ELEMENTARY
PHYSICAL GEOGRAPHY

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AN OUTLINE OF PHYSIOGRAPHY

BY

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"The waste of the Old Land is the material of the New"

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PREFACE

The science of Geography sets forth the relations of life and its environment to the earth, and it is the function of both the writer and the teacher of geography to explain these relations. In the elementary geography the pupil studies the various peoples of the earth and the countries in which they live; in the advanced geography there is presented in addition a discussion of the industries of life and their geographic distribution. The present volume, is designed to show that the distribution of life is governed very largely by the conditions of geographic environment, and that human history and industries are always closely connected with geographic laws—in many instances the direct resultants of them.

The science of Geography as now understood includes something more than a mere description of topographic forms—it comprehends the gradual and progressive development of these forms and their results as regards life, as well. It includes also the effects of temperature and moisture, for life and its activities depend also on them. That is, it naturally involves the principles of descriptive geography, physiography, and economics; and this volume is designed to show their interrelation.

In scope this book contains all the principles recommended by the Committee of Fifteen, and such other features as have suggested themselves to the author. It is designed to be used in the junior grades of the High School, and in Normal Schools. The arrangement of the subjects is logical, but the teacher may readily organize a course of study in the subject without reference to the present arrangement. To make this more easily accomplished, the *principles* of the subject are set forth in the larger type; relevant matter that is illustrative but non-essential is presented in smaller type. In general, the teacher should not hesitate to omit a topic, the discussion of which is too difficult for the class.

In this edition the notes are inserted in connection with the text and a brief laboratory manual is added to the appendix. There is no change in the arrangement of chapters, and none in the sequence of topics except as noted.

The Questions and Exercises are designed to stimulate observation and independent thought.

In the preparation of the new edition I take pleasure in acknowledging the most valuable counsel of Principal Myron T. Pritchard, Everett School, Boston.

The books designated for reference and collateral reading are intentionally few in number, and those most commonly cited should be in the school library. The teacher will also find it very advisable to keep in close touch with the publications of the United States Geological Survey, and the Weather Bureau.

J. W. R.

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PHYSICAL GEOGRAPHY

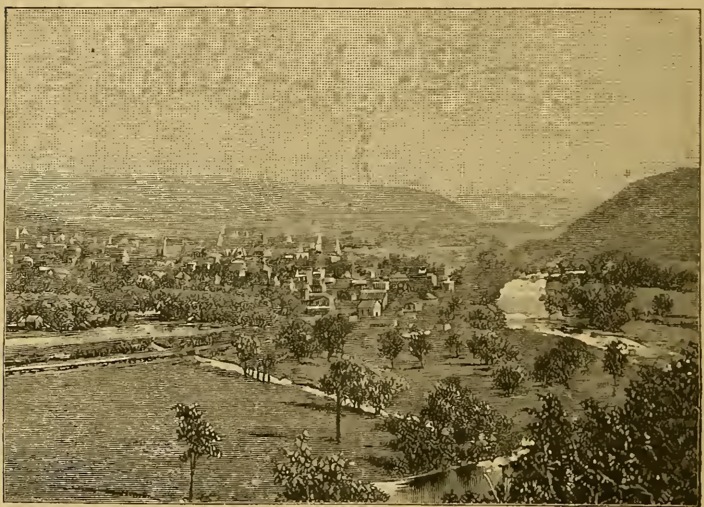
INTRODUCTORY

Only a casual thought is needed to make it apparent that life on the earth, as we now find it, depends on a very delicate adjustment to its surroundings. Living beings require certain conditions of heat, moisture, and geographic environment; and if these are changed ever so slightly the life forms must adjust themselves to the new conditions, or else they must seek a new abiding-place; or, perhaps, they may perish altogether.

For instance, turf grass requires water at very short intervals, and if for several successive years there are droughts five or six months in duration, it will die. And if there are herds of cattle in the region, they must adjust themselves to the changed conditions. They must adapt themselves to other food, or they must migrate. Otherwise they too will perish.

Were the temperature of the earth to change only a few degrees there would be a similar disturbance that would involve almost every living thing. And if it should fall so low that the water were everywhere frozen, life as we now know it could not exist any great length of time, because living beings need in their structure a large proportion of water, and the latter must be taken into the structure in a liquid form. For a similar reason, if all the water were in the form of vapor, life could not long endure unless the life forms were very different in structure from those with which we are acquainted.

Life is by no means evenly distributed over the earth, however. A few species spend the greater part of their existence in the air, and a larger number live in water only. By far the greater number of species, moreover, live at the plane of contact between the atmosphere and the earth's



A FERTILE VALLEY, NEW YORK
Capable of producing abundant food-stuffs, and densely peopled.

rock envelope—that is, on the land surface of the earth. Their distribution is governed by the conditions of warmth, moisture, and surface, and if these conditions were to change ever so slightly, the distribution would be disturbed. Life and its distribution are governed by geographic laws; if the latter change, so must the former.

Man, who stands at the head of animate nature, is able to endure a much wider range of warmth, moisture, and surface features than most other living beings. He can withstand extremes of heat and cold that are fatal to most other animals, and he can live indifferently in places of great drought or of excessive moisture. The arctic regions are not so cold, nor the tropical lands so hot that man cannot dwell there; and throughout the wide world one can find scarcely an ice-clad summit or a sun-beaten desert in which human beings have not lived.

On account of these varying conditions—all the result of geographic laws—the study of the earth is both important and interesting, because it is the home of man. Like all forms of life, man requires food; more than any other animal, he needs shelter. His food, of which he consumes about eighty tons during the three or four score years of his existence, comes from the earth—the land, the water, and the air each yielding part—and the materials that are used for clothing and shelter come also from the same source—the earth.

So, in order to understand the story of life, its history and its industries, one must learn about the physical geography of its surroundings—that is, about its *environment*, or the various conditions of heat, moisture, and surface features. Land animals could not live until the waters were separated from the land. Before they could maintain life, vegetation must have spread itself over the land; and before vegetation could endure, there must have been soil. And before there could be soil, the surface of the land must have been folded, broken, worn, and furrowed, so that the fragments of rock could be ground fine and formed into soil. All these earth-weathering processes must have been going on before the higher forms of life could exist, and all over the surface of the land such changes are even now going on from day to day. Scarcely a summer shower falls that does not leave its marks; and, indeed, throughout the physical history of the earth the most apparent feature is constant change.

From the time the land was first divided from the waters, the continents, or great bodies of land, have been ever

ARCTIC LANDS

Too cold and not enough soil for the support of life.

changing. In places, alternately sinking, rising, and warping in various ways, the shore outlines have taken various forms. Rugged coasts sinking below sea-level have resulted in the fjorded shores, such as those of the North Atlantic States, making the harbors where so much of the manufacture and commerce of the country have centred. Rising coasts have lifted natural harbors above sea-level, making the approaches to the land so difficult that vessels can find no sheltered anchorage. Old sea-bottoms, covered with sediments that form the richest soil, have been lifted above the sea, and in time have become densely peopled areas.

Certain forces are causing the surface of the rock envelope to wrinkle and fold, forming plateaus, mountains, and valleys; and at the same time the waters of the atmosphere, falling as rain or snow, are constantly at work wearing away the wrinkles and folds, carrying the material back to the sea.

It is necessary to know about these processes, and to understand how they are going on, because almost every form of life is more or less modified by them, and certainly the history and the industries of man are very largely governed by them. Man may rise superior to his environment—that is, his geographic surroundings—but he is always more or less modified by it. Mountains and valleys, plains and plateaus, oceans and rivers, have all been potent factors in making the destiny of peoples.

The rugged and barren slope of Norway forbade any great development of agriculture, while the deeply fjorded shores invited the pursuits of the sea. The Norse people, therefore, became sea rovers and magnificent sailors. The uncultivable mountains of Greece could not well yield the food-stuffs necessary for the population, so we find a history of "Greece scattered." From the remotest times the rich valley of the Tigris and Euphrates, because of its fertility, has always attracted people, and we therefore find it a densely peopled region.

Unless there is something to unfit them for human habitation, lowlands are favorite places of dwelling, and by far the greater part of the world's population is found in them.

How is the statement borne out in the case of the Central Plain of North America?—the swampy, forest plain of the Amazon?—the great lowland region of southeastern Asia?—the northern plains of Eurasia?

River bottom-lands, also, are nearly always densely peo-

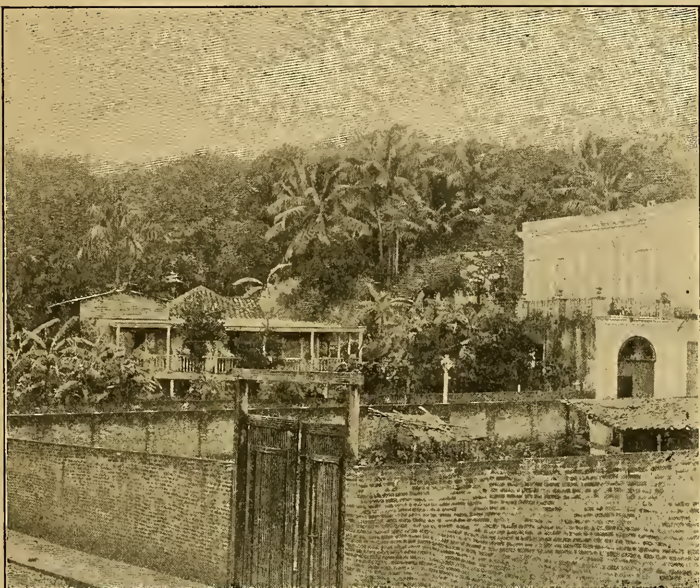
A RUGGED NORWEGIAN SLOPE

A locality not suitable for farming; a few food-plants may be grown.

pled. How is this illustrated in the history of Egypt?—with regard to the nations dwelling in the Mesopotamia?—the valley of the Ganges?—the bottom-lands of the Mississippi River?—the Sacramento-San Joaquin Valley? Extensive desert regions are always sparsely peopled;

why? How is this illustrated in the eastern and western halves of the United States? The population of rugged highlands and mountain ranges is usually sparse; is there a good reason therefor?

The hot regions of the land are almost always densely peopled, the deserts and forest swamps excepted. Is this



A TROPICAL SCENE

Both temperature and moisture are favorable to a great productivity of food-stuffs.

true of the intensely cold regions? Life thrives best in regions of warmth and of strong sunlight. Are all parts of the earth equally warmed? Have all parts the same intensity of light? Compare the density of population of cold and dimly lighted parts of the earth with that of the warm and strongly lighted parts: in which is it greatest?

The study of the distribution of heat and cold, of rain and drought, of highlands and lowlands, and of fertile and infertile regions forms an essential part of the study of geography; the study of the progressive changes that have been and are now taking place on the earth's surface constitutes the science of *physiography*, or "nature-writing." The object of this book is to show that the fundamental laws of geographic science not only control the structure of life forms and their distribution over the earth, but that they also largely control and modify the history, the activities, and the various economies of man, as well.

QUESTIONS AND EXERCISES.—What are the leading industries of the city or town in which you live? Note and describe a geographic feature that favors any one of these industries, and without which the industry could not thrive.

What would be the effect, so far as the habitability of the surrounding region is concerned, were the rainfall to be diminished one-half?

How would a material change in the surface features affect the industries?

On p. 369 is a map of New York Harbor; what would be the effect on the commerce of the port if the surface of the water were lowered two hundred feet?

Mention two or more reasons why lowland regions are more densely peopled than highlands.

Quito, the capital of Ecuador, is in the midst of a fertile region nearly two miles above sea-level; what are its advantages over the coast plain region to the westward?

Make a list of half-a-dozen or more extensive regions that are not habitable, and explain the geographic reasons for their condition.

COLLATERAL READING

MILL.—Realm of Nature, pp. 331–336.
SHALER.—Nature and Man in North America.
ADAMS.—The New Empire, chap. I.
FROUDE.—History of English Literature—The Saxons.

CHAPTER I

THE EARTH AMONG PLANETS

The Solar System.—The cluster of heavenly bodies called the solar system is one of many groups in space. The members of this group revolve about a common centre of gravity, however, and for this reason they form collectively a *system*.

The members of this system vary greatly in size. The largest is about 886,000 miles in diameter, and the smallest are probably too minute to be measured by ordinary standards. Eight of them are about three thousand miles, more or less, in diameter; about four hundred vary approximately from ten to five hundred miles in diameter.

The largest member of the solar system, the sun, is about eight hundred times as large as all the other members together, and the common centre of gravity around which the various members revolve is very near to or within it. The eight bodies next in size are called *planets*, and all but two of them are attended by one or more *satellites* or *moons*. The four hundred or more small planets are called *asteroids*, or *planetoids*. There are also several *comets* and groups of *meteors* which have a permanent place in the solar system.

The asteroids move in orbits in the space between Mars and Jupiter. Many of them do not exceed twenty or thirty miles in diameter, and the largest probably does not exceed five hundred miles. Their combined volume is less than one four-thousandth part of the mass of the earth. Eros, one of the recently discovered asteroids, has an orbit so eccentric that it crosses that of Mars, and at times is nearer to the earth than is Mars.

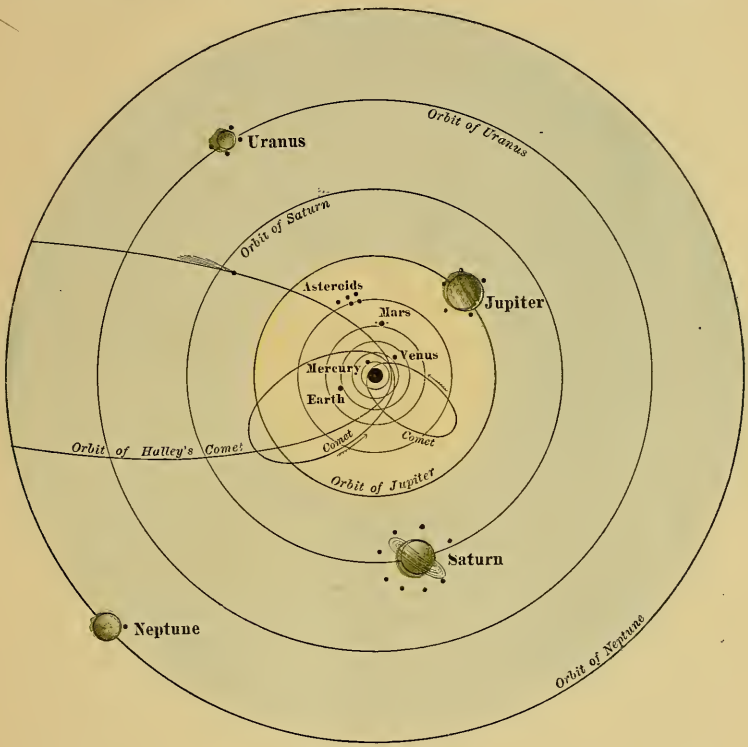
But little is known about the nature and structure of comets, but some of them are composed largely of gaseous matter. One comet, Tempel's, undoubtedly consists of a vast swarm of meteors; but it is probable that comets are constituted of different kinds of matter. Several of them belong to the solar system, but many are temporary visitors, coming from unknown regions of space, whirling around the sun and again vanishing into space.

Meteors, or shooting stars, are small bodies that seem to exist generally throughout space. In sweeping through space, the earth and the other planets encounter them without number. Most of them on reaching the earth's atmosphere are heated to whiteness and are dissipated as white-hot vapor. Many of the larger ones reach the earth, and some of them have been analyzed. They consist mainly of iron and nickel in a metallic form, or else of matter not differing materially from lava. No element has yet been found in a meteor that does not occur in the earth. In one instance gold, in another minute diamonds, were found in a meteorite.

The planets are composed of the same kinds of matter as the earth, but they are unlike one another in physical condition. Some, bulk for bulk, are but little heavier than water, others are about as heavy as iron ore. Some of the planets have apparently lost the greater part of their heat; still others are very hot. The sun, for instance, is a glowing mass at white heat.

The Sun and the Planets.—The similarity between the sun and the planets is very marked. They whirl from west to east around a common centre of gravity, and each turns or spins on its axis in the same direction. Each is nearly spherical in shape, and is more or less flattened at its poles. So far as is known, each is surrounded by an atmosphere.

According to the *nebular theory* of La Place, which is held by many scientists, the members of the solar system formerly existed as a body of gaseous matter, or, perhaps, of minute masses. The force of gravity drew the particles together, toward the centre of gravity. and a rotation



THE SOLAR SYSTEM

The space within the orbit of Jupiter shows the relative size of the Sun

of the mass around the centre of gravity resulted. Finally, parts of the mass were thrown off, one after another in the form of rings, a planet developing out of each ring. In a similar manner, the rapid rotation of each planet threw off portions of its mass forming the satellites.

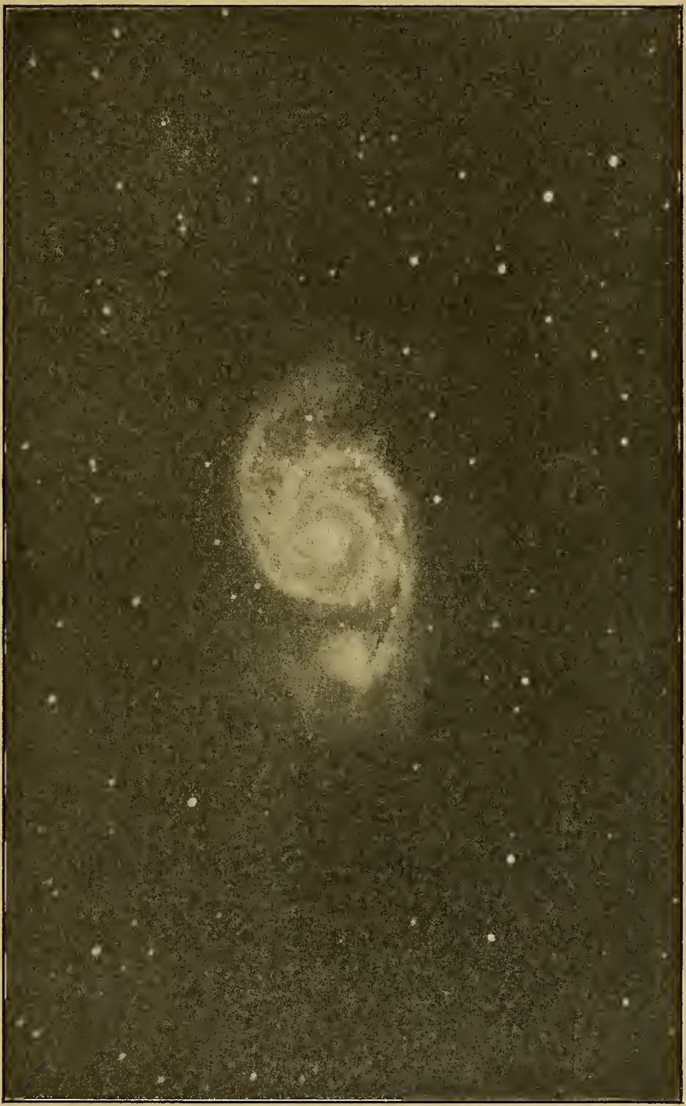
The researches of Chamberlain and Moulton, however, make it probable that solar systems develop from spiral nebulæ, the planets having been formed around nuclei of considerable size. The nuclei, in turn, attracted the scattered matter near which it passed. This theory, known as the "*planetesmal hypothesis,*" accords with many facts not explained by any other theory.

So far as is known, matter exists in at least three physical forms—

A PORTION OF THE MOON'S SURFACE

solid, liquid, and gaseous—and nearly every chemical element and many of their compounds may assume each of these forms. In the solid form the molecules are bound by a strong cohesion; in the liquid form they are slightly cohesive; in the gaseous form they repel one another. Most of the substances that in the earth are solids, in the sun exist as white-hot vapors.

Although the assumed formation of the solar system by either process is a matter of theory, both theories are supported by evidence. The telescope reveals many such masses of gaseous matter showing planetary



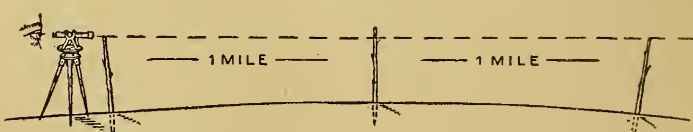
A SPIRAL NEBULA—CANES VENATICI

formation. The spectroscope, an instrument for analyzing a substance by the kind of light which it emits, reveals not only the matter of which the nebulæ are composed, but also that the matter is in rapid motion. Calcium, hydrogen, iron, and sodium, the substances of greatest abundance in the sun, are also among the most abundant substances of the earth.

The Form of the Earth.—The earth is one of the planets. From Table I: (*Appendix*), find how it ranks among the other planets in size;—in distance from the sun. Like the other planets, it is nearly spherical, but slightly flattened at the poles. It is usually said to be an *oblate spheroid*—that is, a flattened sphere. As it deviates slightly from this form, the term *geoid* is sometimes used to designate its irregular shape.

The spherical form of the earth is shown in various ways; it is best demonstrated by surveying a horizontal straight line along a level surface, such as that *of a pond*. The line thus projected is not parallel to the surface of the pond; the latter curves away from it, and the curvature is such as corresponds to the surface of a spherical body.

This may be illustrated in the following manner: Three stakes are set in line, or as nearly in line as is practicable, one mile apart, along the shore of a canal, a pond, or the sea shore. Sighting marks are then



EXPERIMENT TO SHOW THE EARTH'S CURVATURE

made on the stakes each at a uniform distance above water-level. An engineer's level is then placed so that the cross-wires cut the sighting marks of the first and third stakes. If the telescope of the level be turned upon the middle stake it will be found that the cross-wires cut the stake at a point eight inches below the sighting mark. The head and shoulders of a man standing in a boat five miles from shore are visible, but the boat itself is not. Among other facts that serve to establish the spherical shape of the earth are: The circular shadow of the earth projected upon the moon at the time of an eclipse; the variation of time with respect to longitude; and the more practical fact of circumnavigation.

Were the earth a true sphere, the weight of a body would be the same at every part of its surface. This, however, is not the case; a given body weighs a little more in polar than in equatorial latitudes, and from the difference in weight the amount of flattening at the poles has been determined.

A pendulum consisting of a ball weighing about one hundred pounds swinging on a wire of fixed length is allowed to oscillate freely. When all errors are corrected the rate of vibration will be the same at all points of the earth's surface equally distant from the centre. At any place on the earth's surface that is nearer to its centre, as the poles, the rate of vibration is slightly faster; at any place more remote it will be slower. The United States Coast and Geodetic Survey has carried on a series of pendulum observations covering a period of many years with the results as noted below. Professor Ferrel has shown that, theoretically, the level of the sea between the 20th and 27th parallels is about thirteen metres (40 ft.) higher than it would be if the earth were a true spheroid.

Size of the Earth.—The following are the earth's dimensions:

Polar diameter	7,901.5 miles
Equatorial diameter	7,926.6 miles
Circumference at equator	24,912.2 miles
Surface (approximate)	197,000,000 square miles

What is the difference between the polar and the equatorial diameter? Compare the diameter of the earth with that of the sun (Table I., *Appendix*). Large as the earth seems to us, it would require about one and a quarter million bodies of its size to make a globe of the same size as the sun.

Motions of the Earth.—The earth has several distinct motions. It revolves about the sun in an elliptical path, making a complete journey of about 585,000,000 miles in very nearly 365¼ days—a period of time called a *year*. It also rotates, or spins on its axis, the time required for a complete rotation being called a *day*. The axis of the earth also swings or oscillates in a path which resembles that of the peg of a "sleeping" top.

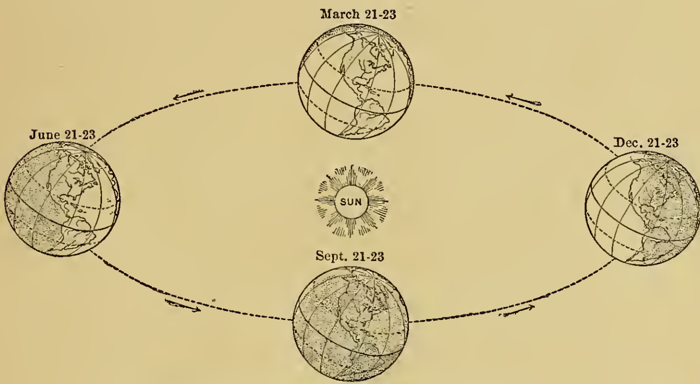
The revolution of the earth around the sun, together with the inclination of the axis, causes the successive change of the seasons and the varying length of sunshine and darkness. Rotation upon its axis causes the succession of day and night. The oscillation of the axis causes the precession of the equinoxes.

In long intervals of time it is thought that this motion is connected with certain changes of climate. It is a subject, however, that belongs to the science of astronomy, and not to physical geography.

The Inclination of the Axis.—The axis of the earth is not perpendicular to the plane of the earth's path, called the *plane of the ecliptic*, but inclines about 23½ degrees, as shown in the accompanying figure. The degree of inclination varies in long intervals of time, but practically this change may be neglected; practically the axis is always parallel to itself. The north end of the axis if prolonged would extend nearly in the direction of a star named Polaris; this star is called the *north*, or *pole star*.

If the earth's axis were perpendicular to the plane of its orbit, each place on the earth's surface would have an unvarying season. It would be always mild in mid-latitudes, and equally cold in the same latitudes of polar regions.

With an inclined axis, however, the case is different. In June (see diagram below) the sun's rays are almost vertically on mid-latitude parts of the Northern Hemisphere, while in the corresponding latitudes of the Southern Hemisphere they are very oblique. At this season, therefore, the Northern Hemisphere receives more light and more heat than the Southern. Six months later the conditions are reversed; the vertical rays are on the Southern Hemisphere, while on the Northern they are oblique. In



INCLINATION OF THE EARTH'S AXIS

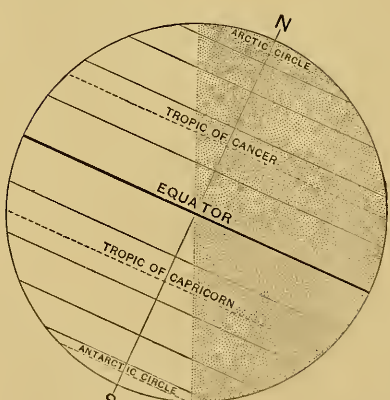
The unshaded hemisphere shows the position of the light circle at each of the four seasons.

December, therefore, the Southern Hemisphere receives its greatest warmth.

Thus each of these hemispheres has a period of warm and long summer days, alternating with one of short days and cooler temperature. In equatorial latitudes the difference is not great, but beyond the tropics it is the difference between winter and summer. In polar latitudes the sun is shining on the greater part for six months. Each hemisphere, therefore, is alternately in light and darkness during this period. As a result, the season of sunshine, or summer, may become oppressively hot, while the season of darkness, or winter, is very cold.

Any change in the inclination of the earth's axis would produce decided changes of climate. For instance, were the inclination increased, the limits of the frigid zones would be pushed farther toward the equator. If the inclination of the axis were forty degrees, the polar circles would each be forty degrees from the poles, and the tropics would be each forty degrees from the equator.

The Effects of Rotation.—The rotation or spinning of the earth on its axis causes the succession of daylight and darkness. One-half the surface, being always toward the sun, is illuminated; the opposite side is in darkness. The rotation of the earth presents every part of the surface successively toward the sun, lighting all parts in turn. Were the axis of the earth perpendicular to the ecliptic, day and night would be of equal length at all parts of the earth's surface. On account of its inclination, the relative length varies, not only in different latitudes, but with the changes of the seasons in the same latitude.



RELATIVE LENGTH OF DAY AND NIGHT

The shaded part of each parallel shows the length of the night; the unshaded part, the proportionate length of the day.

In the torrid zone the period of daylight and darkness does not vary much in length, and at the equator the days and nights are each twelve hours long. In the temperate zones the days are longest near the polar circles and shortest near the tropics, varying from thirteen to twenty-four hours. Within the frigid zones day and night correspond practically to summer and winter. There, both the day and the night vary from a few moments to six months in length.

The relative length of daylight and darkness and the changes of the seasons have much to do with food crops. The long days and short nights of summer in the temperate zones make possible the cultivation of plants that would not mature were the day only twelve hours in length.

Only a few species of animals and plants thrive in regions of long-continued darkness, and they are mainly the lower forms; the higher species require an environment in which light and darkness follow one after the other in periods of short duration. Most plants fail to mature and fructify unless exposed to strong light, and many species will not live at all.

QUESTIONS AND EXERCISES.—Make a circle one inch in diameter on the blackboard, and from the centre of this circle, with a radius fifty-five inches long, draw as much of the arc of a circle as the size of the blackboard will permit. The two circles represent the relative size of the earth and the sun.

In the diagram, p. 17, the axis of the earth is inclined 23½° from the dotted line; which of these positions represents summer in the Northern Hemisphere?—In the Southern? Copy the diagram, p. 18, and mark the point the sun's rays reach beyond the north pole; how many degrees from the pole to this point? What circle passes through this point? Mark the point on the circumference where the rays are vertical. What circle passes through this point? From each pole to the equator the angular distance is 90°: find the distance in degrees from the Arctic Circle to the Tropic of Cancer; this distance is the width of the Temperate Zone. If the inclination of axis were 28°, what would be the width of each light-zone? If

32°? Ninety degrees less twice the angle of inclination equals the width of the Temperate Zone.

From the datum given on p. 15, calculate the speed of the earth per second at the equator; compare this with the speed of a train scheduled at sixty miles per hour. With reference to the earth's rotation on its axis, what is the speed per hour of a point on the equator? In latitude 60° it is about half as great; how great is it at the poles?

In the diagram, p. 18, the proportionate length of the longest day and shortest night are shown by the shading; determine by measurement the length of the longest day in latitude 40°; in latitude 60°. Subdivide the parallel into twenty-four parts by halving it three times and dividing the last subdivisions each into three parts; each of the smallest subdivisions has practically an hour value.

COLLATERAL READING AND REFERENCE

Mill.—Realm of Nature, pp. 63–81.

Redway —Manual of Geography, pp. 64–78.

Howe.—Elements of Astronomy. Problems, *a–g*, p. 83.

Jackson.—Astronomical Geography.

Todd.—New Astronomy, chaps. v–vi.

Newcomb.—Popular Astronomy, pp. 88, 397.

Museum of Natural History, New York City.—Collection of meteorites, photographs of planets, nebulæ and other celestial bodies.

CHAPTER II

THE STRUCTURE OF THE EARTH

In the long period of time that has elapsed since the earth was glowing with intense heat, the substances composing it seem to have adjusted themselves in accordance with the laws of gravitation—that is, the heaviest kinds of

IDEAL SECTION THROUGH THE EARTH

The thickness of the various envelopes is greatly distorted.

matter are nearest the centre. Structurally the earth consists of a dense and practically solid globe, the *lithosphere*, nearly covered with a comparatively thin layer of water, the *hydrosphere*, the whole being surrounded by an envelope of air, or *atmosphere.*

The shape of the lithosphere and the condition of the substances composing it, show that in times past it was intensely heated, and that much of the rock composing it has been in a molten condition. The globular form is the only one that would naturally result from the action of gravitation on a plastic or a fluid body; and the flattening at the poles is most reasonably explained by a hypothesis that, while it was still plastic, the earth spun, or rotated on its axis.

The density of the lithosphere, together with the waters, is about that of iron ore—that is, bulk for bulk, it is about five and one-half times as heavy as water. At the surface, however, the density of the rocks is about half as great as that of the whole globe; it is certain, therefore, that the substances forming the interior are much heavier than those at the surface.

The outer part of the lithosphere, called the *rock envelope* or, popularly, the "crust of the earth," surrounds an intensely heated interior, the *centrosphere.*

That the centrosphere is very hot cannot be doubted; for in every place where the rock envelope has been penetrated by deep borings, a constant increase of temperature is observed—the greater the depth the higher the temperature. The thickness of the rock envelope is not known, but at a depth of less than forty miles it is thought that the temperature is high enough to fuse the most refractory substances.

It must not be inferred from this, however, that the centrosphere is liquid; on the contrary, the earth behaves like a solid but somewhat elastic body. The melting or fusing of a substance depends not alone on temperature, but also on pressure. With increase of pressure, the fusing point is also raised; and the great weight of the overlying rock produces pressure enough to prevent liquefaction. The increase of temperature varies in different kinds of rock and in different localities, the average being one degree (F.) for every sixty or seventy feet.

Four-fifths of the surface of the rock envelope is covered by a layer of water, the hydrosphere, averaging a little more than two miles in depth. The water not only exists in a free state, at the surface, but also as a chemical constituent of various kinds of rock.

The crystalline form of many rocks is due to the water they contain in chemical combination, and there are but few rocks of which water does not form a considerable part. It is by no means impossible that the free waters of the earth, in time, may be absorbed in this way, to reappear in chemical combination.

Water forms a most important constituent of the earth. It is essential to the existence of life; for not only does it form the greater part of every plant or animal, but it is also the chief means by which nutrition is distributed throughout the various parts of the body of the animal or the plant.

Within a range of a very few degrees of temperature, water exists in one or another of three forms—a solid, ice; a liquid, water; and a vapor, steam. In one or the other of its forms water is the chief agent by which the surface of the rock envelope has been sculptured; therefore it has an important place in the science of physiography.

The Atmosphere.—The atmosphere consists of a mixture of gaseous substances, namely—nitrogen, oxygen, water vapor, and carbon dioxide. Oxygen is required in the respiration of animals; carbon dioxide, the gas formed when coal burns, is essential in the breathing of plants; nitrogen forms a part of the structure in both animals and plants; and water vapor is the form in which the fresh water is carried from the sea to the land. The atmosphere, therefore, is just as essential to life as the water envelope.

The thickness of the atmospheric envelope is not known. Various estimates place it between one hundred and two hundred miles. At the latter estimate, on a globe three feet in diameter, the proportionate depth of the atmosphere would be about one-half an inch.

At the plane where the atmosphere rests upon the land and the sea the physiographic processes which are most noticeable are continually in action.

The Rock Mantle.—The three envelopes of the earth are constantly acting and reacting upon each other. Movements of the rock envelope have divided the waters from the land. Moreover, the rock envelope has been crumpled, and folded so as to form plateaus, ranges, and valleys. The heat of the sun causes a part of the ocean waters to take the form of vapor, and the latter, mingled with the air, flows over the land. Being chilled, the vapor again takes the form of rain or of snow, and falling on the land wears away its surface. The water, gathering into channels, carries the particles of rock waste mingled in its flood to the sea, and there deposits them.

As a result, almost every part of the rock envelope is covered with a layer of loose rock that has been worn from its surface. This layer is called the *rock mantle*, or sometimes the *waste mantle*. It is usually thick in the valleys and along the coasts to which it has been carried by running water; it is apt to be thin, or absent altogether on mountain slopes. The rock mantle is composed of about every mineral substance that enters into the structure of the rock envelope. The top of the rock mantle is commonly mixed with the remains of decayed vegetation. It contains the elements of plant food and constitutes *soil.*

For convenience, the constituents of the rock mantle are classified as follows: *Clay,* a silicate of the metal aluminium, is derived from the mineral felspar. *Sand* consists of grains of uniform size derived from the mineral quartz. As a rule, sand is a seashore product, and the uniform size of the grains results from the sorting power of the waves. Sand is also formed by the action of the wind. The name is applied loosely to any deposit of finely sorted grains of rock. *Gravel* is a term loosely applied to any accumulation of small pieces of rock. For the greater part, gravels are found along stream beds, in glacial drift and on shores. *Peat* is a black, slimy muck, composed mainly of carbon, that results from the decay of vegetable matter. It occurs chiefly in swamps, and old lake bottoms. The name is also applied to the stems of certain swamp plants. *Marl* is a limy substance, usually mixed with clay, that results from the decay of minute living organisms, shell-fish, etc. It is valuable as a fertilizer. The rock mantle consists chiefly of a mixture of sand, clay, and the products of decayed vegetation.

Movements of the Rock Envelope.—The most apparent changes in the surface of the rock envelope are the wearing away of the rock from the higher surfaces and the transportation of the rock waste to lower levels. That is, water in its various forms loosens particles of rock, and the streams carry it seaward. If the land were everywhere level, the run-off of water could wear away but little of it. But vertical movements of the rock envelope are taking place, and these, by making new slopes, give the run-off waters increased wearing power.

These never-ceasing changes make a fairly complete cycle. Thus, vertical movements of the rock envelope form mountains and plateaus. By the action of water in its various forms, these are gradually worn down, and the rock waste that once composed them is transported to the shores of the continents and there spread out in the form of a long margin of sediment. The sediments, in turn, become layers of rock; in time these are folded into mountain ranges or uplifted in the form of plains and plateaus. Practically every part of the earth's surface has undergone changes of this sort.

In areas to which extensive sediments are being carried, evidence of sinking is usually apparent; while, as a rule, areas that are being denuded are rising. It is probable, therefore, that vertical movements of the rock envelope in many instances are connected with the wasting of the land and the transfer of sediment.

The causes of these earth movements are not known, but it is believed that the gradual contraction of the rock envelope to fit itself around a more rapidly shrinking interior is the chief factor. There is evidence, too, that gravitation is a factor. The removal of great amounts of rock waste—from one locality to another, relieves weight at one place and increases it at the other. Therefore it is inferred that a sinking occurs at the latter place, and an uplift at the former.

According to this principle the rock envelope of the earth always maintains a state of balance, adjusting itself to the load it carries. This condition, called the *isostatic balance*, is regarded as an important factor in the explanation of the various movements of the rock envelope.

In general the vertical movements of the rock envelope are of two kinds: the uplift, folding, crumpling, and breaking which may be observed in the formation of mountain ranges; and the gentler movements observed in the slight uplift or the depression of areas of considerable size. Between the two kinds there is no broad distinction. Usually such movements are slow, covering periods of many centuries in duration. Occasionally, however, it takes the form of a sudden break of the rock envelope, thereby producing an earthquake.

Rock and its Structure.—The term rock is applied to every mineral substance that forms a part of the earth, and likewise to any mixture or combination of minerals. Thus, clay, sand, gravel, limestone, quartz, granite, lava, and even the fine, wind-blown rock waste, are each called rock. Beyond a depth of a few thousand feet from the surface, nothing positive is known about the character of the substances which compose the earth. Nothing at all is known about the centrosphere, and but little is known about the lower part of the rock envelope.

No one knows what the *primitive* or first rock that formed the crust of the earth may have been, but certain kinds of rock have been found underlying the water-formed sediments, from which the latter seem to be derived. Ordinary granite is an example of this kind of rock, and granitic rocks are very abundant. There are various kinds of granite, but the most common varieties contain the minerals of which nearly all the elementary rocks are composed.

One of these minerals is *silica*, of which quartz and sea sand are the best examples. Another is *felspar*, a mineral which, decomposed, yields clay, potash, lime, and soda. Another mineral is *hornblende*, which decomposes mainly into iron, lime, and silica. Still another constituent usually present is *mica*, popularly called "isinglass"; like felspar mica also decomposes into clay, silica, lime, and other substances.

Igneous Rocks.—In many instances there is no doubt how the rock has been formed, or whether it has been altered, because the whole process of its formation has been carried on in plain sight. Thus, when a volcano pours out a flood of molten lava there is no question about how the rock got into place, or whence it came. When it has hardened, the lava always has qualities about it that determine its character.

Of the rocks that have cooled from a molten condition, the lavas of volcanoes are perhaps the best known. The Hawaiian Islands are mainly great piles or domes of lava. Lava is common in most mountainous regions. In many

IGNEOUS ROCK: A FLOW OF LAVA

instances it has been ejected from long fissures and has cooled slowly, forming great dykes; in this form it is usually known as *basalt*, or, if it breaks into regular blocks, *trap*. The Palisades of the Hudson, Fingal's Cave, and the Giant's Causeway are examples.

All the foregoing are commonly called *vulcanic* or *igneous* rocks. Igneous rocks are found not only in mountainous regions, but also in localities from which the sedimentary rock has been removed. Granitic rocks prevail in the New England Plateau; dykes and sheets of lava are abundant in the Western Highlands.

Normally, granite is a mixture of mica, felspar, and quartz. If it contains hornblende instead of mica it is called *syenite;* if both mica and hornblende are present it is *syenitic granite.* If the felspar contains soda the granite is *diorite.* If it occurs in layers, it is called *gneiss.*

SEDIMENTARY ROCK, NEAR OLEAN, N. Y.

The face of the cliff is one side of a channel of the river.

Sedimentary Rocks.—Most of the rock now at the surface consists of sediments carried thither by running water and deposited in the form of layers, or *strata,* that afterward hardened into compact rock. Moreover, there is but one place from which the sediments could be derived—namely, from the rock envelope itself.

Although the sedimentary rocks are derived from granitic and other vulcanic rocks, there is nothing to indicate their close relation to them. The making of firm rock out of loose sediments is sometimes a complex process, as may be seen in the formation of sandstone.

In the first place the grains of quartz composing the sandstone are rounded; they also are uniform in size. The rock from which they came, probably granite, has crumbled, and water has sorted the various minerals from one another. The waves, beating the fragments of quartz and rubbing them against one another, have not only separated them from the rest of the granite, and rounded the grains; they have also sorted them according to size, and piled them in nearly flat layers along the beach.

In time the beach was lifted above sea-level and covered deep with loam. Water, in one form or another, flowed over upon the surface; the lime it contained in solution, leached through the layer of sand, and cemented the grains, forming *sandstone.* In a similar way, water containing lime, or perhaps iron, in solution has cemented gravel into *conglomerate, breccia, "pudding stone,"* or *"brown stone."*

In most instances, clay banks are derived from granitic and similar rocks. Felspar decomposes into clay, and the latter, being very light and fine, is carried off by the water, to settle by itself. In many instances clay has been spread over large areas. Possibly it remained in the stiff, pasty form by which it is commonly known; very likely pressure, heat, and moisture, acting together, converted it into *shale* or into *slate.*

An interesting example of rock-formation occurs at Sweyney Cliffs, Shropshire, England. A small stream of water pours over a red sandstone cliff. The water contains a considerable proportion of lime and magnesia; and a species of coarse moss grows freely in the saturated earth about the stream-bed. The mineral salts of the water are deposited copiously on the moss, and little by little the latter, together with the other matter entangled, has become completely incrusted and forms a dyke about twenty feet wide. The dyke has built itself out from the edge of the cliff a distance of ten feet or more.

Rivers and other running waters are active workers in making rock, and one can almost always find clay banks, gravel beds, and other sediments that have been brought down stream and distributed by the current.

It is not so easy to understand how rocks are found at the bottom of the sea; as a matter of fact, more sedimentary rock has been formed in ocean and lake beds than elsewhere. Many of these rocks are composed largely of the remains of minute animals.

The sea, especially in regions of warm water, contains many thousand species of such animals, all of which multiply with great rapidity. When they die their bodies sink to the bottom. The mineral remains of these organisms consist mainly of lime or silica, and in time the thick layer that accumulates finally becomes cemented into rock. The growth of such rock is slow, but time alone is required to make layers of great thickness. The chalk cliffs of England and France were formed in this manner, and they aggregate nearly half a mile in thickness. The limestones of the Mississippi Valley also accumulated on sea-bottoms and have about the same thickness.

There are very many forms of sedimentary rock, though only a few kinds. Thus, the limestone that gathers about springs is called *tufa* when soft and porous; or *travertine* when white, hard, and partly crystalline. If it is composed of small, rounded grains, it is *oölitic,* or *"bird's-eye" limestone.* Shale takes many forms; and clay, though white when pure, is usually gray, or reddish-brown. If it contains a considerable proportion of vegetable matter, it is black "*adobe*."

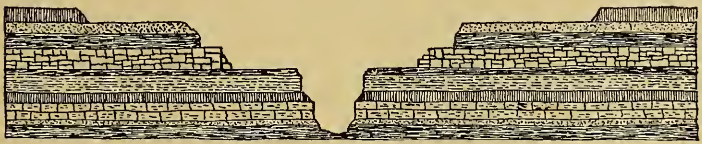
Metamorphic Rocks.—In many instances the character of sedimentary rocks has been materially changed. Thus, by pressure and heat, moist beds of clay have been transformed into layers of gritty *slate*; chalk and limestone have become crystalline *marble*; shales have been converted to mica *schist*; and bituminous coal has become *anthracite*. Older granitic rock has crumbled, and the rock waste has been cemented into firm rock again with but little alteration, as in the case of certain kinds of *gneiss*. Such rocks are said to be *metamorphic*.

Substances ordinarily insoluble in water are quickly changed when subjected to water under a high temperature. If a thick steel tube, filled with water and fragments of granite, be intensely heated for several hours, the larger part of the rock will be dissolved. Hot alkaline water also dissolves granitic rocks, the dissolved matter being precipitated when the water cools.

In most cases the older and deeper stratified rocks have been thus changed. The weight of the overlying rock produces immense pressure, and the changes resulting from the moisture within them greatly alter their appearance. Many of the metamorphic rocks, indeed, are like igneous rock in appearance. Rocks that form a part of mountain folds are apt to be metamorphic on account of the pressure that has resulted from the folding and crumpling.

Order of the Rock Strata.—Most of the sedimentary rocks were deposited in horizontal layers, but, on account of the movements of the rock envelope, they are often found in oblique positions. Sometimes they occur in gentle folds; but in mountainous regions they are much crumpled and broken. In some of the old sea-beds now raised above sea-level the strata are undisturbed.

The story of the earth has been read by the study of the upturned edges of broken and tilted strata. Each stratum is a chapter by itself; and to read the history prop-

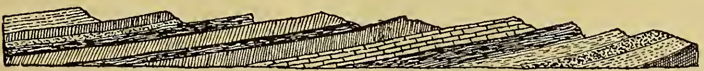


SEDIMENTARY ROCK: SECTION THROUGH THE CAÑON OF THE COLORADO RIVER

The level of the strata has not been disturbed.

erly it is best to begin with the lowest. It is not always easy to tell the relative position of strata at some distance from one another, but as each stratum has *fossils*, or animal remains peculiar to itself, the position is usually determined by the character of these.

The total thickness of the stratified rocks is not far from twenty miles; the average thickness is, perhaps, between five and ten miles. There is no locality in which all the various strata are found; no locality is known in which even

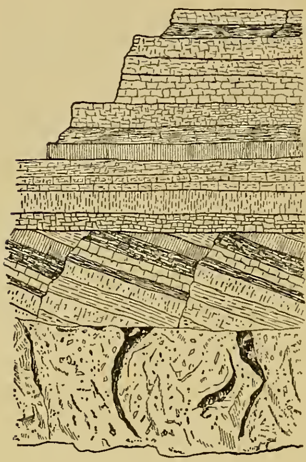


SEDIMENTARY ROCK: TILTED STRATA

any considerable number occur. Sometimes the oldest rocks are overlaid by the most recent formations; the intermediate strata are missing.

Thus, the rocks of the Mississippi basin belong to a very old and remote geological period. A thin cover of rock waste that belongs chiefly to a very recent period overlays them.

As a rule, the lowest strata do not differ much from the granitic rocks and possibly include some of them. To these the name *Archæan* is given. These strata are regarded as the foundation of the continents and the floor of the oceans. The decay and wearing away of these has formed the material of which nearly all the sedimentary rock, the limestones excepted, is composed. "*The waste of the old land is the material of the new.*"



UNCONFORMABLE STRATA: CAÑON OF THE COLORADO RIVER

The tilted strata, originally horizontal, were deposited on the surface of the igneous rock. Subsequently the upper layers were deposited on the broken surface of the tilted layers.

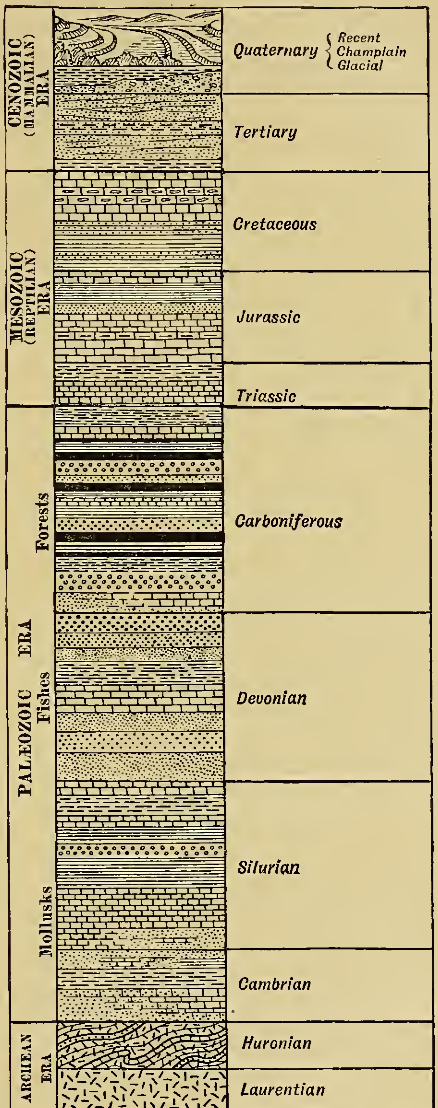
The remaining strata are named in accordance with the character of the life forms that existed when the rocks were undergoing formation. Note the eras in the order of their occurrence.

The word *Archæan* means "the beginning"; *Palæozoic* is derived from two Greek words meaning "early life"; *Mesozoic*, similarly, is "middle life"; and *Cenozoic*, "recent life." The *Silurian* age was named from "Silures," a former name for the people of Wales; *Devonian* comes from "Devon," England; *Huronian*, from "Huron"; and *Laurentian* from "St. Lawrence." All these names are derived from the localities in which the rocks were first studied.

The Archæan Era.—In Archæan times North America consisted mainly of a narrow, V-shaped strip of land south of Hudson Bay. The crests of the Appalachian Mountains were just above the sea-level; the Black Hills and one or two peaks of the Rocky Mountains had also just emerged. The general form of the American continent was outlined in Archæan times. With the possible exception of a few species resembling the sponge, no forms of life are found in Archæan rocks.

The Palæozoic Era.—The Palæozoic era was of very long duration. The sediments composing it are in places 25,000 feet thick. The greater part of Europe and North America were above sea-level during this period, but the land was many times upheaved and submerged. In North America the greater part of the Mississippi Valley was a shallow inland sea, that later became an immense marsh.

In the variety and extent of life forms the Palæozoic era is the most noteworthy of all the geological periods. It began with the lowest form



ORDER OF STRATA

of sponges and closed with the advent of mammoth reptiles. During this period animals with backbones appeared for the first time. Insects were numerous, and toward the close reptiles existed. Fishes and mollusks seem to have been the prevailing forms.

The climate was warm and moist. The vast accumulations of vegetable matter that now constitute the coal fields were found in swamps of this era. In North America these swamps covered much of the area that is now the central United States.

Coal measures are not confined to the Carboniferous age; they occur in all geological ages. Those of the Carboniferous age, however, supply nearly all the coal consumed in the United States. The coal measures of the Pacific coast belong to the Tertiary age.

The Mesozoic Era.—During the Mesozoic era both North America and Europe had about reached their present shape. In the former continent the Gulf of Mexico reached as far north as the mouth of the Ohio, and a northwestern branch of it extended nearly to Canada. In Europe the higher elevations of land, the Pyrenees excepted, had probably been elevated above sea-level.

NORTH AMERICA IN ARCHÆAN TIMES

The shaded area shows the part of the continent above sea-level.

It was an age of gigantic reptiles. The animals of some species were from sixty to eighty feet in length. For the first time birds appeared. They were very much like reptiles, however, and some species had jaws with socket teeth, instead of horny beaks.

The Cenozoic Era.—This era was largely one of uplift and mountain-making, although both in North America and Europe the various ranges and systems had received definite forms. The former was a continent of vast fresh-water lakes; the latter of inland seas.

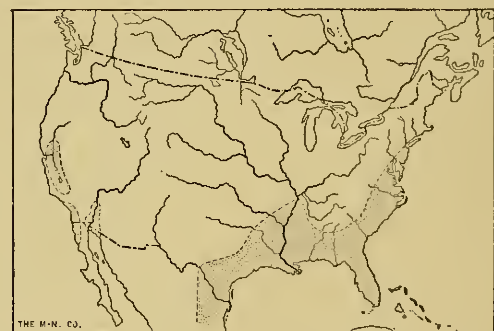
Many of the life forms which had flourished in preceding ages were common, but one great step in advance may be noted—the first appearance of mammals. These included the elephant, camel, rhinoceros, wolf, deer, and horse. The forest trees both of North America and Europe included most of the species found to-day.

NORTH AMERICA IN CENOZOIC TIMES
The unshaded area shows the part of the continent above sea-level.

There were several species of camel during these times. It is interesting to note that this animal, now confined to the Asian continent, was a native of the American. The earliest species of horse had five toes instead of one. In subsequent times two of these gradually disappeared. The horse of modern geological times has but one toe, but the "splint bones" just above the hoof are the toes of the Quaternary horse.

The Glacial Epoch.—The close of the Cenozoic era was very abrupt. It was probably due to an elevation of a large part of North America and Europe from 1,000 to 2,000 feet, and was accompanied by a decided lowering of temperature. The ice and snow of the north polar regions crept southward until they enveloped nearly all of Europe. In North America the ice reached as far south as the Ohio and Missouri Rivers. This prevalence of ice constituted the *glacial epoch.* It is marked by a scattering of drift on a stupendous scale similar to that which marks the glaciers of the present time.

In the area covered by glacial ice most of the species of



THE UNITED STATES AT THE BEGINNING OF THE QUATERNARY AGE
The shaded area shows the part added in recent times.

larger mammals perished. The cave bear, horse, wolf, and reindeer survived. Many species of plants were destroyed.

It seems certain that man existed before the close of the glacial epoch. In the caverns of Belgium, Germany, and Italy the bones of man have been found in caves together with the skeletons of animals and various implements of the chase. From the few scraps of unwritten history it seems that preglacial man was a savage of the lowest type.

He lived in caves and obtained his food by hunting and fishing. He did not cultivate the soil nor did he have any domestic animals. He had learned the use of fire, however, and from that moment his intellectual development was rapid.

QUESTIONS AND EXERCISES.—It is sometimes assumed that the rock envelope is about forty miles, and the atmosphere about two hundred miles, in thickness. Construct a diagram on the blackboard or on paper, showing the relative thickness of each on scale in the ratio of 4000 : 40 : 200.

Unburnt clay can be moulded and shaped when wet; is this true of burnt clay? "Burning," or heating clay drives off the water of crystallization, leaving a hard mass. What great industries depend upon this fact? Examine grains of sea sand under a magnifying glass, and note their characteristics. Compare them with the loose dust in the streets. Compare stream gravel with ordinary broken rock, and note the difference.

Note and describe any instances within your personal knowledge of the action of water on the rock envelope; explain the nature of the changes and how they have been brought about.

Study the various rock formations in the neighborhood in which you live and classify them according to their origin—that is, as sedimentary, metamorphic, or igneous.

Make a collection of them for future use.

A stream flows over a bed of limestone rock that is slightly soluble, into a lake without an outlet; what changes in the formation of rock are likely to occur? Will the rock formed be stratified or unstratified? In what way may it become fossiliferous?

From the official State reports, or from the United States Geological Survey, find the order and distribution of rock strata in the State in which you live, and from the information given construct a geological map.

Procure one or more specimens of granite, and with the aid of a magnifying glass observe the following directions. Look for small clusters of foliated or "leafy" mineral; it may be whitish or, perhaps, green, or brown; this mineral is *mica*. If no mica is found, look for jet black crystals or masses; this is *hornblende;* it is usually opaque, but sometimes translucent. Find the white, translucent mineral with glassy lustre; it is *quartz,* or *silica,* and it is apt to form the chief bulk of the rock. Look also for an opaque mineral varying from yellowish-white to pink in color; possibly it will break into fragments having flat sides, or *cleavage planes;* this mineral is *felspar;* it has different crystalline forms accordingly as it contains lime, potash, or soda. Study the character and appearance of trap, basalt, and obsidian ("volcanic glass"), if possible.

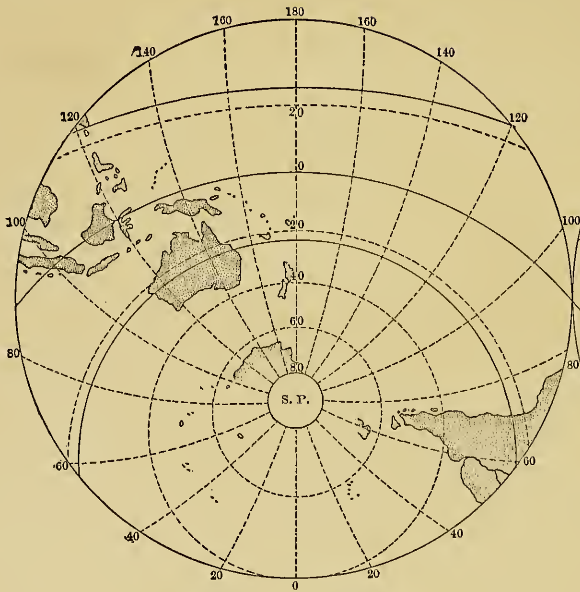
Procure pieces of limestone of various kinds, including chalk (not crayon), specimens of clay and shale, and one or more kinds of sandstone. Touch the limestone with a drop of strong acid held on the end of a glass rod; note the result. If possible collect some of the escaping gas in a bottle and put a lighted match into it; note the result. The gas is carbon dioxide. Shake a lump of clay vigorously in a bottle partly filled with water and note whether the sediment falls quickly to the bottom, or remains suspended. Try the same experiment with sand. In how many directions does the shale split or break?

Obtain specimens of iron ore, marble, and dry clay, and compare the weight of pieces of the same size. If possible find the specific gravity of each. Determine, or judge by "hefting," the relative weight of the various kinds of rock in the neighborhood in which you live.

Procure specimens of clay and slate, chalk (not crayon) and marble, bituminous (soft) coal and anthracite. Examine each pair with reference to hardness, foliation, crystalline appearance, and density (weight of pieces of equal size). Make a list of the rocks occurring in the neighborhood in which you live, and classify them as igneous, sedimentary, or metamorphic.

COLLATERAL READING

Powell.—Physiography of the United States, pp. 22–29.
Le Conte.—Elements of Geology, pp. 127–132.
Mill.—Realm of Nature, pp. 211–230, 249–261.
Shaler.—First Book of Geology, pp. 107–124.



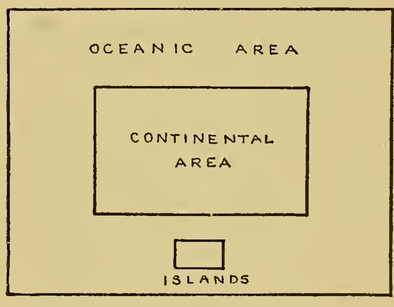
WATER HEMISPHERE

LAND HEMISPHERE

CHAPTER III

LAND AND WATER, AND THEIR OUTLINES

The surface of the rock envelope is not smooth, nor is any considerable part of it perfectly level, as the word is commonly used. More than three-fourths of its surface is covered by the sea, but the remaining part consists of very irregular areas that are higher than the level of the water. The great body of water that covers so much of the rock envelope is the *sea*; the areas above sea-level constitute the *land*. The lowest part of the rock envelope below sea-level—that is, the lowest part of the sea-bottom—is about five and one-half miles, and the highest point above it is just about the same distance. The average elevation of the land is not far from 2,000 feet, but the average depth of the sea is about 2,000 fathoms.



RELATIVE AREAS OF LAND AND WATER

The land aggregates about 53,000,000 square miles. It clusters around the north pole, and from this circumpolar region it radiates toward Cape Horn, toward the Cape of Good Hope, and toward Tasmania. In which hemisphere is the greater part? Which of the two temperate zones includes the greater area? The two largest masses are nearly divided at the central part. The smallest is separated by an arm of the sea which seems to have severed it from the largest. The three largest land masses are called *continents*; the smaller ones *islands*. The line at which the land and the sea meet is the shore; the narrow strip of land next the shore, the *coast*.

The notable separation of the land masses has been aptly called the "zone of fracture." The isthmus of Panama is scarcely thirty miles wide and the isthmus of Suez is only one hundred miles across. Yet these two necks of land are all that connect the divisions of each continent. Twenty-five thousand miles of open navigation are obstructed by a width less than one hundred and thirty miles of land. Even these commercial barriers are disappearing because of canals completed or projected.

The Continents.—The continents are so called on account of certain features of their structure. Each one, for

RELATIVE AREAS OF THE CONTINENTS AND GRAND DIVISIONS

convenience, is divided into *grand divisions*. In general, the continents have a high border on one side and a lower one on the opposite side. They are variously named, but they are usually styled the Eastern, or Asian; the Western, or American; and the Australian. The shore of a continental body of land in the south circumpolar regions is known to exist, but very little is known of its extent.

It is now the custom to restrict the term "continent" to the largest land masses, but it is sometimes more convenient to apply it to a grand

180° 150° Longitude 120° West from 90° Greenwich 60° 30°
Lincoln Sea
ARCTIC OCEAN
Kane Sea
GREENLAND
Baffin Bay
Davis Strait
ASIA
ARCTIC CIRCLE
Hudson Bay
Bering Sea
BRITISH ISLES
NORTH AMERICA
VANCOUVER I.
Tuscarora Deep
AZORES
ATLANTIC
BERMUDA IS.
TROPIC OF CANCER
Gulf of Mexico
WEST INDIES
Sargasso Sea
Porto Rico Deep
HAWAII
Caribbean Sea
PACIFIC
OCEAN
EQUATOR
OCEAN
SOUTH AMERICA
FIJI IS.
TROPIC OF CAPRICORN
NEW ZEALAND
FALKLAND IS.
ANTARCTIC OCEAN
LAND
over 10,000′
2,000′ to 10,000′
0 to 2,000′
below Sea Level
80° 60° 40° 20° 0° 20° 40° 60°


30° 60° Longitude 90° East from 120° Greenwich 150° 180°
FRANZ JOSEF LAND
SPITZBERGEN
NOVA ZEMBLA
ARCTIC OCEAN
Kara Sea
Gulf of Obi
Lena Delta
ARCTIC CIRCLE
EUROPE
Baltic Sea
Black Sea
Caspian Sea
Aral Sea
Sea
ASIA
Okhotsk Sea
Bering Sea
Tuscarora Deep
Kurile Deep
Japan Sea
Yellow Sea
PACIFIC OCEAN
TROPIC OF CANCER
Nero Deep
Arabian Sea
Bay of Bengal
CEYLON
China Sea
PHILIPPINE IS.
EQUATOR
AFRICA
INDIAN OCEAN
MADAGASCAR
TROPIC OF CAPRICORN
OCEANICA
FIJI IS.
AUSTRALIA
TASMANIA
NEW ZEALAND
80° 60° 40° 20° 0° 20° 40° 60°
F THE WORLD
showing
GHT OF LAND
and
TH OF WATER
WATER
0 to 3,000′
3,000′ to 12,000′
12,000′ to 18,000′
over 18,000′
ANTARCTIC OCEAN
THE M.-N CO
30° 60° Longitude 90° East from 120° Greenwich 150° 180°

division. Europe and Asia are also called continents, but the real boundary between them is the desert highland that separates western from oriental civilization. Physically it is better to treat Eurasia as a whole. Politically and historically the two divisions are best considered separately. That part of Africa north of the Sahara historically is a part of Europe; the unity of history involves the *whole* of the Mediterranean basin, and not a part of it.

The entire extent of the continent is not apparent; in many places each one comprises an area somewhat greater than the part above water, being surrounded by a margin which varies from a few rods to one hundred miles or more in width. Upon this margin the sea is comparatively shallow; beyond it the surface slopes abruptly into deep water.

The submerged margin is very properly considered a part of the continent. The depth of water along its extent varies, and in places the margin itself reaches above sea-level. This margin, which is more or less continuous, forms a high surface in comparison with the surrounding sea-bottom. It is usually called the *continental shelf*, or *continental plateau*. The map, pp. 44–45, shows both the highland and the lowland regions of each continent and also its submerged shelf.

The highlands are represented by the area above the level of 2,000 feet: compare the extent of highlands and lowlands in each continent. Each highland is a great plateau rimmed by lofty mountains. About one-fifth of the Australian, two-fifths of the American, and three-fifths of the Asian continent are above the 2,000-foot contour. If we consider the land surface as a whole, a little more than one-fourth is below the contour, or level, of six hundred feet; three-fourths are below the contour of 3,000 feet.

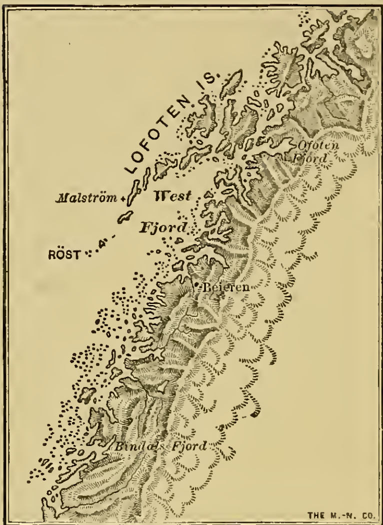
Elevation of the Land.—There is a great difference in the altitude of the high regions of the continents. The great plateaus of North America are from one to one and a half miles above sea-level; those of South America, about two miles; and the highest parts of Asia are more than three miles above sea-level. The mountains that rim the highlands in many instances are about twice as high.

The slopes toward the Arctic and Atlantic Oceans are long and gentle; how does this fact compare with the slopes of the Pacific and Indian Oceans? As a rule, the lowland regions are more nearly level than the highlands. On which side of the eastern continent are its principal lowlands? On which side of the American continent are they situated?

The mean elevation of the continents varies considerably. If their surfaces were levelled off Australia and Europe would be not far from one thousand feet high; North America and Africa about two thousand feet; and Asia nearly three thousand feet. Africa would be probably a little higher, and South America not quite so high as North America. If all the land above sea-level were thrown into the Atlantic Ocean it would not fill the latter.

In a few localities there are depressions below sea-level. The surface of the Caspian Sea is eighty-four feet below that of the Mediterranean; the Dead Sea, situated in a gash north of the Red Sea, is thirteen hundred feet below sea-level. There are two small depressions in North America, north of the Gulf of California; and several in Africa, south of the Atlas Mountains. These were former arms of the sea which were severed from the main body.

Islands.—The islands have an aggregate area of about three million square miles, or about one-seventeenth of the entire land surface of the earth. Most of them are situated on the continental plateau, and are at no great distance from the continents to which they belong. Some are the higher summits of partly submerged mountain ranges. They are parallel to the maritime ranges of the continent, or possibly, they extend from it. Find two such chains near the American continent, two near the Asian continent. Islands of this character are usually called *continental islands*; and the reason is obvious.



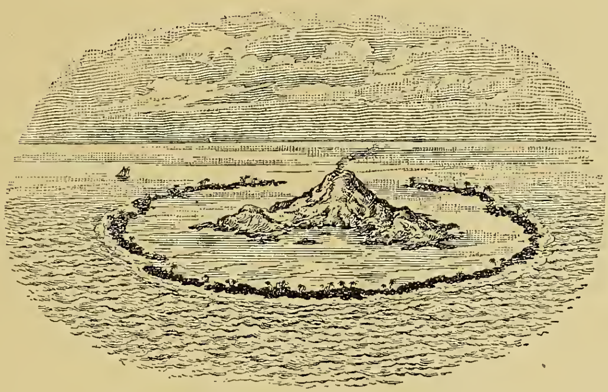
A STRETCH OF THE COAST OF NORWAY

The coast, deeply indented with fjords, is bordered by many thousand rocky islets.

Here and there are islands in mid-ocean, far distant from any large body of land. They are called *oceanic islands*. There is no doubt regarding the origin of some of them; they consist of the lava that has been ejected from volcanoes. In some instances these islands are solitary, as Jan Mayen and St. Helena; in others they form a chain, as the Hawaiian group.

The numerous islands in the Pacific Ocean form the grand division Polynesia. These islands occur in regular chains that are roughly parallel; they are the higher summits of submerged mountain-ranges. In some instances a volcanic peak is in sight, but in others the position of each peak is marked by the reef of coral growth that encircles it. The islands themselves are popularly known as *coral islands.*

The coral polyps, of whose mineral remains these islands and reefs are formed, are an animal growth not unlike a tree with its branches. The mouths of the polyp completely cover its upper surface somewhat as the flowers of the hollyhock or mullein cluster about the stem. In a single community the growth of the polyp is chiefly upward, but where the communities are thickly clustered, their branches interlock and finally form a compact mass. The living portion of the coral reef is at the surface of the water or a few feet below it; the dead parts may extend a hundred fathoms or more below the surface.



AN ATOLL, ENCLOSING A LAGOON

It is thought that the coral polyps began their growth on the slopes of the volcanic peaks, and that the latter gradually subsided until they were covered by the sea. But while the peak was slowly sinking the coral polyps steadily built their reefs upward, keeping the top always even with the wash of the waves. This opinion, first made prominent by Darwin, is borne out by the fact that, while the coral polyp cannot live more than twenty fathoms below the surface of the sea, the reefs sometimes extend almost vertically to a depth of several hundred fathoms.

In other instances it seems certain that the accumulation of marine remains raised the ocean floor to a level upon which the coral polyp could live and grow. Whatever "building" may have been done above the surface of the reefs and islands, is the work of the waves.

As a rule, these islands consist of an irregular ring of reef waste, broken and tossed up by the waves. The reef is called an *atoll*; the enclosed water a *lagoon*. Usually the atoll is broken in one or more places, and the lagoons may form good harbors. The reef is rarely more than a few feet high, and its vegetation is confined to a few species, mainly of palms.

The Sea.—The sea covers more than half the northern and about seven-eighths of the southern hemisphere. For convenience, it is also assumed that the edge of the continental plateau, and not the actual shore line of the continent, is the rim of the ocean basin. Although the area covered is continuous, the continents separate it into great divisions called *oceans*. Name them. The polar circles are taken as the boundaries of the polar oceans, and the equator conventionally divides the two largest oceans into northern and southern divisions.

The Pacific Ocean comprises about one-half the entire Sea; the Atlantic about one-quarter. The shore line of the latter, however, is considerably longer; explain why.

In general, the average depth of the oceans varies with their size—the larger the ocean the greater its depth. The Pacific is about 2,500 fathoms, the Atlantic and Indian not far from 2,000 fathoms. The polar oceans are shallower, but not enough is known about their depth to compare their average. The greatest ocean depths are much in excess of the average depths.

There is a large 3,000-fathom area in the north Pacific and several smaller areas in the Atlantic and Indian Oceans. The deepest soundings so far obtained are 4,655 fathoms by the U. S. S. *Tuscarora*, east of Japan, in an area now known as Tuscarora Deep; 5,147 fathoms, one hundred miles E. N. E. of Sunday Island; and 5,155 fathoms a few leagues east of Macarthy Island, not far from the Kermadec group. The two last were made by Commander Balfour, H. M. S. *Penguin*. North of Puerto Rico a sounding of 4,651 fathoms has been obtained. The cable ship *Nero* reported a sounding of 5,200 fathoms east of the Hawaiian Islands. Formerly deep-sea soundings were made with heavy Manila rope, and in very deep water it was impossible to tell when the sinker had reached bottom. With the method perfected by Admiral Belknap and Captain Sigsbee, steel piano wire takes the place of the rope. The wire carries at its lower end a sinker which detaches itself on touching bottom, at the same time closing a cup that secures a specimen of the bottom. Very few of the deep-sea soundings made prior to 1870 are now considered trustworthy.

The greatest depth of the sea scarcely surpasses the height of the loftiest mountain peak; yet while four-fifths of the sea basin is six thousand feet deep, less than a tenth of the land reaches six thousand feet above it.

The floor or bed of the sea is by no means so irregular as the surface of the land; and, the vicinity of the coral islands and the continental shores excepted, no steep slopes or abrupt changes of level are known to exist. The soundings made for the telegraph cables disclosed no slopes nor inclines too steep for a railway grade. After deep water was reached, the soundings for the Atlantic cable of 1866 did not vary more than seven or eight hundred feet in two thousand miles.

Arms of the Sea.—In places the sea extends a considerable distance into the outlines of the continents, forming seas, gulfs, bays, estuaries, etc. Many of the smaller coves are shore formations, having been made or shaped by the action of waves or by currents of water. The larger arms are structural, and have resulted from upheaval or depression of the coast of the continent.

The borders of a continent may be flanked by lofty highlands, and the trend of the coast usually conforms to the trend of the ranges. Thus, the highland that gives to the west coast of Africa its shape also gives a similar form to the Gulf of Guinea. Where parallel ranges extend seaward, the sea usually enters the valley between them. On a map of North America, note the position of the Gulf of California, and Puget Sound; on a map of Europe, the Adriatic and Baltic Seas. Similar examples occur along the west coast of Asia.

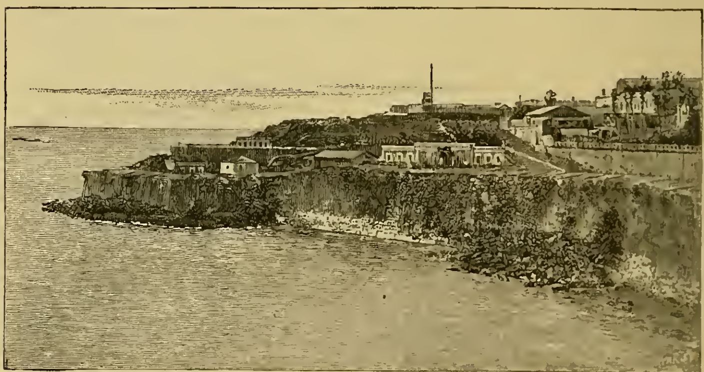
A partly enclosed portion of an ocean is called a sea, and the Caribbean and North Seas are examples of a type of enclosed waters. Of this type the Mediterranean Sea is a noteworthy example, and such arms of the ocean are often called *mediterraneans*. Such indentations as the Gulf of Mexico, Hudson Bay, the Gulf of California, etc., are properly included in this class. Nearly all the larger arms of the sea are depressed parts of the continents, or of the plateau on which they are situated.

Color names are of frequent occurrence in the nomenclature of the arms of the sea. The color of sea-water is both apparent and real. The apparent hue is often due to reflection from the sky; the real color to the substances in solution. Shallow water is commonly greenish; deep water a dark blue. The water of the Gulf Stream has a peculiar blue color and is instantly distinguished from the lighter colored water on either side. The phosphorescence of sea-water, usually observed in warm regions, is due to a microscopic organism, *Noctiluca miliaris*, that, like the common firefly, has the power of emitting light. At times the wake of a vessel seems a track of fire.

A ROCK-BOUND COAST: THE CYCLOPS. COAST OF SICILY

A menace to navigation.

Coast Forms.—The study of shore outlines shows that various parts of the coast differ materially. A striking difference may be observed in comparing the coasts of Maine and Florida. The illustrations on pp. 48 and 53 are also examples of shore forms. One of them, a rock-bound coast deeply indented with fjords and hemmed in by rocky islets, has been worn and frayed by the action of glacial ice; it has also subsided until the valleys are submerged



A CLIFF-GIRT COAST, SAN JUAN, PUERTO RICO

by the sea. Name the various coasts that resemble it. Are they situated mainly in high or in low latitudes?

In the illustration on p. 55, the plain bordering the sea dips so gently below sea-level that the water is shallow half a mile or more from the shore. The drag of the waves rolling in and combing on the coast picks up sand and rock waste brought down by muddy streams and piles it in the form of long spits and beaches at a little distance from the shore. Find other coasts that resemble it.

Marine currents frequently attempt to carry away the rock waste piled up by the waves; as a result, it is dragged into a curved form making a *hook*. Sandy Hook, New Jersey, is an example.

Sinking Coasts.—Along many parts of the coasts the sea is encroaching on the land. The waves beat against the shore, breaking it away until the latter has become a high cliff. This, in turn, is undermined with each successive storm and, as the cliff is battered down, the rock waste composing it is swept away by the waves and currents. The west end of Long Island and the Jersey shore at Long Branch have suffered in this way, and buildings have been repeatedly moved farther inland in order to save them. Much of the coast around the Gulf of Mexico, the Zuyder Zee, and the delta of the Ganges-Brahmaputra is sinking. The coast of the New England Plateau has subsided until the sea has flooded the former coast plain and the lower valleys.

A STRETCH OF NORTH CAROLINA COAST

The barrier beaches nearly enclose the coast; the inlets are kept deep enough for navigation by the tidal currents. The estuaries are drowned river-mouths.

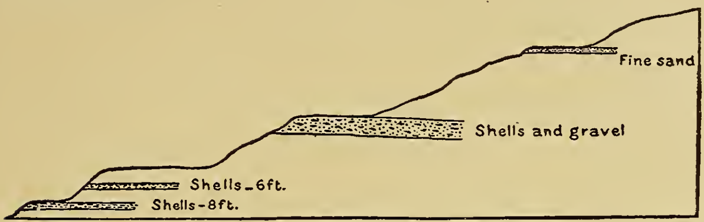
The east and south coasts of the British Isles have lost to the sea an aggregate of several hundred square miles. On one part of the Cheshire coast the sea has advanced about 2,000 feet within a century.

The site of Ravensburg, once a city as large as Hull, is now covered many fathoms deep, and a similar fate almost befell Dunwich. A few centuries ago about two miles of forest lay between the city and the sea. In 1677, however, the waves had removed all the intervening land and had battered down the market. A few years later St. Peter's Cathedral was engulfed. Of Wales, Professor A. G. Ramsey says: "More land has gone into the sea than now remains above sea-level."

As the land sinks, the river mouths become broad estuaries, and the coast lowlands and valleys are converted into coves, bays and sounds. "Drowned" valleys are therefore an indication of a sinking, or sunken coast. New York Bay and the lower Hudson form a remarkable example of a sunken coast and drowned valley. The old channel of Hudson River has been traced more than eighty miles outward from the present mouth. Chesapeake Bay, Delaware Bay, and the estuaries opening into Pamlico and Albemarle Sounds are also examples. In Holland, where subsidence is going on, the dykes and revetments that protect the cultivated lands from inundation have been more than once increased in height.

Drowned valleys and estuaries usually contain good harbors, and most of the great seaports of the world have been built at convenient places on their water fronts. The drowned valleys of the North Atlantic coast of the United States contain the ports through which about ninety per cent. of the foreign commerce of the country is carried.

Rising Coasts.—Along a considerable part of the California coast there are evidences of elevation that has been both recent and rapid. Former sea beaches are found several miles inland and, imbedded in their sands are shells and the bones of marine animals that belong to a recent period. In one part of Alaska the upheaval has been so recent and rapid that marine shells are still clinging to the rocks.



AN UPLIFTED COAST, SAN PEDRO, CAL.

From a survey made by Merick Reynolds, Jr. The successively formed beaches are shown by the strata of shells and sand.

At San Pedro, California, the upward movement has been unusually rapid. Several layers of shells mixed with sand are found one above another, at heights varying from five to fifteen feet or more. The shells belong to species some of which are not now extinct, and most of them have been preserved in their natural state. The highest beach is nearly three hundred feet above sea-level. The various beaches are so slightly weathered that they seem scarcely altered.

Coral Formations and Coast Outlines.—Coral formations are important factors in shore lines and usually they are associated with sinking coasts. On shore they are called *fringing reefs*; farther out, *barrier reefs*. Almost the entire east coast of Australia is shut off from open communication by a barrier reef more than twelve hundred miles long. There are a few channels across the reef, but it is nevertheless a great obstacle to commerce. Fringing reefs occur on the south coast of Florida, and are perhaps the most common examples of coral formation. They are common along the shores of the Bahama Islands, and occur along the Hawaiian coast.

Coral growths are confined to warm, littoral waters, and the reef-building polyp is limited to waters whose temperature does not fall below 25° (67° F.). Absolutely clear water is requisite, and for this reason coral reefs are rarely found along the shores of continents, and never within the reach of river sediments.

Coast Outlines and Civilization.—The coast forms of a country have not a little bearing on its prosperity and its enlightenment as well. A coast with good harbors invites commerce and intercommunication. Along the North Atlantic coast of the United States, where a rugged surface slopes abruptly below sea-level, good harbors are numerous. The same conditions prevail on the coast of Europe. Commerce and intercommunication always seek a region having good harbors. Africa and South America have but very few good harbors, and to this fact the half-savage condition of the native tribes is largely due.

QUESTIONS AND EXERCISES.—Which of the oceans is nearly landlocked?

At what place do the Pacific and the Arctic Ocean meet?—the Atlantic and the Arctic?

Compare the coast of Europe with that of Africa, with respect to its regularity; which has the greater length of coast line?

How have good harbors affected the progress of the English people? What has been the effect of closed ports on the Chinese?

Compare the commerce of the North Atlantic coast of the United States with that of the South Atlantic coast. To which type does each of these coast forms belong? Where are most of the large seaports of the Atlantic coast of the United States? Explain the reason for their location.

Why should Australia be considered a continent rather than an island?

Does the cutting of the Suez Canal give Africa any insular properties that it did not possess before?

Make a list of the principal mediterranean seas of the world.

Mention several instances in which peninsulas enclose waters so as to form gulfs or bays.

From a good map of the British Isles find the names used as synonymes of " cape " and " strait."

Find the centre of each hemisphere on p. 41.

Study the position of the submerged part of the continents on the map, pp. 44–45.

COLLATERAL READING

DANA.—Manual of Geology, pp. 145–152.

REDWAY.—New Basis of Geography. *Chapter IV.*

SHALER.—Sea and Land, pp. 187–222.

UNITED STATES GEOLOGICAL SURVEY.—Norwich and New London Sheet (drowned valleys); Sandy Hook and Barnegat Sheets (spits and barrier beaches); Port Washington Sheet (cliffs).

CHAPTER IV

THE RESULTS OF SLOW MOVEMENTS OF THE ROCK ENVELOPE: PLAINS, PLATEAUS, AND MOUNTAINS

THE larger vertical forms of the land are the results of the slow movements of the rock envelope. Any considerable area of land but little higher than sea-level is called a *plain*; if considerably higher, a *plateau*; if wrinkled, folded, and broken, a *mountain system*. There is no fixed elevation at which an area ceases to be a lowland, or *vice versa*, but in general, surfaces more than two thousand feet above sea-level are called highlands, while those of less altitude are lowlands.

As a rule, the various features that constitute topography are distinct one from another; but in many instances lowlands gradually increase in altitude and become highlands; an almost imperceptible swell in a level plain may develop into a cliff or a ridge; and a mountain-range, little by little, may lose its characteristic form among other features of the landscape. So it often happens that a single topographic form may have the character of several kinds of relief.

Plains.—Any level or nearly level stretch of land is commonly called a plain. Most plains are lowlands, but in a few instances the name is applied to surfaces that are more than six thousand feet above sea-level—an elevation considerably greater than that of some mountain-ranges. The plain east of the Rocky Mountains is an example;

it is higher than the crests of the Appalachian Mountains, and about as high as the highest peaks. In fact, no exact limit fixes the altitude of a plain, although an elevation of two thousand feet is sometimes conventionally employed.

Plains are variously named. The grassy plains of the New World were named *savannas* by the Spanish, and *prairies* by the French—both of which names are still commonly employed. In South America the vast plains of Argentina are called *pampas*; the grassy plains of the

A ROLLING PLAIN, VIRGINIA

It is now a peneplain. The forestry is deficient, and the soil only moderately fertile.

Orinoco, *llanos*; and the forest-covered plains of the Amazon, *silvas*. In Eurasia, the vast plains that almost girdle the Arctic Ocean are known as *steppes*, their frozen, swampy coast fringe being known as *tundras*. In England and Scotland the terms, *meadow*, *heath*, and *moor*, are used.

The difference in the surface features of these plains is due to latitude, altitude, and rainfall. The pampas somewhat resemble the high plains east of the Rocky Mountains. Both slope from a high to a low level, and both are covered with "bunch-grass." The llanos are watered by periodical rains and are alternately a swamp and a sun-baked desert. The silvas lie in a region of almost constant equatorial rains; hence they are adapted to tropical forest growth. The pampas and llanos produce wild cattle and horses; the silvas, rubber and ornamental woods.

Formation of Plains.—Most plains have been formed by the action of water, or have received their surface configuration by it. If formed by the uplift of a former sea margin they are known as *marine*, or *coast* plains; if old lake bottoms, they are *lacustrine* plains. The sediments deposited by running streams become *alluvial* plains; those levelled by moving ice, *diluvial* plains.

Coast and Marine Plains.—Probably every part of the earth's lowland plains at some period of their existence have been a part of the sea bottom. The waves which batter the shores of the continents and the running waters that sculpture the land are constantly accumulating material along the shores. Waves and currents scatter and level this rock waste; in time an uplift raises it above sea-level, forming a gently sloping plain. Because of its position along the coast it is called a *coast plain.* Such a plain situated at a considerable distance inland is sometimes called a *marine plain,* but nearly every marine plain was a coast plain at the time of its formation. If there be deep water along the shore, the coast plain is apt to be narrow; on the other hand if the plain has been formed by a gradual uplift of a part of the continental shelf, it is apt to be broad.

Practically the whole Atlantic coast of the United States is bordered by a coast plain. North of New York Bay it is narrow, but south of the bay, where the continental shelf is broad, its breadth is over two hundred miles. The line where the coast plain joins the foothills or "piedmont lands" is called the *Fall Line.* East of this line the rivers broaden into navigable estuaries; falls and rapids at or near the heads of the estuaries furnish a considerable water power. As a result of these two features a dozen or more important cities have been built along the Fall Line. The Gulf Coast plain is somewhat more complex; it consists of several blocks or "cuestas," each of which is a coast plain of separate formation.

The Baltic coast plain consists of land that once formed a part of the bed of the Baltic Sea. Much of its top layer consists of wind-blown sand, mixed with fertile loam. It is remarkable in one respect: it is the best known region in the world for the production of the sugar beet.

The great Russian plain is the largest in the world. Its situation, however, is unfortunate from an economic standpoint. The northern part of the plain is too cold for the growth of foodstuffs and much of it is a tundra, producing nothing but coarse mosses. In winter it is ice-covered; in the short arctic summer it is an impenetrable morass. The central part is a peneplain, or much worn surface, that may be called an "old" plain.

The prairies of the Mississippi basin are marine plains. In the central and southern part much of the old sea-bed has been covered by the deposits of fresh water and brackish lakes that once existed there; the northern part is covered with a drift deposited by the melting waters of glaciers. To this drift its fertility for food crops is largely due. It produces about one-quarter of the world's wheat, and about three-quarters of the maize, or Indian corn.

The region east of the Rocky Mountains, known as the "Plains" is an elevated plain that is properly a plateau. Much of its surface is covered deep with wind-blown rock waste. But the streams of the Rocky Mountains are cutting their channels well below the surface. Here and there are alluvial plains formed by rivers of a previous age. The newer streams are now carving their valleys into the older courses. In places this region has been greatly sculptured. Such lands of this region as can be irrigated produce alfalfa, macaroni wheat, sugar beets, and fruit.

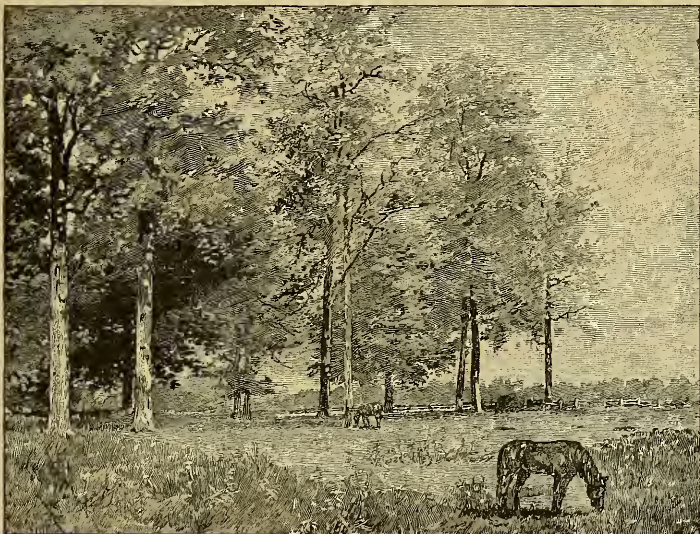
Lacustrine Plains.—Lacustrine plains are the level floors of old lake basins, or the margins of lakes that have greatly shrunken in size. Such a plain may have come into existence in any one of several ways. A notch may have been cut in the rim of the basin, causing the water to flow off; the rainfall may have decreased so that water of the lake disappeared by evaporation; river sediments and vegetation may have filled the basin.

One of the finest examples of lacustrine plains is the valley of Red River of the North. This plain resulted from the draining of a lake, and so recently was it formed that the surface is scarcely notched by the river that now imperfectly drains it.

The plain surrounding the Caspian Sea is an excellent example of a plain in the process of formation. On the northern side, the gradual shrinkage of the lake has left a plain more than two hundred miles wide, and this increases in size as the lake shrinks. The valley or basin of Great Salt Lake is passing through a similar period of development.

Alluvial Plains.—Alluvial plains are best developed along the lower courses of rivers, although they exist in narrow reaches along almost the entire length of the stream. The bottom-lands of the lower Mississippi and the Danube; the mazy deltas of the Nile and the Ganges-Brahmaputra, and the broad, fertile plains of the Po are examples. Name other illustrations.

Alluvial plains are among the most productive lands in the world. Because their soil is constantly replenished



A PRAIRIE PLAIN, KENTUCKY

A very fertile plain with a considerable forest growth.

by overflows and freshets, they rarely wear out; the nutrient elements are supplied about as fast as they are exhausted.

Distribution of Plains.—Alluvial and lacustrine plains are incidents in the physiography of rivers and lakes; and coast plains are formed on nearly all shores. The great plains of the world are mainly on the slopes of the Arctic and the Atlantic Oceans. From west to east the Russian plain stretches a distance of about nine thousand miles; from north to south, about three thousand miles. In Asia it is high and rolling; in Europe the greater part is low and comparatively level.

In the northern part of North America it loses many of the topographic features of a plain and, in places, is a low, but rugged plateau. Its slope, like that of the Eurasian plain, is toward the Arctic Ocean and, like the latter, its coastal portion is bordered by tundras. Generally considered, the great Arctic Plain is the rim of a vast basin that almost shuts the Arctic Ocean from the rest of the sea.

In the New World the great continental plain extends from the Arctic Ocean to the Gulf of Mexico, and there is an apparent extension from the Caribbean Sea southward through South America. Its continuity is broken by occasional ranges and arms of the sea. It presents certain marked contrasts to the plain of the Asian Continent. The latter extends east and west; the former, north and south. The latter is a margin of the continent; the former is an interior plain, bordered by mountain ranges.

Physiographic Aspect of Plains.—Plains are quite as subject to the weathering processes of nature as are mountains and plateaus but, because of their gentler slopes, the wearing process is not so rapid. Water is the chief agent in their formation; it is likewise the chief factor in their destruction. From the moment a plain comes into existence, storm waters and running streams begin to carve channels in its surface. These waters extending in area, carry the greater part of the surface material away.

A plain thus channelled is said to be "dissected." That part of the South Atlantic and Gulf coast nearest the sea is young. Its slope is so gentle that the streams have not yet carved their channels to any great depth. Nearer to the piedmont lands it is older and therefore has been much more dissected. The more nearly the dissected plain approaches a level surface the slower is the process of its wasting. A plain that has been first dissected and then worn down is called a *peneplain.*

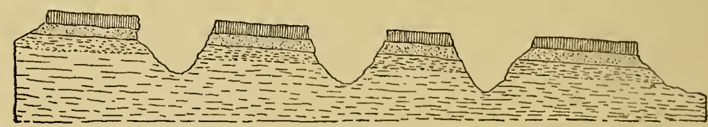
The plains bordering Lakes Erie and Ontario show signs of greater age. The streams have accomplished much dissection and the channels are deep. The "Bad Lands" of South Dakota and Nebraska are remnants of an old lacustrine plain that has been so greatly dissected that the region is well-nigh impassable.

Economic Value of Plains.—Because of their comparatively level surface, plains are more accessible to commerce and more easily cultivated than mountainous regions. Railways can be built across them at the minimum of cost, and the larger rivers that traverse them are usually navigable.

Moreover, their soil is usually deep and fertile. Therefore they are capable of supporting a denser population than mountainous regions. In remote times the alluvial plains of the Nile and of Mesopotamia were the seats of dense population and vast industries. In later times the plains of Europe and of the United States have become the great producers of wealth. It may be said, therefore, that the greater part of the world's wealth and power is centred in the plains of the temperate zones. About ninety per cent. of the world's population lives below the altitude of 1,000 feet. Only a small fraction of the world's population lives above the altitude of 2,000 feet, and but few of the great cities are more than six hundred feet above sea-level.

Plateaus.—A broad extent of country having an elevation of a thousand feet, and an irregular or dissected surface, is called a plateau. The name, originally meaning "flat," or "level," has acquired an almost opposite signification. A level plateau of small area is usually called a *mesa*, a *table-land*, or a *table-mountain*, according to its general form and structure.

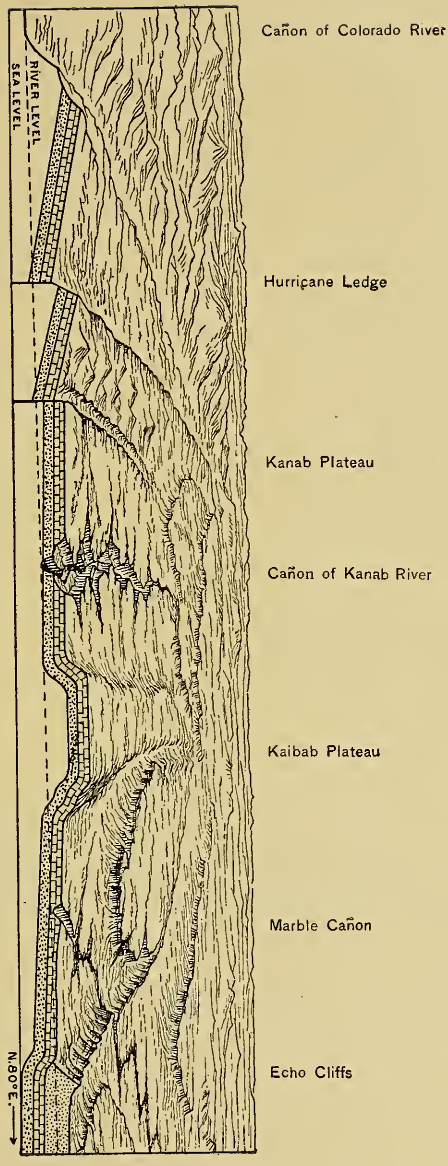
Like most other elevations of the earth's surface, plateaus are a result of the gradual uplift of parts of the rock envelope. Most of the great plateaus of the earth are rimmed by lofty mountain-ranges, and their surfaces are



A DISSECTED PLATEAU, JOHN DAY VALLEY, OREGON
The sheet of lava at the surface has been removed here and there, leaving a series of mesas.

generally traversed by ridges and valleys. Thus, the plateau region of western North America, nearly a mile and a half high, is bordered by the lofty Rocky and Sierra Nevada mountain ranges; the great Bolivian plateau is edged by the highest summits of the Andes; and the highest plateau in the world, that of Tibet, is rimmed by some of the loftiest ranges of the earth.

Many mesas or table-lands are the result of unequal weathering. The top of the mesa is commonly a layer of rock resting upon softer substance. The latter is protected from the action of the elements by the harder material and, in time a table-land is formed. As a rule, such table-lands are the outlying or isolated remnants of plateaus. They are noticeable objects because of their flat



A SECTION ACROSS THE PLATEAUS AND FOLDS ADJOINING THE CAÑON OF THE COLORADO RIVER, WITH A BIRDS-EYE VIEW OF THE TERRACES AND PLATEAUS NORTHEAST.—*After Powell.*

tops and the steep cliffs or escarpments that form their slopes.

A high plateau sparsely covered with vegetation is much more readily dissected by streams than a grass-covered surface. The region through which the middle course of the Colorado River flows is an example. Here the plateau has been cut to a depth ranging from three thousand to six thousand feet. Only a small part of the plateau has been removed, and large areas show as yet but little of dissection. In other parts, however, such as the "Land of Standing Rocks," denudation has been considerable, and only the towers that are remnants of harder rocks remain.

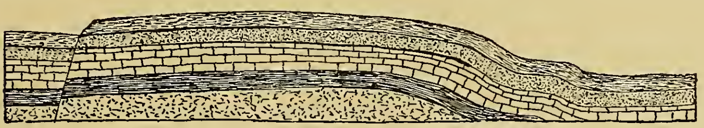
Distribution of Plateaus.—The highest plateaus are in the great highlands that face the Pacific and Indian Oceans. The lesser highlands that border the Atlantic Ocean also contain plateaus. If the highlands border the sea, the plateaus may take the form of peninsulas; name several examples on the map of Asia.

Among the plateaus of the Asian Continent, that of Tibet is remarkable for its size and height, being nearly three miles above sea-level. To the westward are the Pamirs, a series of grassy plateaus, like the "parks" of Colorado, about three and a half miles above sea-level. In North America, the plateaus of the western highlands are a little more than a mile high, while those of the eastern highland have less than half that altitude. In South America the plateaus of the Andes are about two miles high, while those of the eastern region have less than one-third that height.

Economic Aspect of Plateaus.—As a rule, plateaus are arid regions; they are therefore not so productive as lowland plains. In some instances they are so high that but little rain falls on them; in others the mountain rims shut off the moisture that is borne with the winds. The rugged slopes and deep cañons almost always make commercial intercourse very difficult. Because of their unproductiveness high plateaus, as a rule, are sparsely peopled; and because of the lack of intercommunication the civilization of the native peoples is seldom of the highest type.

In the lower plateaus the conditions are different; there is generally a rainfall sufficient for the production of foodstuffs, and the land that cannot be cultivated is often well adapted to grazing; meat, cattle products and wool-growing are usually associated with these plateaus. Hides are a product of the Mexican plateau; mohair is a specific feature of the Bolivian Plateau; merino wool comes from the Iberian Plateau; and the best rug-making textiles are confined almost wholly to the Plateau of Iran. The New England Plateau has a generous rainfall and the rugged surface makes it a region of a considerable water-power. The broken and dissected rock strata in many instances yield minerals and metallic ores useful in the arts and sciences, and the rugged character of the surface often furnishes an abundance of water-power.

Mountains.—Mountains are the most characteristic and remarkable features of the earth. In form, they are

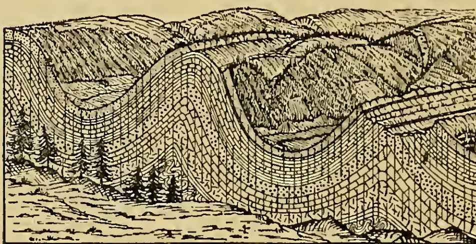


A SECTION ACROSS THE UINTA MOUNTAINS

A single fold with fault. After Powell.

great ridges with very rugged surfaces. In structure, they are folds or wrinkles in the strata of the rock envelope, or else they are immense blocks of rock, broken and partly upturned.

Mountains occur usually in *systems*, each of which consists of many ranges. A very extensive system is sometimes called a *cordillera*. Thus, the Rocky and Andean Systems form the great cordillera of the Western Continent. Ranges or folds that seem to be continuous are said to be a *chain*, as the Sierra Nevada and Cascade Mountains. A single fold may be worn away so that the broken strata form *ridges*; or the crest may be weathered so unevenly that it presents the appearance of a series of notches, thereby forming a *sierra*. Any part of the crest or summit materially higher than the rest forms a peak. Sometimes the peak is a high crag, or a pinnacle of rock, but the name is also applied to volcanic cones. Elevations that properly are plateaus—as Broad Mountain, Pocono Mountain, and Broad Top, in the Appalachian system—are also called mountains.



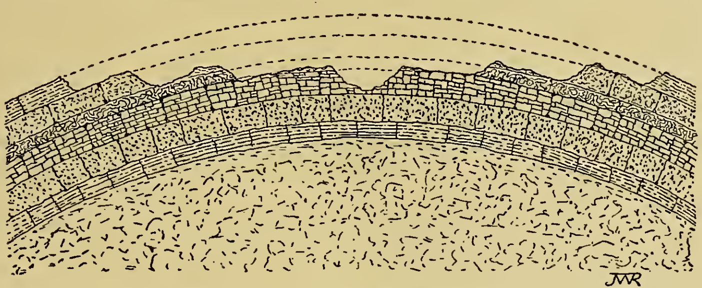
THE JURA MOUNTAINS

A series of gentle folds, partly worn into ridges.

Isolated peaks, or "monadnocks," are not uncommon, but for the greater part they occur in mountain ranges that have been greatly worn. Mount Holyoke is one of several examples in Massachusetts. It was not thrown up in its present form; on the contrary, it was left when the rest of the range, being softer, was worn away. Mount Monadnock, New Hampshire, a peak that has given its name to the type, is a similar example. Isolated ridges or ranges are more common than isolated peaks, and excellent examples may be found in the Great Basin. In some instances the apparent isolation is due to the fact that the ranges are half buried, the exposed upper parts extending from a level plain of loose rock waste.

A mountain system is generally of great extent, several of the more important exceeding four or five thousand miles in length. A range, on the contrary, rarely exceeds a few hundred miles in length. It gradually takes form, continues a short distance, and then disappears, another range to the right or the left taking its place. The rolling hills that form the approach to a system are called *foot-hills* or, better, *piedmont lands*. The hollow or depression between adjacent ranges forms an *intermontane valley*; or, if wide and nearly enclosed, a *park*. A valley that extends across the range is called a *pass*, a *gap*, or a *cañon*.

Structure of Mountain Ranges.—In the simplest form, as in the Uinta Mountains, there is a single fold; in the Jura



SECTION OF A DISSECTED RANGE

A single fold is dissected into a number of ridges.

Mountains there are several; in the Rocky Mountains there has been a mashing and crumpling of the strata, producing irregular and complex results as though the leaves of a book had been pressed and crumpled sideways by a tremendous force.

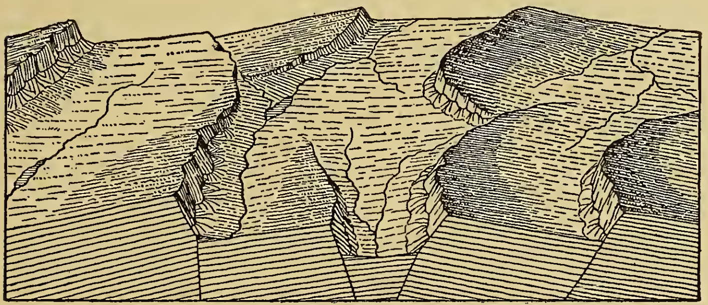
The process of uplift and folding takes place so slowly that it cannot be measured except after long intervals of time. This is shown by the conduct of certain rivers that flow across the folds. The streams cut their channels downward quite as fast as the folds are pushed upward. So when the fold has become a lofty range, it is severed transversely by the stream.

Excepting the core of granite, or similar rock that is present in the lower part of many folds, mountain-ranges are composed of strata of sedimentary rock. Moreover, it is a notable fact that the strata which form them are much thicker along the folds than elsewhere. Thus in the Appalachian Mountains, the sediments composing the folds are about 40,000 feet thick, while the same strata in the Mississippi Valley are scarcely more than 4,000 feet in thickness. Not only were the deposits that became sedimentary rock thicker before the folding took place, but they were made still thicker by side pressure and crumpling.

The ideal system with its parallel folds exists; but in general, mountain architecture is very complex. The system, in fact, consists of a tangle of ridges and ranges so greatly worn by the weathering forces of nature, that in many instances it is difficult to trace their real direction. Not infrequently several ranges seem to radiate from a marine uplift, as in the case of the Pamir highland, from which radiate the ranges of the Himalaya, Tian Shan, Hindu Kush, and Suliman folds.

Block Mountains.—Not all ranges present the aspects of folds. The ridges in the Great Basin of the United States are great blocks of sedimentary rocks that, having been broken and tilted, are left with edges partly upturned. The Sierra Nevada and Cascade Ranges are both folded and broken, and their abrupt eastern slope is the edge of an immense block tilted upward from the Pacific.

The folds of the strata take various names, according to the position of the rocks. Thus, a bend in the rock layers that forms a trough, is a *synclinal valley;* if the bend is upward, so as to form a ridge, it is an



BLOCK MOUNTAINS, BASIN REGION

The upturned edges of the great blocks form the ranges.

anticline, and a valley along the crest as its upper surface is an *anticlinal valley;* both are illustrated in the Jura Mountains (p. 72). A valley formed by broken and tilted strata, such as those of block mountains, is a *monoclinal valley.* A break in a stratum, or of several strata, in which there is a displacement so that one side is higher than the other constitutes a *fault.*

Physiographic Aspect of Mountains.—From the moment the process of uplift commences, the waters of the atmosphere begin to level off the folds. The more prominent a topographic feature is, the more exposed it will be to the factors that destroy it; and although every part of the land undergoes wearing, the higher surfaces generally suffer most. As the process of elevation goes on, the mountain torrents carve the slopes of the range, diversifying it with valleys, cañons, ridges, and hogbacks.

At the mouth of every cañon there is usually a fan-shaped pile of coarser material, carried thither by running water, called *talus.* A pile of talus is usually found at the bottom of every steep, rocky cliff. It is an example of cliff waste.

Not only are the slopes of the ranges sculptured, but the crests are also worn away. The tops of the folds are broken and, little by little are removed, leaving the upturned edges of the strata in the form of long *ridges*. Most of the ridges of the Appalachian Mountains are formed in this manner; there are few folds, but many ridges.

The amount of material removed from the slopes and crests of mountains is enormous. The crests of the Appalachian folds in Pennsylvania are scarcely more than two thousand feet high at the present time; but if all the material that has been removed could be again heaped upon them, their summits would be more than ten miles high.

In many instances, notably in the Appalachians, the ridges are the floors of old valleys. The latter were firmer than the broken crests of the folds, and therefore were better able to resist disintegration and erosion; consequently the crests of the folds in time were worn down to a level lower than that of the original valleys.

Probably most of this material has been removed by running water, but the moving ice sheet that at one time covered the northern part of the Appalachian highlands was also a powerful agent in sculpturing their crests and slopes. In New York, where they received the full force of glacial ice, the highlands are worn down to base level. In Pennsylvania, where the wasting was less effective, they are about two thousand feet high. But in the South Atlantic States, beyond the limits of glacial ice, the ridges are more than four thousand feet high.

The Catskill and Adirondack groups were apparently severed from the system during the glacial epoch. The former have been cut so deeply by streams that they are now ridges extending east-west in direction. The summits at the Adirondack peaks were probably higher than the surface of the glacial ice sheet.

As a rule, mountain-ranges which show but few effects of weathering are comparatively young. The tilted blocks that constitute the ranges of eastern Oregon are scarcely notched by streams, and are very slightly weathered. The ridges of Nevada are greatly weathered and carved, and the Rocky Mountains, though young as compared with the Appalachian folds, are much worn.

The Laurentian folds, among the oldest in North America, are likewise worn nearly to base level. The Huronian ranges about Lake Superior are worn down nearly to the level of the surrounding land. They may therefore be called *relict mountains*.

The character of the weathering, and the landscape, depend partly on the character of the rock and partly on conditions of climate. In the Appalachian ranges all the forms are rounded, subdued, and graceful. In arid regions they are apt to be angular. The notched crests of western ranges of the United States and Mexico have suggested the name "sierra" (*saw*), the sharp, enduring crags of the Alps, "aiguille" (*needle*), "horn," and "dent" (*tooth*).

Distribution of Mountains.—Mountain-ranges are incidental chiefly to highland regions. The great highlands that border the Pacific and Indian Oceans are rimmed throughout much of their extent by lofty folds. In North America the Rocky and Sierra Nevada ranges are the rims of a high plateau whose surface is traversed by block ranges.

The great system of southern Europe, extending from the Caspian Sea to the Atlantic, belongs to the principal highland of Eurasia. The Alps form the northern, and the Atlas ranges of Africa the southern rim. What sea fills the intermontane valley? A partly submerged chain extends along the east coast of Asia; name the peninsulas and principal island groups belonging to it. The great systems are nearest the Pacific and Indian Oceans.

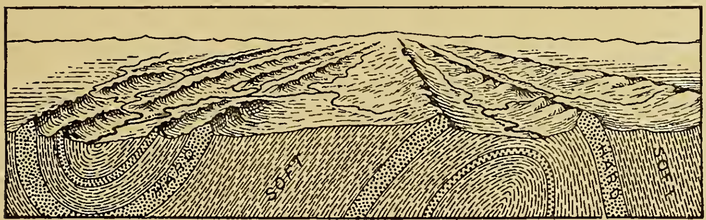
Intermontane Valleys.—The folding of strata into parallel ranges naturally forms valleys between them, and these may be termed *original valleys*. The great intermontane valley of California, Oregon, and Washington is of this character. Name the ranges between which it is situated. Although interrupted by cross ranges it practically extends from Puget Sound to the Gulf of California. The valley, a part of which the St. Lawrence River now occupies, is similar in structure. A great valley extends along the eastern part of Africa from north to south; it is known as the *rift valley*.

In a few instances the cross spurs that join parallel ranges enclose valleys of considerable extent. The Parks of Colorado, and the Pamirs, both frequently classed among plateaus, are examples. The latter are situated in a high mountain knot which, because of its great height, is often called the "Roof of the World."

Stream Valleys.—The valleys and cañons formed by running water are due to slopes that are more or less steep. They are not a part of mountain structure, but are a result of it. Such valleys are most common in mountainous regions and in plateaus.

Most valleys show the results of stream-cutting and the weathering action of water. Shenandoah Valley, the depression crossing Virginia, is an example. The rocks along the line of the valley were more easily worn away than those to the east and the west, and hence the valley resulted from their removal.

The water may wear the rocks at the crest of a range more easily than it can remove them at other places. In this way *canoe-shaped valleys* are formed at the summit of a fold. More commonly, however, the streams on opposite



CANOE VALLEYS, APPALACHIAN MOUNTAINS

sides of a range wear their channels to the crest, making deep notches across it. Some of the passes in the Sierra Nevada and Rocky Mountains are examples; and so, too, are the gaps of the Delaware, Susquehanna, and Hudson Rivers. If at a level with the base of the range, such transverse valleys are commonly called *water gaps*; if at a considerable altitude, they are *passes*.

Among famous passes are Argentine, 13,100 feet, the highest wagon road pass in the world; Marshall Pass, 10,900 feet, one of the highest railway passes in the world; Alpine Pass, 13,550 feet, and Mosquito Pass, 13,700 feet—all in Colorado. Simplon, St. Bernard, and Brenner are famous passes across the Alps, and for centuries they have been highways of commerce. A railway pass in the Andes is nearly 14,000 feet above sea-level.

In many instances the pass is not fully surmounted; instead of building the railway over the divide, it is more economical to construct a tunnel under it. Some of these tunnels are marvels of engineering skill. St. Gotthard and Mont Cenis tunnels have been driven through the Alps; Hoosac tunnel pierces the range of the same name in Massachusetts; San Fernando tunnel, in California, and the tunnel of the Transandine Railway are examples; each is one mile or more in length.

In other cases the railway surmounts the range by zigzags, or by long and intricate loops, crossing and recrossing itself through tunnels that often are sharply curved. Near Caliente, California, the Southern Pacific Railway is built in sinuous loops aggregating about twenty miles in order to cross a divide scarcely two miles from the head of the valley. The famous loops of the Colorado Midland over Hagermans Pass is also a well-known example of the railway builders' skill.

Economic Aspect of Mountains.—Although mountains are sparsely settled, and include a very large area of uncultivable land, they nevertheless exert a great influence on life. Ranges that face rain-bearing winds may be lofty enough to intercept the moisture, so that little or none falls on the leeward side. How does this affect the habitability of the region west of their summits? In various localities the ranges chill the winds that pass over them and condense moisture that otherwise would not be precipitated. Mountains, therefore, are factors in the distribution of rain.

The broken folds of the strata frequently expose metals and minerals that otherwise would not be accessible. Almost all the gold and silver come from mountain-ranges; and so, also, does most of the copper. Practically all the anthracite coal and much of the best iron ores are associated with the rocks of mountain-ranges. The latter are, therefore, essential to the industries of mankind.

Because of the difference of climate on opposite sides of high ranges, the distribution of species is restricted. The dense forests of the Pacific coast cannot extend across the Cascade and Sierra Nevada Ranges, because there is not enough moisture to support them. On the other hand, not many of the plants of the arid side can cross the ranges and survive because climate and soil are unsuitable.

Mountains as Factors in History.—Mountains affect life and its industries also because they are barriers to intercommunication. The Greek peoples of early times found it much easier to spread along the shores of the Mediterranean and across the Ægean Sea than to cross the Balkan Mountains. For the first fifty years of our national history there was no transcontinental intercourse between the Atlantic and Pacific coasts of our country. It was easier to go sixteen thousand miles around Cape Horn than to traverse one thousand miles of mountainous surface.

The effects of a lack of intercommunication are seen in the case of the Basques. More than two thousand years ago they were driven from the lowlands of Spain and France into the almost inaccessible valleys of the Pyrenees Mountains. During the succeeding years they have been so little in contact with the rest of the world that their language and customs have been changed but little. A similar effect is noticeable in settlements of the Southern Appalachians. The rugged surface has shut them from the great lines of traffic; the people have not materially changed their customs in a century of time.

Intermontane valleys are usually productive. Their fertility cannot be easily impaired, because fresh soil is brought to them with every flood. As a rule, therefore, they are densely peopled.

Passes have even greater importance than valleys. A mountain-range is an obstacle to communication, and the pass, therefore, is the channel toward which intercourse must be concentrated. Railway routes through mountainous regions are always surveyed and built through the passes. Almost every railway to the various commercial centres of the Atlantic seaboard seeks a way through the passes and water-gaps of the Appalachian Mountains.

The wonderful development of New York City is due to Mohawk Gap, a pass that is the principal traffic route

A MOUNTAIN PASS, THE ANDES

Not too difficult for a railway.

between the Great Lakes and the Atlantic seaboard. It is more nearly level than any other route across the Appalachian Mountains, and for this reason it furnishes a standard by which freight rates between the Atlantic seaboard and the Mississippi basin are regulated.

Khaibar Pass, a narrow defile a few miles east of Kabul, for more than two thousand years has been a part of one of the great overland routes between Europe and India. Indeed, it is the chief gateway to India; and the truth of the old saying, "whoso would be master of India must first make himself Lord of Kabul," is every day more and more emphasized.

QUESTIONS AND EXERCISES.—Name and classify the vertical forms in the State in which you live. On an outline map, shade or otherwise designate the areas of highland and lowland, using such *contours*, or lines of equal altitude, as may be available. If possible use the Relief Map of the United States noted below.

Make a relief model in sand or paper pulp of any locality, the topography of which you know—State, county, township, or other region of interest.

What results might occur were a mountain fold to be formed across the channel of a river?

Make a sketch restoring the plateau or mesa dissected by weathering processes, as shown on p. 73.

Name some of the benefits and the disadvantages resulting from the presence of the Appalachian Mountains between the industrial centres of the Atlantic coast and the Mississippi Valley.

Explain why Fort Ticonderoga and Crown Point were important localities during the colonial wars. (*Consult any good map of Lake Champlain.*)

On an outline map of each continent, or grand division, draw heavy lines representing the positions of the principal mountain-ranges.

In what general drection does the rock waste of mountains move? Explain why.

Give reasons why lowlands are more densely peopled than highlands.

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Powell.—Exploration of Grand Cañon, pp. 181–193.

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CHAPTER V

DESTRUCTIVE MOVEMENTS OF THE ROCK ENVELOPE: VOLCANOES AND THEIR PHENOMENA

Of the various phenomena that attend changes in the level of the rock envelope, two of them, volcanoes and earthquakes, are noteworthy because the results are more

VESUVIUS, A TYPICAL CINDER CONE
From a model.—After Nasmyth.

or less destructive. In the one case, great quantities of molten matter are ejected from fissures or vents, covering very large areas; in the other, there is a movement at some part or other of the rock envelope, so sudden that a tremor, or even a severe shock, occurs.

Volcanoes.—A channel or vent in the rock envelope from which steam and molten rock are ejected with great force constitutes a *volcano.* In most instances clots of half-molten rock fall about the vent and build up a conical pile. This is sometimes called a "volcano," but more properly, a *cinder cone.* At the top of the cinder cone is a cup-shaped depression called the *crater* or, if very large, a *caldera.*

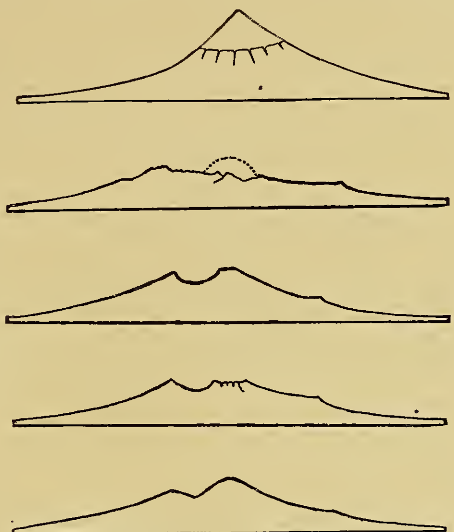
The channel or tube is the essential part of the volcano, and the "mountain" or cinder cone, though rarely absent, is merely an incidental feature.

The craters of the earth are small, compared with those of the moon. Terrestrial craters are rarely more than half a mile in diameter; lunar craters, on the contrary, frequently exceed twenty or thirty miles in diameter; Tycho and Copernicus are each more than forty miles. (See p. 12.)

Volcanoes displaying energy are said to be active, quiescent, or inactive, according to the character of their energy. In a few instances the activity seems to be continuous. Thus, the smaller cinder cones in the caldera of Mauna Loa are nearly always active, and Stromboli, "the Lighthouse of the Mediterranean," has been a mariner's beacon for more than two thousand years. Most active volcanoes, however, are intermittent in action; their eruptions alternate with long periods of rest.

Volcanoes in which all signs of activity have disappeared are said to be *extinct.* As a rule such volcanoes belong to previous geological ages. They are not easily distinguishable. Usually the cone has been almost obliterated, nothing remaining except the masses of lava that are not easily affected by moisture and atmospheric elements. Mount Tom, Massachusetts, is an example of an old volcano.

Phenomena of Eruption.—Most volcanic outbursts are similar:—that is, lava and steam are ejected from a vent or channel in the rock envelope. A volcanic eruption is therefore practically a steam explosion. Beyond this, however, the various types of eruption have but little in common. Frequently the eruption is preceded by earthquakes, although these warnings are not always present. The explosion shatters the top of the cinder cone, the plug of hardened lava is blown out; most likely a new channel is formed on the one side or the other.

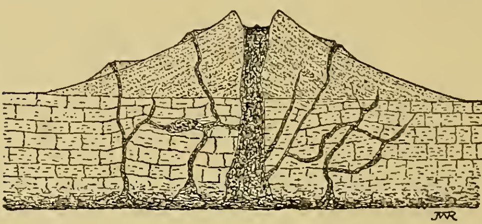


ALTERATIONS IN THE SHAPE OF VESUVIUS
A.D. 63, 79 *to* 1631, 1767, 1822, 1868.

The eruption of Vesuvius in 1756 took place, not at the former crater, but a little to one side of it. One of the old crater walls remained standing, and for many years was called Monte Summa. During the eruption of 1872 many vents were formed, and the flanks of the mountain were dotted with monticules. Professor Palmieri, who remained in his observatory on the mountain during the entire period of the eruption, said that the whole side of the cone "seemed to sweat fire at every pore." The eruption of 1906 did not greatly change the form of the cone. Since 1887, eruptions of Ætna, on the island of Sicily, have changed the form of the cone materially.

In many instances the outrush of steam is mingled with mud and rock waste, and a cloud of inky blackness quickly envelopes the cone. The condensing steam frequently produces heavy rains; and if sulphur gases are present, the rain may become so corrosive that vegetation is blighted and crops are destroyed.

A flow of lava follows the outburst of steam. At first the lava is ejected with explosive violence. Later, the flow becomes steady and regular, behaving as though it were forced out by gases under high pressure. The clots of lava shot out of the crater sometimes contain so much steam as to burst explosively, flying into minute fragments when they strike the ground. Such clots are called *volcanic bombs.*



IDEAL SECTION OF A VOLCANO

Minor eruptions are taking place through fissures in the flanks of the cinder cone, building parasitic cones.

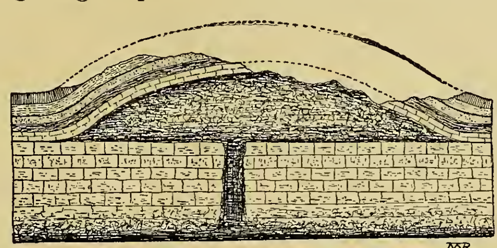
The ejection of substances takes place, not only at the main vent, but also at new ones formed on the flanks of the old. At each vent small *monticules,* or *parasitic cones,* are formed, and the eruption from them does not differ from that at the main vent.

The eruptions of some volcanoes are attended with no great violence, because the lava contains but little steam. Stromboli, a cinder cone of the Lipari Islands, is a notable example. From an overhanging crag of this volcano its eruption may be safely studied. At intervals of fifteen or twenty minutes gigantic bubbles form in the caldron of seething lava. In a few moments they rise to the top and bursting, hurl a shower of lava clots into the air. The phenomena are simply those exhibited by a viscous body in a state of slow boiling. In the case of Stromboli it has been noted that when the barometer is low, the level of the lava is higher than at other times, and *vice versa.*

The eruptions of the Hawaiian volcanoes are materially different from those of the Strombolian or the Vesuvian type. Instead of the intermittent bubbles of Stromboli, or the violent outburst of Vesuvius, the lava rises in the caldera until it overflows the lowest part of the rim, or breaks through cracks and fissures in the ramparts of the caldera. The flow of lava—often an enormous quantity—continues for several days, or perhaps for several weeks, and then subsides as quietly as it began.

Occasionally, clots of lava are shot into the air, and as soon as the ejected mass cools, the escaping steam or vapor blows the viscous lava into the fine, tenuous threads known as "Pele's hair." The threads are so gossamer-like that they are carried a long distance by the wind.

Fissure Eruptions.—Some of the eruptions that occurred in previous geological periods resembled those of the Hawaiian volcanoes. There were apparently none of the phenomena that mark outbursts of the Vesuvian type. Great fissures were formed, through which the lava was forced. From some of these the flow of lava was enormous; in others the lava merely filled the fissure and hardening, left dykes of volcanic rock. The plains of the Columbia are the remnants of a lava flood from fissures in the Sierra Nevada Mountains. Large



A LACCOLITE

A section through Mount Hillers, one of the Henry Mountains. The dotted lines indicate the strata removed by erosion.

areas of California, Oregon, Washington and Idaho were engulfed, and in several places the Columbia River was pushed out of its channel. Many small cinder cones were afterwards formed on the surface of the lava. In places, the sea of lava is nearly four thousand feet deep, and the average depth is not far from one thousand feet. The area involved was not far from one hundred thousand square miles. The Palisades of the Hudson form a dyke of similar character. In these sheets and dykes there is no evidence of explosive steam.

The great lava floods came, not from craters, but from *fissures*. No crater in the world is large enough to have ejected a lava flood like that which covered so much of Oregon, Washington and Nevada. Calderas like those of Hawaii would have built up a dome-shaped mass of lava. The lava flood in question was a *sheet*. It could have come only from a fissure many miles in length.

Small cinder cones represent volcanoes that formed on the lava flood after the surface had hardened. This fact indicates that vulcanism occurs just as readily from a *supramontane* as a *sub-mountain* reservoir.

In many instances volcanic action has been nothing more than a mere filling of the fissure—an *intrusion* of lava, but no *extrusion*. In a few cases the upper edges of the fissure walls have been worn away, leaving the harder volcanic rock in the form of a ridge or dyke. The Devil's Slide, in Weber Cañon, Utah, is an illustration. In this instance there are two dykes about twenty feet apart.

Laccolites.—In a few instances, lava thrust upward, has raised the outer strata of the rock envelope in the same manner that a blister of the skin is formed. No extrusion of lava took place and none reached the surface. Irruptions of this kind are commonly known as *laccolites*. The Henry Mountains, a detached group of knolls in Utah, are examples. The Black Hills of South Dakota are possibly a similar formation.

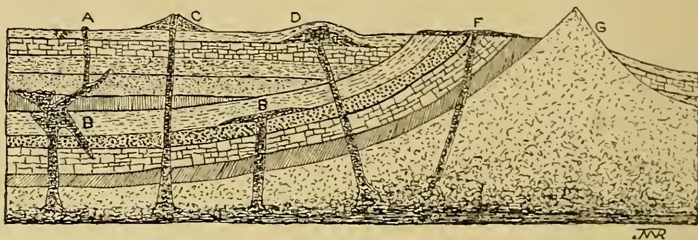
Products of Eruption.—Excepting the small amount of sulphur gases emitted, but two substances are ejected from volcanoes—steam and lava. In the eruption of Vesuvius that occurred in 1872, it is estimated that ninety-eight per cent. of the material ejected consisted of steam. From the Hawaiian volcanoes, however, the matter thrown out consists almost wholly of great quantities of lava.

The term *lava* includes every form of molten rock of volcanic origin. Lavas, therefore, differ not only in appearance, but in chemical composition as well. The spongy clots of lava, or *scoria* resemble furnace slag, and have much the same composition. If it contains much steam, it is vesicular, or spongy; pumice-stone, or "volcanic froth," is so porous that it floats on water. Obsidian, or "volcanic glass," another form, does not differ materially from black bottle-glass.

Most lavas are readily decomposed by the action of air and moisture, and the Hawaiian lavas make excellent soil in the course of a few years. The economic value of lavas, therefore, may be considerable. Sulphur, or "brimstone," is a common mineral in and about the craters of volcanoes. It is formed by the action of sulphur gases that, on mixing, decompose each other and deposit the sulphur.

Nature of Volcanoes.—That volcanic action is due indirectly to the gradual shrinkage of the crust of the earth is generally admitted. To what extent contraction becomes a direct cause, however, is a matter of uncertainty. It is generally believed, also, that the material ejected comes, not from an assumed "liquid interior" of the earth, but is formed at a moderate depth below the seat of eruption.

Various theories have been advanced to account for the possible causes of eruption, but of these only one or two are supported by positive evidence. When the rock layers fit themselves about a shrinking interior, the pressure that results is sufficient to heat the rock upon it far beyond the temperature of fusion; and if a break or fracture occurs, the pressure being relieved, the superheated rock at



FORMS OF ERUPTION

A, a dyke; B, B, subterranean intrusions; C, a cinder cone; D, a laccolite; F, a lava sheet; G, granite core of a range.

once liquefies and is forced out of the fissure. An intrusion of water upon intensely heated matter may have caused such an eruption as that of Krakatoa, in Sunda Straits, but it is improbable that this is a cause of ordinary eruptions.

There seems to be a relation between volcanic vents situated at no great distance from one another. Thus, while Vesuvius was dormant, Epomeo on the island of Ischia was active; but after the eruptions of Vesuvius began again, Epomeo became quiet. A similar condition existed in past times, for the Phlegrean Fields, an area south of Vesuvius, is honeycombed with old craters at which eruptions took place at successive intervals.

The same phenomenon is observed in the Hawaiian and the Ecuadorean groups. Activity is usually confined to a single caldera, and if this becomes dormant for any length of time the seat of activity is transferred to another vent. In the cases of the Italian and the Ecuadorean groups, the cessation of all activity is usually followed by a period of frequent and destructive earthquakes.

A misunderstanding of volcanic phenomena has led to the adoption of certain names that often give erroneous ideas of volcanic action. There are no "flames" about volcanic outbursts; the so-called flames are merely the reflection of the white-hot lava from the under surface of the dense clouds of steam.

This may be illustrated by a very familiar example. When a railway train passes through a long tunnel, a flood of mellow light illuminates the tunnel and the interior of the coaches. The light comes from the fire-box of the locomotive. When the furnace door is opened the light from the glowing coal is reflected by the steam that fills the tunnel. Each globule of water dust is a tiny mirror, and as a result the tunnel is flooded with light.

"Smoke" is also absent, except as the clouds of dust and steam can be thus called. Volcanic "ashes" are not ashes at all; they consist merely of fine lava. This form of lava results from the action of steam which, forced through the lava by intense pressure, carries much of it along in a fine, powdery state.

Results of Vulcanism.—Notwithstanding their stupendous display of energy, the physiographic effects of volcanic outbursts are comparatively unimportant, and as a rule they are confined to the vicinity of the volcano. The most noticeable feature is the cone, dome, or peak that popularly is called a volcano. Each volcano builds its own cone, and, for the greater part, the cones have been formed along the folds of mountain-ranges.

The lava usually collects at the vents, and at the same time builds the cone higher. The successive eruptions of the calderas of Hawaii have formed a dome 14,000 feet high, covering an area as large as the State of Connecticut.

Most of the volcanic mountains of the Hawaiian Islands are dome-shaped rather than conical peaks. The shape results from the liquid condition of the lava and the absence of any great amount of steam.

Some of the lava flows of the Iceland volcanoes have been extensive. Of the thirteen or more cinder cones, Hekla and Skaptar Jökul are the best known because of the frequency of their eruptions. In 1783, there occurred a flow of lava from the latter that continued for two years.

A SMALL CRATER WITHIN A CALDERA, HAWAIIAN ISLANDS

Two streams each about fifty miles in length flowed in nearly opposite directions from the crater. More than 1,000 square miles were covered by the lava. A score of villages was swept out of existence. Streams were dammed by the lava and floods added to the destruction. Thousands of cattle were killed, and a large part of the population perished in the famine that resulted from the eruption.

The ashes sometimes accomplish more ruin than the lava flow and the corrosive rain. Herculaneum and

Pompeii were destroyed by the eruption of Vesuvius A.D. 79. Pompeii was covered with loose material, and much of the city has been excavated in recent years. Herculaneum received a heavy fall of rain in addition to the ashes, and the latter were cemented into rock.

Volcanic ashes have been hurled to a great distance by the wind. During the eruption of Tomboro, in Sunda Straits, dwellings forty miles distant were crushed and large areas of forests were destroyed.

Appalling effects resulted from the eruption of Krakatoa, also in Sunda Straits. The explosions culminated with the disappearance of half of the island. Forests seventy-five miles away were crushed by the falling mud and rain, and the fine material covered the city of Batavia to a depth of several inches. Some of the lighter dust was carried more than 1,000 miles.

Volcanic outbursts have occurred from time to time in the West Indies. Several eruptions have taken place in the cinder cone, La Souffrière. One in 1812 covered a large area with mud and ashes, destroying a town of ten thousand population; another in 1902 wrought great havoc in the cultivated region near by. An eruption of Mont Pelée, Martinique, in 1851, destroyed much property. A most disastrous outburst in 1902 wrecked the city of St. Pierre and killed about 25,000 people.

Islands are both formed and destroyed by the outbursts of marine volcanoes. Off the coast of Tunis, a reef called Graham's Island was formed during an eruption, and remained in existence for several years. It then gradually disappeared. The island of Santorini, in the Greek Archipelago, was formed as a result of eruptions. It is now inhabited.

This island, better known as Thera, is a few miles north of Crete. According to one myth it grew from a clod of earth hurled from the ship *Argo;* according to another it was the product of submarine fires. Both legends are a testimony to its volcanic origin. The topography of the island was considerably altered by an eruption that occurred in 1866. The area covered by ashes and scoria is now cultivated land.

Vulcanism is a trustworthy index of processes going on within the earth's crust which affect the level of a region. Measurements show that, in regions of volcanic activity, an elevation of the surface usually is taking place. Along much of the Mexican and South American coast, upheaval is occurring. In the South Pacific Ocean, on the contrary, where vulcanism seems to have ceased, there has been a subsidence.

Distribution of Volcanoes.—Active volcanoes are commonly found along the lines of the younger mountain folds, and they are almost always near the sea. The Pacific Ocean is nearly girdled by chains of mountains that are comparatively young, and in these folds are situated a majority of the active and dormant volcanoes of the earth.

Another short chain extends along Java and the remaining Sunda Islands to New Zealand. It contains about one hundred active and dormant volcanoes, and is the chief seat of volcanic activity on the earth. The Hawaiian Islands are the most notable group situated in mid-ocean. This chain is about a thousand miles long, but the seat of activity is confined mainly to the island of Hawaii, on which there are three calderas—Kea, Loa, and Kilauea.

A chain of volcanic islands extends along the Atlantic Ocean from Jan Mayen Island through Iceland, the Azores, Canary, and Cape Verd Islands, southward as far as Tristan da Cunha. Another extends through the West Indies.

Graham Land, in the Antarctic Continent, contains at least two volcanoes that have been active in recent times.

Among South American volcanoes the Peruvian and Ecuadorean groups are famous for their great height. The Mexican group contains four of interest, because they are so far inland. In what direction does the line extend? They are active or quiescent at short intervals.

The North American group contains a great many dormant and extinct cones; but at least four—Shasta, Tacoma (or Rainier), and Lassen must have been active within recent times. A small cone near Lassen Peak has been in eruption probably within seventy-five years, and the stumps of trees, many of them in a good state of preservation, are still protruding through the sheet of lava.

Cinder cones and volcanic "necks" are abundant all through the plateaus of the Western Highlands. In Arizona there are several hundred. One of the most imposing, San Francisco Peak, has been in eruption within recent times. In New Mexico there are also many small cones. Almost all the high peaks of the Cascade and Sierra Nevada Ranges are cinder cones.

The Aleutian group contains about thirty cones, quiescent and active. One of these, Bogoslov, north of Unalaska, has been in eruption almost constantly since 1880. Many of the peaks of the West Indies are cinder cones. The remains of old cones are abundant in the Appalachian and Laurentian Mountains, but they seem to have long been extinct since early geological times. One of them, Mount Royal, has given to the city of Montreal its name.

QUESTIONS AND EXERCISES.—Explain the nature of the so-called smoke, flames, and ashes of volcanic eruptions. Why are these terms inapplicable?

Prepare a written description of the geographic distribution of volcanoes, taking into consideration their position with reference to mountain-ranges, proximity to the sea, latitude, and situation with reference to continents and islands. Consult the map on the opposite page.

Note the features in the diagram, p. 92, and prepare a brief description of the various ways in which lava is extruded.

COLLATERAL READING AND REFERENCE

Pliny.—Letters—Book vi., 16—vi. 20.
Shaler.—Aspects of the Earth, pp. 46–97.
" First Book of Geology, pp. 88–97.
Le Conte.—Elements of Geology, pp. 89–103.
Redway and Hinman.—Natural Advanced Geography, p. 12.
United States Geological Survey.—Shasta and Lassen sheets.

DISTRIBUTION OF VOLCANOES

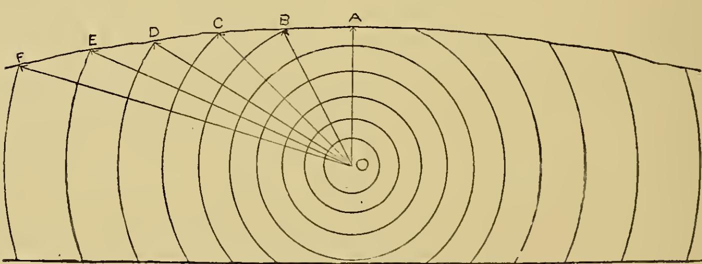
CHAPTER VI

DESTRUCTIVE MOVEMENTS OF THE ROCK ENVELOPE: EARTHQUAKES

Rigid and solid as it seems, the rock envelope is elastic. This is noticeable when an underground explosion occurs, or even when a very heavy weight falls to the ground: the latter trembles for an instant, causing a slight shock.

The explosion under Flood Rock, for the purpose of widening Hell Gate Channel, produced an earth shock that did not differ from those produced by natural causes. The earth shock resulting from this explosion was recorded at a distance of forty miles from Hell Gate. The velocity of the wave varied from 5,000 to 8,000 feet per second in the vicinity of the explosion.

Any instantaneous disturbance, therefore, such as a subterranean explosion, the collapse of a cavernous space, or



THE PROGRESSION OF EARTHQUAKE WAVES

the sudden breaking of strata, causes a vibration or trembling of the surrounding rock. These tremors are *earthquakes*. They may be perceptible for several seconds, or even a minute. Usually several shocks follow at brief intervals, involving an area of many square miles.

Nature of Earthquakes.—No matter how far below the surface of the rock envelope the centre of the disturbance may be, as soon as the vibrations reach the surface they behave like the circular waves that form when a stone is thrown into still water.

The vibrations as they form underground are spherical waves and much like those formed in the air by the discharge of a firearm or the ringing of a bell. When the waves reach the surface of the rock envelope they spread out in the form of circular waves.

In the diagram on page 100 the shock originates at O, and immediately above, the resulting wave will have an up-and-down motion. These are called *vertical* waves. As the successive waves move outward, the vertical movement gives place to one that is both horizontal and progressive, and the latter may be called a *horizontally progressive* wave. At F the waves are nearly horizontal; at B and C they partake both of the vertical and the progressive character.

Researches, however, indicate that the tremors or vibrations do not always spread out so evenly from the centre of disturbance as the waves that result when a stone is thrown into water. Some kinds of rock seem more elastic than others, and so the concentric waves, instead of remaining circular in form, become irregular in shape. If the waves of water strike a rigid surface, they are reflected, the reflected wave often crossing the original. Earth waves are similarly reflected, and sometimes they produce the effects of a vorticose, or whirling movement.

Such waves have a terrific shattering force; but those in which the horizontal and vertical components are combined are even more destructive; they not only shatter, but they produce a rocking motion as well. Vertical vibrations may only shatter a building; a "roller" will not only shatter, but overthrow it.

Although earthquake waves are similar to the circular waves formed at the surface of water, it must be remembered that they differ greatly in velocity and energy. The latter progress only a few yards a minute; the former have a velocity of more than forty miles a minute.

It has been calculated that the amplitude, or up-and-down motion, rarely exceeds one-quarter of an inch in height; and ordinarily, in severe shocks, it is seldom more than one-twentieth of an inch. The horizontal oscillation is scarcely more than half an inch, and even when it is less than half as much, the shock has great shattering power.

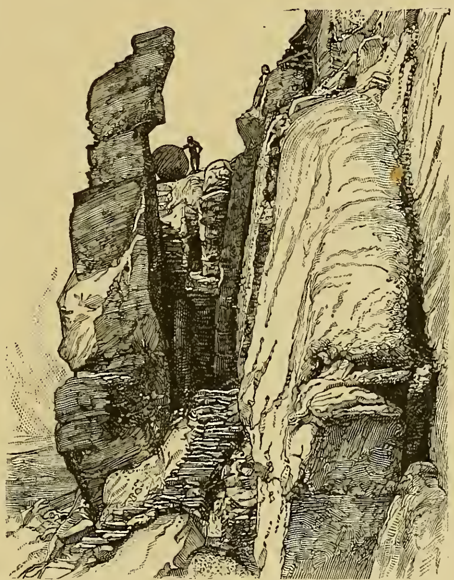
The velocity of the wave depends partly on the elasticity of the material through which it travels, and partly on the energy with which it is propagated. In hard, crystalline rock it travels rapidly and extends a great distance; in sand and loosely coherent rock the velocity is much slower, for the waves quickly lose their energy, but they are even more destructive than those passing through rock.

During the earthquake at Riobamba, Ecuador, the vertical movement was sufficient to hurl heavy objects a hundred feet into the air. The bodies of men were thrown several hundred feet across the river.

In severe earthquakes a series of shocks follows one after another with increasing intervals of time. The first shocks are commonly the most violent. The duration of the shock is not perceptible to the senses for more than four or five seconds, but careful measurements by the seismograph, an instrument for the detection of shocks, show that it may last for more than a minute.

At St. Thomas, one of the Lesser Antilles, there were nearly three hundred shocks during the earthquake of 1868. The earthquakes that shattered San Salvador, the capital of the State of Salvador, lasted for about ten days. The Charleston earthquakes did not cease for nearly a month, and a hundred similar instances might also be added. All this accords with the well-known law that a mass of rock envelope, in changing its foundations, cannot adapt itself to its new position at once, but does so gradually.

The focus of the shock may vary from a short distance to several miles below the surface of the earth. The area involved in the earth-waves may be either circular or elliptical. The diameter of the area seldom exceeds one thousand miles.



A ROCK COLUMN LIKELY TO BE OVERTURNED BY AN EARTHQUAKE

The rock has broken away from the cliff, splitting along a naturally formed plane. Rock waste, falling into the crevice, has become saturated with water, which by freezing, has expanded and pushed the mass farther and farther from the cliff.

The elliptical form is especially noticeable in mountain regions, and the major axis, or long diameter of the ellipse, coincides with the trend of the range or system. The reason is that the strata of rock are more elastic along than across their masses.

Attending Phenomena.—Earthquakes are frequently attended by sounds—sometimes like low, rumbling thunder; very commonly, however, the noise is like that of a heavily loaded wagon going rapidly down a gravelled incline.

In the great majority of earthquakes the effects are not severe; they rarely extend beyond the stopping of clock pendulums, the swinging of chandeliers, or the breaking of delicate substances. In severe shocks the walls of houses are wrenched and cracked, and the ground is fissured. In disastrous shocks buildings are shattered and the surface of the earth is seamed with deep fissures and chasms. Lakes have even been formed or, perhaps drained, and stream channels are sometimes changed.

The earthquake that destroyed the city of San Salvador broke down the rim of a small lake and drained it. The famous earthquake of New Madrid, Missouri, changed the level of the land to such an extent that a permanent swamp was formed at a locality that before the shock was high and dry. This area has since been known as the "Sunk Region." During this shock the current of the Mississippi was greatly disturbed as was shown by changes in its channel. Reelfoot Lake, in Tennessee, was considerably enlarged at the same time.

If the centre of the shock is in or near the ocean it is commonly followed by a series of gigantic waves, popularly but incorrectly called "tidal" waves. Following the Lisbon earthquake in 1755, enormous waves rolled in from the sea, and wrecked whatever the earthquake had left. The ocean-waves that followed the earthquake at Arica, Peru, carried the United States Steamship *Wateree* nearly seven miles inland, leaving her stranded in a dry stream bed.

Probably the most disastrous waves on record, however, followed the Lisbon earthquake. After the town had been felled by shocks so terrific that thirty thousand people perished, most of the survivors took refuge on the massive sea-wall. Hardly had they reached it when the water began to recede, leaving the harbor dry. Then an enormous wave, sixty feet high, rolled in and completed the destruction, and thirty thousand more lives were swept out of existence before the waves ceased. At Cadiz the waves were thirty feet high, at Madeira eighteen, and along the Irish coast they were four or five feet in height.

The sea-wave resulting from earthquake at Arica crossed the Pacific Ocean and was recorded at Yokohama, Japan, twenty hours afterward. On the American coast the wave was observed as far north as Alaska, and to the westward as far as Australia. The earthquake that in 1854 devastated a part of Japan was followed by a destructive wave. At Simoda the wave was thirty feet high; at Peel's Island, one thousand miles away, it was fifteen feet; on the California coast it was from twelve to eighteen inches in height.

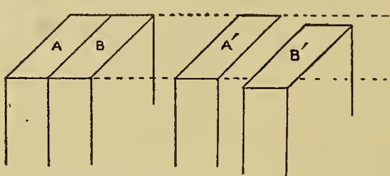
AN EFFECT OF THE EARTHQUAKE AT CHARLESTON

The crack was about two feet wide; it is a definite fault. From a photograph.

Cause of Earthquakes.—It is generally believed that earthquakes are the result of the movements of the rock envelope. If the strata slowly adjust themselves, no vibratory effect is noticeable, but if the strain increases until a fracture, or a collapse takes place, the shock produces the vibrations that constitute the earthquake.

When fissures are formed, one wall usually slips upon the other, so that the two edges are no longer in the same level. The resulting inequality is called a *fault*, and wherever such faultings are found, they indicate, if not an earthquake, at least a surface disturbance. The existence of such faults, therefore, is evidence that the outer shell of the earth is constantly under stress, and that the release of the strain produces the earthquake.

The investigation of the San Francisco earthquake has made this fact quite clear. Several faults extend along the ridge of the Coast Range next the Pacific Ocean. The shock of April, 1906, resulted from a movement along the line of the San Andreas fault. The vertical displacement along the fault scarcely exceeded four or five feet at any place: for the greater part it was hardly more than one foot. The lateral displacement in several places was about sixteen feet. This is illustrated in the accompanying diagram and photograph (p. 107). At this point the lateral movement pulled the fence out of line about six feet.



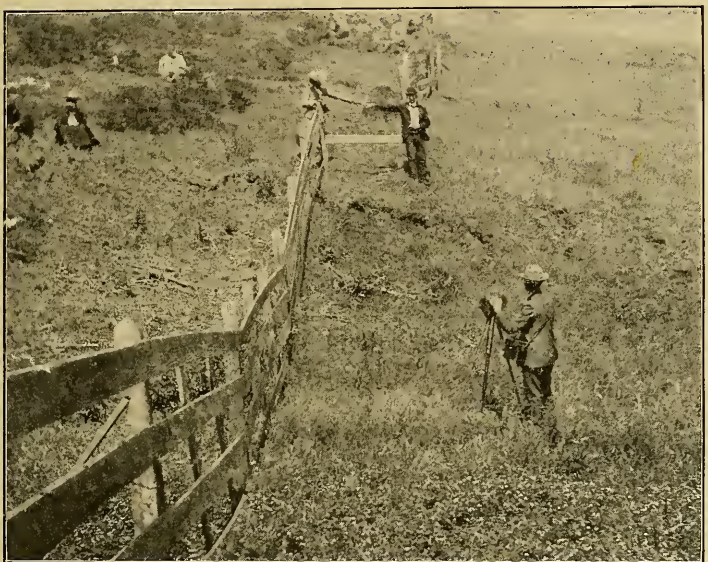
SAN FRANCISCO EARTHQUAKE: LATERAL DISPLACEMENT

AB, *the position of the blocks before the shock;* A′B′, *the position after the shock.*

The destruction of Babispe, a small village in northern Mexico, is also an excellent illustration. The shocks made a fissure extending several miles in length; when equilibrium was restored, the fissure had become a fault—one wall being from ten to fifteen feet lower than the other.

The rock in the large quarries usually exhibits signs of heavy strain. At Monson, Massachusetts, Professor Niles observed that pieces, before their ends had been detached, were split along a horizontal plane and bent upward at the middle. One mass, measuring 354 × 11 × 3 feet, increased an inch and one-half in length after it had been detached. These facts indicate the enormous pressure to which rocks may be subjected; incidentally they show that even the hardest rocks are decidedly elastic.

Distribution and Occurrence of Earthquakes.—No part of the earth is free from earthquakes, and recent observations have shown that, somewhere or other, they



LATERAL DISPLACEMENT, SAN FRANCISCO EARTHQUAKE
From a photograph by C. T. Wright, Redlands, Cal.

are of almost daily occurrence. As a rule, they are so feeble that scarcely one in fifty is perceptible, without the aid of instrumental measurements.

An instrument for *measuring* any of the elements of an earthquake shock is called a *seismometer;* if it merely *records* a shock it is a *seismograph.* The horizontal element of the shock is recorded by means of a delicate pendulum carrying a pencil or stylus. The jar sets the pendulum in vibration, and the pencil records the direction of the oscillations.

Earthquakes are more frequent in younger mountain-ranges than in the older ones. They are still less frequent in plains, unless the latter are undergoing a process of uplift or depression. They also accompany most volcanic disturbances, and the sudden formation or the rapid motion of gases will account for the shocks at such times. Volcanic earthquakes do not differ in effect from others; they are due merely to a different cause.

The study of several thousand earthquakes shows that shocks are a little more frequent when the earth is nearest the sun, and that they are also more prevalent when the moon is nearest the earth. An explanation for this is not hard to find. Owing to the tendency to adjust itself, the rock envelope is constantly under an increasing stress. But when the earth approaches either the sun or the moon, the increased mutual attraction adds its force to the strain, and a shock results.

Of a total of 364 shocks in the United States, 147 occurred in the Atlantic Highlands and Coast Plain; 66 in the Great Central Plain; and 151 in the Pacific Highlands. These figures have only an approximate value, however, inasmuch as many of the earth shocks occurring in the sparsely settled regions of the Pacific Highlands escape notice. Of 66 shocks recorded in Canada, the United States and the West Indies during one year, 24 were in the Atlantic slope and the West Indies; 3 were in the Great Central Plain; and 39 in the Pacific Highlands, including Mexico and Central America.

QUESTIONS AND EXERCISES.—If you live in the vicinity of a body of water, study the waves that form when a good-sized stone is tossed so that it falls vertically into still water.

What is the relative position of the vertical and the horizontally progressive waves? Repeat the experiment until the results obtained are familiar.

If possible, clamp a brass or metal plate, about a foot square, to a firm table, so that the clamp holds the plate at its centre. Sprinkle dry sand on the plate and draw a violin bow across the edge. From the figures produced by the sand note the direction and character of the vibrations.

COLLATERAL READING AND REFERENCE

Rockwood.—Notes on American Earthquakes.
Shaler.—Aspects of the Earth, pp. 1–45.
Le Conte.—Elements of Geology, pp. 154–171.

A MATURE RIVER LOOP: MOCCASIN BEND, TENNESSEE RIVER

The flood plain enclosed by the loop is rich farming land.

CHAPTER VII

THE WASTING OF THE LAND: THE WORK OF RIVERS

WHILE internal forces result in wrinkling and folding the strata of the rock envelope, other agents are constantly at work wearing away those same folds and irregularities, and are wasting or degrading the surface of the land to its lowest, or *base level.*

Weathering Processes.—Water in its various forms is the chief agent in the wasting and changing of the earth's surface. Falling on the land as rain, it loosens and carries off particles of earth. It also sinks into the pores of the rock, perhaps dissolving some of it or else breaking off small pieces. This process of degradation is called *erosion.* Gathering in swift torrents, the waters cut their channels deep into the surface, producing the effects called *corrasion.* Flowing against cliffs and banks, it saps their foundations and breaks them down by *undermining.*

Gravitation aids in the process of degradation, for not only does the water flow downward, but the *detritus,* or rock waste, is likewise moving to lower levels. For a time it may lodge in a hollow, or basin-shaped depression, until the latter is filled; then the downward progress again begins.

Disposition of Storm Waters.—An average of about three feet of water falls on the land each year. In regions of ordinary rainfall, some of the water evaporates and mingles with the air; a part sinks into the ground and fills up the underground channels; the remainder flows back to the sea.

Streams of water flowing upon the land are variously called rills, rivulets, brooks, creeks, and rivers—the name usually depending on the size of the stream. The largest streams are *rivers*. Almost every river is made up of branches and tributaries, and these, in turn, are fed by smaller branches. A stream with all its branches is called a *river system*. The area drained by the river system is its *watershed* or basin, which is partly surrounded by a ridge or *divide*, that separates it from adjacent basins.

The term "watershed" is often used as a synonym of "divide." Technically used, however, it is not a divide but a basin.

Sometimes the crest of a mountain-range forms a divide, but occasionally the latter is an almost imperceptible rise of ground only a few feet high. Thus, at Chicago, the divide between Lake Michigan and a tributary of Illinois River is only ten or fifteen feet higher than the level of the lake. There are instances, also, in which the divide is so ill-defined that the same pond or lake may discharge its waters into streams whose mouths are a great distance apart. At high-water, Two-ocean Pond, in Yellowstone National Park, has two outlets—one through the Yellowstone to the Mississippi, the other through the Columbia. The one has Atlantic drainage; the other flows into the Pacific Ocean.

In some instances, too, the land is so flat that the drainage is difficult to determine. Such is the case of the Cassiquiare, a South American stream. In its course it bifurcates, discharging simultaneously into the Orinoco and the Rio Negro, the latter a tributary of the Amazon. Between the headwaters of the Parana, and those of the southern tributaries of the Amazon, the land is so flat that, in places, the drainage is undecided.

A high mountain-range is not necessarily a divide, for there are many instances where ranges are crossed by rivers.

From any good map find the divide between the Susquehanna and Allegheny Rivers; between the Great Kanawha and Ohio Rivers. Compare the divides with the ranges.

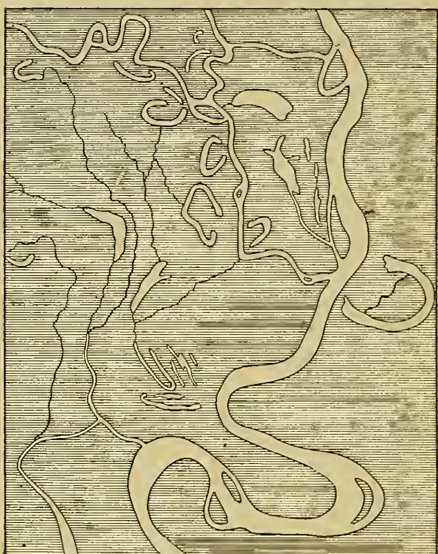
Physiography of Rivers.—The beginnings of most large rivers are in the mountains, where the rainfall is heavy and the greatest accumulation of snow is found. The water let loose from a spring or from a winter's snowdrift trickles down the slope in tiny rills. On their way the rills unite into streams that tumble down the mountain slopes in self-made gorges. Soon they become mountain torrents that rush down the steep inclines, cutting channels into hard rock and tossing to the one side or the other the obstacles in the way. Almost always the mountain torrent flows in a deep cañon.

The cutting and the carrying power of water depends on the speed of the current. A slight difference in the velocity makes a great difference in its carrying power. Water flowing at the rate of four miles an hour will carry *sixty-four* times as much material as water flowing at half that rate of speed; that is, the carrying power varies inversely as the *sixth power* of the velocity.

When the stream emerges from the cañon it is burdened with rock waste brought from the mountain side. No longer able to carry all of the rock waste, because of the lessened slope of its bed, it drops the coarser material, which forms a fan-shaped pile, or *alluvial cone.* Thenceforth, because its current is slower, it cannot remove the heavier obstacles in its way, but must flow around them.

The lighter rock waste, called *silt,* or sediment, is still carried by the flood of the river. Some of it is dropped, being built into flood plains, but the lightest material is borne to the coast plain, which itself is the "made-land" formed of river sediments. When the river reaches tide-water, most of the remaining sediment is deposited—either to be spread out in the form of a delta, or to be piled up near the shore in spits and bars.

As a stream *degrades*, or wears away the land, three processes are usually going on, namely—*corrasion* and *undermining*, *transportation*, and *deposition*. From the moment the water falls on the rock envelope it is picking up particles of earth; it is carrying them; or else is dropping them. Whichever it does, depends on the velocity of the current. Increase the velocity, and the water will pick up more particles; decrease it, and the water will drop and flow around them. In the upper, or torrential part, streams usually cut their channels deeper. In the lower course the reverse is apt to be true; the stream clogs its channel with sediment and must therefore make a new one around the obstruction.

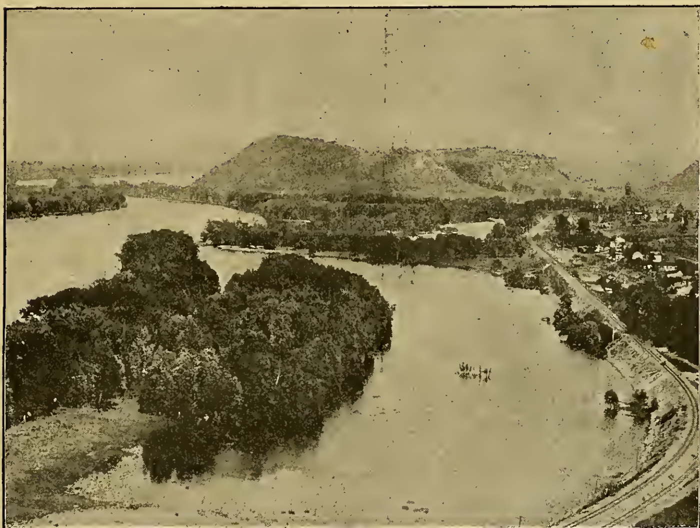


LOOPS AND CUT-OFFS OF THE LOWER MISSISSIPPI

The abandoned channels form an intricate network of passages.

In the study of such rivers as the Mississippi, the reasons for this are not hard to find. Because the slope of its channel decreases, the velocity of the current is checked, and because of the slackening current, the water is constantly dropping sediment.

Islands are common in rivers carrying a considerable sediment. The anchoring of a snag, or any other obstacle, slackens the current and causes deposition of sediment. The latter increases in amount until finally it reaches the

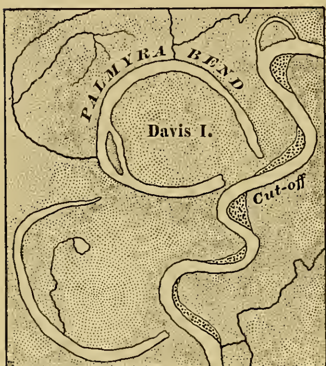


ISLANDS IN THE MISSISSIPPI RIVER

surface. Then vegetation takes root and an island results.

Drifting timber may clog the channel. The roots of a floating tree catch on the bottom, forming a snag. Other timber lodge upon it, and in time form a "raft." Perhaps the latter may float down stream, but more likely it forms a permanent obstruction. The famous Red River raft is many miles in extent.

The Formation of Loops.—The river which flows over a decreasing slope has a tendency to form *loops* or, "*oxbows*," in its lower course. In general, such loops are long lived, but if there is a succession of years of high water, the conditions are changed. The volume of water is increased, the current is quickened, and the water begins to pick up the sediment which it had dropped. In time, the neck of the loop is cut away, and the river shortens its channel — sometimes by twenty or thirty miles. The line of *moats*, or oxbow lakes, along the lower Mississippi marks the old loops and abandoned channels along this river. It is evident also that the great amount of sediment removed when a loop is destroyed must be carried farther down stream and there deposited. New bars were formed at various places below the cut-off, and the navigable channel was materially changed.



PALMYRA BEND—NOW PALMYRA LAKE

Davis cut-off at Palmyra Bend, near Vicksburg, Mississippi, is the channel across the narrow neck of an oxbow. The distance around the loop was twenty-two miles; across the neck, it was scarcely half a mile. An obstruction anchoring in mid-channel forced the current against the narrow neck, and the latter was cut away by the stream. Finally the neck was severed and the river poured through the cut. Around the loop the fall of the river was about four inches per mile; through the cut it was more than five feet. The river scoured a channel about one hundred feet in depth; and so swift was the current that more than a week elapsed before steamboats could ascend it. The effect of the cut-off was far-reaching, and extended both above and below Palmyra

Bend a distance of over one hundred miles. More than a year elapsed before the changes in the channel ceased.

Growth and Development of Rivers.—A river and its basin are not an unchanging feature of the land. On the contrary, a river passes through the various stages of infancy and maturity; its legitimate work is to carve away and remove the material of its basin until every part is worn down to a base level.

THE LEGITIMATE WORK OF A RIVER

It removes the rock waste from A and carries it toward B: A B, the old; a' b', the new profile.

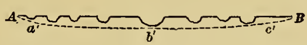
The moment that a plain or surface—such, for instance, as the coast plain of New Jersey—is uplifted and exposed to the action of the weather, the water falling upon it begins to gather and to form channels. Such a river may be called an infant stream.

INFANT STAGE OF A RIVER

The stream has notched its channel in the plain A B.

It is also called a *consequent* river because its formation is consequent upon the elevation of the plain. A river is an *antecedent* stream when its existence dates before that of some other feature. Thus Green River existed before the formation of the Uinta Mountains and with respect to them is an antecedent river.

A young stream at first drains its basin very imperfectly. It encounters many obstacles; and if the slope is gentle, it finds great difficulty in making a channel. Because of the many inequalities in the surface, lakes and swamps form in the slight depressions. The channels are apt to be shallow and the divides between the adjacent branches are

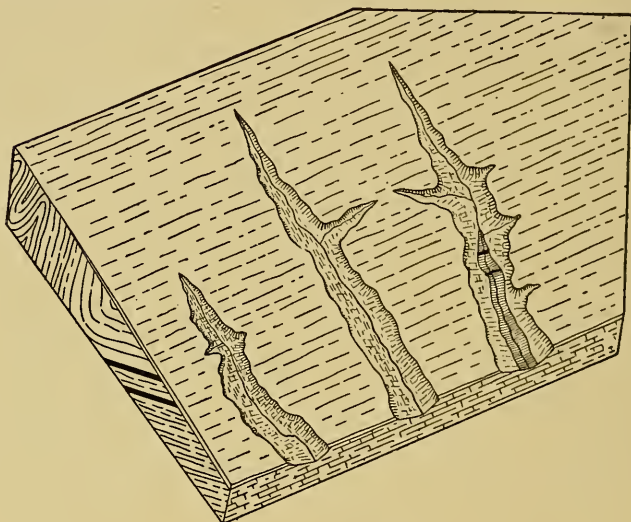


THE MATURE STAGE OF A RIVER

The main stream and its tributaries have carved deep channels in the plain A B: In a' b' c' the remaining material has been carried away.

neither permanent nor well defined. In consequence, any unusual flood may result in the abandonment of an old and the selection of a new channel. Red River of the North is an example of an infant river.

As a stream reaches maturity its character is changed. The channel is deepened and is more permanent. The

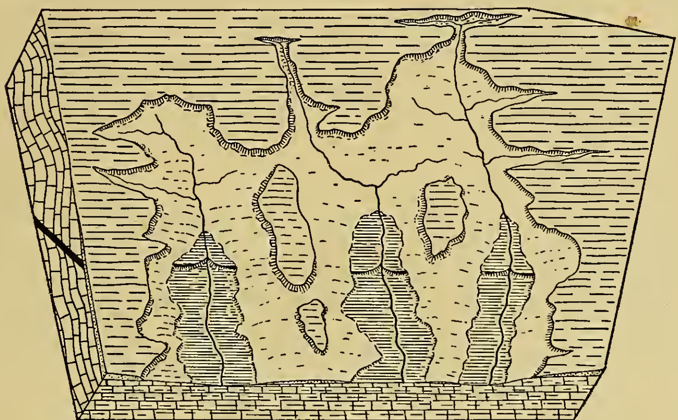


YOUNG RIVERS

The stream on the right has uncovered the ledges of hard rock shown in the margin, and falls have resulted.

gullies of the tributary streams are deepened into ravines, or, possibly, are sculptured into broad valleys. The tributaries extend their channels backward and often capture the waters of other streams less vigorous (p. 119). The mature stage is the age of its greatest vigor and power. It may lengthen itself by forming a delta at its mouth, and it may also cut its headwater channels backward.

The old age begins when the river has cut away and transported all the available material within the reach of its various branches. As a matter of fact, however, a stream rarely ever reaches old age. Changes in the elevation of its basin are constantly taking place. A slight elevation of the basin or some part of it, or an increase in the volume of water, may rejuvenate the stream. Just



A GROUP OF MATURE RIVERS

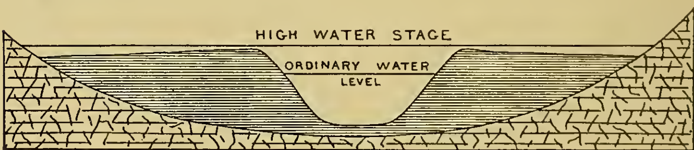
The greater part of the basin of each has been removed. The tributary of the central stream is carving its way into the basin of the river on the right and will eventually absorb the headwaters of the latter.

as a log moved against the saw results in cutting the timber, so a gradual uplift of the stream channel gives to the river youth and fresh cutting power. An increase in the volume quickens the current and also increases its cutting power. Uplift is nearly always followed by extensive stream corrasion.

Flood-Plains.—In its mature age a stream removes more material from the upper or torrential part than it can carry. Just as soon as the slope decreases, the current is checked and sediment begins to be dropped. Much of this is spread along the sides of the stream, thereby forming the "bottom lands" or *flood-plain.*

In its infant stage the river has but little cutting power and usually can carry all the material it removes. When the headwater streams acquire greater vigor, however, formation of the flood-plain begins.

The deposition of sediment is constantly going on. The river may build its bed and banks a little higher than the level on either side, continuing the process until the coming of high water; then it breaks through its banks and makes a new channel in lower land.



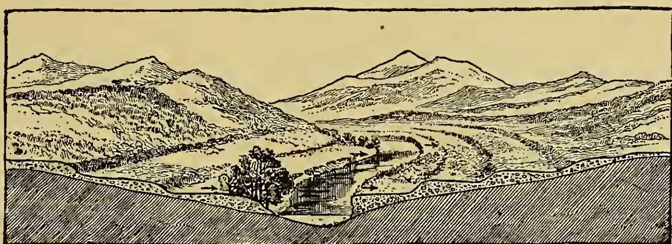
SECTION SHOWING A FLOOD-PLAIN
The dark shading represents the sediment deposited by floods.

The Destruction of the Flood-Plain; Terraces.— After a river has cleared away the rock waste at headwaters, it may then attack its flood-plain. Instead of depositing sediment, on the flood-plain the water begins to remove it. Then it forms a deeper channel, along the sides of which a new and lower flood-plain is formed. The new flood-plain with the remnant of the old one form *terraces.* Of these there may be several.

Flood-plains and terraces are, therefore, incidents in the history of a river. Perhaps most of the rivers of the United States are in the flood-plain stage of their existence. Some of the streams of the northeastern part are in the terrace stage and are approaching the period of old age.

Deltas.—Salt water has a remarkable effect in clearing muddy, fresh water, and the moment the two mix, the sediment held in suspension is deposited. Unless the sediment is swept away by currents and tides, a considerable accumulation will form at the mouth of the river.

The mouth of the Mississippi River shows an interesting type of delta formation. In this case it is evident that the banks of the delta are self-made, and they have been formed because the current has been checked more effectually at the edges than in mid-stream. Since the lower Mississippi has occupied its present channel, the river has extended its



TERRACES IN A FLOOD-PLAIN

Each marks a stage of down-cutting. The darker shading shows the old bed of the river.

lower part about one hundred miles into the Gulf of Mexico.

The deltas of the Volga, and Ganges-Brahmaputra are older and more complex than that of the Mississippi. They are also more compactly filled with sediment. The delta of the Ganges-Brahmaputra is perhaps the most extensive known. Its frontage on the Indian Ocean is about two hundred miles, and its area is greater than that of Texas. Much of the land consists of shifting mud-flats, and the whole region is subject to destructive inundations.

The delta of the Adige-Po has developed in a manner not unlike that of the Ganges. Probably no other river of its size brings down more sediment than the Po. As a result, its delta is filling and extending so rapidly that the town of Adria, in Julius Cæsar's time a seaport, is now more than twenty miles inland. Ostia, once at the mouth of the Tiber, is now about seven miles inland.

Delta lands surpass almost all others in productivity.

A DELTA MOUTH: THE DELTA OF THE MISSISSIPPI RIVER

The soil is very rich, and, because of the constant additions from the river, it is enriched as fast as it is impoverished. The Nile delta has long been known as the granary of Egypt—the delta lands of the Ganges-Brahmaputra are among the foremost rice-producing fields of the world.

Estuaries.—While some rivers reach the sea through deltas, others with equal power flow into estuaries. The

Mississippi and the Delaware are contrasting examples. In the former case the river has a tendency to block its mouth with sediment; in the latter, a downward movement, or sinking of the coast, has practically drowned the mouth of the river. Moreover, between its tide-formed bars, the tidal current is usually strong enough to keep the channel clear. So, between the scouring action of the tide and the sinking of the valley, there is a broad and a deep area of water in most estuaries. If the mouth of the river is in a coast plain, the estuary usually takes a form much like that of Delaware Bay. Along a rugged coast, however, the estuaries are more like the indentations of the Maine coast. Along the coast of Norway they are called *fjords*.

CHESAPEAKE BAY: AN ESTUARY, OR "DROWNED" RIVER-MOUTH

A part of a comparatively level plain has subsided below sea-level.

The lower part of the Hudson River is a drowned valley in which many characteristics of the fjord are observable. The real mouth of the Hudson is near Troy. Below this point the river is an arm of the sea, swept by tides. The explorations of the United States Coast Survey have disclosed the old channel of the river which extended southeast from lower New York Bay, a distance of eighty miles. Were this part of Atlantic coast again to be raised, it is not unlikely that the river would recover its long-buried channel.

The sediment of rivers that flow into estuaries is deposited in the form of *bars*. In most instances two bars are formed, one at the mouth, the other at the head of the estuary. The double deposition of sediment is due to the tides. Bars are formed in comparatively still water, so, when the tide is slack at flood, the deposition takes place at the head of the estuary; when it is slack at ebb, the deposition forms the bar at the lower end.

The estuary favors commerce and navigation, while the

A FJORD MOUTH OF A RIVER

Its situation adapts it for the centre of commerce of a newly-settled region.

delta is a hindrance. The navigable channel of the Mississippi delta has been kept open at an enormous expense. All the great commercial seaports are on the shores of estuaries.

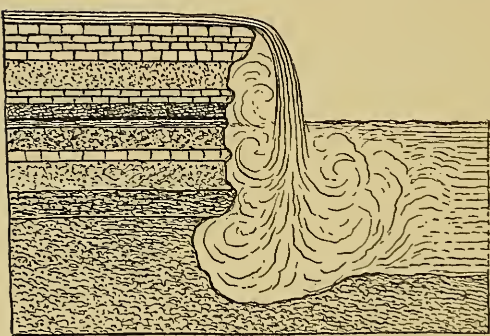
In many instances the water of a small stream reaches the sea indirectly. This happens when the force of the sea is greater than that of the river. Its mouth may be blocked by bars, and the stream is compelled to make a new one as it flows along the coast to find a place where its current has force enough to keep a clear outlet; or the mouth may be completely blocked so that the water gets to the sea by percolating the sand. Some of the streams flowing into Lake Michigan are imperfectly, others are completely blocked. Blocked rivers and "bottle" estuaries are common on the west coast of the Atlantic States.

Cascades and Rapids.—In flowing to lower levels, if the slope is abrupt, the water descends in rapids to comparatively level *reaches*. The river bed is therefore more or less terraced. The streams of the New England Plateau, and the torrents of mountainous regions are illustrations. In some instances, however, the stream plunges over a vertical embankment in the form of a *cascade* or *fall*. Of these, Niagara Falls, Spokane Falls, and those of the Zambesi River are illustrations. Some mountain streams make tremendous leaps. In the Yosemite Valley, Merced River falls 2,600 feet in three plunges; and Bridal Veil Fall, with a sheer pitch of 1,500 feet, reaches the lower level in the form of fine water dust. The Staubbach ("brook dust") of the Alps is a similar cascade, having a fall of 900 feet. The Cascade Range of the United States and the Lauterbrunnen ("nothing but fountains") of the Alps are names that suggest the character of these regions.

Sometimes the stream has little to do with making the cliffs over which it plunges; in other cases, the river itself has made the falls. If a stream flows over the edge of a hard layer that rests on a softer material, the latter will be more quickly removed; moreover, as the softer layer is worn away, the height of the fall becomes greater and the water acquires an increased cutting power because of its greater fall; a cataract therefore results.

In this manner the falls of Niagara River were formed. There, an upper layer of hard limestone surmounts several layers of softer rock. The upper layer offers considerable resistance to the water; the lower rock is easily cut away. Hence the falls are increasing rather than decreasing in height; but the upper layer, however, is being undermined and the falls are receding upstream at the rate of about two and one-half feet a year.

As Niagara River flows toward Lake Ontario, it encounters a layer of hard Niagara limestone that comes to the surface midway between the two lakes. When the river reaches the edge of this hard stratum, it pitches a depth of 160 feet. Below the Niagara limestone are soft shales, sandstones, and a layer of hard limestone. The falling water beats these away, clearing a deep pool under the cliff of Niagara limestone. The edge of the latter breaks off, the underlying strata wear backward, and the whole front of the falls recedes.

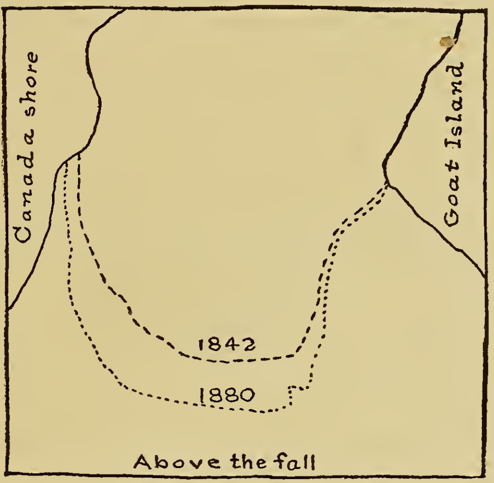


A SECTION OF A WATERFALL

At the point where the angle in the ledge is formed, the recession since 1875 has been more than two hundred feet; at the American Fall, since 1842, it has been very slight. It is a question of time only until the Canadian Fall will recede to a line between Dufferin and Sister Islands. When this has taken place the American Fall will have nearly or quite disappeared. Had the conditions of a hard stratum at the top and a softer one at the bottom been reversed, there would now be no cataract, even had there been one at the beginning of the present epoch. The softer rock would have been worn away until the perpendicular front had become an incline extending to a point below Whirlpool Rapids; and instead of the sublime cataract, there would now be a succession of rapids like those which mark the passage of St. Lawrence River.

Many cataracts are the result of accident. Thus, a flow of lava across Columbia River dammed the channel and formed rapids at several localities. A similar lava flood obstructed its chief tributary, the Willamette River, forming the cataract at Oregon City.

Falls and rapids are rarely found in the flood-plain age of a river, because in the formation of the flood-plain all inequalities are buried. After the stream has carved away its flood-plain, it may uncover and develop its former rapids and cascades.

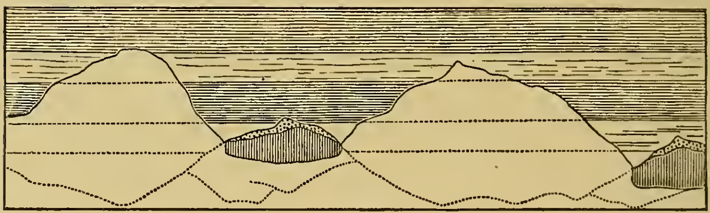


THE RECESSION OF NIAGARA FALLS

Migration of Divides.—As a general rule, a stream works most actively in the upper or montane part, where its current is swiftest. As the head-water streams deepen their gullies they frequently extend them backward; a very vigorous stream may even cut its channel backward across a ridge. The crest of the latter then ceases to be the water-parting; the divide therefore is said to "migrate."

In cutting its channel backward across a ridge or height of land a stream sometimes captures and diverts a feebler stream flowing on the opposite side of the divide. Most of the "wind gaps" of the Appalachian region are the results of this sort of river piracy. They are abandoned stream channels. They have been abandoned because the former occupants have been captured farther up the valley by a more vigorous stream which crossed the divide to get it. At least one stream in Northwestern Ohio and several in Pennsylvania have obtained some of their headwater tributaries by the robbery of neighboring streams on the opposite side of the divide. The Vistula has probably gained some of its headwater tributaries in this manner.

Unusual Adjustments.—In selecting a new channel, or in adapting itself to the changing conditions of an old one, a river is said to *adjust* itself. Several causes may



TUOLUMNE RIVER, CALIFORNIA

The old stream channel is under the lava cap which forms Table Mountain: the present channels are at the base of the mesa.

compel a stream to change its course. It may clog its channel with sediment, or the latter may be obstructed by accident. Thus, by long-continued silting, the Hoang River, "China's sorrow," built its channel higher than the divide, near the top of which it flowed. In 1852, during a season of high floods, the river broke through its banks. Before that time it had flowed southeasterly into the delta of the Yangtze; after the break its course lay in a northeasterly direction into the Gulf of Pechili.

The flood of lava that covered the area now called the plains of the Columbia, buried beneath it a long stretch of the river basin, and the river was forced to make a new channel around the lava. Tuolumne River, California, was similarly buried, but finally succeeded in making another channel around the obstruction.

In several other localities the Columbia has cut its channel through similar obstructions. In at least one case the river reclaimed its former channel by cutting through the entire thickness of lava, to a depth of about 2,500 feet. Deschutes River, a tributary of the Columbia, is readjusting itself by cutting a new channel into the same sheet of lava.

It is highly probable that Saskatchewan River formed the upper part of the Missouri, and that the uplift of the height of land across its course cut the river in two. The waters of the Saskatchewan were ponded, forming Lake Winnipeg. The latter then overflowed its rim and found an outlet into Hudson Bay.

The Work of Man.—By cultivating the land, man is indirectly responsible for the abnormal conduct of certain rivers. In order to make his land productive the farmer must not only clear it of growing timber and destroy the smaller vegetation, but he must also provide rapid drainage. Forest growths, shrubbery, and sod all serve to retain water in the soil and therefore prevent rapid drainage.

The removal of vegetation has exactly the opposite effect. The rainfall is rapidly collected by the tributaries, and as quickly poured into the main stream. As a result, high and quickly-forming floods occur. In late years the Ohio and the Susquehanna have suffered much from disastrous floods, and these are largely a result of deforesting their watersheds.

Geographical Distribution of Rivers.—Rivers are the offspring of rainfall and, as a rule, regions of great rainfall are regions of the largest and most numerous rivers.

This is shown in the case of the Amazon and the Kongo. Both rivers are situated within the belt of equatorial rains. Each has a large number of great tributaries, and each discharges an enormous quantity of water.

A river cannot develop great length and size unless its watershed is also large. When Columbus entered the mouth of the Orinoco, he at once declared the country southward to be a continent, because so large a river could not exist on a small body of land.

There is no apparent law governing the distribution of rivers except the position of slopes and the amount of rainfall. The largest rivers are not in the largest continents, nor are the longest streams in regions of greatest rainfall. The Atlantic receives the waters of more large streams than any other ocean; the Arctic Ocean is the next in order. The reason therefor is the fact that the largest plains slope toward these two oceans.

The plains and slopes of the Western Continent receive the full benefit of moisture-laden winds; and the rivers, as a rule, reach a higher state of development than those of the Old World. The Mississippi and the Amazon drain watersheds each half as large as Europe. The Mackenzie, La Plata, Yukon, Columbia, and Colorado about equal in size the great master streams of the Old World.

The broadest part of South America is crossed by the tropical rain belt, and therefore is in the region of heaviest rains. The ocean winds have a sweep of about 2,500 miles before they are arrested by the Andes Mountains; and because precipitation covers such an enormous area, there necessarily results a river system of vast proportions. The Amazon discharges a greater volume of water than any other river.

Most of the chief plain of the Old World faces the Arctic Ocean. It is the largest plain in the world, and is drained by large rivers. None of them equals the Amazon nor the Mississippi-Missouri, however, for the reason that they are situated in a region of moderate rainfall. The Yangtze and the Amur are the most important rivers of the Old World, and each has a large commerce. The three large rivers of the Indian Ocean are commercially of very great importance.

The southern part of Europe does not extend into the region of tropical rains; hence the absence of large streams on the southern slope. The southern part of Asia is under the tropical rain belt, but the drainage slope is comparatively short, and but few large streams have formed. Thus it may be seen that the large plain of Eurasia is unfavorably situated for large rivers. On the other hand, the areas which are favorably situated are too small for the development of great streams. The great number of smaller rivers compensates for the absence of such rivers as the Amazon.

Africa possesses several large rivers, two of which, the Kongo and the Nile, are of great importance. Like the Amazon, the Kongo is an equatorial stream, and the two are much alike. The Nile is remarkable for its annual overflows, and from the fact that in the lower 1,200 miles of its course it receives not a single tributary, a result of the rainless region through which it flows.

Australia possesses but few permanent streams, and these are of small size. This continent is unfortunately situated. It is under the Calms of Capricorn, and it contains no high mountain-range. The Murray-Darling is the only river of importance. In the summer season most of the streams disappear altogether, or else form a succession of shallow pools.

Continental Rivers.—There are several large areas that have no drainage to the sea. Such rivers are therefore called *continental rivers*, and their watersheds, *inland basins*. Where is the continental region of Eurasia? Name the four largest rivers. In Africa the only large continental rivers are those flowing into Lake Chad. There are many continental rivers in Australia. Practically all of them are dry in summer and some are filled only when an occasional cloud-burst pours a flood of water into their channels.

The Humboldt, Carson, and Jordan are the principal continental streams of North America. What do they indicate with reference to rainfall? In South America the Desaguadero, the outlet of Lake Titicaca, is the principal continental stream, although one or two of the larger rivers in Argentina are occasionally cut off from the sea.

As a rule, continental rivers are a result of scanty rainfall. An increase of rainfall would swell the volume of the river until its waters finally reached the sea. The soil of an enclosed basin is usually rich, because none of the nutritive elements are leached out of it by storm waters.

Economic Importance of Rivers.—Rivers are the most important highways of commerce and are the lines along which civilization and settlement penetrate to the interior of a country. Merchandise can be carried by means of river navigation at a less cost than in any other way. Most of the great migrations of peoples have followed the valleys of rivers; and in mountainous regions the cultivated areas are confined mainly to their narrow flood-plains. Outside the Great Central Plain of the United States most of the railways of the country have been built along river valleys, so that these are practically "lines of least resistance" to the activities of a people.

In its relation to life and its industries, the flood-plain is the most important part of river physiography. The surface is always level, making the region accessible to transportation. Moreover, the rock waste is mixed with the elements that form the food of plant life, and therefore the flood-plain has a most fertile soil. In the Mississippi Valley, for instance, where the bluff lands produce twenty bushels of wheat, the bottom lands yield thirty; and if an acre of bluff soil yields one bale of cotton, the same area of bottom lands yields two. The greater part of Chile is a simoom-swept desert with scarcely a sign of life excepting that which pertains to the mines and the mountain valleys. The real Chile is found in the densely-peopled flood-plains of the Andine streams. In these short valleys are concentrated nearly all the activities that go to make a great state.

The Egypt of history is not found in the broad stretch of land lying between the Red Sea and the Libyan Desert. On the contrary, the four thousand years of history that has so much to do with modern civilization dates back to the flood-plain of the Nile.

QUESTIONS AND EXERCISES. — Under what conditions and at what times is the stream with which you are best acquainted muddy?

Note and describe any place at which the stream is cutting away its banks.

Note and describe some place where sediment is being deposited. If possible, account for the action in each case.

An embankment of freshly turned earth receives the full force of a rainfall; how will its general form most likely be affected?

RIVER S

AND DR


30° 60° Longitude 90° East from 120° Greenwich 150° 180°
FRANZ JOSEF LAND
SPITZBERGEN
NOVA ZEMBLA
ARCTIC OCEAN
Kara Sea
Gulf of Obi
Lena Delta
ARCTIC CIRCLE
EUROPE
Baltic Sea
ASIA
Okhotsk Sea
Bering Sea
Black Sea
Caspian Sea
Aral Sea
Mediterranean Sea
Japan Sea
Yellow Sea
PACIFIC OCEAN
TROPIC OF CANCER
Arabian Sea
Bay of Bengal
CEYLON
China Sea
PHILIPPINE IS.
AFRICA
EQUATOR
INDIAN OCEAN
MADAGASCAR
OCEANICA
FIJI IS.
TROPIC OF CAPRICORN
AUSTRALIA
TASMANIA
NEW ZEALAND
ANTARCTIC OCEAN
TEMS
AGE.
THE M.–N CO
80° 60° 40° 20° 0° 20° 40° 60°

What effect has sod, shrubbery, and forestry on a surface that is exposed to rain?

Name some results that might occur if the channel of a stream were blocked.

How would the Mississippi be affected if the Ozark highlands were elevated considerably higher? (*See any good topographic model or relief map.*)

What effect will the approaching old age of the Mississippi have on the size of the Gulf of Mexico?

On p. 123 is a map of Chesapeake Bay; make a sketch-map and restore the river channels on the supposition that the surface were uplifted until about the lowest point is higher than sea-level.

Does the appearance of the cañon of the Colorado River suggest an abundant or a scanty rainfall? How would a great increase in the rainfall affect the scenery so far as the topography of the valley is concerned?

What does the absence of tributaries indicate concerning the rainfall of the lower Nile?

From the cyclopædia, or any convenient reference-book obtain a description of the Volga and its delta.

Make a list of ten or more important cities situated on estuary mouths;—two on or near delta mouths.

COLLATERAL READING

Shaler.—Aspects of the Earth, pp. 143–196.

Mill.—Realm of Nature, pp. 241–251.

Davis.—Rivers of New Jersey. *National Geographical Magazine.*

Mississippi River Commission.—Map of the Alluvial Valley of the Mississippi River.

Powell.—Physiography of the United States, Monograph II.

Russell.—Rivers of North America.

Hall.—Geography of Minnesota, pp. 109–149.

CHAPTER VIII

THE WASTING OF THE LAND: THE WORK OF UNDERGROUND WATERS

About as much water sinks into the porous rock waste as gathers in the various external channels. *Telluric*, or underground waters, may not be so active in wearing away the rock envelope as are the surface streams, but they are very important factors in shaping the earth's topography. Surface streams flow quickly away in their channels, but the underground waters must slowly force their way through channels that are ill-adapted to the work; they must also keep these passages clear of obstructions. The work of underground streams is vastly more difficult than that of surface waters.

If the prevailing rock of a region be clay, or slate, or other impervious rock, the underground drainage will be close to the surface, for such rocks not only prevent the passage of water, but most of them are insoluble. In such cases the water must trickle through the top soil much in the same way that water passes through a filter made of sand and gravel—that is, it must flow in the spaces between the particles of rock waste.

If the rocks are near the surface and the amount of water is considerable, swamps may result. That is, swamps may be an incident of imperfect underground drainage, as they are of imperfect surface drainage.

On the other hand, if the rock of a region is mainly of limestone, and more especially if the strata be broken and faulted, underground drainage is usually extensive. The fissures between the faulted strata are likely to become the channels of springs. Not only does the water clear a passage for itself along the lines where the rock is broken, but it also dissolves enough of the limestone to make caverns of vast extent. Singularly, however, the channel may be filled up subsequently with the mineral matter deposited from the water itself.

It must not be assumed, however, that these waters always remain underground. On the contrary, they are constantly in motion, and they finally emerge to the surface.

DIAGRAM SHOWING THE FLOW OF PERCOLATING WATERS

Underground waters are of three kinds—*percolating waters*, *springs* and *artesian wells*, and *underground streams*.

Percolating Waters.—When water sinks into porous ground it fills the spaces between the grains of sand, gravel, or other soil. Some soils are so porous that a cubic foot will contain more than one-quarter of its bulk of water. The latter sinks through the ground until it meets a layer of rock through which it cannot pass. It therefore accumulates until its level is as high as the rim of the impervious rock.

Flowing over the lowest part of this rim, it goes on, perhaps to fill a similar basin lower down the slope; possibly it comes to the surface in the form of a swamp, a pond, or a lake. If the plain or slope is traversed by a river valley a great deal of the water oozes through the soil into the stream. In many instances waters of percolation are an important supply of streams.

This may be seen in the cases of streams that flow through a region of pervious soil. Such streams steadily increase in volume, although for many miles they receive no apparent tributaries. As an example, Spanish Fork, on the west slope of the Wasatch Mountains, receives only two or three small tributaries from the summit to the base of the mountains. It begins as a rivulet, scarcely larger than one's arm; it reaches the base of the range, a mountain torrent twenty feet across. Most of the increment is due to percolating water.

Wells are always filled by percolating waters, and to obtain an abundant supply it is necessary only to sink a shaft below the level of the water. Unless the well is so shallow as to catch the surface drainage, the water is usually cold and wholesome.

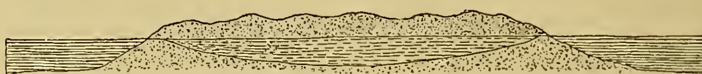
If the area of porous soil is large and has a considerable depth, an enormous quantity of water may be held. The city of London is supplied with water that percolates through the adjacent chalk-beds. The water supplies of many of the towns and villages of the high plains east of the Rocky Mountains are derived in a similar manner.

The "sand valleys" of Western Kansas, Nebraska, and Dakota furnish an excellent example of percolating waters. The storm waters falling in these valleys are almost all absorbed and held in suspension by the deep deposits of porous rock waste. During dry seasons these sand valleys furnish about the only supply of water to the people living in that region. The amount thus held in the porous rock waste is generally sufficient to irrigate the crops that otherwise would perish from drought.

These accumulations of sand, though apparently *hills*, in most cases are valleys filled with rock waste carried thither by winds. In the holding of water capillary attraction is not only an agent of accumulation, but one of retention, also.

The Fresh Water of Islands.—The water supply of small and low islands is obtained in a similar manner. The storm waters fall on the island and immediately sink into the sand until they reach salt water. But inasmuch as the fresh water is lighter it rests upon the surface of the salt water without mixing with the latter.

Artesian Wells.—Underground waters are often confined between strata of impervious rock. In such a case, if the porous layer is reached by boring, the water will be



THE WATER SUPPLY OF LOW SANDY ISLANDS

The lighter fresh water rests on the sea water.

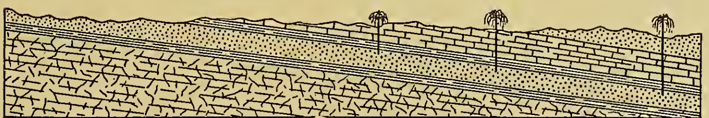
forced up the bore to its normal level. Artificial springs of this character are called *artesian wells*. The "driven" or "piped" wells so common throughout the Mississippi Valley and the prairie region are also examples of such wells. These wells are shallow, however, and tap only the superficial percolating waters. The water is usually brought to the surface by ordinary lifting pumps.

In some artesian wells, however, the water is forced to the surface, not by gravity, but by the pressure of the air or other gases within the reservoirs. In the "gas belt" of the Middle West there are many instances of this sort.

Along the low coast plain of Southern California many artesian wells have been driven, and many acres have been made productive thereby. The first wells were spouters, but subsequently the water failed to reach the surface unless forced. Many artesian wells have been bored in the Sahara.

The amount of desert land made productive solely by artesian wells is not very great. As a matter of fact, not all the artesian wells in the world would supply an area equal to that of Delaware with the water necessary to produce its crops.

Springs.—A small stream of water issuing naturally from the ground is a *spring*. In some cases the water spurts from a sloping wall, such as the face of a cliff, but in most instances it gushes out of comparatively level ground near the foot of a slope. Usually the discharge does not amount



THE WATER SUPPLY OF ARTESIAN WELLS

The porous stratum of the anticline is both covered and underlaid with impervious rock.

to more than a few gallons per minute, but sometimes it is sufficient to fill the channel of a good-sized stream.

The difference between springs and percolating waters is mainly one of degree; issuing from a channel it is a spring, but if the water merely oozes through the soil it is an example of percolation. In Florida several springs, so-called, discharge an amount of water sufficient to fill a river bed. Orange and Silver Springs are so large that small river craft easily enter the mouths. As a matter of fact these springs are the exits of underground rivers.

As a rule, a spring makes its channel. Sometimes the force of the flowing water is sufficient not only to force a passage, but also to keep it clear; in many cases the water makes a channel by dissolving a part of the rock through which it flows. If the quantity of material dissolved be considerable, a *mineral spring* results. Such springs are very common. Those at Saratoga, Vichy, and Carlsbad, are known all over the civilized world.

In volcanic regions, where the rocks are seamed with fissures, the water trickles downward until it comes in contact with heated rocks, and when it again emerges to the surface the water may be at a boiling temperature; it is therefore a *hot spring.*

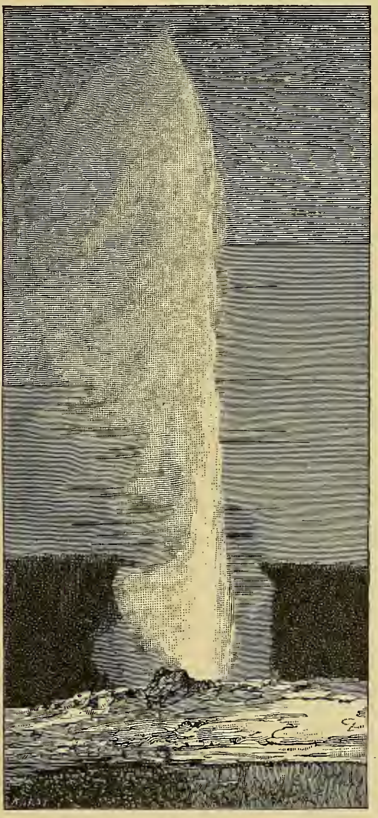
So long as the mouth of a spring is lower than the surface of the waters from which it is derived, the spring will continue to flow, and will be a *constant* spring. If it be situated in a region of periodical rains it is apt to be a *periodical spring*—flowing during the rainy season only. If the flow depends partly on the pressure of air or other gases, an *intermittent spring* may be formed.

From time immemorial the periodical spring has been explained by the existence of a siphon-shaped channel. Doubtless such channels occur, but not a single one is known to exist. In a few instances the pressure of accumulating gases is known to be a cause of intermittent flow, but in the great majority of cases the cause of periodicity is unknown. One of the most remarkable periodical springs occurs in Palestine near the old convent of Mar Jirius. This spring is quiescent for about two and a half days; then its flow begins, lasting for several hours. It is probable that the stream flowing from this spring is the Sabbatic River described by Josephus, which rested for six days, flowing on the seventh.

A spring near Rogersville, Tennessee, is celebrated for the enormous quantity of water ejected. Its period of flow occurs about every half hour, lasting only a few minutes. The Bullerborn, once a famous intermittent spring of Westphalia, has now a constant flow. In regions of very high tides, periodical springs are sometimes formed by tidal action. The fresh water is pushed back by the tide, until it emerges to the surface through self-made channels.

Geysers.—In certain volcanic regions there are springs, which at intervals eject great quantities of hot water and steam at regular intervals. The eruptions occur with almost clock-like regularity. These are called *geysers*.

The essential feature of the geyser is a long, irregular tube that extends deep into hot volcanic rocks. The tube is formed probably by the water itself which, when cool, deposits the silica which its waters had previously dissolved.



A GEYSER, YELLOWSTONE NATIONAL PARK

The water that collects in the lower part of the tube becomes heated far beyond the temperature at which water ordinarily boils, but boiling is prevented by the great weight of the water above. Finally a little steam is formed, and some of the water is forced out at the top of the spring. As soon as this occurs, the pressure being relieved, the superheated water flashes into steam—not gradually but explosively.

Eruptive springs of this character are not common; but three regions are known in which they occur—Iceland, Yellowstone National Park, and Northern New Zealand. Hot mineral springs occur in many other localities, but they are not eruptive.

The geyser region of Iceland has been known for more than a century. It is near active volcanoes and includes about one hundred eruptive springs. The New Zealand group, situated near the volcano Tarawera, is small in area, and contains but few spouting springs.

Yellowstone National Park, Wyoming, contains several groups of geysers, mainly in the basin of Firehole River. It comprises more than ten thousand geysers and hot springs. Of this number about twoscore discharge water to a height of one hundred feet or more; one, the *Giantess*, spouts a column of water two hundred and fifty feet high, while the steam is forced nearly a thousand feet higher. Geyser eruptions occur at periods varying from thirty minutes to about as many hours. Each is preceded by a gentle overflow of water, and commonly lasts from a few seconds to fifteen minutes; but the eruptions of several continue for about two hours. The intervals between eruptions rarely vary more than a few minutes, but careful observations show that their length is increasing, and the energy of eruption is diminishing. The flow of many has ceased altogether.

The deposition of silica from the cooling waters forms terraced basins. As a rule, the deposits thus produced are richly colored with variegated bands. The "Pink-and-White Terraces" of New Zealand derive their name from this fact.

Mud Volcanoes.—Mud volcanoes are hot springs that have piled cone-shaped mounds of mud about their vents. The mud ultimately hardens into a compact mass. Steam and sulphurous gases are commonly the products of these alleged volcanoes. The energy displayed is feeble, and the mud cones are seldom more than twenty or thirty feet high. The mud consists of fine clay formed from the mineral matter of the spring. Mud volcanoes are common in all volcanic regions, and it is thought that the gases given off by decomposing rock create the energy necessary for the miniature eruptions. But this is not true of all.

Underground Streams.—In addition to the multitude of surface streams, much water finds its way to the sea—not simply by percolation but in underground streams. The run-off of streams is mainly above ground, but a considerable part of a stream may, and usually does flow below the surface.

There are several reasons for this. In the first place, whenever a stream flows in a gravelly channel, a great deal of the water sinks into the gravel and flows along the bed-rock bottom. The same is true of rivers that flow through light, sandy rock waste, such as those of the Basin Region of the Rocky Mountains. The underground flow of such rivers is strong even during the fierce heat of summer.

In the daytime, the enormous evaporation frequently causes the water to disappear. In the night, or during cloudy days, when evaporation is lessened, the percolating waters rise to the surface. This phenomenon is occasionally noticed in the lower courses of Humboldt, Carson, and Reese Rivers, in Nevada. The underground part of the river is nearly always to be found.

In many instances small stream channels have been obliterated by filling or grading. Now, although the surface flow may be destroyed, the underground current is not; on the contrary, it is apt to be strengthened. Thus, in some of the larger cities many drainage courses have been covered up in making streets, and it has been found necessary to excavate many of these old water-courses and sewer them.

In most large cities of America and Europe the channels of such streams are plotted, and drainage maps showing their former courses are in common use by engineers and builders. Not infrequently these streams, becoming obstructed, have forced their way to the surface and flooded the streets. Such experiences occur in almost every large city.

Considerable trouble from this cause occurred near the junction of Oxford Street and Edgeware Road, London, the reason being that the famous Tyburn flowed in this locality. About four hundred square feet of Broadway, New York, recently caved in from a similar cause. The foundations of a costly church in Philadelphia sank in the quicksand and the large sewer under one of the principal streets has caved in several times—all because they were undermined by buried streams.

"Lost" Rivers.—Of still greater interest, though not more important, are "lost" rivers. These streams receive their name because they flow for a part of their courses on the surface, and then disappear to flow through subterranean channels. The waters of some lost rivers disappear by percolation, but in most instances the stream pitches into its underground channel through a "sinkhole."

Underground rivers are very common in the limestone area of southern Indiana, Kentucky, and Tennessee. One of these rivers winds its way beneath the floor of Mammoth Cave. Its waters contain fish and two or three species of insect life that have rudimentary eyes only; they have no use for perfect organs, for no light penetrates to their abode.

At Orangeville, Indiana, an underground stream comes to the surface and flows with sufficient force to turn a mill-wheel. Only a few miles away, Lost River, a considerable stream, sinks out of sight. San Pedro Springs, near San Antonio, Texas, is the outlet of an underground stream. Giant Spring, near Great Falls, Montana, is the outlet of Little Belt River, which disappears and flows underground for thirty miles of its course. In Alabama, the engineers of a railway discovered an underground stream sixty feet below the bed of Coosa River.

According to Greek legends, the Alpheus, the river of Peloponnesus, which Hercules turned through the Augean stables, sank underground and emerged to the surface somewhere in Sicily. As a matter of fact a considerable part of the course of the Alpheus is underground; and there is also a spring in Sicily discharging a large volume of water. It is hardly necessary to add that the two have no connection.

Similar streams are found in Weir's Cave, in Luray Cavern, and, in fact, in almost every limestone cavern. In Derbyshire, England, the Hampo and the Manifold flow many miles through underground passages. In both instances the identity of the stream is proved by throwing a floating body into the water above the beginning of its underground course and capturing it when it reappears.

In Southern California, where water is required for irrigation, underground streams have been forced to the surface by building dams across them where they emerge from the cañon. The dams extend from the surface of the ground down to bed-rock. The water is thereby forced to the surface. Where such submerged dams have been constructed, the artesian wells in the plain below are seriously impaired, the flow of water being greatly reduced.

Physiography of Underground Waters.—The work of underground waters is by no means so extensive as that of surface waters, but it is, nevertheless, of great importance. Water has a great solvent power; hot water, especially if under pressure, will dissolve rock that is not affected by cold water. When the solution cools, much of this matter is again set free. In the meantime, if the water has been forced to the surface, the substances dissolved will be carried along and there deposited.

Sometimes the deposits are spread over the surface of the ground, forming *sinter* or *tufa*. If the latter happens to cover loose rock waste or soil, a cavern or cave will result if the material under it be removed.

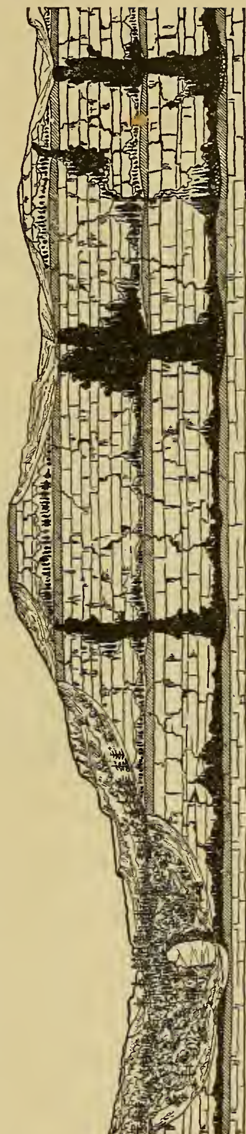
In other instances the hot mineral waters flow into deep fissures in the rocks. As the water cools the mineral matter is deposited on the walls of the fissure until, finally, the latter is filled, thereby forming a *mineral vein* or *lode*. All through mountain regions, veins of banded or "ribbon" rock containing the ores of gold, silver, copper, lead, and

BLUE GROTTO, ISLAND OF CAPRI, ITALY

other valuable metals have been deposited in such fissures. Thus underground waters are a vehicle by which many useful metals are carried from the interior to the surface of the earth.

Caverns.—Most caverns and caves are formed by underground waters. The water dissolves the rock and carries it off, leaving a cavern. Clay, slate, granite, and sandstones are not readily dissolved; and in regions underlaid by such rocks, caverns are rare. Limestones, on the contrary, are soluble, and in localities where they prevail, caves and caverns are common. A joint or fault in the rock is usually the beginning of the formation of a cavern such as is shown in the accompanying illustration. Along this line the water can readily collect. Thereafter the formation of the cavern is a question of time and the solubility of the limestone.

In the cavern district of Kentucky, Tennessee, and Virginia small pieces of sharp flint are plentifully distributed throughout the limestone. These are tossed about and carried along with the water and thus become powerful cutting tools.



THE CHANNEL OF AN UNDERGROUND RIVER—SHOWING THE FORMATION OF SINKHOLES AND CAVERNS

Mammoth Cave, Kentucky, is a labyrinth of passages aggregating more than two hundred miles; the length of the cave on a straight line is about ten miles. Some of the vaults and domes are two hundred and fifty feet high. There are other caves in the vicinity nearly as large. Weir's Cave and Luray Cavern, both in Virginia, are smaller than Mammoth Cave. Howe's Cave, Schoharie County, New York, is one of the few large caverns of interest in the northern Appalachian region. In the grotto of Lueg, Illyria, there are three galleries, one over another. The cavern of Adelsberg, Austria, is the abandoned channel of the Poik River. Its length is about two miles; its labyrinthine passages aggregate many miles. A considerable part of the course of the Poik is underground. Probably the underground passage and caverns of the Timavo have been more thoroughly investigated than those of any other

A SINKHOLE, EDMONSON COUNTY, KENTUCKY

The throat leading to the cavern below has been artificially closed.

stream. The river flows to the Adriatic, a few miles north of Trieste, and its character has been known for more than two thousand years. Concerning it Virgil wrote:

> . . . et fontem superare Timavi
> unde per ora novem vasto cum murmure montis
> it mare proruptum, et pelago premit arva sonanti.
>
> —*Eneid* I., 247.

Virgil's description is no longer true of the delta, for the *nine* mouths have become only three in number.

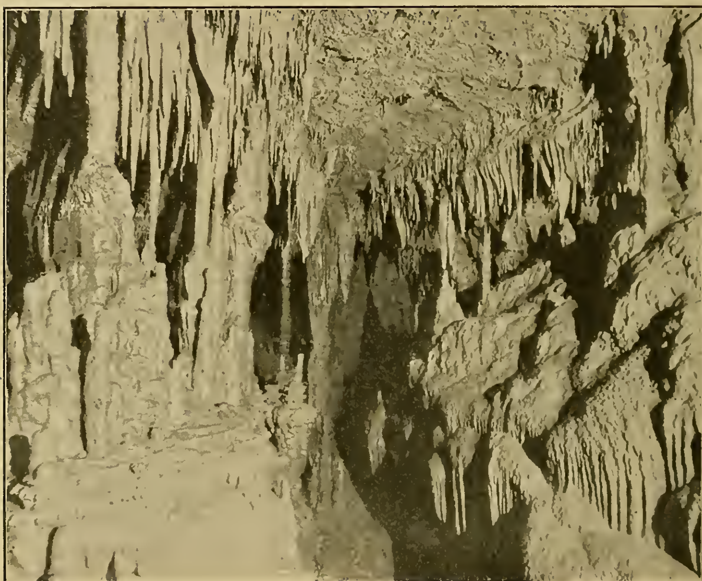
Between the solvent power of the water and the incessant cutting done by the flint particles, the underground channel is worn deeper and wider till a cavern, perhaps a score of miles long and many feet deep, is formed.

But the forces that made the cavern just as surely will destroy it. Surface waters are constantly wearing away the rock that forms the roof of the cavern. In time, holes are worn through the roof and sinkholes are formed. These increase in size and in number until the roof is destroyed. The stream then becomes a surface river flowing in a limestone cañon. Natural Bridge, in Virginia, is a remnant of one of these roofs; the rest of the roof has been carried away.

Many natural bridges of similar origin exist. Near Bogota, Colombia, a natural arch spans a chasm nearly four hundred feet deep. A natural bridge spans Pine Creek, in Gila County, Arizona. The arch is about four hundred feet wide and the span is about a thousand feet in length. The underside of the arch is water-worn, but since it was formed the creek has cut its channel more than two hundred feet downward. In some instances the arch more properly constitutes a tunnel. One, near Clinch River, Virginia, is more than half a mile long, and is a part of the route of a railway. Nearly always a stream of water flows under the arch of a natural bridge, and its current carries away the fragments that fall from the roof.

In the course of time caverns are apt to be filled up by limestone itself. The water charged with limestone leaks or filters through the top of the roof drop by drop. The water leaves a minute portion of limestone at the roof; at the floor of the cavern a little more is deposited. So, little by little, the limestone gathers into icicle-shaped columns, both at the roof and the floor of the cavern. The former are called *stalactites,* the latter *stalagmites.* Finally the two join, forming a single column, and as the water trickles down their sides they increase in size, and thus fill the cavern.

Subsequently, perhaps, this same mass of limestone may be dissolved away and redeposited elsewhere. At all events, the process illustrates the general law that governs



A PASSAGE IN LURAY CAVERN—STALACTITES AND STALAGMITES

cavern-formation in these regions. *Water in motion dissolves limestone and makes caverns; still water deposits limestone and fills them up.*

QUESTIONS AND EXERCISES.—If possible find the depth of each of half a dozen or more wells in the neighborhood in which you live: compare the distance of the surface of the ground to the surface of the water in the wells.

To what depth must a well be sunk beforc it will fill with water?

Will one be apt to find percolating waters in regions having but very little rain?

Explain why water in very shallow wells is apt to be impure.

How do springs become "mineral" in character?

Why does rain water contain no mineral matter in solution?

Why are geysers and hot springs confined usually to volcanic regions?

Under what circumstances or conditions can water be heated above the ordinary boiling point? (*See almost any text-book in physics.*)

Describe a way in which caverns may be formed at the foot of sea cliffs that face heavy waves.

How are the sinkholes in the limestone regions formed?

By using lime-water such as is obtainable at the druggist's, suggest a way in which stalactites may be artificially formed.

COLLATERAL READING

SHALER.—First Book in Geology, pp. 66–87.

SHALER.—Aspects of the Earth, pp. 96–142.

POWELL.—Irrigation and Artesian Wells, pp. 203–290. *United States Geological Survey, 11th Annual Report*, Part 2.

LE CONTE.—Elements of Geology, pp. 103–113.

UNITED STATES GEOLOGICAL SURVEY.—Map of Yellowstone National Park.

CHAPTER IX

THE WASTING OF THE LAND: THE WORK OF AVALANCHES AND GLACIERS

Snow and ice are also important agents in the waste of the land. A great deal of the moisture of the air falls in the form of snow. Very cold regions excepted, the snow that falls below three or four thousand feet melts with the coming of spring and flows away in the various stream channels. In high mountain regions some snow falls on slopes whose temperature is rarely higher than the melting point of the snow. In such localities, therefore, but little of the snow can melt.

Snow rarely accumulates to a depth of more than ten or twelve feet on a level area. On mountain slopes, however, the snow is not evenly distributed, most of it finally lodging in ravines and places not exposed to the sweep of the wind. In laying the foundations for the observatory at the summit of Mont Blanc, the snow and ice were so deep that no rock bottom could be found at a depth of sixty feet. On the western slope of the Sierra Nevada Mountains the accumulation of snow sometimes reaches twenty feet on the level, while the drift may be much thicker.

In the Alps and the western United States, the heaviest snows fall between the altitudes of six thousand and nine thousand feet. Very little accumulates below four thousand feet, and but little falls above twelve thousand feet.

At high elevations, even though the fall may be slight, one might suppose that the accumulation would increase indefinitely; but in high mountain regions various agencies prevent such accumulation. Among them are evaporation, wind, avalanches, and glaciers. They not only remove the snow and ice, but they are also powerful factors in wearing away the land and in transporting rock waste.

Evaporation is active in the removal of snow. Ice and snow evaporate just as does water; and at great heights, where the air does not press so heavily as at sea-level, evaporation is sometimes rapid.

This is seen when frozen roads become dry and dusty without thawing. Wet clothing hung out to dry in very cold weather first freezes and then gradually dries. An inspection of Table III., Appendix, shows that even at a temperature of – 40° F. a small amount of moisture may still exist in the atmosphere.

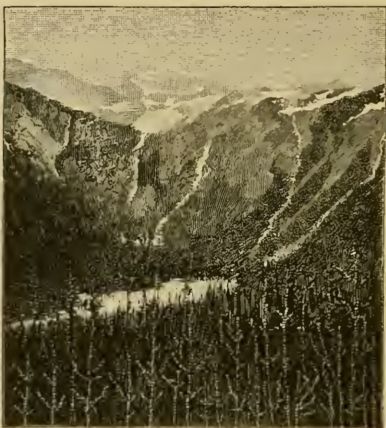
Winds are also a potent factor in the removal of snow. In high mountain regions the wind has a terrific force, and the gales that rage among snow-covered peaks quickly drift the dry snow-dust into ravines and cañons. The power of wind in drifting loose soil has already been noted. But snow is less than one-quarter as heavy as soil; hence the work of wind is far more effective.

There are two factors at work, that are interesting, not only because they remove an enormous amount of snow, but in transporting it they become physiographic agents of great importance. These are avalanches and glaciers.

Avalanches.—When a great body of snow, resting on a steep slope, suddenly slips and plunges down the incline, the moving mass is an *avalanche*, or *challanche*. Excepting the kind of material transported, which is mainly snow, the avalanche does not differ from an ordinary landslide. But although a second landslide rarely takes place in the same track, an avalanche may occur every time the snow falls on the slope. The snow accumulates on the steep slope until its great weight causes it to slip, and the great mass gathering speed, moves downward with a terrific roar.

In certain parts of the Rocky, Cascade, and Sierra Nevada Mountains avalanches are frequent, but they are not so common as in the Alps.

In the Alps, where the slopes are steep, avalanches occur frequently and regularly. In many places the avalanche tracks are as definitely marked as river channels. Indeed, one may consider an avalanche track as the torrential part of a stream whose flow is occasional and spasmodic. Like the mountain torrent, too, it carries to lower levels an enormous amount of rock waste. Not only are avalanche courses distinctly marked, but expert mountaineers are able to predict the occurrence of snowslides with great certainty. The avalanche, therefore, is a feature of mountain economy not less normal than the mountain torrent.



AVALANCHE BASIN, MONTANA

The slopes are too steep to permit the accumulation of snow, and the latter, gathering within the basin, has formed the lake at the bottom of the cliff.

The most destructive avalanches occur in the first hours of sunshine, just after a snow-storm. The flakes are then so fine and smooth that almost any disturbance will start them. A footstep or a gust of wind imparts motion to a handful of snow, and it begins its descent. Gathering fresh material as it advances, and increasing in velocity, it soon sweeps everything before it, carrying havoc and destruction perhaps into the region of cultivated fields, far beyond the foot of the slope. Rocks crash right and left and the whirl of the wind carries eddies of snow a thousand feet or more into the air.

These, the *poudreuses* (powdery snow), are the most dreaded of all snowslides. Damp snow does not shear and move readily; it is the light, dry snow, that has little or no coherence, that is the distinctive feature of this form of avalanche.

When avalanches follow their customary tracks they are neither especially dangerous nor destructive, unless they reach beyond their ordinary limits. But sometimes they take place in localities previously free from them, and these are the cases in which the havoc is greatest. Not only is everything destroyed along the path of the moving snow, but the effects are even more apparent along the edges; for the blasts of wind set in motion by the avalanche, fell every vestige of timber, perhaps a thousand feet or more on both sides. Places that the experienced mountaineers have discovered to be possible avalanche tracks, are now artificially guarded, in order to prevent, so far as possible, the formation of dangerous snowslides.

Another form of avalanche occurs in the Alps at the beginning of warm weather. Instead of light, powdery snow, its volume consists of ice and coarse snow mixed with rock waste. The lower part of the snow and ice are undermined by water as the ground thaws. Finally the whole mass slides down the incline. These avalanches, which do not differ materially from landslides, are rarely destructive.

Landslides.—The sudden descent of great masses of loose rock waste does not differ materially from the ava-

MER DE GLACE—A "STREAM" GLACIER

lanche. It is the sudden degradation of a highland, and the transportation of rock waste to a lower level.

The small landslides along railway cuts differ but little from those that occur on a larger scale on mountain slopes. A considerable volume of loose rock, undermined by water, slides to a lower level because coherence is weaker than gravity. Perhaps the loose material may rest on a sloping surface of rock. Possibly, running water may undermine a cliff until the overhang breaks and falls. In a few instances the landslide has been many acres in extent.

Glaciers.—A great part of the snow that falls on high and steep slopes is either blown into ravines by the wind or is tumbled into them by avalanches. In the upper part of the ravine the snow is light and flaky, but farther down it has begun to melt, and instead of crystals it consists of little granules of ice, called *névé*. Still farther down the ravine, the névé has a striped or banded appearance.

The bands are alternate layers of ice and dirty snow. The ice is formed of snow that has been subjected to great pressure. Because of the pressure all the air has been squeezed out, and for this reason the ice is clear and blue. The bands of snow contain air and are therefore whitish and opaque.

Farther down, the surface is traversed with irregular wave-shaped ridges, and finally it becomes a field of hummocks, half-drowned in streams of muddy water. It ends at length in a mountain torrent.

The ice hummocks are conical in shape and are found at the lower end. Not infrequently one or more of them is surmounted by a large bowlder. The bowlder protects its support from the heat of the sun, while the latter melts the ice around the lower end of the column. Sooner or later the ice column breaks and the bowlder falls to a lower level, where the same process is again repeated.

All this mass of ice and snow constitutes a *glacier*. It is in motion and, excepting the imperceptibly slow motion, its movements are much like those of a stream of water. The flow is faster at the surface than at the bottom, and swifter in mid-stream than at the edges.

Motion of Glaciers.—Because the glacier moves more rapidly in the centre than at the sides, the surface is scored with cracks and chasms called *crevasses*. These are roughly parallel and cross the glacier in oblique lines which point upstream.

CREVASSES AND MORAINE, NISQUALLY GLACIER, WASHINGTON

This peculiar feature gave rise to the opinion that there might be an upstream motion to a glacier. The reason for their direction, however, is evident; the crack or break is necessarily at right angles to the direction of the strain. The movement of the ice is twofold — downstream and away from the bank. Therefore when the ice breaks the crack points diagonally up the slope.

In various cases the crevasses form curving lines that are like the ripples in a river. Ordinarily, the crevasse is narrow and only a few feet deep; but in some places it becomes a chasm fifty or sixty feet in depth. Crevasses are most numerous where the slope is the steepest; in general, they mark what in a river would be the rapids.

The velocity of the flow varies. On a gentle slope it may not be more than three or four inches a day; on a steep incline it may be half as many feet. In summer, when the temperature is above the freezing point, the motion is twice as great as in winter.

Moraines.—As the ice stream makes its way down the ravine, fragments of rock fall from the banks and lodge at the edges. These accumulate until they form walls of considerable regularity. These walls constitute the *lateral moraines* of the glacier. If two or more glaciers flow into the same ravine, the moraines on the sides that join unite to form a *medial moraine.* Several medial moraines may stretch with great regularity a long distance.

Toward the lower end of the glacier, much rock waste gets to the bottom. In summer, when the lower end of the glacier melts, the rock waste, consisting mainly of bowlders and gravel, is strewn along the bed. But in winter, when the ice front again advances, the scattered material is pushed forward, forming the long ridge that constitutes the *terminal moraine.*

The moraines of a glacier are one of its most interesting features. Frequently the shape of the ravine is such that the rocks of the lateral moraine are pushed against the sides, forming walls as regular as though laid by human hands. The lateral moraines may decrease in size, but the terminal moraine constantly grows in volume.

Glacial Ice Sheets.—Glacial movements are not confined to the ice streams of ravines. The sheet of snow that projects over the edge of a roof is a perfect illustration of glacier motion; and so, too, is the patch of snow on a steep hillside that gradually creeps downward or acquires a distorted shape.

But there are remarkable fields of ice many miles in extent, that exhibit the phenomena of glacier movement. These are found mainly in polar regions. They are not confined in ravines; they are sheets that cover large areas. The greater part of the sheet is gradually settling downward; and the ice in many places is projecting beyond the edges of the slope and is breaking off.

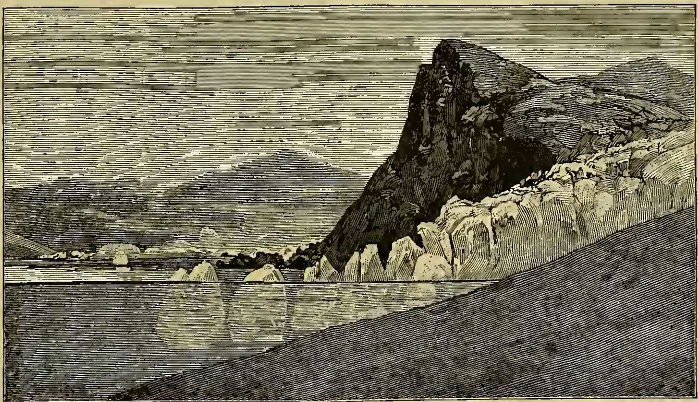
The Greenland ice sheet is a striking example. Almost the entire island is covered with ice and snow that have been accumulating during long periods of time. So far as known, the only rock that reaches above the surface of the ice is found near the coast, where the ice-covering is thinnest.

Along the southern coast much of the ice and snow disappear by melting. Farther north, however, the ice descends into the fjords, sometimes presenting an unbroken wall several miles in extent. In places the flow of the ice sheet is comparatively rapid—as much as forty feet a day.

Humboldt Glacier, on the west coast of Greenland, is a striking example of the ice sheet. For about sixty miles, its ragged front, broken here and there by rock cliffs, forms a sea wall several hundred feet high. The most stupendous ice sheet is in antarctic regions, where it is more than half a mile in thickness.

Icebergs.—The fragments broken from the ice front of glaciers that reach the sea are *icebergs*. Some tumble from the top; most commonly, the edge of the glacier is pushed out into the water and the buoyant force of the latter breaks off fragments. The formation of icebergs along the sea-front of glaciers becomes an important factor in several ways. The icebergs from the west coast of Greenland float southward and during May and June cross the routes of transatlantic steamships, thus becoming a menace to navigation. Several hundred of them at times drift about in the vicinity of the Newfoundland Banks, and remain there until they melt or are broken up by storms.

The huge blocks broken from the Antarctic ice sheet drift about over a very large area, sometimes being found as far north as latitude 40° S. In the North Pacific Ocean the icebergs are small and are rarely found beyond the partly enclosed waters of the Alaskan coast and Bering Sea.



BIRTH OF THE ICEBERG

The buoyant force of the water is breaking off fragments, and the latter float away.

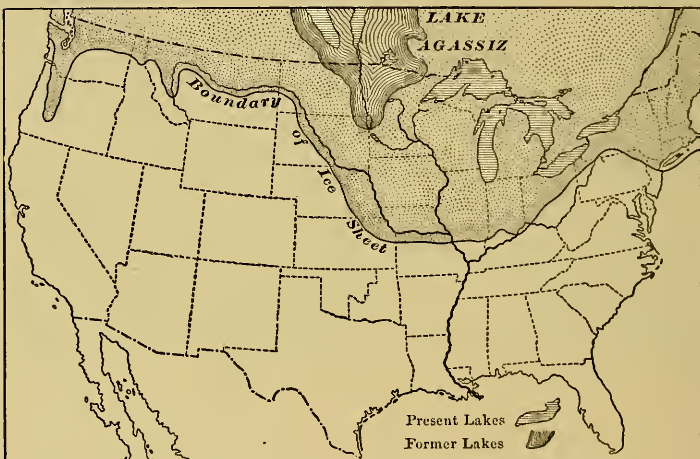
Occurrence of Glaciers.—In general, glaciers begin above the line of perpetual snow and extend a short distance below it. In low latitudes they rarely occur below the altitude of fifteen thousand feet, while in polar regions they may flow into the sea.

The largest stream glaciers known are in the Himalaya Mountains; the best known are those of the Alps. Along the northern coast of Norway there are fine examples; in the Patagonian Andes, and along the Alaskan coast, almost every arm of the sea contains one or more of them. In the

Rocky Mountains there are numerous glaciers, but none of them is of great size. Several of the glaciers of Mounts Shasta and Tacoma (Rainier) rival the Alpine ice streams in extent. Muir Glacier, Alaska, has a frontage of two miles on the sea.

Most of the rivers flowing from the slopes of mountains that reach above the snow line have their sources in glaciers.

Physiographic Effects of Glaciers.—The results of



REGION OF GLACIATION IN THE UNITED STATES

The heavy line shows the limit of terminal moraines: erratic bowlders and small areas of drift occur in occasional localities a little farther south of the line.

glacial action are readily observed in the glaciers of the present time. They are full of character and form an excellent key to study those of prior geological times.

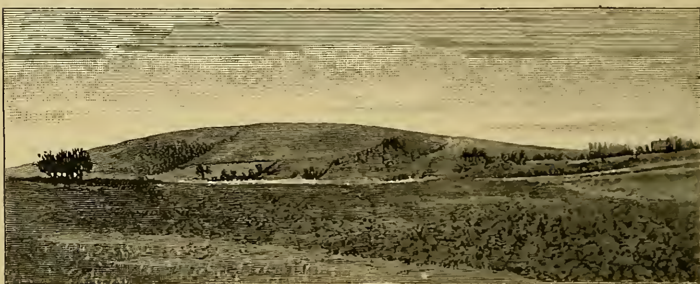
The chief effects of glacial action are erosion and transportation. Ice is so soft that it has little or no wearing effect on hard rock, but if a moving mass of ice drags fragments of rock at the sides and bottom, it becomes a cutting tool of great power, planing, gouging, or scratching, according to the character of the rock which it thus holds, and over which it moves.

All through the northern United States and Canada, westward to the Pacific, the surface has been scoured by glacial ice. Many thousand lake basins have been made or shaped by it. In New England and New York, the grooved and rounded surfaces of the rock are a marked feature, and everywhere the erosion reveals its origin. The northern Appalachian Mountains were worn and broken, and the wide gap between the Adirondack and Catskill ranges was probably made during the glacial epoch. That the surface of the ice sheet did not reach quite to the top of the highest peaks of the Adirondack and White Mountains is inferred from the fact that certain alpine species of plants, still found at their summits, do not occur at a lower level.

The same markings are equally plain throughout northern Europe, and the coasts of Norway and the British Isles probably received their present frayed and ragged appearance at the time when so much of North America was covered with glacial ice.

The Transportation of Drift.—The transportation of material is a still more noticeable effect of glaciation, and the rock waste that has been removed is commonly known as *drift*. Glacial drift is unsorted material, the pieces varying in size from grains of sand to bowlders weighing many tons. The character of the drift differs materially from that of stream gravel; for while the latter is composed of uniformly rounded pieces the fragments of the former are quite as apt to be rough and angular, with one or more faces planed smooth.

Glacial rock waste or detritus has been deposited in various forms. Much of it has been spread over the surface as an imperfectly mixed mass of clay, sand, and gravel. These deposits are the well-known *till* plains of northern Europe and the United States. Sometimes the material takes the form of rounded hills of considerable size, called *drumlins*. These are normally heaps of clay and irregular bowlders, and usually they occur in groups or clusters. They are common in New England, New York, and the region about the Great Lakes. Several of the islands in Boston harbor are drumlins. In many places the waste has been spread out in the form of a long, winding ridge, which extends for miles in the direction which the ice sheet apparently moved. These ridges, called *eskers*, are common in New England and the southern part of New York. It is thought that they were formed by streams of water that had forced a passage under the ice. Irregu-

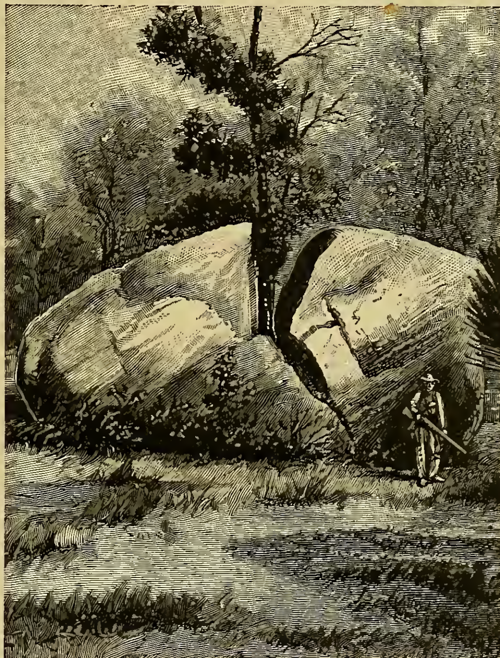


A DRUMLIN

In many instances the surface is covered with fertile soil.

lar clusters of gravel heaps, the material being usually stratified, are also of common occurrence. These heaps are smaller in size than drumlins, and contain little or no clay and large bowlders. They are known as *kames*. Sometimes they have the form of low, winding ridges. Drumlins, eskers, and kames are common in Europe as well as in North America; usually they occur at or near the lower limits of the glaciated region. *Kettle holes*, or bowl-shaped depressions, found where huge blocks of ice have melted and left diffusions, are also common along the lower limit of glaciation. Kettle holes most frequently occur in terminal moraines. They should not be confused with the "pot holes," which are formed by the grinding motion of rock fragments at the bed rock of river channels.

At the southern limit of the glacial ice sheet near the Atlantic, the drift occasionally takes the form of long ridges of bowlders—perhaps many miles in extent, and one hundred feet or more in height. In nearly every instance these heaps are moraines. A part of Long Island is probably a terminal moraine, as also are several of the ridges that cross New Jersey. Many of the low ridges extending into the valleys of Colorado are moraines.



SPLIT ROCK: AN ERRATIC BOWLDER

The butternut-tree, growing from the cleft, is forty years old.

The finer drift of glaciation has been strewn over the northern Mississippi Valley, and now constitutes the surface of the prairie plains. There are several strata of this drift, and the material differs much in productivity. In the northern part of Illinois a creek marks the edge where two areas of drift join. On one side of the stream the land is worth about one hundred dollars per acre; on the other side, it is worth less than one-half as much.

A remarkable form of drift is found in the rounded blocks of stone strewn over the surface of the New England and Middle Atlantic States. These are commonly known as *erratic bowlders*. In mineral character the bowlders are of many kinds; those of the northeastern United States are mainly of granite. The most interesting feature about them is the fact that they are unlike the rock in the locality where they are found; in some instances they have been brought from a long distance. Some of them are of enormous size; one, Split Rock, near Mount Vernon, New York, weighs not far from five hundred tons.

Many years ago this bowlder broke into two parts along a cleavage plane. A butternut-tree grew up in the cleft and in time its trunk has wedged the two fragments apart in the form of a V-shaped opening. In the northern part of Westchester County a huge erratic block has been deposited on the top of three smaller stones, the latter forming a very firm tripod. In a number of instances a bowlder has been deposited on the top of a boss of rock in such a position that the equilibrium, while more or less unstable, cannot be readily overthrown. Examples are found throughout the New England States, and they are popularly known as *rocking stones*. There is a fine example in Bronx Park, New York City. Rocking stones are also common in the glaciated regions of northern Europe.

QUESTIONS AND EXERCISES.—Describe any effects you have noticed with relation to snowslides on the roofs of buildings or steep slopes.

A mass of snow weighing ten thousand tons moves with a velocity of twenty-five feet per second; what is its momentum in foot-pounds? Would this force be sufficient to break off or uproot large trees?

In a previous paragraph it is stated that the water issuing from the end of a glacier is muddy; account for the presence of the mud.

Explain the way in which rock fragments may get to the bottom of a glacier. Why are the scratches made by these fragments parallel?

Why are there no glaciers in the Appalachian Mountains?

The map on p. 164 shows the terminal moraine of the great ice sheet; describe its course and location. Name two large lakes situated in the basin of former Lake Agassiz.

Describe any evidence of glaciation in the neighborhood in which you live, noting drumlins, eskers, moraines, markings and scratches, erratic bowlders, or drift. If possible delineate them on a map.

COLLATERAL READING AND REFERENCE

TYNDALL.—Forms of Water.
TYNDALL.—Hours of Exercise in the Alps.
LE CONTE.—Elements of Geology, pp. 569–583.
HALL.—Geography of Minnesota, pp. 54–74.

CHAPTER X

THE WASTING OF THE LAND: THE RESULTS OF IMPERFECT AND OBSTRUCTED DRAINAGE. LAKES AND MARSHES

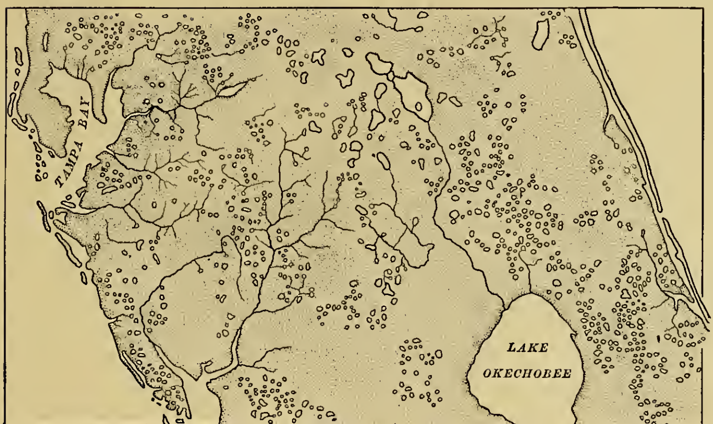
In flowing from higher to lower levels along lines of least resistance, the water may find its passage temporarily obstructed, or perhaps wholly blocked by obstacles. Sometimes a ridge of land prevents its progress; in other cases a landslide or, perhaps, a stream of lava athwart the channel prevents its progress. The water therefore spreads out, forming a *lake, pond,* or *marsh.* In places where the flow is obstructed, one of two things must occur —either the water will collect until its surface is high enough to flow over the lowest part of the rim, or else it will spread over the surface until the amount that evaporates just equals that which flows in. The area whose waters flow into the lake constitutes its *basin.* A large basin usually has several rivers and many small streams that are its tributaries or feeders.

Marsh Lakes.—In a region of considerable rainfall, if the general slope be very decided, perhaps there may be no lakes and ponds, for the reason that the water flows off, meeting no obstructions which cause it to collect in basins. On the contrary, if the surface be flat, the water, finding no definite channels, spreads over the surface and forms a multitude of small ponds. In Florida and along the Gulf

Coast there are excellent examples, and they are commonly called *marsh lakes.*

Marsh lakes are rarely more than a few feet in depth. They are seldom navigable, and commercially they are of but little importance. In Europe many such lakes have been drained in order to make cultivable land of their beds. There are several instances where such basins are filled with water and used for fish culture for a period of several years, and then drained and cultivated for a like period.

Marsh lakes of large size or considerable depth could not form in perfectly flat lands, for the reason that the



MARSH LAKES, FLORIDA

water would flow off as fast as it was supplied. For a similar reason, such lakes could not be very numerous on a surface that had a considerable slope.

Glacial Lakes.—There are many thousand lake basins that are the result of factors with which rainfall has no direct connection, except to fill the basins after they have been made. The most important are those whose basins have been shaped largely by the action of glaciers.

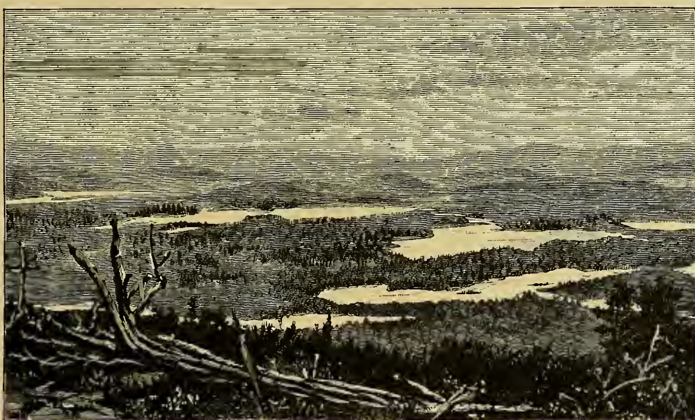
A map of the northern part of North America shows that the lakes of this region are its most remarkable surface feature. As a rule they are long and narrow, and the axes, or lines of greatest length, of each are nearly parallel. Careful investigations have shown that such lakes are comparatively deeper than the marsh lakes previously described, and that, in most instances, their basins have been wrought in the hardest rocks. In certain instances, such as the "walled lakes," their rims consist of walls of bowlders that could scarcely have been more regular had the courses of rock been laid by human hands.

Walled lakes are common in Iowa, Minnesota, and Dakota. So regular are the walls of their shores that for many years it was commonly believed they were built by a prehistoric race of people. As a matter of fact, the walls are the work of ice. In severe winters these lakes freeze nearly to the bottom. When the water freezes, the ice expanding, pushes the bowlders shoreward. This process has been repeated until the rocks were pushed back to a position where the resistance of the earth back of them was equal to the pushing force of the ice.

In many instances glacial lakes occur in chains, a river following the course of each chain; indeed, these lakes are merely incidents in the history of the river. A cluster of such lakes radiates from a central point, as is seen in the "finger" lakes of New York. Glacial lakes are closely associated with the great accumulation of glacial ice that formerly covered a large part of the northern hemisphere. The lakes themselves are found in glaciated regions only—never elsewhere. In the carving and sculpture of their basins, the fragments of rock held in the grip of the ice were the cutting tools.

Accidental Lakes.—Occasionally, a lake is the result of accident—such as the destruction of a river loop, the damming of a stream, the formation of a bar across an estuary or cove, or the sinking of an area of land.

In the illustrations pp. 114 and 116 there is shown a type of lake that is common along the bottom lands of the Mississippi and of other rivers that flow through level plains. The origin of such lakes is apparent. They are manifestly the abandoned loops of the river, and they are formed when the latter straightens its channel. The *moat* thus

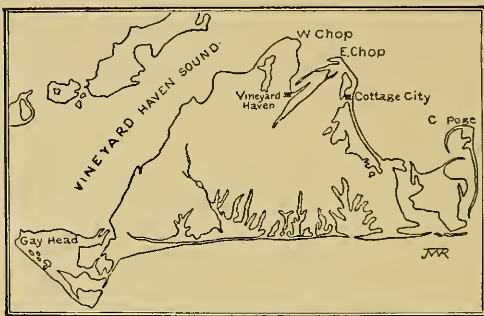


GLACIAL LAKES

A group in the Adirondack Mountains, New York.

formed remains filled with water. A bayou or small stream may remain as a feeder, but sooner or later the moat becomes a stagnant pool—possibly to be overgrown by vegetation, or to be buried under the sediment brought down by floods.

Another type of accidental lake occurs along low, flat coasts. These are the *lagoons* of the sea-shore or the lake-shore. The south coast of Marthas Vineyard furnishes an excellent illustration of lagoons of this type. In times past, this shore was a succession of coves and small bays. But the water on this side of the island is so shallow that the waves, dragging on the bottom, finally pushed enough sand before them to make barriers across the coves, and thereby shut them off from the ocean.



LAGOONS: MARTHAS VINEYARD

In the western part is a blocked river.

Not only have coves of the seashore been shut off, or "bottled," by bars, thus forming lagoons, but the same process has been carried on along the shores of lakes. Such lagoons are in process of formation at the head of Lake Superior, Lake Erie, and Lake Ontario. The formation of the lagoon is not always complete, because the current from the river may keep a channel open.

A map of the United States or of Europe will show many such wave-formed lagoons. Those nearest the shore are sounds rather than lagoons. But as the coast extends seaward, many of the lagoons now near the shore will ultimately be at a considerable distance inland. Albemarle and Pamlico Sounds are examples, and they remain as sounds for the reason given. In other words the sound is often an intermediate stage between a bay and a lagoon.

In other instances flowing lava has blocked a river channel and formed a lake. In two places the Columbia River was thus blocked, and the high-water marks of the lakes formed are still plainly visible. But the river succeeded in recovering its channel and the lakes were therefore drained. Accidental lakes, resulting from the blocking of a river channel by coulées of lava, are common in volcanic countries.

Still another form of accidental lake is the *crater* lake, which is merely an old volcanic crater filled with water. Crater Lake, in Oregon, and Lucrine Lake, in Italy, are examples. The former is about 2,300 feet deep.

Salt Lakes.—Salt lakes have no outlets, and they are salt for that reason. Nearly all soil contains more or less mineral salts that are soluble in water. Even the hardest granites and igneous rocks contain some soluble matter. So when the water flows to the basin, it carries with it the soluble matter with which it comes in contact. If the lake or pond has an outlet, both the water and the dissolved matter flow off together. If there be no outlet, however, the water is removed by evaporation, while the mineral salts, which cannot evaporate, remain in the basin. In time, the water becomes so saturated that it will dissolve nothing more. After this, unless there is an inflow of fresh water, the salt sinks to the bottom, and forms also a wide margin of crusted salt along the shore.

In many cases the carbonates of alkaline metals are present in such quantities that the waters of the lake are strongly alkaline. Many of the lakes of the Great Basin are alkaline.

Utah Lake overflows into Great Salt Lake through Jordan River, and its waters are fresh. Lake Chad, in Africa, is normally without an outlet. In seasons of unusual rains, it overflows into the Libyan Desert, and this occasional overflow has been sufficient to keep its waters comparatively fresh until recent times.

The waters of the Caspian Sea are moderately salt. On its eastern border is a lagoon, the Karabogas, connected with the main body of the lake by a narrow strait. The waters of the gulf are very shallow, and so great is the evaporation, that a four or five knot current constantly flows into it from the main body of water. From this inflow about 250,000 tons of salt are deposited daily. If this amount of salt were left in the lake the latter would become a saturated brine. But because of this deposit of salt, the waters have not become materially saltier since measurements have been made.

Temperature and atmospheric moisture are also factors in the origin of salt lakes. High temperature and dryness of the atmosphere promote evaporation; and doubtless there are lakes now fresh, that would become salt were the temperature to increase and the rain-fall to decrease materially.

Although salt lakes have no outlets, it is not necessarily true that lakes without outlets are salt. As a matter of fact, there are many lakes without outlets whose waters are about as sweet and pure as when they fell from the clouds. Of this apparent contradiction there are two explanations.

In the first place the lakes may be young. In this case, time only is required to change the fresh water to a salt lake. The time will be short if the soil through which the feeders flow contains much soluble matter. In the second place, all the soluble matter may have been washed out of the soil at the time when the lake overflowed its basin. There are fresh lakes without outlets in Canada and the United States that will so remain for a long time unless the conditions of their existence are changed.

A salt lake may become fresh by drying up. During a long-continued period of drought, it may dry up, leaving its mineral salts as a deposit upon the bottom. In time the winds cover this saline crust with fine soil; and when the lake again begins to fill, its waters are fresh. Pyramid and Winnemucca Lakes in Nevada are illustrations; their waters are comparatively fresh.

Playa Lakes.—Certain lakes, in arid regions, are periodic in character. During the rainy season they may be of considerable size; they have no great depth, however, and in the dry season their waters evaporate, leaving in each basin a thick crust of salt. There are numerous small lakes of this character in the western part of the United States; some of those in southern Russia are of considerable area. Lakes of this kind are commonly called *playa lakes*. Commercially some of them are important on account of the enormous amount of salt they yield.

Physiographic Aspect of Lakes.—Lakes are the most transitory features of the earth's surface. Rivers and the various relief features of the earth are seldom entirely obliterated; but a lake is almost ephemeral. There are various forces constantly at work to destroy it. Physiographic agents that have no effect on other features of the earth may be fatal to the existence of lakes.

Among them, glaciers are, perhaps, the chief. Glaciers have been energetic factors in making lakes; they have also been quite as effective in causing their destruction. The glacier blocks the channel of a river with ice or with gravel, and a lake is formed. Later it may force a passage through the obstructions made, and in a little while the lake has disappeared. A few old shore marks and, perhaps, a delta or two are all that remain.

Lake Agassiz, a body of water considerably larger than the five great lakes, formerly covered a large part of the valley of the Red River of the North. The destruction of this body of water was caused probably by glacial action. It had several outlets, one of which was the present channel of the Minnesota River.

The elevation or the depression of a lake bed always produces great changes. Such elevation may throw up a ridge so as to form a basin for a new lake; depression may lower the land at the foot of the lake and destroy the basin of an old one. Long before the existence of the lakes whose remnants are now found in the Great Basin, a vast body of water covered much of the surrounding region. But a change in the level of the basin occurred, and this, together with probable changes in climate, caused the internal sea gradually to disappear.

This lake preceded the lakes now in the Basin Region and was older than the Uinta Mountains. The bed of the lake seems to have been lowered, and this was probably a factor in its destruction.

A BURIED LAKE BASIN

The basin has been filled with sediments brought into it by the river.

Rapidly growing vegetation is also a factor in the destruction of lakes. Vegetation has not much effect on deep lakes, but it has a great effect on marsh lakes. The process is simple: the roots, stalks, and leaves of the dead plants fill the basin until there is no more room for the lodgement of water. The plants begin their growth at the edge of the lake and spread toward the centre, little by little filling the basin. The struggle may be a long one, but in the end the vegetation conquers. Buried and partly obliterated lakes of this character are common in all coast plains and level lands.

One near Goshen, New York, covering an area of about sixty square miles, has disappeared within recent times and most of its former bed is now cultivated land—the famous "onion fields" of the State.

Winds may help in the destruction of a lake, especially the lagoons along the sea shore. They merely carry enough fine rock waste into the basin to fill it. The rock waste is piled upon the windward shore; each new deposit narrows the distance between the shores. The former lagoon is filled, and the estuary becomes a part of the coast plain.

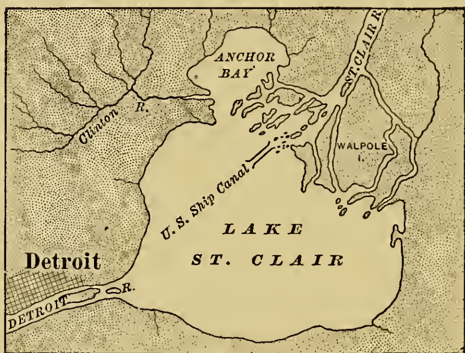
Lake Mœris, in Egypt, was probably destroyed in this way. It was situated southwest of the Nile delta and disappeared within historic times; but until within a few years its exact position was not known. In this region the movement of wind-blown rock waste is incessant, and the amount moved in even a few days is enormous. Canals which formerly crossed the Isthmus of Suez have been filled by wind-blown rock waste, and appearances suggest that the isthmus itself was formed chiefly by winds.

There are other lake-destroying agencies, and though their manner may not be apparent, it is none the less effective. "Rivers are the mortal enemies of lakes" (Gilbert). The stream that flows into a lake carries sediments which, little by little, fill its basin.

At the place where a stream enters a lake, either a delta or a bar forms. This is clearly illustrated by the Volga; by the St. Louis, at the head of Lake Superior; and also by St. Clair River, at the head of Lake St. Clair.

The stream that flows out of the lake is equally destructive. It cuts away the rim of the basin, lowering the level of the lake until the water is nearly or quite drained. Many lakes have disappeared, and many are perceptibly diminishing in size from this cause.

A diminution of the rainfall in its basin will eventually destroy a lake. The lakes and old lake-beds in the Great Basin illustrate this fact. Formerly Great Salt Lake and its scattered remnants covered an area almost half the size of Lake Superior. In a former period, the level of the lake was nearly one thousand feet higher than at present. But subsequently, between elevation of its basin and a decrease of rainfall, the lake has dwindled to its present size.

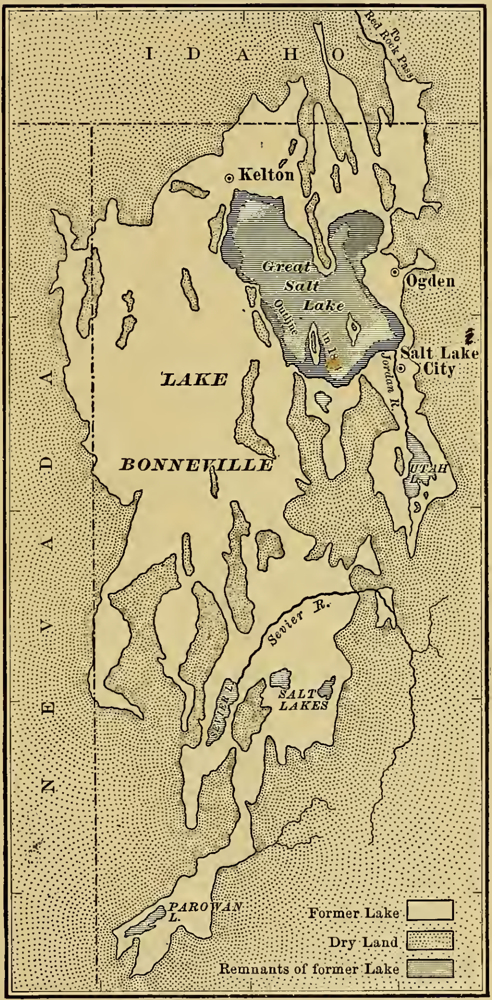


LAKE ST. CLAIR

The mud flats at the head of the lake are the result of sedimentation.

In various parts of the world old shore-lines occur high above the present surface of the water. In some instances they mark the sites of lakes that have ceased to exist; in others, of lakes that are disappearing. In any case, they demonstrate the transitory character of lakes.

The old shore-lines of Great Salt Lake are still strongly marked, and have been surveyed along almost the entire circuit of the basin. Old shore lines have been found above the present level of Lakes Titicaca and Maracaibo—a clover-leaf bay, rather than a lake. Two old shore-lines of Lake Ontario have been found in New York, one of which may be traced along nearly the whole of the southern shore. Its level has been somewhat warped by a vertical movement.



LAKE BONNEVILLE AND ITS REMNANTS

The area in white shows the former size of the lake; the small lakes south of Sevier River are practically dry.

Many of the lakes of the United States have disappeared within recent times. Sevier Lake in Utah has practically ceased to exist, and Tulare Lake, California, in thirty years has shrunk to less than half its former size; practically it has no outlet. The finger lakes of New York have lost a measurable part of their area in the past fifty years, and the level of Lake Erie has been materially lowered. The diminution has interfered with navigation to such an extent that a barrier across the outlet is contemplated in order to raise its level.

There is possibly a lowering of the basin of the Great Lakes on the western, and an elevation on the eastern side. Recent surveys point strongly to such a movement of the basin. A continuance of this oscillation, aggregating twenty feet, will practically close the lower end of Lake Erie, and cause an overflow of Lake Michigan into the Mississippi.

Waves and wind currents affect lake shores in the same manner as they alter the shores of the sea. Bars and spits are formed in the same manner; and the platforms made along the shores of lakes do not differ materially from marine platforms. The old beach of Lake Ontario (p. 180), is now the course of a famous highway known as the "Ridge Road."

Geographical Distribution of Lakes.—Lakes occur in all parts of the earth, but they are by no means uniformly distributed; about ninety per cent. of them are north of the 40th parallel of north latitude.

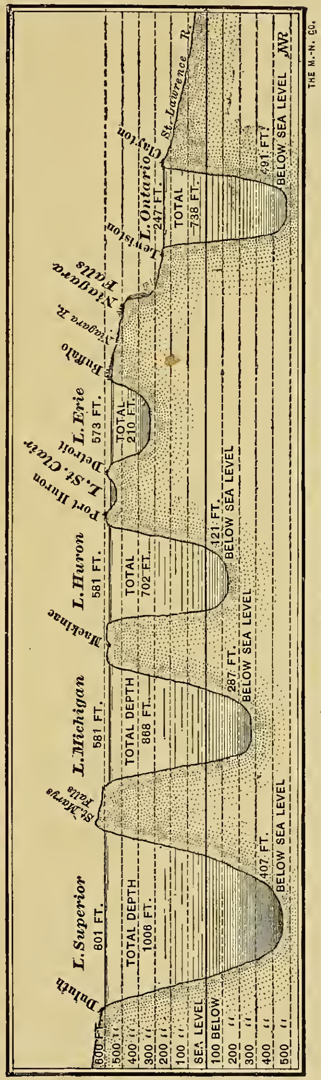
With respect to glacial lakes this law holds almost universally true. The chief exceptions are those found in the southern Andes and the high ranges of Asia. Most of the glacial lakes are in Europe and North America. In the latter division alone there are about one hundred thousand. Why are they of rare occurrence in the torrid zone?

Salt lakes are confined mainly to regions of deficient rainfall. Why are they not common in regions of abundant rainfall? Most of them occur in the basin regions of North America and Eurasia; in the latter region there are several thousand. The Caspian "Sea," the largest lake in the world, is in this region; its surface is eighty-four feet below sea-level. Playa lakes are numerous in regions having a level surface and a light, periodic rainfall.

In general, lakes may be grouped in systems which occupy lines of depression on the earth's surface. Two such systems are found in the Western and three in the Eastern Continent. The lakes of the Western Continent are chiefly in North America, and are embraced mainly in two systems. The largest and most important is the belt stretching across the northern part of North America.

An arc of a great circle drawn from the city of Buffalo to Point Barrow passes through or near the groups that include the largest bodies of fresh water in the world. Another system extends from the northern boundary of the United States southward through Mexico and the Central American States. Most of these are situated in a basin region; describe their drainage and character.

South America has remarkably few lakes. There



A PROFILE ALONG THE GREAT LAKES

are playa lakes along the eastern base of the Andes, but the only lake of importance is Titicaca, a large body of water near the summit of the Andes. Its surface is 13,000 feet above sea-level, and it is the highest large lake in the world. Although Lake Titicaca has an outlet, its waters do not reach the ocean.

In the Eastern Continent a wide belt of lakes, situated mainly between the 50th and 60th parallels, extends across Eurasia. These lakes constitute the great majority in number, but they are not important.

A second belt follows the high mountain-ranges that stretch from west to east across the continent. It embraces the glacial lakes of the Alpine and Himalayan folds, and the playa and salt lakes of the basin region. The largest and most of the important lakes of the continent are in this group. A third system in Africa follows the line of the great rift and, unlike the other systems, extends north and south. Next to those of North America the African lakes are the largest bodies of fresh water in the world.

In one respect the Australian lakes are remarkable—almost every one is either a playa or a salt lake. Not one of importance has an outlet to the sea. What does this indicate with reference to the rainfall of the continent?

Swamps and Marshes.—In some places the drainage waters cannot flow off, but remain at the surface, thereby forming *swamps, morasses, pocosons, bogs, and marshes.*

It is difficult to draw the line between marsh lakes, swamps and meadow lands. The difference is practically one of degree. A lake or a shallow lagoon passes through all the intervening stages.

In many instances the emergence of underground waters to the surface by percolation causes swamps. The various *bolsas* on the coast plain between Los Angeles, California, and the ocean are formed in this manner.

Inasmuch as imperfect and obstructed drainage results in marshy ground, it is evident that the latter may be caused by many different factors. For instance, the surface of the land may be so nearly level that the water cannot run off until it has saturated the soil. This is a common occurrence in coast plains, and the marsh lakes of Florida are an example. They also occur along the low flood-plains of rivers, where they are known as river *terrace swamps*. Frequently such morasses occur at the mouths of rivers, where they form *delta*, or *estuary swamps*.

In some instances the accumulation of vegetable matter results in swamps. The leaves and twigs of forest growths quickly decay if they fall on dry ground; but if the ground be wet there may be no complete decay. The vegetable matter gradually forms a black slime and a mass of fibrous material called *peat*. The accumulated matter may prevent drainage and a swamp may result. Most *woodland swamps* are formed in this way.

The character of the vegetation is an important factor in swamp-making. Several species of *sphagnum*, a kind of moss, are intimately connected with swamps. One of these water mosses consists of long, thread-like stems which, while dead at one end, are living and growing at the other. The dead portions do not decay; they simply accumulate, packing tightly like an immense mass of sponge.

It is well to bear in mind that peat is not a *plant*, but a *condition of imperfect decomposition* that, under certain conditions, almost all vegetable tissue may assume. The softer parts of the tissue have been changed to a black slime, or *bitumen*, a mixture of nearly pure carbon and hydrocarbons; the wood fibre remains. It is likely that the incorrect popular notion has arisen from the fact that nearly all the peat used for fuel is derived from species of sphagnum.

If, therefore, the ground becomes wet enough for the water-loving sphagnum to thrive most likely the area will become a swamp. In time a hollow, a pond, or even a marsh lake will be entirely filled with the stems of sphagnum, thus forming *peat bogs* and *lacustrine swamps*.

EFFECTS OF VEGETATION

Swamp vegetation beginning at the shore, is extending outwards.

Although all lacustrine swamps are old lakes that have been destroyed by vegetation, not all of them become peat bogs. In many instances the lake is situated north or south of the latitude in which sphagnum grows. The peat bogs of Ireland are historic, but they are not more extensive than those of the Danube. Peat bogs occur in nearly every country in which sphagnum grows.

If sphagnum once takes growth, a level surface is not necessary for the formation of swamps. The sphagnum will make its way up a slope of four or five degrees and thus form a *climbing bog*. Such bogs are common in the Scandinavian Peninsula, in Nova Scotia and in the New England States.

EFFECTS OF VEGETATION

Swamp grasses and sphagnum have nearly filled the lake, and a quaking bog has formed at the edges.

Sphagnous growths not only overwhelm shallow ponds and lakes, by filling their basins, but they sometimes attack deeper waters. If the moss stems cannot find lodgement at the bottom of the lake they will float at the surface, spreading until the surface is covered. The mat of sphagnum grows thicker and broader, and is made firmer by slimy matter, which results from decomposition. In time the surface becomes firm enough to serve as the bed of a wagon road, or even a railway. But the surface never becomes quite firm, and when a wagon is driven over it, the shaking is perceptible. In this manner a marsh lake is changed to a *quaking bog*, or *prairie tremblante.*

Quaking bogs are very common in the swamps of the South Atlantic States. Usually the mat of sphagnum spreads from the margin toward the centre, but in many instances patches of the plant accumulate in the open water, forming islands. Generally the insular patches are attached to the bottom, but sometimes they float, spreading marginally until the surface is covered. In California a branch of the Southern Pacific Railway was built across a quaking bog. Subsequently, the surface caved in, engulfing several cars of a freight train.

Canebrakes have more or less to do with swamp formation. Canebrakes are sometimes associated with swamps as a *result*; as a matter of fact, they are frequently a *cause* of swamps. The roots of the plant, spread below the surface of the ground in much the same manner as does the sphagnum above ground, and the accumulated matter finally becomes an impervious mat that almost wholly obstructs drainage.

Coast Marshes.—Coast or salt marshes are destitute of water mosses, but they contain other species of vegetation quite as effective in the formation of marshes. The first step in the formation of a salt marsh is an area of shallow, still water. This condition results as soon as a sand-bar is thrown across the cove. Along an open coast, waves prevent the formation of a marine swamp, but in throwing up a bar they make the conditions which are necessary for its existence.

The growth of eel grass, a plant with a long, slender blade, is the next stage. The eel grass grows rapidly, and the half-decayed remains help to fill up the marsh. But eel grass grows only when covered with salt water. And when the decayed vegetation, mixed with wind-blown rock waste and the mud deposits of high tides, has filled the cove to low-tide level, the eel grass perishes. After a time the marsh receives additional layers of sediment that build its surface so high that it is awash at high tide only.

By this time true salt-marsh grasses, reeds, and rushes obtain possession. These species thrive best when their roots are covered with salt water at short intervals. They accumulate until the level of the marsh is built above the level of the highest tides. When this stage is reached turf grasses gradually take the place of salt-marsh grasses, and the marsh becomes meadow land.

Another plant active in the formation of coast swamps is the mangrove tree. This tree thrives only in salt water. It propagates itself partly by upshoots from the roots that trail under water, and partly by seeds. The spreading of mangrove roots and trunks is so great that coast outlines are extended. In Florida mangroves and corals are adding measurably to the swamp-land surface of the state.

The tundras of the Arctic coast plain furnish an interesting example of the combined action of ice, fresh water, salt water, and moss. These shores are almost constantly covered with ice. Not only are they inundated by tidal waters, but also by stream waters. When the mouths of the streams are frozen, the flood water, finding its channels blocked with ice, spreads over the surface.

During flood seasons the stream waters are filled with sediment, which is spread over the plain. Moreover, the sediment furnishes sufficient nutriment to heavy growths of coarse moss, and the latter, in turn, not only holds the sediment in place, but it also helps to prevent the melting of the ice. As a result, this plain is perpetually a half-frozen morass.

Physiographic Aspects of Marshes.—Although the area of marsh lands at any one time is comparatively small, much of the land surface of the earth has been a marsh in some period of its existence. Marine marshes may be considered as land at an intermediate stage between submergence and elevation. Hence, volcanic areas excepted, the lagoon, the eel grass swamp, the mud flat, the salt marsh, and the meadow is each, in turn, an incident in the final elevation of a body of land above sea-level.

Along the coast of the South Atlantic States one may find the lagoons and the eel grass swamps; along the shores of the Gulf there are, in addition, very broad mud flats. Surrounding New York and San Francisco Bays are many square miles of salt-grass and tule marshes; and almost everywhere beyond the reach of tidal waters there are meadow lands.

The mud flat stage is the area that is uncovered at low tide. If the slope is gentle this belt may have considerable width; and this is seen along the coast of the South Atlantic States and the shores of the Gulf.

The range of fresh-water swamps may not be so great as that of marine swamps, but economically the latter are quite as important as the marine marshes. Their evolution is more complex than the development of marine marshes, but in two respects they are alike—namely, *vegetation makes them and, in the long run, it likewise destroys them.*

Vegetation may, and usually does, create swampy conditions, but the process of destruction does not differ from that of creation. The accumulation proceeds until the surface is at a level where the waters may flow off.

Cultivation destroys swamps, and the process of destruction is simple. Most grains and food-stuffs require a comparatively dry soil, and the very act of ploughing creates drainage channels in which the water flows off. Where ploughing has not been sufficient, ditching and tile-draining accomplish the same results.

But swamps themselves exert a considerable influence on vegetation and its distribution. Many species of trees and shrubs that thrive in dry soils perish if the soil be saturated. Therefore, a swamp once forming in a woodland may destroy much, or even all the forest growth. In almost every fresh-water swamp one may find an abundance of stumps and trunks of dead trees—a result of the development of swampy conditions.

Economic Value of Swamps.—Though practically uninhabitable for human beings, swamps, marshes, and bogs have had a very far-reaching effect in the development of civilization. In evidence of this the coal beds may be cited. The enormous development of commerce and manufactures is due almost wholly to the coal fields of the world, and these almost without exception are products of the swamps and marshes of prior geological ages.

The swamps of the present time will be the productive areas of the future. The soil is deep and its nutrient qualities are great. Swampland crops are important and the rice-swamps probably supply food to a greater number of people than all the other grain fields in the world. Incidentally, the world's supply of cranberries comes mainly from swamps, and the peat bogs furnish fuel to fifty millions of people.

The Movement of Rock Waste.—In this and the preceding chapters it has been shown that the higher parts of the land are almost everywhere crumbling and wasting away under the action of water in one or another of its different forms. Rain, snow, ice, running streams, and even the winds are factors that are unceasingly active, and their legitimate work is to wear away the land and transport the waste to sea-level.

On the steeper slopes, as a rule, the rock waste is coarse, the fragments sometimes weighing many tons. On its way downward it is broken and worn in various ways until, at sea-level, it is very fine. Much of it is also mingled with the remains of vegetation, and becomes soil. The latter is deposited in river valleys and becomes a part of the structure of flood-plains, delta-plains, estuary plains, and coast plains. Some of the waste, temporarily retarded along its downward journey, fills depressions, and forms lacustrine plains; and all of these are factors not only in economic history, but in political history, as well.

The waste of the old land is the material of the new.

QUESTIONS AND EXERCISES.—Study any lake or pond near which you live and classify it as marsh, glacial, swamp, or salt; make a map of it.

Note whether a coast plain is present, or whether the water-level is at the foot of cliffs or banks.

If there is a fringe or belt of coast plain what does it indicate concerning the present and the former size of the lake?

Note whether or not the border is marshy and thickly covered with vegetation, or whether it is strewn with large bowlders.

In what, if any, part are the waters muddy? From this determination endeavor to find where the sediment is chiefly deposited.

From the foregoing write a description of the body of water.

From the profile of the Great Lakes, together with a good map, p. 183, prepare a description of these lakes. What will be the effect of the recently completed ship canal at Chicago, on the level of Lake Michigan?

What would be the effect on the character of the water were the basin of the Caspian Sea to fill until it overflowed?

If the basin of the Black Sea were elevated twenty or thirty feet what would the water be, salt or fresh?

Mention some of the benefits resulting from the Great Lakes of North America, with reference to commerce, industries, and climate.

Which of the two Great Lakes may be regarded as a single body of water? Why?

The level reach of land in the illustration, p. 178, was formerly a lake; explain how it became the flood-plain of a mountain stream.

From any convenient source of reference write a description of Death Valley, or of the Dead Sea, Syria.

From the map of the marsh lakes, p. 171, prepare a description of them, concerning their depth, altitude, and navigability.

COLLATERAL READING AND REFERENCE

Russell.—Lakes of Nevada, *Physiography of the United States*, pp. 101–130.

Le Conte.—Elements of Geology, pp. 80–82, 580–581.

Shaler.—U. S. Geol. Survey, An. Rep't, 1800.

Hall.—Geography of Minnesota, pp. 169–220.

CHAPTER XI

OCEAN WATERS AND THEIR MOVEMENTS: WAVES, TIDES, AND CURRENTS

Almost all the phenomena connected with the wasting of the land, with climate, and even with the existence of life, in one way or another depend on the sea. In at least two ways the sea differs from other bodies of water. It is many thousand times the size of the largest body of fresh water and, two or three inland lakes excepted, its surface level is lower. The sea supplies the land with fresh water, and because of its lower level, almost all the waters of the land sooner or later flow back into it.

Sea water is briny and bitter; doubtless it has always been thus, but inasmuch as the stream waters flowing into it are constantly dissolving mineral matter from the rock waste and carrying it to the ocean, the amount in the latter is constantly increasing. Every one hundred pounds of sea water, on an average, contains about three and one-half pounds of saline matter; most of this is common salt, the remainder being chiefly lime and magnesia. The percentage of mineral matter varies. In localities where evaporation is rapid, the proportion of salt is larger. Thus, in the Red Sea it is more than four per cent., while in the Baltic Sea it is less than one-half as great. It is somewhat greater in tropical than in polar regions.

Bulk for bulk, sea water is heavier than fresh water. A cubic foot of fresh water weighs about 1,000 ounces; on

THE SEA: FAIR-WEATHER WAVES

Reproduced from a photograph by courtesy of H. S. Wyer.

account of its mineral matter the same volume of sea water weighs at least thirty-five ounces more. Temperature also affects the density of water; if 1,000 cubic inches of water at the freezing-point be heated to the temperature of a hot summer day, its volume will be increased seven or eight cubic inches. The differences in temperature and density have far-reaching results; for upon these variations the general circulation of the waters of the sea in part are due.

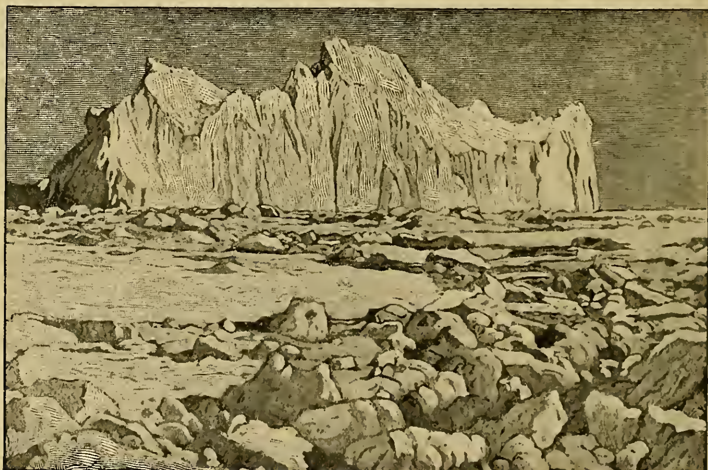
The temperature of the sea varies with both latitude and depth. In general, the surface waters of equatorial regions are warmest, and in the broader extents of the sea their temperature is not far from 26° (79° F.). Toward the poles it gradually falls, and in polar regions it is rarely much above the freezing-point. The variation of temperature with latitude is by no means uniform, however, for in various places warm water dragged by the "skin friction" of winds is frequently found in high latitudes.

With relation to depth the variation is remarkably uniform. In low latitudes the bottom temperature of deep water is a degree or two above the freezing-point of fresh water; in polar latitudes, a degree or two below it. In shallow waters and land-locked basins, however, the variations in temperature are usually very irregular. Thus, the entrance to the Gulf of Mexico is blocked by a submarine ridge whose crest is 1,200 feet below the surface, and because of this, water whose temperature is lower than that of the 1,200-foot level cannot enter the Gulf. But even at a depth of 12,000 feet, the temperature varies but little from that of the 1,200-foot level.

The freezing temperature of salt water is lower by two or three degrees than that of fresh water, the difference depending mainly on the amount of mineral salts in solution. The ice of the sea is therefore formed in high latitudes, where the temperature is much below the freezing-point.

Bulk for bulk, ice is lighter than water. Solid sea ice floats with about one-eighth of its mass above the surface. It it contains air bubbles, however, a greater proportion is out of water.

Sea Ice.—Sea ice takes various forms. The nearly level and narrow shelf that in polar regions forms along the



ICE OF THE SEA: FLOE, PACK, AND BERG

shore, and skirts almost its entire extent, is called the *ice foot.* Any considerable extent of undisturbed or unbroken ice forms an *ice sheet* or *ice field.* When on-shore winds become so strong that the ice field is crushed and piled up against the shore, it forms *pack ice.* Detached masses floating about constitute *floes*; finely broken ice floating on the surface is called *sludge.*

The formation of pack ice is sometimes sudden and frequently violent. The crunching from side pressure, due to the friction of the wind, is so great that not only is the ice piled up in huge blocks, but the blocks, often weighing many tons, are shot up into the air ten or twenty feet.

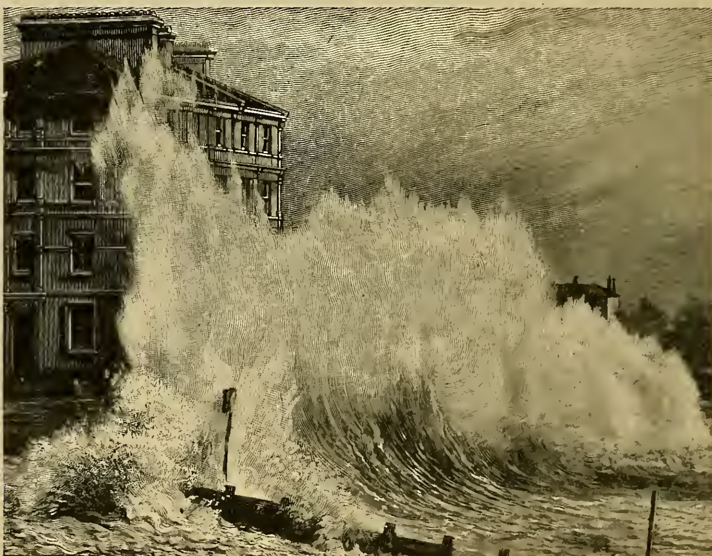
Anchor ice results from the freezing of fresh water at the bottom of an estuary into which salt water flows. The ice accumulates on the bottom until its buoyancy overcomes the force with which it adheres to the bottom; then the whole mass rises to the surface. It receives its name from the fact that it is very apt to begin forming about anchors or other metallic substances lying at the bottom. Not infrequently these have been lifted from the bottom and floated. Large areas of anchor ice at times are suddenly detached from the bottom, and the estuary, previously free from ice, becomes filled with sludge. This form of ice is called *ground ice.*

Some of the glacial ice, in the form of icebergs, is carried by currents or blown by winds, into warmer latitudes, there to melt, but by far the greater part, however, never leaves polar regions. Some may accumulate, but much of it melts during the brief polar summer.

The difference in the form of the Greenland and the south polar icebergs is due to the character of the glaciers from which they are broken. Antarctic icebergs are derived from *sheets* of land ice; Greenland bergs, on the contrary, are derived mainly from the hummocky ice of glaciers. Most of the icebergs floating down through Davis Strait come from Disko Bay.

Waves.—Waves vary in size from the tiny ripples made by a summer breeze, to the huge billows that toss the largest ships. Waves are caused by the friction of the air against the surface of the water. The motion of the water of the wave is up and down, combined with a rotary movement. Under a strong wind, however, the top of the wave is pushed forward and, if the gale be very strong, it breaks into foam, forming *white caps* and *scud.* Before the strongest storm winds much of the water is blown into spray, and the whole surface of the ocean becomes covered with foam.

When waves roll in upon a shallow coast their motion is also modified. The moment the bottom of the wave touches bottom it begins to drag. The top of the wave not being impeded, advances more rapidly, and finally *combs*, or falls forward, making *breakers*. The water and foam that flow upon the shore constitute the *surf*.



STORM WAVES: SURF BREAKERS

The distance from the shore at which waves begin to comb depends partly on the depth of the wave, and partly on the depth of water along the shore. Ordinary waves rarely exceed three or four fathoms in depth, and therefore do not comb until they are within a few rods of the shore. Along certain shores of the Indian Ocean, where the coast waters are shallow and the waves are deep, the latter may begin to comb at a distance of three or four miles from shore.

For the formation of the highest and largest waves, a deep, open sea is required. In calm weather, the waves of the open sea are from six to ten feet in height; their breadth is about ten times the height.

With a wind of twenty or thirty miles an hour, the height of the wave is increased, and the largest steamships pitch considerably as they ride over them. With the wind at sixty or eighty miles the breadth of the wave is about two thousand feet; its height may reach twenty or thirty feet, and its progressive motion may reach forty miles an hour.

Waves do not run highest when the wind is at its maximum velocity; they do not reach their greatest height until the lull of the wind; then they sometimes roll to a height of forty-five or fifty feet. A very high wind pushes their crests forward rapidly, practically flattening them.

In navigation, the chief damage from storm waves is due to the battering of the lighter woodwork above deck. In recent years the old custom of spreading oil on the surface to the windward has been revived. The oil spreads quickly and forms a covering or "skin," on water that offers comparatively little friction to the wind. As a result the waves, although rolling high, no longer break upon the vessel, and the latter is enabled to withstand storm waves that otherwise would be destructive.

A stanch vessel with her head to the wind needs to fear but little from the waves. The waves may smash everything above deck, but the hull will ride them safely so long as they do not board her. If the waves strike broadside, however, the case is more serious, and the boarding waves may cause the ship to founder. Head on, a vessel can ride waves of twenty feet as safely as those of six.

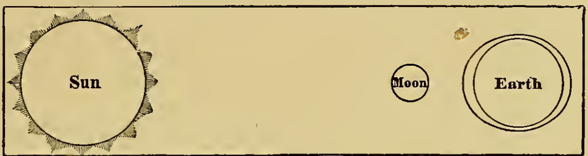
In the use of oil the problem before the sailing master is to prevent the breaking of waves. For this purpose it is found that sperm oil and oil of turpentine are the best. The oil is poured into a coarse canvas sack filled with tow, and the latter is floated to the windward of the vessel, being held in position by any convenient outrigging. The oil oozing through the canvas spreads rapidly over the surface of the water. The friction of the wind against a surface of oil is so much less than against a surface of the water that at once the waves cease to break.

The following from the log of the Swedish brigantine *Drott* is one of many similar testimonials gathered by the United States Hydrographic Office: "I had seen upon the pilot chart that oil had been used with good effect in calming heavy seas. I started to try it and had two bags made of the capacity of two gallons each. These bags were stuffed full of oakum, and then one gallon was poured into each, half fish oil and half petroleum. A very small hole was cut in the bottom of each bag which allowed the oil to drop out freely. One of these bags was suspended from each cathead, just out of the water, and the result was simply a wonder to me, so much so that I could hardly believe my senses. No more seas were shipped and all hands turned to secure the main hatchway properly, which was impossible to do before on account of the risk of being washed overboard. The former combers were now great rollers only, not a sea breaking nearer than thirty feet from the vessel. The crew were now able to pump out the ship and clear up the decks in perfect safety. About 11 P.M. the sea broke over the starboard side and smashed in one of the boats, but this was found to be due to the loss of one of the oil bags, and as soon as another was put out and kept supplied with oil no more waves came on board."

The force with which waves strike an opposing surface is very great. On the coast of Scotland, measurements show that calm-weather waves may strike with a force of six hundred pounds per square foot; the momentum of the heaviest storm waves is about ten times as great.

Notwithstanding their tremendous energy, waves are superficial. The effects of calm-weather waves do not extend more than a few fathoms; the fiercest storm waves do not reach more than two hundred feet below the surface.

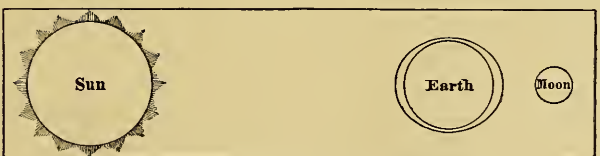
Tides.—The alternate rise and fall of the sea twice a day is familiar to everyone who has visited the sea shore. For six hours the level of the water gradually rises, spreads over the shore and fills the river estuaries. For a few moments, the water is stationary; during the next six hours it falls—ever repeating, never ceasing its oscillations. Nei-



THE TIDE WAVE: MOON IN CONJUNCTION

ther the high nor the low water level varies much at any one place. As the level rises and the water flows in upon the shore, the tide is *flood;* as it recedes it is *ebb;* its highest level is *high water*, and its lowest, *low water.* During the few minutes at the turn of the tide it is *slack water.*

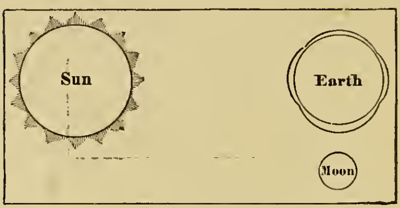
This movement of the water is practically a wave several thousand miles broad. Both the sun and the moon at-



THE TIDE WAVE: MOON IN OPPOSITION

tract the earth. The solid portion of the earth does not perceptibly bend or yield, because it is rigid; the water envelope, on the contrary, is drawn into the elongated form (*Appendix, Table VI*), giving the appearance of two wave-crests, one on each side of the earth. No matter whether the sun and the moon are on the same side, or on opposite sides, their combined attraction will produce the same results. If, however, they pull at right angles, four tide waves will be formed—two of the sun and two of the moon.

In much of the Northern Hemisphere, where the continents interrupt the tide waves, the solar tides are merged into those of the moon. Only in the broader expanses of the ocean, among the islands of the South Pacific, are they distinguishable. At new and full moon, the pull is exerted in a straight line; the tides are then materially higher at flood and lower at ebb than when the two are pulling at right angles. The former are *spring tides*; the latter *neap tides*.



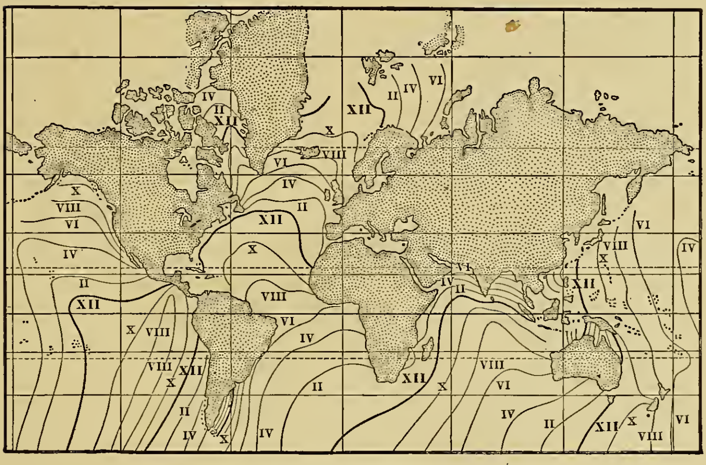
THE TIDE: MOON IN QUADRATURE

As the moon revolves around the earth, the waves are dragged after it as though they were fastened to it. Each wave makes the circuit in about twenty-eight days.

But while each wave is making its revolution, the earth at the same time is turning on its axis, every twenty-four hours. The *daily* motion of the tides, therefore, results from the earth's turning on its axis. Every point on the earth, accordingly, *overtakes and passes* the two waves daily, very much as though it were slipping under them.

If the surface of the earth were covered with a uniform depth of water, the direction of the tide waves would be nearly east and west. As a matter of fact, the position of the continents prevents any such uniform direction. Every mass of land is an obstacle in the path of the advancing wave, and the latter cannot sweep over a continent.

Only in the open waters of the Southern Hemisphere do the tides move in their theoretical direction from east to west. In the North Atlantic the wave is turned to the northward, and, entering the Arctic Ocean, it is diverted to the eastward. At Lady Franklin Bay, northwest of Greenland, explorer Greely observed that the tide came from the north.



CO-TIDAL LINES

The lines show the position of the crest of the tide wave for each two hours.

The height of the tides is also affected by the land masses. In mid-ocean the difference between high water and low water is scarcely three feet. Along the coast of the United States it varies from four to ten or twelve feet. From New York to Savannah spring tides are about five feet, and neap tides about four feet. In the Gulf of Mexico the rise and fall is only about one-half as great; along the Maine coast it is ten or twelve feet; and at Sitka, Alaska, from twenty to thirty feet.

the tides is due chiefly to the shape of the shores. If the tide wave faces a V-shaped estuary the advancing body is compressed by the narrowing shores. Not being able to spread sideways, it is therefore increased both in depth and velocity. In the Petitcodiac River, at the head of the Bay of Fundy, the tide enters in the form of a rolling wave at times nearly six feet high. The advance of the tide in the form of a wave is called a *bore*. It is a marked feature in the Amazon, the Seine, and in several rivers of the China coast. It is also noticeable in many of the estuaries of the British Isles. The spring tide in Bristol Channel is sometimes forty feet high and the bore is four or five feet in height.

If the waters of the advancing tide are separated by an island lying near the shore, again uniting in the strait between the mainland and the island, *races* and dangerous whirls are formed. Thus, at Long Island the advancing wave is divided, one part entering New York Bay, the other, Long Island Sound. The two currents meet in the narrow Hell Gate, which has been strewn with wrecked vessels. The Maelstrom, an eddy formed off the coast of Norway, is a similar current.

In pleasant weather the eddy of the Maelstrom is hardly noticeable during slack water, or at the time of neap tides. When the flood or the ebb of spring tides is strong, the current also is strong; with a hard northwest wind, it is a dangerous locality.

Ocean Currents.—The sea is traversed by *currents* that flow in definite directions with a fairly uniform velocity. As a rule, the water of an ocean current has an energy of its own, and its motion is practically the same as though it were flowing from a higher to a lower level. In certain instances, however, the movement is caused almost wholly

OCEAN CURRENTS

by the wind. The direction of such a current is due to the wind; such wind-blown waters are called *drifts.*

Currents are deep, sometimes extending to the bottom; drifts, on the other hand, are superficial. A current may become a drift, and a drift may become a current.

The winds, and the unequal heating of the waters in equatorial and polar regions are thought to be the main causes of the general movement of ocean waters; the winds and the rotation of the earth on its axis are the chief factors in making them currents and in determining the direction of their flow.

According to Herschel and Carpenter the winds are the chief agents in piling the waters in equatorial latitudes, thereby bringing about a condition of inequilibrium. Lieutenant Maury held that the difference in specific gravity between the saltier waters of equatorial and the fresher waters of polar regions is competent to account for ocean currents. That each is an important factor cannot be denied.

In equatorial regions the water receives the vertical rays of the sun and is heated. Being heated, it is also expanded and flows toward polar regions. At the same time, cooler water flows toward the equator in the form of an undercurrent. Thus a constant circulation is taking place—a surface movement from equatorial, and an undercurrent from polar latitudes. This general movement is modified by the winds and by the rotation of the earth.

Owing to the turning of the earth on its axis, a point on the equator travels 25,000 miles in twenty-four hours—a speed of about 1,000 miles an hour. In latitude 60° the speed is only half as much. Consequently water which flows from latitude 60° toward the equator has a tendency to lag behind as it reaches a latitude when the speed of rotation is greater.

In equatorial latitudes the prevailing direction of the wind is toward the west, and this gives the waters a westerly movement. A flow of water, nearly 1,000 miles broad, called the *Equatorial Current,* is the result; except the places at which it is interrupted by the continents, it girdles the earth. Its flow is scarcely more than a drift, and its rate is about ten or fifteen miles per day. Most of the warm currents of temperate latitudes are branches of it.

The Atlantic part of the Equatorial Current is divided at the eastern angle of South America. The southern branch flows along the eastern coast of this grand division for nearly 2,000 miles; what is its name? Gradually it becomes a drift, and finally it returns to the Equatorial Current. Describe the course of the northern branch. As it emerges from the Caribbean Sea and gathers off the Florida coast it becomes the Gulf Stream. The Pacific part of the Equatorial Current is more than 9,000 miles long. At the edge of the Eastern Continent it is again divided; what is the name of the northern branch? of the southern?

In the midstream of the Equatorial Current is found a narrow belt of water flowing in the direction opposite to that of the main stream. It is called the Equatorial Counter Current; no satisfactory explanation for it is known.

The *Gulf Stream* is by far the most important of the currents of the Atlantic Ocean. A part of its volume flows through Santarem Channel; a greater part is gathered into Yucatan Channel; a small but measurable part is drawn from the Gulf of Mexico. These branches unite in Florida Strait, and here the current begins.

At Florida Strait its velocity varies from three and one-half to five and one-half miles an hour. To the northward the velocity decreases until, off the Labrador coast, it becomes a drift dragged by westerly winds.

The velocity varies not only with the season, but also with the passage of the moon—that is, the variations are yearly, monthly, and daily. Its flow is swiftest during summer and slowest in winter. An adverse wind will retard; a favorable wind will increase its velocity. A quartering wind or one blowing athwart is apt to push some of the surface water out of the track of the stream, at the same time pushing colder water into it. The fact that Gulf Stream water is occasionally pushed against the Atlantic coast has given rise to the statement that the position of the stream itself is subject to change.

The Gulf Stream is a very warm current. Off the Florida coast its summer temperature is 30° (86° F.), and even near the Greenland coast its drift is twenty or thirty degrees (F.) warmer than the surrounding waters. It is not a shallow current; from Florida Strait to Cape Hatteras, it extends to the bottom of the ocean. Its drift is pushed northward and eastward, but much of it forms a circuit returning to the Equatorial Current. A considerable volume, keeping northward, finds an entrance to the gulfs and bays of western Europe, reaching even to the north coast of Norway.

The *Kuro Siwo* is the Gulf Stream of the Pacific. Some of its waters issue from the Bay of Bengal, but the greater part of its volume passes among the Malaysian Islands and thence along the east coast of Asia. Off the Japan Islands it becomes a drift, and its waters are dragged by the prevailing winds toward the North American coast. Some of the drift makes an oval-shaped circuit like that of the Gulf Stream; a part is blown northward to the Alaskan coast.

The Kuro Siwo is a much feebler and colder current than the Gulf Stream. Its summer temperature rarely exceeds 22° (72° F.), and its winter temperature is not far from 17° (63° F.). In summer it extends as far north as the Kuril Islands; in winter it scarcely reaches the Japan coast.

No part of the Kuro Siwo enters the Arctic Ocean through Bering Strait. The prevailing movement in Bering Strait is a feeble flow from the Arctic Ocean.

Much of the circulation of the colder ocean waters takes the form of undercurrents, but no complete survey of an undercurrent has been made. Two very definite cold currents have been observed and their position is fairly well known. These are the *Arctic Currents*. One flows southward along the east shore of Greenland; the other, flowing on the west shore, emerges into the Atlantic and meets the Gulf Stream off Newfoundland.

Off the coast of Cape Hatteras, almost in the track of the Gulf Stream, is an adverse current known on pilot charts as "*Little Hell.*" It is marked by heavy, choppy waves, and persists, even in the face of a strong southerly wind. Its waters are cold, and it is thought to result from the rising of an arctic undercurrent to the surface.

The *Antarctic Current* is the chief cold current in the southern hemisphere. It is a drift rather than a definite current, and its waters are several degrees cooler than those with which they finally mingle.

Economy of Ocean Currents.—One of the important effects of marine currents is the equalizing of the temperature of ocean waters. Without this interchange the heat of equatorial waters would sooner or later become fatal to many forms of life, and the polar ice caps would intrude far into temperate latitudes.

The more practical effects are seen by comparing the coast of Labrador with that of the British Isles, in the same latitude. The harbors of the former are blocked with ice for five months of the year; those of the British Isles are open the year round. The former is bathed by cold waters; the latter by the drift of the Gulf Stream. The port of Hammerfest, situated within the Arctic circle, is free from obstructive ice all the year round. It is doubtful if warm currents have any material effect on the temperature of a region at any great distance inland, but they keep the coast free from ice. How does this affect commerce?

Evaporation is very great along warm currents and the moisture borne with the wind adds much to the rainfall of the nearby regions. Cold currents have a chilling effect on the air, and if the air has much moisture it is apt to take the form of fog. This is notably the case off the Banks of Newfoundland, where the Gulf Stream drift meets the "cold wall," and the dense fogs of the Newfoundland and Labrador coasts are due to this cause. Ocean currents are thus indirect factors in climate.

Sargasso Seas.—Within the ovals formed by the branches of the Equatorial Current and their drifts there are extensive accumulations of marine plants. These were named by Spanish navigators *Zargazzo,* or grassy seas. The accumulations are sometimes attributed to the eddying motion of the current and its drift, but such a theory is not necessary to the explanation of their presence. Calm water is necessary for the growth of the species forming such accumulations, and the latter occur most frequently in such localities.

Physiographic Effects of Oceanic Movements.—So closely related is the work of waves, tides, and currents, that their physiographic effects cannot well be separated from one another. In general, the work of waves is both destructive and constructive—they not only batter down coasts, but they build them as well. On the other hand, the work of tides and currents is mainly transporting—they carry material from one place to another. Although waves act at the surface, their work is none the less effective. Throughout the whole extent of coast material is either being removed from the shore or else is being added to it.

Along the South Atlantic coast of the United States, the effects are still more noticeable. The shores of Cape May, New Jersey, are wasting away at the rate of several feet a year, and those of Charleston Harbor require almost constant repair, so destructive is the incessant battering of the waves. On the east coast of England, owing both to waves and swift tidal currents, the yearly waste is considerable (p. 55).

On the Sicilian coast is a spectral rock detached from the shore, rising almost like a lighthouse tower. Breaking waves have battered a hole through it near the top, forming a giant eye—and Cyclops to this day is represented with one eye (p. 53).

Along the west coast of Scotland, and especially among the Hebrides Islands, many thousand rocky islets rise from the sea like watch-towers. They are witnesses of the destructive force of the waves.

The constructive and building power of waves is finely shown along the South Atlantic and Gulf coast and that of the Netherlands. The noticeable feature is the multitude of spits, barrier beaches, and islands that border it.

In the building of shores much depends on the direction of tides and local currents. If the latter strike the shore broadside, or at right angles, the bars and spits take the shape so common along the Gulf coast; if they strike it obliquely, the sediment is caught in the swirl of the current, and deposited in the form of *sandy hooks*.

Cape Cod, Monomoy Point, and Nantucket Beach are nothing but sandy hooks; Marthas Vineyard and Nantucket Islands contain half a score of such examples. Sandy Hook, now an island obstructing the navigation of New York Bay, is a striking example.

Certain effects of tidal currents at first, are not obvious. Waves are capable of battering down a cliff, but they are not able to remove the rock waste. This, lodging at the foot of the cliff, protects it from further assaults of the waves. But if the currents remove this material, the waves have fresh surface upon which to work.

The bars at the mouths of rivers are nearly always the work of tidal currents, and so are many of the "banks" or shoals that obstruct straits and sounds. The North Sea contains many examples, and Lower New York Bay is full of them.

Ocean currents undoubtedly transport an enormous amount of material. The Gulf Stream sweeps the shells of certain marine organisms from the Caribbean Sea as far north as the Carolina coast. The icebergs floated by arctic currents bring down a large amount of gravel and bowlders which are finally dropped in lower latitudes. It is by no means impossible that constant deposition of matter carried by ocean currents may have resulted in extensive changes of level in various parts of the earth's surface.

QUESTIONS AND EXERCISES.—If possible, evaporate a small quantity of stream water of any kind in a beaker, or a porcelain dish, and note the result. Repeat the experiment with rain water. What inferences can be drawn that are applicable to the second paragraph of this chapter?

Prove that ice, bulk for bulk, is lighter than water.

If possible observe the effects of waves on the shore of any convenient body of water. Note the character of the work they do, or that you find they have done. Explain how waves make beach sand.

If you are near the ocean, find the season of the year when the tides are highest.

Refer to the map, p. 203, and note the direction of the tide waves in various parts of the Atlantic Ocean. What is their general direction in the South Pacific?

Explain how ocean currents may affect navigation, either favorably or adversely.

In one of the first chapters of his narrative, Robinson Crusoe speaks of the great indraught of the Gulf of Mexico; what feature is meant?

Of several thousand sealed and registered bottles thrown into the Gulf Stream, off the Florida Coast, a number were found afterward in the Caribbean Sea, along the West Indies; from the current chart, p. 205, explain their movement.

From any available cyclopedia, or other work of reference, prepare an account of one or more of the following: the Gulf Stream, the Maelstrom, the bore of the Amazon, the tides of the Bay of Fundy, the Hell Gate, or the effects of storm waves.

COLLATERAL READING AND REFERENCE

Pillsbury.—The Gulf Stream. *United States Coast Survey.*

Mill.—Realm of Nature, pp. 154–184.

Shaler.—Sea and Land, pp. 1–74, 187–222.

U. S. Hydrographic Office.—Use of Oil in Storms.

CHAPTER XII

THE ATMOSPHERE AND ITS PROPERTIES: WINDS

The atmosphere, or air, is the gaseous substance that forms the outer envelope of the earth. It rests on the land and the water, and probably penetrates both to a considerable distance. Being a part of the earth, the atmosphere partakes of all the general motions of the latter, but it has also certain movements of its own, which are very closely connected with life and its environment.

The air is not a simple, or *elementary* substance; it is a mixture of several elements. The chief constituents, nitrogen and oxygen, have the proportion of about four parts of the former to one of the latter. Each of the remaining constituents, water vapor, carbon dioxide, and floating matter varies greatly in proportion.

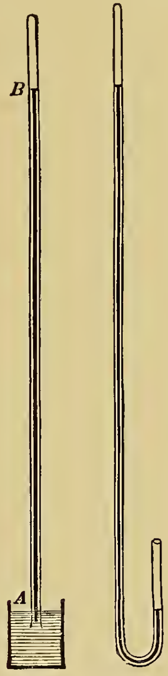
The newly discovered elements, argon, krypton, xenon, helium, and others form a very minute proportion of the atmosphere.

The vapor of water rarely exceeds one part in one hundred of air. It is nevertheless a most important constituent, for it is in this form that the water is borne from the sea and shed upon the land. The floating particles of smoke, dust, and other matter are also essential, for they aid materially in condensing the water vapor.

Physical Properties.—Air is highly elastic. Pressure decreases the volume, making the air *denser*. When the pressure is relieved, the air again expands and is *rarefied*.

Air next the ground is denser than that above, because of the pressure or weight of the air overlaying it. The density decreases with the distance above the sea; at an altitude of two miles the density is only two-thirds that at sea-level.

At a height of fifteen thousand feet the air is so rare that breathing is labored and the pulsations of the heart are very rapid. Climbing becomes difficult and any form of exertion is wearying. Water boils at about 85° (185° F.), a temperature so low that it is difficult to cook vegetables by boiling.



THE BAROMETER

At sea-level a cubic foot of air weighs a little more than one Troy ounce.

The force with which the air presses upon a given surface is called its *tension*; and, practically, the tension is a form of expressing the pressure of the air. At sea-level, the pressure of about fifteen pounds on every square inch, or a little more than a ton on each square foot of surface. The tension varies slightly in different latitudes, being a little greater near the tropics than elsewhere.

It is most convenient to measure the tension of the air by noting the height of a column of mercury, or quicksilver, that will just balance it.

The instrument used for this purpose is called a *barometer*. It consists of a glass tube closed at one end, and filled with mercury. The tube is inverted, and the open end is placed in a small cup filled with mercury. The pressure of the air on the surface of the mercury in the cup sustains the column in the tube. If the column in the tube rises it signifies that the pressure of air overhead is increasing; if it falls, the pressure is decreasing.

At the level of the sea, the height of the barometer varies usually between 29.4 and 30.4 inches. Mercury is the most convenient substance to use for this purpose; it is a liquid metal that is heavy, and is not easily altered in physical properties. A water barometer would require a tube about forty feet in length; moreover, water freezes at 32° F., while mercury remains liquid about seventy degrees lower. In the *aneroid barometer,* a vacuum box whose collapsible side moves a series of levers, takes the place of the mercury.

Effects of Temperature.—The atmosphere is warmed partly by the direct rays of the sun and partly by the heat radiated from the earth. It is also heated by compression and cooled by expansion.

The intensity or degree of its heat is its *temperature.* The temperature of the air is measured by the expansion of a very fine column of mercury held in a glass tube—a *thermometer.* When a volume of air is compressed, it becomes greatly heated. Thus, air that descends from higher to lower levels, becomes heated because it moves into a region where the pressure is greater. In the same way, a volume of rising air expands and is cooled, because it goes into a region where the tension is less. Heat expands the air; bulk for bulk, warm air is therefore lighter than cold air. If a volume of air is warmed from freezing temperature to that of intense summer heat its volume is increased nearly one-fifth.

It is well to bear in mind that the common expression, "hot air rises because it is lighter," is not strictly correct. The hot air does not rise; it is pushed upward and floated on the surface of the heavier cold air.

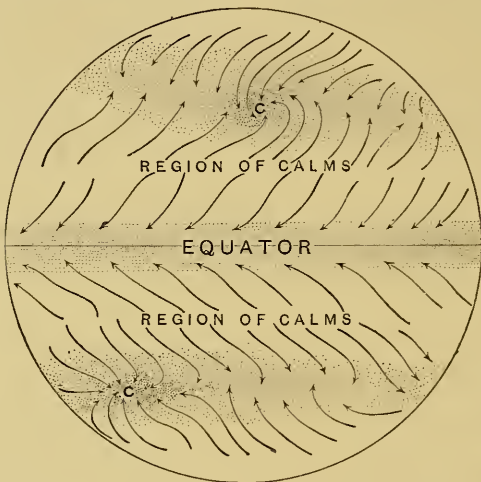
The temperature of the air varies both with latitude and altitude. In equatorial latitudes the mean temperature of the air over the sea is not far from 32° (90° F.); in polar regions it ranges much below 0° (32° F.). With respect to altitude the temperature falls at the rate of about one degree for every three hundred feet of ascent. The effect of altitude is very noticeable in the Andes. At the base of the mountains the heat is intense; at an altitude of ten thousand feet the air is mild; at seventeen thousand feet, one is in a region of perpetual snow.

Convectional Movements of the Atmosphere.—The air is everywhere in motion. The attraction of the sun and the moon undoubtedly causes atmospheric tides something like the tides of the sea, but the effects are not well known.

Sensible movements of the air are called *winds*. They are caused by changes either of temperature, or of pressure. When air is heated to a temperature higher than that surrounding, it expands and is pushed upward by the heavier air that flows in. Thus, at any locality where an updraught of warm air is taking place the pressure is reduced, thereby forming an *area of low barometer*; on the contrary, if there is an accumulation of air at any locality the pressure is increased and there occurs an *area of high barometer*. When such inequalities of pressure exist, it is evident that winds will blow toward an area of low barometer, and away from one of high barometer. Such movements of the air are everywhere taking place, and they are examples of the force of gravity.

Equatorial and polar regions are not equally heated. The former receives the almost vertical rays of the sun; the latter only oblique rays. This results in two great movements, namely—*a surface flow toward the equator, and upper currents from the equatorial toward polar regions.*

But the colder air comes from the regions where the speed of the earth's rotation is comparatively slow, and enters latitudes where it is much greater; and not being able to acquire this speed at once it apparently lags behind, but practically produces a current to the westward. The rising air moves into a region in which the speed of rotation is not so great. It therefore moves to the eastward, as well as toward the polar regions.

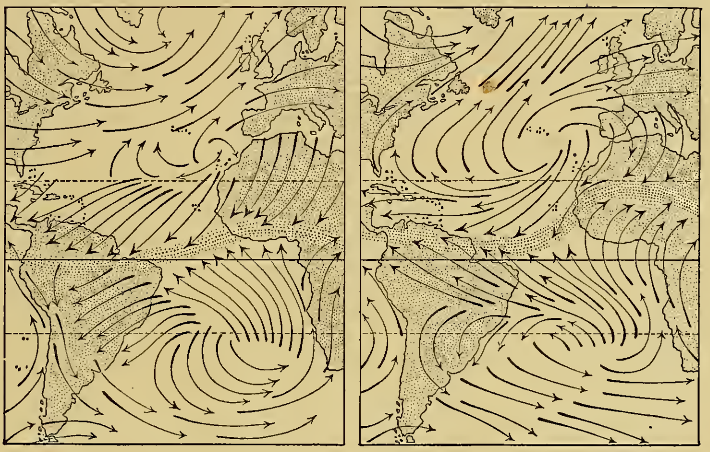


GENERAL MOVEMENTS OF THE ATMOSPHERE

But in the two great movements described the easterly and the westerly components are much more noticeable than the polar and equatorial movements. The several areas in which the wind direction is fairly constant, constitute three great belts of winds—a belt of equatorial or *easterly* winds between two belts of *westerly* winds. These general movements are strongly marked on the oceans, but are greatly modified by the continents. In inland mountainous regions their direction might escape notice; in the great lowland plains they are more regular.

The great convectional movements of the air result in belts of differing pressure. In equatorial regions, the updraught of warm air creates a belt of pressure that is a little lower than the normal. In the region of the tropical calm belts, the downward movement of the air creates a belt of pressure a little greater than the normal.

Trade Winds.—The surface winds which flow into tropical regions to take the place of the warm air that is pushed upward, form the well-known Trade Winds. They therefore blow from the northeast and from the south-



PREVAILING WINDS OF THE ATLANTIC

east. Toward the centre of the belt they are practically steady easterly winds.

The zone of Trade Winds is about fifty degrees in width. Its position is not stationary; it swings alternately north and south, as the seasons change. In the Atlantic Ocean the shifting of the belt is from eight to ten degrees; in the Pacific it is slightly greater. The belt reaches its northern limit in early autumn; its southern limit in early spring. The city of New Orleans is in the belt of Trade Winds in midsummer, and in that of the Prevailing Westerlies in winter. The Trade Winds are regular and constant the year round, their velocity being twelve or fifteen miles an hour.

Formerly, when ocean commerce depended on sailing vessels, these winds were of great importance—hence their name. A vessel entering the Trade Wind belt could rely on steady winds with but little interruption.

Along the line where the northerly and the southerly components of the Trade Winds meet, there is a narrow belt which is characterized by an absence of steady winds, but marked by almost constant rains. This belt is the updraught air and is called the *Equatorial Calms*, or *Doldrums*. It is scarcely more than two or three hundred miles in breadth. Sailing vessels are sometimes becalmed, requiring several weeks to cross it.

Prevailing Westerlies.—The air that flows from equatorial regions as an upper current, sinks to the surface in temperate latitudes, forming two belts of westerly winds, called *Prevailing Westerlies*. Like the Trade Winds both belts move northward and southward with the changes of the seasons.

The height to which the updraught rises before it turns toward the pole is not known, except in two or three instances. On the Island of Hawaii, the Trade Winds reach an altitude of about twelve thousand feet. Above this elevation the winds have almost an opposite direction; they are the winds that, a few degrees farther north, descend to become the Prevailing Westerlies. These winds are also called *return-trades*, *anti-trades*, and *counter-trades*.

In the Northern Hemisphere the Prevailing Westerlies are neither so strong nor so steady as the Trade Winds, and in higher latitudes they often give way to winds of northerly origin. On the coast of the Gulf of Mexico the Prevailing Westerlies, in the summer season, are reinforced by Trade Wind currents which are deflected by the highlands of Mexico. The resulting winds sweep up the Mississippi Valley and thence turn across the Atlantic, carrying with them the moisture that supplies the Eastern United States with rain.

In the Southern Hemisphere, the Prevailing Westerlies are best known as the *Roaring Forties*. They cover a broad zone, and are an excellent illustration of the theoretical movement of the constant winds. When the trade route between Europe and the East Indies lay around the Cape of Good Hope, the Roaring Forties were an important factor in commerce; the sailing master could depend on a twenty or thirty knot breeze the year round. It was then a common practice for vessels bound for Australia or New Zealand to continue eastward and return by way of Cape Horn.

The descent to the surface of the upper currents which form the Prevailing Westerlies, is marked by calm belts—the *Calms of Cancer*, and the *Calms of Capricorn*. Like the zones of winds the calm belts also shift north and south with the season. They are interrupted by the continents and are scarcely noticeable within a hundred miles of their coasts. The Calms of Cancer are the well-known "Horse Latitudes." The Calms of Capricorn are the more continuous of the two calm belts.

Many years ago, when most of the foreign carriage was made in sailing vessels, there was a brisk trade in horses from the ports of the New England States to the West Indies. Frequently the vessels were becalmed in the Calms of Cancer, and it became necessary to throw overboard half the number of horses, in order to save the remaining animals; hence the name.

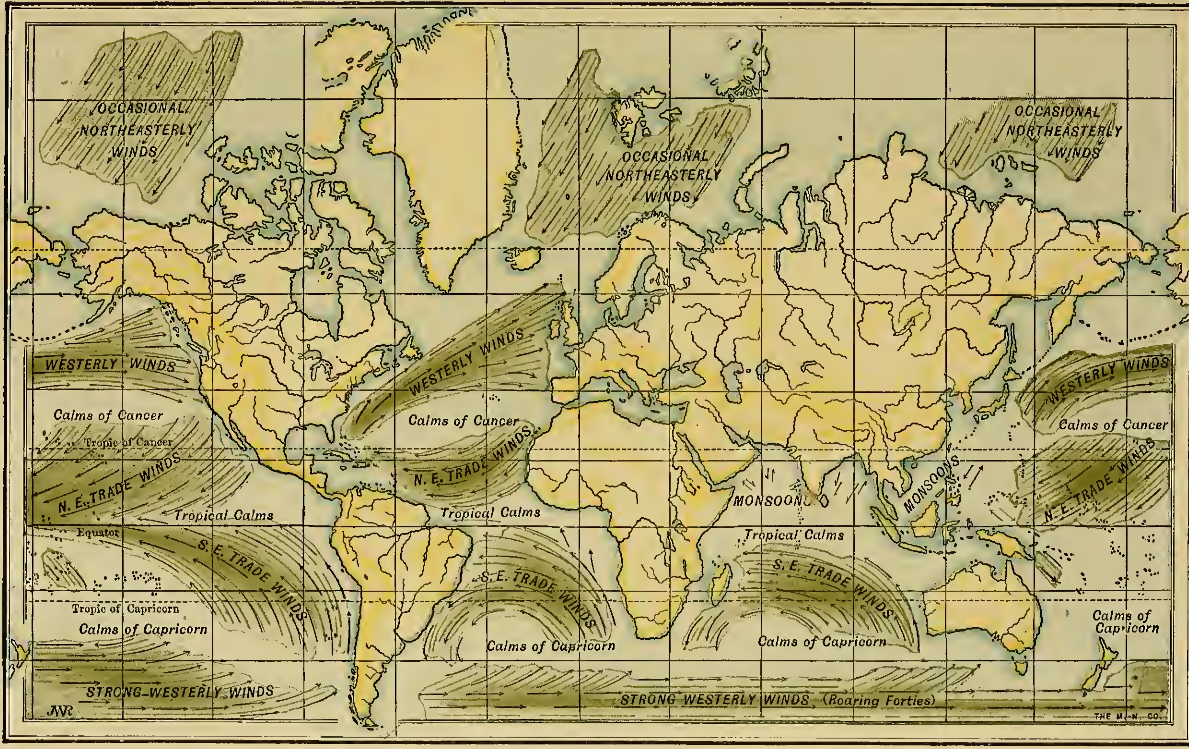
Polar Winds.—The air that flows from equatorial regions toward the poles is deflected in an easterly direction, because of the earth's rotation. In theory, the polar winds should be a whirl of wind, from west to east. In the north circumpolar regions the theoretical whirl is noticeable to a limited extent; in south circumpolar regions it is marked.

Monsoons.—Along coasts having a southerly or a southwesterly exposure, the summer winds have a direction nearly opposite those of the winter season; that is, about half the year they blow *from* the sea; the remaining half *toward* the sea. These winds are called *monsoons*—a Malay word meaning "season." Two causes give these winds their character.

In the first place, any great body of land is apt to become much warmer than the sea in summer and colder in winter. During summer there is an inflow of sea air. In winter the conditions are reversed; cold air flows from the and to the sea. In other instances, a region may be swept by southeast Trade Winds at one part of the year, and by the northeast belt the remainder. The monsoons of the Mexican coast are probably due to this cause.

The monsoon season does not keep pace with the apparent motion of the sun in its oscillation north and south. Like the "temperature season" it is about a month slow. The changes therefore occur in April and October instead of March and September, the dates of the equinoxes.

The most remarkable monsoons, however, are those of the Indian coast. From April to October the southerly half of the belt of Trade Winds reaches far inland, pouring a deluge of rain upon the land. During the rest of the year the southerly part of the belt has moved southward, and the northerly half covers the coast, parching the land and withering vegetation. The tremendous updraught of warm air aids materially in giving strength to these winds.



PREVAILING WINDS

The "breaking" or change of the monsoon is usually attended by terrific storms.

On account of its inland position, the central part of Asia is marked by great extremes of temperature. During summer its vast deserts are almost like a furnace, and the updraught of heated air is so enormous that it causes atmospheric disturbances two thousand miles away. In winter the dry air is chilled many degrees below that of the warm sea-air; being correspondingly heavier, it flows outward toward the ocean.

The winds of the Gulf Coast and the lower Mississippi Valley may be regarded as monsoons, but they are neither so regular nor so strong as the Indian monsoons.

Day and Night Breezes.—The difference between the temperature of day and night is sufficient to cause strong local winds. Thus, along the coasts, especially in warm regions, the updraught of the land causes a stiff on-shore wind during the day; at night, the air over the land, being more quickly chilled, flows down the slopes toward the sea. Coast fishermen frequently take advantage of such winds; they go out in early morning with an off-shore, and return at night with an on-shore breeze.

Similarly, in mountainous countries the air upon the higher slopes is heated and cooled more rapidly than in the valleys. There often results a strong wind blowing *up* the valley by day, and flowing *downward* at night. *Mountain valley winds* of this character are very common in almost every rugged country.

A similar movement of air is noticeable in many large caves—especially those that have openings at different levels. In the daytime air in the cave may be colder than that outside, while at night it is warmer. At night a strong indraught of colder air at the lower entrance, and an updraught at the higher opening results. In the daytime these movements are reversed.

Local and Variable Winds.—Certain local winds are common in desert regions and arid lands, or else result from the proximity of the latter. Almost always they are dry winds. In general, they are either hot blasts blowing from a desert, or cold winds blowing into it.

Thus, the *Northers* of Texas and Mexico are cold winter winds that blow from the highlands of the Plateau region. The *Chinook* and *Santa Ana* winds of the western highlands of the United States are descending, and therefore warm winds. In southern Europe they are called *Foehn* winds.

These names are applied to winds that have certain principles in common. Warm, moist air is pushed up the side of a mountain-range; being cooled, its moisture is condensed; the air then descending on the opposite, or possibly the same side, becomes warm very rapidly by its own compression. The effect is very marked; snow disappears quickly —hence the popular name "snow-eaters." The descending air is not only warm, but it is so dry that in summer it withers vegetation. The Chinook wind gets its name from a locality in Oregon, but the name is now applied to warm winds that flow from the Rocky Mountains out on the plains to the east. Following a blizzard, it quickly melts the snow that covers the scanty feed of the cattle herds. The Santa Ana is a hot wind common in southern California and Mexico. These winds are now recognized as a factor in the wheat-growing region of the Saskatchewan and Athabasca valleys, in Canada.

The *Pamperos* are similar winds flowing from the cold slopes of the Andes over the arid pampas of Argentina. The *Puñas* of the Peruvian table-lands are of the same nature.

In the vicinity of the African desert are the famous *Mistral* and the *Etesian* winds, both blowing from the snow-clad Alpine ranges toward the desert, while the *Sirocco,* like the Chinook, is a hot wind that in summer blows from the desert. The *Harmattan* is a warm winter wind, blowing from the desert to the Guinea coast. Aside from these there are several winds peculiar to desert regions. Chief among them is the *Simoon,* a fierce blast of hot air and rock waste, that neither man nor beast can face. It is common both in the Old World and the American deserts. A milder form of this wind along the lower Nile valley is called the *Khamsin.*

Desert Whirlwinds.—The most interesting desert winds are the sand whirls, which occur when the air is still. Under a hot sun the air next the earth becomes considerably heated, having a high temperature. Above the ground the air is cooler at the rate of one degree F. for every three hundred feet. Thus, a layer of heavy, cold air rests on a surface stratum that is much lighter. Such a condition cannot last long, and sooner or later a slight disturbance starts a column of air upward.

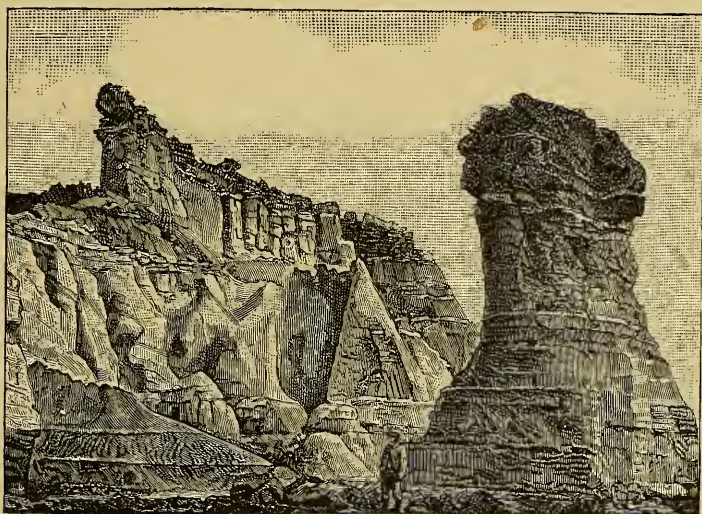
Immediately the cold air begins to settle; as it descends, it forces the warm air upward through the self-made passage. The ascending column begins to whirl, and soon its motion is rapid enough to carry with it a cloud of fine rock waste.

As a rule these whirls begin when the sun is two or three hours high, and continue until the wind begins to blow. The latter, by mixing the warm air with the cold, prevents their formation. Occasionally such whirls are vigorous "sand spouts."

Physiographic Effects of Winds.—As an agent in wearing away the surface of the land, the wind acts in different ways. It may alter the chemical composition of the rock with which it comes in contact. It may carry minute particles that cut away softer material. It may transport material from one place to another. The chemical action of air is due mainly to the water and carbon dioxide which it contains. It is manifested in the gradual crumbling of many granite and iron-bearing rocks, when the latter are exposed to the air. Dry air may affect rocks by chemically withdrawing the moisture they contain; moist air may affect other kinds by chemically imparting water to them. In either case the rock may sooner or later crumble.

The impact of minute particles carried by the wind is noticeable in dry regions. Where sand storms are prevalent the surfaces of the hardest rocks are channelled, and polished from this cause. The "needles" or rock spires of such regions frequently are sculptured into fantastic forms by *æolian* or wind-blown rock waste.

Some years ago the author left an octagonal steel drill in an upright position exposed to the full sweep of a desert wind. Six months after-



SAND-BEATEN ROCKS

ward the angles of the drill had become almost obliterated by the impact of rock waste. The telegraph poles in the desert regions are frequently cut in two by the wind-blown rock waste.

The transporting power of the wind is confined chiefly to sea shores and regions unprotected by vegetation. The wave-formed islands and barrier-beaches of the Atlantic and Gulf Coast have foundations of sea sediments, but the part above water consists of wind-blown material.

The sand dunes of ocean and lake shores are excellent illustrations. In regions swept by monsoons the dunes travel seaward during one season and landward the other.

A wave of sand about a mile long and seventy feet high at one time inundated a part of Cape Henlopen. A fire, which in 1828 burned off the woodland, started this dune on its travels. In 1845, General Joseph E. Johnston, then a United States Army engineer, noticed that north winds were picking up sand from the seaward face of the dune and carrying it over the crest to the landward side. Little by little the wave of sand overwhelmed a strip of pine barrens and filled a salt marsh beyond. Then it advanced upon a heavy growth of timber and, in time, covered all but the tallest trees, killing them as effectually as though they had been swept by fire. As the years passed by, the wave steadily advanced, and the wind began to uncover the buried surface in the rear. First the strip of pine barrens reappeared, and then the salt marsh was cleaned out and promptly reclaimed by the tide. Even the pine barrens began to show signs of life and a growth of young trees sprang up. Still later, the advancing sand began to uncover the forest, and a border of dead trees now flanks the rear slope. Near the eastern end of the dune is Cape Henlopen lighthouse. A straggling ridge of the wave entered the yard, covered up the oil-house and the garden, and then took possession of the keeper's cottage. The Government acknowledged its inability to cope with the dune by erecting a new cottage on the other side of the tower.

Between the silt brought down by the Colorado River, and the fierce winds of that region, the Gulf of California has been cut in twain, and most of the severed portion filled with rock waste to a height now considerably above sea-level; indeed, all through this region dunes are constantly forming, shifting, and re-forming. In western Nebraska, where the rainfall is not sufficient to grow protective vegetation, dunes are common.

On the Gascon coast of France, from the Gironde to the Adour, almost every stream has been blocked at its mouth by sand-drifts, and only the larger streams are powerful enough to force their way to the sea. In various parts of the Mediterranean and the Baltic coast, the farmer is compelled yearly to shovel away tons of sand, and in the former locality an abandoned olive orchard half buried is no uncommon sight.

Notable examples of the transporting power of wind occur in China. In the basin of the Hoang River deep æolian deposits cover many thousand square miles. These deposits, called *loess*—from a German word meaning "loose"—are thought to come from the desert region to

DUNES OF SAND

the westward. In many places the rivers have cut their channels through the loess, and the latter not only colors the water of the river, but imparts a yellow tint to the sea into which it flows.

Æolian deposits have filled most of the valleys of the Basin Region of the western highlands. The ranges stand out in bold relief from an ocean of level, wind-blown rock waste. Many of the valleys of the Rocky Mountains have been filled and levelled in the same manner. Wind-blown drifts are very common in the northern part of the Mississippi Valley, where they are usually covered with growths of scrub oak.

Various schemes for preventing the encroachment of dunes are employed. These are mainly of two kinds—barricades and vegetation. For the former the "sand fence," or movable panels much like the snow fence are employed. By far the most successful method, however, is the use of certain species of grasses. These are sown or planted when the sand is wet and their roots grow down far enough to reach sand that is always moist. Golden Gate Park, San Francisco, once an area of shifting dunes, has been reclaimed in this manner, and the plan has proved successful on Cape Cod, and the North Sea coast.

QUESTIONS AND EXERCISES.—Devise or describe an experiment to show that air has weight; show that it is elastic; show that heating a volume of air causes it to expand; using a bicycle pump, show that compressing air warms it.

What is the prevailing direction of the wind in the locality in which you live? Consult the records of the nearest weather station and compare the number of days of westerly winds with the number in which the wind is from other directions.

The tropical calm belts are regions of descending air-currents; is the air apt to be chilled or warmed by this movement?

Read Stedman's poem, "The Simoon," and compare it with the description in any standard cyclopedia.

Why are northerly winds of the North Temperate Zone cold?

Explain the manner in which street whirlwinds are formed.

Note any instance of the physiographic effects of winds in the locality with which you are best acquainted; prepare a description of it.

In what way do the general winds affect the temperature of the earth?

Note any examples in which winds accomplish work that has an economic value.

COLLATERAL READING AND REFERENCE

U. S. Coast Survey.—Atlantic Coast Pilot Chart, for March and September, or February and August—any year.

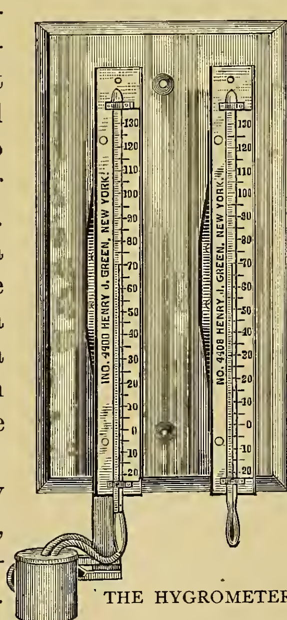
Le Conte.—Elements of Geology, pp. 1–8.

Department of Agriculture.—Year Book for 1898, sand-binding grasses.

CHAPTER XIII

THE MOISTURE OF THE ATMOSPHERE, SEASONAL AND PERIODICAL DISTRIBUTION OF RAINFALL

THE water vapor of the atmosphere, in a way, may be properly considered a part of it; but, if all the other constituents were absent, the water vapor would exist as an atmosphere in itself, and its movements would be the same practically as those of the winds. But while the proportion of oxygen and nitrogen of the atmosphere do not perceptibly vary, that of water vapor is subject to rapid changes. The amount that is present at a given locality depends on one thing only—temperature. With a high temperature there may be a great deal of vapor mingled with the air; with a low temperature there can be but little.



THE HYGROMETER

Changes in humidity are usually apparent to the sense of feeling, and one readily learns the difference between moist and dry air. In many instances they may be forecast by observing the clouds. If the latter form rapidly, or if small patches of cloud increase in size, the humidity is increasing. On the contrary, if the cloud area is becoming smaller, it is highly probable that the humidity is decreasing.

Dew-Point.—At times it may be noticed that wet clothing exposed all day to the air refuses to dry. The reason is that the air is already saturated, and because of this no further evaporation can take place. When all the vapor that can exist at a particular temperature is present, the air is said to be *saturated* or at the *dew-point.* This condition is unusual, however, except when rain is falling or during foggy weather; generally the amount present is considerably less than that required for saturation. From the amount present one may easily compute the *relative humidity*; thus, if half the quantity required to saturate the air is present, the relative humidity is fifty per cent. If the amount is near the dew-point, the air is moist; if the relative humidity is low, it is dry. Air that is moist at a given temperature may feel very dry at a higher temperature, even though no more moisture is present. The amount of moisture present in the air at any time is determined by an instrument called the *hygrometer.*

Table VII., Appendix, shows the amount of water vapor there may be in the air at various temperatures. With the thermometer at 66° F., for instance, there may be seven grains in each cubic foot of atmosphere. There might be less, but there can be no more; if more be added it would immediately *condense*—that is, change to rain or snow. From this table find whether or not there may be vapor in the air when the temperature is below freezing-point of water.

Latent Heat of Evaporation.—Water may be changed to vapor by heat. When water *boils* it reaches the temperature at which it begins to change rapidly to steam. No matter how fierce the heat may be, the water (unless it is confined) gets no hotter, and the steam given off has a temperature no higher than that of the boiling water.

All this heat is absorbed in the work of changing the water to steam, and it is called the *latent heat of steam.* It has not been lost, however; it is merely stored-up energy. It is retained just so long as the water remains in the form of vapor; it is given out the moment the vapor is condensed, or changes to a liquid.

This property of water is one of the greatest importance, for, as will be shown, it is a chief factor in the atmospheric disturbances called storms. The energy of the heat thus rendered latent is very great. For every pound of water converted to steam, about as much heat is required as would raise half a ton of water one degree F.

Dew.—Dew is the moisture that gathers on the ground, or on exposed objects, after sundown. Both the air and the ground lose a part of their heat. But the latter cools more rapidly, and the layer of air next the ground is chilled below the dew-point. When this occurs, the excess of vapor in the form of minute drops gathers on the grass and on other objects near the ground. The moisture that gathers on the outside of a glass of iced water is an example.

Dew does not always form at night, and for this there are several reasons. A stiff breeze may keep the air thoroughly mixed, and thereby prevent any part of it from being chilled to the dew-point. The air may contain so little vapor that a fall of fifteen or twenty degrees does not bring the temperature to the dew-point. A cloudy sky, especially if the clouds hang low, prevents the radiation of heat, and the formation of dew.

Sometimes dew forms copiously with but a slight fall of temperature, while perhaps on a following night, none may appear, though the temperature is much lower. An inspection of the table on p. 380, will explain how this may occur. If there were seven grains of water vapor in each cubic foot of air, a fall of temperature from 68° (F.) to 64° would be attended with dew; but if only three grains were present, the thermometer might sink as low as 40° without any sign of dew. A cloth screen within four or five feet of the ground will sometimes have the same effect as low clouds in preventing the gathering of dew.

The amount of moisture in the air varies much, both in time and place. In tropical regions, and those near the sea, the amount is usually great. Sometimes it is so near the point of saturation that the air becomes hazy. In such regions dew forms copiously. In temperate latitudes the amount is much less than in tropical regions.

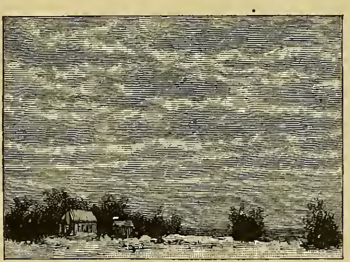
In the lowlands of the Pacific coast, where there are no summer rains, the fall of dew in early summer is excessive. The same phenomenon occurs in most mountain valleys.

If the temperature of the surface be lower than 0° (32° F.), the moisture may pass immediately into the crystalline form, *hoar frost*, or *white frost*. Sometimes the minute frost crystals form in the air, but usually they accumulate on the grass, the leaves, and other objects near the ground. Sometimes the frost is simply frozen dew; and if it takes the form of a thin varnish of ice that does not appear crystalline, it is called *black frost*. The latter term is also applied to the peculiar appearance of plants whose juices are frozen.

Except at considerable altitudes frost does not occur in tropical regions. In temperate latitudes it may occur at any time between late fall and spring. Late spring frosts are apt to occur after fruit-trees have budded, and they are therefore commonly known as *killing frosts*. The cold wave that follows a spring storm is very apt to lower the temperature to the freezing-point, and if the air be moist, a killing frost commonly occurs. Fortunately its occurrence usually can be predicted with a considerable degree of certainty.

Clouds.—When the temperature falls so low that a part of the vapor is condensed, the latter does not at first gather into large drops; on the contrary, the drops are so minute that they float in the air. This floating mist of the air is called *fog* if at the ground, or *cloud* if it forms higher in the air.

Nearly always the air is filled with dust motes and other floating matter, and much of the condensing vapor gathers on these. Not only do the dust motes form a lodgment for the condensing vapor, but they cool more rapidly than the air, and thereby quicken the process of condensation. The floating matter in the air thus becomes an active agent in cloud formation.



CIRRO-STRATUS CLOUDS

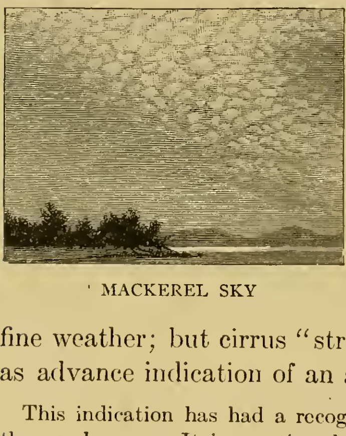
The cooling of the air below the dew-point is the essential feature, and this may occur in several ways. Thus when a mass of air, is pushed upward, not only is it chilled by going into a cooler position, but it is also cooled by its own expansion. It is probable that the greater amount of cloud is formed in this manner. Thus, in equatorial regions, where the updraught of warm, moist air is constant, there is a perpetual cloud-belt.

The intrusion of warm, moist winds into cold regions, or *vice versa*, is also a common cause of fog and cloud. The fogs and cloud banks so common off the coast of Newfoundland are formed in this way.

Whenever a warm sea-wind blows against a high mountain slope, a part of the air is driven up the slope, and, some of its moisture being condensed, cloud is formed. Almost always high mountain crests near the ocean are shrouded in clouds, and not infrequently a cloud banner streams from the leeward side of a high peak.

Cloud banners were noticed in the Alps by Professor Tyndall, and were first described by him. They may be often seen streaming from the summit of Mount Tacoma and of Mount Hood.

Cloud Nomenclature.—Clouds usually take characteristic forms, and these are governed mainly by the presence or absence of wind, and also by their height. *Cirrus* clouds are light and feathery in appearance and commonly white in color. These clouds take various forms. When they are flaky or fleecy they are the "mackerel" clouds heralded by sailors as forecasters of fine weather; but cirrus "streamers" are frequently found as advance indication of an approaching cyclone.



MACKEREL SKY

This indication has had a recognized place in weather-lore for two thousand years. It is mentioned in Virgil:

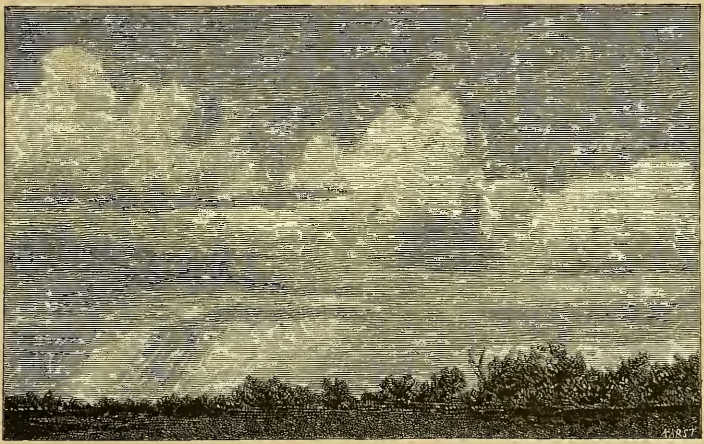
Tenuia . . . lanæ per cœlum vallera ferri,

and it is found among Teutonic peoples, as well; hence the popular saying:

Mackerel sky, twelve hours dry.

Often the patches of cirrus cloud are ranged in parallel strips; and occasionally they radiate like the spokes of a wheel. Commonly their altitude is between five and ten miles. On account of their great height it is obvious that they consist of minute ice crystals. Cirri may form above another cloud, the two being apparently related, but they never form under other clouds.

Cumulus clouds are the day clouds of summer weather. They appear like great, rounded domes resting on a horizontal base. A gently warmed current of air rises until, being chilled both by expansion and altitude, condensa-



CUMULUS CLOUDS

tion begins. The process continues until a dense mass of cloud is formed. This form is the almost universal cloud of tropical regions. It is abundant in warm temperate climates, but rare in cold latitudes. It does not form at night nor in cold weather, for the simple reason that the updraught of warm air is too feeble, and there is not enough vapor present to form clouds of sensible dimensions. Cumulus clouds have no especial significance as weather forecasters. They indicate nothing more than the presence of moisture and, as a rule, their size shows whether there is considerable vapor or only a little. If, however, any cloud mass loses its flat base, becoming ragged or festooned at the lower side, high winds and local showers may be expected.

Stratus clouds are so called because they are flat layers of nearly uniform thickness. Usually they are very low, and contain a great amount of foreign matter. They are commonly observed at morning and evening, and stillness of air is essential to their formation.

STRATUS CLOUDS

Not infrequently a column of smoke, from a factory chimney or a steamer's smoke-stack, becomes the nucleus of a stratus cloud. The smoke ascends until buoyancy and gravity balance each other, and it then settles in the form of a thin, flat layer. Each particle becomes a surface of condensation, and the cloud matter continues to gather until it is swept away by the wind, or the conditions of temperature are changed.

The *Nimbus* is the shapeless rain-cloud. The upper part consists of light fog or mist; the lower, of falling drops. Usually it seems to form in clear air, and it gathers when the temperature reaches the dew-point.

All clouds are moved hither and thither by the wind, but the matter composing the cloud itself is usually in motion even when the cloud is still. A study of a summer cloud shows that it is constantly moving within itself. Cloud may be considered as floating "water dust," but in reality the minute drops are always slowly falling. The droplet falls until it reaches a region of greater warmth; then it is changed to vapor, and the latter at once ascends until it is again condensed—the process being constantly repeated.

Rain.—The difference between rain and cloud consists very largely in the size of drops, but there is also a difference in their physical condition. The drops of cloud matter are minute, and practically they float in the air; those of rain are each many thousand times as large, and fall quickly to the ground. The causes that operate to produce fog and cloud, however, also produce rain—namely, the cooling of water vapor below the dew-point.

The vapor precipitated as rain may pass through the cloud stage, it is true; but the latter is one of short duration, and, as a rule, when condensation begins, it proceeds rapidly. Rain is rarely associated with fair-weather clouds and, excepting local showers, it is not derived from them. In general, rains are derived from warm ocean winds that, blowing inland, are chilled.

More rain falls in tropical regions than elsewhere; the equatorial cloud-ring is also a rain-belt, and under it precipitation is almost continuous. The amount of rain falling in the torrid zone is sufficient to cover it to a depth probably of more than one hundred inches. In the temperate zone it is a little more than one-third, and in polar regions about one-eighth as much.

Rainfall is not uniform for all places in the same latitude. On slopes that face ocean winds it is greatest, while in regions shut off from the sea by high ranges it is little or nothing. For example, on the southern slope of the Himalayas the precipitation varies from two hundred to six hundred inches; on the north side it is less than ten. On the western slope of the Sierra Nevada and Cascade Ranges it is ten times as great as on the eastern.

MEAN ANNUAL RAINFALL

The heaviest annual fall is probably at Cherrapunji, India, where the average is about 500 inches. In August, 1841, the total fall for the month was 264 inches, and in 1861 the yearly fall reached the enormous amount of 905 inches—about 2.5 inches a day. On June 14, 1876, 40.6 inches fell in twenty-four hours. In the three days ending February, 1893, an aggregate of 35.8 inches fell at Brisbane, Australia. In the United States 21.4 inches fell at Alexandria, Louisiana, in one day, and at Triadelphia, West Virginia, 6.9 inches fell in fifty-five minutes. All these instances, however, are very unusual. Commonly, not more than two inches fall in a day.

As a rule, precipitation is greatest in the vicinity of the coast and decreases toward the interior. If a mountain range faces the coast, however, it may be heavier on the slope facing the sea than along the immediate coast.

On the Atlantic coast of the United States the rainfall is forty inches or more; west of the one hundredth meridian it is less than fifteen. On the northern shores of South America it is over one hundred inches; a few hundred miles inland it is about one-quarter as much. In the uplands of the eastern slope of the Andes it again increases.

The greater the distance from the coast the more abnormal also is the character of the rainfall. In the Basin Region of the western United States, the rain is restricted to showers of short duration, and these often take the form of *cloud-bursts*. There is a sudden darkening of the sky, a terrific downpour of water—perhaps three or four inches in fifteen minutes—and then the sun is again licking up the water from the almost hissing rock waste.

Periodical Rains.—Not only does the amount of rainfall vary in different localities, for the reasons noted, but there is also much difference in the *time* of its distribution. In some localities it comes in the form of occasional showers; in others long periods of rain and drought alternate at given intervals—that is, the rainfall is *periodical* and *seasonal.*

A study of the wind chart, p. 240, will help to explain the periodical character of rain in certain localities. The slopes of the continents that face ocean winds, as a rule, have periodical rains. Thus, most of the western coast of North America faces the Prevailing Westerlies of the Pacific Ocean. In summer these winds are blowing into a region that is warmer, and therefore but little rain falls. In winter, on the other hand, the temperature of the land is much lower, and therefore rain may be of daily occurrence.

On the Mexican coast, where the climate is almost always mild, but little rain falls. Along the coast of the United States it varies from ten or twelve inches at San Diego to sixty or seventy at Puget Sound; at Sitka, Alaska, it is about one hundred inches. How will the difference in latitude explain this? On the Atlantic coast of Europe the conditions are much the same; most of the precipitation occurs during the winter months, but on account of high latitude a considerable rain falls in summer.

In regions visited by periodical rains, not infrequently the air is so loaded with dust, at the end of the dry season, that the first rain is discolored and even muddy. The yellow and golden rain, once a great mystery, is commonly due to the pollen of pine. Examined under a microscope the character of this pollen is such as to leave no doubt as to its origin. Showers of frogs, fishes, and angleworms have been reported, but not an instance has been substantiated. It is not impossible that a water-spout might whirl a school of fishes into the air, and then over the land, but no tornado known has been so selective as to confine itself exclusively to frogs and angleworms. The latter simply emerge from their hiding-places at the onset of the shower.

Among other abnormal showers are the rains from cloudless skies. Instances are common, especially in mountainous localities. The precipitation in such cases is very slight and the showers rarely cover more than a few square miles. The sky is cloudless merely because there are not enough drops in the air at any moment noticeably to interrupt the light.

In tropical regions, where the winds have an easterly origin, the easterly slopes receive the heaviest fall of rain.

In these regions, however, the rain follows the passage of the equatorial cloud-belt back and forth. This belt is comparatively narrow—scarcely five hundred miles in breadth. During the spring months of the Northern Hemisphere it moves northward with the sun, deluging the land over which it passes with almost continuous rain. After reaching its northern limit it turns southward, repassing over the same belt. In the American continent the cloud-belt does not pass far south of the equator; in Africa it reaches much farther south.

At each tropic, the limit of the cloud-belt, there will be one rainy and one dry season, while at intervening latitudes there may be two. Which of these conditions applies to Cuba?—to the Caribbean coast of South America?

Regions swept by monsoons usually have seasonal rains. During one part of the year the winds blow from the land; the remaining time from the sea. The rains of the Indian coast of Asia are an excellent example. During the winter months the prevailing winds are land winds; but with the bursting of the April monsoon the season of heavy rain begins.

Storm Rains.—A large part of the land surface of the earth is watered, not by seasonal and periodical rains, but by the rain that comes with the movements of the atmosphere known as *storms*. These regions as a rule are either far inland, or else high mountain ranges shut them off from the reach of ocean winds.

That part of the United States east of the Rocky Mountains is an example. The great highland ranges precipitate the moisture brought from the Pacific, and there are no seasonal rains. Moisture gathers from the Gulf and the ocean, but for the greater part it is not condensed until the whirling movement of the air which constitutes the storm, takes place. These storms occur so frequently that almost every part of the region receives a plentiful supply of moisture.

Effects of Altitude.—As a rule, more rain falls at sea-level than at higher altitudes; very little falls above the height of ten or twelve thousand feet. On mountain slopes, however, the greatest precipitation takes place below three thousand and five thousand feet. The reason is twofold. In moderately warm regions rain clouds commonly do not reach much above this altitude; moreover at this height the ground may be cold enough to condense moisture when it is too warm to do so at a lower level. This fact is often observed in desert regions.

Rainless Regions.—There are two principal causes for the existence of rainless regions. There may be a barrier of high mountains that shut off rain-bearing winds; or, vapor may pass into a warmer region where it cannot be condensed. The Basin Region of the western highlands, the basin north of the Himalaya Mountains, and the Andine desert, are examples showing the effects of mountain barriers. The mountains reach higher than the rain winds. The two African deserts and much of the Mexican coast show the effects of hot inland regions. The ocean winds that penetrate these regions are warmed and not cooled, and therefore the air becomes relatively drier.

Snow.—When the condensing vapor freezes before it can gather into drops, *snow* results. It is evident, moreover, that snow cannot form unless the temperature of the air is as low as 0° (32° F.). If condensation takes place very slowly in still air, the moisture aggregates into beautiful crystalline forms, but if condensation is rapid or if there is wind, the flakes consist of tangled masses of broken crystals.

With one or two exceptions all the illustrations of snow crystals are copies of drawings made in the arctic regions by Captain Scoresby. A few drawings have been made by Professor Tyndall, and recently excellent photographs have been obtained; these show that ice crystals and snowflakes are not so regular as those observed by Scoresby. In order to obtain good specimens of crystals, they must be gathered on a perfectly still day when the temperature is several degrees below the freezing-point. It is best to catch them on a piece of black cloth, and if they are to be examined under a microscope the glass slide on which the flake rests should be covered with the same material. The crystalline forms observed in sunshine are materially different from those found in cloudy weather.

Inasmuch as snow depends on a low temperature, it is evident that its distribution is governed both by latitude and altitude. In polar regions snow covers the ground the greater part of the year, and at a little distance from the sea it never melts. In equatorial regions the line of perpetual snow is about sixteen thousand feet above sea-level; in temperate latitudes it varies from seven thousand to twelve thousand feet.

Hail.—Hail consists of pellets of ice, formed in the air, and a shower of them constitutes a hail storm. Usually a hailstone consists of alternate shells of snow and crystalline ice. In some instances sharp, dog-toothed crystals of ice project from the outer surface. Hailstones vary in size from tiny pellets to masses an inch in diameter. Larger stones occur, but usually they are formed by the cohesion of small ones.

Hail storms are more frequent in warm weather than in cold. For reasons unknown certain localities are especially subject to them. They frequently accompany thunderstorms, and the formation of the ice pellets results from whirling updraughts that carry the rain drops far upward into air of freezing temperature. As a rule, hail storms are of only a few minutes' duration, and the amount falling is a small fraction of an inch in depth.

In 1888, at Moradabad, India, hail fell to a depth of several inches, and in one district two hundred and thirty-five people were killed. In June, 1879, a storm swept over central New York and Massachusetts, during which stones seven inches in circumference fell. In July, 1880, a hail storm destroyed the crops in the vicinity of Waupaca, Wisconsin. The shower covered an area of forty square miles. Stones from six to ten inches in circumference fell. In July, 1881, the fall of hail at Cumberland, Maine, was so great that drifts two feet deep were observed twelve hours afterward. In June, 1882, at Dubuque, Iowa, stones weighing twenty-eight ounces were found. In August, 1883, at Gray, Iowa, the drifting hail covered the fence tops. In June, 1886, so much hail fell in Grand Forks County, Dakota, that it did not all melt for thirty hours. In a single storm that passed over a small area in Dakota, a quarter of a million acres of wheat were destroyed.

QUESTIONS AND EXERCISES.—Observe the temperature and find the greatest amount of moisture there may be in the atmosphere at the time of recitation. Find the annual rainfall of the neighborhood in which you live by striking an average of the yearly precipitation for at least ten years. (*The statistics may be learned from the nearest Weather Station.*)

Fill a brightly-polished tin cup, or a nickel-plated shaker half full of water; add finely-broken ice and stir until a mist appears on the outside of the cup. Ascertain the temperature of the water; this is approximately the dew-point.

Make a record of the early and late frosts for the year. What fruit crops are injured by killing frosts in the neighborhood in which you live?

Learn, from the nearest Weather Station, the months in which the greatest amount of rain or snow falls;—the least.

What crops or plants of commercial value would suffer or perish if the rainfall in the State in which you live were decreased one-third?

Note the character and kinds of cloud visible during several days; at what time were stratus clouds visible?

Explain how smoke may gradually gather cloud matter. Why is this most apt to take place toward evening?

The receiver of a rain gauge is a cylindrical cup four inches in diameter. For convenience of measurement the water caught is poured into a glass tube one inch in diameter: a depth of one inch of rain in the receiver will make how many inches in the tube?

Explain how a crust forms on the surface of snow.

At a convenient opportunity, catch flakes of snow on a piece of black cloth; examine them with a magnifying-glass and make drawings of their shape. (*Observe the conditions noted on p.* 245.)

COLLATERAL READING AND REFERENCE

TYNDALL.—Forms of Water.

U. S. WEATHER BUREAU.—Monthly Weather Review. Midsummer and midwinter issues of any year.

GREELY.—American Weather—pp. 77–81, 134–162.

WALDO.—Elementary Meteorology—pp. 142–165.

CHAPTER XIV

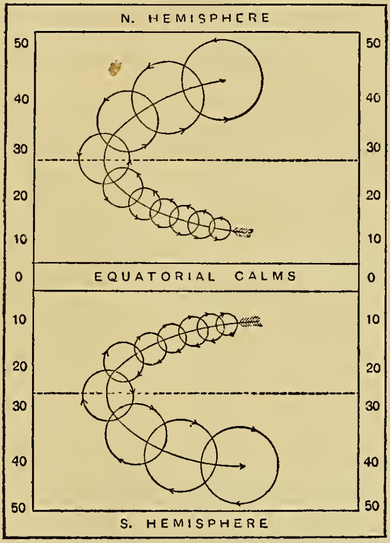
THE MOISTURE OF THE ATMOSPHERE. CYCLONIC STORMS

Both on the land and at sea there are regions of considerable area that normally are not swept by regular and constant winds. On the sea these are the calm belts; on the land they are regions from which the winds are shut off by mountain-ranges, or disturbed by broad stretches of land. On the sea the shifting of the calm belts with the season brings various parts successively under the influence of the regular winds. On land the regular winds usually exist as upper currents, while at the surface the winds are local and variable; the upper currents, moreover, are so high that they are too cold to contain much moisture.

STRATUS CLOUDS DISTURBED BY AN UPDRAUGHT

Such regions do not receive seasonal rains. The land areas, in some instances, receive none at all, except from an occasional cloud-burst; but in many cases a considerable rainfall results from the movements of local winds. That part of the United States east of the Rocky Mountains is an excellent illustration. It receives no moisture directly from the constant winds; yet about every part of it east of the 2,000-foot contour is so generously supplied with rain that it is one of the most productive regions of the world.

Whenever a local wind occurs, one of two conditions is pretty apt to exist. Either there is an updraught *toward* which the wind is blowing, or else there is a great accumulation of air *from* which the air is spreading outward. These local disturbances constitute the conditions popularly known as *storms*. Moreover, in either case the movement of the air sooner or later develops into a whirl. The wind that blows toward an updraught or a depression forms a *cyclone*; that which blows outward from a high bank of air, an *anticyclone*. These disturbances originate both on the land and at sea. They are usually indicated by a changing barometer; hence a cyclone is often described as an area of low barometer—or simply a "Low"—and the anticyclone, one of high barometer. As a rule, both the cyclone and the anticyclone are local disturbances, and therefore they are carried along by the great currents of the air, just as an eddy formed in a river is carried along in its flood.



NORMAL CYCLONE TRACKS

Cyclonic movements therefore travel westwardly in low latitudes and eastwardly in latitudes beyond the tropics, because these are the prevailing directions of the winds. Therefore, when a cyclone has formed, the track which it is likely to follow can be predicted with considerable accuracy. The direction of the whirl is also certain; in the Northern Hemisphere it is opposite that of the clock hands; in the Southern Hemisphere, with the clock hands. A knowledge of these facts enables the mariner not only to avoid a cyclone, but also to steer out of it whenever he may be overtaken by one.

In the tropics the cloud-ring rarely exceeds five hundred miles in diameter, and the circle of dangerous winds is scarcely more than half as great. In higher latitudes, however, the diameter of the storm increases. The wind is more violent in tropical than in higher latitudes.

The direction of the whirl probably results from the conflict of winds as they approach the updraught. Of all the currents setting toward the storm centre, the northeast Trade Wind is the strongest. As it approaches the storm centre it is opposed by weaker winds from the north, northwest, and west. The Trade Wind is bent therefore toward the east and forced to rotate in the manner described.

Tropical Cyclones.—Tropical cyclones usually originate within a few degrees of the equator. They are the *hurricanes* of the West Indies and the *typhoons* of the China Sea. The storm area extends over a surface varying from a few hundred to more than a thousand miles in diameter. The illustration, p. 249, shows roughly the track which, ordinarily, one of them follows. What is its direction in tropical latitudes? in latitudes beyond the tropics?

"STREAMERS" OF CIRRUS CLOUDS —THE FORECAST OF A CYCLONE

The real beginning of the tropical cyclone is the dead calm that for a few days precedes it, for a quiet atmosphere is a necessary condition to its formation. The first essential condition is the overheating of the air next the water—precisely the same condition that formed the beginning of the desert whirl (p. 226). But while the stratum of air that causes the desert whirl is only a few hundred feet in height and of very small area, the atmosphere disturbed by the tropical cyclone is, perhaps, several thousand feet high and many thousand miles in extent.

The longer the sun beats upon the glassy surface of the water, heating the air nearest to it, the greater will be the energy of the storm when it begins. Moreover, there is one element present in the tropical cyclone that is not found in the case of the desert whirl—namely, *the vapor of water*. This is the most important distinction between the two. Finally, an updraught of air occurs where the resistance is least. The moment this occurs, the rising air already near the dew-point is chilled by its own expansion, and a part of its moisture is precipitated. The fall of rain sets free an enormous amount of latent heat, and a furious updraught at once takes place.

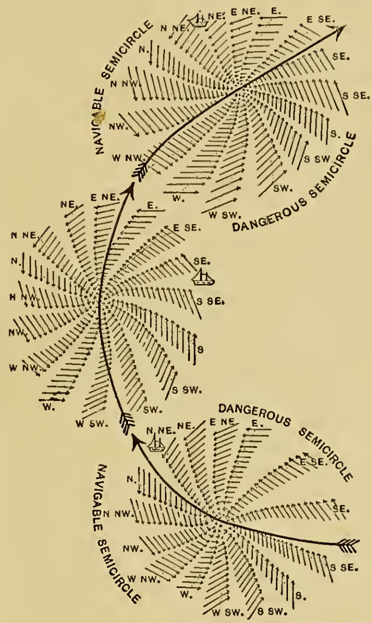
The latent heat of the moisture set free gives to the cyclone its great energy. This is its fuel, and so long as the supply lasts, just so long will the cyclone continue. The ascending air at first is moist and warm; but after its moisture has been condensed, the heat set free renders it warmer, thereby increasing the updraught.

The nearer the centre of the cyclone, the stronger is the wind. The "eye" of the storm, or the centre of the whirl, is the updraught of the cyclone, and here brief intervals of sunshine alternate with torrents of rain. In the centre of the storm the barometer stands lowest—perhaps two inches lower than it is beyond the edge of the storm.

The barometer gives first warning of the approach of the cyclone. During the few days preceding, the barometer is perhaps above its normal height and the weather pleasant and clear. Sooner or later the barometer begins to show signs of unsteadiness, and at the same time a long, low, ocean swell becomes perceptible. Possibly a streamer or two of cat-tail clouds pointing toward the zenith is seen in the south or southwest, and a whitish arc near or on the horizon indicates the bearing of the centre. In a short time the barometer begins to fall—slowly at first, and then more rapidly. A halo gathers around the sun; the ocean swell increases, the sky grows purple, and fitful puffs of wind come from the north. There can no longer be any doubt of the approaching storm, and the prudent master has already made everything snug and ready for the coming blow. Soon a heavy bank of cloud looms up from the horizon. This is the cloud-ring that marks the edge of the storm, and the circle of dangerous winds is not far away. Finally the wind, already very squally, bursts into a gale, and veers to the northward, and soon the storm is in full force. If, by any means, the course of the ship has not been altered, or if, through accident, it is carried with the wind, the latter will increase to hurricane strength, and not even the smallest storm-sail will stand against it. Then almost in a twinkling, the wind lulls and the ship is in the eye of the storm. The sky alternates between inky blackness, with terrific down-pours of rain, and moments of misty, yellow light. Perhaps half an hour passes, and the opposite side of the cyclone strikes the vessel. At that moment the wind again bursts upon the ship from the opposite direction. Nothing but a stanch vessel can ride through such a storm. A square-rigged ship is apt to have her yards stripped off, even if the masts are not snapped.

The cyclone may be considered as an eddy in the great tropical easterly current of the air along with which it moves. When the whirl has reached the belt of Prevailing Westerlies, it is carried along with that current also. Knowing the direction of the whirl and the path of the storm, it is not difficult to lay the course of the vessel out of the way of the cyclone. For this purpose "storm cards," or diagrams similar to that below, are convenient. The distance of the storm centre can be estimated only to a rough degree, but the bearings can be obtained with a high degree of probability. Facing the wind the storm centre is on the observer's right hand.

The accompanying storm cards are adapted for use in any cyclones of the northern hemisphere; the upper diagram is available for the route between New York and English ports. The small arrows fly with the wind; the long arrow represents the storm track through the belt of latitude to which the diagram applies. For West Indian hurricanes the storm track recurves as follows: June and October, latitude 20° to 23°; July and September, latitude 27° to 29°; August, latitude 30° to 33°. When a falling barometer and other signs indicate the approach of a cyclone, select the diagram that applies to the latitude and plot the position of the ship according to the direction of the wind. In low latitudes, for instance, the wind is N NE; the vessel is then in the position that is shown on the lower diagram, and is in the dangerous semicircle. If possible it is best to lie-to (on the starboard tack), and observe the wind. (*a*) If it freshens *without shifting*, the vessel is certainly in the storm track. In this case the navigator keeps off, with the wind on the starboard quarter, holding to the course. (*b*) *If it shifts to the right*, the ship is to the right of the storm track and should be put on the starboard tack, making as much headway as possible until obliged to lie-to. (*c*) *If it shifts to the left*, the ship is on the left of the storm track and should be brought about until the wind is on the



STORM CARDS

starboard quarter, lying-to on the port tack if necessary. In scudding, the wind should be kept always on the starboard tack to run out of the storm. If the vessel is in the latitude where the cyclone probably recurves (according to the month) the middle diagram is applicable. Suppose that the wind is S E; the vessel then has the position marked in the middle diagram. It is on the right of the storm track and should run out as in (*b*), previously noted. In high latitudes the upper diagram is indicated. Suppose that the wind is N E. The ship then has the position shown to the left of the storm track, in the navigable semicircle, and should be brought about as in (*c*), previously noted.

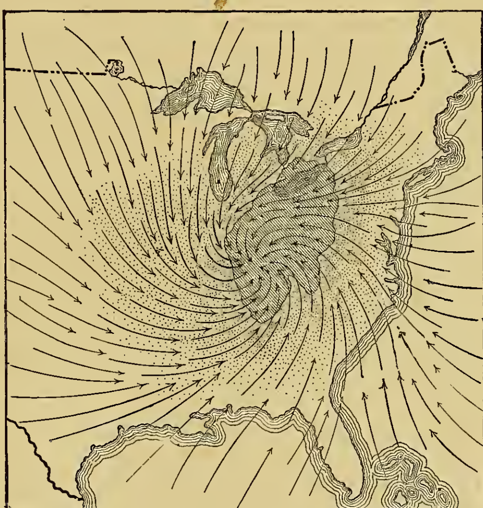
Winter Cyclones.—Some of the fiercest storms of the higher latitudes, however, do not originate anywhere within tropical regions. These are the extra-tropical or winter cyclones, and the fierce winter storms of the North Atlantic Ocean are examples. These storms do not originate in a dead calm, because there is no long-continued calm weather where they form; and it is apparent that they are not formed by the overheating of the air next the surface of the water.

It is thought that they result from the intrusion of cold, north winds into the region of warm and moist air, to the southward. In any case the condensation of moisture creates an updraught that quickly develops into a whirl. But if, at the time of intrusion, the cold air takes the upper position, the equilibrium becomes much more unstable, and the storm very likely develops into one of great fury.

It is unstable because the cold air is resting on a layer of air that is specifically lighter, and when the latter is pressed upward it soon develops into a whirl. Winter cyclones are not confined to definite localities, as are tropical cyclones, and in comparison with the latter their tracks are erratic. Their general direction is easterly, however.

Land Storms.—The occasional local squalls excepted, all the storms of the middle and eastern United States are cyclonic in nature, and except in violence they do not differ materially from the cyclones of the sea. In nearly every case they follow the same courses that are taken by the latter—westerly in tropical and easterly in temperate latitudes.

In many cases a storm may originate at sea and end somewhere at a considerable distance inland, or *vice versa*. Many West Indian hurricanes sweep into the Gulf of Mexico and thence into the Mississippi Valley. On the other hand, many north Atlantic storms begin far in the interior of the continent. In some instances storms originate in the Pacific, cross the United States and the Atlantic, and finally disappear in the interior of Eurasia. Many of the cyclonic storms of California and Oregon travel southward between the Coast Ranges and the Sierra Nevada Mountains. Perhaps they are dissipated in the arid region to the southward, but occasionally a cyclonic storm finds enough moisture to enable it to pass into the Mississippi Valley.



A STORM, OR AREA OF LOW BAROMETER

The shaded part is the area of rain; the dotted region the area of cloudiness. The arrows fly with the wind.

Storm Tracks of United States.—Since the establishment of the various weather bureaus, the storm tracks have been closely studied, and it is found that most storms follow certain lines. In the United States two such tracks are apparent. The lesser number follow the trend of the Atlantic coast. These storms usually overlap the coast plain, but they seldom extend west of the Appalachian highlands. They belong to the class of West Indian cyclones, originating in the Caribbean Sea, and turning northward, along the Middle Atlantic coast.

Most of the storms form near the great highlands of the west—very frequently near the eastern base of the Rocky Mountains, crossing the continent in a northeasterly direction. These storm tracks have a distinct tendency to shift north or south with the apparent motion of the sun, the belt being a little farther north in summer than in winter. The valley of the St. Lawrence River and the basin of the Great Lakes is a common track for summer storms.

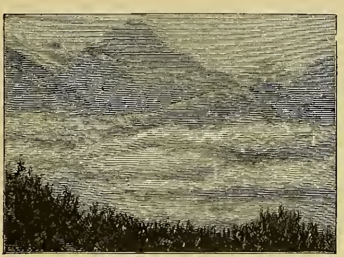
Characteristics of Land Storms.—Although they are sometimes accompanied by local thunder squalls, land storms rarely exhibit the fury of ocean cyclones. The area of the storm is usually larger, but the wind seldom attains a velocity greater than forty miles an hour. The storm centre is distinct, but the barometer may not fall more than half an inch.

Clouds, and rain or snow accompany the majority of storms, but the area of rain does not always cover the whole extent of the storm; as a rule, most of the cloud area, and the rain as well, occur in front of the storm centre. As the latter passes there are occasional showers in which the rain falls vertically, or perhaps drives slightly toward the east. These are the "clearing showers."

Because the wind blows toward the storm centre, it is evident that storms of the second class will be preceded by easterly and will clear with westerly winds. Those from the West Indies will begin with northeasterly and clear with southwesterly winds—the *nor'easters* and *sou'westers*.

Storms may be accompanied by thunder-showers, cold waves, tornadoes, and waterspouts. Thunder-storms and tornadoes are local in character, and often occur independently of general storms. Waterspouts and tornadoes are local, the former being confined to the water. Cold waves are general.

Anticyclones.—Just as the trough of a wave of the sea is followed by the crest of another wave so, in the aërial ocean, an area of low barometer is followed by one of high barometer. The latter is practically a descending, or downdraught of air, which flows outward at the bottom in every direction.



CLEARING WEATHER CLOUDS

The paths along which anticyclones move are not materially different from cyclone paths; that is they each follow an easterly track in the wake of a cyclone. The whirl, however, is in the opposite direction, being from west to east, corresponding to the movement of the hands of a watch, lying face up. On the eastern side of the anticyclone the air is apt to be dry and cold; on the west side, dry and warm.

Cold Waves.—In many instances the barometric pressure is much higher on one side of the storm track than on the other. If the bank of air lies north, or northwest, its temperature is pretty apt to be low, and the depression will fill with cold air, forming a *cold wave*. Many winter storms are followed by cold waves, and a body of air whose temperature is much below the freezing point will flow as far south as the Gulf coast. To this form of cold wave the destruction of the Florida orange groves is due.

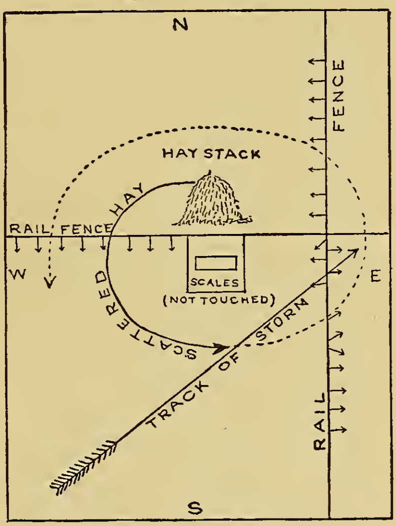
Occasionally the wind blows with a velocity of sixty miles an hour or more, carrying fine snow and ice crystals. These anticyclonic winds are *blizzards*. They are very severe in upper Mississippi Valley, and are the most destructive storms that sweep the cattle ranges.

The blizzard was first noted in the records of an exploring party which, in 1747, wintered on the shores of Hudson Bay, at a place now called York Factory. The name was introduced as a technical name into the weather service in 1876. The blizzard of January, 1888, is an example of the effects of the translation of cold air from the extreme north. At Helena, Montana, the temperature fell fifty degrees in four and one-half hours, and sixty-four degrees in less than eighteen hours. At Crete, Nebraska, the thermometer fell eighteen degrees in three minutes. This wave covered almost the whole United States, carrying freezing weather into Florida, California, and southern Texas. In March, 1887, a cold wave, extending along the valley of the St. Lawrence River, was marked by a fall of temperature ranging from fifty to seventy-one degrees in twenty-four hours. In Denver, January 15, 1875, there was a drop in temperature of forty-eight degrees in one hour. Practically, the northern limit of the torrid zone in the United States is the southern limit of the cold wave; this line crosses the southern parts of Florida and Texas.

Warm Waves.—On the other hand, if the bank of air is on the south side of the storm track, the mass of air drawn from the south is very apt to be warm and very moist. Under such conditions a warm wave results. Although the difference between the temperature warm waves and normal weather is not so great as that between cold waves and normal weather, yet the former are far more fatal. In all the densely populated parts of the country the advent of a warm wave is marked by an enormous increase in the death-rate.

During several warm waves that, in July, 1881, covered the Mississippi Valley, there were more than one thousand deaths from sunstroke —probably a greater number than have resulted from the cold waves of a score of years. Warm spells may result also from settled conditions, and not disturbances. The air resting upon a given area may not be disturbed in the course of several days. Its warmth therefore increases, and may become intolerably hot.

Tornadoes.—Tornadoes are whirling storms of the land. Though they cover an area smaller than that of any other storm, they are probably the most violent atmospheric disturbances known. The path of the tornado seldom exceeds thirty or forty miles in length, while the destructive part of the whirl is not more than a few rods in width. Like other cyclonic disturbances, the tornado is formed in an area of low barometer. Seen at a distance of one or two miles, it appears as a dense, black, funnel-shaped cloud hanging from rapidly whirling clouds above. The funnel is the centre of the storm, and so rapid is the whirl that it forms almost a vacuum. The rotary velocity of the wind is thought to be not far from two miles a minute.



A TORNADO TRACK

The position and direction of the rails show the direction of the whirl.

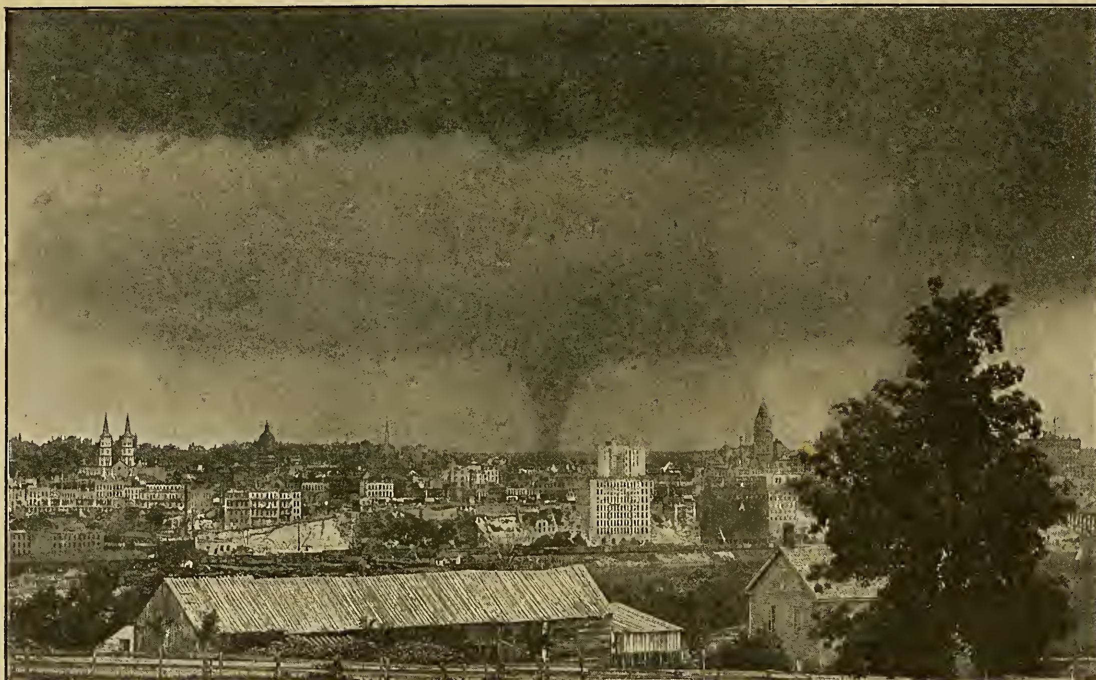
Between the terrific wind and the vacuous centre, nothing can withstand the force of the tornado. The stoutest tree-trunks are twisted as though they were ropes, and in many instances pulled clear out of the ground. Buildings in the way of the funnel cloud burst into pieces outwardly the moment the latter envelops them; heavy locomotives are lifted from the railway track; and iron bridges are blown from their foundations, twisted into shapeless tangles, and carried long distances. Another noticeable feature is the lane or "windroad" made when a tornado passes through a forest.

The study of several hundred tornadoes has shown the manner in which they originate. At the beginning of a storm it sometimes happens that a great volume of cold, dry air lies on one side of the disturbance, while a mass of warm, moist air lies on the other side.

During the progress of the storm large volumes of cold air are whirled into regions of warm and moist air. Now, if the heavier cold air lies next the earth, no disturbance follows. But if it comes to rest on the top of a thick layer of warm air the case is different. There will result an updraught of warm air, and soon the tornado is in full vigor.

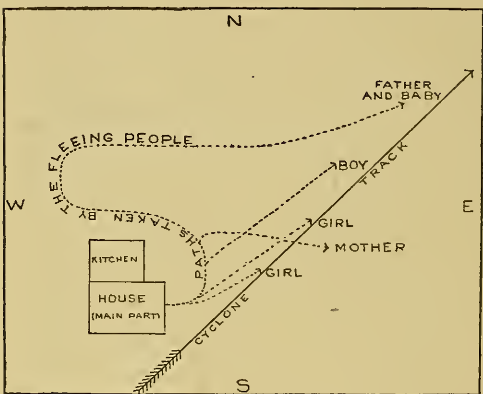
In about ninety-five per cent. of the tornadoes studied the whirl accords with that of other storms in the Northern Hemisphere. Almost always they move from the southwest to the northeast. In nearly every instance the tornado track lies south of a general storm.

Major-General A. W. Greely, U. S. A., formerly Chief of the Weather Service, notes twenty-five tornadoes, in which the aggregate damage reached the sum of $15,000,000, while the loss of life was nearly fifteen hundred people. Concurrent with a storm that on February 9, 1884, crossed the United States, there were sixty distinct tornadoes. On that day eight hundred people were killed, twenty-five hundred were wounded, and more than ten thousand buildings were destroyed.



A TORNADO AND ITS FUNNEL CLOUD, LAKE GERVAIS, MINN.

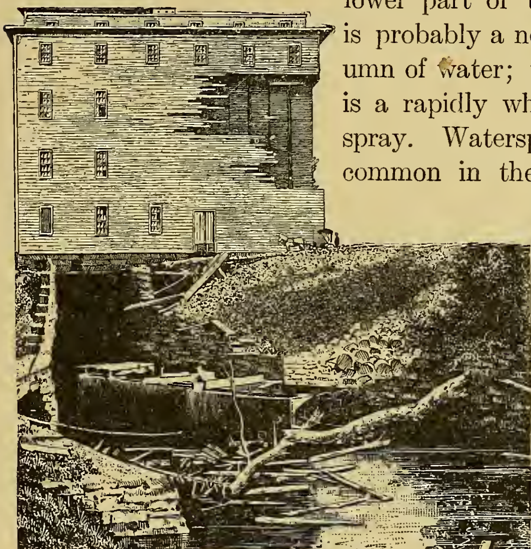
The story illustrated in the accompanying cut is grewsome. The house was surrounded by a grove of trees. To the east of the house the trees were felled and twisted from right to left; those west of the house were untouched. The house itself was demolished and the debris hurled into the creek-bed near by. When the tornado cloud swooped down upon the house, the family fled for their lives, but unfortunately in the wrong direction. At first they ran northward, a direction of safety. Then, one after another, they turned eastward—first a little girl, who was instantly killed; then an older boy and a girl, who were much bruised and partly stripped of their clothing. The mother ran directly into the whirl and was found crushed and dead against the trunk of a tree. The father, with the babe in his arms, had reached a place of absolute safety, but in his fright turned eastward and ran into the whirl. They were picked up by the wind, thrown several hundred feet, and instantly killed. An inspection of the accompanying illustration shows that the safest path of flight is toward the northwest or the southeast; to the southwest or the northeast is one of the greatest danger.



All parts of the United States are subject to tornadoes, but they are most prevalent in the central Mississippi Valley. West of the 102d meridian they are rare, because there is so little moisture in the atmosphere. They rarely occur in mountainous regions.

Tornadoes are more frequent in summer than winter. The greatest number occur in May, and more occur in May, June, and July than during the rest of the year. They are more frequent in the afternoon than in the morning, and rarely occur at night.

Waterspouts.—A waterspout is a whirlwind of the sea or other large body of water. The whirl is so rapid that the water is carried upward to fill the vacuous centre. The lower part of the waterspout is probably a nearly solid column of water; the upper part is a rapidly whirling mass of spray. Waterspouts are most common in the region of cyclone tracks—especially within the track of the Gulf Stream. It is usually asserted that the water which composes them is fresh. This is not always the case, however; in many instances it is salt-water. At the lower part, the column is not more than ten or fifteen feet in diameter; in the upper part it is whirled into a balloon-shaped cloud of spray several hundred feet in diameter.



EFFECTS OF A TORNADO

The *white squall* is similar in origin to the whirl that results in a waterspout; in fact, it may properly be called a fair-weather whirlwind of the sea. It is sufficiently violent to whirl a considerable volume of sea-water into spray, but hardly strong enough to form a waterspout.

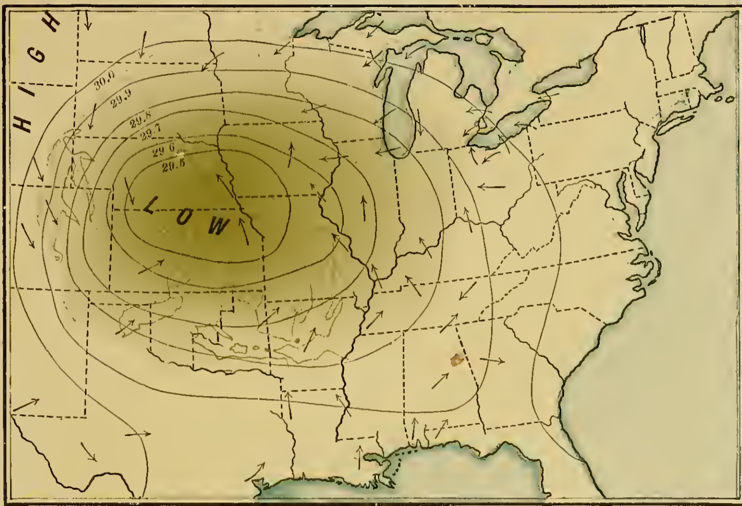
Weather Forecasting.—Knowing the laws of storms it is not a difficult matter to predict weather conditions with considerable accuracy. In the temperate zones weather conditions originate to the westward or southwestward of the observer; in tropical regions, at the eastward.

Except in the extreme southern part, where tropical storms are common in summer, the weather of the United States is essentially of the westerly type. The storms move from the west or southwest to the east or northeast.

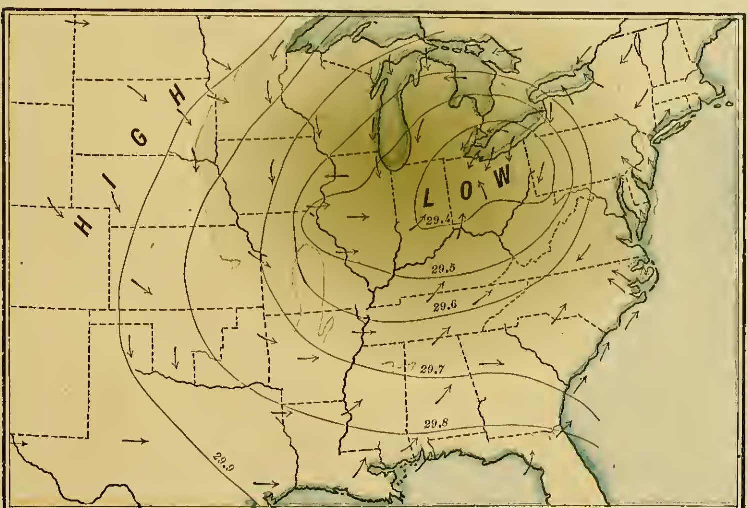
The United States Weather Bureau was organized for the purpose of protecting agriculture, navigation, and commerce by furnishing information of coming storms, dangerous coast-winds, threatening floods, cold waves, and killing frosts. Scattered over the whole territory in selected locations are about six hundred observers who, twice a day, at the same actual time, observe temperature, barometric pressure, relative humidity, direction of wind, amount of rain or snow, etc. These results are telegraphed to Washington and entered upon a weather map.

Lines are drawn through localities of equal barometric pressure, and also through localities having the same temperature. The former are *isobars*, the latter *isotherms*. In this manner areas of high, normal, and low barometer are readily mapped and located. When the direction of the wind is plotted it will be found that it is everywhere blowing toward the area of low barometer.

Twelve hours afterward, when a new set of observations is plotted, it will be found that the area of low barometer has advanced eastward with about the velocity of an ordinary express train. With this information both the direction and the velocity of the storm can be forecast for the succeeding twenty-four hours.



STORM CENTRE: FIRST DAY



STORM CENTRE: SECOND DAY

About ninety per cent. of the predictions may be verified and the number actually verified is very close to the possible limit. Failure of verification is due to several causes—the sudden swerving of a storm from its track; the dissipation of a storm once formed; and the unforeseen development of a local storm. The shifting of a storm one hundred miles on either side of its predicted track may nullify the forecasts over a very large area.

The Weather Bureau of the United States is now a part of the Department of Agriculture. Most of the European nations have established similar bureaus, and daily observations are made on all transatlantic steamships. So complete are these records that scarcely a storm occurs in the North Atlantic which is not followed and its path predicted with a high degree of probability. Flags (or sometimes painted cylinders and cones) are displayed on public buildings in nearly every town in the United States and Europe. A square white flag denotes clear weather; a blue flag, rain or snow. Temperature is indicated by a triangular blue flag. Above the square flag it denotes higher temperature; below the square flag, lower temperature; its absence denotes no change in temperature. Whenever the temperature falls twenty degrees or more (sixteen degrees in the northern states), if the mercury sinks as low as 32° (F.), it is technically a cold wave, and its approach is indicated by a white flag containing a black square. It is commonly called the "black flag." A fifth flag is sometimes employed to indicate local storms. For the benefit of mariners a Monthly Pilot Chart for the North Atlantic is published by the United States Hydrographic Office. This shows storm tracks of the preceding month, and the position of ice, fog, floating wrecks, or "derelicts" and other obstacles, for the current month.

QUESTIONS AND EXERCISES.—Why does the wind blow toward a low and away from a high barometer?

Why do cyclonic movements of the wind move toward the west in tropical, and toward the east in temperate latitudes?

Why does the water flowing out of a sink through a discharge-pipe at the bottom form a whirlpool?

In the map at the top of p. 265, near what city is the centre of the storm? What is the direction of the wind at New Orleans and Baton

Rouge?—at St. Louis and Cairo?—at Chicago and Davenport?—at Duluth?—at Cheyenne?—in the greater part of North and South Dakota?

Name one or two places at or near which the barometer is 29.5 inches; 29.7 inches; 29.9 inches; 30 inches.

About how far has the storm advanced at the time of observation on the second day?

Note the direction of the wind at Pittsburgh, Cleveland, Wilmington, N. C., Cincinnati, Indianapolis, Chicago, Springfield, Ill., Milwaukee, New Orleans, Mobile and Little Rock.

The wind whirls warm, moist air from the south to colder, northerly latitudes; what will be the effect on the moisture?—on the temperature of the region over which the storm passes?

In what position, with reference to the storm centre, is most of the rain, as indicated by the shading?

Whence comes the air in the western part of the whirl—from northerly or from southerly regions?

Will it probably be colder, or warmer? Why?

Make a forecast for Cincinnati for each of the two days.

Make forecasts for New York, Denver, and Chicago for the third day.

COLLATERAL READING AND REFERENCE

Greely.—American Weather—pp. 178–272.

United States Weather Bureau.—Daily Weather Maps.

CHAPTER XV

ELECTRICAL AND LUMINOUS PHENOMENA OF THE ATMOSPHERE

Electricity is manifested chiefly by its effects; of its actual nature but very little is yet known. The laws pertaining to it are fairly well known, however; like most of the other forces of nature, it is a most useful servant when under intelligent control. In the slender thread of the incandescent light and the carbons of the arc light it appears both as light and intense heat. Passing through insulated copper wire that surrounds a core of soft iron, it converts the latter into a magnet, and thus harnessed it becomes a generator of great power. Electrical energy seems to be a form of motion, and it may be produced by motion. It is manifest not only in the earth and the air, but in space as well.

Fundamental Laws.—The laws of electrical energy are not difficult to understand. A pith-ball, hanging by a silk fibre, and brought near a piece of dry and clean hard rubber that has been rubbed by flannel will at first cling to the hard rubber and then will fly away from it. If another ball, electrified in a similar manner, be brought near the first one, the two will repel each other. If, however, the second pith-ball be electrified by a piece of glass rubbed with silk, the two balls will then attract each other.

Such an experiment demonstrates the principal laws of electricity. *Bodies similarly electrified repel; bodies differently electrified attract one another.* The electricity developed when glass is rubbed with silk is called *positive;* that produced by rubbing vulcanite with flannel, *negative.*

Electricity passes quite freely through metallic substances, which are said to be *conductors,* but with difficulty through such material as silk, wool, gums and resins, dry wood, and dry air, which are *non-conductors.* When, however, the electric force is so great that it will pass through these it is said to have a *high potential,* just as steam confined within a boiler is at high pressure. The "sparks" produced by rubbing sealing wax or vulcanite with flannel are of moderately high potential.

The potential of electricity may be also likened to pressure on water flowing through a pipe. If the pressure be low the water will flow quietly through the pipe and fall at no great distance from the end of the nozzle; on the contrary, if the pressure be great, it will be projected a distance corresponding to the force. In a single cell of galvanic battery the potential, about one or two *volts,* is so low that the electricity will not jump across a space of one thousandth of an inch; the quantity, moreover, is very small. In an electric-light wire a current of considerable volume will leap across a space one-tenth of an inch or more; its potential is about 1,000 to 1,500 times as great as that found in a cell of an ordinary galvanic battery, being from 2,000 to 5,000 volts. A good frictional electric machine will cause sparks to leap between points ten or twelve inches apart; the potential is very high, but the quantity is small. During a thunder-storm a stroke of lightning may jump a distance of a mile. Not only is the quantity enormous, but the potential is so great as to be immeasurable by ordinary standards.

Electricity of the Air.—To the electricity of the air and the earth many of the most marvellous phenomena are due. In the simplest form we see its effects when tiny sparks result from rubbing the long knap of woollen cloth or the fur of an animal pelt; we see its grandest effects when flashes of lightning forge across the sky. The electricity of dry air is usually of high potential. Next the earth, however, the electricity of the atmosphere is not commonly noticeable, especially if the air is moist. The moisture is so good a conductor that the electricity is in a condition of equilibrium. At considerable elevations, or when the air is very dry, its presence becomes marked. The hair of the head crackles as a comb is drawn through it, and tiny sparks are given off when woollen clothing is rubbed. In the dry summer climate of deserts, the hair of horses' tails stands out like bushes, and their manes are like fright wigs; sparks half an inch long may be drawn from a metallic body insulated from the ground.

Ordinarily, the electricity of the air is positive, but, with much moisture present, it may be negative. Just before the beginning of a gentle shower it often becomes negative, and during a heavy storm it frequently changes from positive to negative and *vice versa* very rapidly. In such cases the character of the electricity may vary in different places; that is, it may be positive at one locality and negative at another, only a few miles distant.

At different localities, the character of the electricity may be so very unlike, that the earth currents are sufficient to operate telegraph wires without the aid of the batteries. In regions of dry climate such conditions are more frequent than in localities where the air is moist.

Neither physical nor chemical change in a substance takes place without the development of electric energy. Friction likewise is a potent factor in its generation. The flowing of water; the chafing of the winds against the earth's surface; even the friction of the air against itself produces it copiously. Evaporation and condensation also produce it; and inasmuch as an enormous amount of the vapor of water is constantly vaporized at one locality to be condensed at another, evaporation and friction may be regarded as the chief agents in its production.

The vapor of water is not only a good conductor of electricity, but it is an excellent storage reservoir as well. The small globules of vapor that compose the cloud mass carry the charge of electricity each upon the surface. But when a great number of these globules are condensed to form a drop of water, the surface of the drop is infinitely smaller than the aggregate surface of the globules. The potential of the drop, in comparison with that of the globules, is enormously increased. If an electrified body, such as a vulcanite rule, is brought near a sprayer or a sprinkler the fine spray immediately gives place to large drops.

Since these agents are always at work, electricity is being constantly generated. But the electricity of the air and that of the earth are unlike; the two, therefore, neutralize each other. If the air be moist the two kinds of electricity readily pass from the earth to the air, and from the air to the earth, until the equilibrium is restored. This transference goes on so quietly that there is no great accumulation of electricity. It is only when the air is very dry, or during an electrical storm, that the transference takes place with difficulty.

Thunder-Storms.—When clouds are present in the air, however, there is often an enormous accumulation of electricity, either within or upon their surface, and the transference or exchange, therefore, may become violent. Such disturbances are *thunder-storms.*

When large masses of cloud hover over the earth it sometimes happens that they are differently electrified. Under such circumstances the two clouds are mutually attracted. The potential is very high and the transference takes place in the form of great flashes of lightning. Usually the interchange takes place between the two clouds, but quite as frequently it is between the clouds and the earth. The form of lightning varies. The interchange takes place always along the line of least resistance, and as this is seldom, if ever, a straight line, it has taken the name, *zigzag* lightning.

The flash of light that accompanies the electrical discharge heats to whiteness the foreign matter in the path of the discharge. The air being a poor conductor offers considerable resistance to the passage of the electricity, and is therefore intensely heated along the line of discharge. The thunder is produced in exactly the same manner as is the noise that accompanies the discharge of a firearm. The air at the point of discharge is rarefied almost to the extent of being a vacuum; the rush of air to fill the vacuum is the thunder. The rumbling of the thunder is due partly to echo and reverberation, and partly to the fact that the sound along the line of discharge reaches the ear at different intervals—the greater the distance the longer the time required for the sound to reach the ear.

In paintings and illustrations it has always been customary to depict the electric discharge in the form of a zigzag line of many sharp angles. In the past few years photographs of the lightning stroke have been successfully made. One of these on the following page shows the fallacy of former notions on the subject.

Another form is known as *sheet lightning*. This interchange takes place, not along a line, in the form of a "bolt," but simultaneously over a large area. The discharge is not attended by a crash of thunder, nor by a blinding flash of light. On the contrary there is nothing but a quivering glow that lasts sometimes for eight or ten seconds. A sheet lightning discharge takes place usually between the earth and the clouds. The electricity is of low potential and therefore not destructive. This name is also applied to flashes of lightning that, occurring at a considerable distance, are reflected from the under surfaces of clouds.

This reflection is also called *heat lightning*. It is rarely observed except at the horizon when the latter is overcast by clouds. The reflected flashes of light are usually so far away that the accompanying thunder is not heard. Still another form is commonly called *ball lightning*. Of this kind of discharge but little is known, and although its occurrence has been alleged for more than two hundred years, its existence is somewhat in doubt.

Occasionally the discharge takes unusual forms. Among them, but rare in occurrence, is the phenomenon known as *St. Elmo's fire.* This discharge, though best known at sea, is also occasionally observed on land. At the time of its occurrence there is usually a considerable electrical disturbance though not necessarily a thunder-storm. Owing to

LIGHTNING

From an instantaneous photograph by W. F. Cannon.

the feebleness of the light emitted, it is not frequently noticed in the daytime. It consists of a pale, shimmering light, at the tips of the yards and spars of a ship's rigging, or from the branches of trees. The glow lasts for a few moments and then disappears. It is probable that the St. Elmo's fire is identical with the bluish glow that is seen when a frictional electrical machine is worked in the dark—a phenomenon commonly known from its shape as the "brush" discharge.

While Cæsar was carrying on his military operations in Africa, he relates that, during a severe hail-storm, the spears of his fifth legion were tipped with fire. The phenomenon was undoubtedly identical with that of St. Elmo's fire. It is not improbable that the "ignis fatuus," "Jack o' lantern," or "Will o' the wisp" is a similar electric phenomenon. This is a hazy indistinct light occasionally seen in swamps. According to tradition, the ignis fatuus is a bright light that moves rapidly from place to place mainly for the purpose of alluring unsuspecting travellers into dangerous places. As a matter of fact it is practically motionless.

In some instances a thunder-storm passes along a path a thousand miles long, spending its energy and disappearing when the electrical equilibrium is restored. It may also move along at the front of an air current. The centre of energy is marked by a brisk cyclonic movement, and as the storm progresses along its path the area gradually increases. The conditions of formation are not unlike those which result in tornadoes. Like them, progressive thunder-storms occur usually on the south side of a general storm, and there are apt to be several of them following in quick succession. The progressive motion varies from fifteen to about fifty miles an hour.

The Aurora Borealis.—The magnificent display commonly called the "northern lights," is an electrical phenomenon similar in appearance to the "brush" discharge. It is most common in high latitudes, though it is occasionally observed between latitudes 30° and 40° N. In appearance, the aurora is an arch of light stretching across the sky fifteen or twenty degrees above the horizon. It has a tremulous motion, and the upper streamers sometimes mount to the zenith.

The aurora is not confined to northern regions; it occurs in southern circumpolar regions as well. In the southern hemisphere, however, it is called the *aurora australis*, but the southern aurora is neither so brilliant nor so frequent in occurrence as that of the northern regions.

It must not be thought that the aurora occurs at night-time only; it may take place at any time—day or night. It is not visible in day-time, however, on account of the greater brilliance of the sun.

In color the aurora varies between pale green and crimson. Sometimes it closely resembles a green curtain edged and lined with gold. Auroras are most frequent during sun-spot periods; they are usually coincident with magnetic storms also. In circumpolar regions, at times, they are almost constant in occurrence. The cause of auroras is not with certainty known, but they are thought to be an exchange between the electricity of the atmosphere and that of the earth. The arch of the aurora nearly always surrounds the earth's magnetic pole.

Professor Balfour Stewart has advanced the opinion that both auroras and earth currents are secondary currents due to small but rapid changes in the earth's magnetism. The body of the earth may be compared to the magnetic core of an induction coil, the lower strata being the insulating medium, while the upper strata, which are much better conductors, take the part of a secondary coil.

Magnetism.—A bar of steel, iron, or nickel, or a piece of lodestone that has the property of attracting and holding to its surface small pieces of similar metals is called a *magnet.* Steel retains its magnetism permanently, and for all practical purposes the magnet is a flat bar of polished steel, eight or ten inches in length. Sometimes, however, it is bent into a U-shaped form called a *horse-shoe magnet*.

When a bar of steel is magnetized, it is found that the magnetic force is not uniformly distributed throughout the bar, but is most intense at the ends. These are the *poles* of the magnet; they are designated as positive +, and negative −, according to the direction they take when the magnet is suspended at the centre of gravity. The north-pointing end is usually marked – ; the south-pointing end is rarely marked.

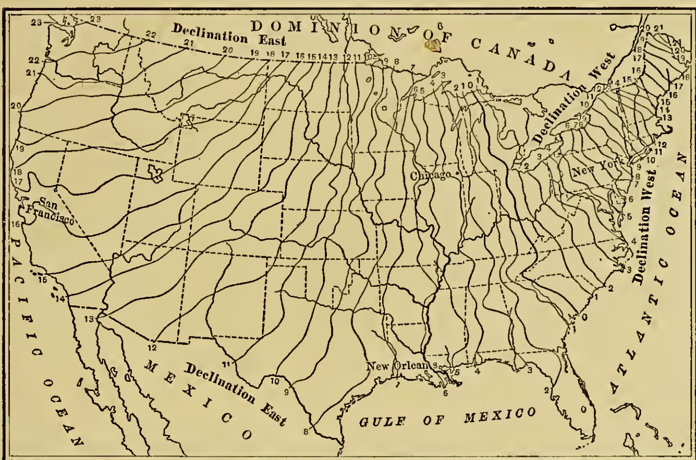
A slender bar of ordinary steel suspended by a silk fibre from its centre of gravity, will lie indifferently in any direction in which it is placed. If the bar be magnetized, however, it takes new properties. It no longer remains indifferently in any position; it swings to a direction that is nearly or quite north and south. It no longer remains balanced, but the north-pointing end dips toward the earth.

If now another bar magnet be brought near it, the latter shows no little sensitiveness. If the + end of the bar be presented to the + end of the suspended magnet, the latter will instantly turn away; if the two – ends be brought together the same thing will be noticed. On the contrary if + and – poles be brought together they are strongly attracted. From these experiments the laws of magnetism are deduced. *Like magnetic poles repel; unlike poles attract.* Either pole of the magnet, however, will attract alike an unmagnetized piece of iron or steel.

It is upon these laws that the science of navigation by the compass depends, for the earth behaves as a magnet and the essential part of the mariner's compass is also a magnet.

Magnetic Variation.—The earth's magnetic poles are not situated at the geographical poles. The magnetic north pole is situated west of Boothia Land, a few miles north of the crossing of the 97th meridian and the 70th parallel. Its position is not fixed, and it is moving in a westerly direction. The position of the magnetic south pole is not known, although roughly approximated.

The shape of the earth is not such that its magnetic force can possess much intensity. Several magnetic poles are known to exist, but only the two north poles of great intensity are usually charted. The pole of greatest intensity is the one commonly known as the magnetic north pole. Since its discovery by Ross, it has moved about forty miles westward. In 1879 it was approximately located by Lieutenant Schwatka in the open space between Victoria and Franklin Straits. Its exact position has not been determined since 1831, and it is doubtful if its location at that date was so precise as might be inferred from the figures, which are expressed in minutes of arc. At that time there were no instruments sufficiently delicate for such precise determination. In 1884 the position of this pole was again approximately determined to



LINES OF EQUAL MAGNETIC VARIATION

be in lat. 70° 30′ N.; long. 96° 40′ W. The position of the magnetic south pole was also approximately determined in 1905.

Observations made at Paris on the movement of the magnetic north pole cover a period of more than three hundred years. In 1580, the declination at the city was 11° 30′ E. It decreased until in 1683 it was nothing, after which time the variation became west. The westerly variation increased until, in 1814, it amounted to about 22° 30′ W. Since that time it has dropped to about 22°, and, it is thought, is slowly decreasing. In 1790 the variation at Norfolk, Va., was nothing; in 1893 it was about 3° 16′ W. In New York City the variation in 1686 was 9° W.; in 1790 it had decreased to 4° 15′ W.; after this time, however, it gradually increased until, in 1907, it was about 9° 26′ W.

Because the magnetic poles are not situated at the geographic poles, it is evident that the magnetic needle can point due north and south in but few places. In the accompanying chart, a heavy black line passes through these points. This line, called the *agonic*, is the line of no variation. West of this line the north-pointing end of the needle turns toward the east, and east of it it swerves to the west. Along each of the lighter lines the needle has the same deviation at all points, and these lines, therefore, are called *isogonics* or lines of equal variation. This deviation from the true meridian is called *declination*.

Besides the force that causes the needle to take a north-south direction, there is another that causes it to dip or incline one end toward the earth. This is called the vertical force, or *inclination*. Along an irregular line passing around the earth, sometimes north of the equator and sometimes south of it, the needle has an absolutely horizontal position. This is the magnetic equator or *aclinal*. North of this line the north-pointing end dips toward the earth. The farther the observer goes northward, the stronger becomes the vertical force, and when the magnetic north pole is reached the needle has a vertical position, the − pole being next the earth.

South of the *aclinal*, the conditions are reversed. The + pole dips more and more, until, at the magnetic south pole, the needle is again vertical with the + pole next the earth. A line on which the dip is everywhere the same is called an *isoclinal*.

Not only does the position of each isogonic vary from time to time, but the rate of variation is not uniform; even at the same place the rate varies from year to year. In the northwestern part of the United States the yearly variation is at present from 3′ to 7′; in the southwestern part it is, at present, nothing; in the eastern and central parts it varies from 3′ to 5′.

The deviation from the true geographical meridian also varies from day to day. Most of these variations are periodical. Some are daily, some monthly, and some yearly; they are probably caused by the daily rotation of the earth, the passage of the moon, and the annual motion of the earth. There are also irregular changes in variation which cannot be accounted for.

Such changes in variation are rarely great; in temperate and in low latitudes they cannot well be detected except by close measurements. In the vicinity of the magnetic pole, however, they are more marked. At Point Barrow and at Lady Franklin Bay, during a period of twenty-four hours, a change of nearly eleven degrees was recorded.

In order to study these variations, magnetic observatories have been established in various parts of the world. The essential part of such an observatory is a series of magnets each carrying a small mirror, mounted in such a manner that a spot of light is thrown on a sheet of photographic paper. The sheets of paper are fastened each to a cylinder revolved by clockwork, so that the spot of light draws a photographic line along the whole length of the sheet in twenty-four hours. If the magnet were motionless the line would be straight, but if the magnet turns even a small fraction of a minute, the spot is thrown out of position and the line becomes irregular. Usually three magnets are employed—one to measure variations in horizontal force; one for variations in vertical force; and one to measure the strength of the horizontal force.

Magnetic Storms.—Not infrequently the irregular variations of the needle are so violent that they have been called magnetic "storms," and during the progress of one of these disturbances the needle is in a constant tremor. Magnetic storms seem to be closely associated with the spots that at times are visible on the surface of the sun; but they are doubtless due to electrical storms also. The sudden formation or change in the position of a sun spot is nearly always attended by great magnetic disturbances. The period when they are most frequent, moreover, corresponds to the period when sun spots are most numerous.

This period recurs every eleven years. In 1882 the formation of a sun spot was attended by a magnetic storm that was recorded at Point

Barrow, Lady Franklin Bay, Los Angeles, Kew (London), Cape Horn, and Paris. Telegraph instruments were affected, and in some instances long circuits were worked by ground currents. At the magnetic observatory then in Los Angeles, California, the tremor of the magnets was so great that for several hours one of the instruments failed to make a legible record.

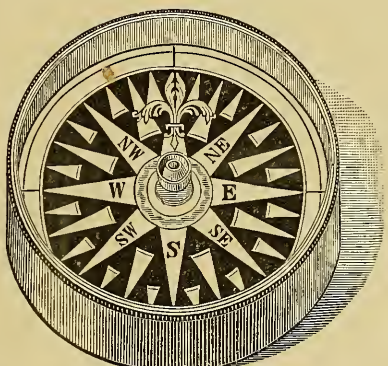
The Mariner's Compass.—The compass is a slender bar of magnetized steel, so constructed as to balance on a pivot and turn freely upon it as well. Usually it is armed with a sliding weight, so adjusted that it exactly counterbalances the dip or vertical force, thereby keeping the needle in a horizontal position.

On land the compass is of but little practical use except in rough surveys. On the sea, however, it furnishes the only means by which a vessel may be kept continually on her course. For this reason the mariner's compass is constructed with the greatest care and precision. The needle, which consists of one or more slender bars of steel, is fastened to a circular card subdivided into thirty-two parts, on which are printed the cardinal directions. These are called *points of the compass*. The compass box is mounted on gimbals, so that, no matter what may be the motion of the vessel, the box always retains a horizontal position.

In the Ritchie compass, now generally used in the United States Navy, the compass box is filled with alcohol in which the card and needle almost float, the object being to relieve the bearing of the weight of the card, and thus make the needle more sensitive. The compass of Sir William Thomson (Lord Kelvin) consists of a battery of six or more very slender magnets held in a skeleton frame. The latter is so light that the friction on the bearing is imperceptible. This compass is used in the English Navy, and by most of the transatlantic liners.

The use of steel in the construction of vessels has added materially to the difficulties of sailing by compass. The hull of a steel or iron vessel has poles of intensity peculiar to itself, and these are apt to change in time, so that frequent tests of the compasses are necessary. There are various devices for obtaining the proper correction for the compass on steel vessels; a very effective method is to swing the vessel, stem and stern, along a geographic meridian and then compare the observed with the normal variation. On battle-ships either the addition or the removal of the armament, or the substitution of a steel for a wooden mast, is apt to make readjustment of the compasses necessary.

Along nearly every travelled ocean route, the variation of the compass changes day by day. On the regular routes of the transatlantic liners, the variation increases from about nine degrees at New York to more than thirty-five degrees at the crossing of the 40th meridian. It then decreases to about twenty degrees at Liverpool.



MARINER'S COMPASS

An ordinary pattern.

In arctic regions, where the horizontal element of force is so weak, and the dipping force so strong, sailing by compass is a very difficult matter. Not only does the variation change rapidly over short courses, but the needle becomes exceeding sluggish. On whaling vessels it is customary to attach a line to the compass box so that the steersman, by occasionally shaking it, may better judge the course over which the vessel is sailing.

Luminous Phenomena.—Transparent though the atmosphere seems, not all the light transmitted passes through it. Rays of light are not only *refracted,* or bent out of the direction in which they started, but possibly they are *decomposed.* The distortion that one may observe by looking at an object across the top of a very hot stove, or a chimney is an example of refraction. On the other hand, the color effects observed when light passes through a glass prism, such as a chandelier pendant, or even the bevelled edge of plate-glass, are examples of decomposition.

A ray of light striking a polished surface is *reflected*, rebounding in the same manner as does a rubber ball thrown against the floor. The same thing may occur when the ray strikes the surface of water, or even that of a layer of air.

The air contains innumerable dust motes and particles so fine and light that they seem always to float. This is seen when a few rays are admitted into a darkened room; their passage is marked by the light reflected from the motes; a part of the light therefore is scattered, or dispersed.

White light is a mixture of all the rainbow colors. Ordinarily the blue and violet rays are the more easily scattered by the dust motes of the atmosphere. Being reflected to our eyes they give to the sky its blue color. At times, however, when the air is heavy with dust, the sky may acquire a hue that is distinctly red. This was very noticeable in 1883, after the eruption of Krakatoa; for nearly a year the sunsets were exceedingly lurid. At sea, the blueness of the sky is very marked, and the color is purer than on land; with accumulating moisture, however, it may acquire whitish tints. At very great elevations the blue gives way to a purple-black hue.

Mirages.—When a layer of light air rests on another that is heavier, the surface of contact often *reflects* much light. If the surface is a little lower than the eye of the observer, the reflection of the sky much resembles that of a surface of water, and a *mirage* results. In deserts and arid regions, the illusion is so perfect that nothing but experience will enable one to distinguish the mirage from a lake. The "lake" mirages of the Colorado Desert have lured both cattle herds and travellers to their death.

With the reflecting surface above the eye, the character of the mirage differs. Thus, at times, off the lake shore at Chicago, one may see the lighthouse and the shipping at the mouth of the river inverted in the air.

In many instances, however, the rays of light may pass through layers of air that differ greatly in density. In such cases the light rays are so much *refracted* that distorted or blurred outlines of an object result. Some land mirages are of this character.

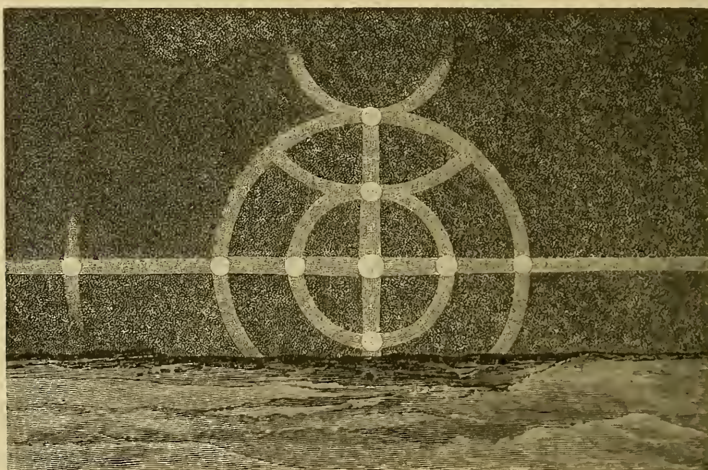
It sometimes happens that the rays of light reflected from an object, are refracted so that they are curved slightly toward the earth, and a distant object that otherwise could not be seen is brought to view. This phenomenon occurs at times along the Mediterranean and Red Seas, and it is not unknown along the Great Lakes. As a rule, a dry, still atmosphere is essential to the formation of the mirage.

Coronas and Halos.—The ring or rings about the sun or the moon are very common phenomena. The small rings are coronas; the larger ones, halos. In the corona, which is not very common, there is usually a series of concentric, colored rings. These, it is thought, result from a scattering of the light by the moisture of the atmosphere. The halo of the moon appears when the air is very moist. For this reason it is apt to portend rain or snow.

The halos of the sun are associated usually with cold weather. They are thought to result from the refraction of the light as the latter passes through the ice crystals of cirrus clouds. Frequently there are several circles. Some of them are concentric; some are tangent one to another;

and others intersect one another. At the places of intersection and of tangency more light is radiated, and these spots, which are very bright, form *sun dogs*, or *mock suns*.

Rainbows.—During a summer shower, when the sun breaks through a rift in the clouds, the light passes through the falling drops of water in such a way that it is not only refracted but decomposed. The resulting decomposition



HALOS OBSERVED BY GENERAL GREELY

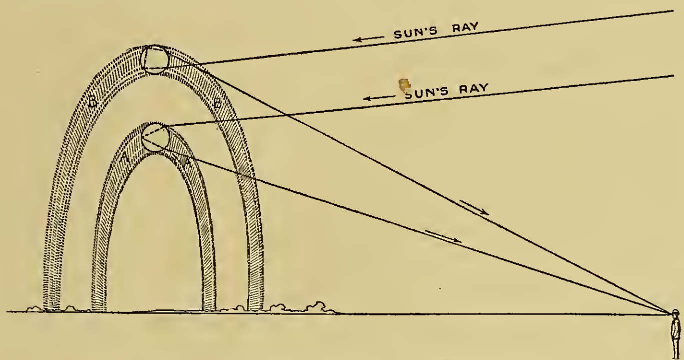
is the arch of colored light that constitutes the *rainbow*. The bow is blue and violet on the inner, and red on the outer side. Sometimes there is a larger secondary bow in which the order of colors is reversed.

The rainbow is best observed when the sun is near the horizon. The observer sees the bow when his back is turned toward the sun. The rainbow is observable in the spray of waves, and also in the spray of cascades.

QUESTIONS AND EXERCISES.—Verify the statements concerning the mutual attraction and repulsion of electrified bodies, observing the directions on p. 268.

Verify the statements noted on p. 275, using one or more stout knitting-needles and strands of untwisted silk. For observing inclination the strand of silk may be fastened by a slip knot to the needle; for the other experiments the needle may be thrust through a bit of paper held by the silk. In magnetizing the needles, rub the ends only.

From the chart, p. 277, estimate the magnetic variation of the place in which you live.



RAINBOWS: PRIMARY AND SECONDARY

The dotted lines show the refraction and reflection of the light. A is the primary, B the secondary bow.

At any time of their occurrence note carefully whatever you may observe with reference to auroras, mock suns, halos, and coronas.

Occasionally, in very dry weather the disc of the sun is considerably distorted at the time of setting; explain why.

The sun and the moon seem to be much larger when near the horizon than at zenith; is this phenomenon real or apparent? The use of a paper or other tube an inch or two in diameter will aid in the solution of this question.

Explain the phenomenon of the "sun's drawing water."

COLLATERAL READING AND REFERENCE

WALDO.—Elements of Meteorology, pp. 166–180.

GREELY.—American Weather.

DAVIS.—Elements of Meteorology.

CHAPTER XVI

CLIMATE AND ITS FACTORS

The conditions of a region with reference to its habitability constitute its *climate.* These, in general, are the results of heat and moisture; and climate, therefore, includes all the modifications due to heat and cold, rain and drought. Climate is modified by latitude, altitude, position of highlands, direction and prevalence of winds, and the inclination of the earth's axis.

To these may be added the effect of ocean currents. Cold currents carry water into warmer latitudes, and cause fogs that sometimes cover large areas. Warm currents flowing into the coves and bays of arctic coasts keep the harbors free from ice.

Latitude.—Latitude affects climate chiefly with reference to temperature. The greater the distance from the equator, the lower will be its average temperature. The sun's rays are never vertical beyond the tropics, and in polar regions they fall so obliquely that they impart but very little heat to either land or water. Illustrate this by means of the diagram on p. 295.

In going from equatorial to polar regions one will pass through every degree of warmth from perpetual summer to the coldest winter. Within thirty or thirty-five degrees of the equator the change in temperature is not great, but beyond the forty-fifth parallel the winter climate grows rapidly colder for every few degrees of increase.

Latitude also exerts an influence on rainfall. As a rule, the rainfall is greatest within the torrid zone. The equatorial cloud belt is a zone of ascending air currents, and the air being chilled by its expansion, the moisture is condensed, and there is an almost constant fall of rain. The cloud belt is therefore a rain belt, and it swings from tropic to tropic with the apparent motion of the sun. In the region of tropical calms, on the contrary, the rainfall is deficient. These calms are regions of descending currents of the air, and the air being warmed instead of chilled by its descent, becomes relatively dry.

Altitude.—The effect of altitude is much the same as that of latitude. The temperature is lower by about one degree for every three hundred feet of ascent. Thus, one may find on the slope of a highland all the intermediate degrees of temperature between summer and winter. In Mexico the effects of altitude are finely illustrated. The city and seaport, Vera Cruz, is intolerably hot and moist; less than two hundred miles away, the City of Mexico, at an altitude of 7,000 feet, enjoys a climate that is cool and invigorating; while the top of Orizaba, about 18,000 feet high, is snow covered.

A striking example occurs in the plateaus of the Colorado River. Hurricane Ledge forms the boundary between two plateaus. On the upper mesa the products are those of a temperate climate; in the lower they are sub-tropical.

At high altitudes the difference between the temperature of day and night is very great. Thus on Mauna Kea, Hawaii, midday temperature frequently runs above 100° F., while the night temperature may be below the freezing point. Observations taken by the aid of balloons show that at the altitude of 40,000 feet the temperature varies from about − 60° to − 80°. Above 4,000 feet in the air there is but little difference between the shade temperature of the day and that of night.

Position of Mountains.—High mountain-ranges often control the quantity of rain falling on the surface of a region. In tropical latitudes rain-bearing winds blow from the east; the eastern slope of high ranges is therefore well watered, while the western slope is dry. In the temperate zones, on the other hand, the rain winds are from the west; and the western slope in consequence receives most of the rain, while the eastern side is comparatively dry. Thus, in the Peruvian Andes, the rain winds deluge the eastern slope, leaving the western side a desert. In the southern Andes, the conditions are reversed; the rain falls on the western side while the eastern slope is arid.

The effect of the absence of mountains is observable in Australia. Partly because of its latitude, but mainly for want of a high range, the greater part of the continent is a desert, and the rain falls on the highlands of the eastern side only. In the great African desert, the few isolated ranges receive considerable rain on their summits, but very little falls elsewhere.

Distance from the Sea.—The proximity of the sea exerts a marked effect on climate, both with respect to temperature and moisture. The climate of a coast region is always more equable than that of a far inland or *continental* area. The reason therefor is apparent; the air over the ocean has a much more uniform temperature than that over the land.

The result is seen when the extremes of temperature are noted. For example, San Francisco and Leavenworth, Kan., have nearly the same mean temperature for the year. But while the difference between the summer and winter temperature of San Francisco is less than ten degrees (F.), that of Leavenworth is almost fifty degrees.

A noticeable and highly important difference between a maritime and a continental climate, is the *daily range* of temperature. In a maritime climate this rarely exceeds twenty degrees (F.), while in a few inland regions the fluctuations may be twice as great.

Not all coast regions, however, enjoy a maritime climate. Because the winds of the temperate zones are, as a rule, westerly, on the eastern coast of such regions land winds are prevalent. The coast region of the northeastern part of the United States is an example. The same is also true of the northeast coast of China. Its climate is distinctively continental, and the influence of the sea penetrates only a very few miles inland. On the other hand, the climate of the southern part of South America is distinctly oceanic.

The climate of oceanic islands is always equable. The Philippines and the Hawaiian Islands, although in the torrid zone, are regions of perpetual spring, with no excesses of temperature. The Leeward and Windward islands of the West Indian group are also examples. Though situated only a few degrees north of the equator their summer temperature is less oppressive than that of New York City.

Prevailing Winds.—Winds are the chief medium for the transmission both of moisture and warmth. The Trade Winds modify the excessive heat of low latitudes, and warm winds blowing into high latitudes soften the rigors of the region into which they blow. The mild temperature of western Europe is due largely to southwesterly winds, and the same is true of the equable climate of western North America. Not only do the winds themselves transfer a great amount of heat by convection, but the latent heat of the water vapor furnishes an enormous supply. When the vapor, mingled with the wind, is carried to colder latitudes and there precipitated, all this heat is again set free. The chart of winds (p. 223) gives the information necessary to determine roughly the climate of a country. The regions invaded by sea winds that have come from low latitudes are the regions of warm and equable climate. Inland and polar regions are areas of climatic extremes.

There are other minor factors that also determine the climatic conditions of a locality. Much cloud and fog prevent evaporation and therefore tend to equalize temperature. Evaporation tends to lower temperature because of the great amount of heat that becomes latent. The penetrability of water to heat is greater than that of rock; moreover, the capacity for heat of the former is about twice as great as the latter. All these facts tend to the greater equability of the water as compared with the land.

Changes in Climate.—As a rule, the climate of a country does not change materially except after long intervals of time. The mean temperature of any given locality rarely varies more than a very few degrees from one year to another, and the averages of long periods show still less variation. Fluctuations in rainfall and cloudiness are considerably greater than those of temperature. In moist regions the rainfall of wet years may be nearly twice that of dry years; in localities of deficient rainfall the difference may be greater.

When time is reckoned by geological epochs, however, it seems certain that great climatic changes of a radical character have occurred in every part of the earth. The Glacial Epoch, already described, is an example of a change in the climate that took place in the North Temperate Zone. The rainfall of the Basin Region of the United States has been subject to periods of oscillation. The few scattered sinks and salt lakes of the Great Basin itself are remnants of two large lakes that existed there at no very remote period, and these in turn are evidence of a greater rainfall than the region receives at the present time.

The knowledge of such changes is circumstantial, and statistics regarding them are wanting. The cause or causes of such changes, moreover, are unknown. A change in the inclination of the earth's axis would be competent to account for changes in temperature, and therefore in rainfall.

That is, if the axis of the earth were to incline forty degrees, then the polar and the tropical circles would have a corresponding distance from the poles and from the equator, and the temperate zones each would be ten degrees in width, instead of forty-three. Or, if the longitude of perihelion were to change so that the winters of the northern hemisphere should become longer by several days than the summers, the ice and snow would collect faster than it would melt, thereby in time causing far-reaching changes.

Changes in the level of a region are also capable of producing variations in temperature, and it is highly probable that elevation and depression have resulted in many of the climatic changes of which there is an unwritten record.

There is evidence to show that the elevation of a region results in a lowering of its mean temperature, and the depression of its surface has an opposite effect. The surface of New York and the New England States was about 1,000 feet higher during the Glacial Epoch than at present.

Zones of Climate.—Zones or belts whose limits are bounded by lines of equal average temperature are called *isothermal zones*, and the lines bounding them *isothermal lines*, or *isotherms*. A comparison of a map of astronomical and climatic zones shows that the correspondence of the two is only general. The former are fixed and their boundary lines are parallels of latitude. The latter change their positions with the apparent motion of the sun, behaving in this respect like the zones of winds and calms. In fact they are all governed by the same law and arise from the same cause—the inclination and self-parallelism of the earth's axis.

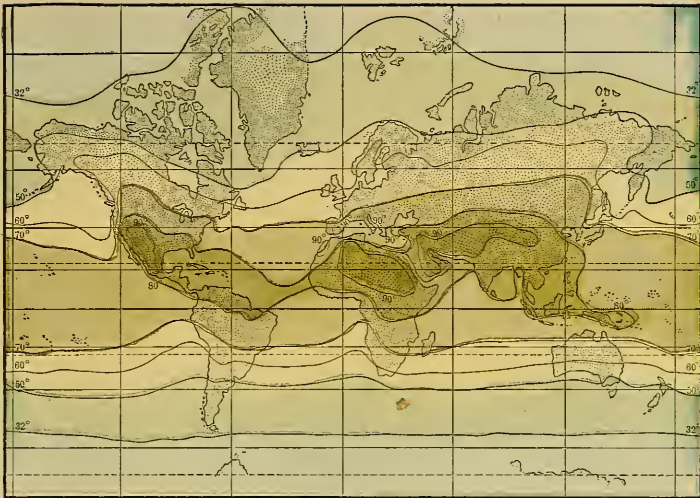
In the southern hemisphere the temperature is very equable, and the isotherms range nearly with the parallels. In the northern hemisphere the isotherms are very irregular. In which direction do they bend in crossing the great highlands of the earth? In the North Atlantic warm ocean currents and their drifts turn the isotherms northward.

By what isotherms is the climatic torrid zone limited north and south? In the spring and the fall its position corresponds roughly with that of the astronomical zone. The hottest areas are situated not on the equator, however, but north of it. In the African desert, Arabia, and the arid lands of the United States, the summer temperature is above 38° (100° F.) and during unusual hot spells it sometimes reaches 49° (120° F.).

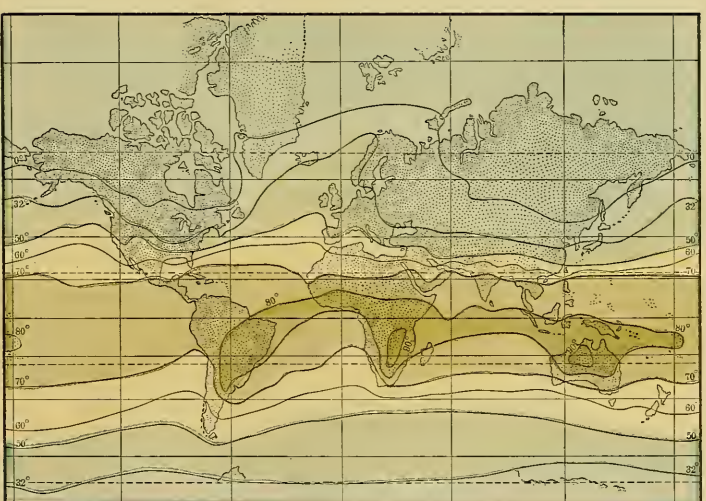
The mean *annual* temperature of a region reveals but little concerning its actual conditions of temperature. These can be studied only from monthly isotherms—that is, by comparing the monthly range of temperature and climate. For this reason, instead of a chart of annual isotherms, it is wiser to study two charts, one showing the isotherms for midwinter, the other for midsummer.

The isothermal temperate zones are conveniently limited by the lines of 21° (70° F.) and 0° (32° F.). The summer limit of the northern zone extends into arctic regions; the winter limit on land approximates the fortieth parallel, but on the ocean it is higher. In the Pacific it reaches to the sixtieth parallel; in the Atlantic, owing to the drift of the Gulf Stream, it penetrates the polar latitudes.

Extremes of Climate.—The isotherm of highest temperature that completely girdles the earth is theoretically the thermal equator. Its temperature is probably between 27° and 30° (80° to 86° F.). There are several isolated regions having a considerably higher temperature, however. An extensive region in the Sahara has a mean temperature of about 29° (85° F.); in Hindustan and South Africa there are other localities equally warm. In the American continent an oval-shaped region extending



ISOTHERMS FOR JULY



ISOTHERMS FOR JANUARY

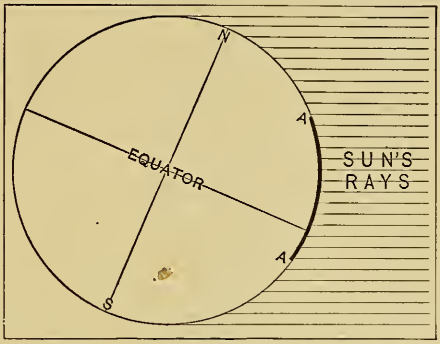
southward from the Gulf of California has about the same mean.

The regions of extreme cold are not in the vicinity of the geographical pole, but at inland localities considerably south of it. In the American continent the area of extreme cold is near the Arctic Archipelago. In Eurasia it is a little to the eastward of the Lena River. In both regions the mean temperature is not higher than – 17° (0° F.). At Verkhoyansk, Siberia, the temperature ranges from – 67° (– 90° F.) to 32° (90° F.). The range, one hundred and eighty degrees, is probably greater than that of any other inhabited region.

The highest temperature taken under standard conditions—that is, shaded by a double roof with an air space between, and exposed at a distance from any radiating surface—seems to have been recorded at Warglar, Algeria, where the mercury marked 127° F. In the Colorado Desert an unofficial temperature of 136° has been noted. In this case, however, it is doubtful if a properly exposed thermometer would have registered so much by ten or fifteen degrees. No temperature in this region recorded by the Weather Bureau has exceeded 122°, though there are several localities, such as Salton Lake and Death Valley, where the temperature ranges higher than at any of the Weather Bureau stations. The author has repeatedly noted temperatures in the Colorado Desert varying from 130° to 145° registered by a thermometer exposed to the direct rays of the sun. The experience of General Greely, U. S. A., Chief Signal Officer, shows the range of human endurance. At Fort Conger, Lady Franklin Bay, he and his party experienced no intolerable discomforts with the temperature as low as – 66°, the same officer served in Arizona where the shade temperature was 119° and that of an unprotected thermometer 144°.

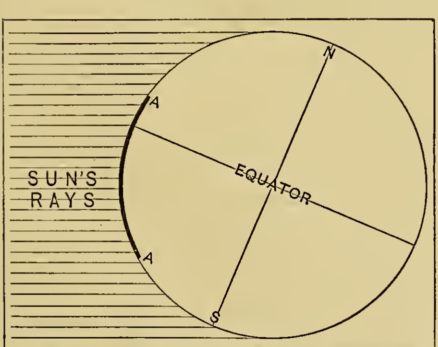
Changes of Season.—Because the earth's axis is inclined to the plane of its orbit, and remains parallel to itself while the earth revolves around the sun, it follows that the rays of the sun do not fall on a given place always at the same angle.

As the earth revolves around the sun, the inclination of the axis, together with its self-parallelism, bring each temperate zone, in turn, to a position where the sun's rays are vertical.



POSITION OF HEAT-RAYS IN JUNE

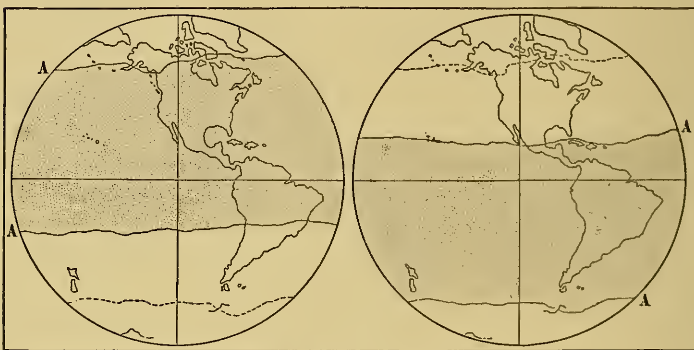
The alternation of the four seasons is realized mainly in the temperate zones. In the greater part of the western coast of North America the seasons are distinguished more by seasonal rains than by variations in temperature. Practically there are two seasons—a rainy and a dry. Within the greater part of the Torrid Zone these are also the chief distinctions of season. In the frigid zones the distinctions of summer and winter are also those of day and night, each of which is six months long.



POSITION OF HEAT-RAYS IN DECEMBER

In general, the weather conditions of the Torrid Zone originate in the east; those of the Temperate Zones in the west. On account of its narrow extent, the climate of the southern part of South America is oceanic in character, while most of that part of North America in corresponding latitudes is continental. In these zones the west coasts are regions of equable; the east coasts of extreme climate. Why?

Deserts.—There are many areas that have little or no rainfall. If the rainfall is so deficient that irrigation is necessary to produce crops the region is said to be *arid*;



ANNUAL MOVEMENT OF THE HEAT-BELT

if it is too dry for food crops, it is generally considered a *desert region.*

The term "desert" is also made to include all regions that are uninhabitable.

There is no sharply drawn line between fertile and arid lands, or between arid lands and deserts. For instance, the Mississippi Basin east of the 2,000-foot contour—produces an abundance of food-stuffs. West of this contour the climate becomes much drier, and beyond the 2,500-foot contour, crops must depend mainly on irrigation.

In this region turf grass is replaced by scanty bunch grass, and beyond the crest of the eastern ranges of the

Rocky Mountains the character of the country in places approaches that of a typical desert. In the northern part of the Basin Region, the cooler climate and the high ridges bring a small amount of rain, but in the south almost all vegetation disappears and the region is absolutely a desert. The same gradation is observed in the great African desert. Both north and south of the equatorial rain-belt, precipitation decreases little by little; fertile lands grade imperceptibly into arid belts, and the latter into deserts.

In the South American deserts the line is pretty sharply drawn. The same is true of the North American desert and the Sahara also, if they are approached from the western side.

Only a small part of the various desert areas is destitute of vegetation, and in such parts the finely pulverized rock waste—the "sand" of the desert—shifts hither and thither with the winds. In such regions fierce simoons and sand-storms prevail. The Colorado Desert, in south-eastern California, is an excellent example.

The climate of desert regions is marked by peculiarities and extremes. The winds are hot sand-blasts and whirls; the scanty rains come usually in the form of cloud-bursts; the temperature is one of intense heat at times alternating with bitter cold; the relative humidity of the atmosphere rarely exceeds thirty per cent. of saturation. Notwithstanding all this, desert climate is wonderfully healthful.

In popular literature the climate of deserts is supposed to have baneful properties, and the expression "poisonous emanations" has a prominent place therein. As a matter of fact, desert air is unsurpassed so far as salubrity is concerned. It is so free from the germs that produce disease, that meat rarely putrefies and food does not ferment. Septicæmia, or "blood-poisoning," rarely if ever follows accidental wounds or surgical operations, and tuberculosis originating in such localities is unknown; indeed, desert regions are regarded as the most healthful of all localities for consumptives.

Oases.—A fertile spot in a desert is called an *oasis*; the latter is fertile because it is supplied with water. For this reason the oasis commonly yields a goodly supply of food-stuffs. Various causes contribute to the formation of oases. The underlying strata may be impervious to water, thereby preventing the latter from sinking deep into the soil, or there may be a mountain-crest that is sufficiently high to condense and precipitate more or less moisture. The water flowing down the slopes percolates through the fine rock waste at the bottom, much of it being held there in suspension. Some of the oases of the North American deserts are of this character.

Geographic Distribution of Deserts.—The distribution of deserts constitutes an interesting study. Practically two zones, situated mainly between the 20th and 50th parallels, north and south, contain nearly all the desert and arid lands of the earth. A belt of desert stretches nearly across both continents. In North America the belt is nearly 1,000 miles east and west. The deserts of the Southern Hemisphere are smaller in area only because of the smaller land area. In South America it lies at the eastern base of the Andes; in Africa, there is one on each side of the Kongo basin.

"The part of the Sahara destitute of oases has a formidable aspect. The path which the feet of the camels have marked out in the immense solitude, points in a straight line toward the spot which the caravan wishes to reach. Sometimes these faint footmarks are covered with wind-blown rock waste, and the travellers are obliged to consult the compass, the horizon, a distant sand-hill, a bush, a heap of camels' bones, or some other indications which the practised eye of the Tuareg alone can understand as the means by which the road is recognized. Vegetation is rare, and the only plants to be seen are the scrub, consisting mainly of thorny mimosas; in some sandy deserts there is a complete absence of all kinds of vegetation. The only animals to be found are scorpions, lizards, vipers, and ants. During the first few days of the journey a few indefatigable individuals of the fly tribe accompany the caravan, but they are soon killed by the heat; even the flea itself will not venture into these dreadful regions. The intense radiation of the enormous white or red surface of the desert dazzles the eyes; in this blinding light every object appears to be clothed with a sombre and preternatural tint. Occasionally the traveller, when sitting upon his camel, is seized with a kind of brain fever, which causes him to see the most fantastical objects in his delirium. Even those who retain the entire possession of their faculties and clearness of vision are beset by distant mirages; palm-trees, groups of tents, shady mountains and sparkling cascades seem to dance before their eyes in misty vapor. When the wind blows hard, the traveller's body is beaten by grains of sand which penetrate even through his clothes and prick like needles. Stagnant pools or wells, dug with great labor in some hollow or other, from the sides of which oozes out a brackish moisture, point out each day the end of the stage. But often this unwholesome swamp, where they hoped to recruit their energies, is not to be found, and the people of the caravan must content themselves with the tainted water with which they filled their flasks at the preceding stage. It is said that in times of great need travellers have been compelled to kill their dromedaries in order to quench their thirst in the nauseous liquid contained in the stomachs of these animals."—*Elisée Reclus.*

Causes of Desert Conditions.—Various causes contribute to make arid and desert conditions; but in any case a desert is a desert, not because of any natural sterility of the soil, but because of the lack of moisture. In some localities a high mountain-range that faces the sea winds condenses all the moisture they contain and the opposite slope with its outlying area is therefore a desert. Thus, the Peruvian desert of South America is west of the Andes, and the desert of Argentina lies to the east of these ranges.

In other instances the desert conditions arise from other and more complex causes. Thus, between the 20th and 30th parallels there is a downward movement of atmospheric currents; explain why these may produce deficiency or absence of rainfall (p. 225). In some localities the winds blowing inland from the sea may enter localities having a temperature higher than that of the winds themselves, and in such instances their moisture is not condensed. The Australian and African deserts result mainly from one or the other, or both, of these causes. They are unfortunately situated with reference to latitude, and they also are lacking in high mountain-ranges.

QUESTIONS AND EXERCISES.—Referring to any good map, determine the climate of South America from the following suggestions, giving a reason for each statement: What are the conditions of temperature of the northern part? How do those of the southern part differ? In which part is temperature the basis of the seasons? In which is rainfall? From which direction do the rains of the northern part come? of the southern part? What is the effect of the Andes Mountains on the distribution of the rainfall? Give the location of the desert and arid regions. Note the effects of altitude on the climate of the highlands; of the lowlands. What evidence does the map give to show whether the rainfall of the Amazon basin is profuse or deficient? Explain why the basin of the Orinoco has two rainy and two dry seasons.

Compare the Asian and American deserts as to origin. How do the African deserts compare in this respect?

Prepare a summary of the climatic conditions of the state or county in which you live, noting especially any facts not ordinarily included in the general outlines of the subject. From the United States Weather Bureau obtain the following: highest temperature observed, lowest temperature observed, mean for each month, mean annual rainfall, mean for each month, number of rainy days for any year, general direction of the winds, other relevant facts.

From the diagrams, p. 295, find the time at which the sun's rays are vertical at the tropic of Cancer. What is the season at this time in the Northern Hemisphere? Are the sun's rays direct or slanting in the Southern Hemisphere? What is the season there?

What are the seasons when the sun's rays are vertical at the equator? On a piece of thin paper trace, with a pencil, the isothermal hot zone on the map for January, p. 293; cut it out along the lines, and place it in its proper position (*i.e.*, for January on the map for July). The parts that overlap show the region where summer is continuous all the year. Compare this result with the diagram on this page. What parts are not covered by the heat-belt? When the heat-belt is far north what is the season in the Northern Hemisphere? in the Southern? From the oscillation of the heat-belt show how five zones of temperature result.

COLLATERAL READING AND REFERENCE

Davis.—Elements of Meteorology.
Waldo.—Elementary Meteorology.
Greely.—American Weather.

CHAPTER XVII

THE DISPERSAL OF LIFE

There are two lessons in nature that probably every human being of mature years has learned, namely—that the earth is full of organisms endowed with that mysterious force called *life,* and that the life-forms are grouped in kinds or *species.* Moreover, while the individuals of a species closely resemble one another, those of different species are commonly very unlike.

Almost every living body or *organism* passes through several stages or conditions. It first appears in the form of a *germ* enclosed in an envelope called an *egg,* or perhaps, a *seed.* Under the action of heat, or moisture, or both heat and moisture, the egg or seed passes through various stages of development in which it gradually approaches its mature form—the condition that immediately precedes death. In general, the egg develops into a life-form, known as an animal, the seed into a plant. The egg may contain both food and moisture as well within its envelope; but the seed contains food only. The egg very easily loses its vitality or life principle; the seed may retain its vitality for months, or even years. The offspring of the egg almost always possesses the power of moving from place to place in one or another of its forms of life; the offspring of the seed, on the contrary, is rarely ever able to move; it spends its life in the spot in which it developed into life.

The seed-form of the organism is remarkably adapted for transportation and dispersal. Commonly the seeds are strong enough to resist no little mechanical force. Those of some species will endure a temperature but little lower than that of boiling water; they will likewise endure the severest cold, and are almost always enclosed in a

A SNOW-CAPPED BARRIER THAT MANY SPECIES CANNOT PASS

water-tight case. The egg, on the other hand, will not endure extremes of temperature, nor will it survive the slightest injury. As a rule, both seeds and eggs float on water, and many kinds are carried in the air.

The stage of growth and development is one of the greatest danger to the existence of the organism. During this period it quickly and easily succumbs to the most trifling changes in its surroundings. At this time, too, it is apt to be the prey of higher organisms that kill and devour it. Indeed, so great is the mortality during the period of development that, in many species, not more than one or two individuals in many thousand reach the state of maturity.

As the enemies to a species increase, its fecundity is apt also to increase. Thus, the spawn of a female cod aggregates several million eggs. If all these were to hatch and mature, the sea could hold only a few generations of them.

The mature stage of the organism follows that of development. In this condition it has but one object toward which all its energies tend, namely—the reproduction of its kind. This accomplished, sooner or later it dies; that is, the vital principle leaves it, and it is quickly resolved into the mineral elements—the "dust"—which gave it external form and structure. Many species have special means for the protection of their bodies; nearly all possess special organs for the purpose of nutrition; the higher species have organs of locomotion.

Laws of Structure.—Many laws are concerned in the growth, development, and reproduction of organic forms, but there are three that govern, directly or indirectly, every form of life. These are *heredity*, *nutrition*, and *variation*.

The law by virtue of which the germs of organisms develop and mature, each into a form of its own kind, is called *heredity*. The germ of a species always reproduces forms like those of the parents or ancestors. Acorns always produce oak-trees, animals beget of their own kind, and the germ that in the human system produces disease, breeds nothing but the same disease.

Since the discovery of the fact that many diseases are due to the growth and development of minute organisms within the human body, the science of surgery and that of sanitation have been greatly aided. Septicæmia, variously known as "hospital fever" and "blood-poisoning," once the bane of every hospital, is now comparatively rare, and such diseases as small-pox, typhoid fever, and cholera may be readily quarantined and stamped out. Dirt and filth may be the soil in which the germs of these diseases breed, but it does not originate them.

A seed or an egg develops into an organism that becomes an ancestor of many thousand generations, aggregating millions of individuals. But in obedience to the law of heredity, the individuals of the last generation will not differ greatly from their ancestor, nor will they differ from one another.

The process by which food, within the body of an organism, is decomposed and then made a part of the structure of the organism is called *nutrition*, or feeding. In obedience to this law, new tissue, that is, flesh, blood, bones, etc., is constantly being made, and older tissue, no longer useful, is cast off and destroyed. The number of substances required for nutrition is few. Nearly three-quarters of the weight of every organic being consists of water; in many instances more than ninety per cent. is water. The remaining part is composed mainly of compounds of carbon, lime, nitrogen, hydrogen, and phosphorus. The food must contain all these substances or the organism will not mature. As a rule, plants obtain their food from the mineral kingdom, and animals, either directly or indirectly, from plants.

The law in obedience to which organisms are changed, or change themselves, to meet the conditions necessary to their existence, is called *variation*. Thus, under cultivation, the wild rose, no longer needing its multitude of stamens, develops them into petals. Under the conditions imposed by its environment, the almond has varied its development by taking the form of the peach and the nectarine.

Birds that for long-continued generations have obtained their food from the water have become either swimmers or waders, and many species that scratch the ground to obtain food have gradually lost the power of extended flight. The great diversity in the various members of the dog family is a familiar example of the effects of variation. The horse of present times has but one toe, but the horse of Miocene times had three, and of Eocene times four toes on the fore feet. The birds of early geological periods were much more like reptiles in character than those of present times. Some of the reptiles, too, have lost their feet and are scarcely a remove from serpents.

Because of the struggle that has been waging ever since life appeared on the earth, only the individuals which can adapt themselves to environment are able to survive. Variation is not always a gradual change in a whole species; it is quite as often a sudden change in individuals; and the transmitted change frequently marks the descendants.

Environment.—Variation of species is the result of food, temperature, and moisture—that is, the conditions of nutrition and environment. These are the conditions with which every organism has to battle for existence, and these determine all its habits. If the environment of a species changes, one of three things is pretty certain to take place: the species dies, it migrates, or else it survives with changed habits.

Thus, if in a given locality, the rainfall lessens materially, the turfgrass quickly discovers it. In order to obtain the necessary moisture, an enormous development of rootlets takes place, and if this development does not procure the necessary amount of water, the turfgrass gradually disappears. If a certain species requires an aggregate of ten inches of rain, distributed monthly, it will perish if the rainfall decreases to nine inches, or if there is a drought of more than thirty consecutive days. It will thrive and possibly extend its limits if the annual rainfall increases to twelve inches.

The fruit of the common gooseberry, cultivated in moist regions, has a smooth surface; but transplanted to arid regions and left to grow wild, the berry finally matures, covered with leathery spines. Cultivation, which is only another name for change of environment, has resulted in all the beautiful varieties of roses; it has produced the domesticated fruits from wild fruits; it has made the difference between the wild fowl and the domestic fowl of the same species. Since the territory inhabited by a species is either enlarged or decreased by a change in food, temperature, and moisture, and since a change in any of these factors sooner or later results in variation, it is evident that the distribution and variation of species are governed mainly by geographic laws.

Apparently trivial causes are frequently attended by far-reaching consequences. For example, the mongoose was introduced into Jamaica in order to exterminate the cane-rat, then a menace to the sugar planter. The mongoose did not lessen the number of cane-rats, but it exterminated one or two species of ground bird, and with their disappearance there came such swarms of cattle-ticks and grass-lice that the existence of the cattle herds was threatened. The ground birds had prevented any great increase of the insect species; and when the former were killed, the latter became an intolerable pest.

Animals and Plants.—Plants are lower in the scale of life than animals. A few species excepted, they have not the power of voluntary motion, and if they possess the power of sensation at all, it is of a very feeble kind. They derive their nutrition mainly from the ground and the air, being able to transform mineral matter, such as water, lime, potash, carbon, etc., into plant tissue. With one or two exceptions, plants inhale carbon dioxide and exhale oxygen.

Plants exhibit faculty of intelligence in the feeblest degree only. This is observed partly in the way they seek their food, and partly by their manner of protecting themselves. The roots of a plant will grow in the direction of water, and the flower will open with the light and close in darkness. No species is known that will pursue its prey or flee from an enemy. And the reason is obvious: the plant does not feed upon other life-forms; it merely transforms dead mineral matter into living matter, which is to become the food of higher forms. Nevertheless, the plant contains a vital force that causes it to live, grow, and reproduce; and when this vital force is spent, it dies.

Animals are far more complex in organization than plants. The animal lives by the destruction of other forms of life, and therefore it must possess the powers of locomotion, prehension, or grasping, and means of defence. All animals possess intelligence, and the higher forms have the faculty of reason. No exact line of division, however, can be drawn between animals and plants.

Dispersal of Life.—The distribution of life is not a matter of chance; on the contrary, it results from the operation of fixed laws. Moreover, the question must be examined from two sides, namely—the means possessed by animals and plants to disperse and, conversely, the barriers that operate to prevent dispersal.

The means of dispersal are many. All the higher species of animals possess the power of voluntary motion. Quadrupeds use their feet; birds fly; nearly all insects have at least one stage of development in which they possess wings; and fishes swim. Marine currents carry many species from the place of their birth to distant parts; and still other species are carried by floating matter, and in the crops of birds.

Seeds of plants are carried by the winds, by running waters, and in the crops of birds or in the digestive apparatus of animals. Commerce is responsible for the dispersal of most species used for food and many that are baneful to humanity. In short, almost every organism possesses means that under ordinary circumstances would give it a far wider territory than it now possesses.

There are many examples of the extension of the habitats of animals as a result of commerce. The Norwegian rat in America, the Colorado potato-beetle in Europe, and the English sparrow in the United States have been spread over a large part of the world in this manner. The California species of the phylloxera, a plant-louse infesting the grapevine, was introduced into France and almost destroyed the vines of that country. The Russian thistle at one time threatened to overrun the wheat-fields of the Mississippi Basin, and the strictest means are necessary to keep it under control. The gypsy moth, whose larvæ infests ripening fruit, has attacked the orchards of the New England and Middle Atlantic States, and an expenditure of a million dollars a year is necessary to keep its mischievous work in check. The area of the cotton-boll weevil has greatly increased.

The natural or unrestricted migration of species presents an interesting aspect. In the temperate zones, as a rule, the dispersal has been from west to east; in the torrid zone it has generally been in the opposite direction. A moment's study will show the reason, namely—the direction of atmospheric and marine currents.

Barriers.—But there are regions in which the species carried by marine currents will not thrive, and quite as many traversed by winds which sow them with seeds, though the soil never fertilizes them. Such extraordinary effects cannot exist without causes, and these are the natural barriers to distribution.

The barriers to dispersal are even more potent than its agents. These may be reduced to two classes—*physiographic barriers* and *environment.* Chief among the former are the high mountain-ranges, oceans and deserts.

High mountain-ranges form an effective barrier to species not provided with means of locomotion; and the more extensive the highland the greater the difference of the species on the opposite sides. There are two reasons for this. In the first place, if animals or plants of a species are unprovided with means for migration they cannot cross the range; in the second place, the conditions of climate on the opposite sides of high mountains are so different that the species might not survive, even if transported. The low temperature of the summit of the range might also be fatal.

The *ocean* and other wide expanses of water are effective barriers to land plants and animals. A few birds endowed with unusual powers of flight have crossed the ocean; seeds and eggs have also been carried across; and not a few species have been transported in vessels. But all these are accidental migrations; even then the question of environment would still remain.

Deserts present the same difficulties. Few species are able to cross them; fewer still to remain in them, and the barrier once surmounted, there may be changed conditions which still forbid the existence of the species.

Environment has been considered a cause of variation, but it is far more potent as a barrier to the existence of a species. If a species requires a temperature higher than 0° (32° F.), it will perish in a climate having a lower range. If it requires an annual rainfall of thirty inches, it will perish if the precipitation is materially less; or if it requires a monthly distribution of rain, it will not survive any considerable number of droughts of more than thirty days.

A DESERT BARRIER

Thus it is seen that every species demands certain conditions of food, temperature, and moisture. If these are of wide range the species will inhabit a wide geographical territory; if they are narrow in range, the limits of its existence will be correspondingly narrow. If the proportion, degree, or quality changes, the species will vary; if environment changes materially the species will perish.

Enemies to Dispersal.—It sometimes occurs, however, that a species, once introduced and acclimated, is unable to maintain itself, or maintaining itself, is unable to spread to any extent over a region whose soil and climate are in every way adaptable. There are several reasons for this. The region may have been already pre-empted by other species

THERE MAY BE ENEMIES THAT OPPOSE THE NEW-COMER

that resist encroachment, or there may be enemies constantly at work seeking to exterminate the newcomer. As a result, there are some species capable of general dispersion that are confined to narrow limits, while others have spread themselves broadcast over both continents.

Thus, turfgrass is easily cultivated, but it has so many enemies that in a few localities only does it thrive in a wild state. The willow, on the contrary, spreads wherever it is introduced. The ostrich does not extend its territory, but the rabbit has become a pest in almost every part of the civilized world.

QUESTIONS AND EXERCISES.—Study the common thistle, the dandelion, or the winged maple, and show how these species may be spread.

In the temperate regions of North America in what general direction will those species depending on the winds for distribution be most apt to spread?

Note any instance that has come under your personal observation in which plants have been carried into new territory by winds, by running streams, or by waves.

Note any instance within your knowledge in which either a natural feature or the activity of man has formed a barrier to the dispersion of a plant or an animal species.

What advantages have each of the following species for dispersal? the camel, man, the burdock, the ant, the snake, the cotton plant.

The sting of the tsetse fly, an insect of Africa, is fatal to most cattle, but the offspring of those that survive, are immune from its attacks; how will this fact affect the dispersal of cattle?

COLLATERAL READING AND REFERENCE

Shaler.—Nature and Man in North America.

CHAPTER XVIII

THE GEOGRAPHIC DISTRIBUTION OF PLANTS AND ANIMALS

Probably 150,000 species of plant and about as many of animal life are known to exist. These are distributed in accordance with the laws noted in the previous chapter—that is, each lives in a locality adapted to it. Plant life includes species that vary as widely in form and structure as the multitude of animal species.

Plants are grouped in five sub-kingdoms.

The *Protophytes* are the lowest form of vegetable life. Each consists of a single cell or of groups of cells. In this sub-kingdom are included the yeast plant, and other similar substances known as ferments, the organisms that produce rotting, or putrefaction, and the host of minute forms commonly known as "microbes."

The *Thallophytes* include the plants in which there is little or no distinction between leaf and stem, such as lichens and fungi. Nearly all the sea-weeds and the vegetable moulds belong to this sub-kingdom.

The *Bryophytes* comprise the mosses and the liverworts.

The *Pteridophytes* include the club-mosses, horse-tail rushes, and true ferns. All the foregoing sub-kingdoms are flowerless; they reproduce by means of minute spores borne in receptacles on some protected part of the plant. The dust coming from a bursting puff-ball consists of spores, and these have the reproductive properties of seeds or eggs.

The *Phanerogams* include the species of grasses, shrubs, flowering plants and forest trees. Their growth, like that of certain lower forms, consists of two parts, the roots and the aërial portion. They reproduce by means of flowers and seeds.

Distribution of Plants.—The distribution or dispersal of vegetation may be considered with reference to both *abundance* and *kind.* These are best studied as to regional position and their altitude.

The abundance of vegetation is governed mainly by the conditions of temperature and moisture. In a climate that is both warm and moist, there is nearly always an abundance of vegetation. Because of this fact, plant life is most abundant in tropical lowlands, decreasing as the latitude and the altitude increase. In tropical regions it is profuse;

A FOREST OF THE NORTHERN REGION: OLD GROWTHS AND NEW

in the temperate zones it is abundant; in cold regions it is scanty.

Two factors, environment and time, seem to control the distribution of species as to kind. In the earlier geological ages certain species seem to have prevailed at certain centres. From these they have spread in various directions. The area over which the species of a region may have spread is a question chiefly of time; the locality, one of environment. The vegetation of a given region is called its *flora.*

With respect to geographic distribution the map (p. 318) shows that the vegetation of the northern regions of the two continents does not differ materially. In each continent it is a zone of deciduous trees, evergreens, grasses, and food-producing plants. Maize, tobacco, the redwoods (including the sequoias), and the yuccas are confined to the *American Region.* The two regions are separated by the Atlantic Ocean, and though the life-forms are not always identical, they are very similar.

The *South American Region* embraces the territory south of the Tropic of Cancer, both mainland and insular. The mahogany, cinchona, india-rubber, and rosewood are among the chief species peculiar to it.

The *African Region* includes Africa south of the Atlas Mountains and tropical Arabia. The baobab, oil-palm, euphorbias, begonias, the coffee-tree, several heaths, and the geranium, are among the native plants peculiar to this region. The *Oriental Region* includes the territory south of the Himalaya Mountains, and most of Malaysia. Among the principal characteristic species are the spices, the ebony, sandal-wood, and the melons.

The *Australian Region* comprises the continent of Australia and most of the islands east and north. The flora of this area is peculiar. The prevailing color of the vegetation is bluish-green and the leaves turn their edges to the sun. The eucalyptus or gum-trees, the various tree-ferns, and the jarrah, a wood much used for street paving, are found in this region. In the north and east the Australian and Oriental Regions have many species characteristic of both. The eucalyptus and the tree-fern have been introduced into California.

The vertical distribution of species is determined by altitude. Thus at the base of the Himalayas and the Andes, the flora is tropical; higher up, the characteristic species of the temperate zones replace tropical plants; and at an altitude of twelve thousand feet, the vegetation is that of polar types.

Most forms of plant life have an important relation to mankind, and this is especially true of those used as food, as medicine, or in the arts. Chief among them are the grains and other grasses, tuberous plants, fruits, those yielding textiles, and those used for building timber. Commerce has been the chief factor in the dispersal of these.

The Grasses and Grains.—The grasses probably extend over a wider area than any other family of plants. Of these the sugar-cane and maize, or Indian corn, are native to the American continent. All the others belong to the Old World, but have followed the march of mankind. The grasses are the sole food of many species of animals, and the seeds are consumed by every race and tribe of mankind. The starch they contain gives them their chief value as a food-stuff.

Rice is confined chiefly to the marine marshes and moist lands of tropical and sub-tropical regions, but there are several upland species. Rice is the staple food of about one-half the people of the world, and is the cereal chiefly used in Southern and Eastern Asia. In certain parts of China and India, wheat is gradually supplanting it. The nutrient value of rice is not quite equal to that of wheat. Maize, or Indian corn, a native of the New World, is an important food-stuff in temperate and sub-tropical

DISTRIBUTION OF ANIMALS

regions. It is the chief bread-stuff of the "mixed" and native races of the New World. In the United States and Canada it is used mainly as animal food, being converted into pork. Its use, both in the form of grain and meat, is increasing among the peoples of the Old World. It is also used in the manufacture of liquor.

Wheat is the bread-stuff of the civilized peoples of the temperate zones and is the fuel of the activity and energy of the world. It is grown in the great plains of the temperate zones, but it thrives in sub-tropical and sub-polar regions.

The world requires about 2,400,000,000 bushels of wheat each year, and the amount required is steadily increasing. The annual crop is somewhat greater, but in an occasional year the visible surplus falls very low. In 1907 the crop was 3,000,000,000 bushels. It is estimated that the maximum crop possible is about twice this amount. About one-fourth of the world's crop is produced in the United States.

Rye takes the place of wheat in many countries, and is one of the most important crops of Russia and Germany. A species of oat is native to North America but the cultivated plant is an imported variety. It is a favorite food for horses. Barley, about the hardiest of the grains, is also much favored as a food for horses, but is employed mainly in the manufacture of malt liquors. Buckwheat is not a wheat at all; but as it contains a large percentage of starch, it is much used as a food-stuff. It is thought to have been introduced into Europe by the Saracens, but it probably came from Manchuria.

The canes include the chief sugar-producing plants. They thrive best in tropical countries, and are extensively cultivated in the sub-tropical belts. In oriental countries the bamboo, a species of cane, is much used as a building material and in the arts.

The palms, next to the grasses, probably yield the greatest variety of useful products. Cocoa-nuts, dates, sago, sugar, wine, and oil, are all derived from this family. So far as moisture is concerned, the palms have a wide range, but in respect to temperature they are restricted to warm regions. They are abundant in both hemispheres.

Tuberous Plants.—Tuberous plants are among the important food-producers. The potato, probably a native of Chile, has been carried to every part of the civilized world. It thrives best in temperate latitudes. The yam and its relative, the sweet potato, are indigenous to tropical America, though a species of the former is found also in the East Indies. The beet and the turnip are native to Europe. The former is now the principal source of sugar. The cultivated onion seems to have come from China, but a wild variety occurs in America. The manioc (or manihot) is native to tropical America, but has been transplanted to Asia and Africa.

Fruits.—The fruits are very important, not only as delicacies, but as foods. Among the foremost are the fig, the date, and the Corinth grape. They are native to the basin of the Mediterranean Sea, and the dried fruit is a necessary article of food in that region. The Corinth grape, an article of no little commercial importance, is sold in American markets as "dried currants."

The cultivated varieties of the apple, pear, peach, and plum are native to western Eurasia; the cherry, apricot, and almond to the eastern part of that continent. The currant is regarded as native to Asia, but wild species are certainly indigenous to western North America. The apple and the plum, said to be native to Eurasia, are also found wild in North America. The peach seems to have originated in Persia, from which the name is derived.

The melons and their near relatives, the gourds (including the pumpkin and squash), are also from Asia. The orange, lemon, and lime probably came from the southern slope of the Himalaya Mountains. So far as written history is concerned, the grape has a greater antiquity than any other fruit, manna possibly excepted. It is found in a wild state in both hemispheres. The fox grape, a wild fruit growing in Canada and the New England States, was discovered and described by the Norse explorers who visited North America about A.D. 1000. The cultivated species of America are mainly imported; the Concord is an improved wild species of American origin. The scuppernong is peculiar to the South Atlantic States. The cranberry probably originated in the temperate zone of North America, migrating thence to Europe. The tomato is also native to America.

The banana, which comes to American markets as a fruit is more properly a food-stuff because of the large proportion of starch it contains. In certain tropical regions, it is almost the sole food-stuff. It is estimated that an acre of wheat will supply about four or five people with the necessary amount of grain food; but an acre of bananas will support not far from three hundred people.

Leguminous Plants.—Most of the succulent and leguminous plants, such as the cabbage, lettuce, spinach, and peas, have followed the migrations of Europeans. The bean seems to have come from Egypt. Celery is undoubtedly of Asian origin, and is found in a wild state over a large part of that continent.

Beverage-Yielding Plants.—Beverage-yielding plants are cultivated throughout the whole civilized world. Tea is sent from eastern and southeastern Asia to almost every other country. The best quality is grown on the chain of islands east of the mainland; it is also grown in the United States. Coffee, probably a native of Abyssinia, is now cultivated mainly in the New World. It grows wild in the former region, and a similar species is native to the warm parts of California.

The cacao-tree yields the cocoa of commerce. The seeds, dried and browned, are used as an infusion; ground with its own fat or with lard it is the chocolate of commerce. It is native to tropical America. Mate (*mä-tā′*), or Paraguay tea, is the leaf of a species of holly native to South America.

Spices.—Spices come mainly from Southern Asia and the Malaysian archipelago. None except pepper has been transplanted to any great distance from its place of nativity. Capsicum, or red pepper (*chile colorado*), is native to tropical America. Nutmeg is a fruit, the covering of which is the mace of commerce; cinnamon is the dried inner bark of a species of laurel; cassia is a similar species growing both in China and the New World; cloves are the dried buds of a tree native to the Molucca Islands and Southern India.

Medicinal Plants.—Medicinal plants are as widely dispersed as is the human race. The opium-poppy, native to tropical Asia and possibly to Egypt, has not migrated far from the place of its birth. The cinchona, a native of South America, but now cultivated in tropical Asia, yields quinine and a score of derivatives. The various members of the night-shade family yield medicinal substances, among them nux vomica, strychnine, belladonna, and gelsemium; they are found in both continents.

The potato, tomato, and tobacco are the most important American representatives of the family. The "jimson" (probably a corruption of *Jamestown*) and other species of the datura stramonium are found in all moist and warm regions of North America.

Rhubarb and ginseng are native to China, but are now cultivated chiefly in the United States. The hemp that yields cannabis indica, or hasheesh, comes from Southern Asia. Coca, from which the drug cocaine is prepared, is native to the Andes. Cascara occurs in tropical and subtropical America. Most medicines widely used are derived from plants found in tropical regions.

Textile Plants.—Plants used in the textile arts have followed man in his migrations. Cotton is the furze attached to the seeds of the cotton plant. Cotton cultivation was introduced into America from Hindustan, but the Barbados and sea-island species of the plant are native to America. Flax and hemp are obtained from the cortex, or outer covering of flowering plants; both probably came from Africa, but four-fifths of the world's product is now grown in the United States. Jute and ramie are native to Asia, but are now cultivated in America. More valuable than either of these is pita, the fibre of the wild pineapple, native to America, and henequen, or "sisal hemp," the fibre of the agave.

Forests.—The forests of the world are distributed with a remarkable degree of regularity. The pines and other conifers, oaks, elms, maples, willows, chestnuts, and beeches, occupy a belt between the 40th and 55th parallels that crosses both continents. The distribution of tropical forests is not so regular. South America has a flora peculiar to itself. The palm, mahogany, bamboo, and representatives of the pines continue through both continents, however.

On both sides of the forest belts there are extensive treeless areas. Some areas are treeless because they are deserts, but in others, such as the plains of Russia and the United States, there are few trees because the seeds have not been carried thither. The winds that blow over the treeless plains of the United States blow from desert regions; those that sweep the treeless plains of Russia come from the ocean and from arid regions.

In the United States forest trees thrive best in a gravelly soil, but they live and increase in a sedentary, prairie soil. In the Champlain period that followed the Glacial epoch, the northern part of the United States was traversed by streams that bore the seeds of various species. Wherever the streams deposited gravel they also deposited seeds. Hence this region was sooner or later covered with trees. As a matter of fact, the timber-covered regions of the northern United States are nearly identical with the area covered by stream gravel and till.

Distribution of Animals.—The animal life of a region constitutes its *fauna*. Of the various classes, the mammals represent the highest types of life, both in form and structure and also in intelligence. All the forms of animal life possess the attribute of instinct—the hereditary power of thought required in the actions necessary to preserve and extend life. The higher—perhaps all—forms have the powers of reason. These faculties have largely controlled the distribution of life.

The animal kingdom is divided into eight great branches or groups; these are again divided into classes and subdivided into the following orders:

Protozoans, the lowest forms of animal life, such as rhizopods, infusoria.

Porifera, of which the sponges are the chief species.

Cœlenterates, of which the coral-polyps, jelly-fish, and sea-anemones are the best types.

Echinoderms, represented by the star-fishes, sea-urchins.

Vermes, or true worms.

Mollusks, or shell-fish, such as the oysters, clams, limpets, snails, and slugs.

Arthropods, including the types of lobsters, crabs, spiders, scorpions.

Vertebrates, or animals having the back-bone.

THE PENGUIN

A type of Antarctic life.

The first four species inhabit the water; the remainder include both land and water animals. The vertebrates comprise various classes of which the principal are *mammals,* or warm-blooded animals that suckle their young; *birds,* mainly aërial in their habits; *reptiles,* including snakes, lizards, and turtles; *batrachians,* represented by frogs and toads, and *fishes.*

The power of locomotion has given a wonderful development to both instinct and reason. These again have been controlled by the most powerful motive of animate life, namely—the sense of hunger.

The accompanying map shows certain centres to which

DISTRIBUTION OF VEGETATION

animal species are confined. But the limits have been determined in a different way from those of plant life. The territory of plant flora is governed mainly by environment; in animal life environment is important, but the power of voluntary locomotion has been the leading factor. The limits of a fauna, therefore, are largely determined by physiographic barriers.

The factors that have governed the dispersal of animal species cannot always be determined. It must be borne in mind that dispersal began in prior geological times, when the conditions of environment were often different from those of the present age. In the case of marine life, the limits to the territory of species are bounded mainly by the temperature of the water. The fauna of cold currents is materially different from that of warm waters, and the fact that the lower reptiles of ocean waters are uniformly cold, may explain the similarity of Arctic and Antarctic marine fauna. Deep-sea species are wholly different from surface species.

In the accompanying map, it is seen that the North American and Eurasian regions have a very broad extent, and are separated by marine barriers that are neither very wide nor impassable. In the south, the regions are surrounded by barriers that practically isolate them. For example, South America is separated from North America by the barriers of sea and climate. The African Region has, in addition to these barriers, a high mountain range on its northern border; the same is true of India; Australia is environed by the sea; it is also marked by peculiarities of climate.

The faunas of the two northern regions are similar. In many instances the species are identical; in others a species may have its representatives in both continents. The faunas of the southern regions, however, are marked by strong contrasts.

Northern Regions.—The North American and Eurasian Regions have in common many kinds of carnivorous, or flesh-eating animals. Various species of wolf and bear are widely dispersed through both regions, and the cat family is represented by the panther and several species of wildcat. Many fur-bearing animals—notably the lynx, otter, ermine, badger, and sable—are common to both regions, and so are species of the deer family and mountain sheep.

The grizzly bear, caribou, bison, musk-ox and black bear are peculiar to America; the first named is found only in the Rocky Mountain highlands. The reindeer, camel, buffalo, and nearly all domestic animals are native to the Old World, but have been transplanted to the American continent. The opossum, puma, bald eagle, humming-bird and wild turkey are native to the American region; the chamois, ibex, fallow-deer and aurochs are peculiar to the Old World.

South American Life.—The South American Region is distinguished by a profusion of animal life. The monkeys are unlike those of the Old World. The camel of the Old World is here replaced by the alpaca, vicuña, llama, and guanaco—all distantly related to the camel, and from which the latter probably descended.

The sloth, armadillo, ant-eater, and peccary are peculiar to this region, and so are the numerous parroquets, and hosts of insect species. The condor is the nearest approach to the European vulture and the rhea to the ostrich.

Tropical Regions.—The Ethiopian Region is remarkable for the absence of the species common elsewhere. On the other hand, the gorilla, lion, zebra, hippopotamus, giraffe, ostrich, five-toed elephant and other species are found nowhere else.

The Oriental Region is the birthplace of most of the domesticated animals. Among wild animals the tiger, mongoose, cobra, and three-toed elephant are peculiar to this region. The rhinoceros, jackal, and leopard are common both here and in the region to the westward.

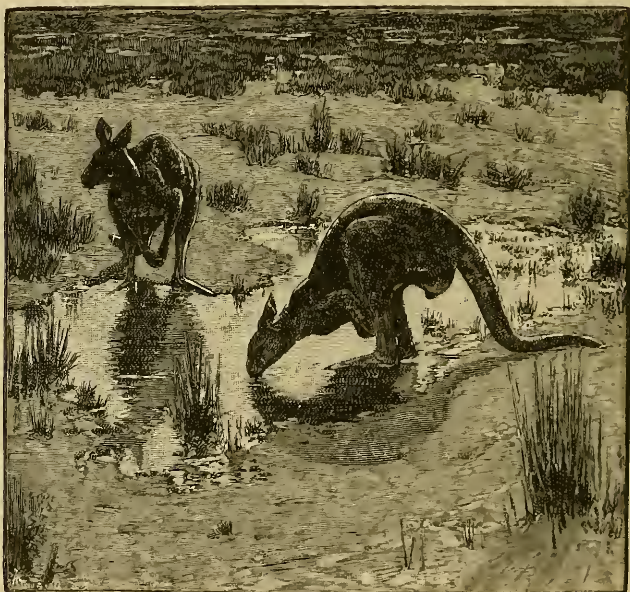
Australian Region.—The Australian Region is marked by unusual types. All its life-forms are peculiar, and but

BORN OF THE SOUTH AMERICAN REGION: SURVIVES IN THE OLD WORLD

few types found elsewhere occur in this continent. Many species are marsupials—that is, the female has a pouch or pocket in which the immature young are carried. Many others, such as the kangaroos, have enormously developed hinder legs.

The Bearing of Organic Life upon Physiography.—The bearing of life and its energy upon physiographic forms is far-reaching and quite as important as the bearing of physiographic forces on life.

Life-forms have been and are now among the important agents in rock formation. Some of the limestone basins of the Mississippi Valley, all the infusorial earths, the various fringing reefs, the barrier reefs, the atolls, and the



THE KANGAROO

A type of the Australian region.

encircling reefs are the work of animal life. The chalk formations of Western Europe are also the results of life.

In the broad areas of the tropical oceans the work of organic life is of still greater magnitude. The water of these regions is swarming with life, and the skeletons of the dead forms, together with other mineral constituents, are accumulating at the bottom. Wherever deep-sea dredging has been carried on, these accumulations have been found.

But the secretion of the lime from the sea-water has still another effect. After the lime and other mineral matter has been absorbed by the organism, the water is specifically lighter; as a result, the change in its density has created a slow, but certain circulation of water.

Vegetable life is also responsible for extensive areas of rock formation. Under certain conditions, such as excessive saturation, the leaves, twigs, and stems of plants accumulate to considerable depths. If these accumulations be covered by overflowing sediment, either fluviatile or marine, the wood-fibre, after long-continued pressure and partial decomposition, is converted into coal.

In the United States coal measures underlie more than 150,000 square miles of territory, and in the various basins of Eurasia a much greater coal area exists. Coal-making has been an incident of every geological age. Diamond, graphite, anthracite, bituminous coal, mineral pitch, petroleum, and natural gas are all the results of organic life.

Vegetation has also been an important factor in preventing general surface erosion. A surface covered with grass or foliage resists the action of rain and winds alike. But denuded of vegetation, the surface quickly becomes scored by running water; gullies grow into ravines, and ravines deepen into impassable cañons.

Not only is vegetation capable of converting a moderately dry region into a swamp, but also it may fill the swamp and reconvert it into a dry region again. It may accomplish even more than this. A single species, such as the

Russian thistle, may exterminate about every other species of plant within the area upon which it intrudes.

As the native vegetation disappears so do the characteristic animals and, sooner or later, the entire flora and fauna are changed. This also alters the character of the soil; and as the topography of a region is due in part to its characteristic vegetation, this also is changed.

The lowest forms of vegetable life, such as the moulds, and the organisms called microbes, perform an important office. As disease-germs, they may exterminate whole species, both animals and plants. In company with the mosses and lichens they decompose and crumble the hardest rocks. In warm, moist regions exposed rock-cliffs and strata are much rarer than in arid regions. Fresh surfaces of rock once exposed are quickly covered with mosses, lichens, and the various protophytes. These, once established, require time only, either to disintegrate the rock, or to cover its surface deep.

The common earthworm plays an important part. It thrives in moist earth, and a colony of these worms, once bred in a given locality, continues to inhabit it until rock waste is changed to a rich soil. Thus it is seen that the lowly and often invisible forms of life become important factors in the physiography of a region.

QUESTIONS AND EXERCISES.—Make a list of the forest trees, shrubs, and other wild plants growing in the neighborhood in which you live.

Make a special study of any plant or "weed" regarded as useless or baneful. If you cannot obtain the information you require, send a specimen to the Department of Agriculture, Washington, D. C.

Follow the same directions with reference to the animal species, especially those injurious to vegetation, applying to the Department of Agriculture for information you cannot obtain elsewhere.

Enumerate the articles of food and table furniture used at dinner, and follow the route of each one from its native place to the table.

Mention the various uses to which maize or the corn plant is put—grain, cob, and stalk.

In what ways does the wheat crop affect the habitability of the United States?

Name some of the chief causes of the destruction of forests. Note an instance in which the cultivation of the cotton plant has affected the history of a people.

Describe instances in which the distribution of animals or of plants has been effected by the agency of mankind.

COLLATERAL READING AND REFERENCE

Mill.—Realm of Nature, pp. 302–320.

CHAPTER XIX

MAN

Man, though at the head of animate creation so far as the development of reasoning powers are concerned, from a physiological stand-point is distinctly an animal, and is closely related to other vertebrates. The skeleton of a man does not differ materially in structure from that of a monkey, a bear, a dog, or a bat; it does not differ very greatly from that of a whale, a lizard, or a bird; it closely resembles that of the gorilla.

With respect to nutrition the resemblance is still stronger. The digestive apparatus and the various processes by which food is converted into blood, bone, and flesh are the same in man as in other mammals. The food, moreover, is practically the same—water, grain, fruit, and the flesh of other animals. The organs by which the blood is circulated are the same, and the processes involved in breathing do not differ in any essential point in man and other mammals. In the structure of bone, muscle, and tendon, and in the operation of special organs, such as nerves, intestines, lungs, and heart, the functions are practically identical.

The chief characteristic of mankind is the great development of the reasoning faculties. The power of reason is certainly common to some of the lower animals—possibly to all species. In man, however, this faculty is enormously developed in comparison with other animals. Moreover, the power of reasoning abstractly seems to be possessed by no other species of life.

The classification of mankind into races and families, however, is one of great difficulty and no two ethnographers are in full agreement. Color of skin, texture of hair, and language have been made bases of classification, but each system, closely followed, leads to confusing difficulties. The following scheme has been tentatively adopted:

Black peoples.—Negroes, Bantus, and Negroids (Australians and Melanesians).

Yellow peoples.—Turanians or Mongols, Malays, Turkomans, Lapps, Huns and Finns.

American peoples.—Aboriginal or "Indian" tribes.

White peoples.—The various families of the Germanic, Latin, and Sclavonic races.

THE BLACK TYPE: A SAVAGE

Black Peoples.—The peoples of this type are characterized by a black skin, kinky or woolly hair, and thick lips. The *Negroes* of Central Africa are the best known of the type. This race, native to Central Africa, has been acclimated in America, also numbering there about ten or twelve millions. The *Bantus* are the finest specimens of the black type, and in their native region are approaching civilization. They are distinguished by a color of skin that is bronze rather than black. The features of most Bantu tribes are fine and sharp, and the lips thinner than those of the Negro.

The *Australasians* inhabit the continent of Australia and the near islands. They are tall and slender, have straight hair, and represent a very low degree of civilization. The *Melanesians* are native to New Guinea and the chain of islands to the southeast. There are also tribes in various parts of the Philippine Islands. The Melanesians and Australasians are also called Negroids, or Nigrettoes. Cannibalism is frequently practised among them.

The black type of mankind is best adapted to a warm climate, and the various races are free from the malarial fevers and other baneful climatic influences that are so fatal to white peoples. In tropical regions the Negro races are by far the most enduring peoples. The religion of almost all the people of this type is obeah worship.

Yellow Peoples.—The yellow or Turanic peoples inhabit southeastern Asia. The type is characterized by coarse and straight black hair, high cheek-bones, and yellowish-brown skins. In some, as the Chinese, the eyes are set at an angle, giving rise to the term "almond-eyed."

Chief among yellow peoples are the *Chinese, Burmese, Anamese,* and *Siamese.* The Caucasians of Transcaucasia, who are sometimes taken as a type of the white races, belong properly among yellow peoples. The civilization of the Chinese is an old one and highly elaborated. In religion they are nominally Buddhists, but in fact they are given chiefly to ancestor-worship. The *Tibetans,* among the best examples of the race, live in the high and cold plateau of Tibet. The Burmese, Anamese, and Siamese live in tropical lowlands. The *Mongols* of western and northern Asia, especially the high plateaus, are a race of nomadic horsemen, courageous and intelligent. In religion they are Mohammedans. Offshoots of the yellow peoples that have settled in Europe—the Turks, Huns, Lapps, and Finns—have reached a high degree of civilization.

There have been many invasions of Europe by Mongol peoples. The Turks, driven from their home in Central Asia by other Mongols, settled in the Balkan peninsula in the twelfth and thirteenth centuries. The Huns in Europe are connected with an invasion, not of Attila, but Balamir, who came from the region northeast of the Caspian Sea, in the fourth century. The Lapps and Finns were living on the Arctic Plain long before the records of written history begin; they belong to the yellow peoples and may or may not be related to the Mongols.

The *Japanese* are a mixed race—Mongol and Malay, with which Hindu blood probably has been absorbed. The Japanese are at the head of the race which they represent, and within forty years their civilization and progress has put them on a plane with European nations.

The *Malays*, or brown race, inhabit southeastern Asia, and the islands to the eastward. Most of them are savage, but they seem to be capable of an advanced civilization, as is apparent in the Javanese and Hawaiians. The *Maoris* of New Zealand are an excellent type of Malay. The *Hovas* of Madagascar belong to this race. Most of the native peoples of the Philippine Islands are Malays. The *Tagals* have reached civilization; the *Visayas* and *Maccabeles* are but little inferior; the *Moros* are savages.

American Peoples. — The aboriginal Americans, or "Indians," characterized by a brown color, are native to the American continent. At the time of the discovery of America several tribes, such as the *Aztecs* and *Peruvians*, were emerging from barbarism into civilization.

In spite of the free use of red pigments which the Indians were accustomed to use on their faces, a prevailing characteristic of the race is the color of the skin, which inclines to a copper-red. This feature is not true of the Pacific-coast Indians, however, who are distinguished by swarthy or black-brown skins.

Among the pre-historic peoples of the continent none have excited more interest than the mound-builders and the cliff-dwellers. According to popular belief both were a distinct race of people whom the Indians exterminated. As a matter of fact, they were nothing more nor less than Indians. At the time of the discovery of America by Columbus, some of the native Americans were approaching civilization. Most of them, however, were still in the stone age, and were therefore in a state of barbarism. Still others were in an intermediate state, and these had begun to forsake the wickiup, or tepé, for houses constructed upon architectural principles. The tribes who had reached this development were responsible for mound-building. The Senecas and Mohawks

AMERICAN INDIANS

had already begun to build the famous long houses; the Shawnees, Cherokees, and Delawares had not reached quite so high a plane, and were still mound-builders. The cliff-dwellers were emerging from barbarism and built their pueblos of selected stone. For better protection they commonly built them on high mesas, on cliff-terraces, or even in caves. The Zuñis and Moquis are thought to be the nearest living approach to the Aztecs.

In South America and Mexico the Indians have become a mixed race, a result of intermarriage with the Latin races—especially the Portuguese and Spanish. In North America, on the contrary, where the association between Indians and Teutonic peoples has always been marked by race hatred, the Indian blood is still pure.

180° 150° Longitude 120° West from 90° Greenwich 60° 30° 0° 30° 60° Longitude 90° East from 120° Greenwich 150° 180°
ARCTIC OCEAN
Greenland
ESKIMOS
ASIA
INDIANS
GERMANIC
LATIN (SPANISH)
INDIANS
Hawaiian Is.
West Indies
ATLANTIC OCEAN
PACIFIC OCEAN
MALAY
INCAS
LATIN (PORTUGUESE)
Arctic Circle
Iceland
British Isles
FINNS
SLAVO
MAGYARS
CAUCASIANS
TUAREGS
BERBERS
SEMITIC
HAMITIC
ARABS
NEGRO
BANTUS
Equator
Tropic of Capricorn
Madagascar
INDIAN OCEAN
HINDU
TIBETANS
CHINESE
MONGOLIANS
JAPANESE
SAMOYEDS
Tropic of Cancer
PACIFIC OCEAN
Philippine Is.
Borneo
PAPUANS
NEGROID
GERMANIC
Tasmania
New Zealand
THE M-N. CO.
Races of Man.
White Yellow Black Am. Ind. Malay
The Density of Population is shown by Strength of Color.

RACES OF MAN

The *Eskimos*, one of the most interesting divisions of the yellow type, are confined to the American circumpolar regions. They are possibly related to the Mongol races, but the relation is distant. They seem to be more closely connected with such peoples as the Lapps, Finns and Samoyads of the Asian part of the Arctic plain. The Eskimos are short in stature, averaging less than five feet in height. They are intelligent and susceptible to civilization. Their habitations are stone huts; their occupation, fishing; their food, raw blubber.

WHITE TYPE

White Peoples.—This race comprises two great divisions, each subdivided into various families. These divisions, moreover, represent language and relationship, rather than structure. The color of the skin varies from light blonde to swarthy, closely approximating black among certain peoples. Intellectually, it is the dominating type of mankind.

The Aryan family is the most widely spread and numerous of the type. In Asia, it includes the Hindus and Persians. In Europe, it includes almost the entire population, the yellow peoples excepted. In the American continent, to which its peoples have migrated, it embraces about one hundred millions of souls.

The Romanic family embraces the peoples usually classed as Latins. But the Romans were a mixture of Latins, Sabellians, and Etrurians, only one element of which is known certainly to be of Aryan descent. An infusion of Greek blood developed the fighting powers of the mixed race, which led to the conquest of the greater part of Europe. When the Western Roman Empire had broken into fragments, the Latin language was finally modified by the different races who had adopted it, to Spanish, French, Portuguese, and Italian. But the Spanish were a mixture of Keltic and Iberian blood, the French were of Keltic and Gallic stock, and the Portuguese of Keltic, Gallic, and Iberian descent. A certain amount of Roman blood was intermixed with all these peoples, but in hardly an instance is there physically a race characteristic among them that is distinctively Roman. A similar mixture took place in the case of the English people. Although popularly known as Anglo-Saxons, the amalgamation is far more extensive; it includes Angles, Saxons, Jutes, and Danes, together with a general mixture of Gothic blood. To this must also be added the infusion of Latin blood that came with the Norman Conquest, a matter of far greater importance.

WHITE TYPE: A REPRESENTATIVE OF THE HIGHEST CIVILIZATION

The *Teutonic, Latin, Sclavonic,* and *Keltic* branches of this family now constitute the most powerful nations in the world. They occupy most of Europe and the greater part of North America.

The Semitic family comprises the *Hebrews, Moors, Arabs,* and *Abyssinians.* The *Assyrians* and the *Phœnicians* were also of this family, but they have been absorbed, or dispersed by conquest. The Hebrews or Jews hold the chief position among Semitic peoples. For about four thousand years, in spite of fearful odds against them, they have had a commanding position.

Springing from a family whose native place was not far from Syria, the Jews became a nation of considerable importance. Because of steadfastness to their faith, neither slavery nor conquest has exterminated them. Diffused over the earth, they are numerically about as strong as ever they were, and their religion and ceremonial rites are as marked to-day as they were four thousand years ago.

A PYGMY

The *Arabs* also form an interesting ethnic group. They occupy not only the Arabian peninsula, but they have extended their habitat through the greater part of Africa and much of Central Asia. They have but little political organization; on the other hand, they are commercial factors of very great power. They are the merchants of Western Asia and most of Africa.

Pygmies.—Scattered over a considerable area of Africa are peoples having no ethnographic relation to any of the foregoing families. These are the pygmies. So far as the color of the skin is concerned, there are two classes—one having a light brown skin, the other being almost black.

The existence of pygmy tribes is mentioned by Herodotus, Pomponius Mela, Aristotle and others, but as recently as thirty years ago it was believed that the accounts of them were mythical. In 1865 the famous African traveller, Paul Du Chaillu, discovered the Obongo tribe. His accounts were flatly contradicted in Europe, but a few years later they were confirmed by Père des Avanchers, an Abyssinian missionary. In 1871, another tribe, the Akka, were discovered by Dr. Schweinfurth.

YELLOW TYPE: JAPANESE

Of the various pygmy tribes the best known are the Akka, Wambutti, and Batua of Central Africa, and the Bushmen of the southern part. Pygmies are characterized by a matted growth of reddish-brown hair upon the bodies, prognathic jaws and retreating foreheads. The average stature of the Bushmen is about five feet; that of the other tribes, about four and one-half feet. The Akka are characterized by misshapen bodies, long, skinny fingers, and withered legs.

Nearly all the pygmy tribes have learned the use of fire, but, as a rule, they eat their food raw. Although they have a very low place in the human scale, they display considerable intelligence. The Wambutti are ingenious in devising nets and traps for securing game, and they seem capable of a low form of civilization.

The pygmies are rarely at war either with the other African tribes or with one another. As a rule, they are protected by the tribes. The Obongo pygmies declare themselves to be related to the monkeys. The Negroids of Australia and the Philippine Islands, and the Hottentots of Africa are notably undersized in physical development. They have been classed as pygmies, but they have no relation to the African pygmies.

Antiquity of Man.—The written history of man, including that which has been recorded on tablets and monuments, extends backward only a few thousand years. The part of this period recorded in Holy Scripture contains data concerning but one or two families and their descendants. Geological history goes back to a period of greater antiquity, but unfortunately gives no clew whereby the age of man can be computed in years. Written history did not begin until man had reached a comparatively high state of civilization, but geological history antedates this period, and discovers man living practically in a wild state, as a dweller in caves.

If man preceded the Glacial epoch, about every trace of the species disappeared. If the cave dwellers of the Mediterranean or the now famous "Nebraska men," were pre-glacial, they certainly were savages. With a few exceptions, upon which doubt has been thrown, the oldest traces of mankind are found just above the unsorted drift of the Glacial epoch, and below that of the river gravels of Champlain times. Above the glacial drift, however, there can be no doubt of the existence of the species.

It is by no means certain that man did not precede the Glacial epoch. A skull found by Professor Whitney among Pliocene deposits and various other relics found among the auriferous gravels of California, indicates a much greater age than post-glacial existence. As a matter of fact, the search for prehistoric and fossil man has been neither extended nor systematic. Practically no investigations have been made among the Miocene deposits of Central and Southern Asia.

Both in Europe and America the bones of man, associated with those of the cave-dwelling animals he hunted, have been found in abundance. With these were also the implements of the chase—ornaments, charred pieces of bone, and in one instance a rude representation of an extinct species of elephant, scratched on ivory.

This piece is now in the British Museum. Of its origin and antiquity there is no doubt.

From the time of the earliest geological history of the species, one feature distinguishes mankind from brute creation, namely—rapid intellectual development. Primitive man had learned the use of fire, and this in itself was to give him supremacy over all other animate nature. He had also acquired the use of tools, and these brought a great increase of power. The earliest race of people employed hammers or axes of rough stone. The next step seems to have been the making of polished stone axes, knives, and arrow-heads. In western Europe, at one time jade, a very hard and fine-grained mineral, supplanted flint as the material out of which stone-cutting tools were fashioned. The commerce of this mineral opened probably the first trade route between Europe and Asia. When, however, the primitive man applied fire to the shaping of his tools and implements made of metal, his civilization was assured, and his power became supreme.

The metal first employed was a crude alloy now known as bronze. At a later period, however, iron was substituted for the alloy. Some of these implements were ornamental in character, but in the main they were tools and weapons. With the increased power afforded by labor-saving tools the people who used them emerged gradually into civilization.

EMERGING FROM A SAVAGE STATE

Migrations of Mankind.—The history of mankind is the history of successive migrations. From the earliest times people have associated in families; families have grown into clans; and clans into tribes. When a region has been sparsely settled, association and government have commonly been patriarchal, the oldest one of the family or clan being the leader.

Where there has been a common enemy, however, the plan of association has often been communal as well as tribal. The families described in the earlier history as recorded in the Old Testament observed a patriarchal rule; in later times, the plan of government became communal and afterward national. The same evolution had begun in the history of aboriginal Americans. Families had grown into clans and tribes; among Aztecs and Peruvians, tribal association had grown into communal government.

But there have always been limits to the growth of a people. They may be absorbed by a stronger race; they may be dispossessed and driven to other lands; they may be exterminated by enemies; or they may find the region overinhabited and incapable of supporting so great a population. For such conditions migration has usually been the remedy.

Thus, tribes of the Tartar race, known in history as the Huns, migrated from the plateaus of Asia and overran a large part of Europe. On their way they drove the eastern Goths from their lands, and the latter, in turn, overwhelmed Italy and Spain. The Lombards, a Teutonic people, migrated from the shores of the Baltic to the Adriatic Sea. The Vandals swept over western Europe, leaving behind a trail of fire and blood. They devastated Spain, crossed to Africa, and established an empire on the site of Carthage. About one hundred years later they were exterminated by a Roman army. Under the teachings of Islam, the Arabs devastated the north of Africa, entered Spain and penetrated France. They founded a Moorish empire, but were afterward driven from Europe.

The foregoing are but a few of the movements of population that occurred in the short space of three centuries, and in the smallest natural division of land. Written history takes no note of similar changes that must have

THE HABITATIONS OF A BARBAROUS PEOPLE

been going on in other parts of the world at the same time.

The records of unwritten history, however, furnish many instances of the dispersions of peoples that must have taken place on a considerably greater scale. In some instances the migration was practically a systematic movement that resembled the advance of an army; in other instances it was a gradual extension of limits.

The migration of the Aryan race is an illustration of systematic dispersion. From some part of Eurasia the various families of this race wandered westward until they occupied all Europe. From Europe, moving still westward, they have subjugated the American continent, and even now the advance guard is knocking at the doors of Asia, after nearly completing the circuit of the world. Another branch, the Hindus, migrated southward and settled in the plains of the Dekkan. There can be but one explanation of such a wonderful dispersion. It is the struggle for existence—the energy put forth to appease the cravings of hunger.

The Effects of Environment.—Two very remarkable factors have tended—the one to change the physical characteristics of man, the other to preserve them. The former is environment, the latter, heredity. The factors of climate changed the color of the Aryan's skin from fair to black when he took up his abode in Hindustan. Aboriginal peoples, such as the Indians of America, the Dravidians of southern Asia, the Dyaks of Malaysia, the Ainoes of Japan, the Tuscans, Sicilians, and Iberians of southern Europe were all dark-skinned people. Their successors, in the main, are either white or else approach the white type. No doubt the variations in the human species were brought about by conditions of soil, food, climate, and occupation. It is also certain that, when the variations were in existence, heredity made them constant.

Man's Relation to Physiography.—The influence of man as an agent in modifying his environment is often overlooked and the far-reaching consequences are not always appreciated. These effects may be classified as interference with the ordinary course of natural events, in respect to the surface of the land, to climate, to drainage, and to the dispersion.

The surface of the land has been modified by man in many ways. Of these the one of most importance is the destruction of forests. In both Europe and the United States a very large part of the surface once forest-clad is now bare. By various artifices, running streams have been made to cover enormous surfaces with fluviatile deposits, and by the same process immense volumes of soil have been removed from one place to another.

Piers and sea-walls have been built so as to extend shores to a considerable distance seaward. Thus, nearly one-third the area of the Netherlands has been reclaimed from the ocean; Venice has become a city of the mainland; and considerable areas of New York, Boston, and San Francisco are built upon land that has been wrested from the sea by the industries of man.

The various highways, roads, railways, and canals, together with the levelling and filling that accompany the growth of cities and towns, form a permanent record of mankind. The surface covered by the rubbish carted from cities aggregates a large area. It is estimated that the surface of Jerusalem has been buried many feet by the accumulating rubbish. In places, the city of Rome has been filled forty feet deep, and the same result has obtained in the vicinity of other cities.

By drainage, swamps have been changed to dry land and their flora entirely replaced by other species. Lakes have been drained by canals and ditches, and the lake basins given up to cultivation. River basins have been limited in area, by jetties and levees, and the area of sediment-depositing has been changed from one place to another.

Perhaps the most important changes that have resulted from the hand of man, however, are connected with the dispersal of life. Through his agency various species have been transported to all habitable parts of the earth; many species have become extinct, and the habits of still others have been greatly changed. Only a brief geological period is required until the interference of man shall become a most important physiographic agent.

QUESTIONS AND EXERCISES.—Why will not the ordinary laws concerning the distribution of life apply to the dispersal of man?

Make a list, as complete as you can, of the various races and families now in the United States; from what part of the world did each come?

Name the advantages possessed by man over other species in overcoming the restrictions imposed by his environment. In what ways can he override such barriers as the sea, deserts, polar regions, and regions not habitable by other species?

How, and in what instances, has the discovery of gold affected the migration and dispersal of man?

Mention one or more instances in which this dispersal has been caused by an enemy.

COLLATERAL READING AND REFERENCE

SHALER.—Nature and Man in North America.
MILL.—Realm of Nature, pp. 320–327.
MARSH.—The Earth as Modified by Human Action.
MINDELEFF.—Migrations of the Cliff Dwellers—*Bureau of Ethnology.*
DENIKER.—Races of Man, pp. 456–466.

CHAPTER XX

THE INDUSTRIAL REGIONS OF THE UNITED STATES

THE main body of the United States extends from the colder part of the Temperate Zone to the Torrid Zone; the isotherm forming the northern boundary of the latter, crosses the southern parts of Florida, Texas, and the lower part of the basin of the Colorado River. This part of the United States is divided naturally into physiographic regions that have fairly well-defined boundaries; and because of their features of surface and climate, each region has become a great centre of industries that are peculiar to it.

The boundaries of these regions are both topographic and climatic, and the regions themselves differ from one another in either climate or topography, or in both. Roughly speaking, the groups of states commonly recognized do not differ very greatly from the industrial groups that result from diverse conditions of climate and topography.

The following are the principal physiographic and industrial regions: The *New England Plateau*, including the eastern part of New York; the *Middle Atlantic States*, including the Atlantic Coast Plain and the middle and southern Appalachian Highlands; the *Great Central Plain*, including the regions commonly known as the Northern States and the Southern States; the *Western Highlands*, including the region west of the 2,000-foot contour, the Rocky Mountains, the Columbia Plateau, the Colorado Plateau, the Basin, the Sierra Nevada and Cascade Moun-

Highlands above 2000 feet in Buff and Lowlands in Green.

The depths of the Oceans are shown by graded Tints.

PHYSICAL MAP OF THE UNITED STATES

tains; and the *Pacific Coast Region.* Make a list of these, grouping each subdivision under its principal division.

The New England Plateau. — This region embraces the northern Appalachian folds, together with areas that belong to the Laurentian highlands. During the Glacial epoch the Appalachian folds in places were almost obliterated. The Green, White, Adirondack, and Catskill

THE WATER-POWER HAS BEEN LARGELY SUPPLEMENTED BY STEAM-POWER

Mountains are the principal remnants. Here and there are isolated "monadnocks"; most of these are bosses of volcanic rock which were able to withstand the erosion and corrasion that resulted during the ice age. Granitic rocks prevail, and their rounded surfaces are generally smooth and polished.

As a result of the Glacial epoch the surface of the New England Plateau is very rugged, the only level regions being the river flood plains and the old lake basins whose waters have disappeared. Many lakes still remain, however, and these, a few coast lagoons excepted, are glacial lakes, or tarns. Name six of the largest. The slope is abrupt and the rivers, therefore, flow in "reaches"; that is, stretches of slack water alternate with rapids and falls.

The coast is a type of the submerged or "drowned"

A HARBOR COAST

region, and the sea now intrudes upon the glaciated regions, making the whole shore-line one of coves and fjords. Practically all the good harbors of the Atlantic coast of the United States are confined to this region and, as a result, about four-fifths of the foreign commerce of the country goes in and out of its ports.

The rugged surface consists of uplands and valley lands. The uplands are characterized by thin and innutritious soil.

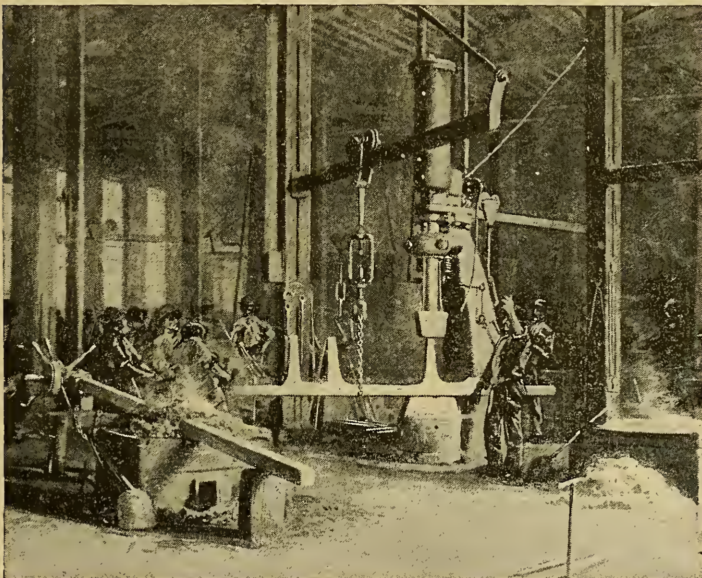
The surface is diversified by drumlins, eskers, and granite hog backs; and much of it is strewn with erratic bowlders. The uplands are not capable of supporting a dense population, and in the past half century there has been no material progress in agricultural pursuits; on the contrary, farming lands have depreciated in value. As a result there has been a constant movement of people from the upland farms either to the cities or else to the more fertile regions of the west.

Manufacture has been the chief source of the industrial gains. Farming is confined to the lowland valleys and restricted to garden and dairy products. This region is celebrated for the manufactures, and these have resulted from the abundant water-power. The manufactures form a large proportion of the nation's foreign exports. The sewing-machines, bicycles, clocks, and firearms made in the mills and factories of this region are shipped to almost every part of the world; the cotton cloth is used by nearly every race of people.

In the last fifty years the increase of the output of manufactures has been so great that steam has largely supplemented water-power. Some great manufacturing establishments have been moved to tide water, the cheaper cost of coal and transportation being more than an offset for water-power.

The Middle Atlantic States. — This region includes the principal part of the Atlantic coast plain, together with the middle and southern Appalachians. The lower part of the coast plain consists of a belt of swamp lands bordered by sandy pine-barrens. Beyond these there is a belt of piedmont lands—the foot-hills of the Appalachian Mountains. The rivers flow into estuaries that reach usually to the foot-hills and are generally navigable to the "Fall Line."

The soil of this region is not well adapted either to cotton or wheat, although small quantities of both are grown. The chief crops are early fruit and garden stuffs, and these find a ready market in the great cities of the manufactur-



COAL GIVES THE POSSIBILITY OF MAKING STEEL

Forging a locomotive frame.—Baldwin Locomotive Works.

ing region. Cotton and tobacco are important crops in the southern part of the piedmont lands; and on account of the water-power, now tardily developed, the manufacture of cotton textiles is becoming the leading industry.

The wave-formed spits or barrier beaches are a peculiar feature of the coast of this region. Because of them, there are but few good harbors, and the volume of ocean commerce is therefore small as compared with that of the New England and Middle Atlantic States. How do these barrier beaches affect commerce? The chief products of these beaches and islands is the famous sea island cotton, a fibre of long staple and great strength; and this is their chief product. The fibre is used in the web of bicycle tires.

THE CHIEF GRAIN FIELD OF THE WORLD

The montane part of this section is low and not very rugged in the northern, but much higher in the southern part. The Appalachian folds contain the most productive coal measures of the continent, and for this reason they are the seat of extensive iron and steel manufactures.

In a few instances the iron ore occurs in the vicinity of the coal measures, but in most instances cheap transportation by water enables the manufacturer to ship the ore from the Lake Superior mines to the smelteries in the vicinity of Pittsburg and other points of easy access. In some instances the fuel meets the iron ore brought in steamers and barges from the Lake Superior iron mines to the shores of Lakes Erie and Michigan, and great steel-making plants have grown up at Chicago, Cleveland, Lorain, Toledo, Ashtabula, and Buffalo.

From the foregoing it is apparent that the entire Appalachian region, both folds and plateaus, is an area of manufacture because of certain geographic conditions, and these are the existence of power. The waterfall is stored-up energy, as also is the coal. The power within the coal not only makes the steam that drives machinery, but in the smelting furnace it also separates the iron from the ore; and inasmuch as iron and steel form the basis of most manufactures, the existence of coal implies the development of a great centre of manufacture. The steel rails made in these great plants are shipped to various parts of the world. The rails and bridges of the railway across Siberia were made of Lake Superior ore, mainly in the vicinity of Pittsburg.

The Great Central Plain.—From Hudson Bay to the Gulf of Mexico the Great Central Plain is characterized by a level or a gently rolling surface, sloping toward the Mississippi River — the whole declining gently from the Heights of the Land, to Hudson Bay on the north and the Gulf of Mexico on the south.

Most of the rivers flow in channels that are from one hundred to three hundred feet lower than the general level of the land, and their high banks are the *bluffs* of this region. For the greater part, the bluffs are from two to ten miles apart, and there is a very level flood-plain between them—the famous "bottom lands." All through the

Great Central Plain the soil is naturally very fertile; that of the bottom lands is especially productive.

The level surface and the general conditions of topography make this region one of sameness so far as external appearance is concerned. Climatic conditions, however, make two separate and distinct areas of history and industry; therefore it is divided into Northern states and Southern states. The two groups are roughly separated by a boundary which practically separates the cotton region from that of food production and manufacture.

A MODERN HARVESTER
It could not be used in a rugged country.

In the Northern states wheat, corn, oats, and grass have always been the chief products. Because of the level surface and the deep, nutritious soil the grain crops can be both planted and harvested at the minimum of expense. Under no other conditions of topography could there have been such a wonderful development of planting and harvesting machinery. As a result, this region has become one of the principal food-producing regions of the world. It produces one-fourth of the world's crop of wheat, a considerable proportion of the dairy products, and about three-fourths of the corn. Moreover, the productiveness of the land is due very largely to the character of the glacial drift spread over the surface.

The western part of this region—the part beyond the 2,000-foot contour — does not receive an amount of rain sufficient to mature grain; but bunch grass and alfalfa, a species resembling clover, are the food of great herds of cattle. As a result, the Northern states produce the flour and meat not only for the United States, but much of that required by the rest of the world.

The Southern states produce about four-fifths of the world's supply of cotton. Grain can be grown in these states, but the crop does not pay nearly so well as cotton; and cotton cannot be grown north of the line that separates the two groups. The industries and social conditions—and, therefore, the history—of the two sections have differed greatly.

There has always been much manufacture in both sections, but the manufactured articles have been closely related to the grain and the meat product in the one section, and to cotton-growing in the other. These manufactures, moreover, have been greatly encouraged by the extensive coal measures mainly in the northern section. Most of the cotton is shipped abroad, to be made into textiles elsewhere. Steel manufacture has also become a great industry in the southern Appalachian region.

The Western Highlands.—The Western Highlands embrace the region between the Rocky and Sierra Nevada Ranges. This region is characterized by ruggedness. The lofty ranges that form the rims of the highland are less than two miles in altitude in few places only. Fremont and South Passes are the chief channels of intercommunication on the eastern side. One of the Pacific railways crosses

HAGERMANS PASS

The ranges and cañons are a barrier to intercommunication.

these ranges at an altitude of nearly 10,000 feet. In the north the cañons of Columbia River and its tributaries afford the grades for railway communication; on the south the river cañons and passes are also the routes of commerce.

The ranges of the Rocky Mountains are lofty folds resting on granitic rocks. The Sierra Nevada and Cascade

Ranges are huge blocks of tilted rock with a gentle slope on the west and an abrupt escarpment on the east. The parallel ridges of Nevada, commonly called the "Basin Ranges," are excellent examples of block mountains, the upturned edge of the block constituting the range. Here and there are the isolated knolls that form the *laccolites* of which the Henry Mountains are examples.

The western slopes of the Sierra Nevada and Cascade Ranges receive a generous rainfall. Within the rim ranges the rainfall is deficient. In the northern part it is sufficient for a rather scanty pasturage, but the southern part is a desert.

The *Columbia Plateau*, or "Plains of the Columbia," is mainly the surface of the great flood of lava that flowed from fissures on the Sierra Nevada Mountains. The general surface of the plateau, the block ranges excepted, is level, but the region has been much dissected by the rivers, whose cañons are from five hundred to more than three thousand feet deep.

In several places the Columbia River has cut its channel deep into the flood of lava. In one place there is disclosed a forest which was overwhelmed by the lava. The trees are felled, but the wood is in a good state of preservation. Coulées of lava flowing across the river channel have created rapids and falls at various places.

The *Colorado Plateaus*, sometimes called the "Alcove Lands," consist of a series of table-lands varying from half a mile to a mile and a half in altitude. The lower plateaus are desert regions of tropical temperature, inhabited by a few tribes of squalid Indians. The middle plateaus have sufficient rain for a very scanty covering of grass; the higher mesas have a moderate growth of grass and timber.

Cañons with angular outlines and steep walls are the chief characteristic of this region. The cañons of the Colorado, which have made the region famous, in places are more than a mile deep. Probably nowhere else on the face of the earth are the features of erosion and corrasion presented on such a stupendous scale. Every river and every tributary is practically an underground stream, so deep are their channels cut into the plateaus.

The *Basin Region* receives its name from the fact that none of its drainage reaches the sea. On the slopes of the block ranges the rivers are vigorous streams, but their waters finally disappear by evaporation, and by percolation in the sea of fine rock waste at their bases.

At times the beds of some of the larger streams, such as Humboldt and Carson Rivers, are dry in the day but contain a considerable amount of water at night, when, by reason of lower temperature, evaporation is lessened.

The lakes are without outlet to the sea, and most of them are the shrunken remnants of two great lakes that once covered a large part of this region. One of these, now called La Hontan, included the present basins of Humboldt, Pyramid, Winnemucca, and several other lakes adjacent. Several of them, including Walker and Owens Lakes, have never wholly disappeared and their waters are saturated brines.

Great Salt, Utah, Sevier, and Parowan Lakes are the remnants of former Lake Booneville (p. 181). Of the various remnants many have wholly disappeared, and Sevier and Parowan Lakes are now dry; Utah Lake is fresh. Great Salt Lake at present is shrinking rapidly. Pyramid, Carson, and Winnemucca Lakes, in recent times dry, are now filling.

Two small areas of the Basin Region are below sea-level. One of these, Salton Lake and its basin, nearly three hundred feet below sea-level, was undoubtedly the former head of the Gulf of California; the other, Death Valley, may have been. The "sink" or dry bed of Salton Lake, once known as Coahuilla Valley, or the Sink of San Felipe, was most likely separated from the present Gulf by the sediments brought down by the Colorado River. This region is now called Imperial Valley, and much of it has been made cultivable by irrigation. The sediments formed a bar or sea wall across the Gulf and cut it in twain. The upper portion in places has become partly filled with wind-blown rock waste, but its lowest part is about three hundred feet below sea-level.

Several of the sinks of this region are fed, not by rivers that normally flow into them, but by the overflows of the Colorado River. When more than bank-full, the latter overflows into the lower land to the westward. Salton Lake is an overflow of this character. New and Hardy's Rivers, frequently chartered on maps of this region, are not streams flowing into the Colorado, but out of it. In this locality the river practically flows around the side of a slope; and at times, when the volume of water is too great to be contained in the channel, the water breaks its confining bank and temporarily flows out into the desert.

At the time of the filling of the basin in 1891, the water was extremely salt, and its temperature was nearly 120° F. At several times there have been propositions to turn the river into the sink and thus make an inland sea. Evaporation is so great, however, that the entire volume of the Colorado would fill but a small part of the basin.

The climate of the Basin is one of great extremes, and the southern part is one of intense summer heat. In places it is a region of dunes swept by simoons, and occasionally deluged by cloud-bursts. To the latter are mainly due the sinks and washes of the region. Yuccas, cacti, mezquit (a species of acacia), and a coarse grass resembling the spinifex of Australia, are the prevailing vegetation of the southern part; sage-brush, a kind of wormwood, is characteristic of the northern region. Wherever irrigation is possible the soil of the river flood plains is highly pro-

MOUNT RAINIER
It is the cinder-cone of an extinct volcano.

ductive. In the southern part several species of lizard, among them the "horned toad," abound. A large species, popularly known as the "Gila monster," inhabits the Gila River and is peculiar to this river valley.

The conditions of both climate and topography will not permit the Western Highlands to become a thickly peopled region. The rainfall is insufficient for the production of any great amount of food-stuffs, and the latter must depend upon irrigation wherever they are grown. The rugged surface is intensified by deep cañons, and these are such obstacles that commerce is carried on at an enormous expense. In one or two instances a cañon half a mile in width forces traffic to make a detour of several hundred miles around. The mining of the precious metals, copper, and lead, is the chief industry.

The Pacific Coast Region.—This region includes the western foot-hills of the Sierra Nevada and Cascade Ranges, the Coast Ranges, and the great intermontane valley between them. A notable feature of this region is the distribution of rain. During the winter months the moist westerly winds are sufficiently chilled and shed an abundance of rain over almost the entire region; very little falls from May to October, and in southern California, none at all.

The foot-hill region is more or less rugged, but the greater part of its area forms excellent ranges for cattle in the north, sheep in the south, and fruit in every part. The Coast Ranges lie abruptly against the shores of the Pacific Ocean and in only a few places is there even a narrow coast plain. The few harbors, however, are deep, commodious, and conveniently situated. In a few places, however, vessels lie alongside a high cliff and receive their cargoes by means of chutes with long outriggers. The lower ranges of these mountains form excellent pasturage; the river valleys produce the best wheat that is grown.

The great intermontane valley is a rift that extends from Puget Sound to the Gulf of California. It varies from twenty to about one hundred and fifty miles in width, but in several places it is interrupted by cross spurs that connect the great ranges. In the north, where it opens to the sea, it is known as the Sound Valley. Farther south the Golden

Gate opens from the sea into San Francisco Bay, one of the principal harbors of the world. This part of the intermontane region is best known as the Sacramento-San Joaquin Valley. Between them is the Willamette Valley.

The northern and southern parts of the intermontane valley form a mammoth wheat field; the middle portion consists of rolling lands that form excellent cattle and sheep ranges, and furnish the possibilities of unlimited water-power not yet utilized. South of Tehachapi Pass, a fertile lowland lies next the Pacific, which yields an abundance of semi-tropical fruits and a very fine merino wool. The conditions of climate and topography make this region capable of supporting an enormous population.

The Adjustment of Industrial Pursuits to Environment.—In the growth and development of a nation two processes usually are going on—the acquisition of territory and the adjustment of the pursuits of a people to the conditions of their geographic surroundings. The latter is usually attended with more or less friction, and the friction is a very large factor in their history.

In the geographic distribution of the industries of the United States, one may follow the processes of adjustment. The New England Plateau, with its abundant water-power —helped also by steam-power—furnishes the country with light manufactures and textiles and exports the balance. The people of the harbor region carry on the foreign commerce and largely control the great railway systems that transport the manufacturer's products and the food-stuffs.

The people of the Appalachian region manage the distribution of the coal and supply the country with steel rails, bridge material, building girders, and power-producing ma-


City of
NEW YORK
and Vicinity,
with
Harbor Approaches.
0 1 2 3 4 5 6
SCALE OF MILES.
Explanation:
Channels:
Light Houses:
Light Vessels:
Lighted Buoys:
Other Buoys:
Borough of the Bronx
Borough of Manhattan
Borough of Queens
Borough of Brooklyn
Borough of Richmond
Hudson River
North R.
East R.
THE PALISADES
Long Island Sound
LONG ISLAND
NEW JERSEY
STATEN ISLAND
Jamaica
Jamaica Bay
Hoboken
Jersey City
Newark
Newark Bay
Bayonne
Elizabeth
Rahway
Governors I.
Upper New York Bay
Lower New York Bay
PASSAIC LIGHT
ROBBINS REEF LIGHT
New Brighton
Port Richmond
FT. TOMPKINS LIGHT
NEW DORP BEACON
Richmond
ELM TREE BEACON
CONEY ID. LIGHT
Coney Island
Rockaway Beach
18 feet depth
WRECK
East Bank
14 Feet Chan.
East Channel
Romer Shoal
LIGHT
Gedney Channel
RED SECTOR
SANDY HOOK LIGHT VESSEL
Old Orchard Shoal
OLD ORCHARD SHOAL LIGHT
Swash Chan.
Flynn's Knoll
South Channel
False Hook
HOOK BEACON
SCOTLAND LIGHT VESSEL
SOUTH BEACON
SANDY HOOK LIGHT
Sandy Hook
Main Chan.
ATLANTIC
OCEAN
GREAT BEDS LIGHT
BOUNDARY BEACON
South Amboy
Staten Island Sd.
Raritan Bay
POINT COMFORT BEACON
Sandy Hook Bay
WAACKAACK BEACON
CONOVER BEACON
Lockport
Keyport
Atlantic Highlands
NAVESINK LIGHTS
CHAPEL HILL BEACON
Matawan
Red Bank
TRUE NORTH
MAGNETIC NORTH
VAR. 8° 50' WEST IN 1900.
East Long Branch
Long Branch
LIMIT OF NEW YORK
THE M-N. CO.

chinery. From the prairies of the Great Central Plain come the breadstuffs and meat, and from the Atlantic Coast Plain the fruit and vegetables required for the laborers in the crowded manufacturing centres. From the south comes the cotton and from the west the wool that is to clothe eighty millions of people. From the Western Highlands are obtained the gold and silver, the medium of commercial exchange, and much of the copper the medium by which electric-power is transmitted. Each section supplies not only the rest of the United States, but a large foreign trade as well.

Natural Resources.—No other nation, China excepted, possesses such a great wealth of resources. Some of these will still last for years, but others are nearly exhausted. The bison and the fur-seal are practically extinct, the former being in part replaced by cattle that certainly are of greater value.

The most valuable *forest trees* of the country are the pines. Of these, a belt of white pine extends along the northern border; and a belt of yellow pine along the Atlantic and Gulf coasts. Both of these regions are nearly exhausted of their supply of merchantable timber. The dense forests of Douglas fir, or "Oregon pine," and redwood of the Pacific Coast will be productive for a much greater length of time. The amount of growing timber is probably greater than at any previous time in the history of the country, but very little of it is fit for building purposes. It is estimated that from five to ten million young pines are destroyed each year for use as Christmas trees.

Forest fires probably rank first in the destruction of timber. The railways make the heaviest demand on the oak, which is used for ties. The paper-makers use an enormous amount in the manufacture of paper pulp; the charcoal burners destroy the rest. Between the railways and the tanneries the Pennsylvania Appalachians are nearly shorn of oak and hemlock.

The *coal fields* cover an area of about 130,000 square miles. Of the amount yielded from these mines, all the anthracite coal comes from three small areas in Pennsylvania; these, it is estimated, will be exhausted in about one hundred years. There are now known to be anthracite fields of considerable extent in Colorado, however. The supply of bituminous coal is practically unlimited. Much of the coal supply is used as house fuel, but by far the greater part is used in the manufacture of iron and in producing steam.

Most of the coal occurs in the rocks of the Carboniferous Age; the coal measures of the Pacific Coast, however, are of much more recent origin, and formed during the Tertiary period.

Petroleum, or rock oil, occurs in various places, usually near but not always in the coal fields. The refined oil of commerce is shipped to almost every part of the world, and is even an article of caravan trade in Africa. The principal wells of the United States are in Western Pennsylvania, Eastern Ohio, West Virginia, and Texas. There is also a productive region in Southern California. Natural gas occurs in the same general area, but the gas and the oil do not seem to be associated. The gas is used for house fuel and for making steam. The supply, much of which has been wasted, is becoming exhausted.

Iron ore occurs in very many parts of the United States, but it is available only when it can be shipped to places where coal is cheaply obtained. The ores of Lake Superior, Iron Mountain in Missouri, and the Appalachian Mountains are the chief supplies. The iron is obtained from the ore by smelting the latter with coal or coke, and is then converted into steel ingots. The ingots are rolled into rails, plates, billets, and other structural material.

Gold is abundant in the Western Highlands. It is obtained mainly by crushing the quartz rock in which it occurs and amalgamating, or dissolving the gold in quicksilver, or by the use of other solvents. In Alaska and in parts of California most of the gold is free, being mingled with gravel. It is obtained by washing the latter away with water, thereby leaving the gold, which is much heavier, to be taken up by the quicksilver. *Silver* also occurs in the Western Highlands. *Copper* occurs in the Rocky Mountains, but the principal part of the product comes from the Lake Superior region. It is mainly used for the transmission of electric power. One of the two great quicksilver-producing regions of the world is in California and this state yields about half the output.

QUESTIONS AND EXERCISES.—Repeat the list of physiographic and industrial regions enumerated in the first page of this chapter.

Why is the New England Plateau ill-adapted to grain-farming? How does topography become a factor in the economic production of grain?

State the various ways in which coal is used as power, both on land and at sea.

Study the furniture and equipments of the schoolroom and make a list of the industries there represented. Trace the geographic source of the raw material employed; where is each manufactured?

Explain how the topography of the northern prairies has affected the development of farming machinery.

Explain why cotton-growing is limited to its present latitude. In what way has cotton-growing affected the social conditions of the people of the Southern States?

Explain how and why the topography of the Western Highlands is a barrier to commerce.

Explain how and why the geographic distribution of industries has resulted in the enormous development of railways.

Describe three railway routes across the continent; two water routes from Chicago to tide water.

How does the grade of a railway affect the cost of transporting freight?

Obtain from the Hydrographic Office, Washington, D. C., any bulletin or publication explaining the kinds and uses of buoys and range lights employed in harbors.

Trace the course of a deep draught steamship entering the main channel of New York Harbor, with reference to the range lights. (*See map, p.* 353.)

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APPENDIX

I

The Elements of the Solar System

Name.	Distance from Sun, in Miles.[2]	Time of Revolution.	Diameter in Miles.	Number of Satellites.	Density Water =1.
Sun........	....	....	860,000	....	1.4
Mercury.....	37,750,000	88 days	2,992	....	6.8[2]
Venus.......	66,750,000	224 "	7,660	....	4.8[2]
Earth.......	92,300,000	365¼ "	7,918	1	5.6
Mars........	141,000,000	1.9 yrs.	4,211	2	4.2
Asteroids....	250,000,000	4.4[1] "	20—300	....	....
Jupiter......	480,000,000	11.8 "	86,000	5	1.4
Saturn......	881,000,000	29.5 "	70,500	8	0.7
Uranus......	1,771,000,000	84 "	31,700[2]	4	1.3[2]
Neptune.....	2,775,000,000	164 "	34,500[2]	1	1.1[2]

[1] The periodic time of the asteroids varies from 3.1 years to 7.8 years; the approximate average is 4.4 years.

[2] These values are approximate.

II

Deep Borings

The following list of borings represents depths existing in 1905. It is subject to change:

	Feet.
Paruschowitz, Upper Silesia........................	6,570
Schladebach, near Leipsic...........................	6,265
Monongahela (thus far sunk)........................	5,532
Wheeling, W. Va..................................	4,920

	Feet.
Sperenberg (gypsum beds near Berlin)	4,559
Lieth, near Altona	4,388
Eu, near Stassfurt	4,241
Lubtheen, in Mecklenburg	3,949
St. Louis, Mo	3,843
Stennewitz, near Halle	3,644
Inowrazlaw, Posen	3,624
Friedrichsaue, near Aschersleben	3,542

There is but little uniformity, however, in the rate at which the heat increases; it varies from one degree (F.) in fifty to one in every seventy or eighty feet of descent. In some cases the heat is due in part to chemical changes in the rock.

III

Heights of Plateaus, Ranges, and Peaks

Plateaus

	Feet.
Abyssinian	6,500— 7,500
Allegheny	1,000— 1,500
Australian	4,500— 5,500
Bolivian	12,000—14,000
Brazilian	2,500— 2,800
Colorado	4,500— 6,000
Columbia	4,000— 5,000
Dekkan	2,000— 2,500
Guiana	2,000— 3,000
Heights of the Land	1,000— 1,500
Iberian	2,000— 2,500
Iran	5,000— 6,000
Mexican	7,000— 8,000
Mongolian	3,000— 4,000
New England	1,000— 1,200
The "Plains"	5,000— 6,000
The Pamirs	10,000—14,000
Tibet	15,000—17,000

Ranges

	Feet.
Alps	7,000— 9,000
Altai	6,000— 7,000
Andes	12,000—15,000
Apennines	3,500— 4,000
Appalachian	1,500— 2,500
Atlas	8,000—10,000
Balkan	4,000— 5,000
Blue (Oregon)	4,000— 4,500
Carpathian	4,500— 6,000
Cascade	7,500—10,000
Caucasus	9,000—11,000
Coast (California)	2,500— 3,500
Coast (Canada)	4,500— 8,000
Dragon (So. Africa)	4,000— 5,000
Himalaya	16,000—19,000
Hindu Kush	16,000—18,000
Jura	2,500— 3,500
Karakorum	18,000—19,000
Ozark	1,200— 1,500
Pyrenees	7,500— 9,000
Rocky (U. S.)	6,000— 7,000
Rocky (Canada)	9,000—10,000
Tian Shan	17,000—18,000
Ural	2,000— 4,000

Peaks

	Feet.		Feet.
Aconcagua	23,900	Marcy, New York	5,467
Ararat	17,260	McKinley, Alaska	20,464
Blanc	15,744	Mauna Kea (volcano), Hawaiian Islands	14,000
Ben Nevis	4,368	Mauna Loa (volcano)	13,600
Chimborazo (volcano)	20,500	Mitchell, North Carolina	6,711
Cotopaxi (volcano)	16,300	Hooker, British Columbia	15,700
Dapsang	28,300	Orizaba (volcano)	18,300
Demavend (volcano)	18,800	Pike's Peak	14,147
Etna (volcano)	10,875	Popocatepetl (volcano)	17,800
Elbruz	18,526	Rainier (Tacoma)	14,441
Everest	29,000	St. Elias	18,024
Fremont Peak	13,790	Shasta	14,440
Fujiyama (volcano)	14,177	Sinai	8,600
Hekla (volcano)	5,100	Teneriffe	12,000
Hood	11,900	Washington	6,286
Kenia	18,000	Whitney	14,898
Kilima Njaro	20,000	Vesuvius (volcano)	4,000
Kilauea (volcano), Hawaiian Islands	4,000	Wrangell	17,500
Logan	19,500		

IV

Lengths of Rivers and Areas of their Basins[1]

	Miles.	Sq. Miles.		Miles.	Sq. Miles.
Amazon	4,000	2,500,000	Murray-Darling	1,100	350,000
Amur	2,500	750,000	Niger	3,000	1,000,000
Brahmaputra	2,000	400,000	Nile	4,000	1,250,000
Colorado	1,100	230,000	Ob	2,800	1,000,000
Columbia	1,400	290,000	Orange	1,200	275,000
Danube	1,800	300,000	Orinoco	1,500	400,000
Dnieper	1,230	200,000	Po	450	27,000
Dwina	700	150,000	Rhine	800	90,000
Elbe	550	450,000	Rhone	550	35,000
Ganges	1,800	450,000	Rio Grande	1,800	200,000
Hoang	2,800	400,000	St. Lawrence	2,100	560,000
Hudson	300	13,000	São Francisco	1,800	200,000
Indus	2,000	350,000	Seine	500	23,000
Irawaddi	1,200	....	Thames	215	6,000
Kongo	3,000	1,500,000	Tocantins	1,000	250,000
La Plata	2,300	1,250,000	Volga	2,300	600,000
Lena	2,800	750,000	Yangtze	3,100	700,000
Mackenzie	2,400	600,000	Yenesei	3,000	1,500,000
Mekong	2,600	300,000	Yukon	2,200	400,000
Mississippi-Missouri	4,200	1,250,000	Zambesi	1,800	500,000

[1] Both the length and the area of the basin are approximate.

V

Lakes

Name.	Area.	Depth.	Altitude.
	Square Miles.	Feet.	Feet.
Aral	25,000[2]	200[2]	50
Assal	1,000[1]	200	− 580
Baikal	13,200	4,500	1,400
Balkash	8,500[2]	135[2]	1,000°
Caspian	170,000[2]	3,000[2]	− 84
Chad	10,000[2]	20[2]	1,000
Chapala	1,300	....	7,000
Crater	....	2,300	....
Dead Sea	320	700[2]	− 1,300
Erie	573	210	9,960
Great Salt	2,300[2]	50[2]	4,200
Huron	23,800	734	581
Ladoga	7,000	730	55
Miehigan	22,450	....	581
Nicaragua	2,800	320	108
Salton Lake[2]	....	....	− 267
Superior	31,200	1,008	602
Tanganyika	14,000[1]	1,200	2,670
Titicaca	12,500	900	12,500
Victoria	26,000[1]	....	4,000
Winnipeg	9,400	72	710

[1] Approximate; the figures given are from the best authorities, but vary from the measurements of others. Lake Assal is situated in a depression near the Gulf of Aden. It is the head of a small bay severed from the sea by æolian sands. It is fed by a small stream that flows from the sea into the lake. The volume of the lake represents the balance between inflow and evaporation.

[2] Subject to great variations; the sign − prefixed to the altitude indicates below sea-level.

VI

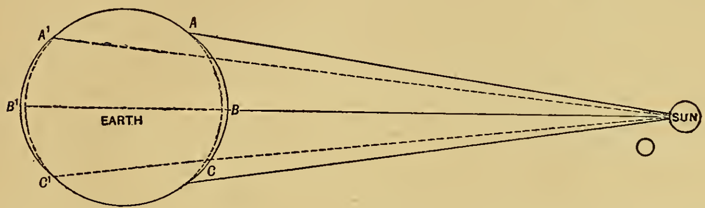
The Tides

The following very clear solution of a much disputed problem is given by Dr. Emerson E. White, author of a series of mathematical text-books. It is only proper to add that no theory on the subject fully explains all the phenomena noted. Dr. White's solution meets the views of most students.

Let E equal the attraction of the earth, and M equal the attraction of the moon at B, and M′ the attraction of the moon at A and C.

Since distance OB is less than OA or OC, $M > M'$. Hence $E - M < E - M'$, and hence the water at B is *lighter* than at A or C—*i.e.*, has less specific gravity, and is lifted or bulged by the surrounding heavier water.

Let E equal attraction of the earth and m equal attraction of moon at B′, and m' equal attraction of moon at A′ or C′. Since distance OB′ is



greater than OA′ or OC′, $m < m'$. Hence $E + m < E + m'$, and hence the water at B′ is lighter or has less specific gravity than at A′ or C′ and is lifted or bulged by the surrounding heavier water. Since distance OB is less than OB′, $M > m$, and hence the tide at B is higher than at B′.

VII

Table Showing the Number of Grains of Moisture, by Weight Necessary to Saturate a Cubic Foot of Air at Normal Density

Temperature.	Moisture in One Cubic Foot of Air.	Temperature.	Moisture in One Cubic Foot of Air.	Temperature.	Moisture in One Cubic Foot of Air.
Degrees F.	Grains.	Degrees F.	Grains.	Degrees F.	Grains.
– 40	.08	45	3.42	68	7.48
– 30	.13	50	4.08	70	7.98
– 20	.22	52	4.37	72	8.51
– 10	.36	54	4.69	74	9.07
0	.56	56	5.02	76	9.66
10	.87	58	5.37	78	10.28
20	1.32	60	5.75	80	10.94
30	1.96	62	6.14	90	14.79
35	2.37	64	6.56	100	19.92
40	2.85	66	7.01	110	26.43

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