of the various processes that go on upon the lands, and in the rapidity of the changes that the processes produce. The surface rocks split apart when water freezes in their crevices, or they rust under the chemical action of air and water. A sheet of loosened rock waste is thus formed over most of the land surface. The various processes by which rock waste is produced are known under the general term *weathering.* Weathering varies greatly under different climates and with different rocks.

In the dry, mild, and equable climate of Egypt, ancient statues have been but slightly weathered in several thousand years. A great stone monument, 60 feet high, known as Cleopatra's Needle, brought from Egypt to New York in 1880, was so much affected by the weather in a single winter that it was necessary to coat its surface with a preservative substance. In Egypt it had stood over 3000 years with little change.

Fig. 59. — A Quarry showing Weathered Rock.

Under the heavy rainfall and luxuriant vegetation of the equatorial forests, weathering advances with comparative rapidity; it is aided by the products of decomposing vegetable matter. On exposed mountain peaks and in high latitudes, where the temperature frequently rises or falls past the freezing point, frost is active in splitting rock masses to smaller and smaller fragments.

Although acting slowly, weathering accomplishes great results in the long course of the earth's history. The occurrence of soil, in which the roots of so many useful plants grow, and the form of the land surface, which constantly exerts so great an influence on the manner of man's living, are both due in large part to the work of the slow but persevering attack of the atmosphere on the rocks of the lands.

Every rock ledge or quarry offers opportunity for observing this widespread process. The weathering of the older gravestones in cemeteries may frequently be noticed. In cities the different amounts of weathering on old and new stone buildings, or in buildings of different kinds of stone, serve to illustrate in a simple way the changes that occur on a much greater scale all over the lands.

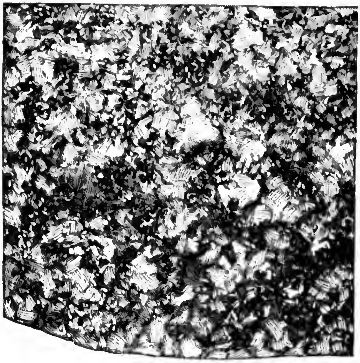

Fig. 60. — Granite.

Varieties of Rocks. — The rocks of the earth's crust are of many different kinds, and vary greatly in their resistance to weathering. Granite, consisting of crystalline grains of several minerals (quartz, feldspar, and mica) closely bound together, is one of the more resistant rocks; but the weathering of one of its minerals (feldspar) unbinds its parts, and it slowly crumbles to a gravelly soil.

Quartz is easily recognized by its glassy lustre and its hardness. It will strike fire with steel, and was employed for this purpose before matches were invented. Feldspar is not quite so hard; its color is usually gray or pink, and it splits with a smoother face than quartz. Mica has the property of splitting into very thin elastic scales.

Sandstone, composed chiefly of grains of quartz, is resistant when the grains are well cemented together, but weak when they are imperfectly cemented.

Sandstone is formed from the waste of such rocks as granite. The sand is washed into the sea or other body of water, and is there spread out in layers which may in the course of ages accumulate to great thickness. Infiltering waters, carrying some mineral substance in solution, deposit it between the grains and bind them more or less perfectly together. Pebbles are often found in sandstones, giving them a coarse texture.

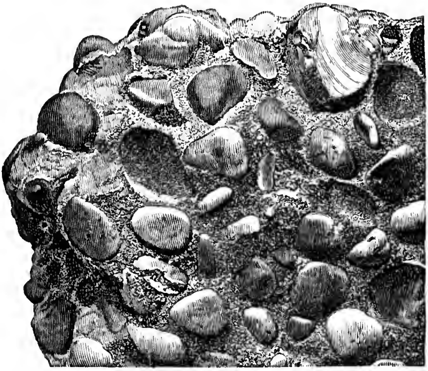

Fig. 61. — Pebbly Sandstone.

The finer waste from such rocks as granite forms muddy deposits when it settles in quiet water. The grains are here much smaller than those of sandstone, and the rocks thus formed, known as shale and slate, are generally of small or moderate resistance. Shaly sandstone is a rock intermediate between a fine shale and a granular sandstone.

Fig. 62. — Limestone with Fossil Shells.

Limestone is generally formed of the remains of the shells or skeletons of sea animals, more or less broken to fragments or even ground to powder in the waves of shallow waters. It often includes shells and corals as fossils, as in Fig. 62. It is not so resistant to the weather as granites or dense sandstones, and is much more soluble in water than other rocks.

Some limestones are formed of the fine ooze that accumulates on the ocean bottom from the shells of minute animals like the globigerina (Fig. 38) that float near the surface when living. Limestone of this kind is called chalk.

There are many kinds of lavas that have been pushed out from the hot interior of the earth through the colder crust. Basalt, a dark and dense lava, is one of the most resistant rocks of this kind.

The lavas that are blown with explosive violence from volcanoes are shattered to fragments. Deposits formed of such fragments may be much less resistant to weathering than heavy sheets of dense lava that, after flowing quietly from a volcano, solidify as they cool.

The Wasting of the Lands. — Surface water, supplied by rain or melting snow, washes the finer rock waste down the slope of the land to the valley floors or to the streams, and the streams bear the waste along their channels, thus sweeping it from one place and spreading it over another, or washing it to the sea. Where streams run, they rasp their channels with the rock grains that they bear along, and valleys are thus slowly worn in the surface of the land. The higher the land, the deeper the valleys may be cut.

Large valleys, receiving many smaller branching valleys and ravines that dissect the surface of the land and lead streams from higher to lower ground, are among the most characteristic features of the continents. They are the result of stream action, and cannot occur on the deep sea floor.

They are sometimes found beneath sea level, extending forward from the present coast line across the shallow continental shelf; they are then taken as proof of the depression of that part of the continent.

The winds act with great effect on bare surfaces, sweeping finer rock waste into drifts (dunes), and raising the dust aloft to settle far away. Waves, currents, and tides wear the edge of the land and the shallow continental margins, cutting cliffs and building sand reefs along the shores.

The wet-weather streams of roadsides and the waves on the shores of ponds or reservoirs exhibit in a small way the processes characteristic of large rivers and oceans. The different effects of winds on dusty roads, on grassy fields, or on forested surfaces, illustrate the contrast that prevails between wind action in dry and in moist regions.

The sea floor is enduringly quiet and silent. The tides of the deep sea are very faint. The creeping of cold polar water towards the equator must be almost imperceptible. Chemical changes of the bottom deposits are slight. The gain of the bottom by the steady shower of organic remains from the surface must be very feeble, and the change of form by this gain must be exceedingly slow.

Although the changes produced in the form of the lands by weathering and washing are slow, they have been so long continued that marvellous results have been produced. Not only are the lands dissected where deep valleys have been worn in plateaus and mountains, but whole mountain ranges have been worn down to lowlands. The forms of the land to-day can be appreciated only when it is seen that they are the present stage of a long series of changes. The description and explanation of land forms thus considered is the object of the greater part of this book.

The general wasting of a land surface is slow, but local changes are easily noted by the attentive observer. Roads are gullied by wet-weather streams. Much soil may be washed from a plowed hillside in a single rainstorm. Landslides produce striking changes on mountain slopes and in the valleys below. Cataracts like Niagara wear back their cliffs even more than a foot a year. Deltas grow forward into lakes and seas so as to gain perceptibly in a century. Ostia, once the port of ancient Rome, is now over a mile inland from the advancing front of the Tiber delta. Sea cliffs may be cut back by the waves; the exposed eastern bluff of Cape Cod, Massachusetts, is retreating at an average rate of three feet a year.

The general process of wasting and washing, by which the surface structures are slowly worn away and the deeper and deeper structures of the earth's crust are attacked, is called *denudation*, or *erosion*. Its rate varies greatly with rock structure, slope, and climate. The lower Mississippi carries enough land waste to lower its whole basin an inch in about three centuries. An inch in from one to ten centuries may be taken as a rough value of denudation averaged for large areas.

Opportunity for Varied Forms of Life. — The land surface, unless too cold, too dry, or too bare of rock waste (soil), is well covered with vegetation, the larger part of which consists of flowering plants, much more highly organized than the plants of the sea.

Land plants gain their food from the soil through their roots, and from the atmosphere through their leaves, and thus utilize the rock waste and the air with which the rock crust of the land is covered. Sea plants make little use of the deposits gained by the sea margin, and take their food chiefly from minerals and gases dissolved in sea water.

Land animals are numerous, varied, and as a whole highly organized. They exceed the animals of the deep sea floor in variety of structure and habit. They are exceeded in number only by the animals of the shallow sea margins or of the open sea surface.

Many animals of the sea are attached to the bottom, like corals; others move slowly, like starfish and shellfish; still others float with the drifting waters, having little movement of their own, like jellyfish. Only the more highly organized, like many fish, swim rapidly. But nearly all land animals move about actively, walking, running, or flying.

The larger and more important land animals (mammals and birds) are warm-blooded. The only warm-blooded animals of the sea (whales, porpoises, etc.) are believed to be the descendants of remote land ancestors, gradually modified for marine life, but retaining many resemblances to the forms from which they are derived.

The rock waste of the land has come to be the dwelling-place of certain forms of land life, such as earthworms, many kinds of insects, and certain mammals, like the moles. Many animals, such as ants, many kinds of bees and wasps, prairie dogs, foxes, etc., burrow in the finer waste. Other animals, such as snakes, find shelter in the hollows between coarse fragments of rock waste.

Apparently owing to the greater mobility of air than of water, many land animals have developed organs for the production of sound, the most remarkable sounds being the songs of birds and the speech of man. The animals of the sea are, with hardly an exception, silent.

Floating and swimming sea animals are of about the same weight as the water that they displace. Birds and insects are much heavier than the air in which they fly; and flying must be regarded as indicating a much higher development than swimming.

The higher development and the much greater intelligence of many land animals than of sea animals should be regarded as a result of the greater variety of physical conditions found on the lands than in the seas.

The class of insects, almost limited to the lands, furnishes many examples of extraordinary instinct, as with bees and ants. Nest building by birds, house building by beavers, "homing" of pigeons and trailing (by scent) of dogs, are examples of highly developed instincts that have no parallel among the inhabitants of the sea.

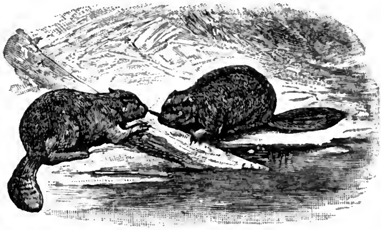

Fig. 63.—Beavers.

The physical conditions of the deep sea are more varied than those of the lands only in respect to the variations of pressure. Land animals are subject at sea level to an atmospheric pressure of about a ton to the square foot of surface. This pressure decreases with altitude, but few animals climb or fly high enough to reduce it by half. In the sea the pressure is increased a ton per square foot by descending a little more than 30 feet; and many sea animals have a vertical range of much greater measure.

Distribution of Life.—The distribution of plants and animals can be explained only when it is understood that the members of every living species are descended from a long line of ancestors. Related species, such as the various antelopes or the hawks, are believed to have sprung from a single species; their existing differences are due to gradual variations by which they have become better adapted to their slowly changing surroundings through long ages of the earth's history.

Among the many changes of surroundings none have been more important than variations in the outline and form of the lands such as may have been caused by the slow raising or wearing down of mountain ranges, or by the slow elevation or depression of a continental border. Continents, once connected, may have been divided by the depression and submergence of the lower lands; the descendants of a common stock would then be separated into two families. The longer the time since such a separation, the more the descendants of one family may vary from those of the other.

Fig. 64. — Caribou.

For example, the reindeer of northern Europe and the caribou of far northern America are so much alike that a recent connection of the lands on which they are found must be inferred. Again, the puma and jaguar of middle latitudes in the New World are cat-like animals, and resemble the lion, tiger, and leopard of similar latitudes in the Old World in so many ways that naturalists have been led to believe they must be descended from the same stock. Hence in some

Fig. 65 — Jaguar.

former time the Old and New Worlds must have been connected in latitudes where the ancestors of these animals could pass from one region to the other. But the American forms are now so unlike the others that a long time must have elapsed since the continents were separated.

Fig. 66.—Tiger.

Life on Islands.—Islands that rise from continental shelves are occupied by many plants and animals similar to those of the neighboring mainland. It is inferred from this that the continental mass once stood higher, and that the continental shelf was then a lowland on which the present islands rose as hills or mountains.

Fig. 67.—Cassowary.

Various species of cassowaries (ostrich-like birds) are found in Australia and the islands to the north, each land area having its own species. From this it is argued that the common ancestors of all these species occupied the region when the continental mass stood higher and the mainlands and islands were connected by the lowland of the present continental shelf. Since then the region has been depressed, the lowland flooded by the sea, and the islands separated from Australia and from each other. The differences between the various species of cassowaries must have arisen since they were separated by the drowning of the lowlands.

Australia, the most isolated continental region of the eastern hemisphere, has no true mammals but is the chief home of marsupials (pouched mammals), like the kangaroo, once widespread over the world, as is shown by their fossils in rock layers, but now hardly surviving elsewhere. New Guinea and several other islands north of Australia, separated from the mainland by a shallow sea, are also occupied by similar marsupials, thus confirming the recent connection of these lands as indicated by the cassowaries. Asia has no marsupials, but many large mammals. The neighboring islands on the southeast, rising from a broad continental shelf, possess many similar mammals; hence here also the islands must have been recently connected with the continent. But the Asian and Australian regions must have been long divided, as their animals are very unlike; the division must have followed the deep-water line between Celebes and New Guinea, known as "Wallace's line," from its discoverer.

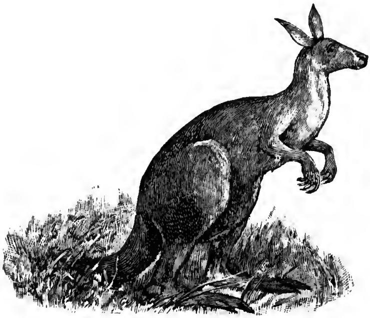

Fig. 68. — Kangaroo.

An island is so distinctly separated from the rest of the lands, that the Latin word for island (*insula*) gives us the words "insulate" and "isolate," meaning to place apart or alone.

Islands that rise from the deep ocean floor far from the continents have no large native animals, but are occupied by such forms of animals and plants as might have reached them by flying, swimming, or floating from the nearest larger land.

The Azores, a group of mid-ocean volcanic islands in the North Atlantic, are so called from the hawks that were common upon them when they were discovered by voyagers from Europe. The Galapagos islands, of similar origin, in the Pacific west of Peru, are named from the tortoises that abound upon them.

Races of Man.—The homes of the races of man, together with their remarkable differences of language, religion, and form of government, correspond in a general way to the division of the lands into continents. Hence it may be believed that the separation of the continents by the oceans has been the chief cause of the division of mankind into several races.

Through the greater part of man's existence on the earth his condition has been uncivilized, and his migrations have been of the primitive sort now seen among peoples still savage or barbarous, like the wandering Bedouins of the Sahara, or the forest tribes of the Amazon basin. Thus distributed, man has come to be divided into several races, with many branches, stocks, and families. It should not be assumed that all mankind can be divided into a few well-defined races.

The greatest of the continents, Eurasia, contains two races. The European race, generally white but with some dark-skinned families, has its home in Europe, part of Africa north of the Sahara, and southwestern Asia. The leading nations of this race are the most advanced peoples of the world, having developed liberal governments in which the rights of the people are considered, and having advanced greatly in the cultivation of the arts and sciences.

The Asian race is found in central and eastern Asia; it is often called the Yellow race. China contains the greatest number of this people. Although comparatively advanced in many arts, the Asians have acquired little knowledge of the sciences, and their governments are usually despotic.

America is the home of the American or Red race; its people is divided into many tribes, each of which is governed by a chief. Africa is the home of the African or Black race, governed by despotic kings or chiefs. Australasia and the peninsulas and islands of southeastern Asia include a number of less important races. Few nations among these races have made important advances toward civilization.

Within the last few centuries the means of travel over land and sea have greatly increased, and to-day the races of mankind are by no means limited to the continents named above as their homes. People of European ancestry are now the chief part of the population in North and South America, southern Africa, Australia, and New Zealand, as well as in Europe. The Chinese are by no means limited to China alone, but are found in large numbers as merchants and laborers in southeastern Asia, Australia, and elsewhere. Many of the African race are now living in North and South America.

It should be noticed that, while the people of the European race are now widely distributed over all parts of the world, and while Asians and Africans are found in large numbers in other lands than their homes, few of the less advanced races have migrated into Europe.

CHAPTER VI.

PLAINS AND PLATEAUS.

The Geographical Control of Population.

Southern New Jersey. — If a traveller should descend from the uplands of southeastern Pennsylvania, cross the Delaware, and proceed over the lowlands of southern

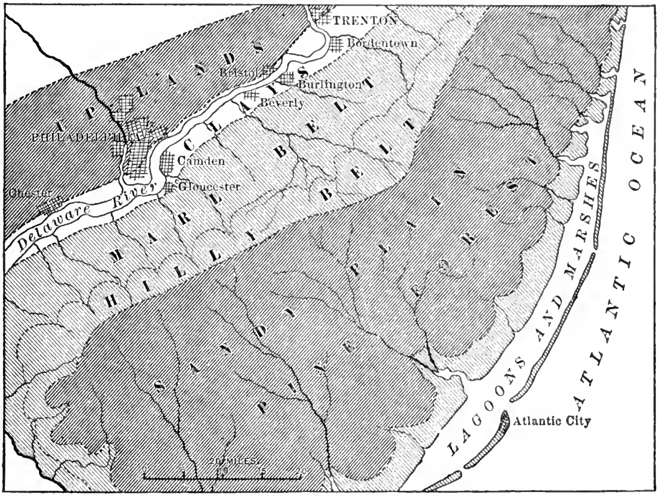

Fig. 69. — Southern New Jersey.

New Jersey to the seashore, he might discover that many geographical features, such as the forms of the land, the arrangement of the streams, the mineral products, and the soils, are here grouped in belts, roughly parallel to the coast line, as in Fig. 69. The upland belt on the border of Pennsylvania has a rolling surface, diversified by narrow valleys. The soil is good, and most of the upland is cleared for farming. The rock beneath the soil is firm and enduring; quarries are easily opened on the valley sides, and many of the older farmhouses and barns are built of stone thus provided. The streams afford water power for mills, in which grain from the farms is ground. A number of good-sized towns on the Delaware have profited from the easy transportation afforded by river steamboats. The open valley of this large river has long been an important path of travel, a century ago by stage, now by rail, on the line connecting the important cities of Washington, Baltimore, Wilmington, Philadelphia, Trenton, Newark, and New York. Next beyond the Delaware there is a narrow lowland belt, free from firm rocks but deeply underlaid by fine clay. Crockery, earthenware, terra-cotta, and bricks are made here for domestic and industrial uses. Then follows a belt of slowly rising ground ending in low hills, the most uneven part of southern New Jersey. The headwaters of many short streams rise among the hills and run northwest to the Delaware; between the streams the slope from the hills includes much good farming country, and here are the best farms in the southern part of the state. Beds of marl (limy clay) occur in this belt, frequently containing shells of sea animals. The marl is often dug out to serve as a fertilizer on less productive soils.

The long gentle slope that leads from the hilly belt southeast to the ocean has for the most part a deep sandy soil generally overgrown with pine forest, and so infertile as to be hardly worth clearing. Here the population is scanty. The surface is so flat that roads and railroads run for long distances on straight lines. Not a hill is to be seen for many miles. A house or tower that rises over the tree tops discloses "an unbroken extent of dark-green pine forest as far as the limit of vision, stretching away in

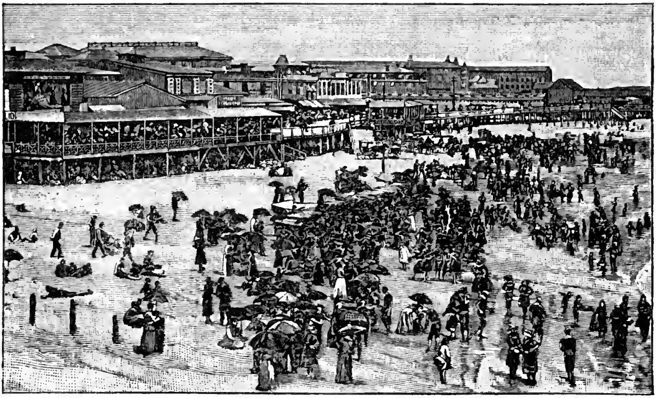

Fig. 70. — The Beach, Atlantic City, New Jersey.

long, gentle swells," nearly as level as the ocean itself. The streams flowing southeast are sluggish, and afford little or no water power. The boggy soil of their marshy valleys is sometimes used for the cultivation of cranberries. Nearer the shore the plain is somewhat interrupted by shallow valleys, and its surface is more generally cleared and farmed. Short arms of the sea enter the lower valleys, giving harborage for small vessels, and many fishermen live in the shore villages. A belt of shallow salt-water lagoons with extensive marshes of reeds border the mainland for a breadth of about five miles. Finally come the sand reefs, half a mile or more wide, enclosing the lagoons. The surface of the reefs is occupied by gently rolling sand hills drifted by the wind; the ocean border is smoothed into a broad beach by the heavy surf. Here thousands of persons from the interior of the country spend their summer vacations, enjoying the mild temperature of the sea breezes, bathing in the surf, and sailing and fishing in the quiet waters of the lagoons, or on the rougher waters of the ocean.

This simple example serves to illustrate the way in which the physical features of a district exercise a control over the distribution and occupations of its people. It is not by accident that a large population has gathered on the interior lowland belt, but because of the advantage given by good soil on an open surface where movement from place to place is easy. Many other examples of the same kind may be found by the intelligent observer in various parts of the world. The careful study of geography therefore requires a good understanding of different kinds of land forms, as well as a knowledge of their soils and their products, in order to make clear the relation between man and his geographical surroundings.

The best method of gaining an understanding of land forms is to study their origin. It would be easier to remember the features of the successive belts described in the preceding paragraphs if some explanation were given of the way in which they have been produced. Explanation as well as description is therefore important in physical geography.

Coastal Plains.

Introductory Example. — In certain parts of the world the hills bordering a mountain range descend directly to the seashore. Waves beat on the headlands, cutting cliffs in their front. The larger rivers build deltas at their mouths, and here the sea is bordered by low land. The rock waste from the mountains and cliffs furnishes much sediment for the smooth sea bottom.

This means that while the land has been worn and roughened by the action of weather and streams, the sea floor has been smoothed by the gain of land waste. The

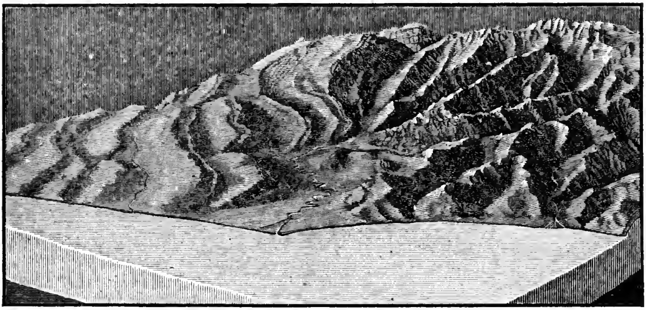

Fig. 71. — Mountains bordering the Sea.

depth and number of the valleys show that already much waste has been carried into the neighboring seas. The dredge brings up gravel, sand, and mud from the sea bottom, the texture of the sediments being finer as distance from land and depth of water increase.

A rugged land like this seldom supports a large population. It is only in the valleys that strips of flat land, suitable for easy occupation, can be found. Most of the population is gathered in villages near the mouths of the large rivers. Roads cannot easily follow the shore, for many of the cliffs are washed to their base at every high tide. In passing from one valley village to another the traveller must climb over a ridge. Many dwellers in the shore villages are seafarers and fishermen, although there are few protected harbors, for the shore line is comparatively straight.

The coast of California presents many stretches of this kind. The Sierra Santa Lucia, south of Monterey, descends boldly to the sea, its spurs being cut off in great cliffs. The shore is thinly inhabited for a distance of 70 miles.

The Mediterranean coast from Nice past Genoa to Spezzia is a famous example of this class, more densely populated than usual. The mountain spurs rise rapidly from the water's edge; the streams run like torrents to their very mouths. Little villages nestle in the indentations of the coast, but their fishing boats are unprotected in on-shore storms. The harbor of Genoa is enclosed by an artificial breakwater. A railroad following this rugged shore is compelled to tunnel through many headlands. No highway has yet been made along the shore east of Genoa. Westward from Genoa to Nice, only with great difficulty and at great expense has a famous highway been constructed around or over the headlands.

Narrow Coastal Plains. — Fig. 72 exhibits a region where the foothills of the mountains descend to a lowland, and the lowland slopes gently to the sea. Such a lowland is called a coastal plain. The gentle slope of the plain is continued in the slowly deepening sea floor. The form of the land may here be much more favorable to human occupation than in the previous example.

The plain is divided into many similar strips by the shallow valleys of streams that flow across it from the mountains. Each strip of the plain is so smooth and so nearly level that a great part of the rainfall enters the open soil, instead of running off in streams. The plain is built of layers of gravel, sand, and clay, the uppermost layer forming the surface of the plain. The pebbles in

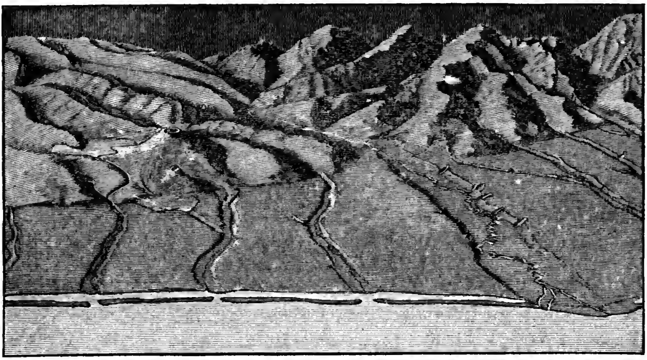

Fig. 72. — Narrow Coastal Plain.

the gravel often resemble the harder rocks of the hilly background; the clay often contains shells similar to those found in the neighboring sea.

Ravines are worn by wet-weather streams in the side slopes of the plains between the larger valleys. Even the larger valleys have been carved by the rivers that flow through them. In the future the plain will be more dissected; in the past it was less dissected. Before any valleys were cut the different parts of the plain were all united in a continuous, even surface.

In view of all this it must be concluded that the coastal plain was once part of a shallow sea bottom, and that this region was then like the sea-skirted mountains of the preceding example. Since then the relative level of the land and sea has been altered, and part of the smoothed sea bottom is now laid bare to form the coastal plain.

As soon as this simple relation is recognized, the background of hills and mountains is seen to be the source of the rock waste of which the strata of the plain are built. The inner boundary of the plain is the former shore line. The rivers from the older land extend their courses across the new plain, guided by its slope. Small streams, rising on the plain, flow directly to the sea. Such rivers and streams may be called *consequents* because their flow is consequent on the slope of the plain.

As the region now stands higher than before, the rivers tend to wear down their valleys to the new level of the sea at their mouths; the valley sides waste away, and thus the valleys slowly become wider; but the streams cannot wear the valleys deeper than the surface of the sea at their mouths. The level of the sea is therefore called the *baselevel* of the region. As long as the land stands in its present position, continually wasting under the destructive attack of the atmosphere, the plain surface will in the course of ages be worn lower and lower, closer and closer to the baselevel. In the coastal plain here figured a good beginning of this great task is accomplished along the line of the chief stream; but the uplands between the valleys are as yet hardly touched.

A simple method of describing land forms may be illustrated by means of this elementary example. The existing forms of the coastal plain must be treated as showing, first, something of the original form of the plain; and, second, the changes it has suffered under the attack of weather and water. In this example the smooth surface of the plain between the valleys still preserves the original form with insignificant change. The valley floors of the extended rivers and the narrow ravines of the side streams are changes from the original form.

The surface of each part of the plain is everywhere so much alike in form and quality that villages may be located here and there upon it without system. Roads run in straight lines for long distances because they meet no obstacle. Boats on the larger rivers coming from the mountains in the background bring the products of mines and quarries, of forests and upland pastures. A city near the sea serves as a market for the agricultural products of the plain, although these are sometimes not of the best, for the sandy soils may be hardly worth tilling.

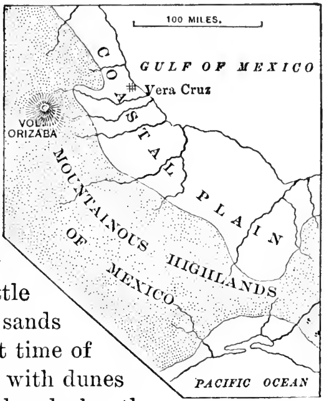

Fig. 73. — Coastal Plain of Mexico.

Sand reefs or beaches may be formed by the waves a little distance off-shore, built of sands washed in from the sea floor at time of storms. The reefs are covered with dunes of sand blown up from the beach by the winds, and enclose quiet, marshy lagoons. Here or there the tide maintains a passage or inlet through the reef, and villages spring up on the mainland near by, whence fishermen go out in small boats to the shallow sea.

The eastern coast of Mexico in the neighborhood of Vera Cruz is bordered by a low coastal plain (Fig. 73) about 50 miles wide, back of which the mountains rise rather abruptly. The plain is partly covered with flows of volcanic mud. It has a hot and unhealthy summer climate. Vera Cruz, the chief port for the interior highlands, has a poorly protected anchorage on the open shore. In the Mexican War (1847), when Vera Cruz was captured, the Mexicans found no other place for resistance on the smooth coastal plain, and therefore concentrated their forces on the hilly border of the old land. Here they entrenched themselves on a spur called Cerro Gordo, between two ravines that had been deepened by streams from the mountains during the erosion of the plain; and here a decisive battle was fought.

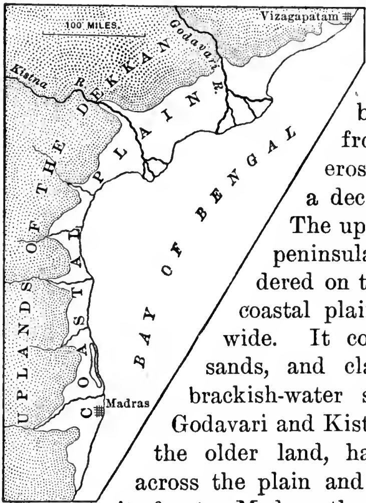

Fig. 74. Coastal Plain of India.

The uplands of the Dekkan in the peninsula of India (Fig. 74) are bordered on the east by a gently sloping coastal plain, not more than 50 miles wide. It consists of bedded gravels, sands, and clays containing marine or brackish-water shells. Large rivers, the Godavari and Kistna, draining great areas of the older land, have extended their course across the plain and built projecting deltas at its front. Madras, the chief city of the plain, has no harbor; it is difficult or impossible to land from vessels during storms, except under the protection of an artificial breakwater.

Broad Coastal Plains. — Fig. 75 represents a broader coastal plain than the preceding example. The outer part of this plain is much like the plain in Fig. 72; but the inner part is more cut by ravines, and the larger rivers have broader valleys than before. A greater change in the relative height of land and sea is indicated by the greater height and breadth of the plain; and a longer time since the elevation of the inner than of the outer part must be inferred from the greater amount of work done by the streams in carving their valleys and ravines.

The strata of an extensive coastal plain are often of coarser texture near the former shore line, and of finer texture near the present shore line. During the slow uplift of the plain,

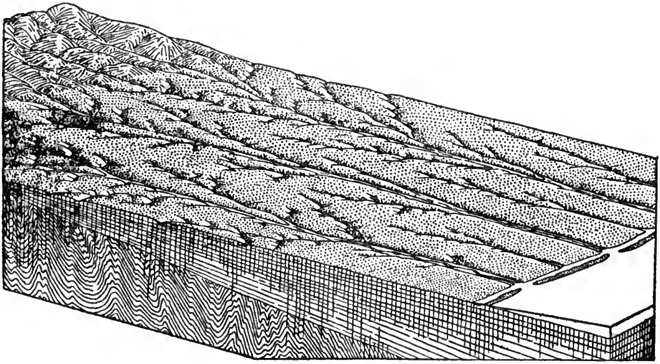

Fig. 75. — Broad Coastal Plain.

different kinds of sediments may have been laid down near the shore, as the sea retired from the plain. Hence the soils of such plains are commonly of different kinds in the inner, middle, and outer parts, being arranged in belts roughly parallel to the length of the plain.

The Atlantic coastal plain of the southern states, of which a characteristic portion is included in South Carolina (Fig. 76), is roughly divisible, according to its form and soil, into belts parallel to the shore line. At the same time it is transversely divided into strips by the several large rivers that are extended from the back country (Piedmont belt), and by the many smaller branches of these rivers that rise on the plain itself.

The outer or coastal lowland is a smooth plain, with open pine woods or grassy savannahs; this division is about 50 miles wide, rising inland 2 or 3 feet to a mile. Its level surface is very poorly drained.

Further inland the plain slowly rises with gently rolling surface; here the soil is better than in the first belt, and much cotton is raised. Further inland still, the surface becomes more sandy again and more hilly, giving extensive views seaward across the lower plain. A hundred miles inland a belt of hilly uplands stands 600 or 700 feet above

Fig. 76. — Coastal Plain of the Carolinas.

the sea, covered with pine forests. Here the original surface of the plain is almost entirely destroyed by the action of many streams in carving their valleys, and by the action of the weather in opening the valley slopes; and this part of the plain may be described as "well dissected." Then come the hills of the older land (the Piedmont belt, here not mountainous, but of moderate relief), whence the strata of the plain have received their sediments, and where the rivers are now cutting down narrow valleys beneath their former valley floors.

The soil belts on this plain exert an important control over the industries of the inhabitants. The less sandy soils are occupied by cotton plantations; the more sandy belts are covered with extensive pine forests, furnishing much lumber and a great amount of tar and turpentine. The moist swampy soils near the coast are well adapted to the cultivation of rice. The more limy parts of certain strata are dug up to fertilize the more sandy fields, and the richest of these limy deposits are exported to other states to be used as fertilizers.

The strata of the plain are generally of too loose a texture to supply good building stone or material for making hard roads; the time that has passed since the strata were deposited has not been sufficient for their consolidation. There are no metalliferous ores, and mining is unknown on plains of this kind.

The rivers that are extended from the older land have incised their valleys 400 or 500 feet in the inner part of the plain, so that they cannot cut down closer to base-level without losing the velocity they need in order to carry along their load of waste. Their branches have dissected the upland for several miles on each side, changing the original surface of the plain into an irregular and hilly form.

Passing seaward the valleys become shallower, and the uplands are less and less dissected. The rivers have developed serpentine or meandering courses on the marshy valley floors. Columbia lies on Congaree river, where it passes from the older land to the dissected plain. Charleston and other ports lie at the edge of the coastal lowland, on the widened courses of certain rivers where the tide comes in from the sea. The outer coastal plain is so even that its railroads run long stretches without a curve.

In North Carolina numerous farms on the coastal plain furnish vegetables for the markets of northern cities. The lower part of the plain is so level that extensive swamps form upon it; for vegetation here hinders the run-off of the rainfall, and in course of time a deep boggy or peaty deposit has accumulated. Water-loving trees, like the cypress and tupelo, form the forest cover, delaying evaporation, and thus favoring the swampy growth beneath. Here the forces that tend

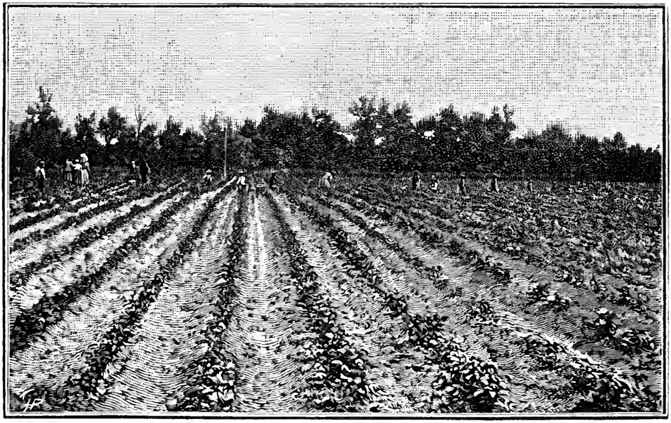

Fig. 77. — North Carolina Truck Farm.

to wear down the land are so weak that they are overcome by plant growth, and the land is built up. Artificial ditches and canals may lead away the water, and some of the swamp land has been farmed after clearing off the trees.

Artesian Wells. — Towns and cities near the shore line of coastal plains frequently secure a good water supply by sinking deep wells until a sandy layer between clayey layers is reached 500 or 1000 feet below the surface. The same sandy layer comes to the surface of the plain many miles inland, where the land is several hundred feet higher than at the shore line. There much of the rainfall soaks into the sandy soil, and slowly follows the descent of the open-textured sandy layer between the close-textured clayey layers. When tapped by a deep well, the water rises from the sandy layer, and may even flow forth at the surface like a fountain; for the level of its discharge is much lower than that of its supply. Wells of this kind are called *artesian wells.*

In Fig. 78, the layers reached by the wells lead ground water from the inner part of the coastal plain toward the ocean. The other layers are of close texture and contain very little ground water.

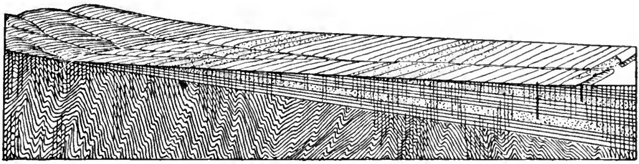

Fig. 78. — Artesian Wells.

Public health is promoted by the use of artesian well water, which is much purer than the water of shallow wells on low coastal plains. Numerous artesian wells are sunk on the outer part of the Atlantic coastal plain of the United States. Even the off-shore sand reefs may gain a supply of fresh water from deep wells, as at Atlantic City, N. J.

The Fall-Line. — A large river whose course is extended across a coastal plain often has a well-defined head of navigation at low falls or rapids near the inner margin of the plain. The falls occur where the entrenched river passes from a steeper slope on the resistant rocks of the older land to a nearly level channel excavated in the weak strata of the plain.

This may be accounted for as follows: *BC* (Fig. 79) was the level of the sea while the strata of the coastal plain, *FBG*, were accumulating on the submarine extension of the old land, *BG*. Before the plain was uplifted, the larger rivers had cut valleys of gentle slope, *AB*, leading to the baselevel, *B*, at the shore line of that time. To-day *DE* is baselevel. The larger river has already cut a nearly level

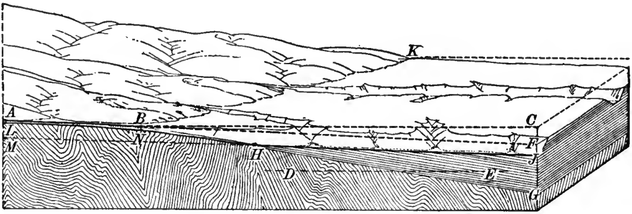

Fig. 79. — Diagram of the Fall-Line.

channel, *HJ*, in the weak strata of the plain, but has only deepened its channel from *AB* to *LNH* in the harder old-land rocks. As long as *NH* is steep enough to make falls or rapids, *H* is the head of navigation; and a line joining such points on successive larger rivers is called the *fall-line.*

In coastal plains of considerable breadth settlements near the mouth and at the head of navigation of the larger rivers often develop into important cities. The lower city is the seaport of the region. The upper city bears closer relation to local industries and traffic; it lies in the midst of a diversified region, with strong water power for manufacturing the varied products of rock and soil.

The fall-line along the inner margin of the Atlantic coastal plain of the United States is marked by important cities on nearly every large river that crosses it. Trenton, Philadelphia (at the falls of the Schuylkill), Richmond, Raleigh, Camden, Columbia, and Augusta are all thus located. The deep and narrow valleys of these rivers in the older land are also conspicuous results of the elevation of the coastal plain.

Embayed Coastal Plains. — The region here figured does not at first sight seem to belong to the family of coastal plains. Long shallow arms of the sea enter between low hilly arms of the land. Large rivers from the back country enter the heads of the long bays; small streams from every little valley between the hills of the land arms enter little bays or coves on the sides of the larger bays.

The bay heads are occupied by marshy deltas; the land heads between the bays are nipped off in low cliffs showing layers of sand and clay. The outer ends of the land

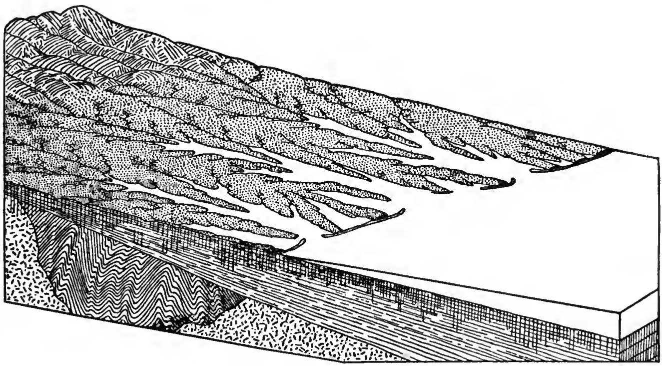

Fig. 80. — Embayed Coastal Plain.

arms, fronting the open ocean, are more or less cut off. Sand reefs are stretched in even line, connecting the outer headlands so that the sea has now access to some of the bays only by narrow tidal inlets; but the broader bays may still be open to the ocean.

This region represents a coastal plain which has been partly sunk or "drowned" beneath the sea. Before drowning, the valleys had been widely opened, and the plains between them had been reduced to strips of hills. Now the outer coastal lowland and the broad valley floors are under water, the latter being occupied by the bays that enter far toward the old land, while the hill strips stand forth as ragged arms of the land. The former simple shore line is thus exchanged for a very irregular shore line.

The relative change in the attitude of land and sea is here opposite to that inferred in the previous examples. Since the depression of the region, the land heads have been more or less cut back by the waves, and the bay heads have been somewhat filled by marshy deltas. But the drowning cannot have taken place long ago, as the earth counts time, for the changes in the land heads and bay heads are of moderate amount. Although at first not seeming to be related to other examples of this series, this irregular land form is now seen to be little removed from them.

The Atlantic coastal plain from Delaware bay to Pamlico sound presents many examples that fall under this class. They are best seen about Chesapeake bay and the lower Potomac, where the relief is stronger and the bays are longer than further north and south. The outer shore line is for the greater distance a smooth sand reef enclosing a lagoon; but at a few points the reef is exchanged for a low bluff cut in an arm of the mainland, as in the southeast corners of Delaware and of Virginia. Low cliffs have been cut in the little land heads and small marshes have been formed in the little bay heads of the inner shore line (see Fig. 117).

Partly drowned coastal plains exert a peculiar control over the distribution and occupation of their population. The greater part of the valley lowlands is lost, and the people must make the most of the hilly land arms that remain above sea level. The axis of each of the larger arms is generally followed by a main road, making its way from village to village among the upland farms, and giving forth side roads to the smaller land arms or to the little bay heads.

Villages are found on the more level parts of the upland and on the better harbors of the bays. The shallow bays are

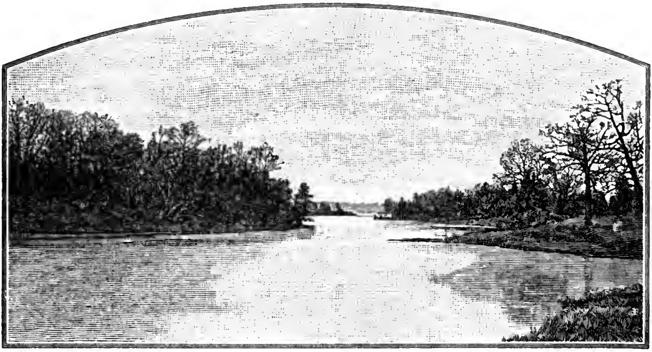

Fig. 81. — A Branch of Chesapeake Bay, Maryland.

valuable for fishing grounds. More important centers of population are found either near the heads of the larger bays, where the large rivers come out from the back country and reach tide water, or near the mouths of the bays where the sand reefs are not continuous and the ocean is easily reached. Baltimore and Norfolk are good examples of cities thus situated. The outer shore line is inhospitable; its long sand reef offers no landing place; and the narrow tidal inlets allow entrance only to small-sized vessels.

In the early history of "tide-water Virginia," the numerous drowned valleys afforded easier communication between the settlements than was found overland through the forests of the coastal plain.

The interesting question of the origin of the forces sufficient to deform the crust of the earth and to elevate or depress a coastal plain cannot be well explained in the present state of science. It is important that the student of physical geography should recognize the facts of elevation and depression, and should understand the importance of such movements in controlling the forms of the lands and in determining the conditions of their inhabitants; but the processes that cause such movements must be left to the more advanced study of geology.

Belted Coastal Plains. — Fig. 82 exhibits a district lying between a hilly inner land and a new shore line, in which the strata have the same seaward slope that prevails in all

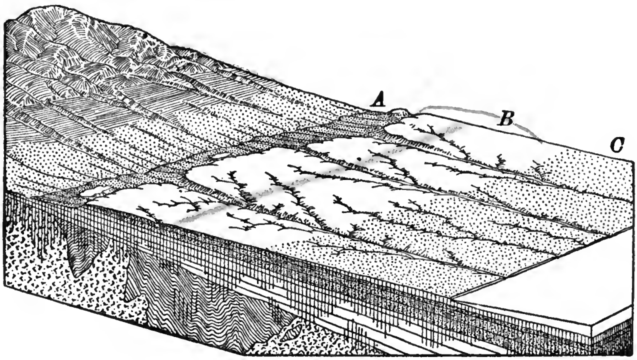

Fig. 82. — A Belted Coastal Plain.

coastal plains, but in which the form is novel. The district may be divided into three longitudinal belts, each one 10, 20, or more miles wide; the innermost (*A*) is a lowland of weak strata and fine deep soils; the middle belt (*B*) is an upland of firmer strata and thinner soils, several hundred feet above the lowland; the outer belt (*C*) is a smooth coastal lowland. The several belts recall the belt-like arrangement of soils described in the case of a broad coastal plain, but this example is peculiar in having the middle belt occupied by an upland that runs about parallel to the shore line and stands between an inner and an outer lowland. The upland descends by a rather steep slope facing inward to the inner lowland, and by a long, gentle, outlooking slope to the coastal lowland, as in southern New Jersey.[1]

The reason for this arrangement of upland and lowland is that the undermost layers of the coastal plain are weaker than the middle layers; hence the under layers, which reach the surface of the plain near its inner border, are already worn down to a lowland, while the more resistant middle layers preserve an upland height.

The drainage of a belted coastal plain possesses some peculiar features. The larger rivers, extended from the inner hills, still run directly to the sea, passing across the inner lowland in shallow open valleys, and trenching through the upland belt in deep narrow valleys. Smaller streams are extended from the older land to the inner lowland, there turning to the right or left and forming longitudinal streams that run about parallel to the upland belt until they reach a large transverse river. The longitudinal streams are also joined by short streams that flow down ravines in the infacing slope of the upland belt.

[1] An upland of this kind may be called a *cuesta*, following a name of Spanish origin used in New Mexico for low ridges of steep descent on one side and gentle slope on the other.

When these arrangements of form, soil, and drainage are well marked, the distribution and occupations of the people become closely sympathetic with them. The outer coastal lowland has its fishermen and sailors, with ports at the river mouths and villages on the smaller streams; it also has interests in pastures, forests, and farms.

The inner lowland is generally an agricultural district, often of great fertility. It provides a longitudinal inland pathway of even surface, often followed by highways and railroads. The junction of longitudinal streams with a large transverse river makes an attractive place for settlement; it has convenient relations with the old land and the inner lowland, with the advantage of open passage to the sea. Water power may be furnished by rapids at the fall-line.

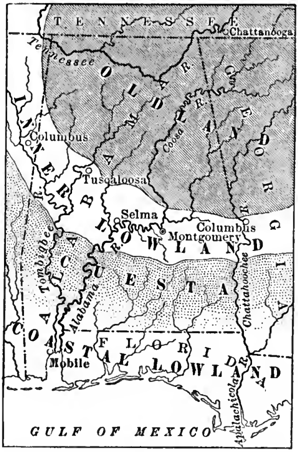

Fig. 83. — The Coastal Plain of Alabama.

The upland belt is more sparsely populated; its thinner soils may hardly repay cultivation, and much of it may remain forested.

The coastal plain of Alabama (Fig. 83), part of the extension of the Atlantic coastal plain around the border of the Gulf of Mexico, possesses an upland belt and an inner lowland. The older land is the southern end of the Appalachian mountains, here of no great height; it is a region of resistant rocks containing iron ore and coal beds, which support the important industries of mining, smelting, and manufacturing. The strata of the coastal plain are generally still of loose texture, those of the upland belt being the firmest. They contain marine fossils, some of the strata being largely composed of shells.

The inner lowland is worn down so smooth and level that the rainfall is drained slowly from its surface; the roads are nearly impassable in wet weather. It is called the "Black prairie" from the dark color of its rich soil weathered from the weak underlying limestone. This belt includes the best cotton district of the state; the cities of Montgomery and Selma are within it.

The upland, locally known as the Chunnenugga ridge, ascends rather abruptly 200 feet above the lowland; it is upheld by a stratum of more resistant limestone. Numerous short streams run down the infacing slope to the inner lowland, wearing short valleys and fringing the inner margin of the upland with hills. The "hill prairies" lie on the broad upland surface.

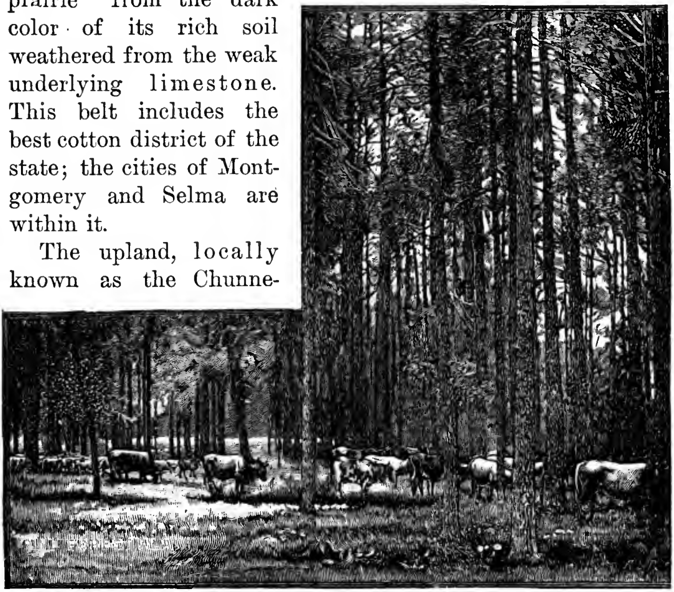

Fig. 84. — Pine Forest on Coastal Plain, Alabama.

The outer slope descends gradually to the "coastal prairies," the surface being dissected by small streams in shallow valleys. Extensive pine forests occur here as well as on the upland. Mobile, an important port of the Gulf coast east of the Mississippi, lies on the slightly drowned lower course of the united rivers of the region.

Ancient Coastal Plains. — In Wisconsin, far inland from the ocean, the northern part of the state is occupied by rugged highlands of resistant rocks. Adjoining on the south and east are plains and uplands arranged in belts, their rock layers sloping gently away from the highlands and lapping on one another like great shingles.

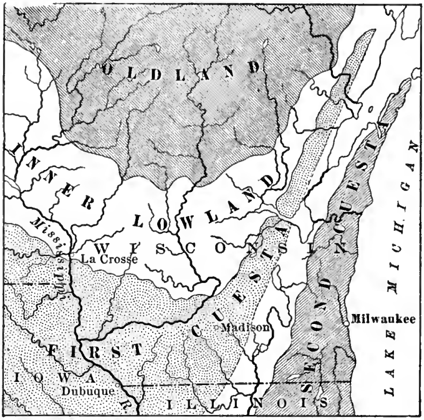

Fig. 85. — Ancient Coastal Plain of Wisconsin.

Fragments of the highland rocks are found in the lower members of the overlapping strata; numerous marine fossils, like corals and shellfish, occur in many layers. All the layers are well consolidated; the firmer ones form the uplands, with distinct infacing slope and very gentle outward descent; the weaker layers underlie the plains.

Although the sea may now be a thousand miles away, the belts of upland and plain are easily seen to be similar to the belted coastal plains already described, while the rugged highlands stand in the relation of the older land from which the strata of the plains and uplands were long ago derived.

The strata here observed are generally so well cemented that they must be more ancient than those of the examples already given; a long period in the earth's history is needed for infiltering waters to bind together sediments grain by grain. Some of the strata are crossed by fissures containing lead ore in quantities sufficient for profitable mining. This also suggests great age; for a vast duration of time is necessary to gather the minerals of the ore from the surrounding strata through which they were originally scattered, and to concentrate them in fissures by the action of slowly infiltering waters. The seashore is now a great distance away, and this also implies a long time during which the continent has grown to its present dimensions by repeated uplifts.

In view of all this it must be concluded that this is not a modern but an ancient coastal plain; that is, a region that began its existence as a coastal plain ages ago in the earth's history, and that has since then been built into the interior of the continent by successive uplifts and additions to the margin of the growing continental area. The upper layers of the original coastal plain have been greatly worn away, and a considerable part of the highland border is stripped of the strata that once lapped over it.

Artesian wells are as important a source of water supply on ancient as on modern coastal plains. Many such wells have been bored in southern Wisconsin.

In passing southward from Canada to western Pennsylvania one crosses an ancient coastal plain with its strata dipping gently southward, and bearing various signs of early origin. The highlands of Canada are the older land. Next comes an inner lowland, the Ontario lowland plain, in part occupied by Lake Ontario. Then follows the Niagara upland belt formed on the firm limestone beds of that name, and famous for the gorge cut by the great cataract. A second lowland, the Erie lowland plain, stands a little higher than the first, partly occupied by Lake Erie; and finally comes a rather strong infacing slope ascending to a dissected upland, the northern part of the Allegheny plateau.

The Niagara upland fades eastward as its limestone layer thins out, and is not seen beyond Rochester, where the Ontario and the Erie lowlands come together. The Allegheny plateau weakens westward, and is not traceable beyond Cleveland. Eastward it becomes stronger; the irregular infacing slope is much dissected by valleys, and frequently consists of several successive benches. It extends to the bold Helderberg escarpment southwest of Albany (see Fig. 92), where the Adirondacks represent the older land and the Mohawk valley is the narrow inner lowland.

Fig. 86.—Ancient Coastal Plain of Ontario and New York.

The rugged highlands of Canada and the Adirondacks are heavily forested. The Allegheny plateau is so hilly that its population is relatively small. The Ontario and Erie plains, where not drowned by their lakes, contain a thriving population. The Mohawk valley in particular has long served as a path of travel and transportation. The Erie Canal connects the tidal Hudson with Lake Erie. Important railroads follow the same course. The southern part of the lowland has thus come to be the seat of many cities in a rich agricultural population. Albany, Schenectady, Utica, Syracuse, Auburn, Rochester, Buffalo, Erie, and Cleveland all lie on the plain near the border of the plateau.

A beautiful example of an ancient coastal plain is found in England. Its successive features are encountered while passing from the older land of Wales to London and down the Thames to the North sea. They are roughly shown in Fig. 87, where the heights are much exaggerated. Here, curiously enough, the mountainous older land (*A*) lies next to the Atlantic, and the coastal plain slopes toward the continent of Europe. The plain no longer retains anything of its original surface, unless in parts of eastern England, where the latest

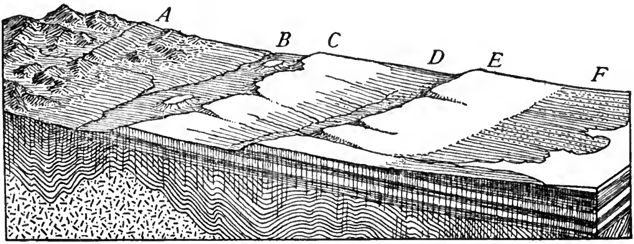

Fig. 87. — Diagram of Ancient Coastal Plain of Middle England.

elevation has added a young coastal lowland (*F*) to the former land area. Nearer the older land there are two well-defined upland belts, the Cotswold (*C*) and Chiltern (*E*) hills; and two lowlands, those of Worcester (*B*) and Oxford (*D*). All these features have a considerable extension to the northeast and southwest, with varying strength and expression.

Inland Plains and Plateaus. — The relation of certain regions, composed of nearly horizontal rock layers, to an older land is not so simple as in the plains thus far described. Several examples of this kind will be given in which the older land need not be considered.

Young Plains. — The great plain of western Siberia, in latitude 50° to 60° N., stands at a moderate altitude above sea level, and preserves an even surface over hundreds of miles. Vast areas, stretching further than the eye can reach, are monotonous in the extreme, almost as uniform in soil as in surface. The flat areas between the streams, having no distinct lines of water parting and no distinct channels of water discharge, are as yet practically undivided among the rivers. Marshes, alternately wet and dry in winter and summer, and many shallow lakes lie in faint depressions; as if slight inequalities in the original surface of the plain had not yet been drained by river action. The valleys are few and far between; they can never be cut deep while the region stands low. They are narrow; hence the rivers have as yet worked only for a comparatively short time in the earth's history. The plains are still young.

The more northern part of the central plains is forested; but about latitude 50° to 55° the plains have a lighter rainfall and are treeless; clothed with thin grass in summer; cold, barren, and wind-swept in winter. Taken with similar low plains further north and south, the vast area from the Caspian sea to the Arctic differs less in form than in climate and vegetation; they are frozen marshes (tundras) in the north, parched deserts in the south, and temperate with grass and forests in the middle.

The plains have long been the home of wandering tribes, whose wealth is not in fixed possessions, but in herds and flocks driven from place to place for pasture. The people live in tents, and move about without definite limits to their lands. Every man is necessarily a horseman, competent in nearly all the arts of a wandering life. The horse, descended from a long line of prehistoric ancestors on open plains, has lost the lateral movement of the limbs that climbing and flesh-eating animals possess, but has at the same time gained in speed and endurance, thus becoming the mainstay of wandering tribes.

Young Plateaus. — Fig. 88 represents part of an extensive upland or plateau that is traversed by deep and narrow valleys or canyons branching in various directions. The plateau is built of horizontal rock layers of various kinds, well shown in the canyon walls. The broad upland has a comparatively even surface, often so monotonous that it receives less attention from explorers than the canyons that dissect it. The irregular course of the canyons indi-

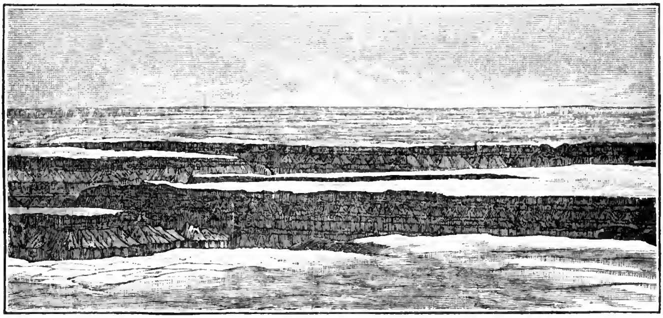

Fig. 88. — A Plateau in Arizona.

cates that the rivers which cut them had no well-defined slope on the original upland to guide their flow. The irregular branching of the side canyons shows that it has been about as easy for the streams to wear back the head-water ravines in one direction as in another.

The great altitude of the uppermost stratum, forming the general surface of the upland, and the depth to which the canyons have been worn down by the rivers prove that the whole region has been broadly uplifted from the sea in which the strata were laid down.

In regions of this kind some of the side canyons are still so narrow that the stream occupies all the space at the base of their walls; it flows mostly on bare rock with rapid descent. Such a stream is deepening its valley by grinding the rock bed with the fragments of rock waste that it washes down. Other valleys are somewhat broader, part of their floor being occupied by narrow strips of

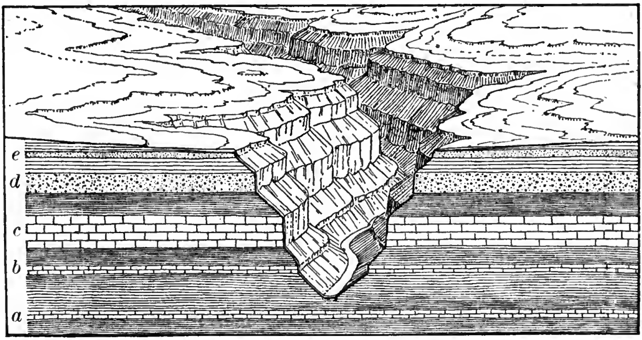

Fig. 89.—Diagram of Narrow Canyon.

flood plain, overflowed by the river at the time of high water. Here the river has almost ceased to deepen the valley; the slope of its channel just gives it velocity enough to wash along the waste that is weathered from the valley walls and worn from the side canyons.

Although a great deal of work has been done in cutting down and widening these canyons, it is manifest that a vastly greater work still remains to be done before the broad mass of the plateau is worn down close to base-level; hence a plateau of this kind must be called young, however deep its canyons may be.

In the narrower canyons the descent from the plateau leads down over a succession of cliffs and slopes. The cliffs are the edges of resistant layers (*b, c, d, e,* Fig. 89) ; they advance around every spur and turn into every side ravine, but always follow the level of the guiding layer. The slopes follow the weak layers; they are covered with coarse rock waste, or *talus,* weathered from the cliffs above. The rock waste weathers and falls from each cliff, and rolls, washes, and

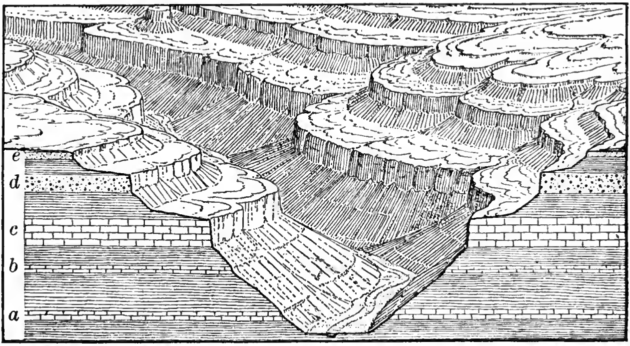

Fig. 90. — Diagram of Widened Canyon.

creeps down each slope to the top of the cliff next below, where it falls again; thus at last reaching the stream, where its finer parts are rapidly washed away. Thus the cliffs and slopes wear back or retreat, and the canyon widens.

As a canyon widens, the thickest and strongest cliff-maker (*c,* Fig. 90) wears back more slowly than the thinner, less resistant cliff-makers. The less resistant cliffs below the stronger one wear back till they nearly or quite disappear beneath the talus, as *a, b.* The faster retreat of the less resistant upper cliff *d* leaves a platform or bench sloping gently forward from the base of the talus to the top of the stronger cliff *c.* In the same way a platform stretches forward from the base of the talus of *c* to the top of the cliff *d*. Fine waste from the talus is washed forward across the platform.

The steeper streams of young plateaus leap in rapids or falls where they descend across the edges of cliff-making strata. The streams rasp and cut back the fall-making strata with the waste that they carry, and the falls therefore retreat up stream. In the larger rivers the falls are worn back and extinguished while the plateau is still young. In the smaller streams falls may survive until the plateaus are thoroughly dissected.

Fig. 91 is a section along a stream in a plateau, in which a fall occurs at *B*. The fall will be extinguished when it is

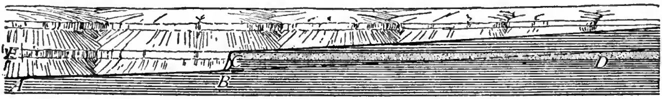

Fig. 91. — Diagram of a Waterfall in a Canyon.

worn back so far up stream that the backward extension *BD* of the river bed *AB* intersects the top of the fall-making stratum *ECD*.

The lofty plateaus of north Arizona, traversed by the Grand Canyon of the Colorado from east to west (see frontispiece), include many illustrations of this class of forms. The Sheavwits plateau, at a general altitude of 6000 feet, may be taken as a type example; it is cut across by the western part of the canyon.

The arid climate of the plateau excludes nearly all vegetation, and lays bare the details of structure and form. The region offers no temptation to settlement, however marvellous it is to the explorer. It is naked and desolate, occupied by a few Sheavwits Indians, who subsist by "cultivating little patches of corn, gathering seeds, eating the fruits and fleshy stalks of cactus plants, and catching a rabbit or lizard now and then; dirty, squalid, but happy, and boasting of their rocky land as the very Eden of the earth."

The great elevation of this plateau permits an exceptional depth of canyon cutting. The massive strong and weak strata of which the plateau is built produce strong cliffs and long talus slopes on the canyon walls. Far down in the bottom of the great trench runs the tawny Colorado, turbid with waste that is showered from the walls in rocky avalanches or swept in from side canyons by cloud-burst torrents.

Deep as the canyon is, it has been cut down only by the river. There is no indication of clefts or fractures along the river course. The strong rock layers in the walls weather more slowly in the dry climate there prevailing than they would in a wetter climate; hence the plateau is advancing with relative slowness toward a well-dissected form.

Unlike most great rivers, whose valleys serve as paths of travel, the Colorado is almost inaccessible along its canyon. Only one exploring party has successfully gone down the canyon; their narrative is a wonderful history of scientific adventure. Once entering the canyon in their boats, retreat was impossible against the swift current. Escape by climbing the walls was hazardous. To descend the river was easy on its smooth stretches, even though hemmed in by great cliffs; but cascades had to be passed where the most resistant beds are not yet cut through, and rocky rapids obstruct the channel where side canyons deliver heaps of boulders to the main river. After many perils the party came out to the open lower country, west of the Sheavwits plateau.

In the young stage of dissection plateaus are, as a rule, occupied only on their upland surface. The elevation of the upland is an advantage in the torrid zone, where the high temperature prevailing at sea level is willingly exchanged by civilized races for a more moderate temperature at altitudes of several thousand feet. But in the temperate zone a high plateau is at a disadvantage from the rigor of its winters as well as from its difficulty of access.

The canyon-like valleys are obstacles to movement; they serve as barriers (except to birds and winged seeds) between the uplands on each side. They are seldom inhabited, unless by the people of a persecuted tribe, who sometimes take refuge as "cliff-dwellers" in the recesses or caves that are often excavated between cliff base and talus top.

Even in a moist climate the bare rocky cliffs of canyon walls are in effect so many small deserts, almost free from plant and animal life. The steeper talus slopes may support trees and bushes; where a little finer waste accumulates, smaller plants may also grow. Caves and burrows among loose rocks shelter many kinds of animals; but a talus slope is too steep and coarse-textured for higher uses. Conquered races, driven from wider possessions, may settle on the broader upland platforms or on the flood plains of the more open valleys; but these surfaces are too limited in extent and, in plateaus of strong relief, too isolated to attract the more fortunate and powerful races.

Dissected Plateaus. — The rugged uplands that extend continuously from New York to Alabama, known as the Catskill, Allegheny, and Cumberland plateaus, may here be treated together under the second name. The whole region consists of nearly horizontal strata. The hilltop view generally discloses an even sky line, which may be taken roughly to define a surface that once extended over the whole region, before the valleys were carved. Thus reconstructed, the upland surface would rise gradually from Ohio and western Kentucky to the east and southeast, reaching the greatest height near its eastern margin, where the plateau descends abruptly to the Appalachian valleys.

At present the upland surface is thoroughly dissected by branching valleys. The region should therefore not be described simply as a plateau; it is a dissected plateau, in an advanced or mature stage of geographical development. The altitude of the original upland in West Virginia (roughly 2500 or 3500 feet) has been great enough to permit the erosion of valleys 1000 or more feet deep; hence some of the intervening plateau remnants have strong relief, and fairly deserve the popular name of "mountains" locally applied to them.

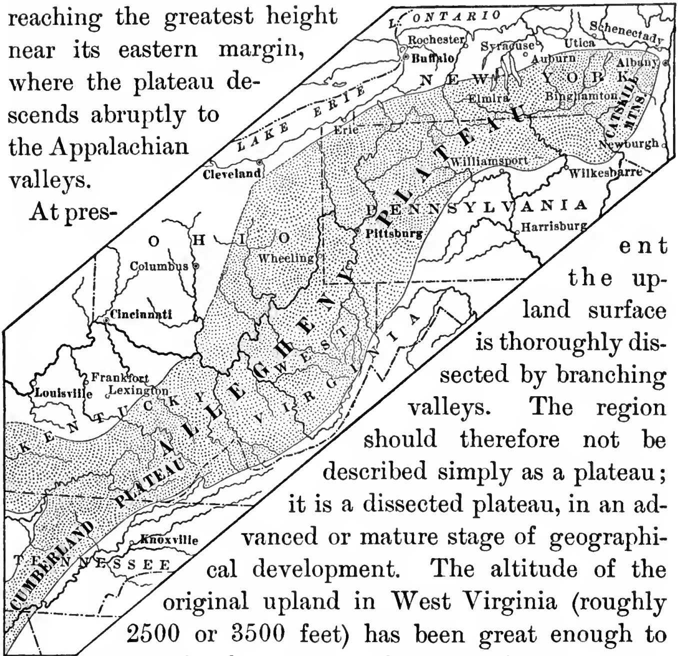

Fig. 92.—The Allegheny Plateau.

Many resistant sandstone layers stand out in cliffs, 10 to 50 feet high, running in bands around the spurs of the great hills. The weak strata occupy the intervening slopes, covered with a thin stony soil and supporting a vast forest. The hills and spurs are all very much alike, for they are developed by similar streams on similar structures. Every side valley resembles all its neighboring fellows; all the members of a local tribe of small streams cascade down over the same number of fall-making strata on their descent to the larger rivers.

In contrast to the previous example, this district has nearly everywhere lost its once continuous upland surface, and is

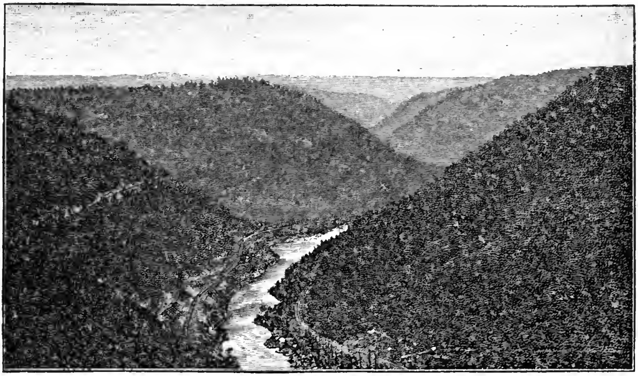

Fig. 93. — Canyon of Kanawha River in Allegheny Plateau, West Virginia.

now transformed into a hill-and-valley country. There are many small cliffs instead of a few great ones; hence platforms are seldom developed to notable breadth. A great part of the surface consists of hillside slopes. Drainage is not delayed on extensive uplands, as in young plateaus; but at times of rain or late winter thaws, water is quickly shed from the hills, and the main streams rise rapidly in destructive floods.

The forests retard but do not prevent the wash of waste from the steep slopes; denudation is actively advancing, and the load of waste delivered to the rivers is greater than in the youth of the region, when the upland was less dissected.

As a whole, the Allegheny plateau is so rugged that its population is small, being generally found on isolated farms upon the disconnected uplands, in villages and occasional small cities in the valleys, or gathered about mines or other industrial works. The isolated hilltop farmers cannot afford to construct and maintain good hillside roads; it is difficult to haul upland products down bad roads to village markets or to railroad stations; and it is doubly difficult to haul supplies up to the farms. Life on the uplands is laborious.

The hillsides are generally too steep for cultivation; if cleared, the soil is rapidly washed away. Wild animals, such as deer and bear, almost exterminated from the lower country on the east and west, still find refuge here; small game is abundant, and hunting is almost as much of an occupation to the "mountaineers" as farming.

The forests supply lumber to the more thickly settled communities on the east and west. The numerous coal seams (vegetable deposits in ancient marshes, now members of the great series of horizontal strata that build the plateau) are well exposed in the deep-cut valleys, and are now extensively mined. Iron ore occurs in certain strata. Rock oil and natural gas are found by boring deep wells. It is chiefly in connection with the industries dependent on these important products that a larger population is to-day attracted to this rough country. In the earlier history of the United States the dissected plateau was (excepting the North Carolina mountains) the most formidable barrier between the Atlantic coastal plain and the open prairies of the Ohio valley.

Intercourse and traffic are still so difficult in the districts of stronger relief, away from the lines of travel, that the people are slow in acquiring the ways of civilization. Family feuds are still maintained among the "mountaineers" of West Virginia and Kentucky. As the uplands decrease in height westward, and the valleys become more open toward the Ohio river, population increases; but Pittsburg is a city of exceptional size in this region. Its growth in early years was favored by its position with reference to the lower Ohio valley, and in later years by the great stores of mineral wealth in the surrounding country.

Parts of the Cumberland table-land have broad uplands holding villages, and traversed by high-level roads. A very rugged part of the plateau is known as the Catskill mountains, in eastern New York; the higher parts are forested and uninhabited. The plateau here descends by a bold escarpment to the Hudson valley.

Old Plateaus. — Broad plains of gently rolling surface, drained by streams in wide-open, flat-floored valleys, are sometimes surmounted by flat-topped "table-mountains." Neighboring tables are of nearly uniform height, each one being capped by a resistant cliff-making rock layer and flanked by a sloping talus; they differ chiefly in area and outline. In the western United States tables of moderate height are often given the Spanish name *mesa* (= table; pronounced may-sa); while the smaller mesas are known by the French name *butte* (= target or landmark; pronounced bewt).

Mesas and buttes of this kind are the scattered remnants of strata that once spread far and wide over the region, forming an extensive plateau. The original surface of the plateau may have been much higher than the tops of the mesas; for the uppermost strata may now be completely swept away. The valleys have widened so greatly that their floors occupy a great part of the surface. A region of this kind represents an approach to the old age of a plateau.

The plains of western New Mexico are surmounted by numerous remnant mesas. Settlement here is chiefly limited to the lower lands. The isolated mesas and buttes, rising several hundred feet over the plain, are generally uninhabited; thus the old age of a plateau reverses the conditions of its youth, in which the uplands alone could be easily occupied.

The mesas of an old plateau are not, like the canyons of a young plateau, obstacles to travel; for while canyons are continuous for long distances and are everywhere difficult to cross, mesas are discontinuous, and many broad passages are opened among them. They are occasionally occupied as natural citadels by barbarous tribes.

One of the most remarkable remnants of an old plateau is the so-called Enchanted Mesa of western New Mexico.

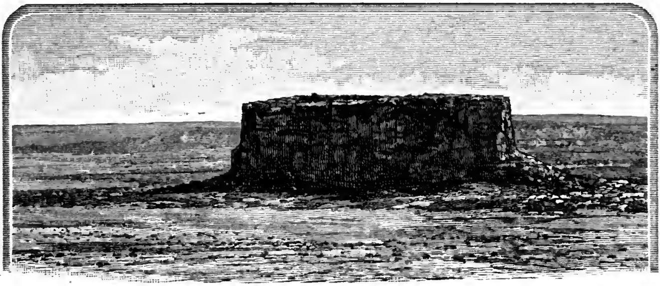

Fig. 94.—The Enchanted Mesa, New Mexico.

It rises more than 400 feet above the surrounding plain, and although no longer inhabited, it was once occupied by a tribe of Indians, who found safety on its almost inaccessible summit.

Other mesas in New Mexico and Arizona are still occupied by small tribes of Indians, whose compact groups of houses on the upland cannot, at a little distance, be distinguished from the rock walls of the cliffs. They cultivate small patches of corn on the lower ground, but do not venture to build settlements there for fear of attack from more warlike tribes.

In the interior of British Guiana gigantic remnants of an old plateau rise over the surrounding lower country. Huge mesas are rimmed round by almost inaccessible cliffs that stand above long talus slopes. One of the highest is Roraima, whose broad table is more than 2000 feet above its base. It is uninhabited, and until recently had never been ascended. The natives of the forested wilderness around it believe that the upland is occupied by spirits.

Old Plains. — It may be imagined that, at a very late stage of development, even the mesas and buttes of an old plateau may be worn away, the whole region being then reduced to a gently rolling lowland, a worn-down plain, or "plain of denudation."[1] Many examples of this kind are known, but most of them have been again elevated, and are now undergoing a new series of changes.

Central Russia is a nearly level region of moderate altitude. It is one of the largest known examples of a worn-down plain. At first sight it might be mistaken for a young plain, so nearly even is the greater part of its surface; but a closer examination reveals many features that do not correspond with those of young plains. The rocks below the soil lie in almost horizontal layers, but they do not consist of loose sands and clays. Many of them have a rather firm texture, showing that they have existed long enough to have their particles bound together by the very slow action of infiltering waters.

[1] A lowland of this kind may be called a "peneplain," because it is an "almost plain" surface.

Besides this, the surface of the plain does not agree with the surface of the uppermost rock layer, as is the case in young plains, but bevels across the nearly horizontal layers at a faint angle, so that in passing from place to place, different layers are exposed, causing advantageous changes of soil and slight variations of form.

A region of this kind must have once had a much higher surface; it may have been high enough to deserve the name plateau. As time passed, rivers must have at first cut narrow valleys across it. Then many branching valleys must have been carved among numerous hills, like those of West Virginia to-day. Finally, the valleys became broader and broader by the wasting of their sides, and even the remnant mesas and buttes were worn away. The plateau must have then been a broad lowland, on whose surface the rivers could cut down no deeper.

Yet to-day the rivers of central Russia flow in rather narrow valleys of moderate depth. Hence it must be supposed that, after the ancient plateau was worn down to a low plain, the whole region was broadly uplifted, and thus the rivers regained the power of carving valleys. In the present series of changes the dissection of the plain has not advanced much further than that of the young plains of western Siberia. Like these, the Russian plains have a vast extent north and south. The difference of climate between the northern and southern parts, due to the globular form of the earth, exerts a great control on their fitness for occupation. They are frozen and barren in the north, where they are overlapped by younger plains that slope to the Arctic shore; here the population is scanty. They are dry and barren in the southeast, where they are overlapped by the young plains of southwestern Siberia; here wandering tribes drive their flocks from place to place. The middle and next southern parts are the most fertile, and here a great agricultural and commercial population is gathered in villages and cities.

The greater part of Missouri is a worn-down plain, now uplifted and again dissected. It is an agricultural district, the broad uplands generally being occupied in preference to the narrow valleys. The strata of the region are gently arched, and their highest part is known as the Ozark plateau. The sky line of the uplands represents the lowland plain that was formed at the close of the previous series of geographical changes. The valleys have been carved since the region was again uplifted.

Fig. 95. — The Ozark Plateau, Missouri.

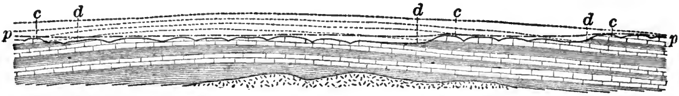

Fig. 96. — Section of the Ozark Plateau.

The weaker layers (*d, d,* Fig. 96) have been broadly etched out beneath the uplifted level (*p, p*) of the region. The uplands (*c, c*) resemble the upland belts of belted coastal plains in having a steep front, made very ragged by the dissection of many short but rapid streams; a broad top, much broken by narrow valleys; and a long sloping back. The height of the uplands over the lower lands is from 100 to 300 feet; their height above sea level reaches 1500 or more feet.

A similar description might be given to a large part of the basin of the Ohio river. It is a region of moderate relief, with the advantages of good soil and sufficient rainfall. Hardly more than a wilderness at the time of the Revolution (1776), it is now occupied by a great agricultural population, dotted here and there with large and growing cities, and crossed in all directions by railroads.

Broken Plateaus. — The plateaus of northern Arizona, of which the Sheavwits already described is one, stand in a curious relation to one another. East of the Sheavwits

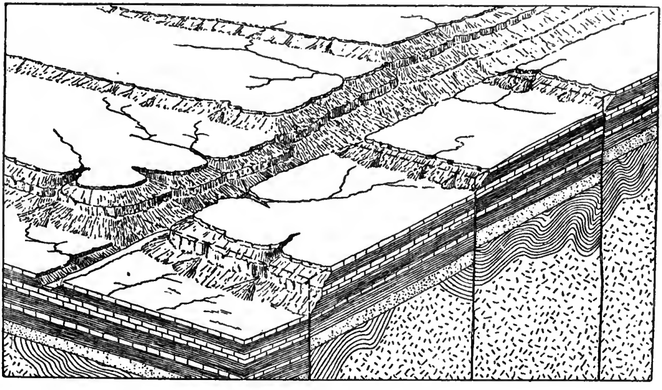

Fig. 97. — Broken Plateaus.

comes the Uinkaret, presenting the same upland (diversified by volcanic cones and lava flows), and exposing the same succession of cliffs and talus slopes in the canyon walls; but the Uinkaret stands about 1800 feet higher than the Sheavwits. The two are separated by a high and ragged cliff or escarpment, known as Hurricane ledge, facing westward.

Tracing this cliff to the canyon, it is found to stand on the line of a great north and south fracture, which divides the whole mass of strata into two blocks; the eastern block (Uinkaret) being lifted nearly 2000 feet higher than the western (Sheavwits). This is easily proved by the displacement of the various cliff-making strata in the canyon wall. Several other similar plateau blocks are found in this region.

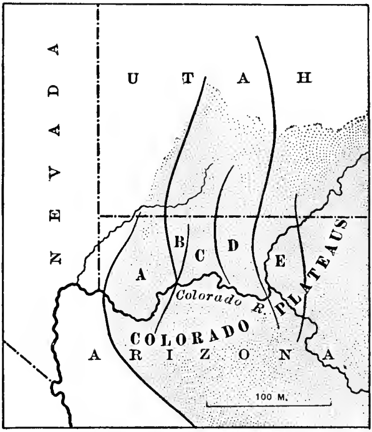

Fig. 98. — Diagram of Blocked Plateaus.

The western boundary of the Sheavwits plateau (*A*, Fig. 98) is another ragged west-facing cliff, 2000 or 3000 feet high, and so bold that it provokes rainfall from winds that must rise as they pass over it. Settlers on the lower arid land use the streams that descend from the gigantic ravines in the cliff face to irrigate their ranches. Great volumes of rock waste have been washed down from this bold escarpment upon the lower land, to which the name of "Grand Wash" is therefore given; and the ragged bluffs of the escarpment are called the Grand Wash cliffs. The Colorado river, coming out from the canyon in the Sheavwits plateau to the lower land on the west, follows a more ordinary valley of moderate depth and open slope; some of the same rock layers that cap the plateau are here seen low down along the river bank. Where the river cuts the base of the Grand Wash cliffs, the fracture by which the upper and lower blocks are displaced may be discovered on the valley sides.

East of the Uinkaret (*B*, Fig. 98) come several other plateau blocks. The barren surface and varied form and colors of the successive strata make the great fractures between the several blocks plainly apparent to the observer who looks from the brink of the canyon to its opposite wall. The Kaibab (*D*) is so high (8000–9000 feet) that, unlike the arid and barren plateaus on each side, its climate is moist; it has forests, park-like groves, and grassy glades well stocked with game. The canyon here has its greatest depth, cutting down 6000 feet through the whole series of stratified rocks into the foundation rocks of buried oldland at the bottom.

The ragged cliffs, by which the ascent is made from one plateau to its highest neighbor, are features of a new

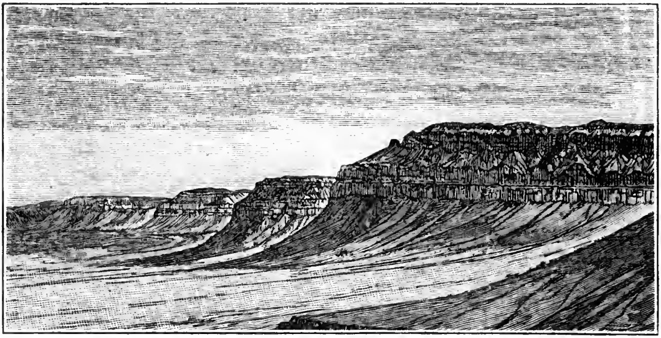

Fig. 99. — Hurricane Ledge — a Dissected Fault Cliff.

class. They are to-day undergoing active weathering and wasting. In the past they were less ragged than now. The fractures between the blocks are commonly known under the name of *faults;* hence the term *fault cliffs* may here be used. It is probable that the displacement or faulting was gradual, and that the cliffs were somewhat weathered even during the time of faulting. To-day they may be called dissected fault cliffs.

It is truly remarkable how little attention the streams of this region pay to the profound fractures by which the plateau blocks are divided. The Grand Canyon, the most fissure-like of all great river valleys, pursues its course entirely regardless of the fissures that run across it. On the surface of the plateaus the fissures are evident in the fault cliffs, now somewhat weathered back from their original faces; but they are not followed by canyons.

The origin of the irresistible forces by which the plateau blocks have been broken apart and uplifted is little understood. It is undeniable that movements of uplift and displacement have really occurred, producing great geographical features in the wonderful plateau country of Arizona and Utah, but the cause of the movements is an unsolved problem, worthy of attention from the advanced student of geology.

The great plateau blocks of Arizona are set apart by their generally dry climate, great altitude, and deep dissection from the easily habitable parts of the world. Where their surface is most rugged and inaccessible, unsubdued tribes of Indians still preserve their savage ways, living in a most primitive fashion on isolated plateaus surrounded and trenched by branching canyons. Travelling over the less dissected plateaus is feasible with a proper outfit of horses and provisions and with a good guide; and no part of the world would better repay a visit by a lover of the marvellous in nature than the lofty Kaibab, where it is trenched by the mile-deep canyon.

CHAPTER VII.

MOUNTAINS.

The Inspiration of Mountain Scenery. — Most of the people of the world live on lands of moderate relief, where an

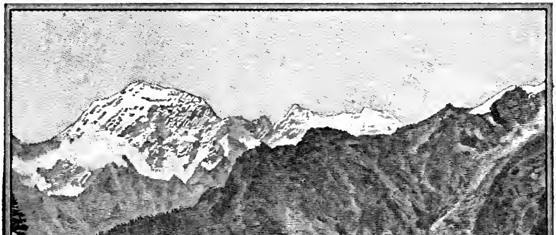

Fig. 100. — The Himalaya Mountains.

abundant soil supplies the needs of agriculture, and where travel and traffic are little obstructed. Rugged regions repel rather than attract inhabitants. The people who live on lowlands have, until modern times, usually looked upon high mountains as places of danger. It has been imagined that they were occupied by evil spirits, and that it must be perilous to cross their high passes or to climb their snow-clad peaks. Uncivilized people living in the valleys among mountains seldom ascend higher than to the pastures on the shoulders of the ridges, or to the lowest notches by which the ranges are broken. But in the eighteenth and nineteenth centuries a better understanding of nature among civilized nations has led explorers to press far into the deep valleys of mountains and to mount their lofty peaks, until now a passion for mountain climbing has arisen and many thousand travellers go every summer into the most mountainous country that they can reach, simply for the enjoyment of its scenery.

To one who has always lived in a low country, it is a novel experience to climb a bold mountain slope and rise high above the lower ground. A wide prospect is spread out beneath and far away, where the hills and valleys, the forests and fields, the roads and streams are displayed as if on a map. The peaks above inspire the traveller with an ambition to reach their highest point and see the country beyond, with nothing but the sky above him. A new sensation is aroused by the grandeur of the view from the summits. The massive vigor of the peaks and ridges excites enthusiasm, and the least imaginative observer can hardly fail to muse on the marvellous processes of nature that have brought such forms into being. The mountain climber who enters with sympathy into the life of the mountains, and who looks upon them as they, had they but eyes, might look on each other, gains a new understanding of the world he lives in, a better and broader understanding than he had before. He may then appreciate the feeling of a guide in the Alps who once said to a traveller: "I like to be on a mountain; one has no evil thoughts there."

The Life History of Mountains.

Block Mountains: Young Stage. — In southern Oregon and the adjoining parts of California and Nevada there are many long narrow mountain ridges, extending about

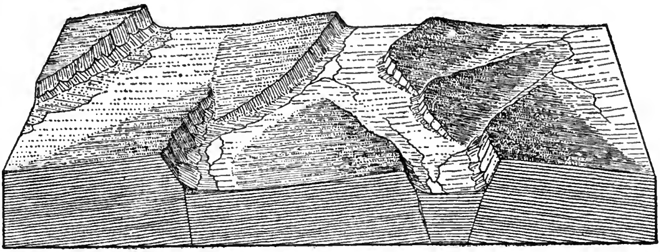

Fig. 101. — Block Mountains.

north and south. Each ridge is a few miles wide, 10 to 40 or more miles long, and 1000 or more feet high. The ridges are steep or cliff-like on one side, of gentler slope on the other, and are separated by flat trough-like depressions of varying breadth and depth.

Each ridge consists of thick layers of rock, the surface of the uppermost layer forming the back slope of the ridge, while the cliff face breaks across the layers. The rock layers are similar in all the rock faces, though the ridges vary greatly in size. A general view of the country shows that the entire region was once a plain, but that it is now broken into long narrow blocks, and that the blocks are tilted one way and the other, so that their uplifted edges form the mountain crests.

It is difficult to account for forces sufficient to break the earth's solid crust in this way, but, as in the plateau blocks, there can be no question that such forces have been at work, and that they have exerted a great influence on geographical conditions.

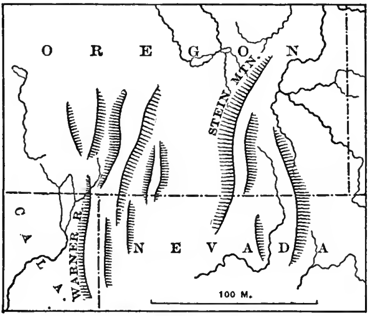

Fig. 102.—Mountains of Southern Oregon.

Some of the ridges retain the form of the tilted blocks hardly changed by weathering. Their back slopes are smooth; their cliffs have little *talus* at the base. Others have shallow gullies worn down the back, while the cliffs are indented by ravines, and every ravine has a fan-like deposit of rock waste spread out beneath it; between the fans the cliffs have a distinct talus slope at their base.

On Satas ridge in southern Washington (*S*, Fig. 130), great bodies of rock have fallen from the cliffs in huge landslides, so steep was the face of the uplifted block. In one case a landslide slipped down about 1000 feet from a cliff 2500 feet high, leaving a scar on the cliff half a mile long, and plowing its way out on the plain below for nearly a mile. The fallen mass is much broken, having a very irregular surface. Around its margin is a rude semicircle of hills 200 feet high, consisting of the material of the plain pushed up ahead of the slide. Although the slide is little weathered, the Indians thereabouts have no tradition of its fall.

The tilted blocks of Oregon are, on the whole, so little worn that they must have been broken and tilted recently in the earth's history. As some of them are more gullied and ravined than others, the different blocks must have been broken at different times. Some of the fans and talus slopes of rock waste are slightly broken along the fracture lines at the base of the cliffs; hence the breaking and tilting of the blocks must have been progressive, and not all at once. The fractures dividing the blocks must be deep, for hot springs rise along their lines.

Earthquakes are not infrequent in this region; hence it is believed that the displacements are still in progress from time to time; a movement of even a few inches would suffice to cause earth tremors, while a sudden start of a foot or more would produce a violent and destructive shock for many miles around. There is no sign that volcanic action has any connection with the fractures and earthquakes of this region.

Here we have to do with a group of young mountains, whose broken attitude was given very lately in the earth's history. The ridges have a massive shape characteristic of unworn forms, not yet ornamented by the varied details of weathering and carving that they will gain when more dissected. They are less beautiful than mountains of greater height and more varied features, but they are of great interest as examples of simple geographical forms. Nowhere else in the world have mountains at once so large and so young been discovered.

The drainage of this region is very simple, for the streams follow the slopes produced by the tilting of the mountain blocks. The smaller streams flow down the slopes of the ridges. The larger streams flow along the troughs in the direction of their slant to the deepest depressions, and there form shallow lakes and marshes.

The finer waste from the ridges is spread evenly over the lower parts of the troughs, concealing their rocky floor.

Like the rivers that are extended across young coastal plains, the streams of the young ridges in Oregon flow in one direction or another in consequence of the slopes given to the land surface that they drain.

Certain features of the region depend on its arid climate. The rainfall is light (15 inches or less a year), for the lofty Cascade range on the west takes most of the moisture from the Pacific winds. Few of the lakes are filled to overflowing; they discharge their water supply by evaporation into the dry air. Most of the lakes are therefore saline, and the plains of fine waste about them are barren.

In dry seasons the lakes shrink; some of them disappear, leaving smooth floors of sun-baked clay. The bottom of the troughs elsewhere and the lower slopes of the ridges are clothed with bunch grass and sagebrush; the ridge slopes, receiving more rainfall than the lower lands, support scattered cedars, and the higher crests bear forests of pine and spruce. Had the ridges not been uplifted, the trees that now grow on them could not exist in this arid region.

Although the ridges are of moderate height, they repel the few settlers in the region, whose ranches are all found in the troughs. The thin grass supports herds of cattle, and the streams suffice for a little irrigation. Thus even in these low young ridges the effect of mountains on the climate and on the location of settlements is well shown. These effects will be found to be much more striking in mountains of greater height.

Dissected Block Mountains. — In Nevada and the adjoining parts of California and Utah there are many north-and-south mountain ranges, adjoined by gravelly plains that slope gently to flat troughs between the ranges. The ranges are from 20 to 80 miles long, and from 5 to 20 miles wide. Their summits rise from 5000 to 7000 feet above the plains. They are generally steeper on one side than on the other; their crests are notched and uneven;

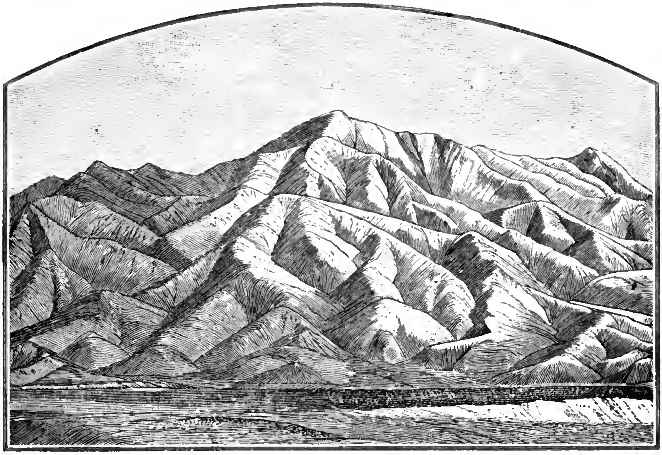

Fig. 103. — A Dissected Mountain Range, Utah.

their slopes are diversified by well-carved spurs between deep valleys. Thus they possess much of the variety of form commonly associated with mountains.

As compared with the ridges of southern Oregon, these ranges are larger and more dissected; but the two agree in having a short and relatively abrupt slope on one side of the crest line, and a long gentler slope on the other side.

The ranges of Nevada, like the ridges of Oregon, seem to have been formed by the uplifting and tilting of long narrow blocks, into which the region had been divided by profound fractures; but in Nevada the blocks must have been larger and the displacements greater; and the breaking and tilting must have begun earlier than in Oregon, for the work of dissection is here much further advanced. The ranges of Nevada are thoroughly or maturely dissected. Yet, as in Oregon, earthquakes and broken fans of rock waste give assurance that the mountains are still growing.

The blocks are now so deeply carved, and their outlines are so irregular, that their original block form is hardly recognizable. With this change, the mountains have become much more beautiful, just as a carved statue is more beautiful than a rough block of marble. The rock waste, worn from

Fig. 104. — Fractured Slopes of Rock Waste at Base of Mountain Range, Nevada.

the valleys in the mountains, forms extensive sloping gravel plains in the troughs, accumulating to so great a depth as to rise on the flanks of the mountains and thus diminish their relief.

The strong ranges of Nevada exhibit more distinctly than the smaller ridges of Oregon the lower temperature, with greater cloudiness and rainfall, that prevails on mountains as compared with the plains between them. The rainfall in the troughs is light, but storm clouds gather round the peaks while the sun still shines on the plains. When the clouds dissolve, the mountains have been refreshed by rain or whitened with snow, while the plains may be as dry as before.

Streams flowing from the mountains often wither away on the plains. Settlements in Nevada are therefore generally limited to a belt around the mountain base, where the streams may irrigate fields. Some of the ranges contain valuable ores; mining towns have sprung up in their valleys.

Old Block Mountains.—In southeastern California there are belts of rocky hills rising to moderate height over long slopes of gravelly waste, beneath which a rocky floor is sometimes exposed in gullies. These hills are taken to be the dwindling remnants of mountain ranges upraised so long ago that now they are worn down to low relief. Their youth, in uncarved blocks, is long past. Even their maturity, varied by many ridges, spurs, and valleys, is remote. They are old mountains, reduced to mere hills under the patient attack of the weather.

Folded Mountains: Young Stage.—The Jura mountains, lying along the border of France and Switzerland, consist of a number of parallel arch-like ranges and trough-like valleys trending about northeast and southwest. Each range consists of a series of rock layers bent upwards; each trough is underlaid by the same series of layers bent downwards. Some of the uppermost layers have been weathered off from the crest of the arches, while the edges of the harder layers remain in flanking ridges. Waste from the arches has accumulated in the troughs here and there, flooring them over with gravel and sand.

The rock layers of these mountains contain marine fossils; they must originally have been horizontal strata on the floor of an ancient sea. Since then they have been crushed into their arch-and-trough structure by a powerful side pressure.

The drainage of the Jura mountains is for the most part like that of the Oregon ridges in following the slopes of the deformed surface. Short streams run down the

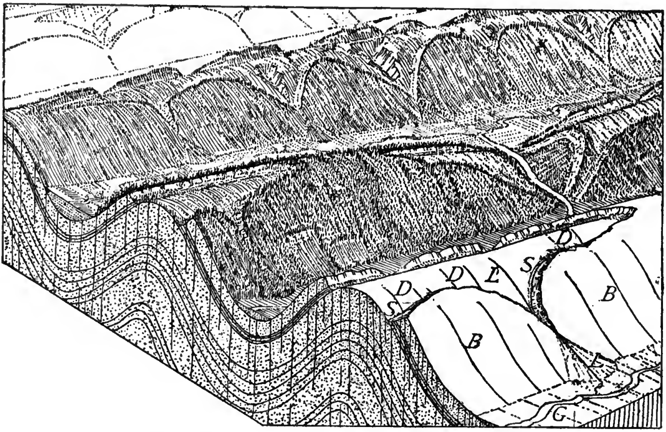

Fig. 105.—Diagram of the Jura, a Folded Mountain Range.

sides of the arches, cutting ravines on the slopes, as shown in the unshaded foreground of Fig. 105. Larger streams gather on the trough floors, and escape at one end or the other as opportunity offers.

Here and there a stream cuts across an arch, wearing a deep gorge from one trough valley to the next, and exhibiting the arched structure, as in the middle ridge of Fig. 105. The origin of these crosswise or transverse streams is not so simple as that of the others. Some of the cross gorges are cut where the arches are least uplifted, as if a sag in the crest of the arch had located the transverse stream. In other cases it seems as if the gorge had been cut down by its stream about as fast as the arch was uplifted, thus indicating a slow growth of the mountains.

As in all mountains of distinct relief, the form of the surface exercises a strong control over the distribution, occupation, and movement of the population. The valley floors are well settled; villages often lie near the mouth of a transverse gorge. Roads are generally limited to the lengthwise and crosswise valleys. By-ways and footpaths lead to the upland fields and pastures. Little villages are sometimes found on the tops of the broader arches. The steeper slopes are generally forested.

Nowhere else in the world have there been discovered arches and troughs of so simple a pattern and so young a stage as those of the Jura. The Oregon ridges and the Jura folds are, as it were, elementary examples of mountain forms, provided by nature for the better understanding of the complicated examples of structure and form in greater mountain ranges.

Domed Mountains. — The Black Hills of South Dakota show a thick series of rock layers that have received a dome-like structure by the upheaval of their foundation. The dome is of oval outline, 100 miles north and south by 50 miles east and west; in area about equal to that of Connecticut. A great part of the covering layers has been weathered and worn away during and after the time of upheaval, and to-day the foundation rocks are exposed, especially in the eastern half of the dome. If built up again, the height of the dome over the surrounding plains would be about 6000 feet; to-day the highest summits are only 2000 or 3000 feet above the plains, or about 7000 feet above sea level.

The edges of the more resistant sandstone layers, whose higher part has been worn off from the dome, form ridges that rim around the margin of the Hills. Many streams have cut deep valleys leading outward in all directions

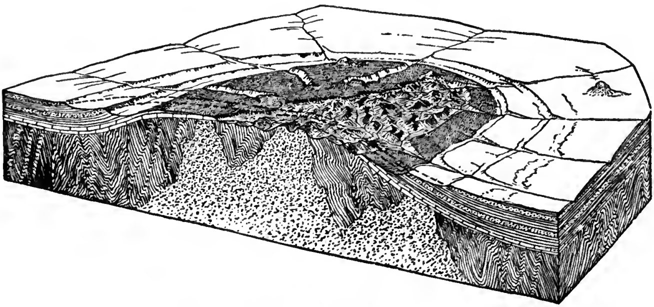

Fig. 106. — Diagram of the Black Hills.

from the central part of the dome, as if they had been guided by the original slope of the uplifted surface. They cut notches or water gaps in the rimming ridges.

The rolling treeless plains surrounding the Black Hills have light rainfall and scanty grass. They are occupied, if at all, by large ranches where cattle range freely, reaching a stream once or twice a day. Approaching the Hills, the rimming ridges rise around them too high and steep for easy occupation. The valleys define lines of travel; the water gaps in the outer ridge are of especial importance as gateways to the Hills. Next inside of the chief rimming ridge is a valley that has been worn down on weak layers of red clays that here and there give a bright color to its soil; hence its name, the Red valley. It is so continuous around the Hills that the Indians called it the "race course."

The central part of the dome still rises high enough to compel an increase of rainfall from the passing winds. The Hills are therefore clothed with dark forests (hence the name Black Hills) and support an active lumber industry.

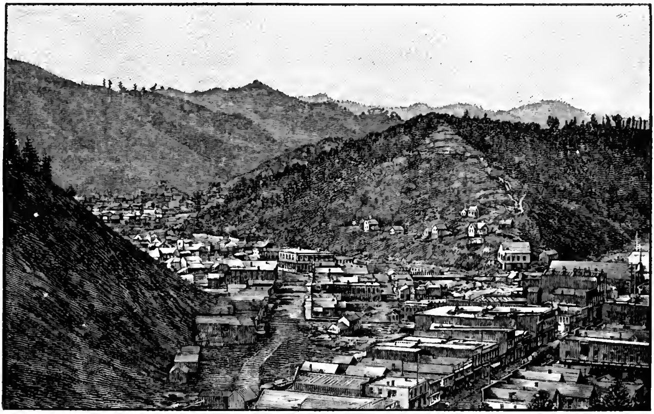

Fig. 107. — Deadwood, a Mining Town in the Black Hills.

The deeper valleys dissect even the foundation rocks, which (as is often the case in ancient rocks uncovered from a long burial) contain valuable deposits of gold and silver. Here mining flourishes and settlements grow, crowded in the narrow valleys. The mines need machine shops and smelting works, and the industries thus created demand means of transportation. Two railroads have therefore been built from the central states across the open country into the Black Hills; their trains resemble steamships crossing the sea-like plains to ports in the island-like hills.

Complex Mountains.—Some mountain ranges, like certain parts of the Rocky mountains, but better represented by the Alps, the Caucasus, and the Himalaya, possess a great

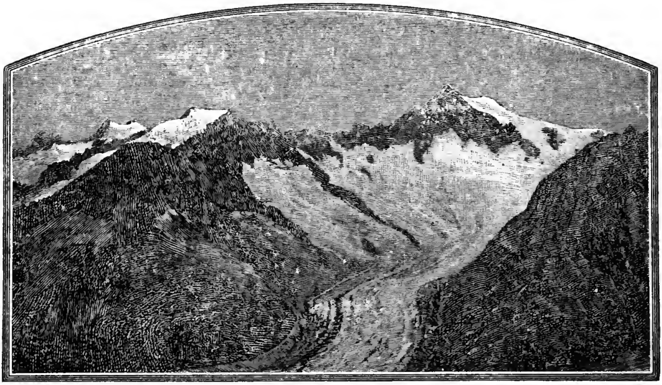

Fig. 108.—Peaks of the Central Alps.

complexity of structure and exhibit a remarkable variety of peaks, ridges, ravines, and valleys. Their higher central peaks usually consist of resistant granite-like rocks, surrounded by slanting layers of bedded rocks that rise in great ridges.

These two parts once had a simple relation like that of "foundation" and "cover," already seen in several examples; but now both the foundation rocks and the covering strata are greatly deformed and dissected, as if repeatedly tilted in blocks, uplifted in domes, and crushed in folds, and as if for a long time vigorously attacked by weather and streams.

The majestic forms of complex mountains usually depend as much on their deep dissection by great valleys as on their lofty uplift. Unlike the simple tilted blocks of

Oregon, or the orderly folds of the Jura, the greater ranges preserve little indication of their original form.

Most mountain ranges have a greater length than breadth. They extend in a general way parallel to the trend of their tilted blocks and folds, as if they represented a belt of country where the crust of the earth had been crushed or upheaved in escaping from enormous pressures from one side or from beneath; but the nature of the forces which produce mountains is not fully understood. One of the most ingenious and successful theories accounts for many ranges as great disorderly folds formed in the outer crust of the earth, which is thought to wrinkle here and there as it very gradually settles down on the slowly cooling and contracting interior.

The discovery of marine fossils in the bedded rocks of high Alpine ridges toward the close of the eighteenth century was

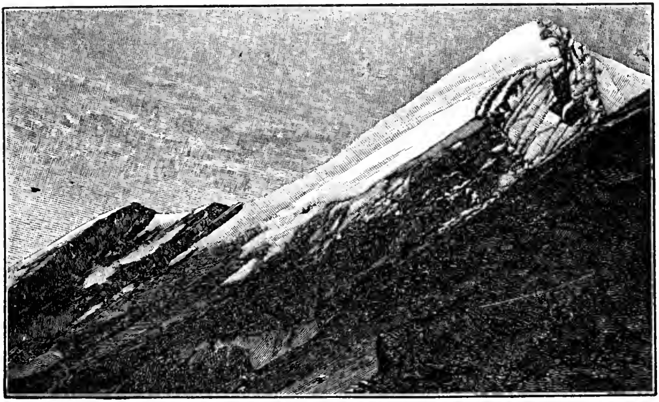

Fig. 109.—An Alpine Peak of Slanting Layers.

received with great astonishment by the scientific men of the time. The occurrence of fossils in so elevated a position was one of the first generally accepted proofs of the changes that have gone on in the past, by which the present form of the earth's surface has been fashioned. But not until the nineteenth century had well advanced was it generally understood how much more the form of lofty mountains depends on processes of land sculpture than on forces of uplift.

Peaks and Ridges. — The highest peaks and ridges of lofty mountains generally consist of the most resistant rocks. Their height is due in part to the great uplift the whole range has suffered, and in part to their success in resisting the attack of the weather, under which the weaker rocks have greatly wasted away. The waste that is shed from the peaks and higher ridges is quickly swept down into the valleys, usually leaving the loftiest summits bare and sharp. The spurs of the ridges are notched by steep ravines, and deep valleys are worn between them. These varied forms are chiefly due to elaborate carving.

The bare rocky peaks and ridges, rising into the cold upper atmosphere, far above the limits of vegetation, are silent deserts. The stillness is broken only by the rush of storm winds and the roar of rockfalls and snowslides. Not less barren are the snow fields and the talus slopes on the higher mountain flanks, and the slanting reservoirs of ice and snow in the upper valley heads, from which ice streams or glaciers slowly creep down to the lower valleys. The lower slopes are generally forested.

Many summits in the Alps are so sharp that they are called "needles" or "horns." They rise as almost inaccessible peaks between the gnawing valley heads. Mt. Blanc, the highest mountain of the range (nearly 16,000 feet) is of dome-like form with a heavy snowcap, not yet sufficiently dissected by valleys to develop sharp peaks.

The Selkirk range of the Rocky mountains in Canada has steep and bare rocky summits surmounting the long waste-covered slopes that descend into the valleys. Having an abundant snowfall, the range bears extensive snow fields and glaciers. In the Rocky mountain ranges of Colorado the snowfall is less plentiful, snow fields are scarce, and glaciers are wanting. Long slopes of creeping waste cover the mountain flanks far up towards the summits; craggy peaks of sharp form are less common than in the Selkirks or the Alps.

Climate of Mountains. — On extensive plains the climate — especially the temperature and rainfall — changes very slowly from place to place, being nearly uniform for hundreds of miles together. On the average, one must travel from 30 to 60 miles poleward to find a difference of 1° in mean annual temperature. The same difference is found on mountains by an ascent of only 300 feet.

Broad plains may have only a scanty rainfall over hundreds of miles together. On lofty mountains the rainfall rapidly increases with elevation. Not only because they are high, but also because they receive much rain and snow, high mountains are usually the sources of large rivers.

Similarity of form and climate over broad plains makes the conditions of life nearly uniform over great areas. In mountains diversity of form and climate is found within small distances, and strong contrasts in the conditions of life are crowded close together.

On account of the lower temperature and the heavier rainfall and snowfall of high mountains, their animals and plants are unlike those living on the surrounding lowlands. On ascending the mountain flanks, hardy cone-bearing trees succeed trees needing a milder climate. As the limit of tree growth or "tree line" is approached, only stunted and deformed trees survive. Then comes a belt in which the slopes bear grass and Alpine flowers. (Alpine is used to refer not only to the European Alps, but also to the animals and plants of any lofty mountain.) Following this is the snow line, above which some of the snow of one winter lasts over the following summer, excluding plant life. The height of the snow line is greatest in the torrid zone (18,000 to 20,000 feet) and decreases towards both poles, reaching sea level in the frigid zones. It is remarkable that many plants found near the snow line on mountains in the warmer zones are also found near sea level in the frigid zone.

Mountains as Barriers. — High mountains serve as barriers, separating the climates and the populations of their opposite sides. The eastern slope of the equatorial Andes has a moist climate because the damp winds from the Atlantic, ascending and cooling, give forth a heavy rainfall there; the western slope has a dry climate because the same winds, descending and warming, not only give forth no more rain, but eagerly take up whatever moisture they find on the way. The eastern slope is densely forested; the western slope is for the greater part a desert, except in valleys watered by streams.

Moist winds from the Pacific give a plentiful rainfall on the westward or windward slopes of the Sierra Nevada and the Rocky mountains of the United States. The same winds, descending on the eastern or leeward slopes, become in winter unseasonably warm and dry (see Appendix H), evaporating the light snow of the plains, and laying bare the dry bunches of grass, greatly to the advantage of the cattle feeding there. The dry wind is called the Chinook. A similar wind occurs in the northern valleys of Switzerland, where it is called the Foehn.

The great populations of India and China, representing different races, are separated by the Himalaya and other ranges in southern Asia. They are thus so well held apart that neither one has had an important influence on the other. Lofty mountain ranges thus rank with the oceans in separating the inhabitants of the lands.

When low countries on opposite sides of a high range are occupied by different peoples, the mountains commonly serve as a natural boundary between the two countries. The range as a whole may serve as a rough boundary between uncivilized nations; but between civilized nations the crest line dividing the rivers of the opposite slopes is often accepted as a more precise boundary, as in the Pyrenees between France and Spain, where the river divide is generally adopted as the national divide.

When the river divide departs from the main range that it was supposed to follow before the mountains were explored, the boundary question may give rise to dispute, as recently between Argentina and Chile, where a number of Pacific rivers rise on the pampas of Patagonia, and cut through the Andes in deep gorges.

The difficulty of crossing lofty ranges gives great importance to the notches or *passes* in their central ridges, through which travel and traffic may go with less effort than over their peaks. The heavy snows of the winter may close the passes for several months. In earlier centuries, when the passes were traversed only by paths, houses of refuge were often maintained on the summit by monks, as on the famous pass of St. Bernard in the Alps.

It is chiefly within the last hundred years that well-planned roads have been constructed over the chief passes of various Alpine ridges. The roads enter the mountains along the larger valleys, and then zigzag up the steeper slopes. They are carefully laid out so as not to exceed a certain moderate grade, about five feet in a hundred. Certain passes are now crossed even by railroads, the ascent from the valleys being most ingeniously made by curves and "loops." Sometimes the last part of the ascent is avoided by tunnelling the ridge under the pass, it being cheaper in the long run to bore through than to climb higher.

Avalanches. — The heavy snowfall of winter often overloads the snow banks on the higher slopes, and great masses of snow slide down to lower levels. Summer melting and rainfall also cause slides or avalanches (*aval*: to the valley). Sometimes the snow mass glides along the sloping surface at a moderate speed. Sometimes it leaps from cliffs, and falls with a terrible velocity to the valleys below; a violent blast of air bursts outward from beneath, overturning trees hundreds of feet beyond the reach of the snow.

Fig. 110. — An Avalanche Path, Selkirk Range, Canada.

Certain villages in Alpine valleys carefully preserve a patch of forest on the slope above them as a protection from avalanches. Highways and railways on steep mountain slopes must here and there be covered in by long snow sheds, over which the snow may slide without blocking or injuring the road.

Heavy masses of ice are occasionally detached from glaciers that end on steep slopes, forming "ice falls." These are even more destructive than avalanches of snow. An ice fall, over 5,000,000 cubic yards in volume, broke from a glacier on the slope of the Altels (Fig. 111; see Fig. 109, from a photograph taken before the fall) in the Alps in September, 1895. It ran down a steep slope two and a half miles long, gathered about 1,300,000 cubic yards of rock waste on the way, and then rushed across the valley floor, dashing far up the opposite slope and falling back again, like a wave from a cliff. A bench on the path of the sliding mass caused it to leap forward, clear of the ground; then falling, the air beneath was violently driven away, blowing out fragments of ice and rock and breaking down trees hundreds of yards distant (shown by arrows turned to the right, Fig. 111).

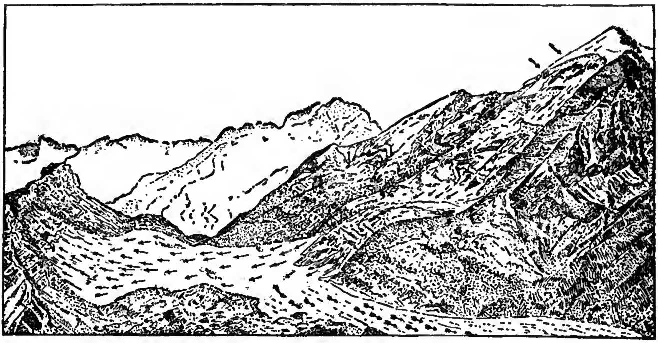

Fig. 111. — Path of an Ice Fall in the Alps.

Valleys among Mountains. — One of the strongest characteristics of thoroughly dissected, lofty mountains is the activity with which the rock waste is weathered from the peaks and cliffs, moved down the steep slopes, swept by the streams along the larger valleys, and washed out upon or across the adjoining lowlands. The waste seems everywhere to be streaming (as the long-lived mountains might say) down from the peaks and ridges. The elaborate carving of the mountains has been accomplished by the long duration of these active processes for ages past.

The greatest work of erosion is seen in the excavation of the chief valleys and their innumerable branches. Unlike young mountains, where the valleys generally follow the troughs between the uplifted blocks or arches, lofty mountains are dissected by valleys that often bear little relation to the original depressions among the uplifts. Just as the peaks and ridges result from the survival of the more resistant rocks, so the valleys in thoroughly dissected mountains generally result from wearing out the weaker layers, which have been thoroughly sought for by the destructive processes.

Some of the valleys among high mountain ranges may be cut much deeper than the troughs by which the streams were originally located. It is not rare in greatly uplifted and deeply dissected mountains to find high ridges bearing the remnant of a down-folded hard layer; the rock arches on each side being now worn down to deep valleys that have been excavated on weak under-layers, as in Fig. 112. Thus an original valley

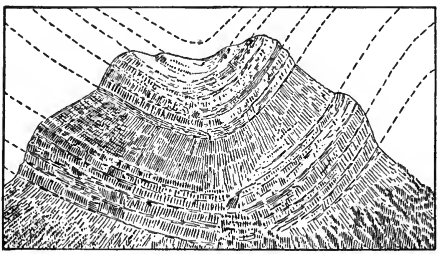

Fig. 112. — A Mountain of Down-Folded Layers.

floor has come to be a mountain ridge, while the adjoining arches have been reduced to deep valleys. The importance of erosion as a means of producing land forms and the great depth to which valleys have been carved are seldom more emphatically taught.

Valley floors among lofty mountains must be at a considerable height above sea level, especially near their heads; for as long as a great volume of waste is swept from the upper slopes and washed by torrents down the ravines and side valleys, even a good-sized river in a main valley cannot cut its channel down to a faint slope, close to sea level. The valley line must have a rather rapid descent, 50 to 100 feet to a mile, in order to give the river a velocity that will enable it to carry away the waste that is washed into it.

In deep and narrow valleys the side slopes are sometimes cut so steep that great rock masses may be detached from the walls and slip to the bottom, forming landslides. This is particularly common where the strata in the valley walls slant into the valley.

In September, 1893, a great landslide occurred in the deep valley of one of the upper branches of the Ganges in the Himalaya, 150 miles above the city of Hardwar, where the river emerges on the plains. In three days 800,000,000 tons of rock fell with deafening noise, darkening the air with dust, leaving a great bare cavity with steep walls several thousand feet high to mark its source, and building a dam nearly 1000 feet deep across the narrow valley floor. A lake gradually formed on the up-stream side of the dam, and grew to be four miles long before it overflowed about a year after the slide.

In the mean time the danger that the lake might burst out in a great flood being perceived by the British engineers in charge of the public works of India, the bridges in the lower valley were removed; safety marks were set up on the valley sides, 100 or 200 feet above the ordinary river level, indicating the height above which the flood would probably not rise ; and a telegraph line was constructed from the dam to Hardwar, to give prompt warning of the outburst.

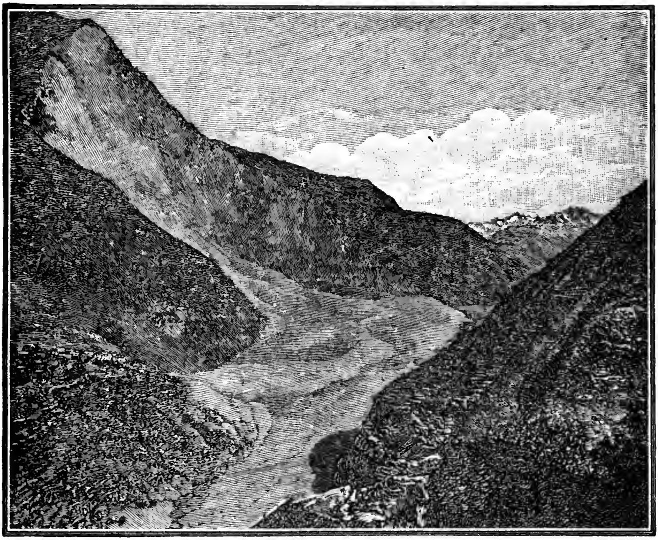

Fig. 113. — A Landslide in the Himalaya.

The flood occurred at midnight, August 26–27, 1894. In four hours about 400,000,000 cubic yards of water were discharged, cutting down the dam nearly 400 feet, flooding the valley to a depth of from 100 to 170 feet, and rushing forward with a velocity of 20 miles an hour. Many miles of valley road were washed away. Every vestige of habitation was destroyed in villages along the Ganges above Hardwar. But so well was the notice of danger given that only one man lost his life, and that because he would not heed the warning. Under a less intelligent control, thousands of people must have perished in such a catastrophe.

Lengthwise and Crosswise Valleys. — When a river has cut down its valley floor to as moderate a slope as the load of waste that it has to carry along will allow, it may still wear away its banks, first on one side, then on the other. Thus in the course of time the river broadens the valley floor. This is especially true in a valley that is worn down along a belt of weak rocks parallel to the general trend of a mountain range; for these rocks weather and wash away at a comparatively rapid rate.

The crosswise valleys, by which the rivers of the long inner valleys find outlets through enclosing ridges, are often narrow and steep-walled gorges; for the ridge-making rocks are resistant and weather slowly. The floor of a crosswise or transverse valley may be hardly wider than its stream; the walls rise steep from the water's edge, leaving no room for a road or path on either side.

It is chiefly in the broader lengthwise valleys that mountain peoples dwell. When the outlet valleys are narrow gorges, the outer world has for centuries been reached only by passes over the enclosing ridges; but modern engineering skill has sufficed to build and cut roads and railroads through many gorges that were impassable a century ago.

Earthquakes of Growing Mountain Ranges. — The actual process of bending and breaking the rock structures within a mountain mass sometimes causes sudden snaps and slips of a few inches or a few feet. Tremors of greater or less strength then spread in all directions from the seat of disturbance, diminishing their intensity as they advance. On reaching the earth's surface they are felt as earthquakes, producing more or less destruction. Shocks of this kind are comparatively common in most of the lofty mountains of the world.

Earthquake tremors travel through the earth's crust with great velocity — from 10 to 40 miles a minute; but, as in the case of water waves, the actual movement of the earth at any point may be only a few inches a second, backward and forward. The shocks produced by earthquake waves are most violent at places directly over the seat of chief disturbance. They may be very faint, causing no damage. They may be strong enough to be felt violently over hundreds of square miles, less distinctly over many thousands, and very faintly (by the aid of delicate instruments) all over the earth.

Earthquakes of moderate violence are still frequent in the Alps, occurring 5 to 10 times a year. Five centuries ago (1348) a violent earthquake in the eastern Alps caused a great landslide by which a valley was barred across and a lake formed up stream from the slide. Countless thousands of shocks must have been produced during the long ages of mountain growth. The association of earthquakes with the young tilted-block ridges of Oregon, with the more mature mountains of Nevada, and with vigorous ranges like the Alps and the Himalaya, is a natural result of the continued disturbance or growth of the mountains.

Inhabitants of Lofty Mountains. — The people who to-day dwell in the valleys of lofty mountains are in many cases the descendants of races who formerly occupied the adjacent lower lands, from which they were driven by conquering invaders. Secluded valleys among mountains serve as refuges, where pursuit is too difficult to be profitable. There the weaker race long remains unmolested, holding little intercourse with the outer world, and preserving old forms of speech and old-fashioned customs. The invaders occupy the neighboring open country; they engage in traffic with the other parts of the world and advance in new ways of living.

The Basques live in the northern valleys of the Pyrenees, near the angle of the Bay of Biscay. They are probably descendants of the Iberians, an ancient people who occupied a large part of Spain and France, from which they were driven by invaders even before Cæsar made those countries subject to Rome, nearly 2000 years ago. The Basque language is the only surviving form of Iberian, and is entirely unlike other European languages.

The Svanetians occupy deep inner valleys in the Caucasus mountains, with difficulty accessible from the outer country. Their ancestors were an ancient people who occupied a far more extensive territory, from which they were driven back to the mountains many centuries ago. There ancient customs and a peculiar language are preserved ; there the people still live, entirely apart from the ways of modern times. Although daring and patriotic, they are ignorant and superstitious. Their wretched houses are dark and dirty; their roads are only rough tracks. Arts and industries are of the simplest order ; traffic is only by barter.

The small country of Switzerland is largely mountainous. Andorra, a very small independent country in the Pyrenees between France and Spain, is a modern instance of the many small political divisions that prevailed in Europe during the middle ages. These two small mountainous countries are in striking contrast to the vast extent of the Russian dominions, of whose area so large a part consists of plains of comparatively even surface.

The broader valleys within high mountains afford many favorable places for settlement and cultivation. The narrower valley floors are frequently swept over by destructive floods ; here the lower slopes of the valley sides are commonly selected as sites for villages, and it is often necessary to make terraces on the mountain flanks in order to gain flat patches of ground for cultivation.

During winter the valleys among lofty mountains may receive a heavy snowfall ; then for a season the people and their flocks are gathered in the villages. In summer, when the snows are melted from the mountain sides, cattle, sheep, and goats are driven up from the valleys to pasture on the grassy slopes of the ridges, and hay is carried, often on the backs of the mountaineers, down to the villages for winter need.

In the Alps the condition of the people has greatly improved since it came to be the habit of tourists to make excursions among the mountains. Excellent roads have been built; good hotels are to be found in little villages; paths lead far up on the mountains, where huts of refuge are constructed to shelter the more adventurous mountain climbers. Entertainment of strangers has come to be an almost national industry.

Fig. 114. — Ibex.

Many animals survive in mountains after retreating from the surrounding lower ground. Various species of Ibex (mountain-goat) are found on the mountains of Eurasia, each range having its own peculiar species. From a common ancestry on the intermediate lower ground the descendants in each range have varied in their own way, independently of the others. This is a remarkable illustration of the effect of mountains in keeping their inhabitants apart from the rest of the world; it may be compared with the effect of isolation on islands.

Subdued Mountains. — There are certain mountain ranges of moderate height, in which sharp peaks are absent and bold cliffs are rare. The slopes are of moderate steepness, and rock waste covers them almost from base to summit. Mountains of this kind do not reach upward into a climate very unlike that of their base; and if not in a dry or a frigid region, they may be forest-clad to the top.

The earthquakes that are common in mountains of active growth and the landslides that happen frequently in mountains where the valley sides are still steep are rare or unknown

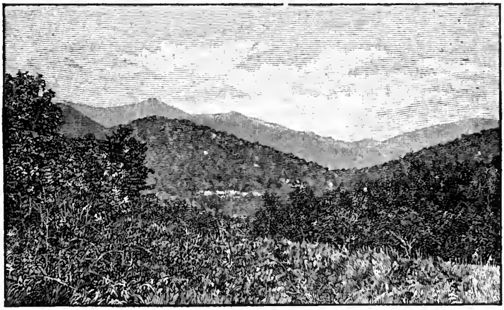

Fig. 115. — The Mountains of North Carolina.

in these mountains of gentler form. Unlike the vigorous forms of lofty mountains in which uplift and erosion are still active, the rounded forms of these mountains express subdued strength, as if their high peaks and ridges had been greatly worn away by the long-continued attack of the weather. They may therefore be called subdued mountains.

The Blue Ridge and other mountains of North Carolina are good examples of subdued mountains. No sharp peaks tower into the sky. The summits generally rise dome-like in rounded outline. Heavy forests clothe their slopes.

As in all regions of rugged form, out of the way of easy travel and active traffic, the people living in the valleys among subdued mountains preserve older fashions than those of the more open lower country. This is seen in the homespun clothing and in the manner of speech of the North Carolina mountaineers.

The mountains of Wales make another group of subdued forms, but more rugged than the mountains of North Carolina. Here remain some of the descendants of the Britons who were driven from the more open lowlands of eastern and central England by Saxon and Norman invaders, 1000 or 1500 years ago. The Welsh language, therefore, represents the original language of Britain, while the English language is a compound of the speech of the invading peoples.

The higher parts of subdued mountains remain wooded long after the surrounding lowlands are cleared and cultivated. Hence many mountains of this kind in central Europe are named for their forests, as the Schwarzwald of Germany, literally Black Forest, but better translated Black mountains. Timber from the forests may be sawed by the abundant water power in the valleys, and the lumber sent out to the more populous lowlands.

Worn-down Mountains. — In certain parts of the world ancient mountain ranges have been almost completely worn away. Their disordered rocks, once rising in lofty peaks and ridges, and perhaps bearing snow fields and glaciers, have been reduced to an almost plain surface, little above baselevel and everywhere open to settlement.

The Piedmont belt of Virginia, between the Blue Ridge and the coastal plain, is in many respects an excellent example of a worn-down mountain range. It is a plain, not monotonously smooth, but undulating in graceful swells between gentle depressions. Bare ledges are seldom seen. The soil is deep, fine, and fertile, and the district is very generally occupied by farms. The height to which the rock masses once rose above the present surface is reasonably estimated

Fig. 116. — The Piedmont Belt, Virginia.

as at least one mile; it may have been two or three. The wearing down of these ancient mountains to the rolling plain

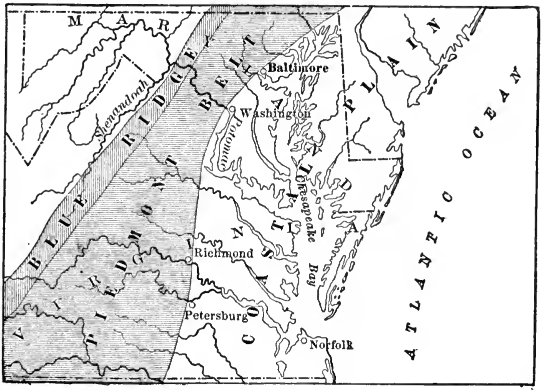

Fig. 117. — Map of the Piedmont Belt, Virginia.

of to-day has required a period of time compared to which that occupied in cutting the Colorado canyon is a brief interval.

It often happens that the plain surface of a worn-down mountain range is here and there surmounted by rounded hills or low mountains, 1000 or more feet high, composed of the most resistant rocks of the whole region. These hills are the last remnants of the mountains that once towered over the surface of to-day. They may be called *monadnocks*, after a mountain of this kind in southwestern New Hampshire.

Several monadnocks are scattered over the Piedmont plain of Virginia, one being shown in Fig. 116. Sometimes the remnant mountains have the form of long ridges. The Allegheny mountains of Pennsylvania are ridges of this kind,

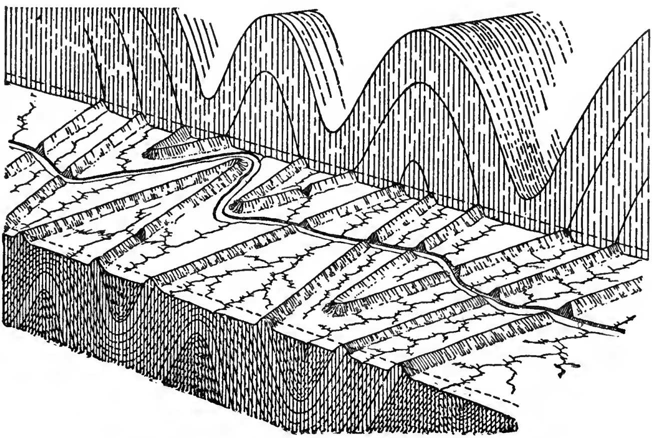

Fig. 118. — Diagram of the Allegheny Mountains, Pennsylvania.

formed of the most resistant sandstones of the region, while the weaker rocks are worn down lower, as in Fig. 118. These mountains have been uplifted and worn down more than once.

It is generally the case that old-mountain lowlands are now uplifted above the position in which they stood when worn down, so that they form plateau-like uplands. Their streams are thus revived into a new period of activity, and at once proceed to trench and dissect the upland. Dissected uplands of this kind, bearing monadnocks in greater or less number, are very common geographical forms.

The Piedmont belt of Virginia now stands several hundred feet above baselevel. It is cut across by a number of active streams that flow in winding, rocky, steep-sided valleys, from 100 to 300 feet beneath the upland plain. It is here that the tilted rock structures of the ancient mountains are best seen.

One of the finest examples of an uplifted old-mountain lowland is found in the plateau-like Slate mountains of

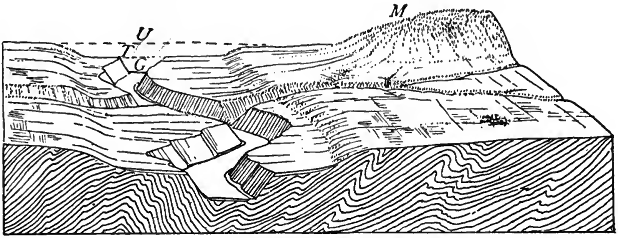

Fig. 119. — Gorge of the Rhine in the Slate Mountains, Germany.

western Germany. The broadly undulating upland is generally cleared and cultivated. Here and there the more resistant rocks stand up in forest-clad monadnocks (*M*, Fig. 119). The Rhine has cut a deep gorge directly through the upland, and the side streams are cutting steep ravines in the bordering slopes.

The valley of the Rhine here consists of an upper trough (*T*), with a narrow gorge (*G*) cut in its floor. The ruined castles for which the valley is famous stand on the edge of the trough, overlooking the inner gorge. The uplift by which the cutting of the narrow gorge has been permitted cannot have taken place very long ago (as the old mountains would count time), for the river has not yet had time to widen its valley floor. Ledges that formed rapids in the channel have been removed by blasting.

Southern New Hampshire and Vermont, central and western Massachusetts, and all of Connecticut include many uplands, above which occasional monadnocks rise,

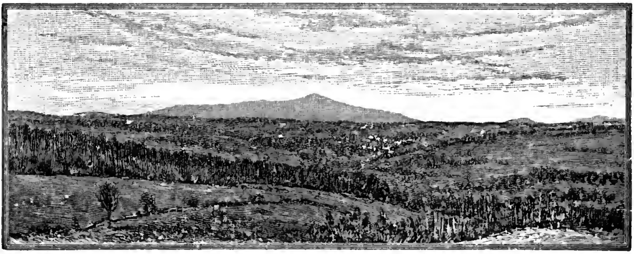

Fig. 120.—The Upland of New England, with Monadnock in the Distance.

and beneath which numerous valleys are worn. When an observer stands on the uplands, the sky line is seen to be comparatively even and independent of the attitude of the tilted rocks whose ledges crop out on the valley sides. If the valleys were in imagination filled up again to the level of the uplands, the worn-down plain of the ancient mountains of New England would be restored.

The plain does not now stand close to the baselevel with respect to which it was worn down. It has been uplifted into a slanting position, so that it slowly rises from sea level at Long Island sound to a height of from 1400 to 1600 feet on the northern boundary of central and western Massachusetts. The valleys have been carved in consequence of this uplift. They are shallow near the coast, but deep (800 to 1000 feet) in the interior, where the upland is higher. They are narrow where the rocks are resistant, but wide open where the rocks are weaker. The chief of the wider valleys is that of the Connecticut river, excavated along a belt of relatively weak sandstones.

The monadnocks that crown the uplands are forested and

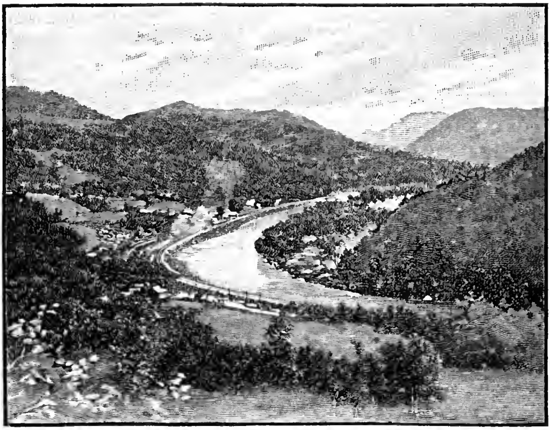

Fig. 121. — Valley of the Deerfield in the New England Upland.

uninhabited. The uplands have a scattered farming population, here and there gathered in small villages. The valley sides are generally wooded, but sometimes hold sloping fields. The larger valleys contain many villages and cities, and lead the chief roads and railroads. Here is gathered the more active manufacturing and commercial population of New England. The valley sides are often quarried for resistant building stones, like granite; the broad Connecticut valley floor yields brown sandstones, easily cut and carved, and much used for ornamental architecture.

The Highlands of Scotland are a bolder example of an old, worn-down mountain region, now uplifted again and dissected by numerous deep valleys. Their sky line is rather uneven, and it is not probable that the old mountains were ever worn down very low; yet the sky line is smooth compared to that of a surface due to the breaking and folding that the ancient rocks of the Highlands have suffered. The valleys are from 2000 to 3000 feet deep. The smaller branch valleys are called glens. The mountains of to-day are the result of cutting down the valleys and glens between them, just as in the so-called "mountains" of the dissected Allegheny plateau of West Virginia.

The form of the Highlands has for centuries had a strong influence on the history of the Highlanders. Like so many other mountaineers, they are the descendants of an early people driven from the Lowlands by invaders. Taking refuge in the Highlands, they have not lived on the mountains, but in the deep glens. Being thus divided into small communities or clans, the members of each clan became closely associated and devoted to their local leaders; and this way of living has given the word "clannish" to our language. It was difficult to survive in their rugged country; hence the survivors became hardy and thrifty. The Lowlands on the south are occupied by descendants of the invaders; their people and language are of different stocks from those of the Highlands. Thus arose the long feuds between the Highlanders and Lowlanders, narrated in Scott's novels and poems. Now that warlike strife has ceased between them, and means of travel have increased, many of the Highlanders have left their rugged glens and emigrated to other parts of the world.

The ancient rocks of worn-down mountains often contain deposits of rare minerals and valuable ores. These have been formed by slow chemical changes that went on deep within the crust of the earth when the rocks now visible were buried far beneath the surface. As a consequence, mining often flourishes in regions of this kind.

The Erzgebirge, or Ore mountains, of Germany are a worn-down and again uplifted ancient mountain range. Many valuable minerals occur in their rocks, and mining has been carried on there for a long time. Indeed, this art is so generally practised in the subdued or worn-down and uplifted ancient mountains of Germany that the German word for mining is *Bergwerk*, or mountain-work.

The gold-bearing veins in the Sierra Nevada of California and in the Klondike district of Alaska both occur in ancient, worn-down mountains, now uplifted and again more or less dissected. The important deposits of iron ore in northern Michigan and Minnesota are similarly situated.

Embayed Mountains. — A mountain range near a continental border will be partly covered by the sea if a

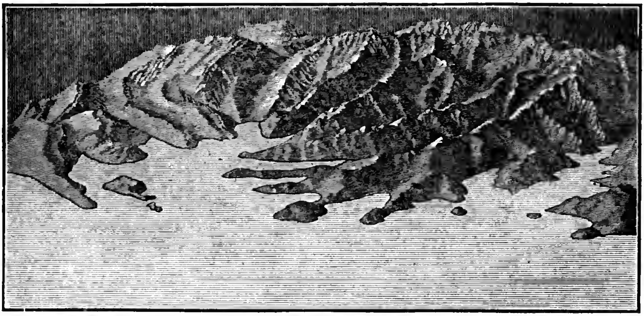

Fig. 122. — Model of Embayed Mountains.

movement of depression lowers the level of the land. The effect thus produced will be similar to that observed in the half-drowned coastal plain already described. The valley floors and mountain flanks will be submerged to a greater or less depth, and many long bays will enter between outstretching promontories and islands. The wasting of the ridges still standing above sea level will continue as before; deltas will be formed at the bay heads, and sea cliffs will be cut on the headlands, with reference to the new baselevel.

A partly drowned mountainous district has a coast line of great irregularity. The long bays, called *fiords*, provide many protected harbors, but their waters are often inconveniently deep for anchorage, and the lands may be too steep for easy settlement. The outlying islands tempt exploration from the mainland. The action of ancient glaciers has been important in smoothing the walls and deepening the floors of fiords (see pp. 345, 346).

The coast of British Columbia and southern Alaska is bordered by high mountains, into whose valleys the sea now enters in long fiords. Lateral ridges, separated from the mainland by water channels or sounds, stand forth as islands. A navigable "inner passage," well protected from the rough water of the open ocean, is thus provided for steam vessels. The steep mountain sides, descending rapidly beneath the sea, generally offer no flat ground for settlement; but most of the fiords now contain delta plains where streams enter their heads; here villages find convenient sites.

Since the Highlands of Scotland were uplifted and dissected, a moderate depression has submerged the lower valleys and carried the sea against the mountain flanks, where strong cliffs are already cut on the headlands by the stormy waters of the Atlantic. The fiords occupying the submerged valleys are here known as sea lochs (loch = lake). Although adding greatly to the beauty of the scenery, the change has decreased the habitability of the coast region, for many valley floors that might have been occupied by fields and villages are now drowned. The deltas growing at the head of the sea lochs form convenient plains for cultivation, but they are seldom of great extent.

Example for Review. — The highlands of northern Wisconsin are part of a very ancient mountain region that was worn down to a lowland of moderate relief before

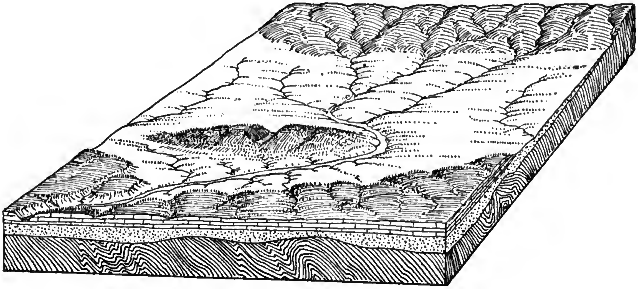

Fig. 123. — Diagram of Baraboo Ridge, Wisconsin.

the rock layers of the ancient coastal plain of southern Wisconsin were formed. Their formation as marine sediments was permitted when the southern part of the old-mountain region was depressed and drowned beneath an ancient sea, the drowned old-mountain lowland serving as the foundation on which the covering strata were laid down. At that time a monadnock that rose above the old-mountain lowland remained for a time as an outlying island; but as the depression of the region continued, it was drowned and finally buried beneath the sea-bottom deposits.

To-day the upper strata of the ancient coastal plain have been greatly worn away in the central and southern part of the state, and the long-buried monadnock is now revealed again as an isolated mountain, known as Baraboo ridge, rising boldly above the floor of the inner lowland.

The lowlands and uplands of the ancient coastal plain are for the most part fertile farming districts; the unburied monadnock stands apart as a forested ridge, quarried for its hard stone. It rises through the weak strata of the inner lowland like a long-preserved monument of the earth's early history.

CHAPTER VIII.

VOLCANOES.

The Violent Processes of Nature.

Most of the processes of nature go on without violence. The usual movements of the winds and currents, the flow and ebb of the tides, the rise and fall of the lands, the weathering and washing of rock waste are all so placid that we gain confidence in the earth as a safe home to live in. But sometimes natural processes of a more violent behavior are witnessed. Hurricanes and tornadoes bring destructive winds and torrential rains, flashes of lightning and peals of thunder. Landslides rush down mountain sides, overwhelming the valleys below. Now and then the rocky crust beneath us quivers and trembles in earthquakes. Great waves occasionally roll in from the sea and sweep over low coastal lands. Here and there volcanoes burst forth with terrible commotion. Nature then seems frightful and destructive. Those who are overtaken by such disasters struggle against them, hopefully awaiting the return of the more peaceful conditions under which their habits of life have been formed, for man could not survive if he were always battling against the wilder forces of nature.

Of all natural catastrophes the explosive eruption of a great volcano is the most terrible. The air resounds with its roaring. The sky is darkened and the sun is hidden by clouds of dust blown from the crater. The sea is burdened with floating ashes. Glowing streams of lava flow down the flanks of the volcano, driving away everything that can take flight before them. Even the earth

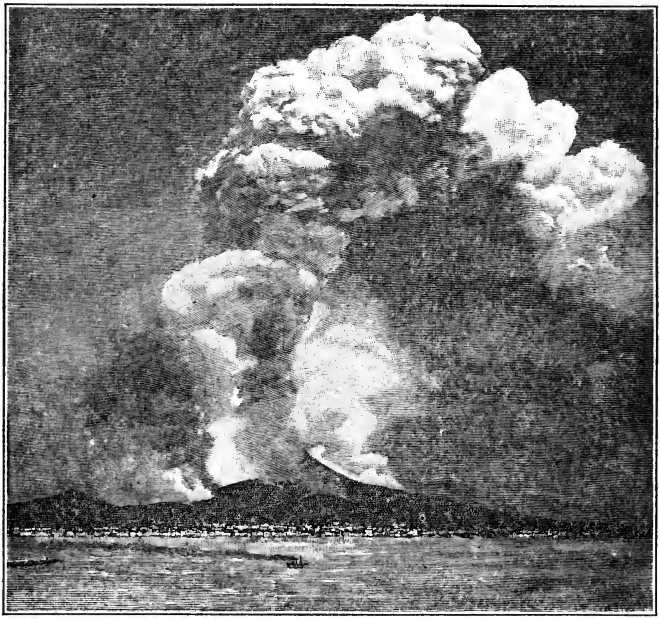

Fig. 124. — Vesuvius in Eruption.

around is made to tremble as the gases and the lavas burst out from their deep sources. No wonder that ignorant races of men have imagined struggling giants to be imprisoned under active volcanoes, nor that even the most learned are baffled when trying to account for these terrific displays of natural forces.

But violent as a volcanic eruption may be, it weakens, and in time ceases. The sky clears, the sun shines again, and nature once more goes on in her quiet tasks. As the years pass by and a soil is formed on the weathered ashes and lavas, plants clothe their surface and man comes to dwell on the flanks of the volcanic mountain. The struggling giant within is forgotten; fields and villages occupy the slopes that once trembled and glowed in eruption.

In the long history of the human race many disasters from volcanoes and earthquakes have been encountered, and the race has gradually gained in courage and intelligence as these and other trials have been survived. Lessons of this kind are hard to learn, but they seem to be among those that the earth has in store for us.

The Growth and Dissection of Volcanoes.

Young Volcanoes. — Volcanoes are formed by the ascent of molten rock, called lava, through fractures or passages leading from unknown depths through the earth's crust to its surface, on the land or on the sea floor. The eruption of the lava is generally accompanied by explosions of steam and other gases.

The cause of volcanic eruptions still needs as much study as that of the various displacements of the earth's crust referred to on earlier pages. It is believed by many that the ascent of molten lava from its deep source is chiefly caused by pressures similar to those which cause movements in the earth's crust. As the lava nears the surface and meets water in greater or less quantities, explosions of steam take a violent part in the eruptions.

The early growth of a volcano has occasionally been observed. The outburst is preceded and accompanied by earthquakes, which indicate the breaking of an upward passage through the underground rocks, before hot lavas make their appearance at the surface. When the eruption is accompanied by gaseous explosions, much of the lava is blown into fragments, of which the smaller are called ashes or cinders. The larger blocks and the coarser ashes accumulate in a conical heap, or volcano, frequently having remarkable regularity of form, a cup-shaped hollow or crater being kept open over the vent by the outbursting gases. The finer ashes or dust may fall far away. When the eruption is less violent, the lava runs forth more quietly in a stream or flow following the slopes of the ground. Explosive and quiet eruptions may alternate in irregular succession.

Monte Nuovo (New mountain) is a small volcano that was formed on the north side of the Gulf of Naples in Italy in 1538. Earthquakes occurred thereabouts for two years before the eruption, when in a week's time a cone was built up 440 feet high, half a mile in diameter at the base, and with a crater over 400 feet deep. Masses of lava "as large as an ox" were shot into the air by the bursting of great bubbles of gas or steam that ascended through the lava in the vent. Finer ashes fell over the country for several miles around. The people of the neighboring villages fled in terror from their homes.

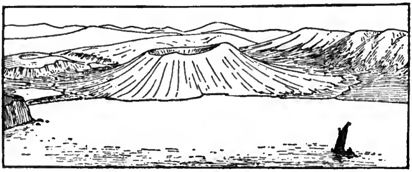

Fig. 125. — Monte Nuovo.

A greater eruption took place in Mexico in 1759, when the volcano Jorullo (pronounced Ho-rūl-yo) was built on the central plateau, burying fertile fields of sugar cane and indigo. The outburst was preceded by earthquakes; the eruption continued half a year, building six cones and pouring out extensive lava flows. The highest cone, Jorullo, rose 700 feet above the plateau. The flows retained a perceptible heat for over 20 years.

Many examples might be given of marine eruptions. In 1867 a shoal was discovered among the Tonga islands of the Pacific (latitude 20° 20′ S., longitude 175° 20′ W.), the surrounding sea floor being about 1000 fathoms deep. In 1877 smoke was seen ascending from the sea surface over the shoal. In October, 1885, an island had been formed two miles long and 200 feet high. At this time a terrific eruption was in progress, enormous clouds of constantly changing form rising over the island. The shocks of the explosions were felt on neighboring islands, and the sound was heard 200 miles away. As the island consisted chiefly of ashes, it has since then been rapidly consumed by the waves and will soon disappear, unless new eruptions occur.

Most volcanoes have not been observed in their early growth, yet even if not now in eruption, so perfectly do they correspond in form and structure with such examples as Monte Nuovo and Jorullo that no doubt can remain as to their origin.

In northern California there is a cinder cone of remarkably perfect form and certainly of recent date, although there is no record of its eruption. The cone, built of loose ashes, is 2000 feet in diameter at its base, and rises 640 feet to a circular rim enclosing a crater 240 feet deep. It is perfectly barren. Although of moderate height, its ascent is difficult, as the ashes slide under a man's weight. A stream of lava emerges near the base of the cone, and, flowing westward into a neighboring valley, forms a lava field a mile wide and nearly three miles long. The surface of the field is so covered with great clinkery blocks of lava as to be almost impassable. It is still unweathered and barren. The edge of the field is a steep clinkery slope 100 feet high. It obstructs a stream from the south, which forms Snag lake, so called from the dead trees still standing in it. The lake outlet runs north along the west edge of the lava. On all sides the surface of the country is covered with a layer of volcanic ashes and

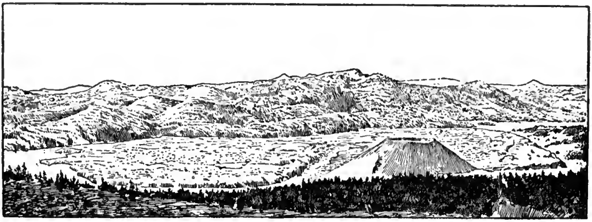

Fig. 126. — Cinder Cone and Lava Flow, California.

dust, six or more feet deep near the cone, thinner and finer further away, yet recognizable at a distance of eight miles. From the size of trees growing on the ashes, it is estimated that the cinder cone was built about 200 years ago. The lava flow is younger, but none of the Indians or early settlers thereabouts (1845) observed its eruption.

Volcanoes are unlike the structures thus far described, in being composed of materials that have been forced up, melted, through vents (pipes or fissures) in the rocky crust of the earth and built upon a land surface or a sea floor. They are peculiar in their relatively rapid formation, so that much attention is attracted to their manner of growth. Mountains of tilted or folded structure that still possess their original form, little changed by denudation, are great rarities. But many volcanoes have been built so rapidly and so lately that their surface is very little affected by weathering.

Great Volcanoes. — Many large volcanoes, whose first eruption must have occurred many thousands of years ago, are still active. After periods of more or less complete rest, they burst forth again, blowing out showers of ashes, building their cones to a height of 10,000 feet or more, and adding new lava streams to their flanks, so as to gain a diameter of 10 or 20 miles or more at the base. The melted lava often breaks forth from the mountain side and flows down to gentler slopes on the flanks and out upon the surrounding country; thus the cone as a whole comes to have concave slopes and a rudely bedded structure of ashy and dense lavas. All the greater volcanoes of the world are the product of many eruptions. It is probable that the periods of rest have been much longer than the spasms of activity.

A rough classification of volcanoes groups them as active, when they are frequently in eruption; dormant (sleeping), when now at rest, though giving signs in hot springs and sulphurous vapors that activity may be resumed; and extinct, when they give no indication of recent or future activity. It is not possible to make certain distinction between the last two classes; great eruptions have taken place in volcanoes after all signs of activity had ceased.

The steam issuing from a volcano is condensed in heavy clouds. At night the glowing lava, white-hot in the crater, yellow or red on the flanks of the cone, illuminates the clouds, often giving the appearance of flames. Showers of ashes as they chance to fall may bury villages, fields, and forests. The commotion in the atmosphere during a violent eruption often causes rainfall. The floods thus supplied may be increased by the water from melted snow on the upper slopes of the cone, and occasionally by hot

Fig. 127.—Excavations in Herculaneum.

water thrown out from the crater itself. The floods gather the fresh-fallen dust and ashes, producing muddy torrents that overwhelm the lower lands.

At the eruption of Conseguina, Central America, in 1835, ashes destroyed trees and dwellings 25 miles south of the volcano; thousands of cattle and innumerable wild animals and birds were killed. Lava blocks in fragments 5 or more feet in diameter are strewn for 10 or 15 miles around the great cone of Cotopaxi, Ecuador.

A tremendous eruption of Galung-gung, a forested volcano in a populous part of Java, took place in 1822 ; torrents of hot water, mud, and ashes rushed down the valleys, flooding the rivers and drowning a great number of men and animals ; for 24 miles not a trace of numerous villages and plantations was left.

The first recorded eruption of Vesuvius, A.D. 79, darkened the sky with its ashes. The ancient city of Pompeii was buried in ashes and about 2000 persons (estimated at one-fifteenth of the population) were killed. Herculaneum, near by, was overwhelmed with torrents of ashy mud. After being long forgotten and overgrown by modern villages, parts of these cities have been laid bare by excavations in this century, affording many illustrations of ancient architecture and of ancient modes of living.

Earthquakes in Volcanic Districts. — The shocks of a violent eruption may shatter the volcano, breaking its sides and causing great landslips. The earthquakes thus caused are felt for many miles around the volcano. The exploding gases produce thundering sounds, sometimes audible for hundreds of miles.

Besides the earthquakes directly produced by the explosive eruptions of volcanoes, it is probable that many other earthquakes in volcanic districts are the result of disturbances within the crust of the earth not directly connected with volcanic action. The numerous earthquakes of Japan and Italy sometimes accompany eruptions, but are more frequently independent of all visible eruptive action.

Great destruction is caused by earthquakes in regions that are frequently shaken. In southern Italy 20,000 lives were lost in the earthquake of 1688 ; 49 cities and villages were destroyed, and 93,000 persons were killed in the earthquake of 1693; 32,000 persons were killed in a district having a population of 166,000 by the earthquake of 1783.

Distribution of Volcanoes. — Volcanoes generally occur near the sea coast or on the sea floor, but a considerable number of cones and flows are known far in continental interiors. Volcanoes are more numerous on the borders of the Pacific ocean and of the mediterranean seas than on the coasts of the Atlantic, but many volcanic islands are known in the Atlantic as well as in the Pacific and Indian oceans.

It is estimated that over 300 volcanoes are now active, about 100 of these standing on the continents. Nearly all the high oceanic islands, far from the continents, are of volcanic origin. Soundings have discovered a number of conical mountains rising from the sea floor, but not reaching the surface; their form leaves little doubt that they are volcanoes. Dacia bank, east of Madeira, rises with steep slope from the Atlantic floor, over 1000 fathoms deep, to within 50 fathoms of the surface.

Extinct volcanoes sometimes occur far inland. Cinder cones and barren lavas are known on the plateaus of Arizona, 300 miles from the ocean; in Colorado, 800 or more miles inland; in Tibet, 500 or more miles inland. Several active volcanoes in Mexico, Central America, and elsewhere are so far from the coast that direct connection with sea water should not be regarded (as it has been) necessary to eruptions.

Like other lofty mountains, volcanoes rise high enough to possess different climates at successive heights. Mt. San Francisco, a volcano built on the plateau (5000 to 6000 feet elevation) south of the Colorado canyon, rises 6000 feet above the desert uplands and bears dense forests on its slopes. Its summit ascends above the tree line, bearing patches of snow most of the summer. Among the Alpine plants there collected, nine are of the same species as those living near sea level in Greenland. Lofty volcanoes near the equator in South America and Africa bear snow on their summits.

Islands formed by the growth of volcanoes in mid-ocean are often bordered by wave-cut cliffs, so that it is almost impossible to find a landing place on their shores. Being nearly inaccessible, as well as distant from the continents, they are all the more lonesome. St. Helena, a volcanic island in the south torrid Atlantic, was for this reason a well-chosen place for the imprisonment of the emperor Napoleon.

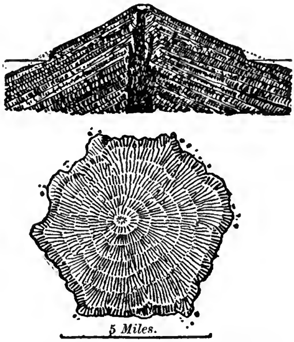

Fig. 128. — A Volcanic Island (section and plan).

A remarkable instance of the effect of isolation on the occupants of a remote volcanic island is seen in the language of the people of Iceland. Icelandic, Norwegian, Swedish, and Danish were all one language a thousand years ago; but while the isolated Icelandic has preserved its ancient form with slight change, the languages of the continental countries have been much modified; that of Denmark especially having been affected by the neighborhood of Germany.

Lava Flows. — Great flows of lava sometimes run beyond the base of the volcano in which they break forth. Their surface is comparatively smooth, if it remains unbroken after first cooling, but extremely ragged and clinkery, if the first crust is repeatedly broken by continued movement. The edge of a clinkery flow may form a bluff 100 feet or more in height. On the Uinkaret plateau of the Colorado canyon district stands a throng of volcanic cones, from which broad streams of lava descend the bordering cliffs in black cascades and form barren lava floods on the lower Sheavwits plateau on the west. The eruptions are therefore younger than the breaking of the plateaus.

In 1783 a great flood of lava rose from a deep fissure in Iceland, the lava issuing tranquilly for the most part, flow-

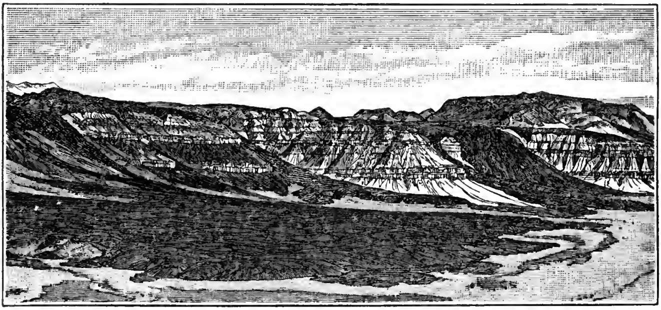

Fig. 129. — Lava Flows on the Plateaus of Arizona.

ing away in vast sheets on each side, and advancing in streams far along the lower valleys. Hundreds of small cones were built over the fissure, which was 20 miles long. In the course of ages successive lava floods of this kind have built up the plateau of Iceland of generally level aspect, the loose slaggy cones of earlier eruptions being gradually buried under later sheets.

Two lava streams of the eruption of 1783 in Iceland flowed down valleys 45 and 50 miles from their source, gaining a depth of several hundred feet where the valleys were narrow, and spreading out in lake-like plains where the valleys were open. The water of side streams was dammed and rose in lakes. Twenty villages were destroyed by the floods of lava or water; 9000 persons (about one-seventh of the island's population) and a great number of cattle perished, not only at the time of the eruption, but afterwards during a famine caused by the burial of the pastures and by the desertion of the coast by fish.

The form assumed by successive lava flows in building a plateau is sometimes imitated on a cold winter night when trickling streams of water, supplied by daytime thawing, are frozen as they advance. If the water is artificially colored successive flows are made plainly visible.

Lava floods, thousands of square miles in area, have been poured forth in Idaho, Oregon, and Washington, where they form an extensive plateau in a broad depression among the surrounding mountains. As these floods cannot be traced to any source in volcanic cones, they are thought to have come from fissures now concealed and long unused.

Between the Columbia and Snake rivers, in eastern Washington, the plain surface of the lava flood meets the enclosing mountains just as the sea meets a half-drowned mountain range. The lava forms level bays between the ridges; the ridges stand forth like promontories; outstanding peaks rise like islands over the plain. A rugged mountainous basin has thus been converted into a plateau. Part of the lava plain has been uplifted in dome-like form to a greater height than the rest, and is now deeply dissected by valleys. This part is called the Blue mountains (*B*, Fig. 130).

Fig. 130.—The Lava Plateau of Idaho, Oregon, and Washington.

Calderas. — In some volcanic regions the high central part of a cone is replaced by a broad and deep basin, or *caldera*, from 1 to 5 or more miles in diameter, only the lower rim of the cone remaining. The inner walls of the rim exhibit the broken edges of lava beds, which slope outwards from the lost cone on whose flanks they were formed.

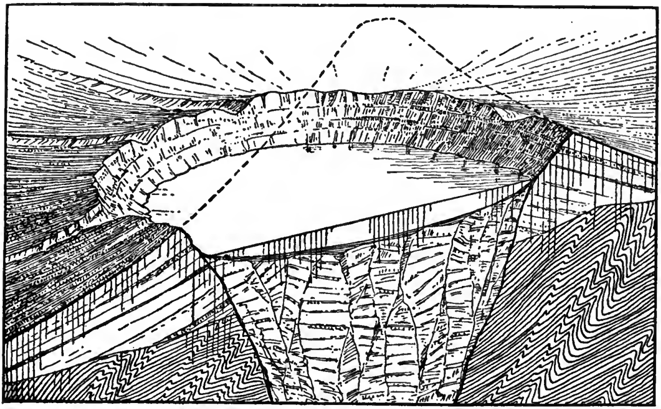

Fig. 131. — Diagram of a Caldera.

When extensive deposits of lava blocks and ashes lie on the surrounding country, it is thought that the cone was destroyed and the caldera was formed chiefly by violent explosive eruptions. When such deposits are absent, it is thought that the caldera was formed by the caving in of the central area, on account of the withdrawal of a large body of lava from beneath.

The Azores, a group of volcanic islands in the North Atlantic, contain a number of large calderas, whose floors are partly occupied by villages and fertile fields and partly by lakes. Other calderas are known in Italy, the Hawaiian islands, and elsewhere.

Deception island, in the South Shetland group, beyond Cape Horn, is the high rim of a caldera, breached on one side by a narrow gap, which gives entrance to a quiet circular bay. Layers of ice are to be seen between beds of ashes and lava on the caldera walls.

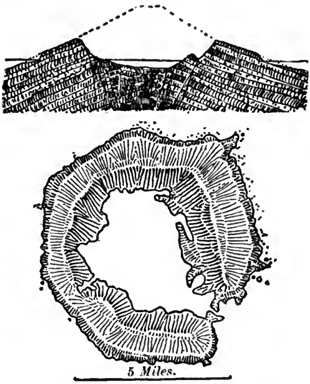

Fig. 132. — Deception Island, a Volcanic Caldera (plan and section).

The cone of Vesuvius has been built in a large caldera of more ancient origin. The cone buries one side of the caldera rim, the other side being known as Monte Somma.

Dissected Volcanoes.—Active streams running down the slope of volcanic cones carve ravines on their flanks. Many ravines are formed during the periods of rest in the growth of the great volcanoes, only to be filled again by later eruptions of lavas and ashes. After eruptions cease, the ravines deepen more and more, leaving sharp ridges between them, and at last dissecting the cone so deeply as to leave little appearance of its original shape. Hence, as in other geographical forms, it is important to describe volcanoes with due regard to their stage of growth or of decay.

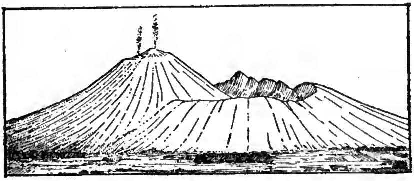

Fig. 133. — The Cone of Vesuvius in the Caldera of Monte Somma.

Mt. Shasta, in northern California, is furrowed on all sides by gigantic ravines, but its conical form is still well preserved (Figs. 134, 135). Many meadows about its base mark the site of lakes formed by lava-flow barriers, and now filled and drained. The best agricultural land of the region is of this origin.

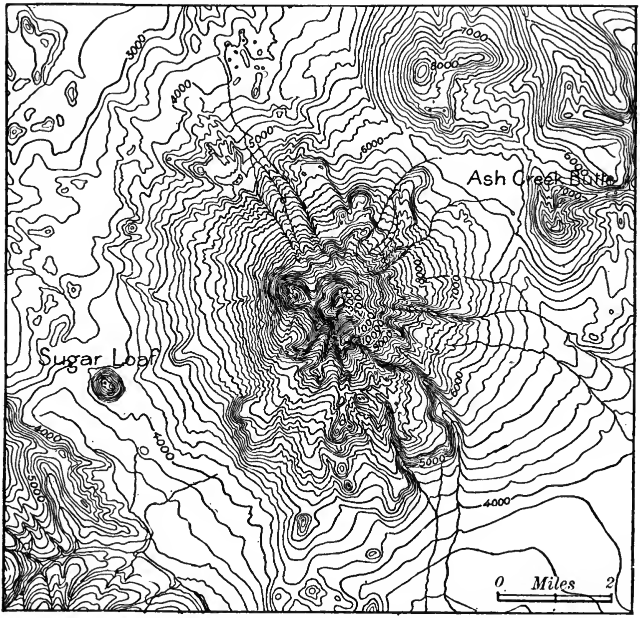

Fig. 134. — Contour Map of Mount Shasta, California.

Mt. Hood, Oregon, is so deeply dissected by radiating valleys between sharp radial spurs that its form has become very irregular. A number of extinct and more or less dilapidated volcanic cones surmount the plateaus of Arizona and New Mexico, Mts. San Francisco and Taylor being among the best examples. The Cantal, an ancient volcanic cone about 40 miles in diameter on the central plateau of France,

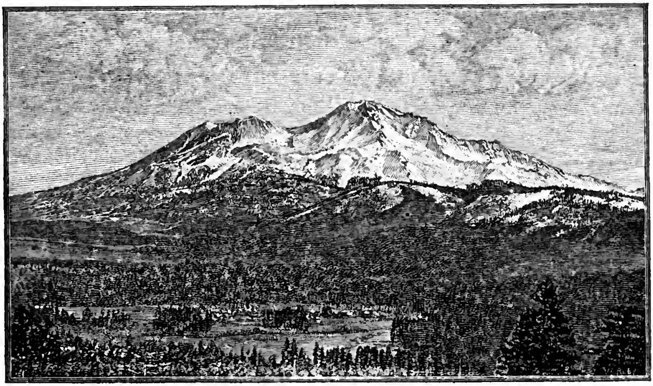

Fig. 135. — Mount Shasta.

is cut to pieces by radiating valleys. Its present height is but a small part of the original height, judging by the attitude of the slanting lava beds in the radial ridges. A railroad and a highway, entering by a valley from the southwest, run almost through the center of the dissected cone on a low pass, and depart by a valley to the northeast.

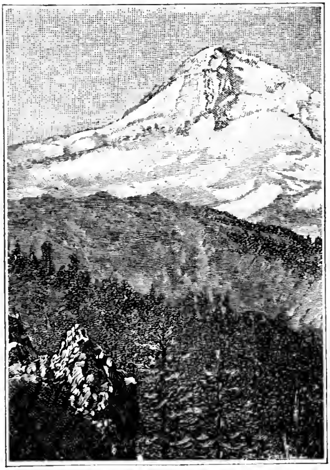

Fig. 136. — Mount Hood.

One of the most superb calderas in the world is that which contains "Crater lake" in southern Oregon.

Its sides were deeply scored by radial ravines before the summit of the cone was destroyed in the production of the caldera (probably by falling in), for the ravines as well as the lava beds are distinctly cut off by the high cliffs of the caldera wall. A little cone, built by a small eruption after the caldera was made, forms Wizard island in the lake.

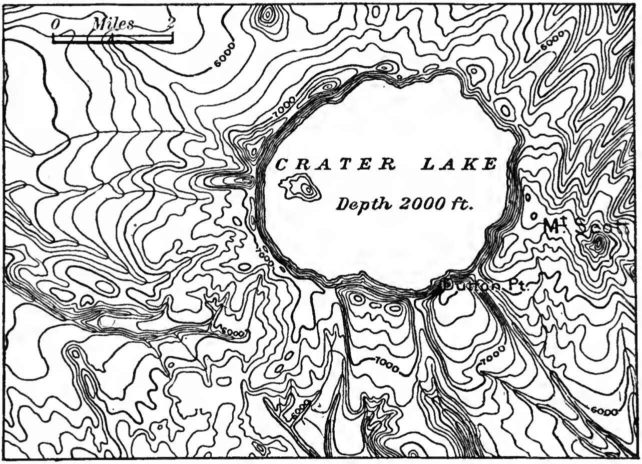

Fig. 137.—Contour Map of Crater Lake, Oregon.

Volcanic Necks and Dikes.—Even when the volcanic cone is entirely worn away, the *neck* or column of lava that rose through a tube-like passage from deep within the earth may still be seen. The lava neck is often harder than the enclosing rock, and it then retains a considerable height above the surrounding worn-down surface, standing up as a butte. In the same way, the lava that rose in a fissure may in time come to stand up above the adjacent surface like a natural wall, structures of this kind being called *dikes*.

The broad valley plain of the St. Lawrence in southern Quebec is surmounted by a number of strong volcanic buttes rising several hundred feet over the lowland, and visible for many miles across its flat surface. One of them gives its name to the city of Montreal (Mount Royal). All of them testify to the great denudation of the surrounding region, for although the lavas rise high above the plain, they give no evidence of surface overflows, such as must have occurred if the region had had its present form at the time of eruption.

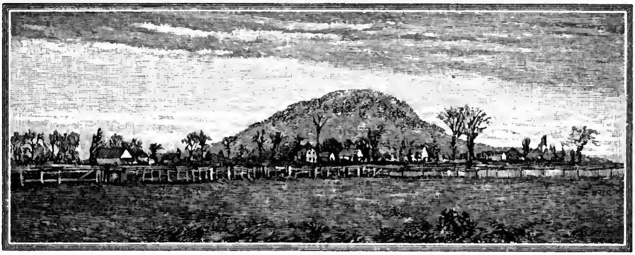

Fig. 138. — Mount Johnson, near Montreal, Canada.

Dissected Lava Plateaus. — The great lava plateau of Idaho, Oregon, and Washington is trenched by many rivers whose courses are extended across the upland from their source in the adjoining mountains. The canyon of Snake river, along the boundary between Idaho and Washington, 4000 feet deep and 15 miles broad, rivals the Colorado canyon, except in varied coloring. Buried mountain peaks are revealed in the canyon walls; one of them rises 2500 feet above the river and is covered by 1500 feet of bedded lava.

Between some of the lava beds are layers of sand and gravel or of volcanic dust and ashes. Petrified tree stumps and trunks occur in some of these layers, showing that there was time enough in the intervals between successive lava floods for the formation of soil and the growth of forests. The young mountains of southern Oregon are broken and tilted blocks of this great lava plain.

An extensive lava plateau occupies southwest India; its western margin is deeply dissected by streams fed by the heavy rains of the summer monsoon. Here, as in Oregon, the horizontal layers of dense lava form cliffs, while the

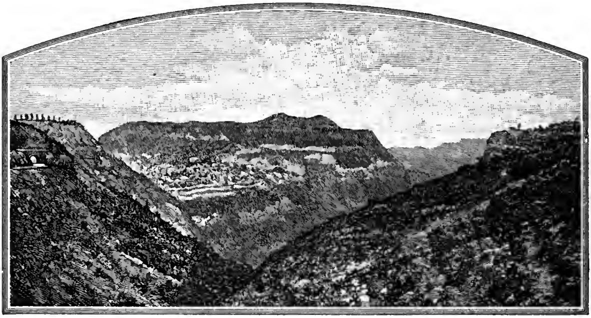

Fig. 139. — Dissected Lava Plateau of Southern India.

more ashy layers are weathered back into slopes and platforms, thus imitating the forms of the dissected plateaus of Arizona.

The Faroe (Danish, meaning sheep islands) are the half-drowned remnants of a deeply dissected lava plateau (originally resembling the lava plateau of Iceland), whose nearly level lava beds form the tables of the several islands. The exposed outer coasts are cut back into great cliffs from 1500 to 2000 feet high. The harborless outer islands are reached with difficulty, their small population being often storm-bound for weeks together. The eggs of sea birds nesting on the cliffs constitute an important article of food supply, and the bird rocks are valuable property for the villages to which they belong. The hardy custom of descending to the nests by a rope let down from the cliff top is here practised.

The Giant's Causeway in northern Ireland is on the margin of a dissected lava plateau, whose cliffs descend boldly to the sea. The name is given because the lava beds are cracked or "jointed" so that their surface imitates an artificial pavement or "causeway."

As lava plateaus are more dissected, their isolated remnants take the form of buttes, and closely imitate the buttes formed

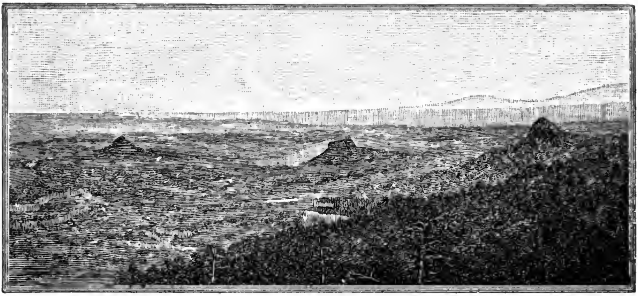

Fig. 140. — Volcanic Buttes, Arizona.

on volcanic necks. The buttes on the plateaus of New Mexico and Arizona belong to one or the other of these classes.

Lava Table-Mountains. — Lava flows occupying valleys near the base of volcanoes frequently weather and waste more slowly than the adjoining rocks. Hence as the region is worn down it may happen that the flows come to a stand above the adjacent country in the form of table-mountains, or *mesas*, flat topped and rimmed around with a cliff and talus slope. The volcano from which the flow issued may have been completely worn away, the table-mountain standing quite apart from the neck or dike that marks its source, as in Fig. 141.

Many lava flows of the extinct volcanic district in central France are thus converted into flat-topped ridges and isolated mesas. On one of the mesas the ancient Gauls built

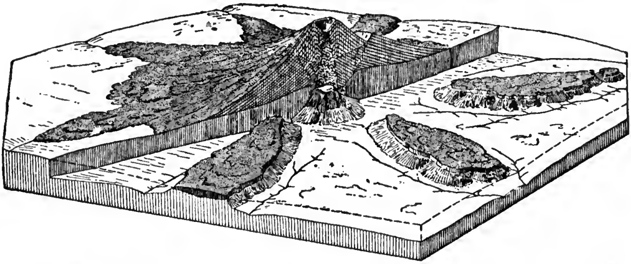

Fig. 141. — Diagram of a Young Volcano in the Background, changed by Erosion to Lava-Capped Mesas in the Foreground.

the town of Gergovia, where they long resisted the attack of the Romans under Cæsar, the cliff rim of the mesa serving as a natural fortification.

A number of table-mountains capped with long lava flows occur on the western slope of the Sierra Nevada of California. The gravels that lie in the ancient valley troughs beneath the lava flows have been mined for the grains of gold that they contain. Sometimes the gravel beds are exposed on the sides of valleys that have been cut down through the lava flows. Even where the gravels are entirely concealed they have been found by driving tunnels in from the side of table-mountains, just below the lavas.

Example for Review. — The gently rolling plains of eastern Montana are trenched by the narrow and steep-sided valleys of the Missouri river and its branches. The upland surface is so even over large areas and so little broken by valleys, except near the larger rivers, that it might at first sight be taken for a young plain raised from the sea in a recent stage of the earth's history. But here and there buttes, dikes, and mesas of lava surmount the plain, telling clearly that the surface of the region was once much higher than now, for the dikes and buttes mark fissures and tube-like passages that were once enclosed by extensive rock layers, now removed, and the mesas are the remnants of lava flows that ran down from some

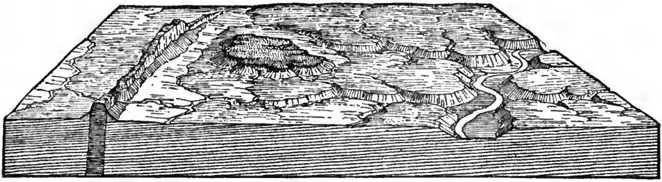

Fig. 142. — Diagram of Dike and Mesa.

volcanic source to the lowest ground they could reach. Hence the gently rolling plain must be an old, worn-down surface, and when worn down it must have stood at a moderate altitude above the sea. The narrow valleys now cut beneath the denuded surface show that the whole region has been broadly uplifted after it was worn down.

The thin grass of the treeless plains gives pasture to herds of cattle that range from stream to stream. The dikes and mesas are rocky and barren. The valley floors contain fertile fields of small breadth, and here the houses and villages of the region are generally located.

CHAPTER IX.

RIVERS AND VALLEYS.

The Lifelike Behavior of Rivers.

It is natural that to one who is ignorant of the carving of land forms from their youth through maturity to old age the surface of the earth should seem lifeless, for it is carved so slowly that even an old man can see no change in the form of the hills and the valleys around the home of his boyhood. But every one may recognize the lifelike behavior of rivers. In possessing active movement they imitate one of the most interesting characteristics of animal life, and thus they seem to have a life of their own. Ascend a river and trace its branches to their many sources, even to the smallest brooks and rills; they are all found to be busy bearing tribute to the main stream. Follow the river down its valley, and its growing volume, flowing steadily onward, leads as if with conscious purpose to the sea. The change of behavior from the active upper waters to the sedate lower current suggests that we might describe our own growth from youth to old age in terms that apply to the "river of life." Indeed the part that rivers take in the work of the world is so full of activity that they enter the figures of poetic literature even more than great mountains or vast oceans.

The more rivers are studied, the more wonderful their place in the system of nature is found to be. They wash along in every part of their course some share of the waste of the land on the way to the sea. They work untiringly. Mountains may tower aloft where the crust of the earth has been upheaved by irresistible forces from within; but the weather attacks them, the clouds gather around their summits, rain and snow fall upon them, and the streams and rivers bear off their waste until they are worn away.

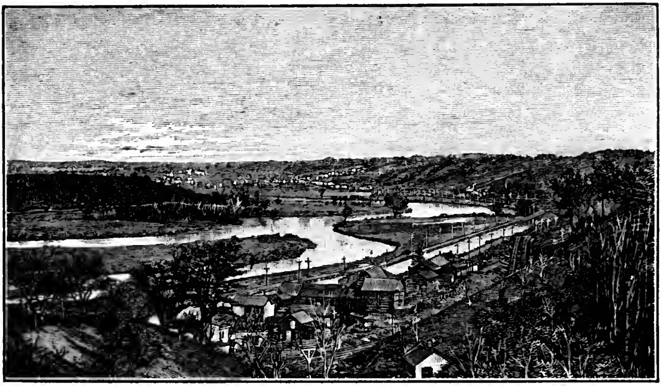

Fig. 143. — The Mohawk Valley.

Only when all the hills are worn down can the rivers rest from their labors; and even then, if the lands are again uplifted, the rivers will at once dutifully resume their tasks.

The broad valleys that well-established rivers carve for themselves in the lands are among the most attractive sites for human settlements. They are somewhat protected from inclement weather as compared to the adjoining uplands. They are floored with an abundant soil of fine texture. Their different parts are in easy communication with each other. Many roads and railways take advantage of the low grades afforded by valleys that have been worn through mountain ridges. Indeed so well are man's needs supplied in fertile valleys, one might almost fancy that the valleys had been carved by their rivers for man's benefit. The truth is, however, that man often makes his home in valleys simply because he there finds more favorable surroundings than on the neighboring uplands.

The Movement of Water Underground.

Ground Water. — The water supplied by rain and snow is disposed of in part by evaporating from the surface, in part by running down the slopes of the land to the streams, and in part by sinking beneath the surface; the last part is called ground water.

The proportions of these several parts vary under different conditions. The greater part of a light and long-continued rain may pass into ground water, especially if falling on a plain. A very heavy rain, or "cloud-burst," falling on strong slopes, is nearly all disposed of by direct run-off, causing sudden floods.

When the ground is frozen, little water can enter it; hence rivers rise in floods when deep snow is rapidly melted by a heavy rain. In arid regions a great part of the rainfall may dry off from the ground.

When a region has been thoroughly dissected, steep slopes lead down to the streams. Then a large part of the rainfall is discharged by direct run-off, and the streams rapidly change in volume with every change from dry to wet weather.

Ground water is essential to the growth of plants, whose roots must reach moist earth. Where grass and trees cover the surface, much ground water taken in by their roots is discharged into the air by evaporation from their leaves.

Loosely consolidated strata and deep rock waste take in much ground water. Firm rocks, such as granites, allow but little water to enter beneath the weathered waste on their surface. A region underlaid by heavy strata of limestone (a comparatively soluble rock) may have many underground passages dissolved along the rock crevices ; thus, nearly all the water may be withdrawn from the surface.

Caverns. — Caverns in limestone districts are the result of the solvent action of underground waters. The Mammoth cave of Kentucky and the Luray cavern of Virginia are famous examples of this class. Streams gathering on the surface descend to underground passages by *sink holes* or *swallow holes*. After flowing underground for some distance, they may issue in an enlarged and turbid current from the mouth of a cavern.

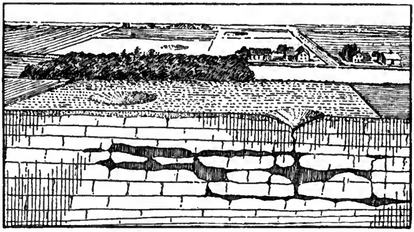

Fig. 144. — Diagram of Cavern and Sink Hole.

Several species of animals dwelling in the complete darkness of caverns are blind, but their senses of hearing and touch are highly developed.

Where sink holes and cavern drainage prevail, so much water enters the ground that surface streams are comparatively rare. When the sink holes or the underground passages become obstructed, ponds and lakes are formed in the surface basins.

The limestone uplands of Kentucky and Tennessee exhibit many of these features. The scarcity of surface water is often an inconvenience. Florida has numerous sink-hole ponds and lakes. The limestone uplands of Normandy in northwestern France have many valleys ending in sink holes.

Fig. 145.—Natural Bridge, Syria.

As denudation progresses, the roof of a cavern may fall in more or less completely. The beautiful Natural Bridge of Virginia is the remnant of a cavern roof. Fig. 145 gives a view of a natural bridge in Syria.

Springs.—Very little ground water remains permanently beneath the land surface. Sooner or later, after descending to less or greater depths, it comes to the surface at a lower level than where it entered, emerging in the form of springs and joining the run-off of streams.

The movement of ground water is comparatively slow while percolating among the particles of rock waste or through the crevices of rocks. Where a large part of the rainfall enters the ground, the volume of the streams fed by springs is less variable than where the rainfall is mostly discharged by direct run-off during and shortly after a storm.

Ground water slowly moves from hills and slopes, descending to lower levels and accumulating beneath the lower ground. It may, therefore, be generally found near the surface in valleys, where the soil is usually damp. At the base of a slope, the ground water may issue in a spring, supplying a small brook. Innumerable small springs occur unnoticed in the banks of streams, increasing the volume of these streams.

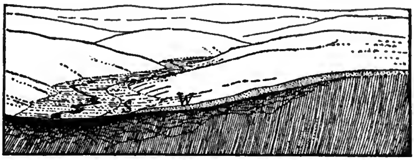

Fig. 146.—Diagram showing Distribution of Ground Water (black).

In regions of sufficient rainfall and moderate relief, the ground water may be reached at almost any point except hill-tops by sinking wells to a depth of from 10 to 40 feet. The bottom of the well should be a few feet deeper than the level at which the trickling stream of ground water enters it from the crevice, so as to accumulate water in sufficient volume to supply ordinary domestic uses.

Ground water and spring water carry very little rock waste (unless in solution), and are generally clear and pure. For this reason wells and springs generally afford a better water supply than the surface streams that receive the wash of fields and meadows.

In coastal regions ground water may flow forth as springs directly into the sea, either on a sloping beach near low-tide level, or at the bottom off shore; there they sometimes have a current so abundant as to supply a column of fresh water that ascends through the heavier salt water to the surface.

When a sloping coastal plain ends in a low bluff descending to a beach, fresh water may generally be found by digging a few feet beneath the base of the bluff. It is supplied by the slow-creeping sheet of ground water on its way to the sea.

It is possible that feeble off-shore springs may rise into sea water of a temperature less than 32°. The spring water may then be frozen at the sea bottom. "Ground ice," sometimes noticed by fishermen to rise from the shallow sea bottom in winter, may be thus explained.

Artesian wells, or deep borings to water-bearing strata several hundred feet beneath the surface, are important sources of water supply in many regions. They have been described under coastal plains. It is essential that the water-bearing strata should reach the surface and receive their rainfall at a higher level than that of the top of the well by which they are tapped. (See Fig. 78.)

Charleston, Galveston, and many other coastal cities receive much water supply from artesian wells. In eastern Maryland deep wells pierce strata that reach the surface and receive rainfall west of Chesapeake bay; the strata lead the water beneath the nearly water-tight layers that floor the bay, and it is still fresh when rising in the wells. Southern Wisconsin and eastern Iowa have many artesian wells, supplied by water-bearing strata that slope gently away from the older land of northern Wisconsin.

Hot and Mineral Springs. — Ground water sometimes descends deep beneath the surface, with a slow supply from a large area, and then returns rather rapidly to the surface along a rock fracture. The water may then reach the surface in warm or hot springs, and bear an unusual amount of dissolved mineral substances. Such springs are frequently of medicinal value.

Springs of this kind are associated with disturbed rock structures, as explained in connection with the tilted block ridges of Oregon. Saratoga Springs, N. Y., White Sulphur Springs, Va., Vichy in central France, and Karlsbad in Bohemia are examples of settlements determined chiefly or wholly by the value of their waters. These and many other mineral springs occur on or near lines of fracture in the earth's crust.

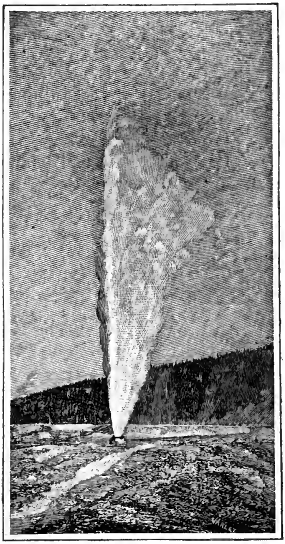

Fig. 147. — A Geyser.

Geysers. — In certain volcanic regions the temperature of the ground water may rise to or above the boiling point. Steam then issues with the water, often in a more or less explosive manner, and such steaming and spouting springs are called geysers. The geysers of Iceland have long been famous; those of the Yellowstone Park are now the most celebrated of the world.

The intermittent action of many geysers suggests that a certain period of time (an hour or more) is necessary to warm the new supply of water that enters the crevice of discharge after a previous supply has been blown out by steam. In the deeper part of the crevice the temperature of the boiling point is higher than at the surface, on account of the pressure of the water column. When the lower water reaches its boiling point, a great part of it is quickly converted into steam, which blows the rest of the water out of the vent.

Rivers and Valleys.

River Systems and their Parts. — A river is a stream of water bearing the waste of the land from higher to lower ground, and as a rule to the sea. A trunk stream and all the branches that join it constitute a river system.

Stream is a general term, with little relation to size. Rill, rivulet, brook, and creek apply to streams of small or moderate size. River is generally applied to a trunk stream or to the larger branches of a river system.

The land from which a river gathers its water and rock waste is called its *basin*. The crest line between the slopes leading to different streams or rivers is called a *divide*.

On smooth plains and uplands there may be no noticeable crest line separating the side streams of neighboring rivers. Such surfaces may be described as *undivided* as to drainage. Undivided areas are often found on young plains and plateaus. When a plain or plateau is well dissected, numerous *subdivides* are developed, as on the Allegheny plateau. The rivers of vigorous mountains are sharply divided by the crest lines of the lofty ridges between the deeply eroded valleys. A worn-down region may have indistinct divides, as on the Piedmont district of Virginia or on the uplifted but not yet well-dissected plains of eastern Montana.

Young Rivers. — The examples of land forms described in earlier chapters have shown that when a region is first raised from the sea, or when a former land surface is uplifted, tilted, or folded, the streams as a rule follow the lead of the land slopes, uniting here and there to form rivers of larger and larger size.

Young rivers thus established proceed to cut down their channels where the slope is steep enough to give them an

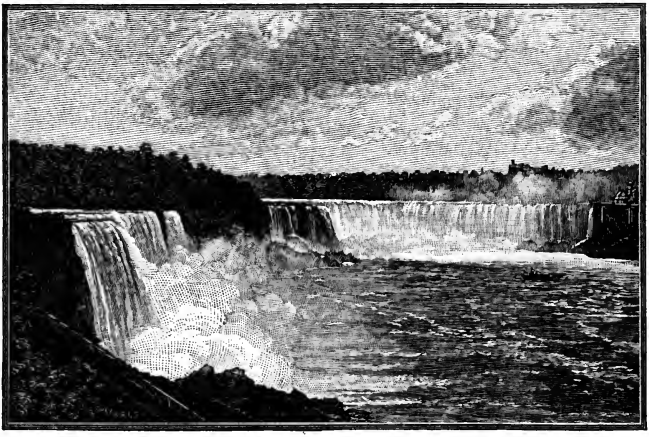

Fig. 148. — Niagara Falls.

active current, by which the waste that they gather can be washed along; but where the slope is faint, or where they enter a basin holding a lake, the streams lay down their load of waste and build up the surface.

The coastal pampas of Buenos Ayres, Argentina, are nearly level, but contain slight depressions that hold water in the wet season, forming shallow lakes of small area. These basins appear to be faint hollows in the original surface of the plain, not yet filled or drained. Their destruction is slow, for the rainfall is moderate, the plains are low and flat, and stream action is weak.

The St. Lawrence system, with its many lakes, falls, and rapids, is a remarkable example of very immature drainage. The outlet of Lake Superior is by the Sault Sainte Marie (*Soo St. Mary*). The outlet of Lake Erie is Niagara, with its renowned cataract and rapids. The outlet of Ontario is the St. Lawrence, with numerous rapids. The lakes favor navigation, but the rapids and falls obstruct it. Canals and locks have now been constructed, by which the rapids and falls are passed.

The drainage of the highland of Canada between St. Lawrence river and Hudson bay bears every mark of youth. Lakes are very numerous and of irregular form. They often have several outlets, no one stream having cut down enough faster than the others to secure all the discharge. The streams are frequently interrupted by rapids or falls on rock ledges, in which channels are as yet cut only to moderate depth. The rivers frequently split into two or more channels, which reunite after wandering in independent courses for 10 or 20 miles across country.

This highland is a rugged, forested, and thinly populated wilderness without roads. All travel is by canoes along the water courses, and the canoes have to be carried past every rapid and fall. The birch tree, from whose bark portable canoes are made, is here as appropriate to the needs of the inhabitants as the camel is to the dwellers in arid deserts.

The region of the great African lakes bears many marks of youthful drainage. The lake basins here indicate a breaking or warping of the earth's crust, like that in Arizona and southern Oregon. The adjacent plateaus are bordered by ragged fault cliffs. The Nile, flowing north from Lake Victoria Nyanza, and the Shire, flowing south from Lake Nyassa, are strong rivers of powerful current, descending over falls and rapids, and are very busy in the work of deepening their valleys and draining the lakes.

By long-continued action the path of a river will in time be everywhere worn down or built up to such a slope that the current will be just strong enough to carry the load of waste that it receives. Such a river might be described as passing from youth to maturity.

Lakes may be generally taken to indicate a youthful drainage system, as in the examples just given. In time they will be destroyed, partly by filling with the waste that is brought by the inflowing streams; partly by the deepening of the outlet valley. Lakes should therefore be regarded as only temporary features in the long life of the river system to which they belong. The rivers may remain long after the lakes disappear.

The distribution of lakes has already been considered in connection with various land forms. The plains of western Siberia and of Buenos Ayres possess lakes because they are young lands. The depressions between the tilted lava blocks of southern Oregon hold lakes because enough time has not yet passed to enable the streams to fill and drain their basins. Lava flows obstruct streams and for a time hold back lakes. Lakes of other kinds will be described later.

As water stands nearly still in lakes, the arrangement of its layers depends on their temperature. Fresh water is densest at 39°. If warmed or cooled from this temperature, it expands and becomes less dense. In freezing it expands still more, and the ice floats.

In warm climates the lowest temperature of a lake surface in the cool season determines the temperature that prevails in the deep water through the year. In cool or cold climates the deep water of large lakes is seldom colder than 39°. The surface layers may be colder than 39° in winter and warmer in summer.

The surface water of a lake will not freeze over unless the whole water body can be reduced at least to 39°. For this reason small lakes may freeze, while large lakes near by remain open through the winter.

Lakes act as filters to the streams that enter them, decreasing their velocity and causing the stream-borne rock waste to settle; thus deltas are formed at the inlets, and the lake bottom is strewn with fine waste or silt.

Lake Geneva receives the turbid Rhone at its east end, where a large delta, 20 miles long, has grown a mile forward since Roman times. The lake bottom is a plain of fine silt. The Rhone at the outlet is wonderfully clear.

Lakes act as regulators of the discharge of their outflowing rivers; for the level of the lake changes little, whether the inflowing streams are flooded or low; and hence the outlet river has a relatively constant volume.

The Ohio without lakes and the St. Lawrence with five great lakes are strongly contrasted in this respect. The latter has no great floods. The floods of the former may rise 50 or 60 feet, spreading to 10 or 20 times the usual width of the river.

Falls and Rapids. — It may sometimes happen that a breaking or bending of the land surface makes a slope steep enough to produce rapids or falls in the streams that run from the higher to the lower area.

It is probable that falls were formed in the Colorado river at the points where it was crossed by the faults that separated the uplifted plateau blocks. These falls must have been rapidly worn away after each of the many slight movements by which the blocks were probably displaced.

When a river is by any process turned across a new path, it falls down any descending slopes that occur on its course. Thus Niagara, when first taking its present

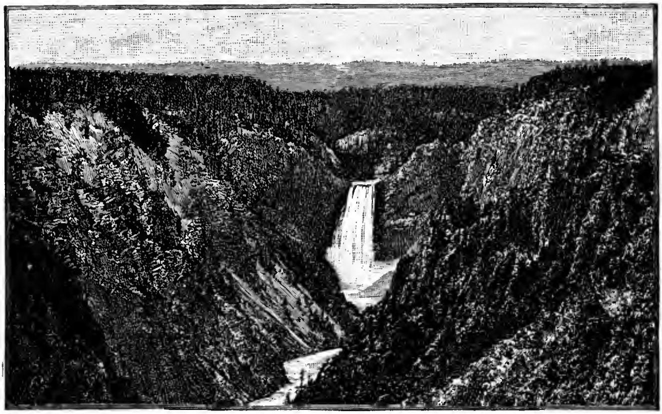

Fig. 149. — Falls of the Yellowstone River.

course, fell over the bluff of the Niagara upland ; since then the fall has cut back a gorge about seven miles long. The larger or Canadian fall is now retreating two or three feet a year at its middle.

The falls of the Yellowstone river are of similar origin. They now occur at the head of a deep canyon cut by the river in the process of deepening its course.

While a river is engaged in deepening its valley, it often flows from a stronger to a weaker rock structure. It will deepen the valley much more quickly in the latter than in the former, and a rapid or fall will be formed on

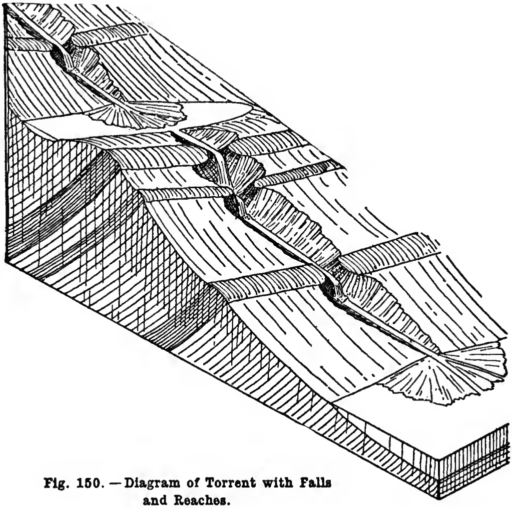

Fig. 150. — Diagram of Torrent with Falls and Reaches.

the slope produced between the two. Falls of this kind are numerous, especially in dissected plateaus and in lofty mountains.

In passing from old-land rocks to the weak layers of a coastal plain a river develops rapids of moderate slope, as has already been explained.

While the channel of a river is interrupted by many rapids and falls, it is serviceable as a source of water power rather than as a waterway for large vessels. In the course of time the rapids and falls will be worn down to an even slope with the rest of the channel. A large river and its branches in this condition permit the entrance of river boats far inland.

The falls in the lower course of the Kongo indicate an uplift of its basin so recent that even that great river has not yet been able to wear the falls away. The Kongo has therefore been less available for exploration and commerce in Africa than the Amazon and the Mississippi have been in America.

Graded Rivers. — A stream wears down its course on each weaker structure with reference to the next downstream harder structure, as in Fig. 150. It thus comes to be divided into smooth reaches and plunging rapids or falls. Many rivers in New England are in this condition. The slope of a stream on a smooth reach is just sufficient to give it a velocity by which it can wash forward its load of waste. This part of the stream is then said to be *graded.*

Rivers with reaches and falls furnish abundant water power for factories, and hence manufacturing cities grow up along them. The industries of such cities sometimes outgrow the water power on which they at first depended. Then steam power is added. Rochester and Minneapolis are cities of this kind.

When a river has been undisturbed by deformation of its basin for a long period of time, few falls remain to interrupt its course, and its graded reaches become longer and longer. It is in this well-established condition that many large rivers of the world are found.

In vigorous mountains, where many successive uplifts occur, even the large rivers are hardly able to grade their courses during the pauses between the uplifts; the small branches are kept in a torrential condition. Only when the last uplift was long ago, as in subdued mountains, can the streams develop well-graded courses.

It is only in streams where valleys are not yet graded that the observer may expect to see the stream at work deepening its valley. No such action is perceptible in graded streams.

When a graded condition is reached in even the smaller streams, the slope will be steepest near the headwaters and least near the river mouth; thus the profile of a well-developed river is a curve of decreasing slope from head to mouth.

The large volume of the lower part of a river enables it to run rapidly even on a gentle slope. Its load is relatively fine-textured and easily carried, having been ground finer and finer while washing down from the upper valleys. Every thread of the river current does its part of the work of washing the load towards the sea. Under these favoring conditions a faint slope will enable the river to do its work.

The small volume of a headwater stream permits friction with the banks and bed greatly to retard its current. The load that it receives from the valley slopes is relatively plentiful, coarse, and difficult to drag along. The only way in which a small stream can do its work under these unfavorable conditions is by maintaining a steep slope.

A swift headwater stream ordinarily has so little fine waste to carry that its water is clear; the coarser waste is dragged along its bed. Only at a time of flood does it become turbid. The slow-moving waters in the lower course of a flat-graded river gather so much fine silt that they are nearly always somewhat turbid from suspended and slowly settling sediments.

Water moves so easily that large rivers assume very faint slopes; the lower Mississippi has a descent of only 2 or 3 inches to the mile, yet it bears along a vast amount of rock waste: 6700 million cubic feet of suspended silt, 750 million of silt dragged along the bottom, and 1400 million of mineral substances in solution every year.

When a river system is found to possess graded valley floors extending without break far up toward the heads of its many branches, it must be concluded that the streams have long been at work to produce so remarkable an adjustment between volume, load, and slope. This beautiful adjustment is one of the best proofs that valleys are carved by the streams that drain them; for by no other process could the adjustment be produced.

The Development of Valleys. — While a young river is deepening its valley, the valley sides are steep and the valley bottom is no wider than the river channel. At such a time the valley floor offers no attraction to settlement, as it affords no level ground for roads or villages near the river; if built in such a valley, they must perch on the side slope. If the valley is deep, it may act as a barrier between the uplands on either side.

The dissected plateau known as the Mesa de Maya in southern Colorado, fronting the Rocky mountains, affords many examples of narrow young valleys in their relatively inaccessible and unattractive stage.

Floods have little room to spread in a steep-sided valley; hence they rise rapidly on the valley walls, even 30 to 50 feet in a day or two. Thus hemmed in a valley, the flood flows rapidly and sweeps away all obstacles, gradually subsiding as its supply of water lessens.

It is for this reason difficult to maintain road bridges across the streams of the Allegheny plateau; the great expense of building strong and high bridges cannot be borne by the scattered population. The streams are therefore commonly crossed by fording. At time of high water, travel is interrupted.

Thus far it has been implied that an active stream cuts its channel directly downward and not at all sideways. But at every bend a stream tends to cut more on the outer than on the inner bank; hence as it cuts down it also cuts outward.

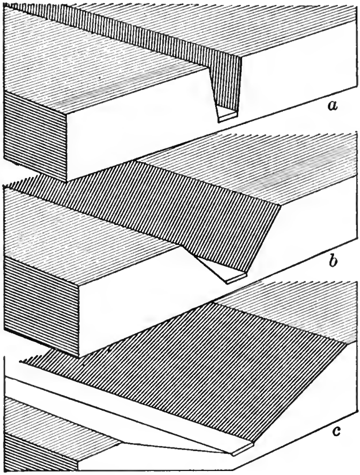

Fig. 151. — Diagram of a Straight Valley.

A perfectly straight stream might cut vertically downward. As the valley sides wasted, the valley would become wider at the top, but not at the bottom, as in Fig. 151 (*a*, *b*, *c*).

If no wasting of the walls occurred, the trench cut by a crooked stream would slant outward at every turn, as in Fig. 152 (*a*). This is sometimes seen to a slight degree in narrow gorges or chasms, for the fastest current is not in mid-channel, but runs near the outside of every turn; hence there is more wearing on the outer than on the inner side of the stream.

The valley walls waste while the trench deepens. When grade is reached, the walls will have flared open; but they will be steep on the outside of every curve where the stream has undercut the valley wall, as in Fig. 152 (*b*). Unsymmetrical valley sides are formed in this way; sloping spurs enter each curve opposite cliff-like bluffs, and the belt of country occupied by the turns of the river is broader than at first.

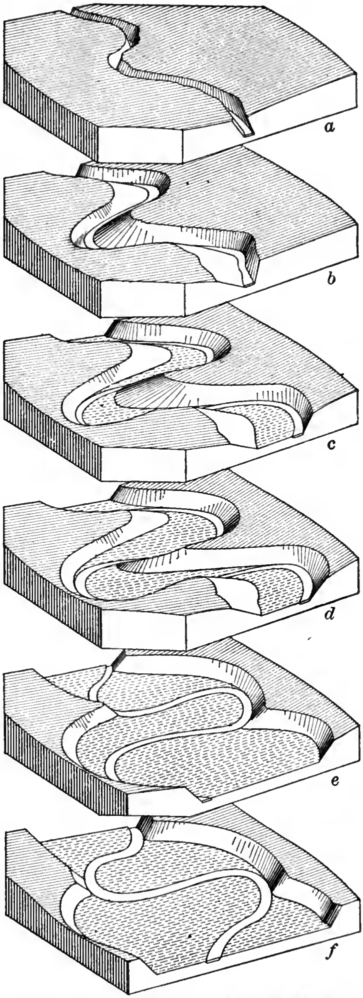

Fig. 152. — Diagrams of a Crooked River widening its Valley.

The Development of Meanders. — When a river has graded its valley, it almost ceases to cut downward, but it may still wear on the outer bank of every turn, and thus continue to broaden the belt that its valley floor occupies. At the same time the turns tend to become smooth curves of regular form, better adapted to the regular movement of the river.

As the outer bank of a curving channel is cut away, the inner bank is filled up to flood level with rock waste from further up stream. A strip of flood plain is thus developed on the inner side of each curve, as in Fig. 152 (*c*); first on one side and then on the other side of the river.

The north branch of the Susquehanna follows a deep and winding valley through the Allegheny plateau in northern Pennsylvania. It has begun to develop strips of flood plain at the base of its sloping spurs; steep cliffs rise above the opposite river bank. The Osage river has worn an extremely crooked valley in the uplands of central Missouri, and it is just beginning to form narrow strips of flood plain.

Fig. 153. — Contour Map of the Missouri River Valley.

With continued action the river consumes more and more of the spurs that enter its curved course, as in Fig. 152 (*d*, *e*). In time it obliterates them, as in Fig. 152 (*f*). Then an open flood plain is formed on which the river takes such a curved course as suits its volume, with only occasional constraint by the valley walls. The narrower the original belt of turning, the narrower the flood plain at this stage of development.

The lower Missouri has a valley floor about as broad as its belt of curves. Villages grow on the uplands above points where the river flows against the valley walls. The valley of the Ohio above Cincinnati now retains only the blunt remnants of the spurs that once entered its turns.

If a stream has a large load of coarse rock waste, its graded flood plain must be relatively steep (a descent of from 5 to 20 feet or more a mile). In this case the stream does not turn far aside from a direct course along the flood plain; but it is constantly embarrassed by the formation of bars and islands of gravel and sand, splitting its current into many shifting channels.

The Platte, fed by branches rising in the Rocky mountains and gaining much waste from the weak strata of the Great Plains, requires so steep a slope that it cannot cut a deep valley, although the Plains in the upper part of its course are high above baselevel. The river is like a braided network of many channels. Many rivers flowing from the Alps to the lower surrounding country are of this kind; gravel bars and islands lie between their divided channels.

If the waste borne by a river is of very fine texture, the flood plain will have a very gentle grade, and the valley will be cut down close to sea level. The slope down the valley is then so faint that the river easily turns aside from a direct course on its broadened flood plain, and in this way (whatever its original course) develops a system of serpentine curves or *meanders*, as in Fig. 152 (*e*, *f*).

The Meander, a serpentine river of Asiatic Turkey, has given name to this river habit.

On a nearly level flood plain any accidental obstacle may divert a stream from a direct course and turn its current toward one bank or the other. Thus turned, its wandering will be increased by constantly cutting away its outer bank.

Even if nearly straight in the beginning, it must come to meander on a flat flood plain.

The size of the meanders increases with the volume of the stream. A meadow brook may swing around curves measuring only 40 or 50 feet across. The curves of the lower Mississippi are from 3 to 6 miles across. The flatter the flood plain, the greater the arc of the meander turning. The Koros (Fig. 154), on the Plain of Hungary, has its meanders remarkably developed.

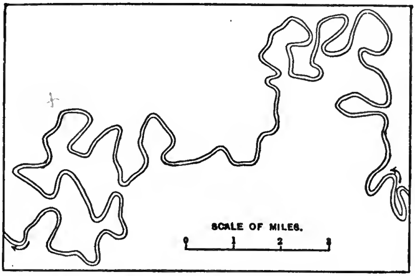

Fig. 154. — A Meandering River on the Plain of Hungary.

Broad Valleys. — Wherever a meandering river swings against its valley walls, they will be slowly consumed. As the meanders slowly change their course through the flood plain (Fig. 152, *e*, *f*), cutting away the valley walls now here, now there, the flood plain gradually becomes wider than the meander belt.

The Mississippi below Cairo has opened a flood plain from 20 to 60 miles wide, that is, five or more times wider than its meander belt. Being a river of great volume, it has rapidly advanced to a thoroughly mature stage of development, while its small branches on each side are still young.

Many New England streams meander on the flood-plained reaches between their falls.

In the fine rock waste of a broad and flat flood plain, a large river changes its course rapidly, taking material from the outer banks, where its current is strong, and depositing it further down stream on the inner banks, where its current is weaker.

The breadth of the meander belt would in time become excessive, if the necks of the flood-plain spurs between adjoining meanders were not gradually narrowed and cut through, the meander around the spur being then deserted for a shorter and straighter course.

Large rivers, like the Mississippi, exhibit all stages of this process. An abandoned meander is occupied by nearly stagnant water, more or less completely separated from the new and shorter channel by deposits of silt in the ends of its arms; in time it becomes an *ox-bow lake*. A group of well-developed meanders may be transformed into a comparatively straight stretch, with abandoned meanders and ox-bow lakes on each side.

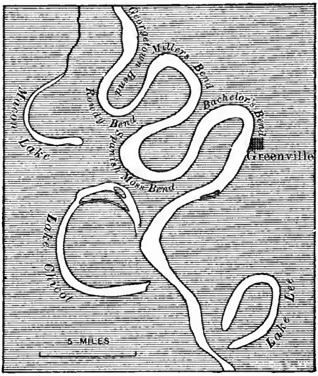

Fig. 155. — Meanders of the Mississippi.

A continuous and deep channel is maintained by a river near the outer bank of a meander, but on the straighter stretches between two meanders the channel is irregular and variable, being clogged with many shifting bars and shoals. It is in these parts that the navigation of a meandering river like the Mississippi is difficult.

When a valley floor is old enough to be widened and when its walls are worn back to gentle slopes, it becomes much more available for human uses than when young, narrow, and steep-walled; but its flood plain is exposed to invasion by the shifting channel, and to overflow at time of high water.

The shifting of the channel may be checked by protecting the outer bank with stone or wood work, but this is expensive. Rising floods may be held back by dikes or levees built on the plain a little distance from the river banks. When the levees are overtopped or breached, wide-spread floods may result, such as occurred on the Mississippi flood plain in April, 1897, when about 13,000 square miles of the plain (two-fifths of the entire area) were under water. The value of live stock and crops lost in this flood was estimated at $15,000,000; many thousand people were for a time driven from their homes.

In March, 1890, a strong flood in the lower Mississippi broke through the levees on the left bank, forming the "Nita crevasse" (a break on the Nita plantation), flooding the plain, carrying river silt into the shallow waters of the Gulf, and ruining the oyster beds east of the delta.

Shifting of Divides. — While a river is wearing down its valley to a smooth grade, ravines are worn into the valley sides. The ravines gradually lengthen headwards and dissect the upland surface. As their size increases they may be called branch valleys.

Many of the great ravines in the walls of the canyon of the Colorado are of this origin. Most of the branch valleys of dissected coastal plains, as in South Carolina, and of plateaus, as in West Virginia, are formed in this way.

The headward growth of branch valleys is more rapid in weak than in strong rock structures. It sometimes happens that a branch valley gnaws its way headward along a belt of weak rocks (*W*, Fig. 156), from the deep-cut valley of a large river (*R*), and taps the side of a smaller river (*S*), whose valley is not cut so deep. The upper waters of the smaller river are then turned to the large river, and the lower course (*D*) of the smaller river is left in diminished volume. As this change progresses, the divide is shifted from its original position (*AB*) and in time takes a position (*AC*) across the smaller valley above the beheaded stream (*D*). Still further changes may occur later.

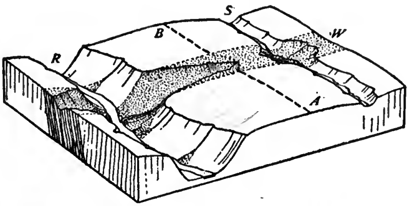

Fig. 156 *a*.—Diagram of a Shifting Divide (first stage).

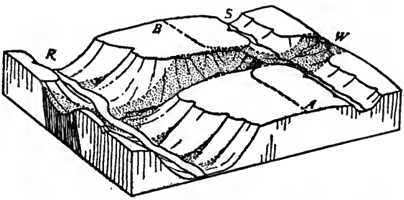

Fig. 156 *b*.—Diagram of a Shifting Divide (second stage).

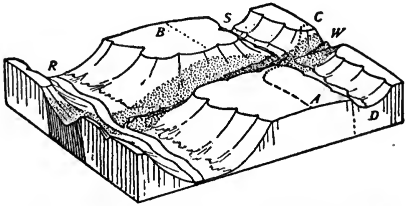

Fig. 156 *c*.—Diagram of a Shifting Divide (third stage).

The arrangement of streams on belted coastal plains may be explained as the result of shifted divides. At first the rivers that are extended from the older land across the young coastal plain follow independent courses to the sea. Branch valleys grow out from the several rivers along the belt of weaker strata on which the inner lowland is to be worn. A branch stream

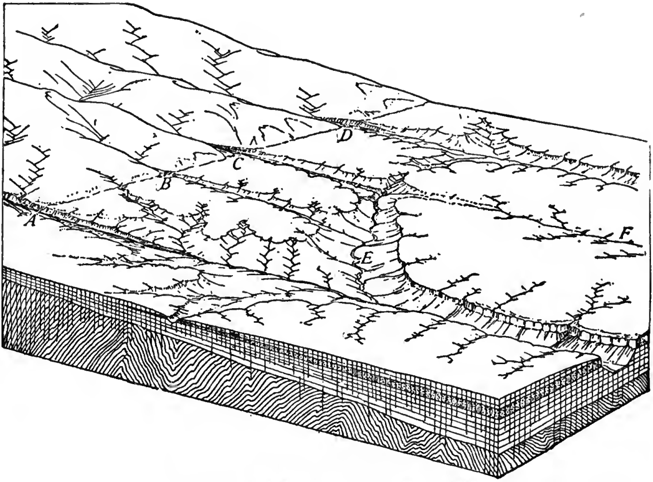

Fig. 157. — Diagram of Shifting River Divides.

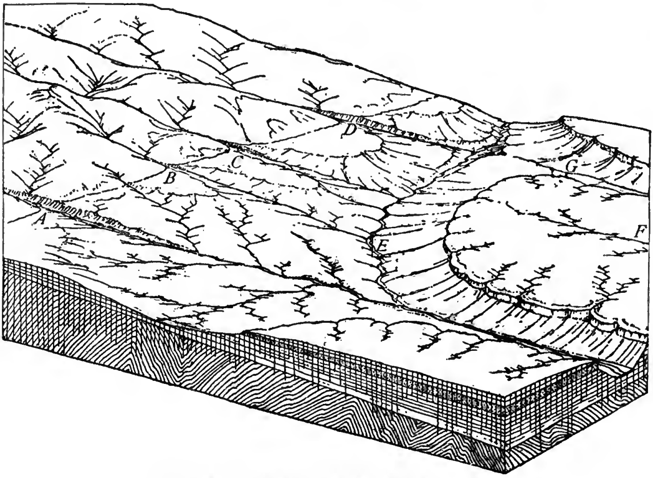

Fig. 158. — Diagram of Rearranged River Courses.

(*E*, Fig. 157) of the largest river (*A*) has the advantage of the greater depth to which the main valley is worn; in time it captures one after the other of the smaller streams (*B*, *C*, *D*) and leads them along the inner lowland to the main river, leaving their lower courses (*F*, *G*, Fig. 158) beheaded.

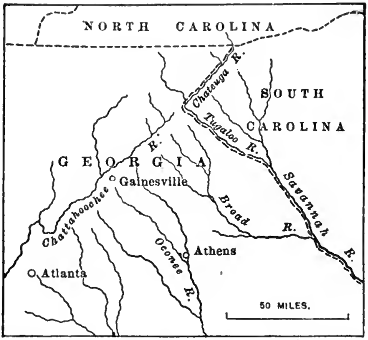

Fig. 159. — Boundary of Georgia and South Carolina.

The western angle of South Carolina marks the place where the former upper waters of the Chattahoochee river have been captured by a branch of the Savannah river. In this case the advantage enjoyed by the Savannah resulted from its shorter course to the sea, in consequence of which its headwaters were enabled to erode their valleys deeper than the valley of the Chattahoochee. A state boundary has thus been determined. Further beheading of the Chattahoochee by the Oconee may take place in the future.

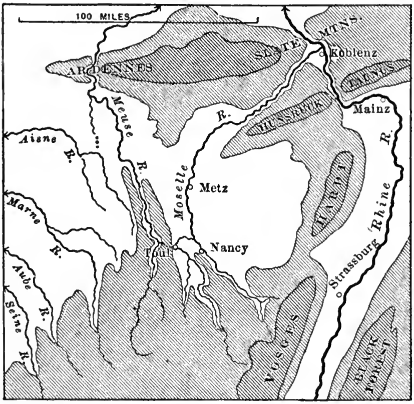

Fig. 160. — Outline Map of Eastern France and Western Germany.

The city of Toul in eastern France stands at a sharp turn in the Moselle river, where its upper waters have been captured from the Meuse, to which they once belonged. Another branch of the Meuse has been captured by the Aisne, a member of the Seine system. Here the captures seem to have taken place because the Meuse was delayed in deepening its valley on account of having to cut a deep gorge in the hard rocks of the Ardennes highlands, further down stream. As a consequence the small meanders of the diminished Meuse no longer fit the larger meanders of its swinging valley, as shown in Fig. 161.

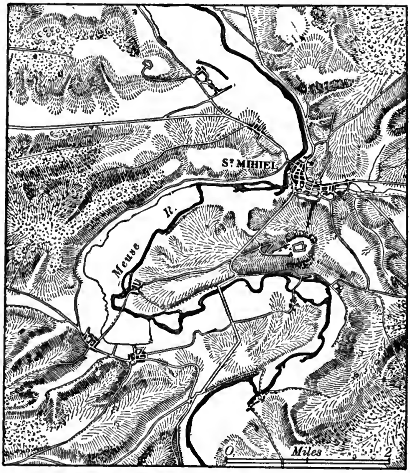

Fig. 161.—Irregular Course of the Meuse in its Meandering Valley.

Mature Rivers.—When a river and its larger branches have destroyed their lakes and falls and reduced their valleys to graded slopes; when the larger streams have broadened their valley floors so that they can meander freely upon them in curves appropriate to their volume; and when the growth of branch streams has shifted the divides so far that no further changes of importance are to be expected, the river system has reached the mature stage of its development.

A river system occupies so large a region that it cannot be easily pictured in the mind; but as its different parts are patiently studied, and as an understanding of their wonderful relations is gradually gained, the system as a whole may be conceived. It will then be seen to be almost as marvellous as any organic forms in its well-ordered arrangement of parts and in their survival by reason of natural selection.

Mature rivers accomplish the drainage of their basins and the transportation of rock waste to the sea in the most active and perfect manner. There remain no undivided uplands from which a great part of the rainfall may be returned to the atmosphere by evaporation. The largest possible share of the rainfall is shed from the well-carved surface of the land, and runs off in the streams with no lingering delay in lakes or undue haste in falls. No hard rock ledges remain in the lower courses to delay the deepening of the upper valleys. Everywhere the waste of the land is washed down the slopes to the streams, and delivered in such quantity that the streams are kept working at their full capacity to transport the waste toward the sea.

Old Rivers. — If no disturbance occurs, a maturely developed river system passes by slow degrees into a quiet old age. The hills waste away to fainter slopes and yield less and less waste to the streams. The texture of the waste becomes finer and finer. More of the waste is carried in solution. As the work of carrying the waste is thus made more easy, the meandering streams very slowly wear their flood plains to gentler slopes, and in this way always maintain a nice adjustment between their ability to do work and the work that they have to do.

The extreme old age of a river system would be characterized by low and ill-defined divides between faint slopes leading to broad flood plains, on which the streams would meander with great freedom. An increasing share of the transported waste would be dissolved. A large amount of rainfall would be lost by evaporation on the gentle slopes.

It is unusual to find an old river system. The lower trunks of large river systems often gain very gentle slopes and free-swinging meanders, but before a correspondingly advanced development is attained by all the small side branches and the headwaters, movements of elevation or depression generally occur with more or less tilting and breaking; and in this way the rivers are made young again and set to work at new tasks.

Revived Rivers. — At any stage of development the region drained by a river may be uplifted to a greater height above sea level. Then the river will at once begin to cut its valley floor down to grade with respect to the new baselevel. The renewed activity of such rivers suggests that they should be called *revived.* One of the first effects of revival and renewed dissection is to bring to life again the falls that had been worn down before the region was uplifted.

The Great Falls of the Missouri in eastern Montana occur in a young valley, where the revived river is dissecting the worn-down plains, now uplifted. No falls could have existed during the old age of the river, when it flowed across the worn-down plains. The water power of the revived falls now determines the site of the growing city of Great Falls, with its important industrial works (see page 221).

A common effect of revival is the erosion of a narrow trench in the floor of a mature, well-opened valley. The gorge of the Rhine, already described (Fig. 119), is an example of this kind.

Kootenai river in the Rocky mountains of northern Montana, and Fraser river in the mountains of British Columbia, both exhibit this combination of mature and young features. The railroad that follows each valley is located on the former valley floor, which now appears as a rock bench or terrace above the present gorge.

Old rivers flowing across low worn-down mountains are rare, but revived rivers flowing through gorges in uplifted lowlands of this kind are common. The rivers of the Piedmont district of Virginia (Fig. 117) are thus explained.

Entrenched Meanders. — If uplift permits a mature or old meandering river to entrench itself beneath its former flood plain, its new valley will be regularly curved, instead of irregularly crooked, as in its first youth. The meander belt will be somewhat broadened as its curves are cut down, for the river will cut outward as well as downward at every turn.

The lower Seine in northwest France affords a beautiful example of a narrow valley of regular serpentine curvature, entrenched in the upland (a worn-down plain, uplifted) of Normandy. Above the reach of strong tide, spurs of the upland enter every loop of the river. Nearer the mouth, where rapid tidal currents aid the action of the river, the spurs of the upland are almost obliterated, and the flood plain is broader.

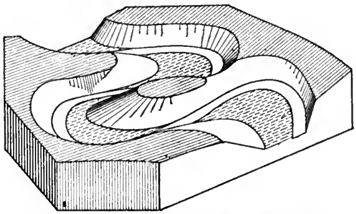

Fig. 162. — Diagram of a Narrowed Spur.

The regular curves of the north branch of the Susquehanna have probably been developed after the uplift of the worn-down plain on which the river formerly meandered.

It sometimes happens that a revived river may wear through the neck of one of the upland spurs that enter its trenched course, and then desert a roundabout course for a more direct one (Figs. 162, 163). Rapids will occur for a time at the cut-off. The village of Lauffen (Rapids), on the Neckar in south Germany, gains water power from rapids of this kind. The former course of the river is seen in a meadow beautifully curved around an isolated hill, the cut-off end of an upland spur (Fig. 164).

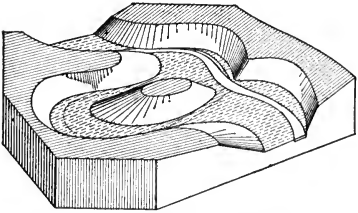

Fig. 163. — Diagram of Cut-Off Spur.

The Moselle in western Germany (Fig. 160), sinking its course in an uplifted old-mountain plateau, has a number of deeply incised meanders (Fig. 165). Incised meanders and cut-off spurs occur on the Allegheny river above Pittsburg. Railroads following an incised meandering valley often tunnel through the narrow necks of the spurs, thus anticipating the behavior of the river by many centuries.

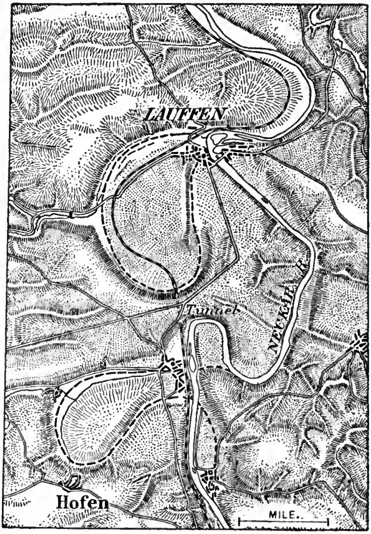

Fig. 164. — Entrenched Meanders of the Neckar.

Lengthwise and Crosswise Valleys. — Revived rivers give a simple explanation of the origin of certain lengthwise and crosswise valleys. The former are often broad lowlands with a deep soil weathered on weak underlying rocks. The latter are steep-sided gorges cut in rugged, hard-rock ridges or highlands.

Fig. 165. — Entrenched Meanders of the Moselle.

For example, the Delaware river gathers many branches from the open inner valleys of northeastern Pennsylvania, and escapes by a deep, narrow notch, called the Delaware Water-gap, in Kittatinny mountain, at the northwestern corner of New Jersey.

In such cases the rivers had their present arrangement before the valleys were excavated, when the whole region stood lower than now and a broad lowland spread far and wide at about the level of the ridge crests and highland summits of to-day, as in Fig. 166. After the elevation of the region, all the revived rivers began to wear down their valleys. No branch stream could cut down faster or deeper than the larger river that it enters. The inner lengthwise streams could not deepen their valleys faster than the crosswise valley was deepened by the trunk river.

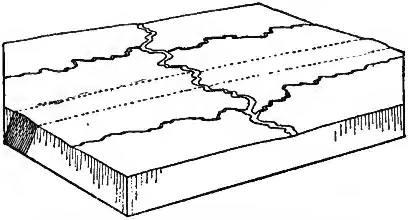

Fig. 166. — Transverse and Longitudinal Streams.

But the inner valleys widen with relative rapidity on their weak rocks, and in time become broad open lowlands, while the outlet valley still retains a gorge-like form in the resistant rocks which now stand up as a ridge or belt of highlands, as in Fig. 167.

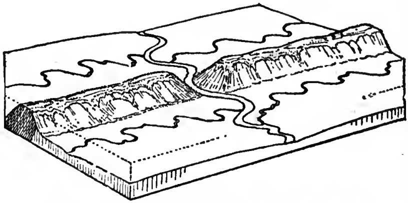

Fig. 167. — Transverse and Longitudinal Valleys.

This explanation applies to the Susquehanna, cutting gaps in the Allegheny ridges, and to the Potomac, cutting a deep passage in the Blue Ridge at Harpers Ferry, and draining the lengthwise Shenandoah valley in Virginia (Figs. 117, 118). The belt of resistant rock which forms the mountain can be traced across the river bed in shallow riffles and ledges.

Erroneous explanations of watergaps are often met. The deep notches in the Pennsylvania ridges have been accounted for by some observers as the result of violent disturbances which have broken a path for the river through the mountains; by others they have been referred to the overflow of great lakes that once occupied the inner longitudinal valleys.

The mistake of both these explanations lies in supposing that the mountain was a continuous ridge after the inner and outer longitudinal valleys had been formed. As has been said above, the broad longitudinal valleys and the narrow transverse valley are the work of the same period of time; they came into existence together. The ridge stands up over the adjoining lowlands simply because of its superior resistance to

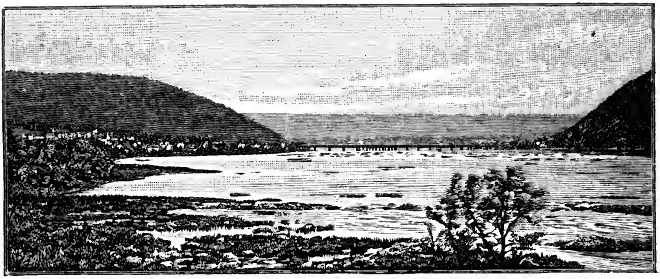

Fig. 168.—Watergap of the Susquehanna above Harrisburg, Pennsylvania.

weathering. Watergaps resemble natural gateways by which roads and railroads may be led into the inner valleys. Vast quantities of coal and other freight are carried through the

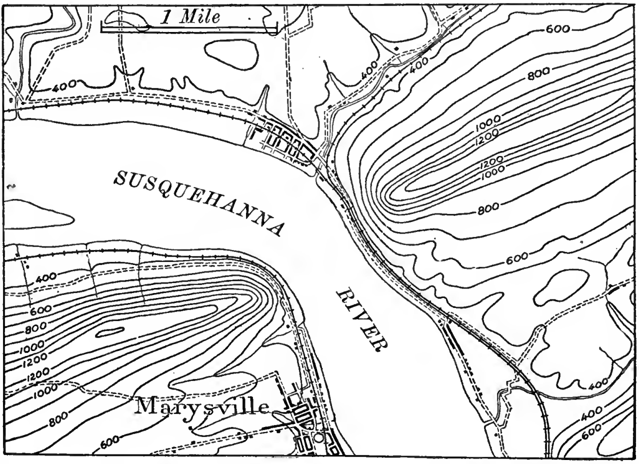

Fig. 169.—Contour Map of the Susquehanna Watergap above Harrisburg, Pennsylvania.

gaps from central and western Pennsylvania to the cities on the seacoast.

Antecedent Rivers. — At any stage in the history of a river a tilting or uplifting movement of the earth's crust may tend to reverse the slope of a part of its valley. If the movement is too rapid for the river to overcome, its current will be turned away to a new path, following the slope of the uplifted surface.

This is usually the case, as has been shown in the mountains of Oregon and Nevada, in the Black Hills dome, and in the Jura arches. In lofty mountains of vigorous growth the main range is usually the divide between river systems that flow away to the lowlands on each side.

It may, however, sometimes happen that a large river is powerful enough to maintain its path by cutting down the uplifted part of its valley, and then it will not be displaced. As such a river existed antecedent to the disturbance of its basin, it may be called an *antecedent* river.

The Kanawha river has preserved its course through the plateau of West Virginia in spite of the uplift by which the plateau was raised 1000 feet more than the upper part of the river was raised in Virginia and North Carolina.

Great rivers, like the Sutlej, gathered in the inner valleys of the Himalaya and escaping to the plains of northern India by deep gorges, have maintained their courses through the marginal ridges which have been uplifted and added to the mountain system in a comparatively late stage of its history.

These rivers may therefore be called antecedent to the marginal ridges. They have cut their outlet valleys down as the ridges were upraised, much in the way that a circular saw cuts its way through a log that is driven against it.

Before the last uplift of the plateau-like Slate mountains (Fig. 119), now trenched by the middle Rhine, the river followed its present path, as is shown by the trough in which the young gorge is cut. It therefore appears to have maintained its course in spite of an uplift across its path. It is an antecedent river in this part of its length.

Engrafted Rivers. — When a region near the sea is uplifted and a submerged continental shelf is laid bare as a coastal plain, the rivers of the older land are extended across it. It sometimes happens that several extended rivers unite on their way to the sea, thus grafting upon one trunk a number of previously independent river systems. It is chiefly in this way that the greater river systems of the world have reached their immense development.

The uplift of the coastal plain that borders the Gulf of Mexico has engrafted the White, Arkansas, Red, and Tennessee rivers on the extended trunk of the Mississippi, whose total drainage area now measures over 1,240,000 square miles.

By similar grafting the great rivers of Brazil have been united with the lower trunk of the Amazon, giving it a basin of 2,500,000 square miles. A further uplift would probably make the Tocantins a regular member of the same system, to which it is now imperfectly attached.

When large engrafted rivers grade their courses (and this they do almost as fast as the new land is raised before them), they become of importance as navigable waterways, reaching far into the interior of their basin. The navigable rivers of the Mississippi and Amazon systems measure many thousand miles in length.

Dismembered Rivers. — When the sea advances on a depressed region, the lower valley of a river system may be submerged, forming an estuary or bay, and leaving the river branches to enter the sea as independent river systems. The entrance of navigable arms of the sea far into the lands may compensate more or less fully for the drowning of the lower valley floors, as in the case of the St. Lawrence.

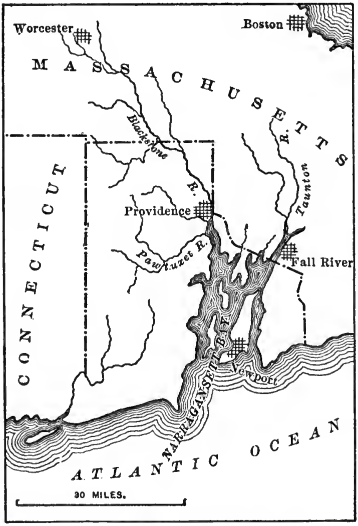

Fig. 170. — Map of Narragansett Bay.

The small rivers that enter Narragansett bay, R.I., formed branches, before submergence, of what may be called the Narragansett river system. All the rivers of eastern Virginia and inner Maryland were once united in a trunk river that flowed across what is now part of the continental shelf, before its larger valleys were drowned to form Chesapeake bay and the Potomac estuary (Fig. 117).

Example for Review. — The Hudson river drains a broad interior valley, a part of the great lengthwise valley of the

Appalachian mountain belt, occupied by farms all along its extent. At Newburgh the river leaves the broad valley and enters a deep steep-sided gorge in its famous passage through the Highlands of southeastern New York, an extension of the uplifted old-mountain plateau of southern New England.

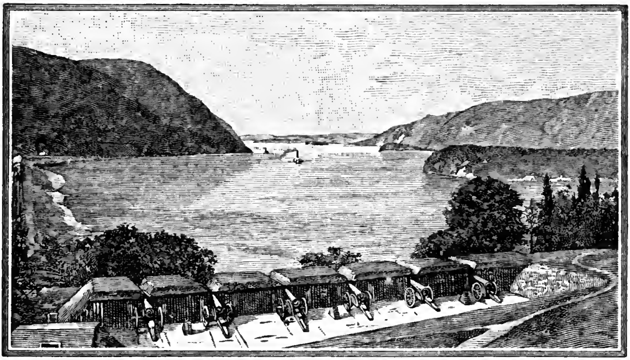

Fig. 171.—The Hudson River, looking North from West Point.

The difference in the dimensions of the broad and narrow parts of the Hudson valley is an indication of the difference in the ability of the underlying rocks to resist weathering. The broad lengthwise valley was worn down no faster than the narrow crosswise gorge through which it is drained; but it widened much faster than the gorge because its rocks are weaker than those of the Highlands. The waste from the broad valley drained by the Hudson has been carried, grain by grain, through the narrow gorge.

The large volume of the Hudson below Albany is due, not to the rainfall on its basin, but to a moderate depression of the valley bottom beneath sea level, whereby it has been drowned to a navigable depth. The former prolongation of the valley, excavated across the continental shelf when the region stood higher, has been traced by soundings for more than 100 miles off shore. The navigable waters now entering through the Highlands have been of great commercial advantage to New York city, whose history must have been very different if the Hudson had been as shallow in the Highland gorge as the Potomac is in its gorge through the Blue Ridge below Harpers Ferry.

The lower branches of the Hudson are, strictly speaking, independent rivers, now dismembered by the submergence of the valley that was excavated by the trunk river of the system to which they once belonged.

CHAPTER X.

THE WASTE OF THE LAND.

Comparison of Waste Streams and Water Streams.

Much attention is given to the forms assumed by the waters that flow from the lands to the sea. Surface and ground water, springs, brooks, and rivers, falls and lakes have thus been treated. A good share of attention should also be given to the forms assumed by the waste of the land on the way to the sea, from their beginning in the layers of soil produced by the weathering of the rocky structures of the earth's crust to their end in layers of sediment spread upon the sea floor.

The movement of land waste is generally so slow that it is not noticed. But when one has learned that many land forms result from the removal of more or less waste, the reality and the importance of the movement are better understood. It is then possible to picture in the imagination a slow washing and creeping of the waste down the land slopes; not bodily or hastily, but grain by grain, inch by inch; yet so patiently that in the course of ages even mountains may be laid low.

There are many resemblances between the movement of water streams and of waste streams. Water flows along stream and river channels, more rapidly at the surface, more slowly at the bottom; it is here delayed in lakes, there hurried down rapids. Land waste may be thought of as moving in streams and sheets down every hillside and along every valley, more rapidly at the surface of the ground, more slowly at a depth of several feet ; more

Fig. 172. — Rock Waste on Mountain Slopes.

rapidly on steeper slopes, more slowly on plains. The shape of the land surface and its usefulness as a home for man depend in no small degree on the character of the sheet of waste with which it is clothed.

Flowing streams of water are valuable in many ways, as affording water supply, water power, and water transportation. Creeping sheets and streams of waste are of even greater value, for upon their surface the most useful plants

Fig. 173. — A Lake-Floor Plain.

grow, and upon plants all the higher forms of animal life depend, directly or indirectly, for food. Many human industries and arts are dependent upon the plants that grow upon the slow-moving sheets and streams of waste.

THE FORMS ASSUMED BY THE WASTE OF THE LAND ON THE WAY TO THE SEA.

The Formation of Soil. — The decay of the rock crust of the earth under the attack of the weather has already been described as a characteristic of the lands. Nearly all parts of the land would be covered with a sheet of waste many feet deep, and bare ledges would be almost unknown, if it were not for the movement of the waste after it has been loosened.

Many processes aid in the production of rock waste. Changes of temperature through day and night, in summer and winter, cause small movements in solid rock, and aid in opening minute fractures near the surface. Water in rock crevices expands as it freezes, and thus helps to wedge apart adjacent blocks.

Most rocks suffer chemical changes under the action of water and air, and as a rule these changes aid decay and crumbling. The changes may go on as deep beneath the surface as water and air can penetrate. They are delayed or stopped when the ground water is frozen or wanting. They are aided when the ground water carries down with it the products of decomposing vegetation from the surface. Hence deep rock decay is less active in frigid or arid than in moist torrid climates.

Where the land surface is well covered with its own waste, a quarry (Fig. 59) or railroad cut may exhibit the gradual change from the solid rock beneath to the fine waste at the surface. While the rock is only divided into large blocks by fine cracks or *joints* here and there, a cubic inch of waste at the surface may be subdivided into millions of minute particles. If plants have long grown on the waste, it is darker near the surface than below, and the darker part is then commonly called *soil.*

Soil is generally understood as including a share of vegetable matter with rock waste, but some soils contain no vegetable matter.

Some rocks may be slowly dissolved by water. Limestone is the most important of these, and the origin of sinks and caverns by solution has already been described. As the limestone weathers and the soluble parts are slowly carried away, much of the insoluble parts of the rock remain; thus it may happen that a blue limestone is covered with rusty clay waste. A foot of the clay may represent 10 or 20 feet of rock. If the clay is stripped off, the limestone is sometimes found etched into curious irregular forms.

Where rock waste is formed on a slope, its finer particles at the surface are washed down a little by the run-off of every rain. Besides this the whole mass slowly creeps down the slope, advancing faster at the surface and more and more slowly beneath.

Every change of condition between cold and warm, dry and wet, melted and frozen, that causes a gain or loss of volume in the rock waste aids its slow movement down hill. With countless minute changes, every particle is led, slowly but surely, from higher to lower ground.

The growth and decay of plant roots aid the downward creeping of the waste. Earthworms, ants, and various burrowing animals bring the smaller particles of waste to the surface, and thus promote weathering and washing.

All causes of movement are greatest near the surface; hence the outer part of the waste sheet moves faster than the under part. As gravity is more effective on steep than on flat surfaces, the waste creeps faster on hillsides than on nearly level plains. In both these respects waste streams resemble water streams.

On surfaces of very gentle slope, such as plains of moderate relief, the waste is removed so slowly that it becomes unusually deep. The deeper the sheet of waste becomes, the less active is the attack of the weather on the under rock, and the slower the waste increases in depth. The surface particles become finer and finer the longer they are exposed; the finer they are, the more easily they wash and creep away. In this way a balance may be struck between slow removal at the surface and slow production at the base of the waste.

It thus appears that plains favor human occupation, not only because they may be easily traversed, but also because they usually possess a fine and deep soil. Fineness of texture near the surface is of great advantage to many plants, although unfavorable to certain kinds of trees. The importance of such waste sheets to mankind can hardly be overestimated.

The even surface of the lava plateau of southeastern Washington is covered with a heavy sheet of waste, at places 50 or more feet thick. Deep sections show hard black lava at the base, gradually changing upwards to a yellowish decayed mass, and becoming a very fine porous soil towards the surface, where all traces of rock structure have disappeared. The soil offers scarcely more resistance to the plow than so much meal. Great wheat crops are raised upon it.

Local and Transported Soils. — Soils may be roughly classified as local and transported. A local soil consists of waste still lying upon or near the rock from which it was weathered. A transported soil consists of waste that has been carried a greater or less distance from the parent rock.

In a region of local soils there may be a great difference in the value of neighboring farms, according as they lie on rocks that yield rich or poor soils. The famous Blue Grass district of central Kentucky possesses a fertile soil weathered from limestone. Adjoining on the south and east is a belt of sandy rocks, where the soil is hardly worth cultivating. The contrast in the value of the farms and in the condition of the people of the two districts is very striking. The same contrast is to be seen in passing from the rich limestone soils around Nashville in western Tennessee to the "barrens" on the surrounding sandstones.

Meadows and valleys generally contain transported soils supplied by the waste that is washed down from the adjoining hillsides and from the upper part of the valley.

Transported soils usually possess a greater variety of composition than local soils, and are therefore more generally suitable to varied crops. Further account of them will be found under flood plains (p. 279), wind action (p. 316), and glacial action (p. 335).

Rock Ledges and Cliffs. — On surfaces of steep descent, such as occur along the fault cliffs of blocked plateaus, or on the flanks of newly uplifted mountain masses, the waste is rapidly moved downward, leaving the bare rock exposed on the upper slopes. The steep sides of young valleys, cut by vigorous streams in structures of any kind, are also usually bare and rocky on their upper slopes, because the waste is there removed as rapidly as it is supplied; their lower slopes are cloaked with sheets and streams of loose stone and gravel.

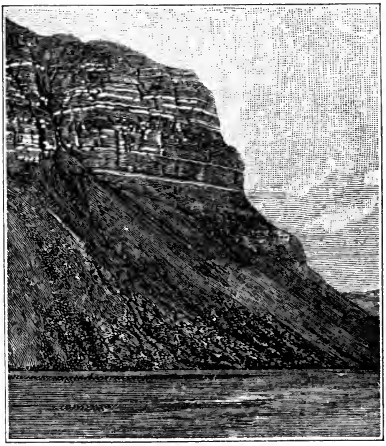

Fig. 174. — Cliff and Talus.

In contrast to the deep and fertile waste sheets of plains, the steep and bare rock ledges of plateaus and mountains are "deserts." They are avoided by nearly all forms of plant and animal life. Lichens and mosses may attach themselves here and there; small plants of higher order may gain root-hold in occasional crevices; lowly refugees, brute or human, may seek shelter in shallow caverns beneath overhanging ledges; but a steep and bare rock surface is too sterile to attract numerous occupants.

Land Slides. — Land slides from rocky cliffs may form tumultuous heaps of waste beneath the cliffs, or may spread smoothly along the valley floor. A slide, in its excess over the ordinary falls of small rock masses from a cliff, may be compared to a cloud-burst flood in the stream channel of an arid region.

Fig. 175. — Land Slides in the San Juan Mountains, Colorado.

Certain valleys of the Rocky mountains of southern Colorado contain numerous slides of great dimensions. It is thought that the slides may have been dislodged by earthquakes. Although soon overgrown with trees, they are easily recognized by their hummocky form, and by their relation to scarred cliffs on the overlying slopes. The slide shown in the valley of Fig. 175 measures two and a half miles along the mountain base.

Waste Slopes. — The rocky talus beneath the cliffs, peaks, and ledges of high plateaus and lofty mountains is a sheet of slowly moving waste. Its angle of descent (generally from 30° to 40°, decreasing somewhat toward the base) is delicately adjusted so as to strike a balance between the supply and the removal of waste.

The active supply of coarse rock blocks from a high cliff requires a steep slope in the talus below, for only on a steep slope can the talus blocks be removed as fast as they are supplied. A slower supply of finer waste allows the production of a less steep talus.

Weathering goes on beneath the creeping talus, and the waste thus supplied joins the rest in a slow movement down the graded slope. An artificial cut may reveal the dragged arrangement of the creeping waste sheet, the faster movement of the surface parts being easily recognizable.

As mountains and plateaus become older, the peaks and cliffs are more worn away and the waste sheet covers a large part of the surface. It is for this reason that the profiles of maturely dissected mountains present so many lines of regular descent at a comparatively constant angle. Only the strongest rocks still stand out in cliffs ; the less resistant rocks are already worn back to smooth slopes, almost wholly cloaked with sheets of creeping waste.

The great painters of several centuries ago sometimes represented mountains with fantastic and impossible outlines, in which the steepness of the slopes was altogether unnatural.

At that time the study of land forms had hardly begun. It is still the habit in modern descriptions to exaggerate the steepness of mountain slopes. In careful descriptions the propor-

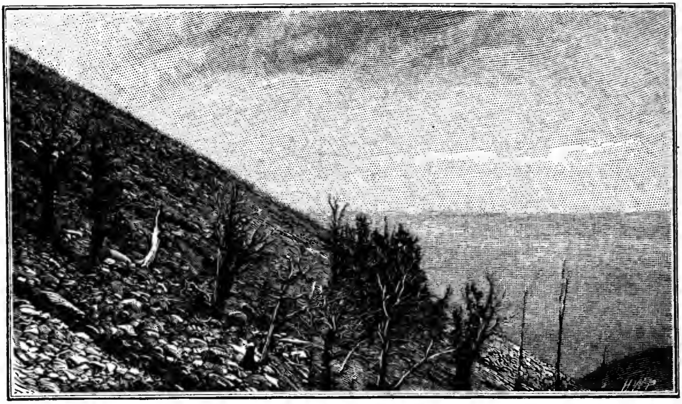

Fig. 176. — The Slope of Pikes Peak.

tions of bare cliffs and of waste-covered slopes should be accurately noted. The flanks of Pikes Peak consist in large part of even waste-covered slopes, and illustrate the importance of this class of forms.

The cloak of rock waste on a graded mountain slope weakens the attack of the weather on the rocks underneath the waste. The bare peaks and ledges that stand out above the slant of the waste slope are unprotected, and in spite of their resistant structure, they crumble away with relative rapidity, until they are worn down to a slope on which the waste sheet will lie. Hence in lofty mountains the sharper peaks must be regarded as comparatively short-lived forms.

In certain mountain ranges many peaks have an almost equal altitude, differing only by a small part of their total height. To an observer standing on one summit many others seem to rise to about the same level, like wave-crests at sea. It has been suggested that the approach to even height results from the rapid weathering and destruction of the bare peaks that rise to unusual heights above the slant line of the waste slopes on the valley sides. The Rocky mountains and the Alps present many cases of this kind. The slopes of the dissected block mountains of Utah (Fig. 103) are generally smoothly covered with waste, above which bare peaks seldom rise to great height.

If for any reason the process of removal gain the advantage on a waste-covered mountain side, the waste sheet will be stripped away, exposing a bare rocky surface of even slope. The weather will then actively attack the uncovered rock ; the weaker parts will be first hacked out, changing the even slope to a ragged profile. In time a new even slope will be established, and the surface will be again covered with waste.

The chief causes that lead to a stripping of a waste-covered slope are: an uplift of the region and a revival of the valley streams, whereby the valley is deepened and the waste on the side slopes is quickly removed ; a tilting of the region, whereby certain slopes are made steeper than before, and the forces of removal on them are strengthened ; a change of climate, whereby the forest cover is destroyed and the processes of washing and creeping are allowed to remove much waste that was before detained by tree roots.

When forests are extensively cut from waste-covered mountain sides, a large part of the waste may be washed off, leaving great slopes of bare rock or of coarse stony waste. Unchecked torrents then cut gulches in the slopes and desolate the valley floors with the gravel and sand washed down upon them. Great injury has been done in this way in the Alps and the Pyrenees. On some deforested mountain flanks terraces have been built and trees planted to detain the waste upon the slopes and to re-forest them.

It is probable that the successive processes of waste-covering, stripping, and covering again may occur as many times as vigorous mountains are disturbed by uplift or tilting. When disturbances become less frequent, graded slopes may be more continually developed; then the more vigorous forms are subdued and the old age of the mountains comes on.

As the old age of a land form is approached, bare ledges decrease in size and number, rock waste is supplied less rapidly, the waste-covered slopes are reduced to gentler declivity, and the movement of waste upon them is slower and slower. With longer exposure to the weather the surface waste becomes less stony; and with slower removal the waste cloak becomes thicker. Thus, as relief decreases, a larger and larger part of the surface acquires a soil suitable for cultivation.

There is a dissected upland of nearly horizontal strata forming a district of gently rolling hills (an upland enclosing an inner lowland) in southern Wisconsin, where the whole surface is smoothly graded over with soil. Hardly a ledge is anywhere to be seen. The activity of the processes by which the waste is supplied is everywhere equal to the activity of the processes by which it is urged to move down the slopes. Along every downhill line the streams of waste are creeping leisurely towards the valleys. But so slowly does even the finer surface waste move that the district is clothed with an abundant prairie vegetation, or yields a rich farm harvest.

The Piedmont district of Virginia and the Carolinas, an old worn-down mountain region, has a thick waste sheet with fine surface soil on its flat interstream uplands. Deep cuts disclose a gradual change from firm rock, 20 to 50 feet underground, to fine soil above, where only the least destructible minerals (like quartz) remain in stony or gritty fragments.

The presence of vegetation is an important factor in determining a balance between the process of waste supply and removal. Hence even on surfaces of moderate relief a change from grass or forest to plowed field calls for constant vigilance on the part of the farmer, lest his surface soil be washed away. "Contour plowing" (furrows running around the slopes in level lines) is then recommended, so as to detain the surface wash.

If a small gully is cut in a hillside field by the run-off of a heavy rain, it should be clogged with stone and brush before it grows to ungovernable size. This matter is so important that an illustrated chart in explanation of it has been prepared for distribution by the U. S. Department of Agriculture, Washington, D. C.

The Forms Assumed by Stream-Swept Waste.

Alluvial Fans of Torrents. — The waste that creeps and washes down the sides of a valley is delivered to the stream that follows the valley floor. The form then taken by the waste depends largely on the behavior of the stream. A torrent receiving much coarse waste from a steep-sided ravine frequently sweeps so much of it into the main valley that it cannot all be carried away by the master river. The coarser part of the waste then accumulates in a cone-like form, known as an *alluvial fan*, spreading with even slope from the ravine mouth into the main valley.

Alluvial fans have a steep slope when formed by small torrents bearing a coarse and plentiful load. They have a flat slope when formed by large streams with a fine-textured load. They are small or wanting in very young valleys; they may grow to great size in maturely developed valleys.

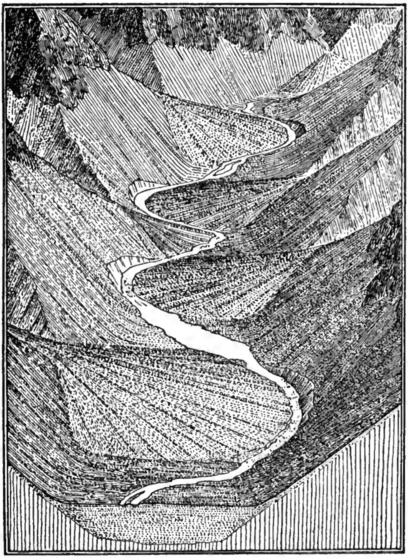

Fig. 177.—Alluvial Fans.

As a young ravine is gnawed into a lofty slope, the fan at its mouth may grow actively forward into the main valley. The fan then drives the master river against the further side of the valley, where it undercuts the valley wall. The fan still growing, the river may be obstructed and thus required to spread over the valley floor up stream from the fan, forming a shallow lake, while on the down-stream side the river descends in rapids over the coarsest boulders brought down by the torrent.

The growth of fans is well illustrated by those formed by torrents entering the east end of Lake Geneva, Switzerland, where excavations have discovered ruins of Roman settlements at a depth of 5 feet, and of the prehistoric "stone age" at a depth of from 15 to 20 feet. Here fan building has gone on at a rate of about 3 feet in 1000 years (Fig. 192).

The channel of a torrent on its fan is enclosed by low walls of coarse waste that is strewn on each side at time of flood. The torrent is thus naturally diked. When a great quantity of waste is brought from the upper slopes, the channel may be choked near the head of the fan. The torrent then switches off on a new course and enters the main river at a new point on the margin of the fan.

Two-Ocean creek, a small stream in the Yellowstone Park, has built a fan that forms a part of the continental divide. Sometimes the stream flows on an eastern radius that leads it to Atlantic creek (Missouri-Mississippi system), sometimes on a western radius, to Pacific creek (Columbia system).

In the Alps, villages are built and fields are cultivated on the fans of large size. When the torrent of such a fan is turned on a new course, it may flood fields and villages, causing much damage. A valley road traversing the fan is swept away where the torrent then crosses it, while the bridge over the former torrent channel is made useless.

Accidents of this sort are common in mountain regions. In 1896 a stream entering a lake in Switzerland overflowed its fan with a stony flood fed by a landslip in the head ravine. It laid waste a strip 2 miles long and over 300 feet wide at the forward end, covering it with a layer of stony mud 10 or 12 feet thick. The advance of this curious flood was sometimes so slow that the grass on the fields in front of it was saved by hasty mowing. Houses were pushed out of place, a road and a railroad were buried. For a time all travel had to go by boat on the lake. The people who lived on the fan had some compensation for their losses in carrying the thousands of visitors to and from the scene of the disaster.

A torrent usually gives much ground water to the loose-textured fan, and therefore decreases in volume on passing out of its rock-walled ravine. The ground water commonly reappears in springs near the base of the fan, and the spring line is often marked by a peculiar vegetation.

Filled and Terraced Valleys. — When a young stream has graded its channel, it begins to broaden its valley floor and form a flood plain by swinging from side to side, as has already been explained. It may then happen that the headwaters and upper branches, still gnawing into the uplands and dissecting them more and more thoroughly, bring a larger load of waste down their numerous gulches and ravines than the main stream can sweep down the moderate slope that it has adopted. Some of the increasing load is then laid down on the flood plain, steepening its slope, and thus hurrying the river to a velocity that enables it to carry the rest of the load. The flood plain thus grows higher and builds up on the valley sides. A similar effect is produced when the slope of the trunk river is lessened by a warping or tilting of the region.

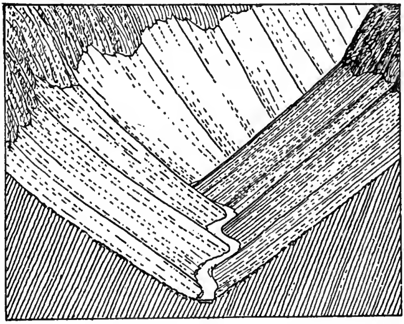

Fig. 178. — An Eroded Valley.

Fig. 178 illustrates a valley in steep mountains, cut down by a strong river. By increase of load from the headwaters, the river comes to be unable to carry along all the waste that it receives. The valley is thus filled with a growing flood plain, as in Fig. 179. The waste is here chiefly supplied by the headwaters, while in Fig. 177 it comes chiefly from the side streams.

The lower course of the Missouri river seems to flow on a growing flood plain, for its alluvial deposits are much deeper than its channel; here the waste is chiefly supplied from the upper waters of the main river.

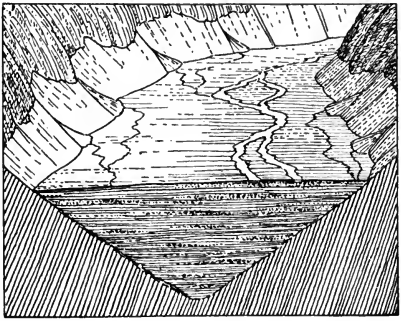

Fig. 179.—A Filled Valley.

Flood plains of gentle slope contain a deep layer of fine rock waste, an excellent soil for plants. The deep waste contains a large quantity of ground water. At every flood a new layer of waste is added to the surface, and the finest particles sink with the water into the ground. Thus the soil is naturally renewed, and its fertility is long enduring.

The Red river of Louisiana offers a remarkable illustration of a growing flood plain. Its headwaters, gnawing into the Llano Estacado of Texas, gather a greater amount of waste than can be carried down the gently sloping valley that the trunk river has developed in Louisiana. The trunk river is therefore slowly building up its flood plain. The building of the flood plain is aided by the growth of the famous "Red river raft," an accumulation of many fallen tree trunks that obstructs the river channel for a number of miles, dividing the current into many small channels, checking its flow, and causing the waste brought from the upper valley to settle.

So rapidly does the Red river build up its flood plain that its side streams cannot build up the plains in their valleys at equal rate; lakes, therefore, gather in the side valleys, like a series of leaves along the Red river stem.

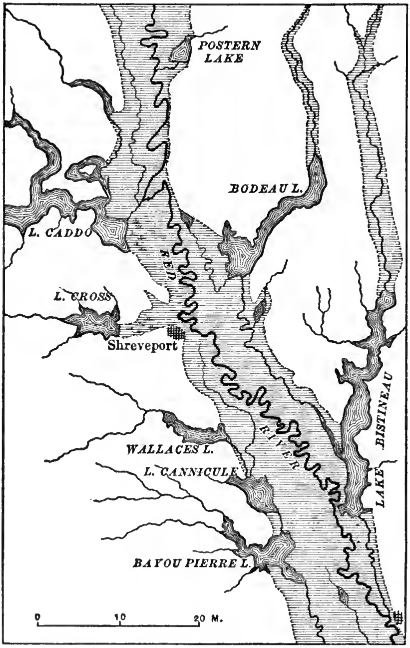

Fig. 180. — Flood Plain of Red River, Louisiana.

After filling its valley with waste for a time, a river may change its action and entrench its course in the built-up flood plain. The part of the plain then remaining above the new valley floor is commonly called an *alluvial terrace*, or simply a *terrace* (Fig. 181). The change in the action of the stream may be either because the supply of waste from the headwaters decreases, or because the lower course of the valley is deepened, or because the slope of the stream is increased by a warping of the region.

Terraces often afford excellent sites for villages, out of reach of floods; but these terraces are generally less fertile than the flood plains, for want of sufficient ground water.

Some of the inner valleys of the Himalaya, up stream from deep gorges, have been heavily filled with waste, producing plains several miles broad among the mountains. But the warping that caused the filling seems to have weakened or ceased long ago, for the rivers have now cut their outlet gorges so deep that the former flood plains are deeply trenched, in some places exposing their layers of sand and gravel to a depth of 3000 feet, and thus forming gigantic terraces.

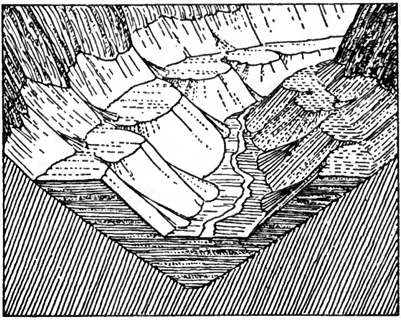
Fig. 181. — A Terraced Valley.

Waste-Filled Basins. — Where rivers have worked long enough, they destroy the lakes of their youth, partly by depositing sediment in the basins, partly by cutting down


Fig. 182. — A Lake-Floor Plain.

the outlet; that is, by filling and draining the lake basin. The lake is then replaced by a plain watered by inflowing streams from the head and side slopes, and drained by a river which escapes through a narrow outlet valley, often rock-walled and gorge-like.

Lake Erie has a smooth floor covered with fine sediment. When the lake waters are withdrawn by the sufficient lowering of their outlet, the lake floor will be revealed as a smooth plain.

The best agricultural land in the neighborhood of Mt. Shasta, Cal., is found in the flat-bottomed basins, or "meadows," which represent the waste-covered floors of lakes that were

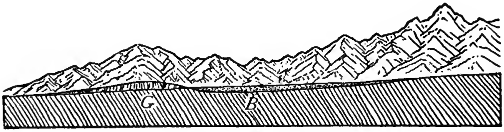

Fig. 183.—A Warped Valley.

formed by lava-flow barriers from the neighboring volcano. The discharge of some of the lakes is so recent that their meadows are still too swampy for occupation.

The effect of warping movements of the earth's crust in making streams fill up one part of their valley and wear down another has already been mentioned. Filled valleys and trenched gorges of this origin are characteristic of lofty ranges where mountain growth is still in progress. The gorges are often so steep as to be impassable; but the filled depressions are important because they offer dwelling places to mountain peoples.

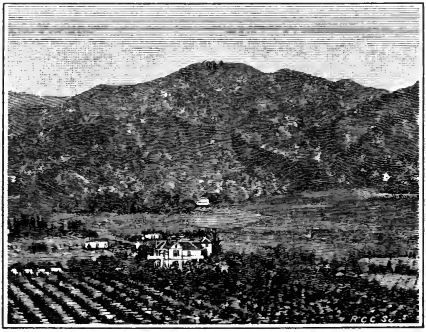

Fig. 184.—A Waste-Filled Basin, Southern California.

The upper Arkansas valley, back of the Front Range of the Rocky mountains, is a warped basin, floored by plains of waste that slope forward from the mountain sides. The river has cut through the enclosing range in a deep canyon, called the Royal Gorge, now followed by a railroad. In the future the deepening of the canyon (where the river is now actively wearing down the rocky bed) may permit the upper river to dissect the basin plains ; but at present such dissection is only just begun, dividing the valley into low bench-land and flat flood plains.

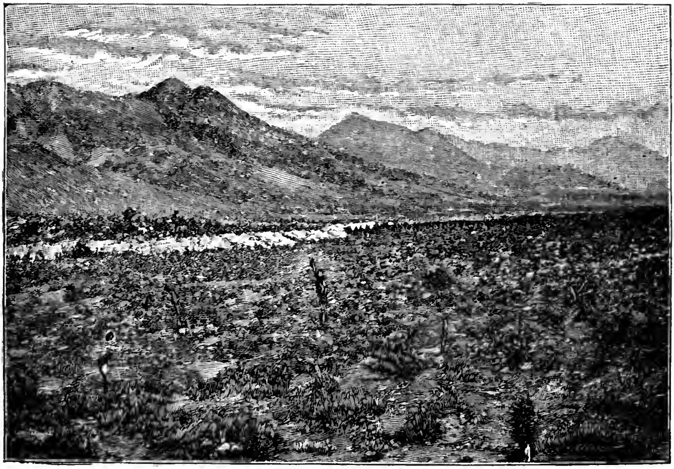

Fig. 185. — A Plain of Mountain Waste, Southeastern California.

At first sight a warped and filled valley of this kind would be taken to mark the place of an extinct lake ; but it is very probable that in many cases the warping of the valley was so slow that no lake was produced, the depression being filled and the uplift being cut down as fast as the warping proceeded.

The waste from the mountains is here detained for a time in its journey to the sea, and in this respect the waste of a filled basin resembles the water of a lake. But just as the lake is short-lived compared to the mountains, so the waste-filled basin is only a temporary feature. As the outlet valley is deepened, the journey of the waste toward the sea will be resumed, and in due time it will reach its goal.

Fig. 186. — A Meandering River, Vale of Kashmir.

The Vale of Kashmir, enclosed by the outer ranges of the Himalaya in northwest India, is a famous example of this kind. It is a waste plain in a broad basin, of area about equal to that of Connecticut, occupying a down-warped district between lofty mountains. Many streams gather from the mountains and unite to form the Jhelam river, which meanders across the plain (Fig. 186) and escapes from the west end of the vale by a deep gorge through the enclosing range.

The outlet gorge has been cut a little below the general level of the plain, allowing the streams to entrench their courses to a moderate depth, and thus forming many fertile flood plains. A shallow lake (Wular) lies near the outlet, as if not yet filled, or as if lately produced by renewed warping.

Until recent years the only access to this beautiful vale was by a high pass over the outer range; but now a road leading through the gorge has been made by British engineers. Although difficult to construct and to maintain, it has greatly facilitated traffic and trade between the vale and the outer plains.

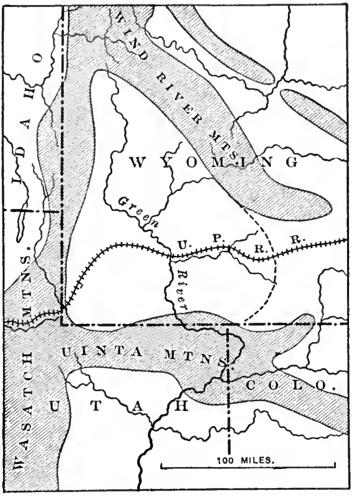

Fig. 187. — The Green River Basin, Wyoming.

The oval plain of Hungary, about 200 miles in diameter, is a fine example of a filled basin enclosed by mountains. The inflowing rivers have cut down their flood plains a little below the level of the gravelly marginal slopes; but they wander freely over the central plain of fine silts (Fig. 154). The outlet, where the Danube has cut the gorge of the Iron Gate through the Transylvanian Alps, has long been obstructed by rocky rapids, recently blasted away to improve navigation. Although the plain has many resemblances to the floor of a former lake basin, the deposits on its surface all appear to have been formed by river action.

Green river basin in southwestern Wyoming is an extensive depression measuring over 100 miles in diameter. Its heavy deposits of waste, once washed in from the surrounding mountains, are now deeply dissected; for the outflowing Green river has cut a deep canyon through the enclosing Uinta mountains on the south. The formerly even floor of the waste-filled basin has been converted into a dissected upland, with valleys sometimes 1000 feet deep. Much of the long-detained waste has gone forward again on its way to the sea. Being dry as well as rugged, the basin is of little value for settlement, except where beds of coal attract mining or where irrigation is possible in the valleys.

Flood Plains of Large Rivers. — The flood plain of a large river is formed at such a slope that its gain and loss of waste are about equal. Loss is caused chiefly by cutting away the outer bank of the curving channel, where the current runs rapidly. Gain is caused by adding waste on the inner bank of the curves, where the current is slowest; and also at time of flood when the river deposits much waste on the plain near the banks of the channel, where the first loss of velocity in overflow greatly decreases its carrying power. The flood plain is in this way built up chiefly near the river, and its surface therefore has a faint slope to the right and left of the channel banks.

On the Mississippi flood plain the slope away from the river, east or west, is 5 or 10 feet to a mile. This is much greater than the general southward slope of the flood plain, which is under half a foot to a mile.

As a consequence of the gentle slope of a flood plain away from the river banks, the sides of the plain are poorly drained and are often occupied by back swamps. Villages on broad flood plains are frequently located close to the river bank, where the plain is highest.

A large river seldom receives small tributaries while flowing through its flood plain; for small streams cannot enter it against the side slope of the plain. Indeed, many small streams may rise on the plain and run obliquely away from the main river, joining streams from the uplands, and following the lowest available channel through the back swamps.

A remarkable example of this kind is seen on the Mississippi flood plain, where the trunk of the Yazoo river system, gathering little branches from the uplands on the east and from the flood-plain slope on the west, flows about 180 miles through the back-swamp district, unable to enter the main river. The Yazoo might pursue an independent course all the way to the gulf, if the Mississippi did not happen at present to swing across to the bluffs at the eastern side of the flood plain (where Vicksburg is located in order to be near the river), and there take in the Yazoo.

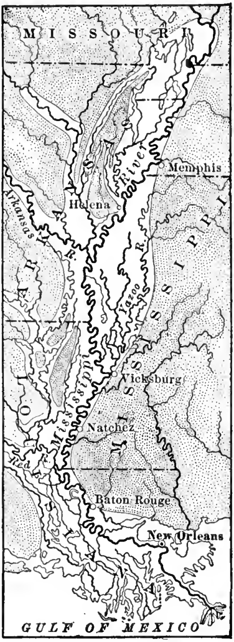

Fig. 188. — The Mississippi Flood Plain.

The waste on a flood plain rests for long periods after it is deposited at times of river overflow. When the plain is cut away as the river channel shifts, the waste moves a less or greater distance forward to another resting place, wearing and weathering finer and finer as it travels slowly down the valley.

The flood plain of the middle Rhine in western Germany is a fertile belt of land, occupied by a large agricultural population, between forested uplands on the east and west. The river has been "corrected," that is, turned from its meandering course into a nearly straight channel; its banks are diked so as to prevent overflow. It is possible that another century may see the vast flood plain of the Mississippi thus made much more available for occupation than it now is.

Stony flood plains may be formed in relatively steep valleys, if they are actively supplied with coarse waste from their head and side slopes. Although washed by streams of rapid current and torrential behavior, such flood plains belong in the same class of forms with the fine-textured flood plains of large rivers. The slope of the plains and the texture of their materials are unlike; but the fact that both are flood plains formed by their streams gives them a close relationship.

Alluvial Fans of Large Rivers. — When large rivers flow from mountains or plateaus to open lowlands, where no valley walls enclose them, they may build extensive alluvial fans of faint slope. The Merced river of California (see *M*, Fig. 190) offers a good illustration of this habit.

The Merced gathers much waste from its steep headwaters in the Sierra Nevada. On issuing from its narrow valley at the mountain base, it is free to turn to the right or to the left on the broad "valley of California," a low trough between the Sierra and the Coast range. Here the river has built a fan of about 40 miles radius, of gravel near the mountains, of fine silt farther forward.

The rain of this region falling chiefly in winter, it is necessary to irrigate the fields for summer crops. Nothing could be better adapted to the needs of irrigation than a gently sloping alluvial fan; for the river may be easily turned into various channels at the head of the fan and led forward on different courses, and thus distributed over thousands of acres. The fan of the Merced was a cattle range under Spanish occupation in the first half of the nineteenth century; it became a wheat region in later years; and since irrigating canals have been constructed, it has been largely planted with fruit orchards.

One of the largest alluvial fans in the world is that of the Hoangho, in eastern China. This great river, bearing a heavy load of fine silt from the basins among the inner mountains, issues from its enclosed valley 300 miles inland from the present shore line, and at a height of about 400 feet above sea level, and then flows to the sea down the gentle slope of its extensive fan.

The great fan of the Hoangho is very fertile, and supports one of the densest populations of the earth; but it is subject to overflow on a vast scale, when the river suddenly changes its course from one path to another, and invades fields and villages on a new course to the sea. Overflow is restrained as far as possible by dikes; but the channel has repeatedly been changed during the many centuries of Chinese history. The mouth of the river has thus been shifted more than 200 miles north or south. The hilly district of Shantung, once an island, has been converted into a peninsula by the forward growth of the great fan.

"The destruction caused by these overflows is awful beyond description; the loss of life is very great, and the destruction of crops that form the means of support of millions produces famine and the overrunning by starving hordes of the more fortunate districts of the adjacent country. The anarchy that rules in this struggle for life is almost beyond the conception of those who inhabit lands where the population is much below the capacity of the country, or which are easily reached by foreign supplies."

During wars "the river has been turned to account as a weapon of offence. Breaking the embankments has been made to accomplish, almost instantaneously, by the destruction of hundreds of thousands of inhabitants, conquests that had been delayed by years of brave resistance." The flood of 1887 covered an area estimated at 50,000 square miles, immensely fertile and swarming with villages. The number of people drowned was at least a million, and a greater loss followed from famine and disease caused by the flood.

River-Made Plains. — When many rivers flow forth from mountain valleys upon a neighboring lowland, their adjoining fans unite in a broad plain sloping gently forward from the mountain base.

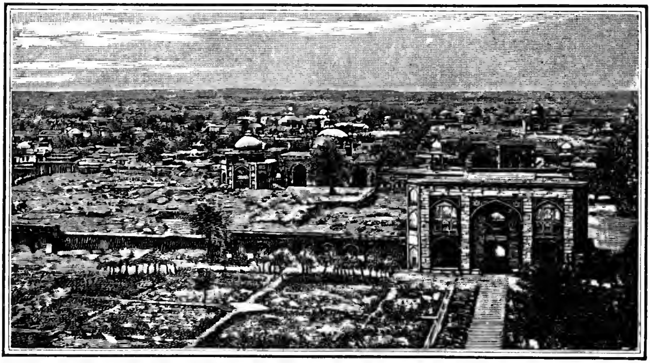

Fig. 189. — View on River-made Plain of Northern India.

This may be called a river-made plain, in distinction from coastal plains, lava plains, and worn-down mountain lowlands. A river-made plain often occupies the depression between two highlands or mountain ranges, as between the Himalaya and the plateau of southern India; it will then slope from each side toward a midway depression. The streams from the various fans will be gathered by a trunk river meandering along the depression.

The many rivers issuing from the valleys of the Sierra Nevada and the Coast range upon the "valley of California" have formed an extensive plain, of which the Merced fan, described above, is only a part. The successive fans are so broad and flat that their slightly convex form can hardly be recognized without the aid of surveying instruments. Nearly all the streams run in shallow channels but little beneath the gently sloping surface of the fans. The fans from the east and west meet in a broad flat-floored trough.

The trunk river in the depression of a two-sided river-made plain is pushed away from the base of the higher mountains by the stronger forward growth of their fans. The fan of a large stream may form a low barrier across the path of the trunk river and enclose a shallow lake.

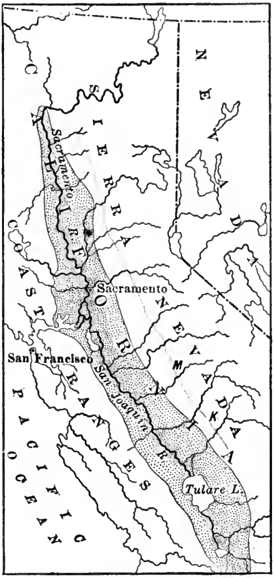

Fig. 190.—The Valley of California.

The San Joaquin river, gathering streams from the Sierra Nevada and Coast range in the southern part of the "valley of California," lies nearer to the lower mountains. The upper streams of the "valley" have been ponded back by the fan of King river (*K*, Fig. 190), forming Tulare lake, a shallow water sheet with indefinite marshy shores much overgrown with reeds (Spanish, *tules*).

Extensive river-made plains built upon piedmont lowlands are the natural accompaniment of deep valleys excavated in the lofty mountain background. The waste taken from the latter has supplied the material for the growth of the former. The two are found together in many parts of the world.

Extensive river-made plains have been formed both north and south of the Alps. On the south, the Po runs between the broad plain built forward from the valleys of the high Alps and the narrow plain built from the valleys of the lower Apennines. Many of the streams here are somewhat entrenched beneath the general level, having begun to cut valleys in the plain they had previously built up. Near the Alps the material of the plain is coarse ; rain and streams sink into the ground, and the surface is relatively dry and infertile. Further forward the ground water issues in numerous springs, and the rest of the surface is very fertile and densely populated. The "spring line" separates these two parts.

North of the Alps the branches of the Rhine and the Danube are entrenched in an uplifted river-made plain that was built when the region stood at a less elevation. Some of the valleys are 1000 feet deep, and the former plain is here reduced to a series of ridges extending forward between neighboring valleys.

Deltas. — When a river enters a lake or the sea, its current is checked. The finest part of the waste may be swept away by waves and tides ; the rest accumulates at the river mouth and builds up a new land surface, called a *delta*, in advance of the original shore line. Small deltas are characteristic of young rivers; the longer the progress of river growth without interruption by uplift or depression, the larger the delta may become.

When rivers bearing fine waste enter the sea, the settling of the waste is favored not only by loss of velocity, but also by the presence of salt in the sea water, which causes suspended sediments to settle faster than they would in fresh water.

The land surface of a delta is built on the same slope as that of the river flood plain further up stream, the delta being only the forward part of the flood plain.

The great fan of the Hoangho may be regarded as its delta, because it has been built forward into the Yellow sea (so named from the color given by the river waste); but it cannot be said that the whole area of the fan was once occupied by the sea; part of it may have been built on land.

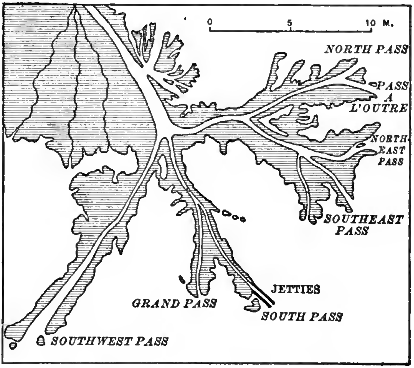

Fig. 191. — The Delta of the Mississippi.

A river frequently splits into several channels on the convex surface of its delta; the outgoing branches being known as *distributaries*. These are well exhibited in the finger-like division of the Mississippi on its outer delta (Fig. 191), and in the many channels of the Ganges and the Brahmaputra on their compound delta at the head of the Bay of Bengal.

The deltas of large rivers consist of fine-textured waste or silt, worn during the long journey from the river headwaters, and weathered during many rests in the flood plain on the way. In a favorable climate deltas are very fertile and attract a large population. The three densest populations of the world (outside of large cities) are in eastern China, northeastern India, and northern Italy ; all on the lower flood plains and deltas of large rivers.

Although attractive on account of fertility, deltas are subject to dangerous overflows from land and sea. River floods spread over them, unless kept off by extensive dikes such as have been built on the above-named deltas.

Sea floods on deltas are also destructive. When low atmospheric pressure and on-shore hurricane winds happen to occur with a strong high tide, the sea water may rise over the shore dikes and overflow great tracts of delta plain. One hundred thousand people were drowned on the delta plain of the Ganges and Brahmaputra, India, by a sea flood during a severe storm in 1876.

The deltas or fans of torrents descending directly from mountains into the sea are of coarse stony texture, relatively unattractive for settlement. Many torrent deltas, the forward part of stony fans, are formed at the base of mountains on the coast of Japan.

The rate of growth of deltas depends on the ratio between the volume of waste brought by the river and the activity of the waves and currents on the shore. Great rivers may build their deltas in the face of waves and tides. The building of deltas by smaller rivers is favored by protection from waves in bay heads and by weaker tides.

The deltas of various large rivers are built in seas having distinct or strong tides. At the Mackenzie delta the tidal range is 3 feet ; at the Niger, 4 feet ; at the Hoangho, 8 feet ; at the Ganges-Brahmaputra, 16 feet.

The forward growth of deltas often partly fills the embayments of half-drowned mountains, as may be seen in many of the fiords of British Columbia. The delta plain of Fraser river is a fine example of this kind. Outlying islands are sometimes tied to the mainland by the forward growth of deltas. Several examples of this kind are known in the Mediterranean.

Rivers of comparatively small size build deltas in the protected bays of (nearly) tideless seas. Deltas are therefore common in the bay heads of Greece; here the partial submergence of a mountainous country has produced a ragged shore line in a sea where the tidal range is small; many of the bay heads have been much shortened by delta growth. The sloping delta plains contain a large part of the coastal population.

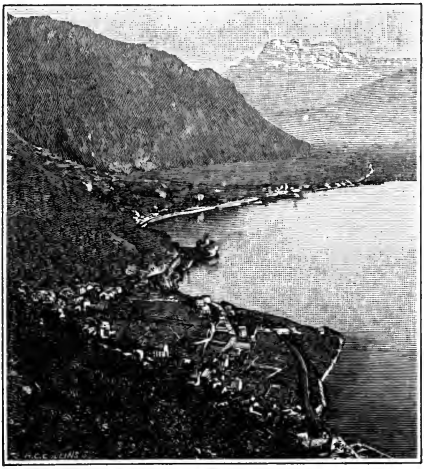

Fig. 192. — Torrent Fan, Lake Geneva.

Small streams may be strong enough to build deltas in lakes. In Lake Geneva, Switzerland, many torrents have built sloping fan deltas in the quiet waters. The fans are generally occupied by villages. When large buildings are erected close to the water's edge, the delta margin is overweighted, and it may slip into the lake. Numerous accidents of this kind have occurred.

The absence of deltas at the mouths of certain rivers is frequently not so much on account of the action of tides in sweeping away the river silt, as because there has not been time enough to build a delta since the present position of the land was taken.

The lower valleys of the Delaware, Susquehanna, Potomac, and neighboring rivers are drowned, forming bays in the partly submerged coastal plain of the middle Atlantic states. Whatever deltas these rivers previously built are now beneath the sea. Soundings in the lower Delaware bay have, it is believed, discovered a drowned delta traversed by the channels of several distributaries. Very little delta growth has yet taken place at the bay heads; hence it must be concluded that the depression of the region is recent; it may still be in slow progress.

Very large rivers may build forward their deltas in spite of a slow depression of the coastal region. Thus the delta of the Mississippi has actively advanced into the gulf waters; while Galveston bay on the west and Mobile bay on the east indicate a moderate depression of the region, which the relatively small rivers entering those bays (formerly valleys) could not wholly counteract by delta building.

Dissected Deltas. — When a region is broadly uplifted, as in the formation of a coastal plain, the deltas of the former shore line will be dissected by the rivers that built them. Such deltas are seldom conspicuous forms, unless built of coarse waste with a steep front slope.

During the submergence in which the topmost layers of the Atlantic coastal plain were deposited, the Delaware built a gravelly delta at Trenton, N. J. Since uplift, the river has trenched the delta, forming terraces on each side of its new valley. It is probable that many similar dissected deltas occur along the inner margin of the Atlantic coastal plain.

CHAPTER XI.

CLIMATIC CONTROL OF LAND FORMS.

The Several Classes of Climatic Controls.

Direct Climatic Controls. — An earlier chapter contains a brief description of the several zones into which the earth's surface may be divided on account of the unequal action of sunshine on its globular surface. The average atmospheric temperatures prevailing in the different zones are certainly among the most important geographical controls that are exerted upon man's ways of living. The distribution of rainfall has also been shown to be an important agent in determining whether a region may be fertile or barren, populous or deserted. Climatic controls of this class, depending on the physical condition of the atmosphere as to temperature, moisture, and movement, act directly on plants, animals, and man, and greatly influence their distribution.

Indirect Climatic Controls. — All the controls exerted on man's ways of living by the various forms of dissected land surfaces are, in a certain sense, indirect climatic controls, for they result from the action of weathering and washing, and these processes are in turn controlled by climatic conditions. The examples of land forms thus far given have been mostly taken from regions of ordinary climate, neither very dry nor very cold, and with rainfall sufficient to fill all basins to overflowing. A number of examples now follow in which the peculiar effects of dry and of cold climates are described. It will be shown that the forms of the land and the condition of its surface vary greatly according to their origin under an ordinary, a dry, or a cold climate.

Changes of Climate. — One of the most remarkable results of this division of geographical study is the discovery that certain existing land forms have been produced under climatic conditions quite unlike those prevailing to-day. There are regions, now dry and barren, where the marks of a former moist climate are very apparent. There are others, now fertile and populous, where the marks of a former cold climate are no less distinct. Not until these curious changes in climate are recognized can the great variety of land forms and the controls that they exert on the earth's inhabitants be clearly understood.

Effect of Dry Climate on Streams and Rivers.

Ledges and Waste Slopes. — Certain parts of the world have so little rainfall that vegetation is nearly wanting. Here rock waste washes and creeps freely down the slopes, not being detained by vegetation long enough to be weathered to fine texture. Narrow valleys among arid uplands are therefore encumbered with stones and gravel. The small streams must maintain a strong slope in order to carry forward their heavy load.

As a consequence, the dissected uplands of arid regions possess a large proportion of bare rock ledges, such as have been described in the plateaus of Arizona. Their rugged forms must be worn to more gentle slopes before they are covered with waste.

The desolate gray forms of desert mountains, like the ranges of northwest Mexico (Sonora) and of northern Chile (Atacama), are much less picturesque than the snowy summits and forested flanks of mountains in a moister climate.

Streams of Dry Climates. —When a light rain occurs in a region of dry climate, much of the water returns to the atmosphere by evaporation, a large part of the remainder sinks into the thirsty soil, and the run-off by streams is small. Much of the ground water evaporates underground and passes from the soil as water vapor, instead of coming out in springs. When a heavy rain occurs, the streams are flooded; but the water soon runs away, leaving the channels dry again.

The streams of dry regions are, therefore, very variable in volume; active for a while after a rain, almost or quite disappearing in the long dry seasons, advancing far down their lower courses when in flood, then dwindling and withering away and leaving their lower channels dry.

In the Sahara dry water courses, known as *wadies*, are commonly used for roads, as their defiles frequently offer graded ways through rocky uplands. Death by drowning would nowhere be so little expected as in a desert; but it sometimes happens that a caravan, following a wadi through an upland, meets a down-rushing flood fed by rainfall in the distance; and before the travellers can climb the steep walls of the defile they may be overwhelmed and drowned.

In parts of the Rocky mountain region, of generally dry climate, heavy rains occasionally fall in summer. Then for a few hours the dry channels are flooded with a rushing turbid stream, that sweeps away the waste that had been washed in by lighter rains. Camping parties, pitching their tents too near a channel that was nearly dry in the afternoon, may be overwhelmed by a rushing flood at night. Fig. 193 illustrates

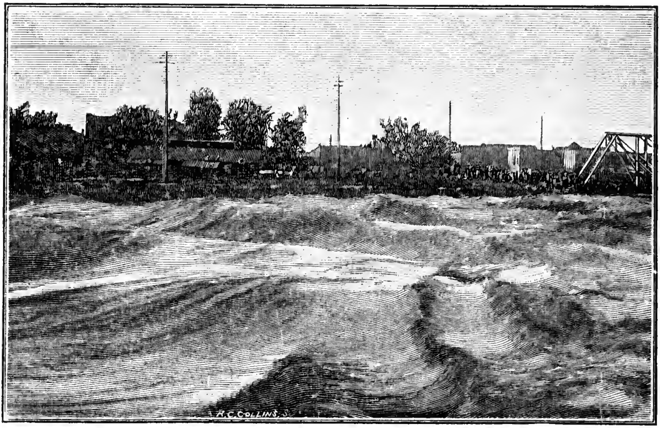

Fig. 193. — Flood in Cherry Creek, Denver, Colorado.

a sudden flood in Cherry creek, where it passes through the city of Denver, Col. The channel of the creek was dry half an hour before this raging torrent rose.

Streams that are supplied by springs in uplands and mountains frequently diminish in volume, partly by evaporation, partly by sinking into the ground, as they advance over arid lowlands. They may wither away and disappear entirely from the surface; but their flow is usually continued as ground water for some distance beyond their visible end. Their load of waste is spread on the surface before them; hence the lower parts of many streams in arid regions build up the surface they flow upon, even though high above baselevel.

Certain rivers of Argentina have not volume enough to carry them across the pampas to the sea. Rising in the mountains, they entrench their valleys 100 feet or more beneath the surface of the pampas for some distance, and here are the chief settlements, such as the city of Cordoba on the Primero; then, dwindling in volume, they flow out upon the pampas, ending in marshes.

Flood Plains in Deserts. — Rivers that rise in well-watered regions sometimes flow across deserts on their way to the sea without receiving branches for long distances, and decreasing by evaporation as they advance. If the rivers have developed open and accessible valleys, nearly all the population of the region is gathered on their flood plains.

The most famous river of this kind is the Nile, which flows 1000 miles without receiving a branch, except a few small wet-weather streams. Its flood plain, entrenched beneath the desert uplands, is about 500 miles long and from 5 to 15 miles wide, broadening on the delta to over 100 miles. Here most of the millions of Egyptians dwell. Their resources are almost wholly agricultural, and as such depend on the annual inundation of the Nile, caused by the northward movement of the belt of equatorial rains in summer. The river flood begins in June, usually rising 25 feet or more at Cairo in late summer or early autumn. For thousands of years the fertility of the flood plain has been maintained by the annual additions of river silt, estimated to amount to 4½ inches a century.

The southward course of the lower Colorado has few branches for about 300 miles. Its water supply comes chiefly from the mountains and high plateaus in its upper basin. The sediments swept from its canyons have built a delta across the depression that holds the Gulf of California. The former head of the gulf, thus isolated from the rest, has been dried out, leaving the arid Coahuila basin in southernmost California, its central part being 300 feet below sea level.

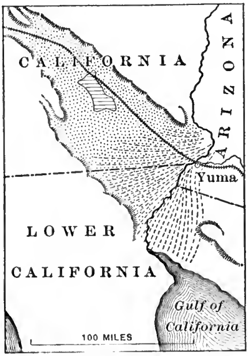

Fig. 194. — Diagram of the Colorado River Delta.

Sometimes a distributary of the Colorado, called New river, turns northwest into the basin, forming a lake, as in 1891. If the lake rises high enough, it overflows southward along the western margin of the delta, this outlet being called Hardy's Colorado; but as a rule its channel is dry.

On the desert slopes of the Andes in western Peru nearly all the population is gathered on the flood plains of rivers that descend from the mountains to the Pacific. Some of the rivers, like the Piura in northern Peru, run dry for part of the year. When the wet season comes, travellers from up the valley are anxiously asked if the river is beginning to flow. As its refreshed stream approaches the town of Piura, bands of people go out to meet it, marching back with its advancing current and celebrating its arrival by a public

Fig. 195. — A River Valley in Desert Mountains, Peru.

holiday. All the fields and gardens of the valley are watered by canals led from its channel.

Bad Lands. — When fine-textured, unconsolidated deposits, such as lake silts, suffer dissection in an arid climate, they acquire an extremely irregular surface;

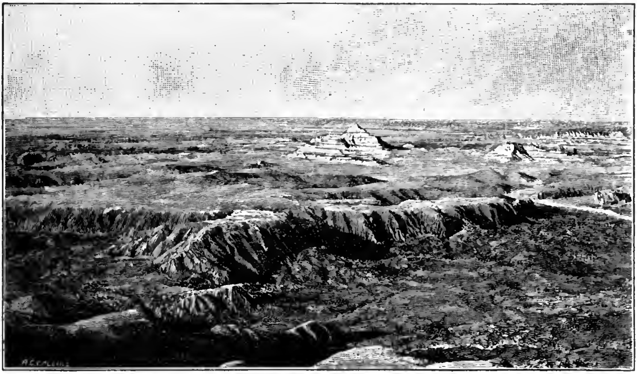

Fig. 196. — Bad Lands.

hence their name, *bad lands*, originally applied on account of the difficulty of travelling over them. The absence of vegetation allows the formation of numerous rivulets when rain falls. Every rivulet carves a channel, thus dissecting the surface in minute imitation of a maturely dissected plateau.

The bad lands of South Dakota and Wyoming are best developed near the branches of the Missouri river system; the wet-weather streams here actively dissect the uplands in which the larger rivers have entrenched their valleys. As the rainfall is light, vegetation is almost absent and no loose soil remains on the dissected surfaces; all the loosened waste is washed into the valleys of the chief rivers.

During the third quarter of the nineteenth century, the Sioux Indians made use of these bad-land districts as natural fortresses, in which pursuit was difficult; here were fought some of the last battles in the unhappy warfare of settlers and soldiers against the native tribes.

Interior Drainage Basins.

Continental Interiors. — Regions situated far inland, remote from moist sea winds, receive light rainfall. In such regions a warping of the earth's crust or a mountain folding may produce great or small basins faster than the feeble rivers can fill them with water or waste, and may raise high barriers faster than rivers can cut gorges through them.

It is in good part for this reason that the rivers of continental interiors so often discharge their waters into enclosed depressions, and fail to reach the sea. On this account, as well as because of diminished volume, the rivers of arid regions are largely busied in building up their lower courses.

The interior basins of Utah, Nevada, Arizona, and Mexico, having light rainfall, fail to support vigorous rivers. Warping and faulting of the earth's crust in this region have produced many enclosed basins; hence the name, Great Basin region. The rivers might easily overflow to the sea under a more generous rainfall.

Many streams descend from the mountains of the basin region and wither away on the sloping waste plains, failing to unite in a trunk river along the trough line between the ranges. Where the streams are a little stronger, a feeble trunk river may be formed, only to wither away as it flows toward the lowest part of its basin.

Salt Lakes. — An interior basin receiving a moderate water supply will contain a lake in its lowest part. The lake, having no outlet, must have such an area that evaporation from its surface shall equal the supply from inflowing streams. Lakes of this kind are usually salt, for all the saline substances gathered in small quantity by the inflowing streams accumulate in the lake and may in time constitute a fifth, or even a third, by weight of the lake contents.

Great Salt lake of Utah, with about 18% of salt, is of this kind, lying on the lowest part of the waste plain that has been built up in the depression among several mountain ranges. Its waters are so dense that a man's body will not sink beneath the surface. The Dead sea, with 24% of salt, is one of the most famous salt lakes, occupying a long, narrow depression in Palestine; its surface is 1300 feet below the level of the Mediterranean. Lake Van in eastern Turkey, containing 33% of salt, is the densest water body known.

As the inflow of salt lakes is disposed of by evaporation, their depth and area vary with change of weather and season. When their shores are flat, as is usually the case, the shore line may shift several hundred feet between the wet and the dry seasons; the strip of land laid bare at the low water stage is charged with salts; it may bear a peculiar vegetation or may be covered with a saline incrustation.

Unlike lakes among mountains, salt lakes lying in shallow basins surrounded by arid plains are not elements of beauty in the landscape. Settlements are seldom made on their unattractive shores. An explorer describes Lake Shirwa in southeast Africa as a shallow sheet of foul salt water, lying in the flat central depression of extensive alluvial plains, its margin occupied by great malarial marshes. All the unpleasant features of a torrid quagmire are accented around its dismal shores, where crowds of flamingoes, cranes, and screaming water birds, jostling one another for room, only add to the depressing nature of the scene.

Playas. — In interior basins where no permanent lakes occur, the larger rivers may, at time of flood, reach the lowest depressions and there spread out in shallow temporary lakes, which soon disappear in clear and warm weather. The silt brought by such rivers is spread over the depression and thus forms a broad plain of remarkably smooth surface, called a *playa.*

One of the largest playas in the Great Basin region is known as Black Rock desert (*B*, Fig. 205), in northwest Nevada. It measures about 100 miles in length by 12 or 15 miles in breadth. It is overflowed in winter by the extension of Quinn river; but so level is the plain that the playa lake is seldom more than a few inches deep. The wind stirs the water and raises the fine silt of the plain, making the water turbid; the lake is then hardly more than "a vast sheet of liquid mud." In summer the playa is smooth and dry, hard baked by the sun, and perfectly barren; one of the most desolate and monotonous surfaces in the world.

Salinas. — Certain basins that formerly contained salt lakes have now been more or less completely dried out, leaving marshy or dry plains of salt, known as *salinas*, in the central depressions, avoided by all plant and animal life.

The Bolivian tableland, a lofty waste-filled basin lying between two great ranges of the Andes, holds Lake Titicaca in its northern part at an altitude of 12,500 feet. The outlet flows 100 miles southeast to a shallow marshy salina about

50 miles long. The water not evaporated here flows southwest and is lost in a broad salina of dazzling white surface. Somewhat further south is a more extensive salina, 4000 square miles in area, a white and level plain covered with a layer of salt about 4 feet thick, impassable when wet, but firm in the dry season.

Salt lakes and salinas yield common salt and other minerals of commercial value. Great Salt lake is estimated to contain 400,000,000 tons of salt. These products would be of greater utility if they did not so generally occur in thinly populated, desert regions.

The Development of Interior Basins. — Just as only a little waste has been worn from the uplifted blocks of young mountain ridges, so only a little waste has been washed into young basins from their rims. Alluvial fans have begun to grow forward around the margins of the basins, and the finer waste is spread to a moderate depth over their floors.

The bottom of the trough occupied by the Dead sea is about 2600 feet lower than the level of the Mediterranean. Ravines in the border of the uplifted plateau on the east lead down to stony fans that are advancing into the sea. But the great depth of the water and the moderate extension of the fans show that the basin contains much less waste now than it will in the future.

Interior basins enclosed by deeply dissected mountains have received the waste that the inner slopes of the mountains have lost. The floors of the basins have in this way been built up and smoothed. By the wearing down of the mountains and the filling of the basins the relief of the region as a whole has been decreased.

Large alluvial fans of coarse waste with distinctly sloping surface are characteristic features of well-filled arid basins. The head of the fan may rise 500 feet above its rim, and its slope may stretch 10 or 15 miles forward from the mountain valley in which it heads. In this way, these arid valleys, like lake basins in moister regions, are gradually being filled with delta-like accumulations of waste.

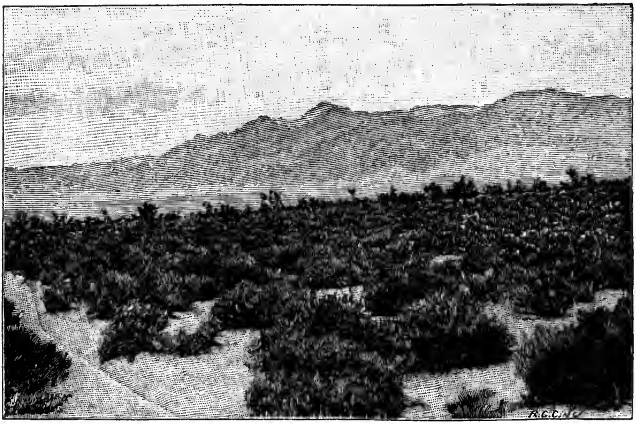

Fig. 197 —Part of an Alluvial Fan, Death Valley, Southeastern California.

The water of mountain torrents is often completely lost in the coarse waste of the fans, whose deeper parts thus gather much ground water. By driving tunnels near the base of the fans the water may be reached and brought out to irrigate the lower slopes. This method has been used for centuries in Persia and northwestern India. It is now employed in southern California, where fans of great size are formed at the base of the mountain ranges.

When many neighboring alluvial fans are spread forth at the base of arid plateaus and mountains, they unite in a long gravel-covered slope resembling a river-made plain, but of steeper descent. The surface becomes less and less steep, and the waste less coarse, the farther the slope extends forward.

Extensive stony slopes of this kind occur in the depressions between the desert mountains of Utah, Nevada, and Arizona. The waste fills the depressions to great depths, and backs up 2000 or 3000 feet on the flanks of the mountains.

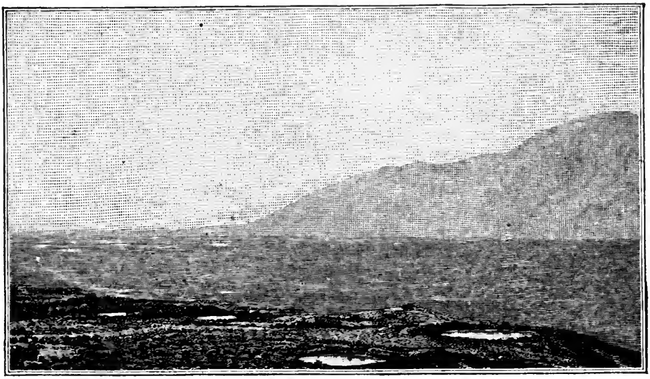

Fig. 198. — Half-Buried Mountain Range, Nevada.

If the depression between the mountains is of small breadth, the gravel slopes grow forward till they meet in a rather well-marked trough line ; here a stream may flow in the wet season. If of great breadth the slopes grade into a dreary plain, with occasional springs around its margin and temporary lakes in the center.

Opposite the mouths of canyons, trains of coarse waste, including boulders weighing many tons, are spread forward by floods from cloud-bursts in the mountains — "immense, sudden, deluging rainstorms, which at rare and exceptional moments discharge their waters into one of these mountain gorges. On such occasions boulders 6 or 8 feet in diameter are swept down the canyon in a fearful rush, and are sometimes carried out on the . . . slope for half a mile." At other points the slope is trenched from 50 to 200 feet deep opposite the canyons, revealing its stony structure.

The farmer ant is one of the most remarkable and numerous of the few forms of animal life on these stony slopes in the southwestern United States, near the Mexican boundary. Each "farm" includes a clean threshing floor, from 5 to 30 feet across, with a belt of grass around it, and a passage to the underground dwelling in the center. "Roads" a foot wide connect the "farms" across the grass rings for hundreds of feet; the "farms" may cover nearly all the surface over scores of square miles.

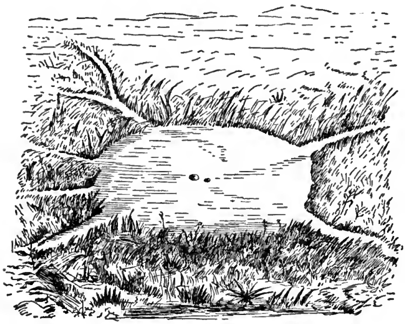

Fig. 199.—Home of the Farmer Ant.

In such a farming district other plants, common in the surrounding region, are carefully kept out by the ants. The grass is their food crop, as they live on its seeds. If the crop failed, they would die of famine by millions. The grass would greatly decrease if it were not cultivated and the other plants destroyed.

As the waste from the higher enclosing mountains is washed into great interior basins, the smaller ridges may be nearly or quite buried. Many small basins, originally separated by ridges, may thus be converted into a few large basins; in time all the basins may unite in a single depression, which will then receive the drainage and waste from all the surrounding region.

A great part of Persia consists of large basins enclosed by mountains and without outlet to the sea. Long waste slopes stretch forward 5 or 10 miles with a descent of 1000 or 2000 feet, stony near the mountain flanks, and gradually becoming finer-textured and more nearly level. The central depressions are absolute deserts of drifting sands, with occasional saline lakes or marshes. The population gathers around the margin of the basins where water is still to be found, avoiding the rugged and barren mountains on the one hand, and the uninhabitable central plains on the other.

Central Asia repeats the same conditions on a still larger scale. The basin of Eastern Turkestan includes many half-buried ranges in its central part. It is quite possible that some ranges are completely covered with waste. Many rivers flowing from the mountain rim wither on their way towards the chief central depression; only the largest river (Tarim) reaches it, there spreading out in Lob Nor (Lob lake). The chief settlements are near the border of the basin, where the larger rivers come out from the mountains.

Outward Drainage of Former Interior Basins. — The lofty desert plateau of Tibet consists of many mountain ranges with waste-filled basins between them. As in all such forms, the gradual wasting of the ranges and filling of the basins tend to make the whole surface more nearly level. In time a lofty plain might here be formed, standing at a great altitude above baselevel.

During the advance of this long process, the active headwater streams on the outer slopes of the enclosing mountains may gnaw their way through the ranges, and thus capture some of the streams of the interior basins, giving them an exterior discharge.

One of the lofty basins on the southern border of Tibet is now deeply dissected by the streams that have been turned outward to the deep valleys of the Himalaya in this way. Other basins (*A*, Fig. 200) are encroached upon by the head-

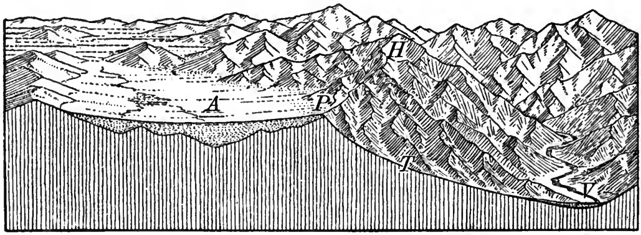

Fig. 200. — Diagram of Outward Drainage of Interior Basin, Tibet.

water torrents (*T*) that have already gnawed their way through the northernmost range of the Himalaya (*H*). The deep notches thus worn in the mountains form the passes by which the plateau of Tibet is reached from the Himalayan valleys (*V*).

An interior basin may gain exterior drainage when its depression is filled with waste until overflow occurs at some low point on the basin rim. Then the outflowing streams will tend to erode their channels with respect to the general baselevel of the ocean surface, instead of with respect to a central lake or playa; and the basin will be worn down instead of built up. As the waste is washed out of the basin the rock floor will be worn down also.

An arid region in southern Arizona and northwestern Mexico (the Sonoran district) includes forms that may be explained in this way. A long rock-floored inclined plain (*QN*, Fig. 201), descending 200 or 300 feet to a mile, leads forward from the base of the mountains (*RQ*). The gravelly waste from the mountains is washed across the plain to a flat trough (*NM*), and the finest waste is washed along the trough to the sea.

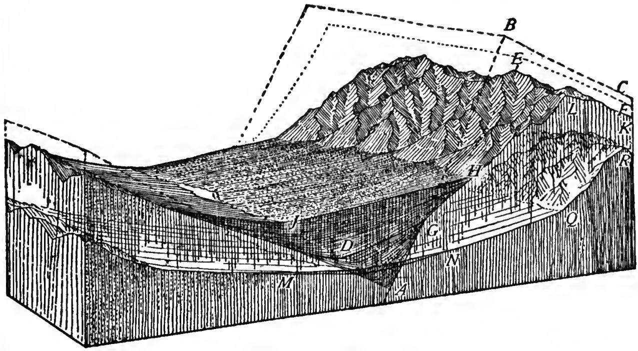

Fig. 201.—Diagram of a Waste-Filled Trough.

It is thought that at an earlier time, when the mountains were much higher (like *KLH*), the trough at their base was broadly filled with their waste (*HJ*). At that time they resembled the mountains of Utah and Nevada, and the troughs did not overflow. An overflow of waste being after a time reached, the surface was gradually worn down lower and lower, and *LHJ* was changed to *RQN*.

Sheetfloods.—The behavior of the drainage in the Sonoran region is peculiar. The rainfall averages only two or three inches a year; for although a single shower may yield almost as much as the annual fall, the showers are very rare; the sky is cloudless for a great part of the time. In the mountains the rainfall gathers in streams in steep-sided ravines, and issues upon the plains heavily charged with waste. There the water finds no channels; it spreads out in a shallow sheet, called a *sheetflood*, which gains a breadth of a mile or more, but a depth of only one or two feet; it rushes down the incline towards the troughs, but rapidly dwindles when it encounters layers of gravel on the rocky floor.

As the sheetflood subsides, its waste is left strewn over the smooth rocky floor, and the ground water soon escapes by evaporation. Another storm, shedding its rain here or there upon the rock-floored inclines or on the flat troughs, washes the waste along a little distance; and thus by degrees it is carried forward, at last reaching its goal in the sea.

The Effect of the Wind on Land Forms.

Comparison of Winds and Streams. — Where the land surface is covered with vegetation, the wind has little effect on the form of the ground. In arid regions where vegetation is scanty or wanting, the wind may become a powerful agent of denudation and transportation. In such regions the whole surface over which the wind acts should be compared to the uneven bed of a broad river.

The difference of wind action on a dusty road and on a grassy field may be taken to illustrate the contrast between wind action in regions of dry and regions of wet climate.

In a general way, the wind raises the finest dust into the body of its current, drifts along the sand at the bottom of the current, and rasps the unmoved stones and ledges with the drifted sand.

The wind that blows over desert mountain tops sweeps away the finer waste so quickly that there is never enough of it to make the upper air dusty. On arid lowlands the dust is blown here and there; what is raised by one storm hardly settles before another storm occurs; here the lower atmosphere is often turbid, the sky is of a dull gray color, and distant objects are obscured.

Uplands, projecting into the great air currents, are stripped of their sand and dust, leaving their surfaces bare and stony. Less exposed surfaces gather the drifting sand in hills, called *dunes.* The finest dust is carried furthest and settles chiefly in protected basins, where the wind tends to stagnate.

Many points of similarity may thus be found between wind and water action. The uplands of the Sahara have extensive surfaces of bare rock or of loose wind-carved stones; the dust and the finer sand have been blown away to settle on the lower lands. The stony uplands in the desert south of Algiers are known as *hammada,* on which travelling is difficult and fatiguing.

Sand Dunes in deserts may grow to a height of from 500 to 600 feet. In a region of relatively steady winds

Fig. 202. — Sand Dunes in the Sahara.

the sand is blown up the windward slope and carried over the crest; hence the dune may slowly advance, gradually changing its place and form.

Drifting sand gives a loose footing and makes travelling in a desert a weary task. A hot and violent wind, known in Arabia and the Sahara as the Simum, raises clouds of sand and dust, rapidly modifying the form of the dunes over which it blows. It sometimes overwhelms caravans — the easier if men and beasts are already exhausted by thirst and fatigue.

The San Luis valley in Colorado and New Mexico is a waste-filled basin enclosed by mountain ranges. It is an oval plain, measuring about 40 by 140 miles, at an elevation of from 7500 to 8000 feet. The greater part of the surface is "as flat as a billiard table." Coarse gravels slope inward around the border; streams wither as they flow towards the center; fine silts floor the central area, where small alkaline lakes occur. Drifting sands, gathered from the basin, form extensive dunes on the eastern or lee side of the plain at the base of the enclosing mountains. A large lava flow covers many square miles near the southwest margin. The Rio Grande receives the stronger inflowing streams, and escapes southward through a deep and gloomy gorge in the mountains.

An extensive dune-covered area is found in northwest Nebraska, occupying thousands of square miles. "The scenery is exceedingly solitary, silent, and desolate." The round hilltops rise evenly as far as the eye can reach; travelling over them is extremely difficult. A scanty vegetation in the hollows, where ground water can be reached by plant roots, once supported great herds of buffalo, and now yields light pasture to wandering herds of cattle.

Fig. 203. — Buffalo.

Dust Plains. — During times of high wind the air of arid basins may be so darkened with dust as completely to hide the sun. The finest dust penetrates all enclosures and makes everything feel gritty. As the winds decrease, the sun becomes visible, at first of a ruddy color; it may disappear again in the murky atmosphere before reaching the horizon.

The long-continued action of winds blowing from an arid continental interior may form heavy deposits of dust on the lower lands to leeward. Hills and valleys are in time buried hundreds of feet beneath the even surface of the dust plain. Such deposits are known as *loess* (a German word meaning loose; pronounced almost like *less*).

There are many loess-filled basins in the interior of China. Their margins, containing gravel and sand washed from the enclosing slopes, are 2000 or 3000 feet higher than the central parts, which are occupied by playa muds or saline deposits. But the greater part of the basin is filled with a fine, almost impalpable dust to a depth of hundreds of feet.

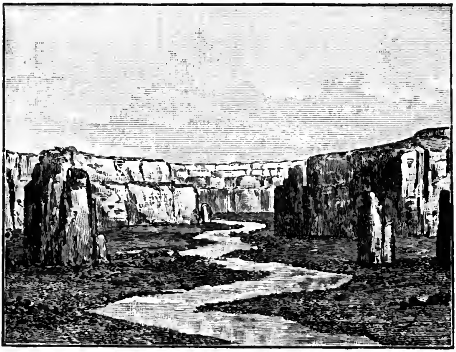

Fig. 204.—Loess Beds, Yellow River Basin, China.

Some of the loess-filled basins of China are now partly dissected; a main river runs through the middle of the basin and receives branches that have worn a labyrinth of forking ravines in the loess deposits.

Millions of Chinese live on the valley floors of dissected basins of this kind; for loess is extremely fertile where well watered. Great numbers of the people inhabit cave-like dwellings excavated in loess bluffs; in a thickly populated district not a house may be seen. The yellowish color of loess prevails everywhere. It gives color and name to the great river of the region and to the sea into which the river flows.

Dry Regions, formerly Moist. — In certain regions, now arid, marks of a former moist climate are found. The dry valleys or wadies in the Sahara seem to be the work of larger and steadier rivers than now follow them. Certain basins now almost without water have been filled with great lakes, even to overflowing; the former shore lines of the lakes are marked by cliffs, beaches, and deltas, and an outlet is sometimes traceable in a trench across the lowest pass in the enclosing highlands.

The basin of Great Salt lake in northwestern Utah once contained a much larger lake, to which the name of an explorer, Bonneville, has been given. Its shore lines are still plainly recorded on the mountain sides nearly 1000 feet above the desert plain around the present lake; the foreground of Fig. 103 shows extensive beaches of this lake. The channel of an outlet leads northward across a pass to the basin of Snake river; hence the former lake must have been fresh. The change from the moister climate of Lake Bonneville time to the drier climate of to-day has caused the almost complete disappearance of the lake waters, revealing the sediments of the lake floor in an arid plain. The ancient lake deltas are now trenched by the streams that built them.

One of the most remarkable features of this change of climate is its rapidity as compared with the changes of land forms. The cliffs, beaches, and deltas on the shore lines of the extinct lake are still remarkably distinct. The same is true of a former extensive lake (Lahontan) of very irregular outline in western Nevada, as well as of similar ancient lakes in various parts of the world.

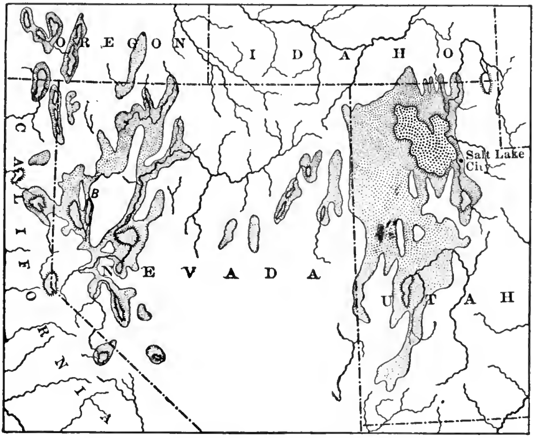

Fig. 205. — Lakes Bonneville and Lahontan.

The causes of climatic changes of this kind are little under stood, but their geographical consequences in replacing extensive lakes among forest-clad slopes by desert plains between arid mountains are of great importance.

Plants and Animals of Arid Regions.

Forms of Life in Arid Deserts. — Plant and animal life is scanty or absent in arid regions, because of the difficulty of securing food and water. The dryness of the soil is unfavorable to plant growth. Leaves are small or wanting, and thus the loss of water by evaporation from the leaf surfaces is diminished. Thorns are commonly developed, like so many signs—"keep off"—as if to lessen the chance of injury to the plant in a region where living is so difficult that every aid must be summoned to protect life.

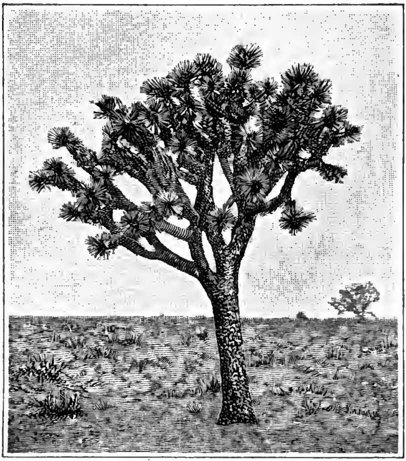

Fig. 206.—The Yucca, a Desert Tree.

During long droughts an arid region may seem almost free from vegetation. If rain falls, small plants spring up everywhere, refreshing the surface with their green color but soon withering away in the succeeding dry period. This is particularly marked on the borders of the subequatorial rain belts, where the ground may be bare and dusty in the dry season and covered with vegetation in the wet season; as on the Llanos of Venezuela. On the desert slopes of Peru, where droughts may last four or five years without rain, plants soon spring up after a shower. These examples show that the plants of arid regions possess great vitality.

The same thing is seen in the subtropical belts, but less distinctly, for there the rain comes in the cool season; as in the Algerian Sahara. In continental interiors, where most of the rainfall is in summer, the wandering of nomadic tribes is largely determined by the search for pasture for their flocks; as on the dry plains or *steppes* north of the Caspian sea.

The larger plants of arid regions are thinly scattered, leaving much bare surface. There is no striving for space, such as commonly occurs in well-watered regions, where plants of more active growth may crowd out the weaker forms. Dry regions seldom produce plants of economic value. Trees are small, and their wood is hard and knotted; they cast little shade on the dry, bare ground. The sagebrush, so abundant on the arid western plains of the United States, finds no use except as an inferior firewood.

The contrast between the open plant growth of dry regions and the crowded forests and jungles of the equatorial rain belt is very striking. The equatorial forest is gloomy, reeking with the damp smell of rotting vegetation. Gigantic trees rise high before branching; lesser trees push their way upward, searching for every foot of vacant space. Thorny creepers and tangled undergrowth twine beneath in an intricate and impassable web. Objects near at hand are hidden from view. On the other hand the glaring light of the sun in the unclouded sky over a desert is tempered only by dust raised from the parched ground. If scattered trees or bushes can grow, they are usually too far apart to obstruct the view.

Fig. 207. — Camel.

The animals of deserts are generally of dull or gray color, not easily seen on the barren surface. Many of them are fleet in movement, like the antelope; or of great endurance under a small supply of food and water, like the camel. Those which are sluggish are often venomous, like the scorpion and rattlesnake.

The People of Deserts. — The human inhabitants of arid deserts are few and miserable, as compared to the more favored races of the world. Their food supply is scanty and of little variety. Their arts are primitive, for raw materials are of few kinds. They possess strength and endurance, without which life would be impossible under the difficulties around them; they have a keen intelligence for every advantage that their desert home affords, but they cannot rise above a low stage of development.

Many of the wandering tribes are, by force of necessity, beggars and robbers. The struggle for existence is so severe with them that they and their animals are frequently on the verge of starvation. Yet so accustomed are they to their wretched life that they do not wish for the changes proposed by strangers.

The Papago Indians of the Sonoran region, south of the Gila river, move from place to place with the failing and flowing of springs. They are noted for strength, speed, endurance, and abstinence. The Seri Indians, living in the desert on the border of the Gulf of California, have no horses and are noted as runners.

In regions of favoring climate and more varied products, the manner of life of civilized people is so complicated by long-growing habits and customs that it may seem in many ways to be independent of geographical conditions. In the simpler life of desert tribes the force of geographical control is more apparent, but not more real.

Oases. — Fixed settlements in desert regions are almost entirely controlled by the occurrence of water. They are commonly made where springs or streams flow upon the open country at the base of uplands and mountains; or near the ends of such streams, where the water can be distributed in irrigating canals; or at points where ground water may be found in the nearly dry channels of withered streams. Such settlements are called *oases* in the Sahara, and the same name may be used elsewhere.

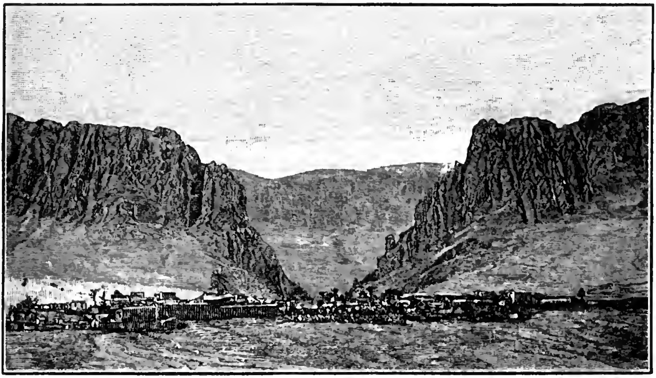

Fig. 208. — El Kantara Oasis, Algerian Sahara.

The barrenness of many deserts is due simply to their dryness and not to an unfavorable composition of rock or soil. Where springs or streams moisten the soil, grass and trees may grow naturally. If the surface can be irrigated, its productiveness may be increased so as to support permanent settlements.

The contrast between a habitable spot and the surrounding barrenness is so grateful that "an oasis in the desert" has come to serve as a poetic figure. But oases are only relatively delightful. Their water supply is often limited and impure; their products are few in variety and small in quantity; their industries are primitive; their inhabitants have to suffer the disadvantages of isolation as completely as the people of islands.

The oasis of Siwa, in the Sahara, 350 miles west of Cairo, "the first halting place on the great desert highroad to the west," is still little changed from its condition in ancient times. Seclusion seems to have bred mistrust, for strangers are looked on as intruders. They and their modern ways of doing things are unwelcome.

The large and important oasis of Merv, northeast of Persia, has a population of several hundred thousand, gathered in many villages. The oasis is on a flat alluvial fan, formed and watered by the Murg-ab (-river). The river is divided into two distributaries, then into forty-eight smaller branches, and again into hundreds of irrigating canals.

The inhabitants of an open country that has a sufficient rainfall, with plentiful ground water easily reached in wells and with numerous springs and streams, are free to settle almost as they like. They seldom realize the importance that a spring or small water course has in the life of dwellers in deserts.

The occasional springs on the arid plateaus of Arizona are regarded as so important that their position is indicated on the government maps of that region. Travellers across the plateaus follow trails that lead from spring to spring.

Ice Sheets and Glaciers of the Present.

Glacial Climate. — Where the temperature is so low that the snowfall of the colder season is greater than the loss by melting in the milder season, a heavy cover of ice and snow many hundred feet thick is formed. The icy sheet slowly creeps from the place of chief supply to lower ground; there it melts and the water runs away in streams. Its edge may enter the sea, where besides melting it breaks off in large masses which float away as icebergs. These long-lived accumulations of ice are called *ice sheets* and *glaciers*.

The change from snow at the surface to ice beneath is aided by water from occasional rains and from surface melting. The water sinks into the deeper snow and there freezes. The ice thus formed is granular, and the motion of the mass is much aided by a slight slipping of grain on grain.

During winter in the northern United States there are frequent examples of the formation of small, short-lived ice sheets, after a succession of snowstorms with prevalent cold weather and occasional thaws. Such an ice sheet is not thick enough to move; but if it should grow year after year to a thickness of 1000 or more feet, it would slowly move from the region of greatest height and thickness to lower ground in a milder climate.

Antarctic Ice-Cap. — A few explorers of the far southern ocean have discovered a great ice sheet ending in cliffs that rise from 100 to 180 feet above the sea. Looking southward, no land was seen back of the top of these cliffs.

Although as yet known only on one side of the South Pole, the ice sheet is thought to form a polar ice-cap, perhaps 1000 miles in diameter. There may be some land on which the cap rests; but it is believed that much of it lies on the sea bottom. It must tend to thicken from snow supply over its desert, plateau-like center; but it slowly creeps towards the free sea margin, where great tables of ice break off and float away.

The Greenland Ice Sheet. — Greenland is covered by a heavy sheet of ice, measuring about 1500 miles north and south by from 300 to 600 east and west. It has a slightly convex surface, and probably rises to a height of 9000 feet in the central part. As far as explored, the ice conceals all hills and mountains except near the margin, where the sheet is thinner; here occasional rocky summits rise above the surface like islands in a frozen sea. Descending gradually towards the coast, the ice either thins out on land, or advances along the valleys in branch-like arms or glaciers, some of which extend into the sea.

Some of the Greenland glaciers are from 10 to 50 miles broad where they enter the sea. Their forward movement is from 20 to 50 feet a day. Many icebergs are formed of great fragments broken from their front. Nansen, the famous Arctic explorer, was the first to cross the ice sheet of Greenland (1888, in latitude 64½°). Peary crossed northern Greenland in 1892. The interior is a monotonous desert of snow and ice, now melting and becoming almost impassable, now freezing over or receiving a new layer of snow. Most of the surface is unbroken; but near the margin, where the motion is faster in one part than in another, the ice is deeply fissured or crevassed.

The only inhabitants of this great cold desert are a simple microscopic plant that sometimes gives a red color to snow, and a minute worm. The Eskimos of Greenland live on the narrow belt of land between the ice sheet and the shore.

Alpine Glaciers. — Glaciers of the Alpine type flow in stream-like tongues from the valley heads between lofty peaks and ridges. The snowfall in the valley, increased by avalanches from the enclosing walls, is gradually converted into granular ice; and the ice slowly creeps down the valley, melting as it descends to a milder climate than that of its gathering ground. The end of a glacier may often reach far below the tree line and even approach fields on the floors of the larger valleys.

In the upper valley reservoirs the snow surface is concave, sagging from sides to middle; here movement is directed inward from the enclosing slopes. Standing in one of these reservoirs in clear weather, one may see only dark ledges and peaks that rise over the dazzling snow under a deep blue sky, — all barren and silent. In the lower tongue of a glacier the ice stream is convex, and moves a little towards either bank as well as downward along the slope of the valley.

Fig. 209. — Rosegg Glacier in the Alps.

A glacier moves faster along the medial surface line than at sides or bottom, thus resembling a river. The movement of Alpine glaciers is from 100 to 500 feet a year on the average, about as fast as the point of the hour hand of a watch. Where the valley steepens, the motion is more rapid and the ice is irregularly broken. Its parts unite again on the next gentler slope, and the ice stream flows on as before.

The Aletsch glacier is the longest in the Alps, measuring about 13 miles from head to end. Glaciers of much greater size occur in the Himalaya and in Alaska.

Creeping glaciers press heavily on their beds, dragging rock waste beneath them and scouring the bed-rock clean and smooth. Loose grains and fragments of rock, dragged along by the ice, scratch and groove the smoothed rock surface. The rock waste thus scoured from the ice floor, as well as that torn from projecting ledges and received in rock slides and avalanches from surmounting slopes, is dragged or carried along by the ice and deposited around its lower margin or at its end. Great boulders may be transported in this way.

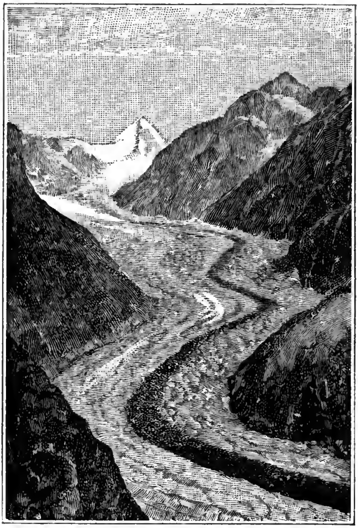

Fig. 210. — Viesch Glacier in the Alps.

The Swiss name *moraine* is applied to various forms of ice-borne rock waste. That underneath the glacier is called ground moraine; it is firmly compacted by the pressure of the ice. The waste on the side of a valley glacier forms the lateral moraine. Where two glaciers unite, the adjacent lateral moraines form a single medial moraine. The rough heaps and ridges of waste deposited around the end of a glacier (or at the margin of an ice sheet) form the terminal moraine. Here the waste is often loosely deposited; it may be laid down in beds by water running from the ice. *Glacial drift* is a more general term for waste moved by ice and ice-water.

Large glaciers are sometimes so heavily covered with moraines near their lower end that a plant-bearing soil is formed upon them. Pasturage is found for the flocks of the mountaineers in the Himalaya on certain grass-covered moraines overlying the ice. Some Alaskan glaciers bear large forests near their ends.

Water received from side streams and supplied from melting ice gathers beneath a glacier and issues from an ice cave at its end. The water is usually whitened by fine "rock flour" ground beneath the ice.

The length of glaciers is found to increase and decrease slowly in successive years. For a time they lengthen or advance; then they melt back or retreat; the change being completed in the Alps in a period of about thirty-five years. This is believed to result chiefly from a variation in the snowfall.

A change of snow supply is sooner indicated by a variation in the end of a short than of a long glacier; hence all the glaciers of a mountain range do not vary together.

These slow variations in the length of glaciers may be compared to the rapid variations in the length of streams that descend from mountains and wither away on deserts. After each rain the streams advance for a time and then retreat. The change is seen first in the end of the short streams.

An advancing glacier at first usually overrides the soil in front of it, overturning trees, if they stand in the way; it slowly drags forward the waste as the weight of the ice becomes greater, and at last grinds and smooths down the firm rock ledges. A retreating glacier, receding from the terminal moraine that was made at its greatest advance, leaves a barren stony bed to be slowly invaded by plants from neighboring slopes. Here the forms produced by the ice in scouring the surface on which it moved may be conveniently studied.

The chief regions of valley or Alpine glaciers are the Alps, the Caucasus, the Himalaya, and other lofty ranges of Eurasia; the New Zealand Alps; the southern Andes; and the northern members of the Rocky mountains, from the Selkirk range of Canada to the St. Elias range of Alaska.

The snowy Selkirk range, crossed in a high pass by the Canadian Pacific Railway, promises to become a center of glacier excursions in North America, like the Alps in Europe. The heavy snowfall of the St. Elias range feeds large glaciers, many of which descend into the sea, like the famous Muir glacier, now visited every summer by excursion steamers from Pacific ports.

From the valleys about Mt. St. Elias itself the uniting glaciers form a great ice fan at the base of the mountains (in shape like a flat alluvial fan), known as the Malaspina glacier. It spreads 20 miles forward to the sea, with a front of 70 miles. Rivers issue from tunnels beneath the ice and build extensive stony deltas. Smoothed rock surfaces, formerly covered and worn by the ice, are well exposed near the border of the glacier.

The Work of Ancient Glaciers and Ice Sheets.

The Glacial Period. — The study of existing glaciers is of much importance from the light that it sheds on the geographical features of certain regions where great glaciers or ice sheets existed during former periods of the earth's history.

The time of the former extension of glaciers and ice sheets is called the *glacial period.* It must have been a time of lower temperature and greater snowfall than to-day. It included several epochs of extensive advance and retreat. Regions that have been ice-covered are said to have been *glaciated.* It is often convenient to refer to periods of time before, between, and after the chief glacial advances as preglacial, interglacial, and postglacial.

The glacial period probably corresponded with the period of moister climate in those interior basins that recently (in the earth's history) contained great lakes.

During the glacial period many glaciers in lofty mountains advanced far down their valleys and overspread the adjoining lowlands. Terminal moraines, formed at the greatest advance of the glaciers or during their retreat, are now found in the lower valleys. Lakes often lie in the glaciated valley floors, as if the enlarged ice streams had scoured out their basins.

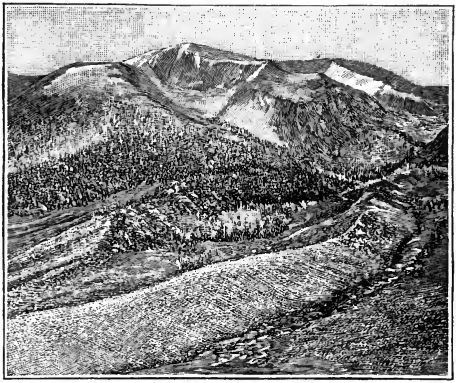

Fig. 211. — Glacial Moraines, Sierra Nevada, California.

Ancient glaciers occupied the valleys of certain mountains that now bear little snow; as in the Rocky mountains of Colorado and the Sierra Nevada of California. Great glaciers descending from the high Sierra into the desert valley of Mono lake in eastern California built strong moraines forward from the mountain base. Twin lakes at the head of the upper Arkansas valley in Colorado are held within heavy terminal moraines.

Around the border of the Alps the lower land near the outlet of the chief valleys is often enclosed for 10 or 20 miles from the mountains by a belt of hilly morainic ridges. The ancient glaciers that descended southeast from Mt. Blanc to the river-made plain of the Po built a huge terminal moraine, whose ridges rise from 1000 to 1500 feet above the plain and enclose a great amphitheater.

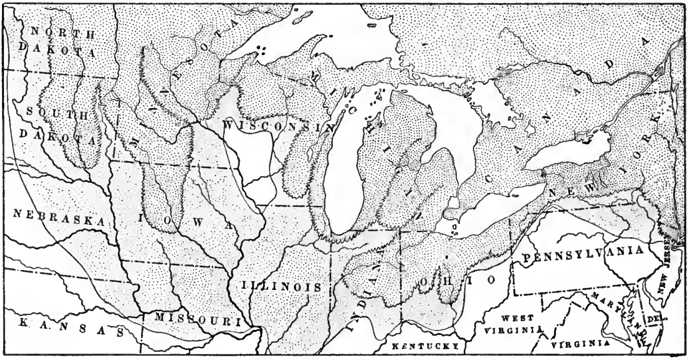

Fig. 212. — Glaciated Area of the Northern United States.

The Highlands of Scotland, to-day without permanent snow fields, were occupied by great streams of ice during the glacial period. Large glaciers extended into the ocean, east and west. The many lakes that lie in the broader valleys result partly from the scouring or erosion of the valley floors by the ancient glaciers, partly from dams formed by terminal moraines.

The most extensive ice sheets of the glacial period were those that spread outward from the highlands of eastern Canada across the basins of the Great Lakes upon the northern United States, and from the highlands of Scandinavia across the Baltic upon northern Germany.

The occurrence of ancient ice sheets is known by the many marks of their presence still remaining, such as moraines and other forms of drift, transported boulders, and scratched rock ledges. The ice sheet that spread from the highlands north of

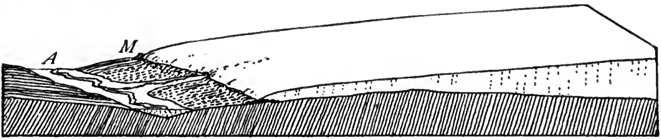

Fig. 213. — Diagram of an Ice Sheet.

the St. Lawrence is known as the Laurentian glacier. It was a desert nearly as extensive as the Sahara. The Scandinavian ice sheet was nearly as large as the desert of inner Australia.

These ancient ice sheets advanced and retreated more than once, reaching different limits in the successive advances. At each advance they drove away the plants and animals of the region that they invaded; at each retreat plants and animals were free to take possession again of the uncovered surface.

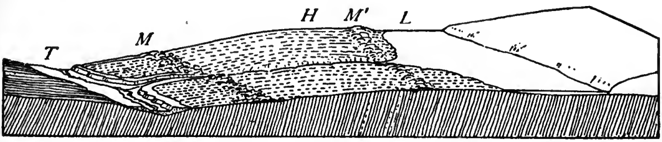

Fig. 214. — Diagram of a Retreating Ice Sheet.

Effects of the Glacial Period. — The geographical consequences of the glacial period are numerous and important. Rivers flowing from the ice sheets were so well supplied with waste that they filled their valleys with broad gravelly or sandy flood plains (*A*, Fig. 213). Since the disappearance of the ice, the rivers have terraced the drift-filled valley floors (*T*, Fig. 214).

The valleys of the south-flowing rivers of Ohio, Indiana, and Illinois, outside of the glacial area, are now bordered by drift terraces from 10 to 40 or more feet in height. The mounds that mark the sites of prehistoric Indian villages are frequently found upon these terraces. Many villages to-day have a similar situation.

Not only at the time of greatest advance but also during the disappearance of the ice sheets, the valleys leading away from their retreating edge were generally more or less filled with washed sands and gravels. It was under such conditions that the Chippewa river of Wisconsin, heading in the retreating ice sheet and carrying much drift down its valley, built a fan delta in the valley of the Mississippi, obstructing the main river and causing it to spread over its flood plain, so as to form the narrow Lake Pepin (*P*, Fig. 219).

The Connecticut and Merrimac valleys in New England, well within the glaciated area, have many drift terraces along their sides. The valleys must have been drift-filled while the ice was retreating; the high flood plains thus formed have been trenched and terraced after the ice had disappeared.

Terminal Moraines were generally formed along the margin of great ice sheets, not only at their furthest advance but also during pauses in their retreat (*M*, *M′*, Fig. 214). The moraines are hilly belts of gravel, sand, clay, and boulders; they may be one or more miles wide, and from 50 to 100 feet in local relief. Although seldom of conspicuous height, they are often the only hills to be seen for many miles in the prairie states of the Ohio basin. Their surface is often too uneven and their soil too coarse and stony for cultivation in competition with the fertile prairies that they interrupt.

Hollows or "kettles" among the morainic hills frequently contain small lakes or swamps. The small lakes of northern Indiana are of this kind; their number is not less than 1000.

Terminal moraines are strongly developed in the Dakotas. They are from 3 to 10 miles wide; sometimes so rough, with

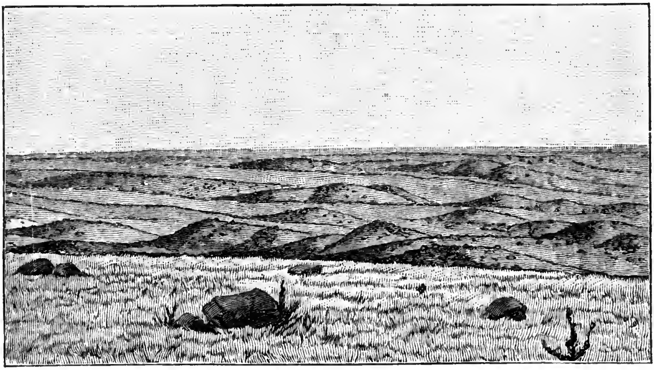

Fig. 215. — Glacial Moraines, North Dakota.

so many stony hills and hollows, as to present a formidable barrier to travel. One may easily lose his way on this undulating surface, where the hills are all much alike and where no conspicuous landmarks serve as guides.

Ground Moraines. — During the occupation of a region by an ice sheet, the terminal moraines receive only a small part of the rock waste that is dragged forward by the slow motion of the ice or washed along by subglacial streams. A great part of the drift remains beneath the ice as a ground moraine, distributed over the glaciated region. It may be spread unevenly, causing irregular changes of moderate amount in the form of the surface. Where it accumulates in greater quantity, it may be of sufficient thickness to bury low hills and shallow valleys, forming extensive plains. It is especially plentiful near the margin of the glaciated area.

The ground moraine left by an ice sheet is an unsorted and compact deposit of rock waste. It is sometimes called "boulder clay" from containing many large rocks packed in a stony clay. It is known as "hard pan" to contractors, who find much greater difficulty in digging foundations or opening railroad cuts in the ground moraine than in the loose sands and gravels that were washed forward from the edge of the ice. The Scotch word *till* is the best general name for this deposit.

Fig. 216. — An Esker.

The hills and valleys of New England are irregularly sheeted over with compact ground moraine, here clogging a valley, there smoothly cloaking a hill, and again leaving a rocky surface bare. Mounds, ridges, and plains of washed sands and gravels are also common in the valleys, the result of stream action at the margin of the latest ice sheet during its retreat. The ridges are called *eskers.*

The till of New England contains many boulders, from 5 to 20 feet in diameter, and sometimes so plentiful on the surface as to make agriculture impossible. Even where less numerous, the boulders must often be gathered from the fields and thrown into heaps or built into walls before plowing is possible.

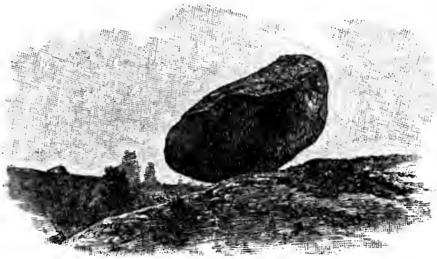

Fig. 217. — A Glacial Boulder.

Northwest Ohio has been converted from a region of hills and valleys into a smooth plain by a heavy covering of till, at many points more than 100 feet thick, and averaging 30 or more feet over hundreds of square miles.

The till of Ohio is less stony than that of New England. It furnishes good soil, for it consists of a thorough mixture of waste from many kinds of rocks, gathered under the ice and not exhausted by plant growth during its accumulation. The till plain of northwest Ohio is for this reason more fertile than the hilly country in the southeast part of the state, beyond the limit of ice action. The same is true of large areas in the northern central states as far west as the Dakotas.

Shallow lakes or marshy tracts occur here and there on the till plains from Ohio to Minnesota. The streams of the region bear every mark of youth. They follow narrow valleys, and are frequently interrupted by falls where they have cut down through the till to the rocky floor. In Minnesota, lakes are very numerous in hollows in the till and among the terminal moraines. The falls and rapids of the upper Mississippi are all of postglacial origin. Glacial action must have been comparatively recent (not many thousand years ago) in these states, as the streams have been so little developed since the ice disappeared.

In southern Iowa and northern Missouri there is an extensive sheet of drift, burying the rock floor for miles together. Here no lakes occur; the numerous valleys are broad-floored and well opened; few falls interrupt the even reaches of the streams. The glacial epoch in which this well-dissected drift sheet was dragged forward must have been much less recent than that in which the smooth and undissected till plains of northern Ohio and Minnesota were formed.

Drumlins. — In some glaciated districts the till was here and there gathered beneath the ice sheet in smoothly arched, oval hills called *drumlins*, commonly half a mile

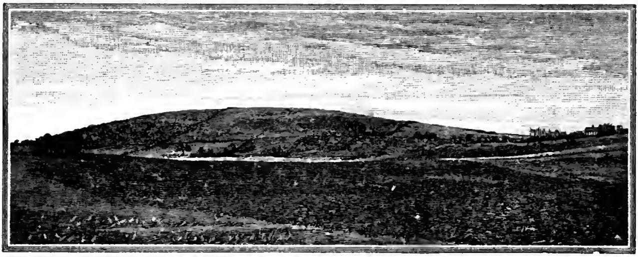

Fig. 218. — A Drumlin.

or more long, and from 100 to 200 feet high, easily recognized when once known. They may be compared to sand bars in rivers or to sand dunes under the wind, all such built-up mounds occurring where more material is brought than is carried further forward.

Numerous drumlins occur within an area enclosed by a well defined moraine in southern Wisconsin. Here the landscape presents a succession of arched hills, with flat marshy plains between them. The streams wander along such courses as the drumlins allow. The preglacial stream courses cannot be determined, so heavy and extensive is the drift cover.

Hundreds of drumlins are found on the Ontario lowland of western New York. On the uplands in central Massachusetts many drumlins are cleared and farmed, in preference to the more rugged rocky hills. Most of the islands in Boston harbor are drumlins. Many hills of this kind are distributed over the lowland of Scotland between Glasgow and Edinburgh.

Marginal Lakes. — When an ice sheet retreated from a land surface that sloped towards it, temporary lakes may have been formed in the depression between the land slope and the ice front (*L*, Fig. 214). The lake floors received layers of fine silt, forming smooth plains when laid bare after the disappearance of the ice. The shore lines were marked by cliffs, beaches, and deltas of greater or less size, now deserted by the waters that made them.

One of the most extensive glacial-marginal lakes has been named Lake Agassiz. When at its greatest size, it stretched hundreds of miles northward from Minnesota and North Dakota into Canada. Its floor is in part a plain of till; in part covered with fine silts, nearly as level as the sea. It is now traversed by the main stream and branches of the Red river, whose narrow valleys proclaim the extreme youth of the plain. Great wheat farms (Fig. 173) and pastures (Fig. 182) now profit from the fertile soil.

The shore lines of the glacial Lake Agassiz are marked by wave-made beaches and by the deltas of inflowing streams. The deltas are often so sandy that dunes have been formed on them by the winds. Following the shore lines southward, they converge and almost unite at a slight depression in the enclosing "height of land"; here the lake outlet is found in a well-defined channel, a mile or more wide, leading southeast to the Mississippi. The Minnesota river, a small stream in comparison with the great current that once flowed from the lake, now wanders along the floor of the channel.

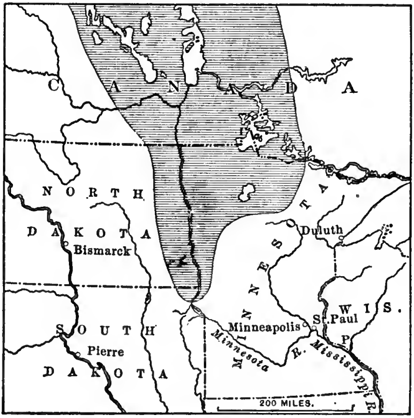

Fig. 219. — The Glacial Lake Agassiz.

All the Great Lakes were temporarily expanded while the retreating ice sheet obstructed their discharge by the St. Lawrence; they rose for a time to higher levels and spread over the bordering lands. Their shore lines, marked by cliffs and beaches, have been traced for hundreds of miles; their silted floors, bordering the present lakes, form many fertile prairies.

When the northward discharge of Lake Michigan was thus obstructed, the overflow ran southwest across a low "height of land" to the Illinois river, and thus to the Mississippi. When the ice retreated further, and Lake Michigan gained an outlet through Huron, the waters sank to a lower level, and the former outlet remained as a low notch, which was afterwards a "portage" for Indian canoes. The site of Fort Dearborn was thus determined; and from this small beginning in a favorable situation between the East and the great Northwest the city of Chicago has grown. To-day the ancient lake outlet has been deepened by cutting an artificial canal; a strong current flowing through it from the lake carries the drainage of the city to the Mississippi system.

When the lower St. Lawrence was blocked by the waning ice sheet, the expanded Lake Ontario overflowed down the Mohawk to the Hudson. The outflow cut down a flat-floored channel at Rome, N. Y., and here is the "long level" of the famous Erie canal, where no lock is needed for many miles. The beaches of the ancient lake shore are very distinct; many of them are used as naturally graded roadways.

The shore lines of the glacial-marginal lakes are no longer level, as they must have been when formed. They ascend a few feet in a mile to the northeast. Hence it must be concluded that the land has risen in that direction during or since the retreat of the latest ice sheet.

Recent observations have shown that the tilting of the land is still in progress, causing a change of level of about half a foot in 100 miles in a century.

A remarkable consequence is predicted if this change of level continues. In a few thousand years, before Niagara can lower the level of the upper Great Lakes by wearing back the great falls between Lakes Erie and Ontario, the uplift of the land in the northeast will have raised the lake waters of southern Michigan high enough to restore all the overflow to Chicago. Only Ontario will then remain in the St. Lawrence system, while the Illinois river will be greatly increased in volume.

Lake Basins. — The drainage of a glaciated region is often greatly disordered by glacial action. At one place a valley floor may be scoured out, producing a lake basin. At another the irregular distribution of drift may divert a stream to a new course, where it is now seen cutting a steep-walled young valley with many falls and rapids. A lake is often formed up stream from the drift barrier.

The Adirondacks, a well-dissected and subdued mountain group, resemble the Black mountains of North Carolina in many features, but are contrasted with them in the possession of numerous lakes and in the frequent occurrence of gorges

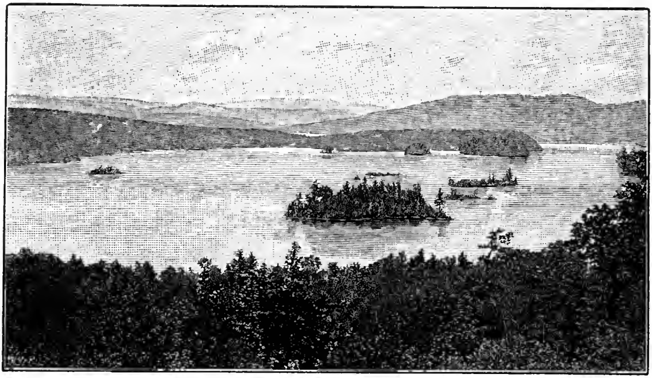

Fig. 220. — Lake in the Adirondacks, New York.

("chasms") and falls along the course of the outflowing streams. These peculiarities result from glacial action, which the Adirondacks suffered in common with the other northern parts of the country, but which the southern mountains escaped.

Rapids and Waterfalls. — When a river carves terraces in its drift-filled valley, it often happens that the new course is entrenched on one side of the preglacial channel, and thus the stream comes upon a buried ledge. Here a fall is formed; for the drift down stream is (relatively) soon washed away, while the ledge is cut down much more slowly. The valley is narrow where the river cuts a gorge in the ledge. The alternation of waterfalls and graded reaches in many northern rivers is thus explained.

The Merrimac is a famous river of this kind. Its falls at Manchester, Lowell, and Lawrence have determined the growth of great manufacturing cities. Rochester, Grand Rapids, Minneapolis, and many other important cities have grown up at the side of falls on rivers that have been turned from their preglacial channels by glacial drift.

Where drift is plentiful and the preglacial relief of hill and valley is moderate, rivers may be displaced far from their former courses. Niagara is one of the most remarkable examples of a large river on a new course; the upland that it crosses is a form of preglacial origin (an upland of an ancient coastal plain), while the gorge and falls are postglacial and extremely young.

It is probable that in preglacial time the region of the Great Lakes was drained by a large river that followed in a general way the main line of the St. Lawrence system; but the precise course of this ancient river has not been determined. Niagara is a new river, whose course was taken across the upland between the Erie and Ontario lowlands after the retreat of the ice sheet. At first the river fell over the northern bluff of the upland. But as the plunging water undermined the capping layers, the gorge was cut backward through them. The falls have now retreated about seven miles from their first position. An international boundary line here follows the accidental path of the postglacial river. A small fraction of the water in the river is now diverted from the falls and carried by a canal to generate electric currents that supply power to factories, drive electric cars, and furnish electric light to cities.

Moraines and other drift deposits, forming new divides, frequently cause important changes in the areas of river systems. The headwaters of the Mississippi in northern Minnesota are separated from Canadian drainage by drift hills, Lake Itasca being but one of the innumerable lakes held in drift basins, all of which are very modern features in this ancient river system. Where the Mississippi rose before the drift hills were formed, no one can say.

The divide between the upper Ohio and the St. Lawrence systems is largely determined by moraines and drift barriers south of Lake Erie. The same is true of many divides and subdivides between the streams of the prairie states of Indiana and Illinois.

Central Areas of Glaciated Regions. — The highlands of eastern Canada, whence the ice sheets moved out to the

Fig. 221. — Ice-Worn Rocks, Coast of Maine.

surrounding regions, and where the ice must therefore have been of great thickness, possess relatively little drift.

Much of the surface is occupied by bare rock, clean scoured, or by a thin stony soil. Here the action of the ice sheet was chiefly destructive; while on the surrounding region, as south of the Great Lakes, it was more largely constructive.

Whatever soil the eastern Canadian highlands possessed in preglacial times has been stripped away; it now lies in the till plains and moraines south of the Great Lakes. The generally even surface of the highlands (a worn-down old-mountain region, somewhat dissected in preglacial time) now consists of low rounded hills of firm unweathered rock separated by shallow troughs that often hold lakes and swamps both large and small. Many of the lakes lie in eroded rock basins; others are held behind drift barriers. The undeveloped character of the streams is an indication of the disorder produced by glacial action in the drainage system.

The immaturity of the drainage of this region is imitated in a small way when the snow and ice of winter melt from a road, whose arched surface may be taken to represent the highlands. Innumerable pools find outlets by irregular rills; the rills have minute rapids on stony sills. During a rain on such a roadway, the rills may be seen to deepen their channels and lower the level of pools, or discharge them entirely; thus imitating the changes that are progressing with relative rapidity on the Canadian highland.

The highlands of Scandinavia repeat many of these features, but their altitude is greater and their valleys are deeper. The innumerable small lakes and the rapids and falls in the streams of Sweden and Finland are all of glacial origin. The great depth of Norwegian and other fiords is best explained as a result of intense erosion of ordinary valleys by heavy glaciers, moving down relatively strong slopes from highlands. It is probable that a heavy glacier, from 3000 to 5000 feet thick, might scour out its channel beneath sea level, so that on the melting of the ice the sea could enter the abandoned channel, forming a fiord. In this case the depth of the fiord would not give directly a measure of the submergence of the region, for part of the depth may have been scoured out beneath sea level by the ice.

The steep and comparatively smooth sides of the fiord walls are also to be taken as evidence of glacial erosion, by which the spurs of the preglacial valley were worn away in the scouring out of the deep and steep-sided glacial channel. It is commonly the case that lateral valleys enter fiord channels high up on the side walls, as if they had not been deepened nearly so much as the main glacial channel. Lateral valleys of this kind are called hanging valleys. Their streams cascade down the fiord walls. Many of the waterfalls of Norway and Alaska are of this origin.

The lakes that occupy many of the larger Alpine valleys are also best explained through erosion by heavy glaciers of relatively strong slope and active movement in their descent from the central snow fields. Not only where lakes occur, but for many miles further up stream, the valleys seem to have been deepened and widened below their preglacial form. As in Alaska and other strongly glaciated regions, side valleys open from 500 to 1000 feet above the floors of the deepened main valleys, and the side streams cascade down the steepened main-valley walls.

The ice sheets of the glacial period have vanished from the northern United States and eastern Canada. The Indians that occupied this region when the Europeans first landed have greatly decreased in number, disappearing entirely in the more thickly settled districts. The Indians are always considered in the study of American history. The vanished ice sheets are of even greater importance in American geography.

CHAPTER XII.

SHORE LINES.

The Border of the Lands.

Next to the prospect gained from a lofty mountain, the view of the sea from the border of a highland is the most inspiring sight that the earth offers. To the traveller from an inland country it is as if the shore line marked the beginning of a new kind of world. There is the mystery of the distant horizon, far beyond which strange lands are hidden. There is the unceasing movement of the waves as they roll upon the beach, and of the tides as they slowly rise and fall; and the thought comes that thus the ocean has been rolling in waves, rising and falling in tides, ever since the lands and the waters were divided. With the sight of the vast ocean comes the thought of unending time.

While the surface of the land has been for ages attacked by rain and rivers, the border of the land has been attacked by the sea. The sun warms the air in the torrid zone, and thus the general circulation of the atmosphere is established. The winds beat on the ocean and form waves; and the waves run ashore and dash in surf upon the lands. The border of the land is worn back under so constant an attack, and the waste taken from it by the surf, as well as that washed into the sea by rivers, is slowly carried away into deeper water by the waves, the currents, and the tides. In time the area of the land would be greatly reduced by the invasion of the sea, were it not for upheavals of the earth's crust by which the land is now and then, here and there, renewed.

The contour of the land border exerts a strong control on coastwise trade and on international commerce; for the dangers of the sea are not so much in the storms and

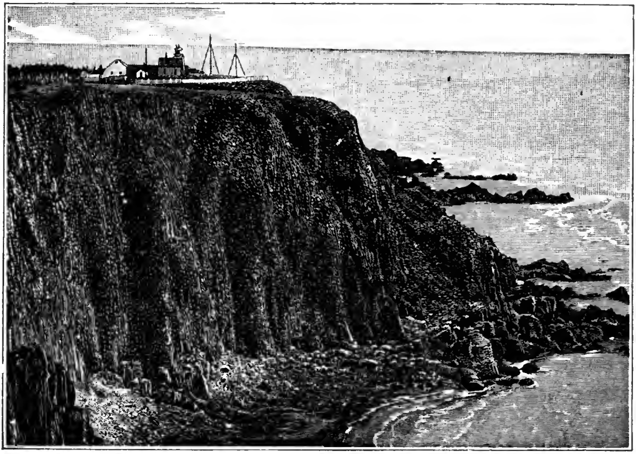

Fig. 222.—Sea Cliffs, Grand Manan, New Brunswick.

waves of the open ocean as in the shoals and reefs of the shore. A rocky coast, descending in bold cliffs to a surf-beaten beach, is justly dreaded when storm winds blow landward. A safe harbor, protected from winds and waves, is eagerly sought for when a vessel nears the coast. The outlines of the shore deserve as careful study as the forms of the land.

The Development of Shore Lines.

Classification of Shore Lines. — Where the margin or coast of the land dips under the sea, the water lies against it and marks the shore line. The original outline of a shore depends on the form that the land had when its present attitude with respect to the sea was taken. Various changes are afterwards made by the action of waves, currents, rivers, and other agents.

It has been learned that in some parts of the world the sea borders upon a smooth coastal plain that was once a sea bottom (p. 118), and that in other parts it lies on the flanks of a depressed mountain range (p. 195); hence this chapter may be begun with an understanding that the attitude of the land suffers greater or less change with respect to the sea; and that, as the land rises or falls, the outline of the shore changes.

It will now be shown that some idea of the time since the present attitude of a coast land was taken may be gained from the form of bars built by waves off shore from a coastal plain, from the area of deltas built by rivers forward from their mouths, and from the height of cliffs cut by waves on headlands.

Shore lines in their original form, unchanged by sea action, may be divided into two classes, according as they are produced by uplift or by depression of the land. The shore line is smooth and simple and bordered by shallow water, where the sea lies on an uplifted sea bottom. It is irregular and complicated and generally bordered by relatively deep water, where the sea lies on a depressed land surface. Shore lines of the first class border lowlands of weak strata; they are comparatively harborless and do not offer easy opportunity for traffic between land and sea. Those of the second class generally have rocky headlands enclosing protected bays, where harbors and settlements are favored.

There are exceptions to this simple classification. The sea bottom is sometimes uneven, as where a hilly region has been depressed. The sediments laid on such a sea floor accumulate chiefly in the deeper parts, and thus tend to reduce the unevenness of the bottom. If uplift occur before the bottom is well smoothed, the new shore line will be irregular, although belonging to the first class.

Shore Lines of the First Class. — The low plain of Buenos Ayres dips gently beneath the sea, whose waters are shallow for many miles off the simple shore line. Large vessels cannot approach close to the land, except where an artificial harbor has been dredged out.

When storm winds blow from the sea, they brush the water upon the low coast and cause destructive sea floods; dikes are built along certain parts of the shore to keep the waters off.

Sand Reefs. — Along the shallow shores of low lands, storm waves beat up the bottom sands and in time build off-shore sand reefs, enclosing long, narrow lagoons. Rolling surf beats on the outer beach of the reef, slowly grinding the sand finer and finer, and sweeping the finest particles far off shore; but the reef is not easily destroyed, in spite of its loose texture, for about as much sand is brought in from the sea bottom as is ground up on the beach and taken away.

The slow movement of tidal or wind-driven currents along the beach gives it a straight or gently curved front. On-shore winds blow sand from the beach, and build sand hills or dunes of irregular form, sometimes 50 or 100 feet high, on the reef. The sand drifts into the lagoon, making the inner border of the reef somewhat irregular. Sediments are brought by streams from the land, and, with the aid of salt-water plants, the lagoon is gradually converted into a salt marsh at high-tide level, intersected by numerous tidal channels, as in Fig. 223, *b*, *c*.

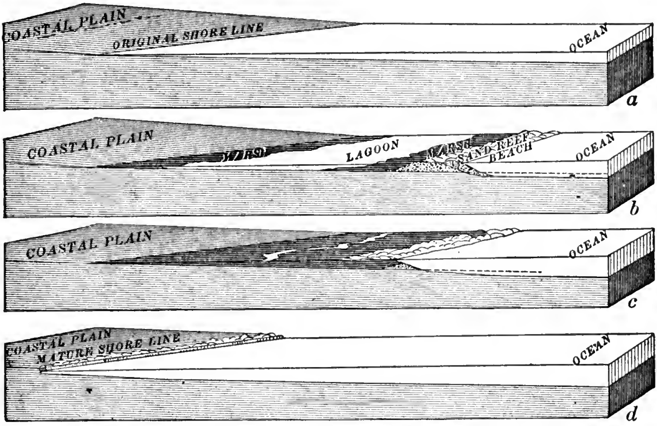

Fig. 223.—Diagrams of Coastal Plain Shore Lines.

Along the coastal plain of Texas the mainland shore line is simple (except where interrupted by small bays caused by a very slight depression of the plain after shallow valleys had been cut in it). It is fronted by a sand reef, whose beach has a remarkably smooth curvature. Much of the lagoon behind the reef is only 5 or 10 feet deep. Galveston, the chief port of the state, is built on the reef (Fig. 238), in order that its wharves may reach deeper water than that of the lagoon, and thus gain the advantage of traffic by seagoing vessels.

A peculiar series of sand reefs fringes the coastal plain of North Carolina (the mainland shore line being indented by shallow "sounds" due to moderate depression of the region after the uplift and dissection of the plain). Here four long narrow reefs, with concave outline to the sea, unite in sharp angles pointing seaward and forming Capes Hatteras, Lookout (Fig. 224), and Fear. The curved reefs appear to result from the action of eddying currents between the continent and the Gulf Stream. Long sand shoals trail off shore from the capes, greatly endangering coastwise navigation. The reefs are locally known as the "Banks"; the few people living on them are called "Bankers." A small breed of horses, known as "Banker ponies," run wild on the reefs. In the absence of springs and streams, the ponies scrape away the sand until they reach fresh ground water. Many of them are sold for use on the mainland.

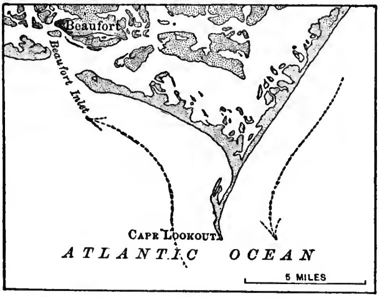

Fig. 224. — The Hooked Spit of Cape Lookout.

Inlets. — The flow and ebb of the tides, reënforced at ebb by river discharge from the mainland, preserve open passages, or *inlets*, through the reefs (Fig. 225). The stronger the tides, the greater the number of inlets.

On the Texas coast, where the range of the tides is small, there are few inlets; one reef is unbroken for nearly 100 miles northward from the mouth of the Rio Grande. Traffic between land and sea is thus almost entirely cut off for long distances. On the New Jersey coast the tidal range is stronger, and inlets are more numerous. On the South Carolina coast the tides are still stronger; there the reefs are so frequently broken that they do not interfere with traffic between land and sea. The strong tidal currents maintain inlet channels deep enough for seagoing vessels to enter the harbors of Charleston and Savannah.

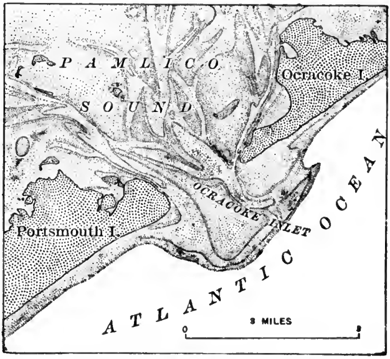

Fig. 225. — A Tidal Inlet and Delta.

Tidal currents in inlets sometimes cause so rapid a change in the form and depth of the channel that the inlets are left blank on sailing charts. Masters of vessels must then trust to local pilots to show them the best passage. The sand swept in and out by the changing currents forms shoals known as *tidal deltas* (Fig. 225), whose outer edge rises in a bar so shallow that vessels must often wait for high tide before crossing it.

Advance and Retreat of Sand Reefs. — When sand is brought (from the bottom or from elsewhere along shore) in greater quantity than it is carried away, reefs broaden on the seaward side and slowly advance into the sea (Fig. 223, *b*). Reefs may thus grow to be a mile or more wide. They retreat when more sand is lost than gained, their dune sands slowly blowing back into the lagoon or upon the lagoon marsh (Fig. 223, *c*). At last the lagoon disappears, and the mainland is directly attacked and slowly cut back in a long low bluff (Fig. 223, *d*).

At Atlantic City, a seaside resort on a sand reef in southern New Jersey, the reef is broadening and gaining on the sea. Some of the hotels facing the beach have been moved forward so as to keep near the ocean front. Further north the New Jersey sand reefs are retreating; for tide-marsh mud, matted by lagoon plants, is found on the outer beach (Fig. 223, *c*).

Still further north the sand reef is absent, and the mainland is cut back in a low bluff on which Long Branch, a noted resort, is built. Severe storms cut away the base of the bluff, sometimes undermining the houses above.

The low coast of the middle Netherlands has retreated two miles or more in historic times; for although the attack by the sea is not so vigorous as on a coast exposed to the open ocean, the land offers little resistance to the waves and tides. A belt of dunes, half a mile or more wide, lies inland from the smooth harborless beach. The chief ports are on the lower courses of rivers, whose channels are broadened by the tides.

The Romans built a castle back of the dunes, near the mouth of the Rhine. In 1520 the dunes had blown inland, grain by grain, leaving the castle close to the sea. In 1694 the castle stood in the sea, about half a mile from land. In 1752 it disappeared, destroyed by the waves.

In 1460 a church that had been built inside of the dunes in the Dutch village of Scheveningen (near The Hague) was reached by the sea. A new church was then built about a mile inland, at the east end of the village. In 1574, the outer part of the village having been gradually consumed by the waves, new houses had been built east of the church, so that it stood in the middle of the village. In a later century the new church stood close to the shore, the body of the village having moved beyond it.

Lake Shores. — Although the waves and currents of lakes are weaker than those of the sea, their shores nevertheless exhibit all of the features above described for the shores of the sea, with the exception of those due to tides.

The shores of the Great Lakes have wasted sufficiently to develop bluffs or low cliffs of comparatively even front for distances of many miles; as along the southern shore of Lake Erie, west of Buffalo. Many other features of lake shores imitating those of seashores might be mentioned.

Coastal Plain Cliffs. — As the margin of a coastal plain is cut back by the sea (Fig. 223, *d*), and the shore bluff increases in length and height, longer and longer stretches

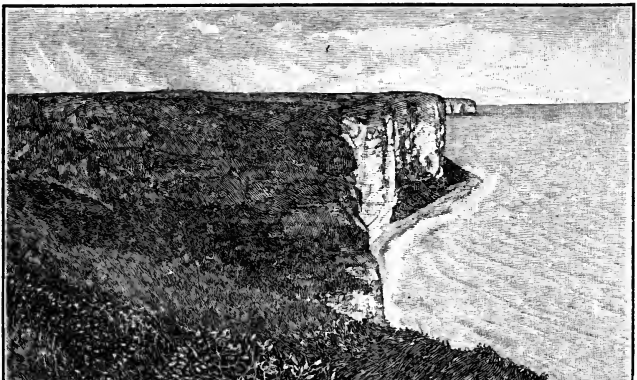

Fig. 226. — The Sea Cliffs of Normandy.

of the shore become harborless; but it is seldom that coastal plains terminate in cliffs of great dimensions. Hence it must be inferred that uplift or depression of the land generally occurs, interrupting the regular development of shore features before the sea has had time to cut far back into the continent.

An exceptional case is found in northwestern France, where the upland plain of Normandy (in general structure similar to that of ancient coastal plains) fronts the sea in a vertical sea cliff, 200 or 300 feet high, with gently curving shore line for many miles. A large part of the plain must have been consumed by the sea in the development of the cliff.

The sea and land are here separated as if by a wall. The plain is cultivated by its agricultural population close to the top of the cliff. So much land has been cut away that the lower trunks of many rivers have disappeared, leaving the upper branches to enter the sea as independent streams, as in Fig. 227. The valleys of the smallest streams end in the cliff face, and the streams fall to the beach below. Larger streams have cut their valleys down to sea level, opening little harbors; here alone are villages built close to the shore line. The stream harbors are kept open with difficulty, on account of the plentiful sand and cobbles that drift along the beach.

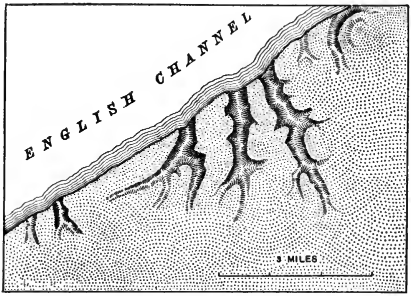

Fig. 227. — Valleys in the Cliffed Uplands of Normandy.

There is good reason for believing that Great Britain has been separated from the continent of Europe in great part by the retreat of the sea cliffs on each side of the English channel. Wolves and other large animals that formerly lived in England as well as on the continent imply the existence of a land connection, as they could not have crossed the waters of the channel, and it is not probable that they were carried across by man.

Effects of Depression and Elevation. — Depression of the land may interrupt the orderly progress of seashore action at any stage in the development of shore lines of the first class. The sea then advances upon the low land, entering furthest along the valleys and thus producing a shore line of the second class, but with moderate coastal relief, upon which a new series of changes takes place.

The irregular shore line, with many sounds and bays along the Atlantic coast from North Carolina to New Jersey, is a good example of the effect of depression. Farmers would have occupied the valley floors if the low land had not been drowned; now fishermen gather from the bays "the harvest of the sea."

Movements of elevation are as common as those of depression, but their effects are generally less apparent. The sea, retreating from its former position, begins the development of a new shore line. The former shore line may be marked by low ridges of sand reefs and dunes, or by bluff-like terraces if an advanced stage of development had been reached before elevation.

A low bluff, interpreted as a former shore line, has been traced on the low coastal plain of Virginia and North Carolina a short distance inland from the present seashore. Further study will probably discover many more examples of this kind on the Atlantic coastal plain.

The coastal plain of Mexico is not a perfectly smooth inclined plain, but is benched by several low terrace-like steps, which are believed to mark the action of the sea during pauses in the elevation of the region.

Shore Lines of the Second Class. — The variety of shore features here included is greater than in the first class, because the forms of the land are more varied than those of the sea bottom. When an uneven land surface is depressed and partly covered by the sea, as in Fig. 228, ridges and hills stand forth as promontories and islands; valleys are entered by arms of the sea; protected harbors are plentiful in the early stages of shore lines of this class.

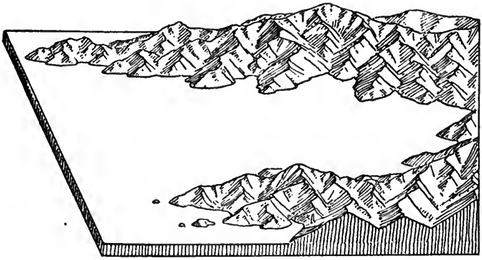

Fig. 228. — Diagram of an Irregular Shore Line.

The western coast of Norway is extremely irregular, having many small and large islands along its "outer shore line," while long arms of the sea, or *fiords,* carry deep water far inland between steep mountain walls.

Sogne fiord, north of Bergen, penetrates the mainland 100 miles, its branching arms giving assurance that it is a submerged valley. It is not known how much of the depth of these and other fiords is due to submergence and how much to glacial scouring.

The walls of the fiords are so steep that roads can seldom follow their shore lines; hence communication is chiefly by water. Settlements are found at the head of the fiords and on deltas built by inflowing streams.

An irregular coast favors the development of maritime arts. Its outlying islands tempt exploration; its protected bays afford safe harborage even for small boats. The people occupying the coastal lands become expert sailors and fishermen.

The numerous bays of southern Scandinavia were known as *viks* to the people who occupied them 1000 years ago; and the inhabitants were therefore called vik-ings, or bay people.

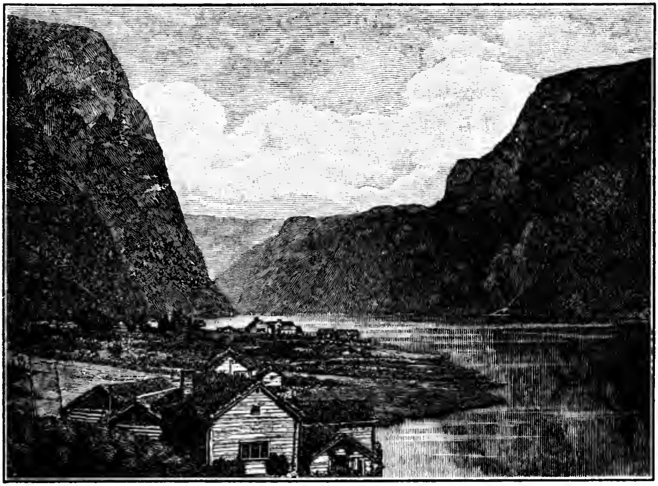

Fig. 229.—A Delta in a Norwegian Fiord.

They became bold marauders, invading and conquering the more southern coasts of western Europe, by whose people the vikings were called "Northmen." Normandy is to this day named after these early sea kings. They were the first European people to venture far out upon the ocean, and thus almost 1000 years ago they discovered Greenland and other parts of the western world.

The west coast of Patagonia (southern Chile) resembles that of Norway. The Canoe Indians dwell here,—a primitive people who find the steep slopes of the land so inhospitable that they live almost entirely in open canoes on the water. A small fire is kept burning on a few sods in the canoes, so that it may be carried from place to place. They have no fixed habitations and make little use of the land, except when they build temporary shelters of tree branches, roughly thatched, in one cove or another where they stop for a time to gather shellfish.

Lake Shores frequently imitate the features of sea-shores of the second class. When mountain valleys are warped, the lake waters rise on the mountain flanks and gain outlines of much regularity. Again, when lakes are formed back of barriers of glacial drift, their waters may rise upon an uneven land surface, transforming valleys into bays and hills into islands.

Lake Lucerne, Switzerland, is an excellent example of an irregular lake in a warped mountain valley; its many arms enter bays between bold promontories of great picturesqueness. The Lake of the Woods, on the northern border of Minnesota, overlaps the border of the rugged highland of Canada; its outline is extremely irregular, and numerous rocky hills rise as islands in the lake. The northern shore of Lake Superior is of exceptional beauty, its bold headlands and outlying islands separating many irregular bays, where the lake waters have risen upon an uneven land surface.

Sea Cliffs and Benches. — The irregular seashore lines above described are relatively little changed from the outline produced by depression, except on the projecting headlands and the outlying islands. Here the sea may beat furiously, cutting a rocky bench beneath bold cliffs and sweeping away the waste of the cliffs into deeper water. Recesses are cut between outstanding ledges. Isolated rock columns, or *stacks*, stand up on the rock bench.

Angular rock fragments, weathered from a rocky coast, are swept about by the dashing waves, and are in time rounded to cobbles and pebbles. In storms the cobbles batter the rock face and grind the rock floor, thus cutting a notch in the edge of the land and forming a cliff that rises above sea level and a bench that is partly bare at low tide. At high tide the waves roll across the bench and undercut the base of the cliff. Great masses of rock fall from the cliff, and for a time protect its base; but their shattered fragments are soon dragged off the bench by the waves and dropped into deeper water, and the attack on the cliff is then renewed. The force of storm waves on an exposed coast suffices to move great blocks of rock, even exceeding 100 tons in weight.

The Orkney and Shetland islands, north of Scotland, have lost much of their former area by the attack of the sea. Headlands break off in lofty cliffs, some of which are nearly 1000 feet high. An isolated stack, known as the "Old Man of Hoy," rises 600 feet above the sea.

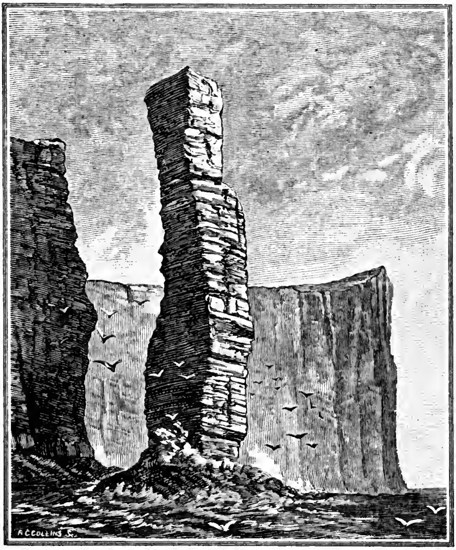

Fig. 230. — The "Old Man of Hoy."

Under the strong attack of the sea a steep coast may for a time be worn into a more irregular outline than its original form (see Fig. 233, *B*).

The stormy promontory of western France, beaten by heavy waves and swept by strong tides, has thus gained a very ragged outline. The shore is dangerous from the many rocky reefs that rise to about half-tide height on the rock bench in front of the cliffs. Light houses on such reefs must be of the very strongest construction.

Sea Caves. — If one part of an exposed sea cliff is weaker than the rest, the waves may excavate a cave in it, cutting away at the head of the cave faster than the overhanging roof weathers down. The length of such caves may reach 20, 50, or more feet.

Fingal's cave, on the island of Staffa, west of Scotland, and many other less famous sea caves are of this origin. The "Ovens," on the coast of Mt. Desert, Maine, are shallow caves of similar nature.

Bay-Head Beaches. — Storm waves sweeping into little bays or coves carry with them some of the waste that is washed from the benches of the enclosing headlands and from the shallow bottom along shore. Beaches are thus formed around the bay heads (Fig. 231), and layers of sediment are strewn over the bay floor, while bare rock benches still front the headland cliffs.

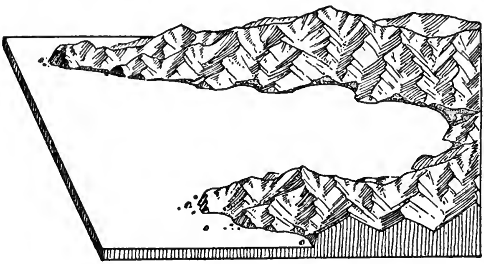

Fig. 231. — Cliffs and Deltas on an Irregular Shore Line.

Bay-head or cove beaches present a smooth curve, concave to the sea, on which the surf breaks evenly, quite unlike the dashing and fretting waves on ragged headlands. The cobbles and pebbles thrown up on the beach during storms may form a wall 5 or 10 feet above high tide, back of which a pond or swamp is often enclosed in the valley that previously opened into the bay. The New England coast has hundreds of small beaches of this kind between its rocky headlands.

Sea Cliffs and Beaches. — As a sea cliff is cut back, the bench at its base becomes so broad that many cobbles and pebbles are not at once washed away into deeper water; thus the beginning of a beach is made at the base of the cliff, and the rock floor of the bench is more or less concealed.

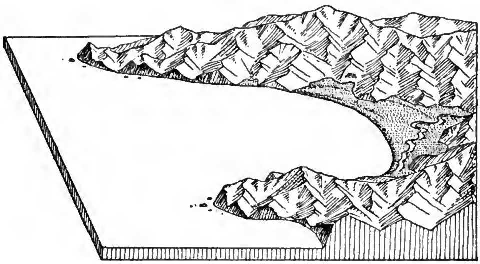

Fig. 232. — A Curved Shore Line.

The breadth which a bench must gain before a beach forms upon it is greater on a coast exposed to strong waves than in more quiet water. In southwest Ireland, exposed to the violent winter storms of the North Atlantic, the ragged headlands have been cut back many hundred feet; yet the benches have only patches of cobbles here and there, and are still for the most part without continuous beaches.

With further retreat of the cliff the beach will be more continuously developed, and much of the material upon it will be washed along shore in one direction or the other, according to the movement of wind-driven waves and tidal currents. The ragged cliff is then worn to a more even front, as in Fig. 233, *C*.

The smoother the front of the cliff becomes, the more steadily may the tidal and wind-swept currents move along it, dragging the pebbles and sand jostled by the waves.

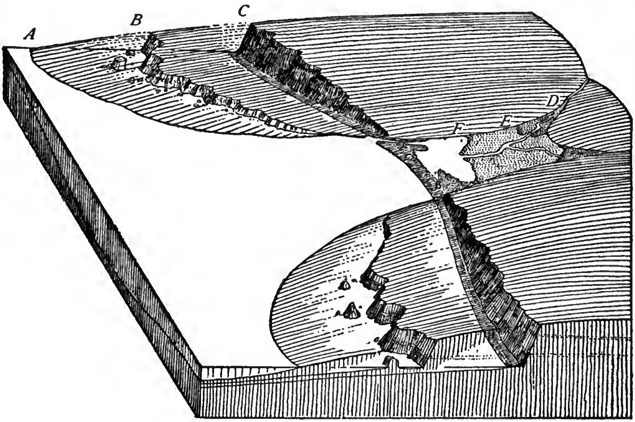

Fig. 233. — Diagram of a Retreating Shore Line.

Instead of following around the curve of every bay, the currents swing across the little bays from headland to headland, building curved *spits*, or *barrier beaches*, with the material brought from the cliffs. The bay heads are in time enclosed and deltas (*E*, *F*, Fig. 233) grow in their quiet waters. The originally irregular shore line thus becomes more and more simplified. As the beached headlands are cut back, the spits and barrier beaches retreat with them, and the coast gains a smoother outline; thus the development of the shore line approaches maturity.

The dangers of the headlands are somewhat lessened when their stacks and rocky reefs are worn away, and when the bench at the cliff base is covered with a somewhat yielding beach, instead of lying bare. At the same time the bays are more or less completely closed, and are therefore less adapted to seafaring settlements.

Tide-Swept Bays. — Strong tides may hinder the formation of beaches across large bays, by preventing the movement of cross currents from headland to headland. The waste that is carried into such bays from the cliffs is ground to fine mud by the tidal currents, and forms extensive tidal flats about the bay head, bare at low tide.

The Bay of Fundy and the Bristol channel are not only kept open but are broadened by the action of the tides, which increase in strength towards the bay heads. The estuary of the Seine is open to the sea, in spite of the mature stage reached by the cliffs on each side. Vessels entering the estuary must keep to the channel between the mud flats, although at high tide a broad sheet of water is spread before them.

A British steamer, some years ago, ran aground on these flats and was swung around square to the channel by the flood tide. When the tide began to fall, the ebb current scoured a hollow under the bow, and the vessel, unsupported bow and stern, broke in two amidships. The next flood tide scoured away the mud on which the middle of the broken hull had been supported; and thus within a day the vessel sank and was buried almost out of sight, a total loss.

Land-Tied Islands. — An island is sometimes attached to the mainland by the backward growth of sand reefs that are supplied with waste from its cliffs. The fortified Rock of Gibraltar, belonging to Great Britain, was originally an island, but it is now tied to the mainland of Spain by a broad sand reef. Part of the reef is "neutral ground," occupied neither by Spain nor by Great Britain.

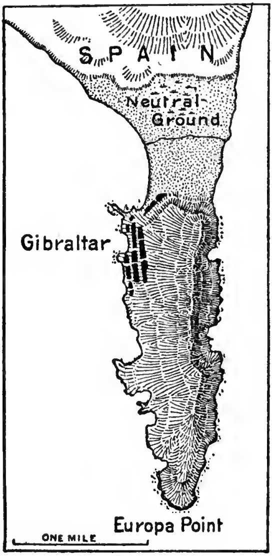

Fig. 234. — Gibraltar.

Effects of Depression and Elevation. — When the further development of irregular shore lines is interrupted by depression, the work of cliff-cutting and bay-filling must be begun again, in much the same way as before.

If a rugged land mass bordering the sea is uplifted, its former cliffs and beaches may be found at a greater or less distance inland from the new shore line. As time passes, the cliffs and beaches are weathered away and the abandoned shore line becomes indistinct.

An elevated shore line, marked chiefly by rocky cliffs and benches with occasional beaches, may be traced along the greater part of the western coast of Scotland, at a height of 20 or 25 feet above sea level of to-day. The present shore line has, as a rule, reached a less advanced stage of development than that reached by the elevated shore line.

This elevated shore line forms a convenient bench along which roads may be laid near the base of the slopes that ascend to the highland summits. Villages and farmhouses are often situated on the broader benches. Sea caves, roughly walled in, sometimes serve as stables for the seaside farmers. Other elevated shore lines are found at greater altitudes.

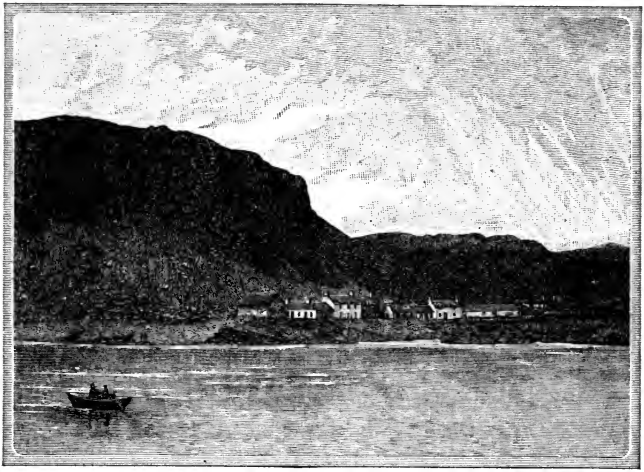

Fig. 235. — Easdale, a Village on an Elevated Shore Line, West Coast of Scotland.

The sediments spread over the bay floors of a former shore line make, after elevation, local coastal plains between rugged headlands. Cliffs are again cut on the headlands, while smooth-curved beaches, sometimes many miles in length, front the little coastal plains (Fig. 236).

Regions of this kind are among the most beautiful parts of the world. Many examples are found along the coast of Italy, the Gulf of Salerno (next south of the Gulf of Naples) being one of the most perfect. When viewed from one of the higher hills on the north, the bay sweeping to the headland on the south and the plain sloping forward from the inner mountains, with the bright coloring of an Italian landscape, form a picture long to be remembered.

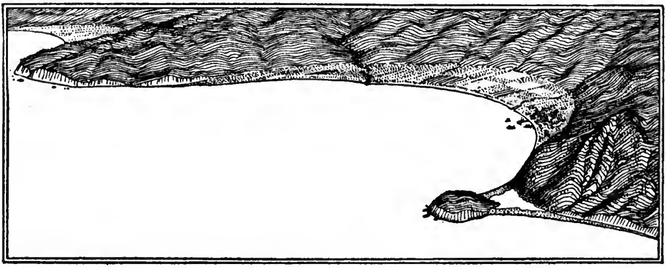

Fig 236. — Headlands and Bays.

The withdrawal of lake waters by a change of climate (p. 318) has an effect on the condition of shore lines similar to that produced by an elevation of the land with respect to the sea. The cliffs and beaches that contour around the slopes of the mountains of Utah, where the waves of Lake Bonneville once beat, in many ways resemble the elevated shore lines of western Scotland.

The western coast of Norway is bordered for much of its length by a belt of low land, sometimes as much as from 3 to 10 miles wide, from whose inner margin a bold ascent leads to the highlands (Fig. 237). The low land is a broad rock bench or platform, cut by the sea when the land stood about 300 feet lower than now. A large part of the population of western Norway dwells on this ancient sea floor.

The former sea cliff, at the inner margin of the platform, is from 500 to 1000 feet high. A number of rocky hills surmount the platform, representing unconsumed islands of the former time. The deep fiords of the highlands and many branching channels traverse the bench, so that its outer part is now fringed with islands. From this it is inferred that, after the cutting of the platform and cliff, the region was deeply eroded by

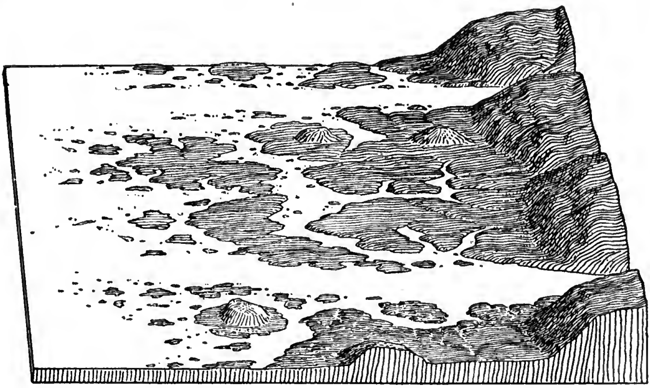

Fig. 237. — The Coast Platform of Norway.

rivers and glaciers, probably while the land stood somewhat higher than now. Since then a depression has occurred, drowning the valleys and thus converting the outer part of the plain into a swarm of islands, many of them so small as to be occupied only by a single family.

The platform is wanting on certain parts of the Norwegian coast, where the sea beats directly against the border of the highlands, as at North cape, a great cliff 1000 feet high and nearly vertical. It is probable that at such points the land stands again in about the same position that it had while the platform was carved. Here the work of making the platform is still going on, and the shore line is becoming more and more mature.

Delta Shore Lines. — Rivers tend to build their deltas forward, and thus oppose the destructive action of the sea.

The outline of a delta will therefore depend on the relative strength of these opposing tendencies, whether on shore lines of the first or of the second class.

A small stream entering an ocean of strong waves or tides can have little effect on the shore line. The action of the waves will cut back the land in face of the effort of such streams to build it forward. Tides of great range will not only prevent small streams from building deltas; they may even widen the lower courses of the streams, forming estuaries.

Streams that enter quiet waters build deltas without interference from strong waves and currents. A small river of a coastal plain, entering a lagoon back of a sand reef, builds a delta of convex front with projecting arms at the mouth of each distributary.

A river of this kind may find no break in the sand reef opposite its mouth for the discharge of its waters into the sea. The nearest inlet may be many miles to one side of the river mouth. As the lagoon is filled by delta growth and tide marsh, the river maintains a channel to the inlet, thus making a square turn from its mainland course, and running for some distance parallel to the coast.

Pedee river in South Carolina receives a branch from North Carolina whose waters flow southwest parallel to the coast at a little distance inland for 70 miles before reaching the point where a break in the shore ridges allows an escape to the sea. This seems to be a result of the process just described.

A great river entering the sea where the strength of waves and tides is not excessive may build a delta which shows little effect of sea action. Examples may be found representing many stages between the extreme cases here indicated.

The powerful Mississippi discharges a great quantity of land waste into the Gulf of Mexico. The waters of the gulf are relatively shallow and the tides are weak. Here the outline of the delta seems to be governed entirely by the action of the great river (Fig. 191).

The several distributaries of the Mississippi build low and slender banks of mud on each side of their channels; hence the delta has several finger-like projections into the sea. In order to increase the depth of water in one of the channels, or "passes," jetties (dikes of wood and stone) have been built forward beyond the end of the delta fingers, thus increasing the current, and forcing it to scour the channel to a depth sufficient for seagoing vessels to enter.

The Rio Grande, a large river, but much smaller than the Mississippi, delivers land waste to the gulf in greater quantity than the waves and currents can altogether remove; hence its delta is built forward (Fig. 238). But the waves are strong enough to smooth the outline of the delta; hence it has a gently convex curve without finger-like projections. The Brazos river, about midway between the Mississippi and the Rio Grande, also causes a slight forward bowing of the Texas coast; here, as in the Rio Grande delta, the lagoon, that elsewhere lies behind the sand reef, is replaced by the delta deposits. It is probable that the Colorado river (of Texas) has aided the Brazos in building forward the coast line, although it now enters a lagoon.

Fig. 238. — Deltas of the Texas Coast.

Example for Review. — The coast of Maine is a worn-down old-mountain region. Like southern New England, the worn-down lowland has been uplifted and again dissected, many valleys being thus formed between ranges of hills. After the valleys were formed, a movement of depression (400–600 feet) converted many of them into bays reaching far inland. The land stood in this depressed position during the glacial period; and while the ice sheet was melting away, much drift was washed from it into the long narrow bays.

Since then a movement of elevation (about 300 feet) has laid bare the bay floors, where marine clays now form an irregular coastal plain enclosed by hills that were formerly promontories and islands. The streams from the interior, flowing forward over the clay plains, have begun to dissect them, so that their surface is now uneven. The coast line is still very irregular, because the postglacial elevation was not so great as the previous depression.

The farmed fields of southern Maine are very generally on the smoother parts of the clay plain. The rocky hills are wooded, except where covered with enough drift to provide a soil worth cultivating. The peninsulas and islands are coming to be occupied as summer resorts by people from the interior states.

Effect of Climate on Shore Lines. — Shore lines, like land forms, are affected by climate; not only by differences between regions of on-shore and off-shore winds, where waves and currents are stronger or weaker, but even more by differences of temperature.

In polar seas the land is often bordered by a fringe of ice called the *ice foot*. This is in part formed of fresh water that freezes on entering sea water whose temperature is below 32°. During the winter the ice foot usually remains attached to the land, unless broken by strong tides; in summer it may melt, loosen, and float away.

The ice foot is often used as a 'longshore roadway for sled travel by Eskimos and Arctic explorers. When loose from the land and moved on and off shore by the tides, stones are dragged beneath it, grinding the shore rocks round and smooth.

In torrid seas, the shores that are not exposed to strong surf may be invaded by certain kinds of trees, forming a network so dense as to make landing difficult.

The mangrove is the most important tree of this kind. It grows freely in shallow sea water on low and muddy shores, and protects the land from the waves. Roots grow out from the trunk above water level. Crabs and oysters live on the stems and roots. Birds occupy the branches. Muddy sediments accumulate in the quiet water among the trees, and thus the land gains on the sea. Shores occupied by mangrove swamps are dismal as compared with the shell-strewn beaches of sand and pebbles, beaten by trade-wind surf.

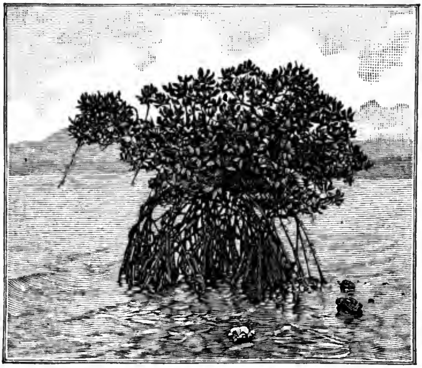

Fig. 239. — Mangrove Tree.

Coral Reefs. — The shallow waters of continental borders or mid-ocean islands in the warmer seas are commonly occupied by coral reefs composed of the limy framework of coral animals. Living corals are found chiefly on the outer side of the reef, where they grow in the shallow water much in the same way that a thicket of small bushes grows on the land.

Reef-building coral animals take the limestone needed for their skeletons from solution in sea water. They are not found where the mean temperature of the water in the coolest month is lower than 68° F., and they do not live at depths greater than about 20 fathoms. There are many different species, but all are fixed to the bottom. Some branch in bush-like forms 1 or 2 feet high ("stag-horn coral"); some grow in round masses from 1 to 3 feet in diameter ("brain coral").

The shores of a volcanic island in water of fitting temperature might be colonized by corals, for the young forms float and are carried far and wide by ocean currents. The following succession of reefs might then be produced.

Fringing Reefs. — When reef-building corals first take possession of a new shore, their growth extends upward from the shallow bottom and outward into the surf, where the constant movement of the sea water supplies them with food. When they are detached from the bottom by severe storms and rolled about

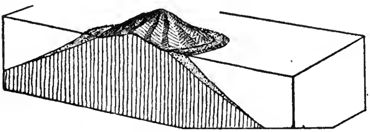

Fig. 240. — A Fringing Reef.

by the waves, the larger fragments of their limy framework are thrown back towards the land, forming shoals, and sometimes rising in a beach a little above sea level; the finer particles are carried off shore and strewn over the sloping bottom towards deep water. The reef thus broadens, forming a fringe close along the shore line. At this stage it is called a *fringing reef.*

Strips of fringing reef are found on the equatorial coast of east Africa, along parts of the Brazilian coast, at various points on the coast of Cuba and elsewhere in the West Indies, and bordering many islands in the Pacific, as the Hawaiian and other groups. The Galapagos islands in the eastern Pacific, close to the equator, are free from reefs, because of the low temperature of the water which there comes in a strong current from far southern latitudes, or which rises from below the surface along the Peruvian coast where the winds blow off shore.

Fringing reefs are generally interrupted opposite the mouths of streams, where land waste makes the bottom muddy and unfit for coral growth. Water passages are often preserved back of the reef, close to the shore. Natural harbors are thus provided, well protected from the surf that breaks on the shoals and beaches of the outer reef.

Barrier Reefs. — A fringing reef broadens by the outward growth of the corals, and the submarine slope is built forward by the supply of coral fragments. At the same time water supplied by rain, by streams from the land, and especially by the surf that rolls over the reef, slowly dissolves and washes away the inner part of the reef where living corals are few or wanting. Thus the reef may come to be separated

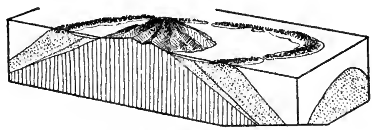

Fig. 241. — A Barrier Reef.

from the land by a shallow lagoon a mile or more wide; and in this way a fringing reef may change to a *barrier reef.*

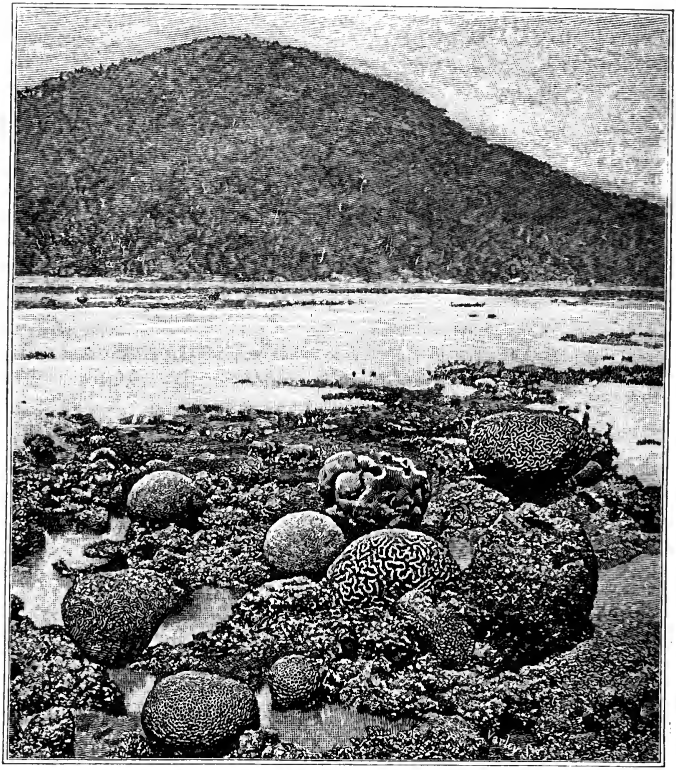

Fig. 242.—Part of the Great Barrier Reef of Australia (as seen at low tide, looking towards the mainland).

The Great Barrier reef stretches along the northeast coast of Australia for about 1000 miles, the largest reef in the world. It is from 20 to 50 miles from the mainland, mostly beneath sea level, interrupted by numerous inlets, and bearing a few low islets. The sea outside descends rapidly to great depths; the water inside is shallow (from 10 to 40 fathoms).

Effects of Elevation. — If a slow uplift occurs, corals will continue to grow on the outer face of the reef. At the same time, rainfall and surf-overflow may wear and dissolve away the uplifted parts so that the reef gains little height above sea level, and the lagoon is kept open beneath sea level. It therefore seems possible that barrier reefs may occur in regions of very slow elevation.

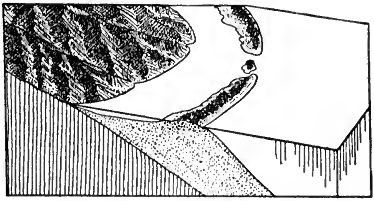

Fig. 243. — Diagram of Part of a Barrier Reef.

If a relatively rapid uplift occurs, a reef may be raised above sea level, forming a terrace-like bench above the new shore line. Elevated reefs are known along many coasts in the torrid zone.

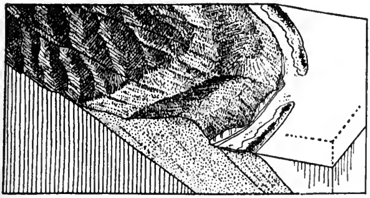

Fig. 244. — Diagram of Part of an Elevated Reef.

An uplifted reef forms a bench at a height of about 30 feet, with a breadth of a mile or less, bordering much of the northern coast of Cuba. Corals are easily recognized in the ragged structure of the reef. It is seldom interrupted, except where rivers cut their valleys through it. The sea has worn a low cliff in the front of the bench; from the cliff top one may look down upon the modern fringing reef now growing in the sea.

Elevated reefs are relatively weak and cavernous structures; they may be worn down much more rapidly than the strong foundation rocks on which they are often based. In this way an elevated reef may be converted into a barrier reef again, the lagoon being dissolved out, while new coral growth takes place on the outer margin. Barrier reefs of this kind may be recognized as long as the island remnants of the elevated reef are not entirely worn away.

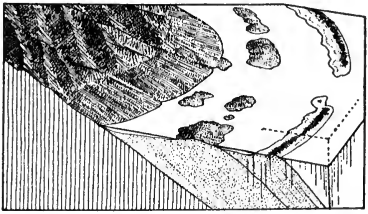

Fig. 245. — Diagram of Part of a Denuded Reef enclosed by a Barrier Reef.

Elevated reefs in various stages of destruction occur on the Fiji islands up to heights of 800 feet. Many of the barrier reefs of this group seem to have grown on the outer edge of platforms formed by the almost complete wearing away of elevated reefs, much of whose surface is now worn and dissolved away even a little below sea level.

Effects of Depression. — If a reef is depressed faster than corals can grow upward, the depth of water above it will increase to a greater measure than that in which reef-building corals can live. Then the polyps are "drowned" and the reef is "dead."

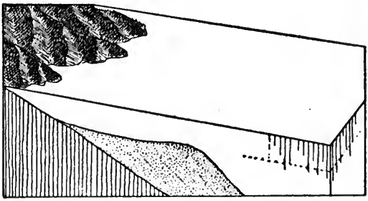

Fig. 246. — Diagram of Part of a Drowned Reef.

The Chagos bank, in the Indian ocean, 1000 miles south of India, is a broad shoal measuring about 100 by 75 miles, at a depth of 40 or 50 fathoms. It is bordered by a ridge 5 or 10 miles wide and 15 fathoms deep, on which a rim about 1 mile wide rises to within 5 or 10 fathoms of the surface, bearing a few low islets here and there with some living coral. The banks appear to have once been an extensive coral reef, now drowned.

The Marquesas islands in the eastern Pacific are a group of dissected volcanoes of irregular outline and steep slopes, with deep water close to shore, as if recently depressed. Cliffs are already cut in the headlands, and the bays contain beaches strewn with cobbles, among which coral fragments occur. There are no living reefs around the shores, although the temperature of the water is fitting and reefs abound in islands to the southward. It is probable that while the Marquesas stood higher, reefs were formed around them, and from these the coral cobbles of the present beaches have most likely been derived; but the depression by which the present outline of the islands was determined appears to have been too rapid to permit the upward growth of the reefs to keep pace with it.

Atolls. — If a slow depression takes place, it may be counteracted by the upward growth of the reef corals. Then the reef will be preserved; it may even increase in size by outward growth during depression, as in Fig. 247. At the same time, the lower slopes of the island around which the reef first fringed will be drowned and its valleys will be occupied by bays; if depression continues, the central island may altogether disappear, leaving only the encircling reef of oval or irregular outline around the lagoon. Such reefs are called *atolls*.

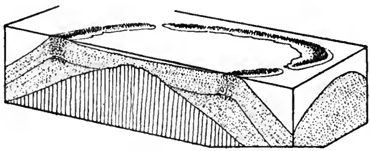

Fig. 247. — A Large Atoll.

If a volcanic island within a barrier reef does not suffer uplift or depression, it must be slowly worn down closer and closer to sea level, while its barrier reef is growing outward. But it is doubtful whether the resistant rocks of such an island could be worn away below sea level, so as not to appear in a lagoon whose depth may be from 20 to 50 fathoms. For this reason the theory proposed by Darwin, that atolls result from the slow depression of islands with fringing or barrier reefs, has had general acceptance.

Life on Atolls. — As coral islands are limited to the warm and uniform climate of the oceans in low latitudes, mostly within the torrid zone, they are bordered with

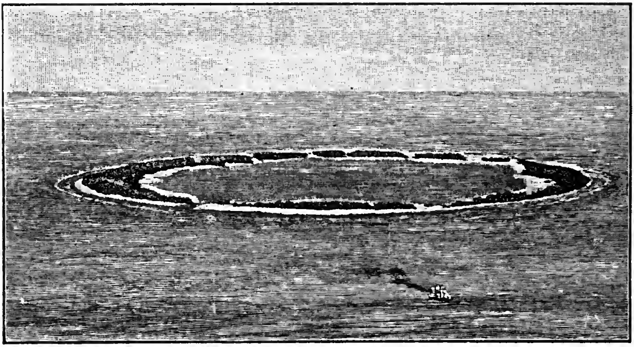

Fig. 248. — An Atoll, or Coral Island.

waters teeming with marine life, and many of them bear a luxuriant vegetation. The natives of the larger atolls lead easy and indolent lives, but their progress towards better conditions than those of savagery is hindered by the small variety in their surroundings and by their distance from lands of more varied form and products.

Although one of the most wonderful objects in nature, a lonesome atoll affords little opportunity for human development.

The small height of atolls subjects them to the danger of being overwhelmed by earthquake waves. Hurricanes sometimes come upon them unobstructed from the open sea, sweeping violent surf far up the beaches; the storm winds break down the cocoanut palms on which the natives depend largely for food and for the materials of many of their simple arts. There are no streams, but fresh water supplied by rains may be found a little below the surface. The thin soil has little variety of mineral matter, but floating pumice is often cast ashore from distant volcanic eruptions, and some of the islanders have learned to gather and pulverize it to use as a fertilizer for their little fields. Floating logs sometimes drift upon the islands, and their roots occasionally carry stones of firmer texture than coral rock (for example, fragments of dense lava from a volcanic island); whetstones, pestles, and mortars are made from these chance supplies.

Although birds are plentiful, there were no mammals on coral islands until rats and mice came ashore from vessels; a few domestic quadrupeds have occasionally been imported by foreign residents.

Until the nineteenth century the natives of most of the Pacific islands knew nothing of the rest of the world. Their highest art was seen in the making of sail canoes, in which they voyaged between the islands of their archipelagoes. It is probable that these islands were originally peopled from larger lands by natives whose small boats had been blown from their intended course.

The Tuamotu or Low archipelago in the eastern Pacific contains 80 islands, only 4 of which rise more than 12 feet above sea level. Most of the islands are atolls. The narrow, irregular reefs are partly below, partly above, tide level, but only $\frac{1}{20}$ of their land area is habitable. The islands are generally higher on the windward (east and southeast) side, where wind and wave supply coral sand to make beach ridges. On the leeward side the surf is not so strong, and here many channels are kept open by outflowing currents.

Like fringing and barrier reefs, atolls may be elevated. After elevation they may be worn down and again converted into atolls of the usual form without any central island.

Metia, one of the Tuamotu group, seems to be an elevated atoll, with cliffs cut on the windward side. It measures about 4 by 2½ miles, with a height of 250 feet. It consists entirely

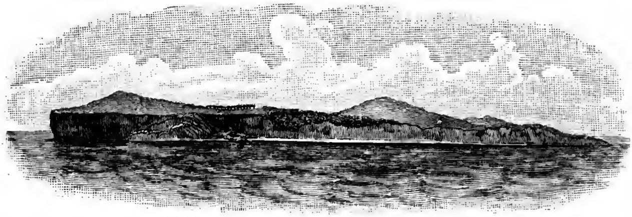

Fig. 249. — Metia, an Elevated Coral Island.

of limestone, containing fragments of coral here and there, but generally of fine texture, as if composed of the coral sand and mud that formed the deeper parts of the former atoll. Many caverns are found in the limestone.

Some of the atolls in the Fiji group are best accounted for by the denudation of elevated reefs, remnants of which are still to be seen standing somewhat above the general level. In these islands the corals that now fringe the atoll have had little influence on the form of the reef; they only form a crust upon the platform of the denuded elevated reef.

If the depression of an atoll is at such a rate that not enough coral waste is supplied to build the submarine slope that descends into deep water, the outer margin of the reef may be slowly worn away, and thus the atoll will decrease in size. It may in time disappear entirely.

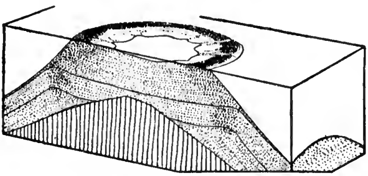

Fig. 250. — A Small Atoll.

Honden island, in the Tuamotu group, is about 3 miles in diameter, with a small central lagoon. The reef rises 12 feet above sea level, and is occupied by a belt of large forest trees. When visited by explorers, about 1840, the island was tenanted only by birds, so tame that they were taken from the trees as if they had been flowers.

Jarvis island is close to the equator in longitude 160° W. It is about a mile in diameter. Its sandy surface is a little depressed at the center, but does not hold a lagoon. This is one of the smallest known coral islands.

APPENDIXES.

APPENDIX A.

Problem of Eudoxus (p. 11). — Eudoxus was one of the earliest of the Greek philosophers to demonstrate that the earth is not flat. His argument may be outlined as follows: Let *NABCS* be a part of a meridian line; the lines *DAE*, *FBG*, and *HCJ* representing the horizons of observers at the points *A*, *B*, and *C*. Each observer can see only those parts of the sky that stand above his horizon. If the observer at *B* travel to *C*, he will lose sight of the stars *X* (supposed to be at a great distance away in the direction of the arrows), while the stars *Z* will come into sight beneath the stars *Y* that he saw before. Eudoxus was in some such way as this led to argue that as he went north or south, his horizon plane tilted one way or the other, and hence that the surface of the earth must be convex. We may imagine that he said: "Observations of this kind might be made by any one who travels north or south. On whatever meridian the observations are made, the result is the same. All meridians seem to have the same curvature, as if they were all circles of the same size. Hence the earth must be a sphere."

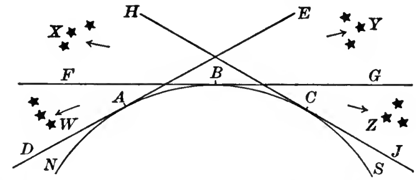

Fig. 251. — Globular Form of Earth shown by Visibility of Stars.

APPENDIX B.

Problem of Eratosthenes (p. 12). — Eratosthenes was the first to measure the size of the earth. His method may be easily imitated as follows: A hill having north and south slopes, *AD* and *AB* (Fig. 252), may be taken to represent part of a small earth, *FBADG*. Set up two boxes, with vertical sticks nailed to their sides, at the points *B* and *D*, on a north and south line; measure the distance *BAD* over the curve of the hill. (If no hill is available for this experiment, set up two boxes on the north and south sides of a school yard, tilting each box slightly away from the other, as in Fig. 253, and representing the curve of the imagined earth by a series of stakes set up between the boxes.)

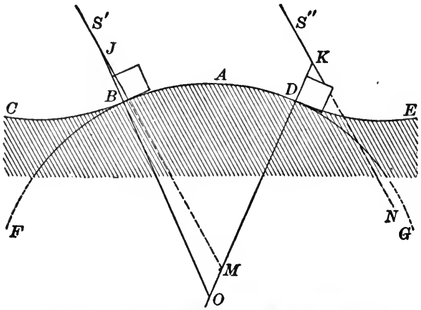

Fig. 252. — Sun Altitudes on the Two Slopes of a Hill.

The vertical sticks *BJ* and *DK* may then be regarded as extensions of the local radii *OB* and *OD* of the imagined earth *FBADG*. At midday, when the sun passes the meridian, the parallel rays of sunshine *S'M* and *S''N* fall in the same plane with the radii *OB* and *OD*. Measure the shadows cast at midday by the sticks *J* and *K* on the upper surface of the boxes.

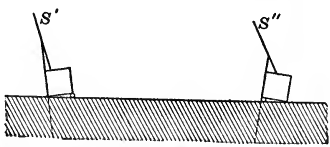

Fig. 253. — Sun Altitudes measured in a School Yard.

Knowing the length of each stick above the box surface, the angles *OJM* and *OKN* may be determined. The angle *BOD* or *JOK* equals the difference between *OJM* and *OKN*. ($JOK = JMK - OJM$. But as *S′M* and *S″N* are parallel, $JMK = OKN$; hence $JOK = OKN - OJM$.) Then we have the proportion:

$$\text{Angle } JOK : 360° = \text{distance } BAD : \text{circumference.}$$

Eratosthenes learned that at Syene (the modern Assouan) on the Nile, vertical objects cast no shadow at noon on June 21. On the same day at Alexandria, about 5000 stadia north of Syene, he measured the angle between the sun's noon ray and a vertical rod, and found it to be $7\frac{1}{5}°$. As the earth-radius at Syene lay in a line with the sun's ray, while the radius at Alexandria made an angle of $7\frac{1}{5}°$ with the sun's ray, he saw that the angle between these radii at the earth's center must be $7\frac{1}{5}°$. He then made the proportion:

$$7\tfrac{1}{5}° : 360° = 5000 \text{ stadia} : \text{circumference of the earth.}$$

There is some uncertainty as to the accuracy of the measure made by Eratosthenes, because the length of the stadium is not accurately known in terms of modern units of distance; but as the distance between Syene and Alexandria is about 500 miles, his result could not have been far from the truth.

The problem of Eratosthenes may be repeated in essence by the students of two schools at places about north and south of each other; for example, at Cleveland and Savannah, or at Chicago and Mobile. At noon upon a certain day, agreed upon by correspondence, determine the angle between a vertical rod and the sun's rays at each place. Measure the distance between the two places (better, the meridian distance between their parallels of latitude) on a good map. Then take the difference between the two angles and repeat the above proportion.

APPENDIX C.

Latitude and Longitude (p. 17). — On the supposition that the earth is spherical, the arc of a meridian from a given point to the equator measures the latitude of that point. The arc of the equator between two meridians measures the difference of longitude between all places on those meridians.

The terms latitude and longitude, or "breadth" and "length," were introduced in ancient times with reference to the countries around the Mediterranean sea, where the dimensions of the known lands were greater east and west than north and south. As exploration proceeded, the same terms were extended all over the globe, although no longer appropriate in their meaning.

Latitude. The latitude of a place may be roughly determined as follows:

In consequence of the rotation of the earth, the sun and stars seem to move around us in circles. The circles thus traced in the sky are arranged like parallels of latitude on the earth; they are all parallel to one another and have the north and south poles of the sky in common.

A few hours' observation on a clear night will aid in understanding the apparent motion of the stars. Several rods may be used as "pointers." Set a rod so that it points to a star. After an hour or two, compare the direction of the star with that which it had before, as indicated by the pointer. If observations of this kind are made on various stars in different parts of the sky, it will be found that over the northern horizon the stars move in arcs of relatively small circles about the sky pole. About 90° away from the pole, and therefore near the equator, the stars move much more rapidly in arcs of larger circles. By leaving the pointers unmoved till the next evening and beginning observations a little earlier than before, the stars may be seen to approach and pass their previous positions. Hence each star makes a whole circuit in a day (strictly, in 23 h. 56 min.). The path of the sun should be traced in the same way.

Observers in temperate latitudes may see a good number of stars in the neighborhood of the sky pole that do not sink below the horizon in their daily circuits; these are called circumpolar stars.

For an observer at the pole, the horizon would stand parallel to the star circles. As the observer moves towards the equator, his horizon is more and more inclined from its position at the poles, and makes a larger and larger angle with the star circles. At the equator, the horizon and the star circles are at right angles to each other. The angle formed by the plane of the horizon with that of any star circle is, therefore, the measure of the arc of the meridian from the pole to the observer. The difference between this arc and 90° is the local latitude. Any student who is familiar with the apparent movement of the stars across the sky may thus roughly estimate his position with respect to pole and equator.

In consequence of the annual motion of the earth around the sun, the (apparent) diurnal motion of the sun is not strictly in a circle parallel to the star circles, but is in a slightly oblique line; the sun thus moves north and south in the sky in the course of a year. But in a single day the sun's path does not depart significantly from a star circle. As the sun may be observed much more conveniently than a star, it may be used for a first rough determination of latitude, in the following manner:

Drive a peg into the ground and to its top attach a pointer that may be easily turned to any part of the sky. At an early morning hour direct the pointer towards the sun (it will be properly set when turned so that it casts a shadow no larger than its cross section on a paper held behind it), and record the position of its end by driving a stake into the ground so that the top of the stake shall just touch the end of the pointer.

Repeat this process several times during the day. The tops of the stakes will then mark part of a circle whose plane is parallel to that followed by the sun. Standing at a little distance to one side, the stake-top circle may be seen edgewise, so as to appear as a slanting straight line, *AD*. The angle *DAC* that this line makes with the horizon measures the arc of the meridian from the observer to the pole. The angle *DAE* that it makes with a vertical line measures the latitude, as ordinarily counted from the equator. The advantage of this method is that it can be performed without knowing the position of the sun with respect to the sky equator.

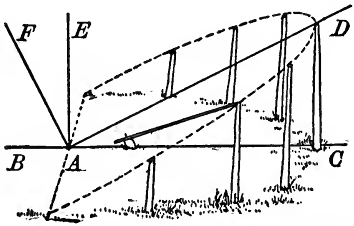

Fig. 254. — Sun-Circle Method of Measuring Latitude.

The latitude of a place is also measured by the altitude of the pole of the sky. (Atmospheric refraction is not considered in any of these problems.) At the equator the sky pole would lie on the horizon; and for every degree of latitude that the observer moves north, his horizon would dip a degree below the sky pole. The North star is about a degree and a half from the north pole of the sky; but, in rough measures, the altitude of the North star may be taken as equal to the latitude.

Latitude may be determined by measuring the noon altitude, or meridian altitude, of the sun, provided the angular distance of the sun from the sky equator is known. The meridian altitude of the sun is SAC (Fig. 255). If its angular distance from the sky equator is SAD, then $SAC - SAD = DAC$ = the meridian altitude of the sky equator = 90° minus the local latitude. This method is commonly employed for determining the latitude at sea, the sun's position with respect to the equator being given in the Nautical Almanac.

On a spherical earth latitude might be defined as the angle in a meridian plane, limited by the radii drawn to the equator and to the place of observation. But on the spheroidal earth latitude must be defined, not by the angle between the radii, but between the verticals AM and QM, or between the horizon planes AB and QB, for $CBQ = AMQ$. Latitude may

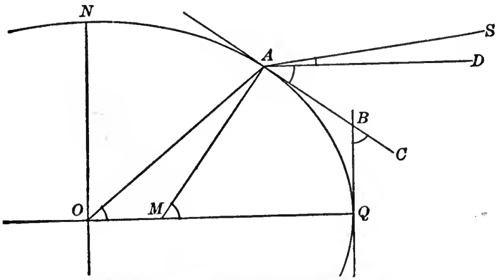

Fig. 255. — Latitude on a Spheroidal Earth.

then be defined as the angle between the tangents to a meridian at the place of observation and at the equator.

Longitude. There is no meridian from which longitude may be counted as naturally as latitude is counted from the equator; but it is customary in English-speaking countries to take the meridian of the astronomical observatory at Greenwich on the Thames below London as the prime meridian. Difference of longitude may be determined as follows:

Imagine two observers on different meridians. Let each observer set his clock to noon, when the sun passes the plane of his meridian. (This moment may be determined by noting the time when a vertical rod casts the shortest shadow on a horizontal surface.) If the two observers could then compare their clocks, the difference of the two local times would give them their difference of longitude, reckoned in hours and minutes (24 h. = 360°). The comparison of times may be made when a lunar eclipse happens, as follows:

The eclipse being caused by the entrance of the moon into the earth's shadow, it must be seen at the same moment by all observers. Hence, if two observers note the local time of the beginning of a lunar eclipse and then by correspondence compare their records, the difference of the local times gives their difference of longitude. This method was first employed by Strabo, about the beginning of the Christian era. The date of eclipses may be found in almanacs.

Another method involves the carrying of a timepiece from one place to the other. Let the students in two schools, as in Cincinnati and St. Louis, set their watches to noon at the passage of the sun across their local meridians. Then let either school send a watch by express to the other school. A comparison of local times can then be made. The result can be confirmed when the watch is returned. This method has frequently been employed in determining the difference of longitude between the capitals of various countries, a number of very accurate timepieces (chronometers) being carefully carried from one place to the other.

Longitude is determined at sea by a similar method. A chronometer set to Greenwich (or some other) local time is carried on the vessel. Local noon is determined by noting the time when the sun rises highest above the horizon in its daily circuit. After certain corrections are made the difference between Greenwich and local time gives the longitude.

A very simple method may be employed for finding the difference of longitude between two places that are connected by telegraph. Let the local time be ascertained, as described above, at each place. At some day and hour agreed upon, let the observers at each place go to their respective telegraph offices and exchange time signals; that is, at certain even five seconds, as indicated by the watch, let the observer at one place send a telegraphic signal to the other observer, who records the time of its arrival. Local times may be thus compared with great accuracy. This method has now been employed not only between neighboring cities, but across the whole breadth of the United States, and by cable across the Atlantic. It may be easily repeated between schools a hundred or more miles apart, at a very moderate cost.

APPENDIX D.

Globes, Maps, and Models (p. 17). In the study of geography it is necessary to represent the earth, or parts of it, in a form convenient for study. This is done on globes, maps, and models. Globes are excellent in showing the general distribution of land and water over the whole earth, with true outlines and correct relative positions; but they cannot be made large enough to exhibit the small features of land forms.[1]

Maps necessarily have some distortion, for it is impossible, without crowding or stretching certain parts, to represent the convex surface of the earth, curved east and west as well as north and south, on a plane surface. But maps of parts of the earth have the advantage of being easily constructed of a size large enough to exhibit even the smaller features of the lands.

Models are less commonly used than globes or maps, but if well constructed they are of great value, as they may represent the form of the lands over moderate areas with great

[1] An inexpensive six-inch globe is made by A. Donnelly, Oxford, N. Y.

fidelity. Views of the Harvard Geographical Models, designed by the author, are given in Figs. 71, 72, and 122.[1] Models are sometimes made with the sea surface convex, like that of the earth; they then correspond to parts of large globes. A model of the United States, on a true-curved surface, is reproduced in Plate A, to illustrate the physical features of the country.[2] It is important that the height of ridges and mountains on models should not be much magnified in proportion to their horizontal measures.

Projection of Maps. In the construction of maps, the meridians and parallels are first drawn as guide lines by a method called *projection* (see below); then the outlines of land and water, the position of boundaries, cities, etc., are drawn in according to their determined latitude and longitude, or according to their distance and direction from known points.

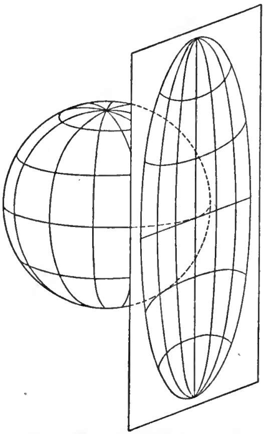

Fig. 256. — The Stereographic Projection.

In order to present half of the earth's surface, the *Stereographic projection* is commonly employed as follows:

Let the map plane touch a globe at the equator, as in Fig. 256. From the opposite point on the equator imagine straight lines drawn through various points on the meridians and parallels; prolong or *project* these lines till they intersect the map plane. The projected position of the guide lines is thus determined. The central

[1] These models are published by Ginn & Company.

[2] This model is made by E. E. Howell, 612 17th Street, N. W., Washington, D. C.

part of such a map is in true proportion; at the margin distances are doubled. In actual practice projection does not require the aid of a globe; the position of the projected guide lines is constructed by an ingenious use of geometry on the map plane itself.

When it is desired to represent nearly all the earth on a single map, the *Mercator projection* is commonly used; it may be approximately constructed as follows:

Imagine a cylinder touching a globe around the equator, as

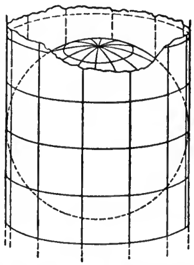

Fig. 257. — The Mercator Projection.

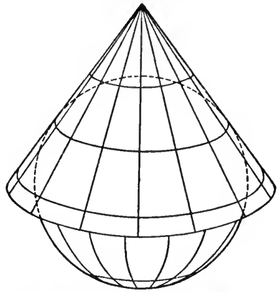

Fig. 258. — The Conical Projection.

in Fig. 257. From the center of the globe project the guide lines upon the cylinder. Cut the cylinder down one side, and open it flat. The equator and parallels are then horizontal lines; the meridians are vertical lines. There is no distortion around the equator, but there is an increasing exaggeration towards the poles; hence the polar regions are not represented on maps of this kind.

When a small part of the earth's surface, such as Germany or Mexico, is to be mapped, the *Conical projection* (or some modification of it) involves relatively little distortion. Imagine a cone touching the earth on a latitude circle that passes through the middle of the country to be mapped. Project lines from the center of the globe to the enclosing cone. When the cone is split and unwrapped, the meridians are divergent straight lines, and the parallels are concentric circles.

Many other methods of projection are also employed.

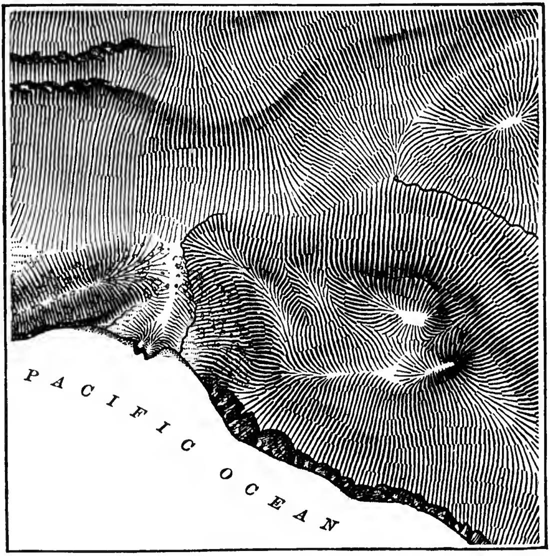

Fig. 259. — Representation of Relief by Hachures.

Relief. The unevenness of a land surface is technically known as relief. Models have the advantage of showing actual relief. On maps relief is shown in various ways. *Hachures* are lines drawn in the direction of the surface slope, — longer and finer for gentler slopes, shorter and darker for steeper slopes. Hachures are used on the maps of the U. S. Coast and Geodetic Survey (generally known as the

"Coast Survey"). *Contour lines*, or *contours*, represent level lines along the side of a slope, as if marking the shore lines of the ocean at successive stages of its rise on the land. They are placed so as to be separated by definite vertical intervals, such as 50 or 100 feet; consequently they stand far apart on gentle slopes and close together on steep slopes. Contours are used on the maps of the U. S. Geological Survey, and should become familiar by frequent use. Examples of contour maps are given in Figs. 134, 137, and 153.

Lists and prices of the maps published by these surveys may be obtained without charge on addressing the Superintendent of the U. S. Coast Survey, and the Director of the U. S. Geological Survey, Washington, D. C. Many of the maps are of great value as geographical illustrations. A general account of many of them is given in "Governmental Maps for use in Schools," Holt & Co., New York. The maps published by the Geological Survey can be had for two cents apiece when bought by the hundred.

Relief is sometimes indicated by shading, so that one side of a hill or mountain appears lighter than the other side. Darker tints are sometimes used to indicate greater heights. Good examples of both these methods have been prepared for the state of New Jersey; they may be bought at moderate price from the State Geological Survey, Trenton, N. J.

Scale of Maps. The ratio of a distance on a globe or map to the same distance on the earth is expressed by the *scale*. A globe 8 inches in diameter is on a scale of about 1 inch to 1000 miles. Many maps are on a scale of about 1 inch to 50 or 100 miles. The scale may be expressed by a fraction — a scale of 1 inch to 2 miles being $\frac{1}{126720}$ of nature. The simpler fraction, $\frac{1}{125000}$, is adopted for many of our national maps. A scale of $\frac{1}{62500}$ corresponds closely to that of an inch to a mile.

APPENDIX E.

Terrestrial Magnetism. — The earth acts as if it were a great magnet; this being one of its most remarkable and useful properties. In response to the earth's magnetism, a magnetic needle, delicately suspended on a vertical pivot, will take a definite direction, about north and south in many parts of the world. The magnetic needle, or compass, thus serves as a guide on pathless lands and seas.

As the needle seldom points true north, its departure from the meridian must be determined. This angle is called the *magnetic variation* or *declination.* It may be found by comparing the direction of the needle with the shadow of a vertical rod at midday. The variation slowly changes from year to year.

The compass was invented by the Chinese. It was introduced into Europe about 800 years ago. When Columbus made his first voyage, the magnetic variation in Europe was west of true north. He found that it decreased as he sailed westward, and soon after passing the longitude of the Azores he discovered a point where the variation was zero. Farther west the variation was found to be east of true north, increasing as he sailed west from the point of no variation.

It is said that when Spain and Portugal were in dispute about lands then newly discovered, it was decided by the Pope that Portugal should have the lands to the east of a meridian that ran close to the point of no variation, and Spain all the lands to the west of it. The eastern point of South America lay east of the dividing line, and hence fell to the share of Portugal, which thus gained possession of Brazil. For that reason Portuguese is spoken there to this day, while Spanish is the language of the other American republics from Mexico southward.

Since the time of Columbus it has been found that the line of no variation (connecting all points where the needle points due north) is not a meridian, and that it shifts its position. About 1500 it lay on the mid-Atlantic. About 1600 it ran from Finland to Egypt. In 1700 it again traversed the mid-Atlantic. Now it runs through the United States from lower Michigan to South Carolina. At all places in the United States east of the line, the compass needle points to the west of the true meridian; at all places west of the line, to the east.

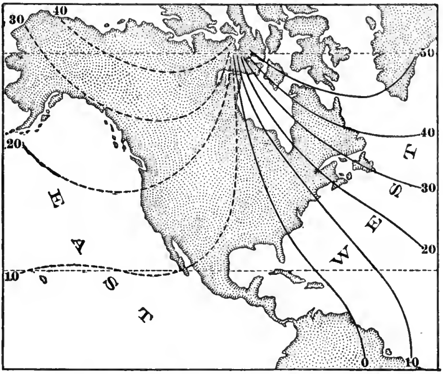

Fig. 260. — Lines of Equal Magnetic Variation.

If lines of magnetic north (often called "magnetic meridians") are drawn through many places and prolonged, always following the guide of the needle, they will converge and meet at a point called the north magnetic pole, in the northern part of the Canadian province of Keewatin (northwest of Hudson bay, latitude 70°). If the magnetic meridians are prolonged southward, they converge towards a south magnetic pole, far south of Australia. On the (true) polar side of the magnetic poles the variation of the compass may be 180°; its north end would there point south.

When the values of magnetic variation are found for many places and entered on a map, lines may be drawn through the places where the values are alike. These are called "lines of equal variation," as in Fig. 260.

APPENDIX F.

The Annual Movement of the Earth around the Sun and its Consequences (pp. 27 and 35) may be best explained after pupils have been led to notice the stars seen in the east shortly after sunset. Observations made once a week or fortnight suffice for this purpose. If they are patiently continued, it may easily be shown that a line from the sun through the earth points successively to different groups of stars; but that at the end of a year it points again to the group with which the observations began. Recognizing that the stars are very far away, much farther than the earth is from the sun, the movement of the earth around the sun once in about 365 days can be thus reasonably proved. An understanding of the earth's revolution thus gained is of much greater value than the memory of a text-book paragraph.

The following construction will be found to give a better explanation of the cause of the seasons, as dependent on the inclination of the earth's axis, than can be gained from a ready-made diagram.

Through the middle of a sheet of paper that measures 10 or 20 inches on a side, draw a straight line parallel to one side. Let this middle line represent 200 arbitrary units of length. Mark two points, one on each side of the middle of the line, so that they shall be 3 units apart. Drive two pins through the paper at these points so that they shall stand firm. Place a loop of thread, whose perimeter measures 189 units, over the pins; stretch the loop tight with a pencil; and thus guided draw a curve around the pins. It will look like a circle, but it is an ellipse, and represents the *true form* of the earth's orbit. Take out the pins, and around one pin hole draw a circle a little less than 1 unit in diameter; this represents the sun, the units being millions of miles.

The distances from the sun along the middle line of the paper to the orbit will be 91½ and 94½ million miles. The earth occupies the first of these points (called *perihelion*) on January 1, and is then nearer the sun than at any other time of the year. The opposite point (*aphelion*) is occupied on July 1. On this scale the earth would be a minute dot, hardly visible. It must be magnified to a globe (wooden ball) about one inch in diameter, and set up on a small flat support with a pin or wire for its axis. The North star being supposed to be above the upper side of the paper, the earth must move around its orbit so that when seen from the sun it passes from right to left. Move the earth back from its position on January 1 by ⅑ of a quadrant; this is the position for December 21. In this position, tilt the upper end of the axis 23½° away from the vertical and away from the sun. The earth is then set in its proper attitude. Now move it slowly around the orbit, always keeping the axis parallel to its oblique position on December 21. It will then clearly appear that the sun's rays will shine unequally on the northern and southern hemispheres in different parts of the orbit. The limits of the zones are easily defined. By turning the earth on its axis, it may be seen that a point, as in latitude 40° N., will have oblique (weak) sunshine and short days with long nights in the winter months, and steeper (stronger) sunshine, with longer days and shorter nights in the summer months. The times of shortest days and shortest nights are the *solstices*, December 21 and June 21, respectively. At two points on the orbit (found by drawing a line through the sun at right angles to the solstitial line), the days and nights are equal; these points are called the *equinoxes*, and are passed on March 20 and September 22. The sun will be vertical at noon at some time during the year at every point within 23½° north or south of the equator — the zone thus defined being called the torrid zone. On December 21 the sun will not be seen from any point within $23\frac{1}{2}°$ of the north pole; on June 21 it will not be seen from any point within a similar space around the south pole — the spaces thus defined being called the north and south frigid zones. The north and south temperate zones lie between the torrid and frigid zones; they never have a vertical sun, or a day in which sunlight does not reach every point within their limits. Frequent practice with school-made apparatus will make the problems of the seasons and the zones well understood.

APPENDIX G.

The Circulation of the Atmosphere (p. 29). — The interesting problem of the atmospheric circulation as modified by the earth's rotation cannot be profitably taken up in a book of this grade. Attention should be given chiefly to the more important members of the circulation seen in the lower currents or winds, as described in the text. It may be briefly stated that, on account of the earth's rotation, there is a force that tends to deflect all horizontal motions (whatever their direction) to the right in the northern hemisphere, and to the left in the southern. This force is zero at the equator, and strongest at the poles. The temperature being unlike at the equator and poles, gravity tends to produce interchanging currents along the meridians. The earth's rotation deflects these motions to the right or left, according to the hemisphere, and the resultant motions greatly affect the distribution of pressure that would result from differences of temperature alone. Instead of finding high atmospheric pressure in the cold polar regions, the pressure there is lower than at the equator; and a belt of high pressure is found about latitude 28° or 30° N. and S., this belt defining the "meteorological tropics." See the author's "Elementary Meteorology," 1894.

APPENDIX H.

Clouds and Rainfall (p. 31 and 45). — A greater amount of water vapor can be contained in warm than in cold air. When as much vapor is present as can be formed at a given temperature, the air is said to be saturated. When air is not saturated, it may be made so by cooling it until the temperature falls to that degree at which the amount of vapor present is as much as can be contained. Any further cooling will make the air cloudy, and if continued far enough will cause rain or snow.

The chief processes by which large masses of air are cooled sufficiently to become cloudy and yield rainfall are: (1) mixture with colder air masses; (2) movement into a region where sunshine and radiation from the earth cannot maintain the preëxisting temperature; and (3) an ascending movement (generally very oblique), whereby the air rises and the pressure of the overlying atmosphere upon it is reduced, so that it expands and cools. The first of these processes occurs in the whirling winds of cyclonic storms, but it is probably of much less importance than the others. The second process takes place when winds move towards the pole, and especially when this movement carries them from warm seas to cold lands, as in passing during the winter season from the Gulf of Mexico or the Atlantic towards the Great Lakes in front of a cyclonic center. The third is of great importance when winds encounter mountain ranges over which they must rise; and again in cyclonic areas, where the whirling winds slowly ascend to great heights.

It should be noted that the cooling of ascending currents is hardly influenced at all by the cold of lofty mountain tops, or by the low temperature of the upper atmosphere that they enter. The cooling is the immediate result of the expansion of the ascending air. Cooling of this kind may be felt in a small way when the air is allowed to escape from its compressed condition in a bicycle tire by opening the valve.

By reversing the above processes the conditions of clear and dry weather are indicated. The clouds of cool winds will be dissolved when the winds mix with warmer currents. Movement towards the equator, where higher temperatures are produced, will increase the capacity of air currents for vapor. They will then dry the surface over which they blow. It is in this way that the trade winds produce deserts. When air descends from aloft, it is compressed by the weight of the air that rolls in upon it above. It is thus warmed; and if it contained any clouds at first, they will be speedily dissolved. Hence winds that become cloudy and give forth rain on one side of a mountain range will be clear and dry when they descend on the opposite slope. In the same way the air of anticyclonic areas is clear and dry, because it settles down from great heights to supply the outflowing winds at the base.

The many forms assumed by clouds afford better material for observation than for definition. Students should be led to describe and to classify the ordinary cloud forms, and to note their prevalent direction of movement and their altitude relative to one another, rather than to learn names and descriptions from a book. The chief classes of cloud form are: the *cumulus*, or heaped cloud, of massive structure and moderate altitude, characteristic of daytime and fair weather; the *cirrus*, or curled cloud, of delicate, fibrous structure and great altitude; *nimbus*, or rainfall cloud, heavily covering the sky, and yielding rain or snow. Cumulus clouds are formed in local ascending currents of air; they sometimes grow into the nimbus of thunder storms. Fibrous cirrus clouds may often be traced westward to a source in thin sheet-clouds, called *cirro-stratus*, and these in turn to a source in the heavy nimbus of a cyclonic area.

APPENDIX I.

Weather Observations and Weather Maps (p. 49). — A thermometer, barometer, wind vane, and rain gauge suffice for elementary observations of the weather. The more accurate the instruments are, the better, but useful results can be obtained with instruments of very moderate cost. Observations should be conducted so as not only to determine the general change of the seasons, but also to exhibit the relation of local weather to the general phenomena exhibited on the United States weather maps. For this purpose it is desirable to give attention to one weather element at a time; for example, first wind, then clouds and rainfall, next temperature, finally pressure. Each of these elements should be noted during the passage of one or two cyclonic and anticyclonic areas represented on the weather maps. After the several weather elements have been studied singly, they may be observed in their natural combination; thus an understanding may be gained of the relation between local and general atmospheric conditions. Local and distant phenomena may be compared; thus a period of settled fair weather illustrates the weather of the trade wind belt; a period of changing weather, the weather of the north and south temperature zones.

Accompanying these observations, exercises on the construction of weather maps may be given. Here, as in local observation, it is well to give attention to one element at a time, as in Figs. 12 and 15. The correlation of the various weather elements in cyclonic and anticyclonic areas, the eastward progress of these areas, and the resulting weather changes, should be discovered by the pupils themselves, as far as possible, from the study of a selected series of typical weather maps. There are few subjects better adapted to the inculcation of scientific methods than the study of weather changes.

Daily weather maps can be obtained from the nearest publishing station of the U. S. Weather Bureau at a nominal cost. If publicly displayed where they may be of general service, they may usually be obtained free of charge. A collection of such maps is of great service in teaching; the more striking examples of cyclonic and anticyclonic areas should be noted as types. Information regarding the distribution of the maps may be had on addressing the Chief of the Weather Bureau, Washington, D. C. Outline maps of the United States are useful in laboratory work on weather elements.

The following outline of a series of practical exercises may be found useful. The work here suggested is described much more fully in Ward's "Practical Exercises in Elementary Meteorology."

1. Dictate the temperatures from a weather map[1] for at least the eastern half of the United States. Let the pupils chart the temperatures on an outline map, and draw in the isotherms for every ten degrees. The facts thus found should be stated orally. It is advisable to select maps showing well-marked examples of warm or cold waves in different seasons.

2. A similar exercise on winds, indicating their direction by an arrow and their velocity by the length of the arrow (scale, 40 or 50 miles to an inch). Let the pupils interpolate additional arrows, until the outline map is fairly well covered with wind lines. Then state the results orally, and after they are well formulated, write them down. Weather maps for this exercise should be chosen to show well-defined areas of high or of low pressure and pronounced wind movements. In describing the spiraling movements of winds, such as are

[1] Instead of dictating temperatures for the stations of the Weather Bureau, which may not be indicated on the outline maps employed in the laboratory, it is convenient to read from a weather map the temperatures for the corners of different states, as indicated by the adjacent isotherms.

found about areas of high or low pressure, it is convenient to indicate their direction of turning by the expressions, "clockwise" and "counter-clockwise."

3. A similar exercise on the state of sky and rain or snow. By selecting weather maps in which well-defined areas of clear and fair sky, cloud, and rain (or snow) are shown, the pupils may draw lines dividing areas of different kinds, and describe the position of the areas thus found.

4. A similar exercise on pressure and isobars. Centers of high (or low) pressure areas should be indicated. Lines may be drawn outward from these centers, at right angles to the isobars, so as to show the directions in which pressure decreases (or increases). If desired, the temperatures of Exercise 1 and the pressures of Exercise 4, or the winds of Exercise 2 and the pressures of Exercise 4, may be dictated from the same weather map; and after the exercise on pressures has been performed, the pupils may be told that the charts of temperatures and pressures (or winds and pressures, as the case may be) are for the same date; and some relation between the distribution of the two elements may then be sought. This leads to the following exercises.

5. Having charted pressures and winds for the same date, discover and state the relation between them. One section of the class may be given an example including a center of high pressure; another section, an example with a center of low pressure. State the results orally. When clearly stated, write them down.

6. A similar exercise with pressure, winds, and temperature.

7. A similar exercise with pressure, winds, and sky.

8. Select a series of maps for four or five successive days, showing the progress of a well-defined area of high (or of low) pressure from the Rocky mountains to the Atlantic coast. Divide the class into as many sections as there are weather maps in the series employed. Dictate to each section

sufficient readings of pressures to define the center of a high (or low) pressure area on a single map. Then let a leader for each section state to the other sections the position of the center of high (or low) pressure that he has determined. Each pupil will thus chart on his map the successive positions of the centers. Connect the points thus indicated, thus determining the path of the center. Describe the path. Determine the velocity of the center for each period of 24 hours; and the average velocity per day and per hour. It will usually be found that the progression of low pressure centers is much faster in winter than in summer.

9. Trace off on a sheet of thin paper the elements constructed in Exercise 6 or 7. Move the traced map over an outline map in the direction of a path, as determined in Exercise 8. Note the changes in weather that would be thus brought to an observer occupying a fixed position upon, north of, or south of the path. This exercise affords good opportunity for careful writing of the results obtained.

10. Compare the weather changes, determined by local observation at school during a passing period of changing weather, with the changes determined deduced from Exercise 9. Infer the situation of the school with relation to the path of the controlling center of high (or low) pressure.

The best maps prepared in a series of exercises of this kind may be preserved to be used as additional exercises for classes in succeeding years.

APPENDIX J.

The Moon and the Tides (p. 86). — Let *C* (Fig. 261) be the common center of gravity of the earth and the moon. Both bodies revolve around this center once a month ($27\frac{1}{4}$ days), the plane of the page being the plane of their revolution, and *AFBD* being the earth's equator. The attraction exerted by the moon on a part of the earth at *E* is just equal to the resistance (centrifugal force) that this part offers to turning from a straight line, *EJ*, into its curved path, *EG*. At *A* the attraction of the moon is a little greater, and at *B* a little less, than at *E*. The resistances to curved motion (centrifugal force) are everywhere alike. Hence at *A* and *B* there must be small unbalanced forces, $t_{\prime}$ and $t_{\prime\prime}$, directed outward from the earth's center, and lying on the line *EM*. As the earth turns on its axis, any point on the equator *AFBD* must be acted on by the forces $t_{\prime}$ and $t_{\prime\prime}$ every 12 hours 26 minutes. The forces are very weak, and the waves that they produce in

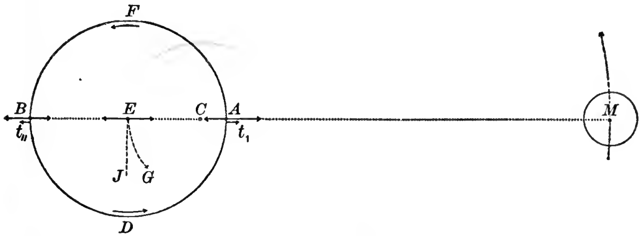

Fig. 261. — The Tidal Problem.

the oceans must be very low; but they are perceptible when increased by running on shore.

The only point that may be obscure in this statement is the constant value of the resistance to curved motion at all parts of the earth. But remembering that the diurnal rotation of the earth may be overlooked while the tidal forces are discussed, it should be seen that the monthly movement of the earth around *C* must be accomplished *without angular turning*, a given side of the earth always facing in a fixed direction. If this be tried experimentally with a disk of paper, or with a small globe, it will be seen that all parts of the earth thus moved will describe circles of the same size as that which carries E round C; and that at any moment *all parts are moving in the same direction with the same velocity.* Hence all parts must have the same resistance to curved motion. If this important point is once grasped, there should be no further difficulty in the demonstration of the unbalanced forces at A and B.

The value of the tidal forces $t_{\prime}$ and $t_{\prime\prime}$ may be roughly calculated in terms of gravity, as follows:

As the moon's mass is $\frac{1}{80}$ of the earth's mass, and as the distance from the moon to the earth is sixty times the earth's radius, it follows that lunar attraction at E is $\frac{1}{80} \cdot \frac{1}{(60)^2}$, or $\frac{1}{288000}$ of terrestrial gravity. Lunar attractions at A and B are $(\frac{60}{59})^2$ and $(\frac{60}{61})^2$ of lunar attraction at E. The excess of lunar attraction at A and the deficiency at B with respect to the value at E will measure the value of the small unbalanced forces to which the tides are due. These will be found to be about 0.0000001 of terrestrial gravity.

The sun also causes tides in the oceans, but, in spite of the great size of the sun, its distance is so much greater than that of the moon that the solar tides have only about one-third of the strength of the lunar tides. Hence the lunar tides are not overcome, but only modified by the solar tides. At time of new and full moon, when lunar and solar tides fall together, the tidal range is increased, low tide being lower as well as high tide being higher than usual. *Spring tide* is the name given to this condition of strong range. At the first and third quarter of the moon, the solar forces attempt to make low tide where the lunar forces make high tide, and *vice versa;* hence at such times the tidal range is decreased, low tide being not so low and high tide being not so high as usual. *Neap tide* is the name given to this condition of weak range. It is often the case that the range of spring tides is twice that of neap tides.

APPENDIX K.

Recent observations indicate that in the polar oceans, where evaporation is small, the cold surface water is somewhat reduced in density by the supply of fresh water from rain, snow, and rivers. The polar surface water is therefore not quite so dense as the somewhat less cold but salter surface water in latitude 60° or thereabouts. Hence the simple plan of the convectional movement of the underwaters between the poles and the equator should be modified by the addition of a subordinate movement that carries dense cold salt water from latitude 60° or thereabouts poleward underneath the still colder but less salt and less dense water of the polar oceans. It is in this way that the slight increase of temperature in the deep polar waters, discovered in the Antarctic by the Challenger expedition, and in the Arctic by Nansen, can be accounted for.

APPENDIX L.

REFERENCES FOR SUPPLEMENTARY READING.

The titles in the following list have been selected with especial reference to their accessibility in public libraries. Frequent mention is made of the publications of the U. S. Geological Survey because of their great value to the geographer as well as of their wide distribution.

General References.

GANNETT, The United States, Stanford's Compendium of Geography, Edward Stanford, 1898.

The Annual Reports, Bulletins, Monographs, and Geological Folios of the U. S. Geological Survey. Many of the more geographical essays are referred to below. (Abbrev., G. S. Ann. Rep., etc.)

The following geographical periodicals contain a great amount of material serviceable in teaching:

National Geographic Magazine, Washington, D. C. (Abbrev., N. G. M.).
Bulletin of the American Geographical Society, New York.
Journal of School Geography, Lancaster, Pa. (J. S. G.).
Geographical Journal, London.
Scottish Geographical Magazine, Edinburgh (S. G. M.).

PLATT, The Better Books in School Geography, J. S. G., May, '98.

(All the books mentioned in the above article would be found serviceable in school libraries.)

DAVIS, The Equipment of a Geographical Laboratory, J. S. G., May, '98.

CORNISH, Laboratory Work in Elementary Physiography, J. S. G., June, Sept., '97.

National Geographic Monographs, American Book Co., 1895.

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Young, Astronomy. Ginn & Company, 1888.

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APPENDIX M.

The following list of map-sheets, selected from those published by the U. S. Geological Survey and the U. S. Coast and Geodetic Survey, will be found of service in illustrating various examples of land forms referred to in Chapters VI to XII. Complete lists of maps published by these Surveys can be had, free of charge, on application. The sheets here named might be supplemented by many others in illustration of special localities. Some account of the cost and of the method of ordering and using the maps is given in the Journal of School Geography, September, 1897, and October, 1898. Coast Survey maps are here marked "C. S." The others, unless specially designated, are published by the Geological Survey.

Chapter VI. — Plains and Plateaus.

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130. Nomini, Md.

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150. Sewanee, Tenn.; Kaaterskill, N. Y.

151. Watrous, Corazon, N. M.; Abilene, Brownwood, Tex.

154. Springfield, Bolivar, Tuscumbia, Mo.

156. Mt. Trumbull, Kaibab, Echo Cliffs, Ariz.

Chapter VII. — **Mountains.**

165. Disaster, Nev.; Alturas, Cal.

170. Deadwood, Black Hills, S. D.

172. Platte Canyon, Huerfano Park, Col.

187. Asheville, Mt. Mitchell, Pisgah, N. C.

190. Atlanta, Ga. (Stone mountain is a fine example of a monadnock on the uplands of Georgia.)

190. Harrisburg, Hummelstown, Lykens, Pa.

192. Chesterfield, Granville, Mass.; Winsted, Derby, Bridgeport, Conn.

196. C. S. No. 710.

Chapter VIII. — **Volcanoes.**

215. Shasta, Cal.; San Francisco Mountain, Ariz.

216. Crater Lake (special sheet), Oregon.

Chapter IX. — **Rivers and Valleys.**

226. Citra, Fla.

229. Gallatin, Shoshone, Yellowstone National Park.

239. Mesa de Maya, Col.

242. Versailles, Tuscumbia, Mo.

243. Minden, Nebr.

245. 8-Sheet Map of the Alluvial Valley of the Mississippi River, published by the Mississippi River Commission, St. Louis, Mo.

CHAPTER X. — **The Waste of the Land.**

CHAPTER XI. — **Climatic Control of Land Forms.**

CHAPTER XII. — **Shore Lines.**

INDEX.

Plate A

RELIEF MAP OF THE UNITED STATES

Plate B

THE CHIEF PHYSICAL DIVISIONS OF THE UNITED STATES

PLATE A.

RELIEF MAP OF THE UNITED STATES.

From Model by Edwin E. Howell.

PLATE B.

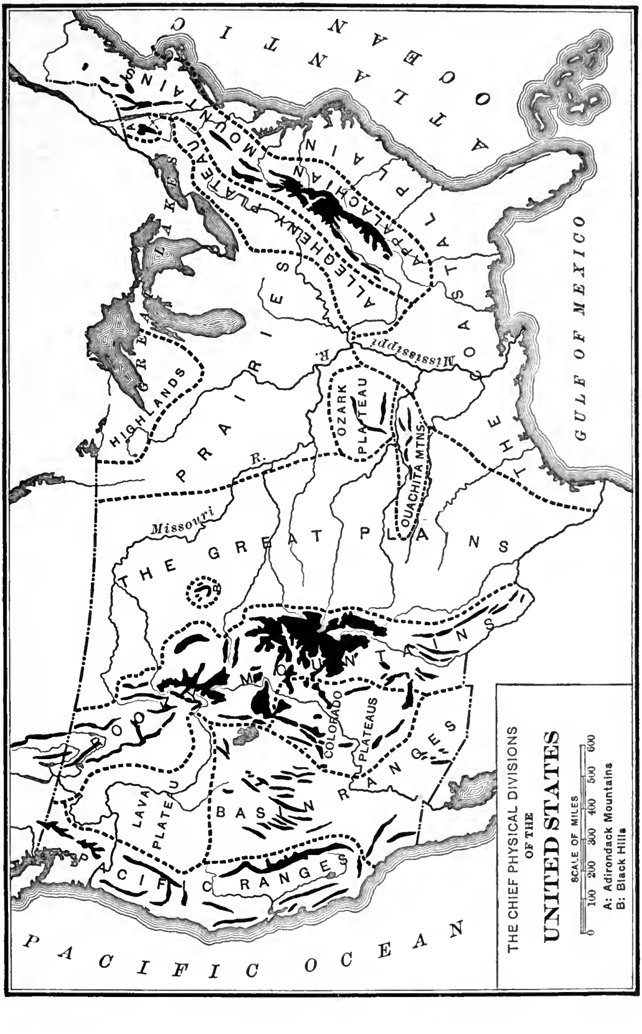
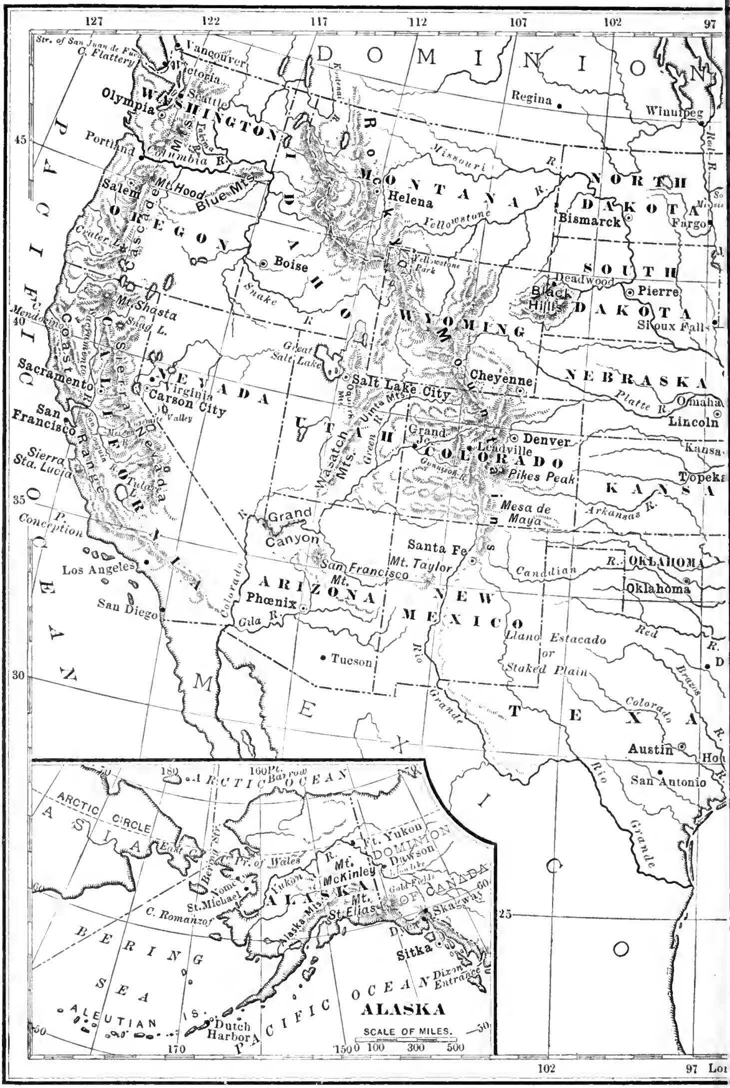

THE CHIEF PHYSICAL DIVISIONS
OF THE
UNITED STATES
SCALE OF MILES
0 100 200 300 400 500 600
A: Adirondack Mountains
B: Black Hills
ATLANTIC OCEAN
GULF OF MEXICO
PACIFIC OCEAN
THE COASTAL PLAIN
APPALACHIAN MOUNTAINS
ALLEGHENY PLATEAU
GREAT LAKES
HIGHLANDS
PRAIRIES
OZARK PLATEAU
OUACHITA MTNS.
Mississippi R.
Missouri R.
THE GREAT PLAINS
ROCKY MOUNTAINS
COLORADO PLATEAUS
BASIN RANGES
LAVA PLATEAU
PACIFIC RANGES

PLATE C

UNITED STATES

PLATE C.


127
122
117
112
107
102
97
Str. of San Juan de Fuca
C. Flattery
Vancouver
Victoria
Seattle
Olympia
WASHINGTON
Portland
Columbia R.
Mt. Hood
Blue Mts.
Salem
OREGON
Crater L.
Cascade
PACIFIC OCEAN
C. Mendocino
Mt. Shasta
Snag L.
Coast
Sacramento R.
Sierra
Sacramento
San Francisco
CALIFORNIA
Sierra Sta. Lucia
Range
Tulare L.
Nevada
P. Conception
Los Angeles
San Diego
NEVADA
Virginia
Carson City
Yosemite Valley
DOMINION
Regina
Winnipeg
IDAHO
Boise
Snake R.
MONTANA
Helena
Missouri R.
Yellowstone R.
Yellowstone Park
ROCKY MOUNTAINS
WYOMING
Great Salt Lake
Salt Lake City
Uinta Mts.
Wasatch Mts.
UTAH
Green R.
Cheyenne
NORTH DAKOTA
Bismarck
Fargo
SOUTH DAKOTA
Deadwood
Black Hills
Pierre
Sioux Falls
NEBRASKA
Platte R.
Omaha
Lincoln
Grand Jc.
Denver
Leadville
COLORADO
Gunnison R.
Pikes Peak
Kansas
Topeka
KANSAS
Arkansas R.
Mesa de Maya
Grand Canyon
Colorado R.
Santa Fe
Mt. Taylor
San Francisco Mt.
ARIZONA
Phœnix
Gila R.
Tucson
NEW MEXICO
Rio Grande
Canadian R.
OKLAHOMA
Oklahoma
Red R.
Llano Estacado or Staked Plain
Brazos R.
Colorado R.
TEXAS
Austin
San Antonio
Rio Grande
MEXICO
45
40
35
30
25
102
97
ARCTIC OCEAN
Pt. Barrow
ARCTIC CIRCLE
ASIA
East C.
Bering Str.
C. Pr. of Wales
Nome
St. Michael
Yukon R.
Ft. Yukon
DOMINION OF CANADA
Dawson
Mt. McKinley
ALASKA
Alaska Mts.
Mt. St. Elias
Gold Fields
Skagway
C. Romanzof
BERING SEA
Sitka
Dixon Entrance
PACIFIC OCEAN
ALEUTIAN IS.
Dutch Harbor
ALASKA
SCALE OF MILES.
0 100 300 500
180
160
170
150
60
50
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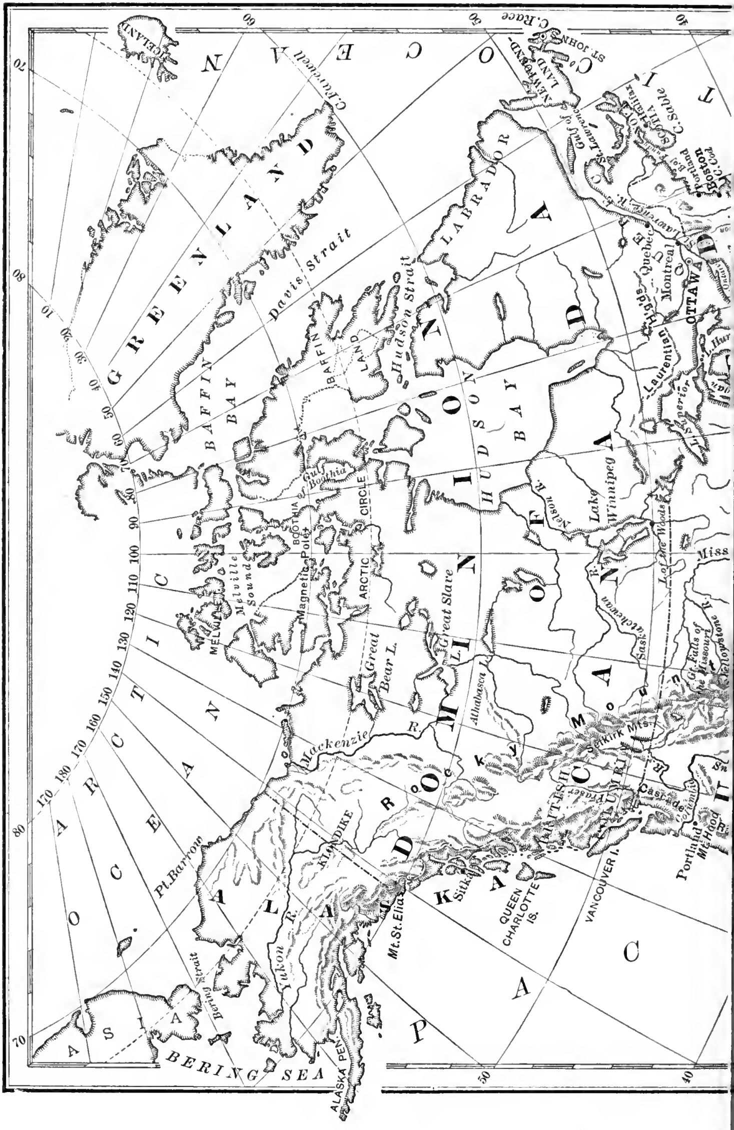
gitude 92 West from 87 Greenwich 82
77
72
67
CANADA
OTTAWA
Montreal
Quebec
Toronto
Gulf of St. Lawrence
Fredericton
Mt. Katahdin
MAINE
Augusta
Portland
Concord
Boston
C. Cod
Providence
R.I.
CONN.
Hartford
MASS.
VERMONT
Montpelier
N. HAMP.
St. Lawrence
NEW YORK
Albany
Rochester
Buffalo
Niagara Falls
Adirondack Mts.
Saratoga Sprs.
Mohawk
New York
LONG
Trenton
Camden
Atlantic City
PENNSYLVANIA
Philadelphia
Harrisburg
Pittsburgh
Susquehanna
Delaware Watergap
Baltimore
Dover
Annapolis
DEL.
WASHINGTON
Richmond
Norfolk
Petersburg
Luray Cavern
Harpers Ferry
VIRGINIA
W. VIRGINIA
Charleston
Wheeling
White Sulphur Sprs.
C. Hatteras
Raleigh
NORTH CAROLINA
C. Lookout
Wilmington
C. Fear
SOUTH CAROLINA
Columbia
Camden
Charleston
Augusta
Savannah
GEORGIA
Atlanta
Altamaha R.
Jacksonville
St. Augustine
C. Canaveral
FLORIDA
Tallahassee
Tampa
C. Sable
Key West
ALABAMA
Montgomery
Mobile
MISSISSIPPI
Jackson
Vicksburg
LOUISIANA
Baton Rouge
New Orleans
Galveston
ARKANSAS
Little Rock
Ozark Mts.
MISSOURI
St. Louis
Kansas City
Jefferson City
Cairo
KENTUCKY
Frankfort
Louisville
Mammoth Cave
TENNESSEE
Nashville
Cumberland Plateau
Blue Ridge
OHIO
Columbus
Cincinnati
INDIANA
Indianapolis
Ft. Wayne
ILLINOIS
Springfield
Chicago
Illinois R.
IOWA
Des Moines
WISCONSIN
Madison
Milwaukee
MICHIGAN
Lansing
Grand Rapids
Detroit
Sault Ste. Marie
MINNESOTA
St. Paul
Duluth
L. Superior
L. Michigan
L. Huron
L. Ontario
L. Erie
Lake of the Woods
Pepin L.
Mississippi
Ohio
Wabash
ATLANTIC OCEAN
GULF OF MEXICO
40
35
45
UNITED STATES
SCALE OF MILES.
50 100 200 300 400 500 600
e West 92 from Greenwich 87
NEW ENGLAND
and Coast of
Middle Atlantic States
(On Enlarged Scale)
SCALE OF MILES.
0 25 50 100 150 200
DOMINION OF CANADA
MAINE
Augusta
White Mts.
Portland
Concord
Manchester
Lawrence
Lowell
Gloucester
Boston
C. Cod
MASSACHUSETTS
Hartford
CONN.
R.I.
Providence
Newport
Narragansett Bay
Montauk Pt.
Newburgh
West Point
NEW YORK
Albany
Saratoga Sprs.
VERMONT
Montpelier
NEW HAMPSHIRE
NEW JERSEY
New York
Long Branch
Trenton
Philadelphia
Camden
Atlantic City
Baltimore
Annapolis
Dover
WASHINGTON
MARYLAND
DEL.
Delaware Bay
Chesapeake Bay
VA.
Richmond
Norfolk
Cape Charles
Cape Henry
ATLANTIC OCEAN
46
44
42
40
72
70
74
The M.-N. Co.

Plate D

NORTH AMERICA

PLATE D.

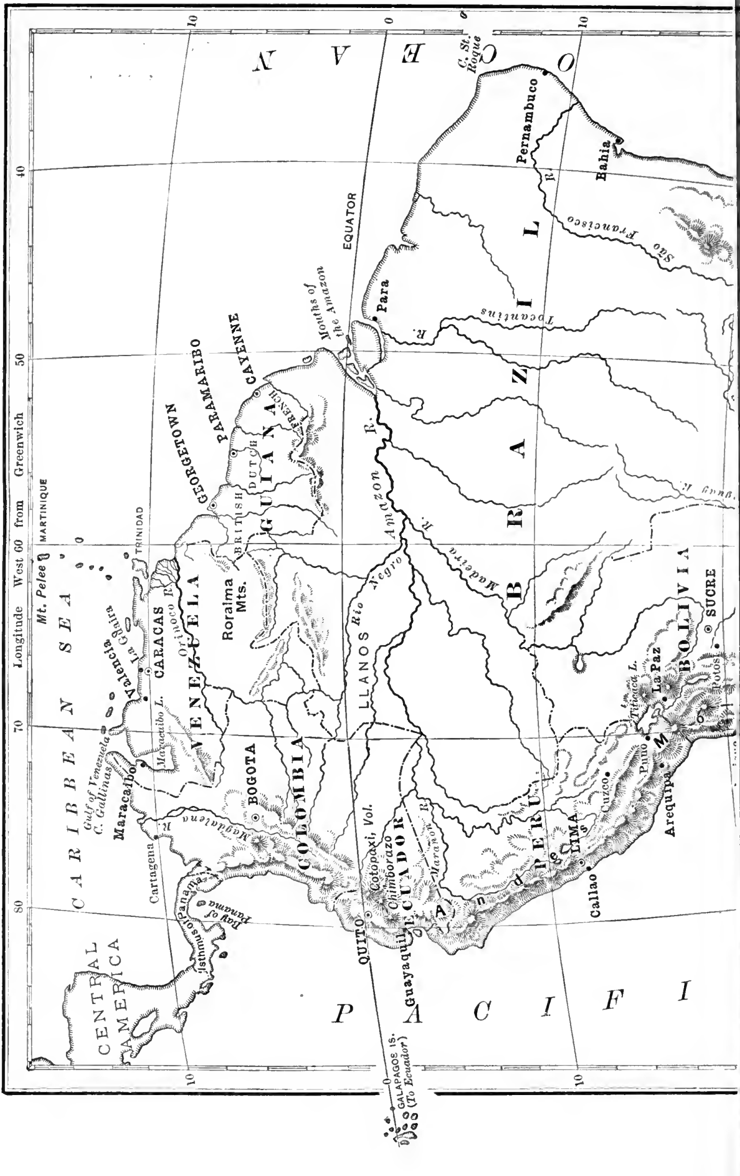

GREENLAND
BAFFIN BAY
Davis Strait
Hudson Strait
HUDSON BAY
LABRADOR
NEWFOUNDLAND
BAFFIN LAND
Gulf of Boothia
Melville Sound
Magnetic Pole
ARCTIC CIRCLE
Great Bear L.
Great Slave L.
Athabasca L.
Lake Winnipeg
Nelson R.
Mackenzie R.
Pt. Barrow
Bering Strait
BERING SEA
ALASKA PEN.
Yukon R.
KLONDIKE
Mt. St. Elias
Sitka
QUEEN CHARLOTTE IS.
VANCOUVER I.
Selkirk Mts.
Cascade
Portland
Mt. Hood
Quebec
Montreal
OTTAWA
Boston
C. Cod
C. Sable
Halifax
C. Race
St. John's
C. Farewell
ICELAND
L. of the Woods
Laurentian
Miss
ARCTIC OCEAN
ASIA
ALASKA
DOMINION OF CANADA
ROCKY MOUNTAINS


NORTH AMERICA
SCALE OF MILES
0 100 200 300 400 500 600 700 800 900 1000
Longitude West from Greenwich
120
110
100
90
80
70
30
20
10
0
San Francisco
Monterey
San Diego
Sierra Nevada
Shasta
Great Salt L.
Denver
Zuni Plateau
Mt. Taylor
Santa Fe
LLANO ESTACADO
Colorado
St. Louis
Chicago
Cincinnati
Philadelphia
Baltimore
WASHINGTON
Chesapeake Bay
C. Hatteras
C. Lookout
C. Fear
Charleston
Savannah
Atlanta
Mobile
New Orleans
Galveston
Arkansas
Red
Brazos
Rio Grande
Mississippi
Tennessee
Ohio
Alabama R.
Blue Ridge
Alleghany
FLORIDA
C. Canaveral
C. Sable
Str. of Florida
BERMUDA IS.
BAHAMA IS.
HABANA
CUBA
Santiago
HAITI
PORTO RICO
JAMAICA
WEST INDIES
GULF OF MEXICO
Gulf of Campeche
Vera Cruz
MEXICO
Mt. Jorullo
Popocatepetl
YUCATAN
GUATEMALA
HONDURAS
NICARAGUA
L. Nicaragua
Conseguina V.
COSTA RICA
Isthmus of Panama
CENTRAL AMERICA
CARIBBEAN SEA
SOUTH AMERICA
SONORA
LOWER CALIFORNIA
Gulf of California
C. San Lucas
GUADALUPE I.
TROPIC OF CANCER
PACIFIC OCEAN
ATLANTIC
UNITED STATES

PLATE E

SOUTH AMERICA

PLATE E.



Longitude West 60 from Greenwich
EQUATOR
C A R I B B E A N S E A
P A C I F I
O C E A N
C. St. Roque
Pernambuco
Bahia
Sao Francisco
Para
Tocantins
R.
Mouths of the Amazon
B R A Z I L
Amazon R.
Madeira R.
Rio Negro
CAYENNE
PARAMARIBO
GEORGETOWN
BRITISH
DUTCH
FRENCH
G U I A N A
Roraima Mts.
Mt. Pelee
MARTINIQUE
TRINIDAD
Orinoco R.
CARACAS
La Guaira
Valencia
Maracaibo L.
Gulf of Venezuela
C. Gallinas
Maracaibo
V E N E Z U E L A
LLANOS
BOGOTA
COLOMBIA
Magdalena R.
Cartagena
Panama
Bay of Panama
Isthmus of Panama
CENTRAL AMERICA
QUITO
Cotopaxi, Vol.
Chimborazo
ECUADOR
Guayaquil
Maranon R.
PERU
LIMA
Callao
Cuzco
Puno
Arequipa
Titicaca L.
La Paz
Potosi
SUCRE
BOLIVIA
A n d e s
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GALAPAGOS IS. (To Ecuador)
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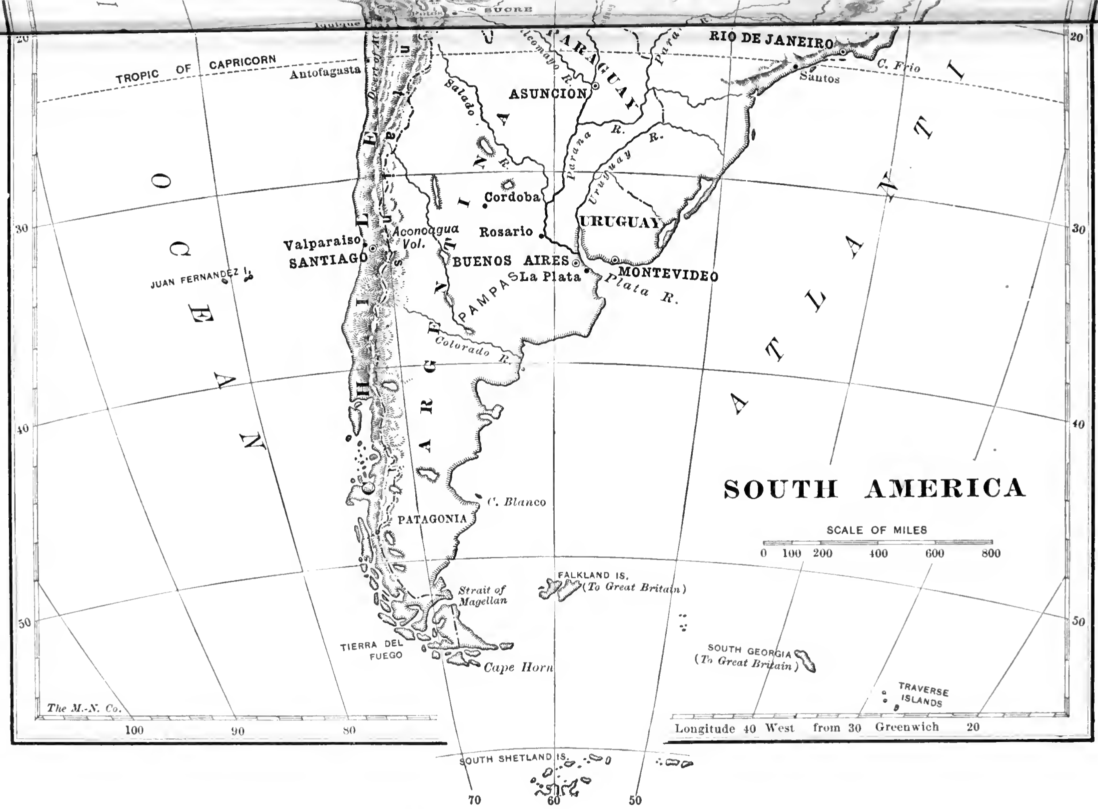
SOUTH AMERICA
SCALE OF MILES
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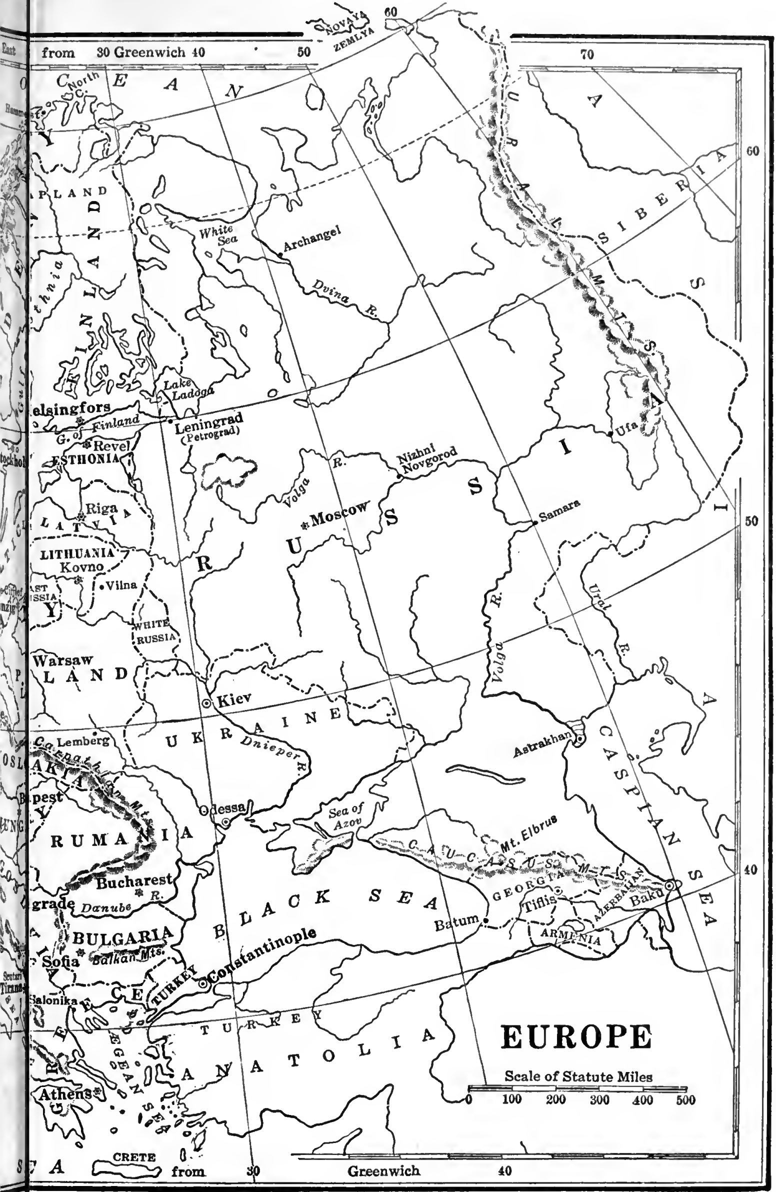
TROPIC OF CAPRICORN
Antofagasta
RIO DE JANEIRO
C. Frio
Santos
ASUNCION
PARAGUAY
URUGUAY
Cordoba
Rosario
BUENOS AIRES
La Plata
MONTEVIDEO
Plata R.
Parana R.
Uruguay R.
Salado R.
Colorado R.
PAMPAS
Valparaiso
SANTIAGO
Aconcagua Vol.
JUAN FERNANDEZ I.
ARGENTINA
CHILE
Andes
PATAGONIA
C. Blanco
Strait of Magellan
TIERRA DEL FUEGO
Cape Horn
FALKLAND IS. (To Great Britain)
SOUTH GEORGIA (To Great Britain)
TRAVERSE ISLANDS
SOUTH SHETLAND IS.
OCEAN
ATLANTIC
Longitude 40 West from 30 Greenwich 20
The M.-N. Co.

Plate F

EUROPE

PLATE F.

30 Longitude 20 West 10 0 Longitude 10 East
ARCTIC
ARCTIC CIRCLE
Reykjavik
ICELAND
Mt.Hekla
OCEAN
ATLANTIC
SHETLAND IS.
Bergen
Oslo (Christiania)
NORWAY
SWEDEN
Stockho
BRITISH ISLES
IRISH FREE STATE
IRELAND
SCOTLAND
Glasgow
Edinburgh
Belfast
Irish Sea
Dublin
Manchester
Liverpool
WALES
ENGLAND
London
NORTH SEA
Göteborg
DENMARK
Copenhagen
BALTIC
Free City of Danzig
Kiel
Hamburg
NETHERLANDS
Amsterdam
The Hague
Antwerp
Brussels
BELGIUM
Cologne
Rhine
LUXEMBURG
SAAR BASIN
GERMANY
Berlin
Dresden
Prague
CZECHOSL
English Channel
Paris
Seine R.
FRANCE
BAY OF BISCAY
Bordeaux
Geneva
Lyon
Bern
SWITZERLAND
Munich
Vienna
AUSTRIA
HUNG
THE ALPS
Trieste
Venice
Fiume
JUGOS
Genoa
MONACO
Marseille
ADRIATIC SEA
San Marino
ITALY
Rome
Naples
Mt.Vesuvius
Scutari
Tirana
CORSICA (Fr.)
SARDINIA (Italy)
Oporto
PORTUGAL
SPAIN
Lisbon
Madrid
Valencia
Palos
Malaga
Gibraltar (Br.)
Str.of Gibraltar
Pyrenees
ANDORRA
Barcelona
BALEARIC IS. (Sp.)
MEDITERRANEAN
Palermo
SICILY
Mt.Etna
MALTA (Br.)
AFRICA
0 Longitude 10 East
60
50
40

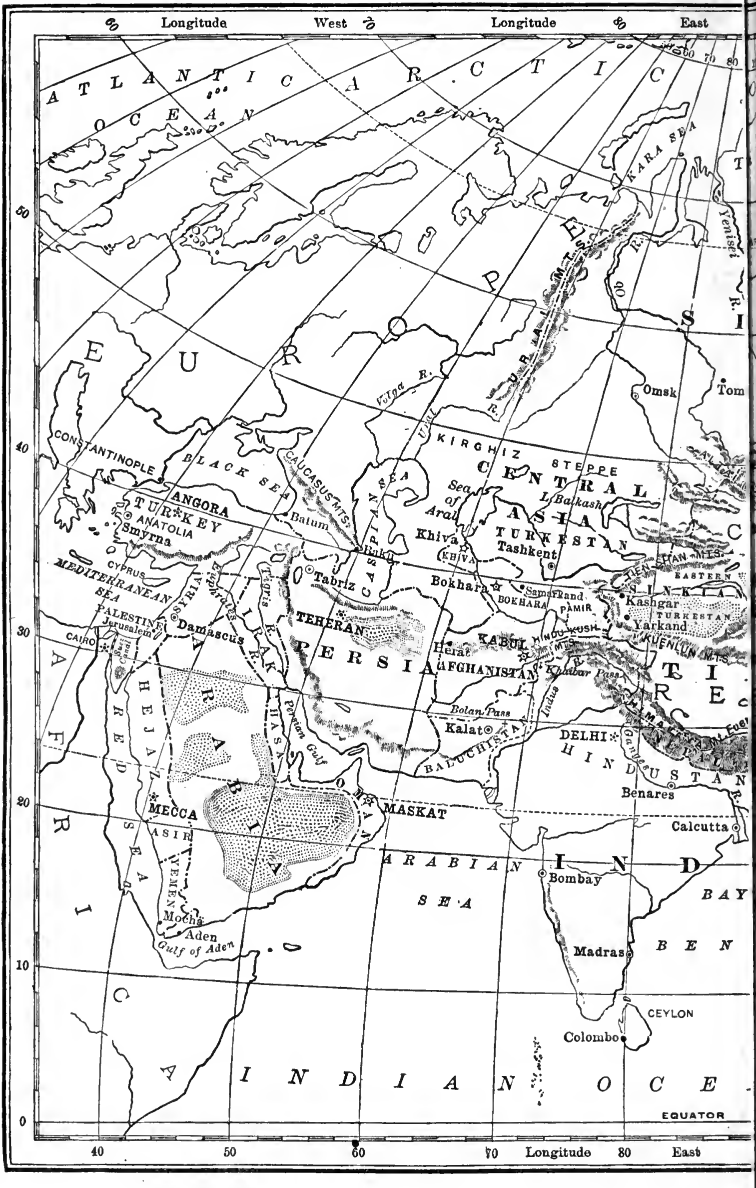


EUROPE
Scale of Statute Miles
0 100 200 300 400 500
from 30 Greenwich 40
50
60
70
from 30 Greenwich 40
NOVAYA ZEMLYA
North C.
URAL MTS.
SIBERIA
LAPLAND
FINLAND
White Sea
Archangel
Dvina R.
Lake Ladoga
Helsingfors
G. of Finland
Leningrad (Petrograd)
Revel
ESTHONIA
Riga
LATVIA
LITHUANIA
Kovno
Vilna
WHITE RUSSIA
Warsaw
Volga R.
Nizhni Novgorod
Moscow
RUSSIA
Ufa
Samara
Ural R.
Kiev
UKRAINE
Dnieper R.
Lemberg
Carpathian Mts.
RUMANIA
Odessa
Sea of Azov
Astrakhan
CASPIAN SEA
CAUCASUS MTS.
Mt. Elbrus
GEORGIA
Tiflis
AZERBAIJAN
Baku
ARMENIA
Batum
BLACK SEA
Bucharest
Danube R.
BULGARIA
Sofia
Balkan Mts.
Constantinople
TURKEY
Salonika
GREECE
ÆGEAN SEA
Athens
CRETE
ANATOLIA

PLATE G

ASIA

PLATE G.



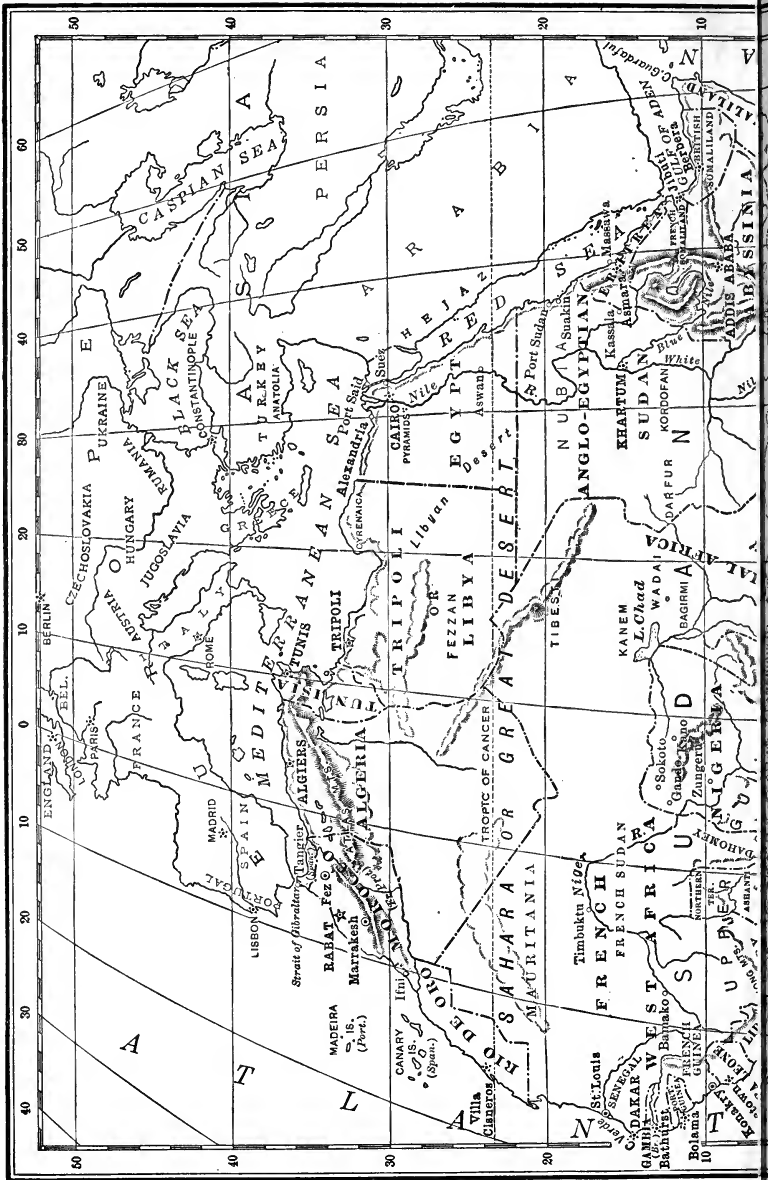
Longitude West 60 70
Longitude 80 East
ATLANTIC OCEAN
ARCTIC
KARA SEA
EUROPE
URAL MTS.
Ob R.
Yenisei R.
SIB
Omsk
Tom
Volga R.
Ural R.
KIRGHIZ STEPPE
CENTRAL ASIA
Sea of Aral
L. Balkash
CONSTANTINOPLE
BLACK SEA
CAUCASUS MTS.
CASPIAN SEA
ANGORA
TURKEY
ANATOLIA
Smyrna
Batum
Baku
Khiva
KHIVA
TURKESTAN
Tashkent
CYPRUS
MEDITERRANEAN SEA
SYRIA
Euphrates
Tigris R.
Tabriz
Bokhara
BOKHARA
Samarkand
PAMIR
THIEN SHAN MTS.
EASTERN
SIN-KIANG
TURKESTAN
Kashgar
Yarkand
KUENLUN MTS.
PALESTINE
Jerusalem
CAIRO
Suez Canal
Damascus
IRAK
TEHERAN
PERSIA
Herat
KABUL
HINDU KUSH MTS.
AFGHANISTAN
Khaibar Pass
TIBET
ARABIA
HEJAZ
HASA
Persian Gulf
Bolan Pass
Kalat
BALUCHISTAN
Indus
DELHI
HINDUSTAN
Ganges R.
Benares
RED SEA
MECCA
OMAN
MASKAT
Calcutta
ASIR
YEMEN
ARABIAN SEA
INDIA
Bombay
BAY OF BENGAL
Mocha
Aden
Gulf of Aden
Madras
CEYLON
Colombo
AFRICA
INDIAN OCEAN
EQUATOR
50
40
30
20
10
0
40 50 60 70 Longitude 80 East

ASIA
from Greenwich
80
70
60
100 110 120 130
NORTH AMERICA
Bering Str.
WRANGELL I.
NEW SIBERIAN IS.
Lena R.
ARCTIC CIRCLE
Yakutsk
SIBERIA
STANOVOI MTS.
OKHOTSK SEA
KAMCHATKA
BERING SEA
ALEUTIAN IS.
SAKHALIN
Lake Baikal
Irkutsk
Kiakhta
Chita
Amur R.
MANCHURIA
KHINGAN MTS.
HOKKAIDO
Vladivostok
Kirin
Mukden
Urga
MONGOLIA
Desert of Gobi
CHINESE REPUBLIC
PEKING
Great Wall
Tientsin
Dairen
KOREA
SEOUL
JAPAN SEA
EMPIRE OF JAPAN
TOKYO
Yokohama
Kyoto
Osaka
SHANTUNG
YELLOW SEA
Hwang ho or Yellow R.
Sianfu
TIBET
Lhasa
Brahmaputra R.
Yangtze R.
Shanghai
NANLING MTS.
Foochow
CHINA
TROPIC OF CANCER
FORMOSA
Canton
Macao
Hongkong
UPPER BURMA
Mandalay
LOWER BURMA
HANOI
HAINAN
Mekong R.
ANNAM
Hue
SIAM
BANGKOK
FRENCH INDO-CHINA
CAMBODIA
Pnompenh
Saigon
Gulf of Siam
COCHIN-CHINA
MALAY PEN.
FEDERATED MALAY STATES
Singapore
SUMATRA
BORNEO
SOUTH CHINA SEA
MANILA
PHILIPPINE ISLANDS
PACIFIC OCEAN
SCALE OF MILES
0 200 400 600 800 1000
50
40
30
20
10
0
from 100 Greenwich 110 120 130 140

PLATE H

AFRICA

PLATE II.



CASPIAN SEA
PERSIA
ARABIA
HEJAZ
RED SEA
BLACK SEA
CONSTANTINOPLE
TURKEY
ANATOLIA
ASIA
EUROPE
UKRAINE
RUMANIA
CZECHOSLOVAKIA
HUNGARY
JUGOSLAVIA
AUSTRIA
BERLIN
ITALY
ROME
GREECE
BEL.
PARIS
FRANCE
ENGLAND
LONDON
SPAIN
MADRID
PORTUGAL
LISBON
MEDITERRANEAN SEA
Strait of Gibraltar
Tangier
Fez
RABAT
Marrakesh
MOROCCO
ALGIERS
ALGERIA
ATLAS MTS.
TUNIS
TUNISIA
TRIPOLI
CYRENAICA
Alexandria
Port Said
Suez
CAIRO
PYRAMIDS
Nile
EGYPT
Aswan
Libyan Desert
FEZZAN
LIBYA
GREAT DESERT
SAHARA
TROPIC OF CANCER
TIBESTI
MAURITANIA
RIO DE ORO
Ifni
Villa Cisneros
CANARY IS. (Span.)
MADEIRA IS. (Port.)
ATLANTIC
Port Sudan
Suakin
NUBIA
ANGLO-EGYPTIAN SUDAN
KHARTUM
KORDOFAN
DARFUR
Kassala
Massawa
Asmara
ERITREA
FRENCH SOMALILAND
Jibuti
GULF OF ADEN
Berbera
BRITISH SOMALILAND
C. Guardafui
ADDIS ABABA
ABYSSINIA
Blue Nile
White Nile
WADAI
KANEM
L. Chad
BAGIRMI
CENTRAL AFRICA
SUDAN
NIGERIA
Sokoto
Kano
Zungeru
DAHOMEY
FRENCH SUDAN
FRENCH WEST AFRICA
Timbuktu
Niger
Bamako
St. Louis
SENEGAL
DAKAR
C. Verde
GAMBIA (Br.)
Bathurst
PORT. GUINEA
Bolama
FRENCH GUINEA
Konakry
SIERRA LEONE
ASHANTI
NORTHERN TER.
UPPER SUDAN

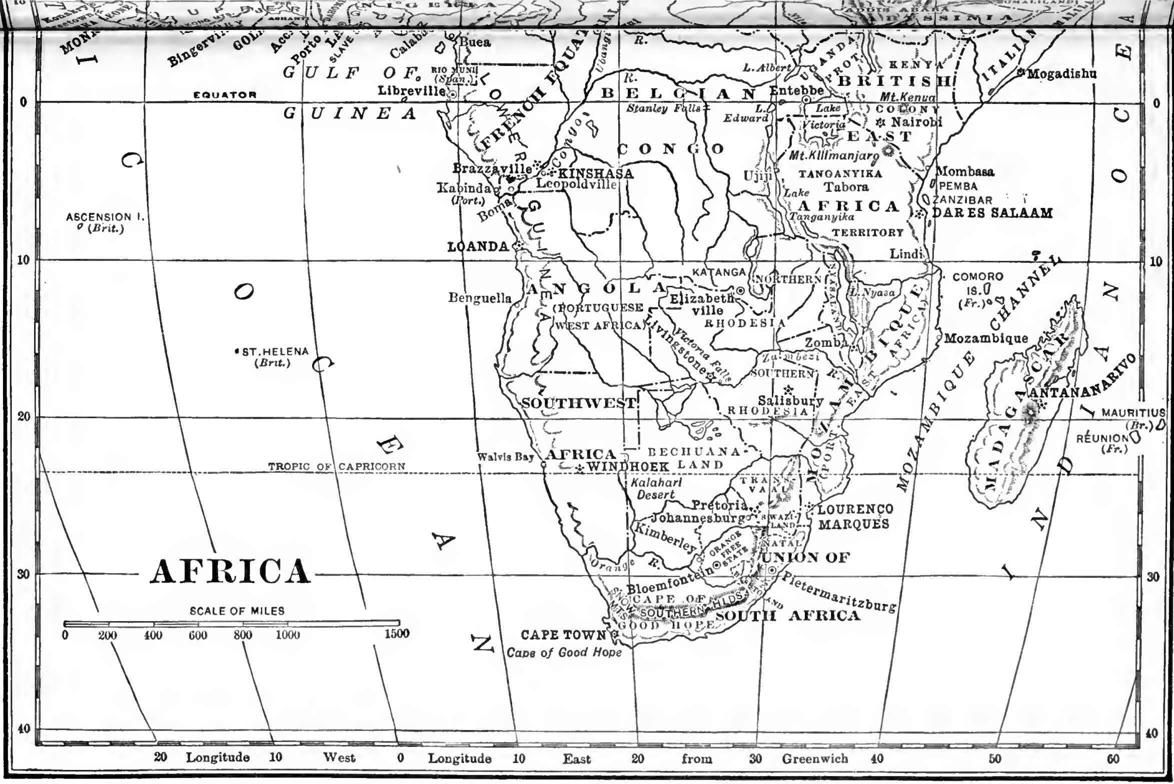
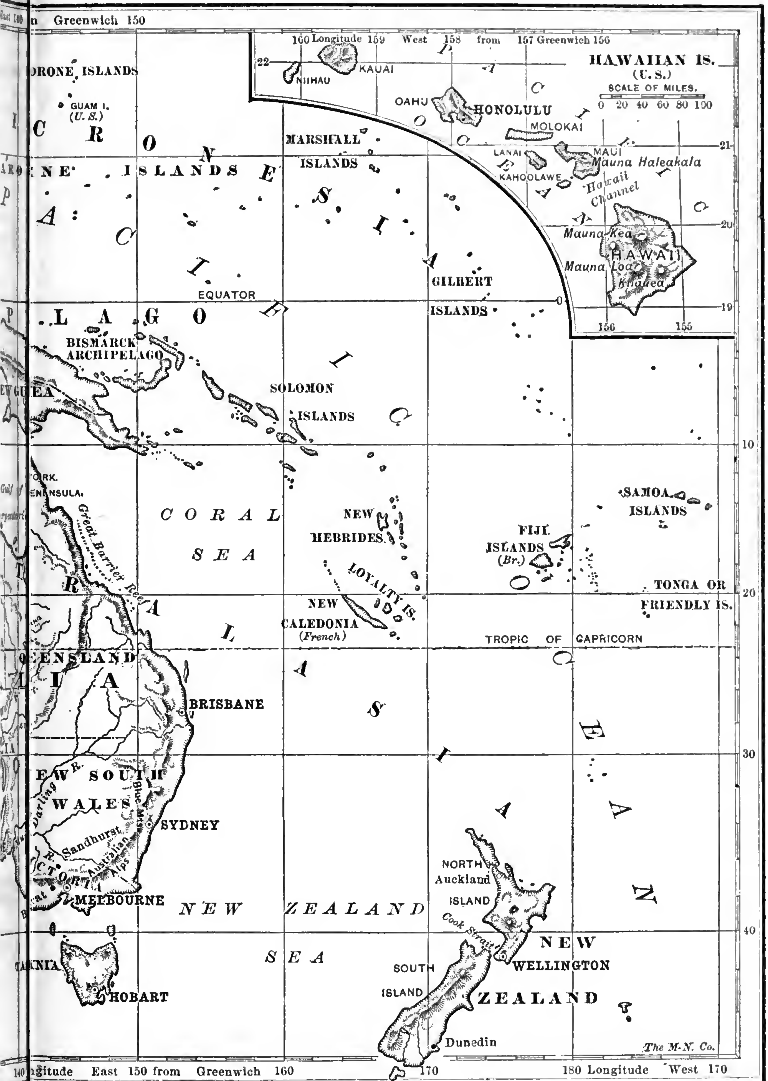

AFRICA
SCALE OF MILES
0 200 400 600 800 1000 1500
EQUATOR
TROPIC OF CAPRICORN
20 Longitude 10 West 0 Longitude 10 East 20 from 30 Greenwich 40 50 60
GULF OF
GUINEA
ASCENSION I. (Brit.)
ST. HELENA (Brit.)
Buea
Libreville
RIO MUNI (Span.)
FRENCH EQUATORIAL
LOWER
GUINEA
BELGIAN
CONGO
Stanley Falls
Brazzaville
KINSHASA
Leopoldville
Kabinda (Port.)
Boma
LOANDA
Benguella
ANGOLA
(PORTUGUESE WEST AFRICA)
KATANGA
Elizabethville
NORTHERN
RHODESIA
SOUTHERN
RHODESIA
Salisbury
Livingstone
Victoria Falls
Zambezi R.
SOUTHWEST AFRICA
Walvis Bay
WINDHOEK
BECHUANA LAND
Kalahari Desert
TRANSVAAL
Pretoria
Johannesburg
Kimberley
ORANGE FREE STATE
Bloemfontein
Orange R.
SWAZILAND
NATAL
UNION OF SOUTH AFRICA
Pietermaritzburg
CAPE OF GOOD HOPE
SOUTHERN HLDS.
SNOW MTS.
CAPE TOWN
Cape of Good Hope
LOURENÇO MARQUES
PORT. EAST AFRICA
MOZAMBIQUE
Zomba
L. Nyasa
NYASALAND
Mozambique
MOZAMBIQUE CHANNEL
COMORO IS. (Fr.)
MADAGASCAR
ANTANANARIVO
MAURITIUS (Br.)
RÉUNION (Fr.)
L. Albert
Entebbe
UGANDA PROT.
L. Edward
Lake Victoria
KENYA COLONY
BRITISH EAST AFRICA
Mt. Kenya
Nairobi
Mt. Kilimanjaro
Ujiji
TANGANYIKA TERRITORY
Tabora
Lake Tanganyika
Mombasa
PEMBA
ZANZIBAR
DAR ES SALAAM
Lindi
ITALIAN
Mogadishu
INDIAN OCEAN
OCEAN

Plate I

AUSTRALASIA, MALAY ARCHIPELAGO AND MICRONESIA

PLATE I.


AUSTRALASIA,
MALAY ARCHIPELAGO
AND MICRONESIA.
SCALE OF MILES ON THE EQUATOR
0 100 500 1000
130 Longitude East 140
SIAM
Bangkok
FRENCH INDO-CHINA
CAMBODIA
Saigon
CHINA SEA
LUZON
MANILA
PHILIPPINE ISLANDS
Sulu Sea
MINDANAO
Straits of Malakka
MALAY PENINSULA
Malakka
Singapore
SUMATRA
Palembang
Brunei
NORTH BORNEO
SARAWAK
Kuching
BORNEO
CELEBES SEA
CELEBES
MALAY ARCHIPELAGO
BILLITON
JAVA SEA
Makassar
KRAKATOA
BATAVIA
JAVA
Mt. Galung-gung
BALI I.
BANDA SEA
TIMOR
MOLUCCAS
NEW GUINEA
INDIAN OCEAN
N. W. Cape
Gulf of Carpentaria
Fitzroy R.
Sturt Cr.
NORTHERN TERRITORY OF SOUTH AUSTRALIA
Great Sandy Desert
WESTERN AUSTRALIA
AUSTRALIA
L. Amadeus
Great Victoria Desert
Murchison R.
SOUTH AUSTRALIA
Warburton R.
L. Eyre
L. Torrens
PERTH
Great Australian Bight
ADELAIDE
JARVIS I. (Br.)
MALDEN I. (Br.)
STARBUCK I. (Br.)
MARQUESAS ISLANDS (French)
VOSTCK I. (Br.)
PACIFIC OCEAN
SOCIETY ISLANDS (French)
TUAMOTU IS. (French)
COOK ISLANDS (British)
TUBUAI OR AUSTRAL IS. (French)
TROPIC OF CAPRICORN
HENDERSON I.
DUCIE I.
PITCAIRN I. (Br.)
RAPA



Greenwich 150
HAWAIIAN IS.
(U. S.)
SCALE OF MILES.
0 20 40 60 80 100
160 Longitude 159 West 158 from 157 Greenwich 156
NIIHAU
KAUAI
OAHU
HONOLULU
MOLOKAI
LANAI
MAUI
KAHOOLAWE
Mauna Haleakala
Hawaii Channel
Mauna Kea
HAWAII
Mauna Loa
Kilauea
GUAM I.
(U. S.)
ISLANDS
MARSHALL
ISLANDS
GILBERT
ISLANDS
EQUATOR
BISMARCK
ARCHIPELAGO
SOLOMON
ISLANDS
CORAL
SEA
Great Barrier Reef
NEW
HEBRIDES
LOYALTY IS.
NEW
CALEDONIA
(French)
FIJI
ISLANDS
(Br.)
SAMOA
ISLANDS
TONGA OR
FRIENDLY IS.
TROPIC OF CAPRICORN
BRISBANE
SOUTH
WALES
Darling R.
Blue Mts.
SYDNEY
Sandhurst
Australian Alps
MELBOURNE
HOBART
NEW ZEALAND SEA
NORTH
Auckland
ISLAND
Cook Strait
WELLINGTON
SOUTH
ISLAND
NEW
ZEALAND
Dunedin
The M-N. Co.
Longitude East 150 from Greenwich 160
170
180 Longitude West 170