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PHYSICAL GEOGRAPHY

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Editor, Nels A. Bengtson

PHYSICAL GEOGRAPHY

BY

ALBERT L. SEEMAN
Late Associate Professor of Geography
University of Washington

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Preface

THROUGHOUT all history man has been a wanderer and an explorer. In his wanderings he was compelled to familiarize himself with his natural environment. He was, unknowingly, a geographer. Then, as population density increased, migrations became more and more necessary and, at the same time, observations became more and more acute. Bits of information relative to the environment and differences from place to place, the beginnings of geography, continued to be considered the sum of geography until the nineteenth century.

In the nineteenth century the keystones to modern science were established by James Hutton and Charles Darwin. Hutton presented, in his doctrine of Uniformitarianism, the idea that the only constant on the earth is continuous change. Charles Lyell popularized this view in his book *Principles of Geology*. When that doctrine became firmly established, the earth was considered as but a phase in the process of constant change. Charles Darwin's *Origin of Species* did for the organic world what James Hutton, Lyon Playfair, and Charles Lyell had achieved for the inorganic world. Darwin, by producing a vast fund of evidence, proved that organic life had evolved slowly and by the processes of evolution had established new types and advanced forms. Thus in the organic and inorganic fields the doctrines of evolution and constant change were firmly established.

These two theories brought about two changes of fundamental significance which completely altered the views and *modus operandi* in geography. It had formerly been considered that each form of life originated and developed in a specific region and that its various characteristics were fitted to the environment. With the acceptance of Darwin's theory it was possible to see that all life was molded by the environment and that the various characteristics of each species—plant or animal—were evolved to fit it for existence in that particular

surrounding. The characteristics not necessary to its survival might be discarded in the evolutionary process, or they might destroy the species. Man, on the other hand, because of his higher evolution, is not only acted upon, but acts and reacts upon the environment.

The second great change which took place was that scholars in physical geography began the important task of classification of the earth's features. Hutton suggested the forces of construction and destruction that produced the changes on the earth. These forces were then classified, and it was possible in turn to classify their results. The data which had been accumulated could then be organized and arranged, and new data could be assembled more easily. Since the source of the data of geography is as vast as the earth itself, it took generations to reach the present stage at which materials relative to the earth can be classified and interpreted from the standpoint of physical geography.

The study, organization, and interpretation of data of the earth's features have produced two groups of scholars, both working with the same material but from different points of view. The first group work with the earth's features and changes *per se,* and are referred to as *geomorphologists.* The second group, *physical geographers,* use the materials of the geomorphologists as a starting point and show the reaction of these earth features on human life. To illustrate, the geomorphologist works with mountains, classification of mountains, erosion in the mountains, as an end in itself. The physical geographer starts with the mountain. He may generalize from the work of his colleague, but he must, if he is a geographer, go on from there and show the influence of those mountains upon human activities.

In recent years the trend has been definitely toward economic geography, in which the emphasis is on the human activity and economic products rather than on the earth itself. Many admirable books have been published in recent years in this field, and they are meeting a definite demand for material on products and their relationship to the natural environment.

Physical geography must describe the earth features, and then the influence of these features must be translated into human activities.

The influence of a particular environment must be given in a general description and, in addition, must be given in a detailed

relationship. Since, in one book, it is impossible to describe in detail all environments, it becomes necessary to select one area and use it as a sample of the whole. Thus the detailed study becomes significant as being a part of the larger pattern. If both general relationships and detailed studies are presented, the student will be able to see that the smaller areal study is a part of the whole and comprehend the position of the specific in the general description, and also realize that the departures are due to local differences. The student will be able to see that the general design of the earth is just as real as the more specific small areas.

Many outstanding geographers have published in the various geography journals excellent studies of small areas, showing the relation of the environment to the activities of man. These studies should not be buried and used only by professional geographers, or be paraphrased by another author and thereby, perhaps, lose much of the original meaning and description. This book uses some of the studies that are available.

This textbook emphasizes the features of the earth such as climate, land forms, surface waters, soil, oceans, and all of the other elements of the environment. Then it summarizes the human activities for each particular element of the environment and presents a type study chosen from the geography journals for its excellence in discussing a specific place to illustrate a detailed relationship in one definite area. For example, there is presented a discussion of the types, characteristics, constructional and destructional processes of mountains and a general description of human activities found in mountains; then for a type study there was chosen an article about a mountain region, in this case, Peattie's study of Andorra. It has been found that students, after reading the type studies, are able to see the application of the general principles to a definite area. The specific type study can then be used as an example for other small areas which may differ in detail; these differing details illustrate changes due to local physical characteristics. There is little mention of products. The emphasis is on the physical, and it has been kept geographic.

Since the inception of this book many helpful suggestions have been received from my colleagues and students who shared my experience in securing teachable materials. Responsibility for the views expressed

and their arrangement rests wholly on the writer. I wish especially to thank Dr. Phil E. Church and Dr. J. Hoover Mackin, of the University of Washington, and Mr. Arch Gerlach, now at City College of Los Angeles. I owe my appreciation to Dr. Howard H. Martin, of the University of Washington, and Mr. Carl H. Mapes, of the Seattle Public Schools, for the use of material which has not been published. I am very grateful to the editors of the various geographical journals for their permission to reprint articles. Dr. Nels A. Bengtson has been most helpful at all stages of the work. To my wife, for the infinite number of ways in which she has helped in the preparation of this work, I cannot give adequate thanks.

A. L. S.

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1

Field and Function of Physical Geography

THE function of modern geography is to discover how man adjusts his activities to the physical environment. The cultural attainment of any community is determined, in part at least, by the degree to which it can benefit from the advantages that nature offers and surmount the difficulties that she places in the way of progress. One cannot begin to understand the larger economic, political, and social issues facing the world today without considering the relationship of human enterprise to the natural environment.

Man has always been interested in the earth on which he lived. Curiosity about places and regions beyond his own and a desire to know something of the source of his subsistence stimulated that interest. In all ages differences in population have been observed as well as differences in economic, social, and political habits. At the same time it was observed that there was a difference in the natural environment at various places. The causal relationship between environment and human activities was not always noted or known. Observations of the earth were, in the beginning, superficial. Then more and more of the earth's surface was observed, recorded, and described. However, these observations became progressively more comparative and more quantitative. In every science superficial description must always precede; comparison and analysis call for increased precision of factual knowledge, and consequently observation becomes continuously more precise.

No longer is man content to make such observations without considering the reasons for the differences in the social, political, and economic life of the people. One of the fundamental reasons for this change in point of view has been the increased density of population.

This increased and increasing density of population has forced peoples in all parts of the world to consider seriously the natural environment, and how they may use that natural environment to improve their living conditions. In order to improve his economic status, man is more and more using his particular environment to produce the things which it can produce more economically than another area. An era of specialization based on the best use of the elements of the environment has succeeded the time when the farmer, for example, produced everything he needed on his own farm. Now a farmer tends to specialize in raising the product which is grown most economically in a given area; he sells his surplus to buy the commodities that he cannot raise as economically as someone else. Under this changed system each region supplies the commodities that it can produce more advantageously than any other region. This has the effect of breaking down individual and regional self-sufficiency and results in greater regional interdependence.

Geography is a science which considers the relationship between man's social, political, and economic enterprises and the natural environment. In these relationships man makes certain adjustments. *Adjustments* implies that man voluntarily chooses and follows a certain course of action, rather than passively responding, as plants might do. It does not suggest that the natural environment determines just what kind of an adjustment man makes. A great many kinds of adjustment may be made in the same environment, and many factors outside the natural environment affect the particular adjustment that may be made. However, there are many adjustments which have a relationship to the environment, and these are topics in geography.

It may be difficult for the beginning student of geography to see that man has made his activities respond to the complex natural conditions that surround him. These elements of the natural environment occur in combinations and may exert a complex influence. A list of the elements of natural environment includes: (a) location and position, (b) size and area, (c) climate, (d) flora and fauna, (e) surface features, (f) soil, (g) surface waters, (h) underground water, (i) mineral resources, and (j) oceans and coasts.

A study of geography involves two elements—the earth, and man making his home on the earth. These two concepts must be kept in mind by the student throughout any study of geography, and the

proper relationship of the two must always be emphasized. On the one extreme the study leads to pure geomorphology, which is a branch of geology. On the other extreme the study often leads to an examination of history, sociology, economics, or some of the other social sciences. Neither aspect of the subject should be studied alone, but rather the *relation* of the earth to man and his activities should be the focus.

If one is to study the earth as the home of man, he must have some familiarity with the earth. This need does not imply an exhaustive study of the physical sciences, such as geomorphology, oceanography, agronomy, and so on, but the student must have enough knowledge of them to be able to use them in the study of geography. To illustrate: Geography should not treat, for the sake of the subjects themselves, such topics as young, mature, and old valleys or land forms or the destruction of streams by piracy. The geologists would treat the topics mentioned, as well as others, by giving the remote history of the land forms. The geographer would discuss the topics from the view of the present. A certain highland, for example, is more to a geographer than an uplifted and immaturely dissected peneplain; that upland becomes an area described by present facts. The geologist will describe the area by using past-tense verbs, while the geographer will be chiefly concerned with present-day description and will use present-tense verbs. In geography, extracts are taken from many subjects and transmuted into geography and used for its ends. In physical geography the aim is to promote a clear perception of the fundamental facts of earth form in their relations to the occupation of the earth by man.

Another illustration may perhaps clarify the point. The extent to which the study of glaciers and glaciation should be carried in a geography class may vary with the teacher; no teacher of geography, however, can neglect a consideration of the effects of the glacial period. At least, there should be a comparison between glaciated and unglaciated areas as well as a consideration of the results of glaciation. A contrast between glaciated and unglaciated areas and the resulting human use is illustrated in the northeastern part of the United States.

The surface of the old mountain region of Maine, while not rugged, is rocky and barren of soil. There is abundant evidence of ancient mountains which have been removed, and the underlying rock structures reflect great variety and complexity. The prominent features of

this area today are but the stumps of loftier mountains of an earlier period and show the great resistance to erosion by ice of hard-rock formations. Continental glaciation has played such an important part that an understanding of the present physical features and human activities cannot be had without a consideration of the ice. Further southward the land was more level and had softer rocks, which were more easily eroded. In the southern part the glaciers deposited a layer of mantle rock.

The systematic use of environmental features gives a clear perception of the fundamental facts of the earth form in their relation to the occupation of the earth by man. There is no occupation in which geographic surroundings do not enter as controls, either direct or indirect. The geographer has to investigate the nature of geographic facts and of the controls that they exert on human conditions. More and more is geography turning from mere matters of location to the more important and interesting questions of the reasons for location, as determined by various classes of controls, such as forms of land and water, their distribution and relative positions; the products of the earth, and their dependence on land form, soil, climate, and so forth; the available sources of power, such as coal, waterfalls, and wind, which in turn influence manufactures, trade, and commerce. In the competition that every one must enter in order to gain a livelihood in an active community, a clear understanding of the manner in which our mode of life is related to the earth on which we live will be found to be of great practical importance.

Geography describes and explains the relationships of man and his activities to the natural environment. The world is treated as the home of man. The elements of the natural environment are analyzed, and adjustments that have been made to that natural environment are examined and interpreted.

Men live in groups, and every group is attached to some place. Every such place affords a certain type of topography, a certain type of soil, location with respect to other places, and a certain type of climate. These things constitute the physical environment of the group. To this environment the social group adjusts itself. It is with this adjustment or relationship that geography is principally concerned.

In making the adjustments, man makes many changes on the natural

landscape. Man is, of course, not the only creature that makes changes, for birds build their nests, rabbits excavate their burrows and beat out narrow tracks across the meadows. But these creatures labor under a disadvantage in that the tools they use are merely portions of their bodies that are modified for the purpose. Man's tools are not part of his body but are objects which he has shaped for his own ends. These tools are more complex and more adaptable. Man's adjustments, whatever they may be, are the result of the activities of society. Geography is interested in the material products of those activities.

In this book we examine the elements of the natural environment in which the features of the human adjustment developed and through the agency of which they have been modified.

In summary, *geography* is the relationship of human activities to the natural environment. In this text the natural environment is emphasized; it consists of all the material objects together in a complex interrelationship between the atmosphere and the lithosphere. While the natural environment is only one of a number of agencies, nevertheless it may help to explain the activities, economic and cultural, that man is carrying on in a given locality, the reasons for those activities, and the problems he is meeting.

2

Maps and Maps Projections

THE earliest conceptions of the earth, like those held by primitive peoples today, are difficult to discover and grasp. Even peoples with a low culture had some ideas of the earth and the universe, its origin, and its arrangement. Their knowledge was chiefly in the form of descriptions of places and the location of areas. Not being able to view an extensive area, they developed a mythology to describe the world beyond their known horizon. Thus there were four zones relative to the world: the *known* zone, the zone of *exploration,* the zone of *contact,* and the zone of *mythology.* Graphically, the concept can be illustrated as follows:

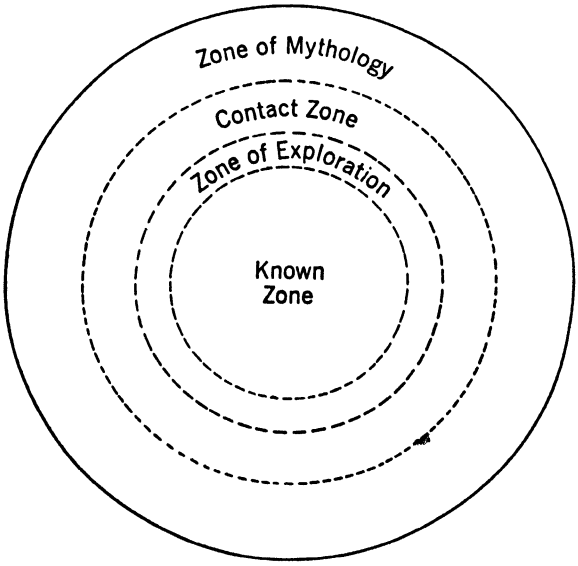


FIG. 1. ZONES OF INFORMATION.

Gradually the tribes emerged from the primitive stage, and slowly there was the emergence and expansion of geography. Most tribal knowledge was transmitted to succeeding generations in folklore, but occasionally and gradually the knowledge was transferred to writing, in the form of maps.

The making of the map is as old as any other form of picture making, for the earliest maps are usually pictographs. This graphic expression was practiced among all primitive peoples over the earth and dates back to very ancient times. The maps were of small areas and therefore relatively accurate. It was when primitive man attempted to map large areas that his problem of measurement increased and his maps became inaccurate. It was then that he made pictures to represent the zone of contact and the zone of mythology.

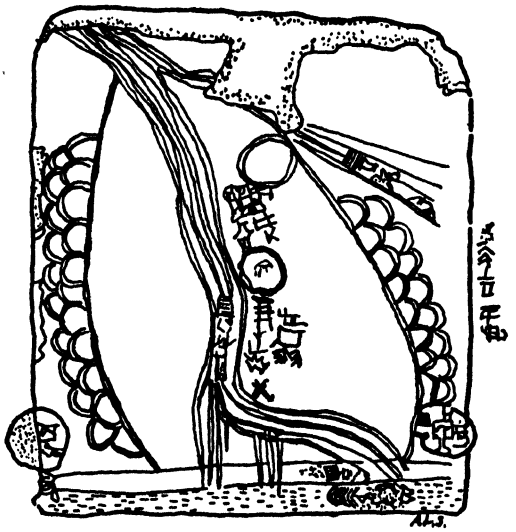


FIG. 2. ANCIENT MAP. Tablet small enough to hold in the hollow of the hand, bearing a map drawn 4,000 years ago, recently uncovered below the site of ancient Nuzi in Iraq. The map, apparently depicting the garden land of a wealthy citizen named Azola, gives names of places, including fortress, and sketches in mountains and streams, with three points of the compass designated.

As travel increased, the known zone became larger and the other zones correspondingly smaller. As this change occurred, two large problems presented themselves. They were how to determine the shape of the earth and how to fit the known zone to that shape. Being able to see but a small part of the earth's surface, men naturally supposed the surface to be flat. In 580 B.C., Anaximander proposed that the earth was a solid body, and that it was suspended in the center of a hollow sphere. From this theory developed, within a few years, the view that the world was a sphere, for the sphere was the most perfect geometric form.

The known zone and the zone of exploration continually grew

larger; the expansion took place by accumulations. While exploration and discovery started from various parts of the world, the movement originated in the individual tribes. To deal justly with the topic, one ought to discuss the process by which knowledge accumulated from the discoveries and explorations of the tribes and groups before the whole world was bound together by modern intercommunication. At least there should be some consideration of the four separate systems of discovery—the eastern, in which Chinese and Japanese explorers acquired knowledge of Asia and felt their way toward Europe and America; the western, in which dominant races of the Mexican and South American plateaus extended their knowledge of the Western Hemisphere before Columbus; the Polynesian, in which the conquering races of the Pacific Islands found their way from group to group; and the Mediterranean. Of some of these we have no definite knowledge, and for others the records so conflict with present-day knowledge that they cannot be used as a definite basis of history. The only practical history of exploration starts from the Mediterranean center.

From all centers the leading motives of exploration were probably the same—commercial intercourse, warlike operations, whether resulting in conquest or in flight, religious zeal, and, in later years, the advancement of knowledge for its own sake. Hence, geography finds its origin in action. Descriptive geography, like any other kind of science, has been built on the experiments prompted by that unappeasable curiosity of men which their intelligence has elevated into the quite respectable passion for acquiring knowledge. Like other sciences, geography has fought its way to truth through a long series of errors.

The foundations of geography, as we know it today, were laid by the Greeks. They were the first to attempt the construction of world maps on the basis of astronomical observations and measurement of terrestrial distances. At first by suggesting, as a purely theoretical hypothesis, that the earth was a sphere, and later by not only giving proofs of its sphericity but actually calculating its circumference, they made a great contribution to human knowledge and present-day geography.

Yet no one race alone invented or perfected the map. It grew, improved, and approached perfection as science advanced with civilization.

Most famous of all early maps are those in the *Atlas of Geography* of Claudius Ptolemy, an eight-volume work dating from about 150 A.D. Six of his eight books consist of tables of latitude and longitude for about 8,000 places. In the remaining books, Ptolemy discusses the stars, mathematical problems of geography, the lengths of days, the sun's course, and differences in time at different places. With his books are maps of twenty-six countries and one map of the world. In his

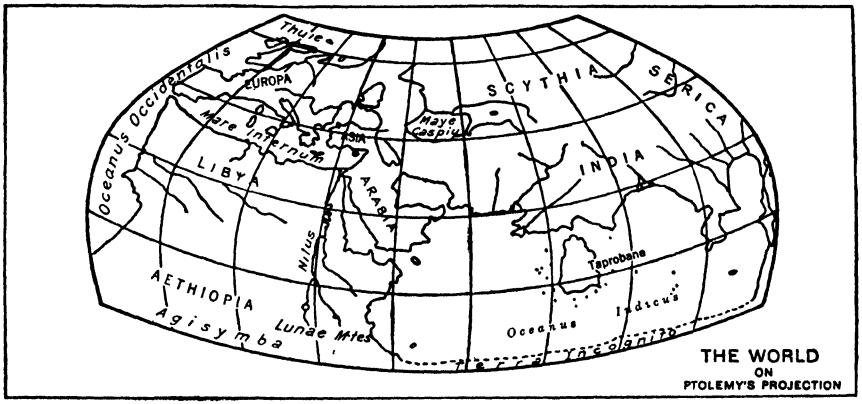


FIG. 3.

task Ptolemy used all the geographic lore that had been collected up to his time. Though crude and full of mistakes, his work was the greatest step that had ever been made in presenting world geography in scientific form. His maps show how traders and adventurers had pushed the rim of the known world as far north as the Shetland Islands and had given size and shape to the British Isles. More of the Nile Basin was shown and a part of Africa below the equator. The Indian Ocean got a new and more accurate mapping based on notes brought by the silk traders from the Far East.

The early Romans made road maps strangely like those used today by motorists and those found in railway folders. One road map of the Middle Ages reached from England to the mouth of the Ganges, in India. To meet the needs of the Crusaders, in their marches from Europe to Asia Minor, there was developed a pictorial road map. Its crude pictures showed the towns along the route from London to Jerusalem.

Printing had the same galvanic effect on map making as on some

other arts. Ptolemy's *Geography,* now translated, became so popular that it went through more than fifty editions. Columbus used it, and, despite its errors, or thanks to them, he accidently found the New World. This discovery set all civilization to revising its maps.

As the world's true pattern took form, medieval maps, with unexplored areas decorated by sea serpents, mermaids, wrecked galleons, and chubby angel faces blowing the winds, began to fade from use.

Gerhard Kremer, known by his Latin name of Mercator, was among the first to break with the old traditions. He was a mathematician and cartographer of Flanders. He drew a map in 1569 on the "Mercator Projection," which gave navigators a new and safer system of plotting their courses. In his time Mercator helped to change map making from an art into a science.

The map has grown in importance just in proportion as our knowledge of the world at large has grown. The map represents in its making and its quality the progress made in other lines of science, especially mathematics, and in the instruments and technique of mensuration, and in the development of engraving and printing.

Globes

For centuries the globe has been regarded as a symbol of geography. In 640 B.C., Thales, a Greek, believed that the earth was a sphere, and he divided his world into five climatic zones. While many scoffed at his view, a few scholars inquired into the mysteries of the universe and established as fact what for a long time had been speculation.

The first known globe or model of the world as a rotating sphere was created by Crates in the second century B.C. In the later part of the fifteenth century, Martin Behaim, the German navigator, astronomer, and geographer, produced globes which were used by Columbus on his voyages. Magellan and other great explorers carried with them globes to aid them in finding new paths through unknown seas.

The modern method of covering the globe with map gores, or segments, was evolved during the fifteenth century. Many cartographers, including Mercator, worked on the problem and devised means of improving globes. In the sixteenth century an Englishman, Molyneaux, made large globes that were the direct predecessors of modern globes. They were over two feet in diameter, set on a stand,

and encircled by a wide wooden horizon ring at right angles to the equator.

The globe shows the correct sizes of countries and continents, and their relation to each other, and thus it is an aid to general orientation. The map is always limited in both these respects.

In the eighteenth century the map, more and more improved, began to take the place of the globe. From that time on, no navigator would attempt to steer a course by the globe. Today, when we have detailed atlases and maps, the venerable implement of early geographers and navigators is, for the most part, relegated to the position of an ornamental accessory to the library or the classroom.

Map projections

The problem that is encountered in making a map of the world, or of any portion of the earth's surface, arises from the fact that the surface of the earth is spherical in shape, and for this reason it is non-developable; that is, it cannot be spread out in a plane without stretching, tearing, or folding. If the map were imposed upon a sphere, the extent of surface could be mapped with an unvarying scale. Globes, as discussed above, are representations of the entire surface of the earth, and if carefully made will have a scale constant at all points. Since globes of any size are unwieldly, they are very hard to use in practical work. Sections of a spherical surface for mapping parts of the earth's surface meet with the same objection. It is much better to use a plane surface for the map and admit the defects than to try to avoid them, and fall into greater difficulties.

The application of these principles to the making of maps brings out the fact that the maps of small areas are most accurate. The topographic maps of the United States Geological Survey illustrate this rule. When maps cover large areas, more or less distortion is bound to occur, since all places must be located in their proper longitude and latitude. The distortion may be of *shape,* so that the area mapped on the plane has a form different from that shown on a globe; it may be a change in *size,* so that one part of the map covers an area different from the same area shown on a globe of the same scale; or it may be an alteration in *direction,* so that a place may have a slightly different direction from another place as revealed on the globe.

Reference points on a sphere

A sphere does not contain in itself a proper singular point or set of coordinates from which directions and distances can be measured. There is neither beginning nor ending as far as differentiation of points is concerned. Places on the earth are located by latitude and longitude.

The earth rotates on its axis once a day; the axis at once establishes a beginning for coordinates. The ends of this diameter are called the

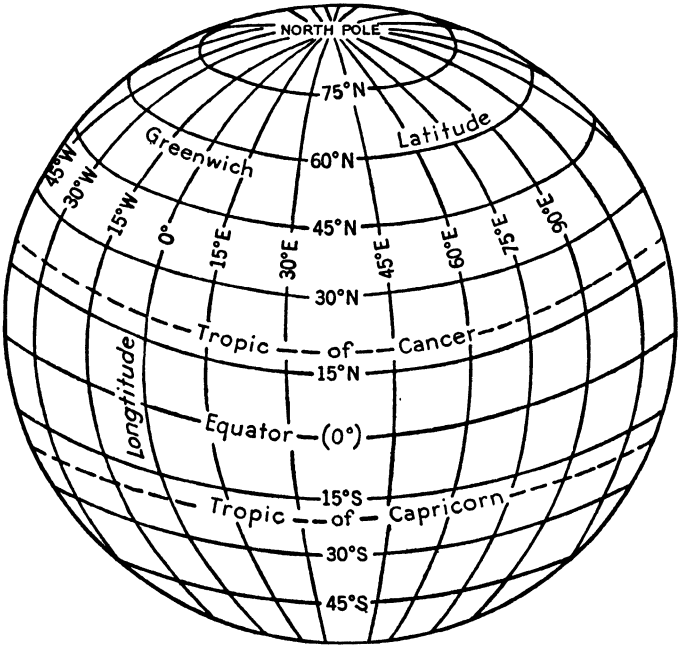


FIG. 4. DIAGRAM OF MERIDIANS AND PARALLELS.

poles. Midway between the poles is another good division, and this line is called the *equator.* The equator is then divided into 360 degrees. But first there must be established a starting point, for there is no definite point to count as zero, or as the point of origin. This difficulty is met by establishing arbitrarily some point. The meridian which passes through Greenwich, England, is the meridian of zero degrees on one side of the globe and the 180th meridian on the other side. A *meridian* is an imaginary circle around the earth in a north and south

direction, and passing through the poles. The *parallels* are then drawn parallel to the equator, and a *degree* is one ninetieth the distance between the equator and the pole.

A *map projection* may be defined as the systematic drawing of lines representing meridians and parallels on a plane surface, for some portion of the earth or for the whole earth.

Points upon the earth's surface are located by their latitude and longitude, or, in other words, their positions are referred to the meridians and parallels. In drawing a projection it is necessary to determine a system of lines on a plane to represent the meridians and parallels, and then it is possible to plot all points on the earth's surface with reference to these lines. Any lines can be drawn arbitrarily for this purpose; in practice it is customary to use some orderly arrangement for these lines. This orderliness is generally expressed in terms of some mathematical formula, and, in fact, almost every projection that is ever used is stated in such terms.

The number of ways in which this orderly arrangement can be determined is infinite. Not all methods are equally good, and no one method is best for all purposes. However, there are four main factors to be considered for every map projection:

1. The scale along the meridians and parallels should be accurate.
2. Areas should be accurate.
3. Shapes should be retained for large as well as small areas.
4. The projection should not be too difficult to construct.

Scale

Of necessity, all maps are smaller than the actual surface areas they represent. Thus, there should be a definite ratio between the linear distance on the map and the corresponding distance in the field. The *scale of the map* is the ratio of a given distance, as represented on the map, to the same distance on the surface of the earth. Scales are of three common types: the graphic, the fractional, and the verbal. A *graphic* scale consists of a line divided into units representing miles or fractions of a mile to be applied directly to the map in measuring distances. Such scales are easily interpreted. A *fractional* scale is the ratio, expressed in the form of a fraction, between a given distance as represented on the map and the distance on the earth's surface. Since there are 63,360 inches in a mile, an inch to the mile, expressed as a

fraction, would read 1/63,360. In the *verbal* scale, the ratio would be expressed as "an inch to the mile."

It would be desirable to have the scale of the map correct in every direction at every point. If that could be done, the map would be a perfect representation of the spherical surface of the earth. But that is impossible, and hence the scale cannot be correct all over the map. The usual procedure is to choose some one direction and hold the scale constant in that direction.

Areas

For many purposes it is important that areas be represented in their correct proportions. A projection that does this is called an *equal-area* projection. Any portion of the equal-area projection map must bear the same ratio to the region that it represents as the entire map bears to the region that it represents.

Shape

The representation of the shape of the various features of the earth, as nearly correctly as possible, is one of the most important functions of a map. It is not possible to represent the shape of a large country correctly upon a map; if that were possible, the map would be perfect. If at any point the scale along the meridian and the parallel is the same, not correct, but the same in both directions, and the parallels and meridians are at right angles to each other, then the shape of any small area on the map is the same as the shape of the corresponding small area of the earth.

Ease of construction

The ease with which a projection can be constructed is of great importance to the person who has the problem of the actual construction. Projections which are not built up of straight lines and circles are hard to draw.

Mercator projection

In the Mercator projection the meridians as well as the parallels are parallel throughout their length. On the globe, the meridians approach each other and coincide at the poles. To compensate for the east-west stretching on the Mercator projection, the parallels become

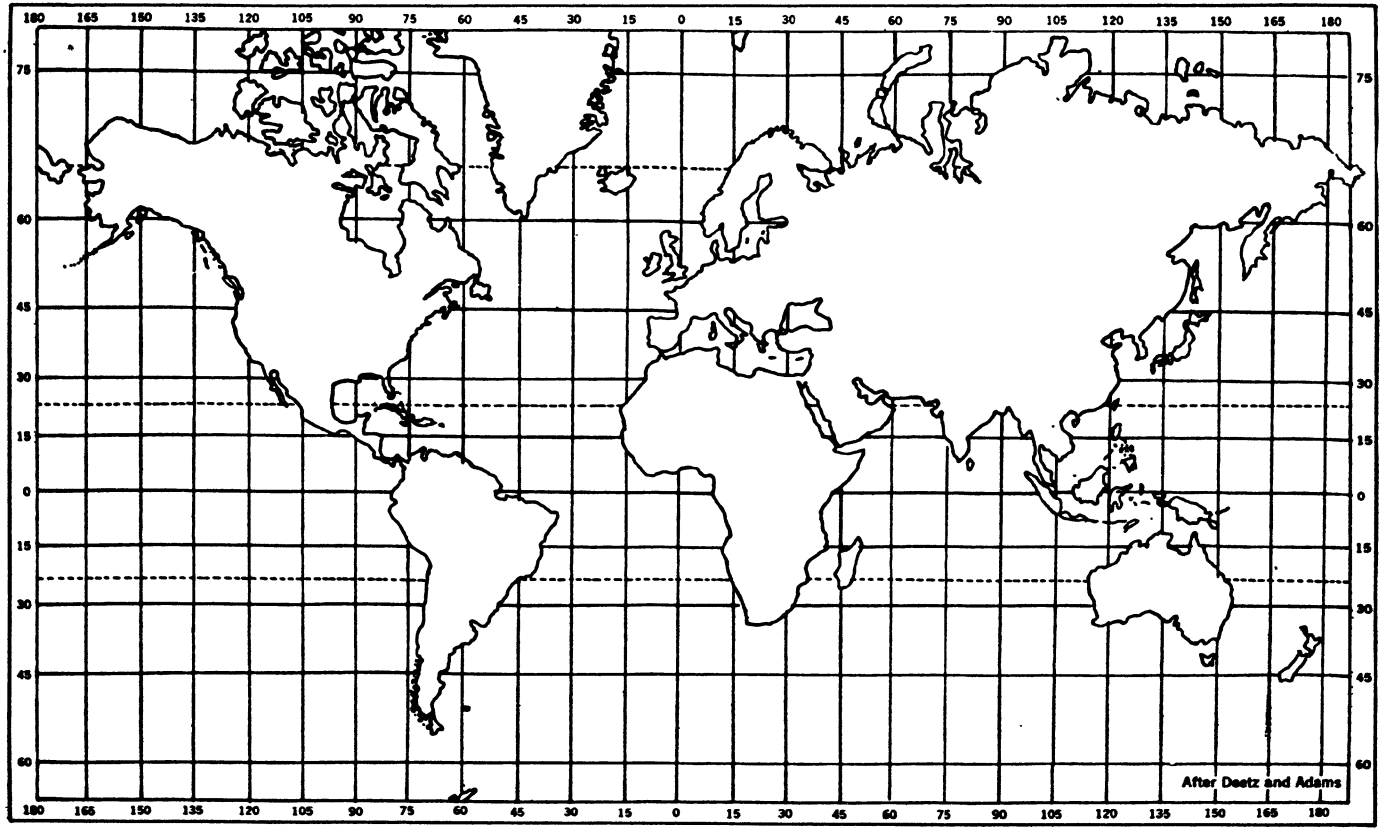


FIG. 5. MERCATOR PROJECTION OF THE WORLD.

successively farther apart from the equator toward the poles. The map is never drawn to the poles; to include polar regions on the map would be stretching the poles, which are points, infinitely. On the globe, at parallel 60° the distance is just one half the distance at the equator, and at 80° the distance is one thirty-sixth the distance at the equator. However, on the Mercator projection the distances at the two higher latitudes are the same as at the equator.

In using this projection one must recognize and guard against these defects. Distances, areas, and shapes are all badly distorted, especially if one is comparing different latitudes. It shows the entire inhabited world on a single sheet, and the map can be prolonged in either east or west direction. This projection is easily constructed, and the latitude and longitude are readily found. The projection is used almost entirely by navigators, since "the great circle can be plotted thereon from a gnomonic chart, or it may be determined by calculation, and these arcs can be subdivided into convenient sailing chords, so that, if the courses are carefully followed, the port bound for will in due time be reached by the shortest practicable route." [1]

Conic projection

In the simple conic projection the center of the projection is the center of the earth. The basis for the construction of this projection is shown in Figure 6. The surface of the earth is projected onto the sur-

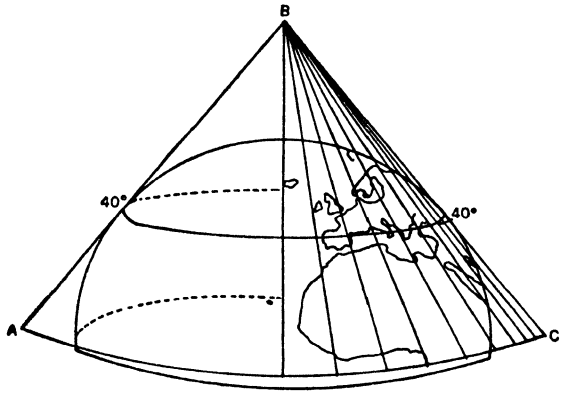


FIG. 6. BASIS OF CONIC PROJECTION: CONE ABC IMPOSED ON SPHERE AND TOUCHING AT 40°.

[1] Deetz and Adams, *Elements of Map Projection*, p. 103.

face of the tangent cone. The surface of the cone unrolled becomes the plane of the map. All meridians are straight lines crossing all parallels at right angles. From the parallel of tangency (which may be

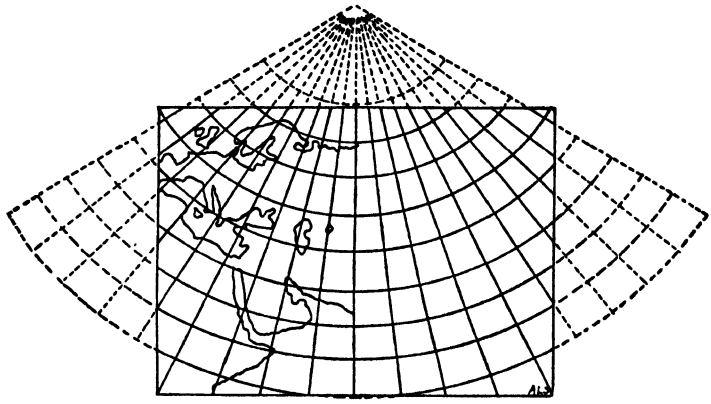
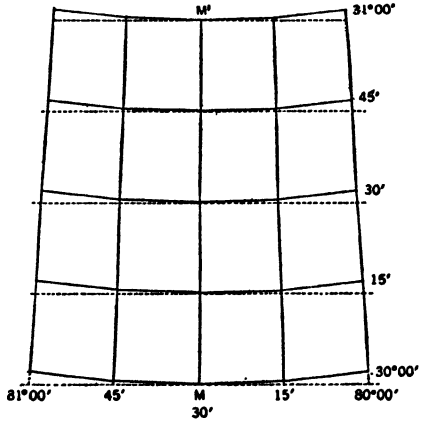


FIG. 7. CONIC PROJECTION. Surface of cone unrolled becomes plane of the map.

any parallel selected) northward and southward the meridians are spaced farther apart than they are on the sphere in corresponding latitudes. The farther the distance from the tangent parallel, the greater the distortion of shapes and areas. The simple conic projection is seldom used, but modifications of it have considerable value.

Polyconic projection

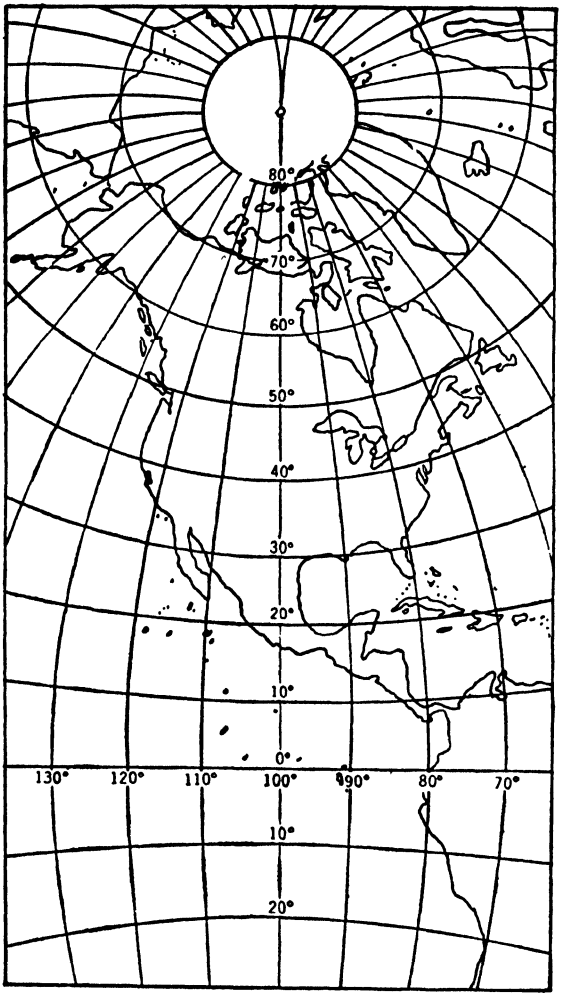
In the polyconic projection the mid-meridian is represented by a straight line. The parallels are drawn as arcs of circles that are not



After U. S. Geol. Survey.

FIG. 8. DIAGRAM ILLUSTRATING 1° POLYCONIC PROJECTION. MM'—Mid-meridian.

concentric; the centers of the arcs lie along the mid-meridian. The basis for the construction of the map is shown in Figure 8. A map of North America on the polyconic projection is shown in Figure 9. The



After Deetz and Adams.

FIG. 9. POLYCONIC PROJECTION OF NORTH AMERICA.

projection is suited to the mapping of areas which are elongated in the direction of the mid-meridian. Distances are exaggerated along the other meridians. A modification of the simple drawing given is used for the topographic sheets of the United States Geological Survey. The

modification consists of developing a mid-meridian for each north-south row of sheets.

Sinusoidal projection

The sinusoidal projection is an equal-area projection. The equator is the standard parallel, and all parallels are straight lines parallel to the equator. The meridians are sinusoids. This projection is good for

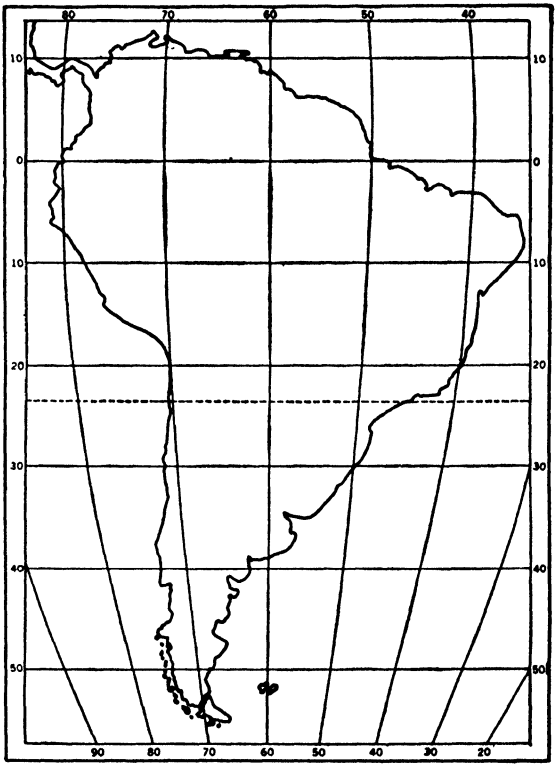


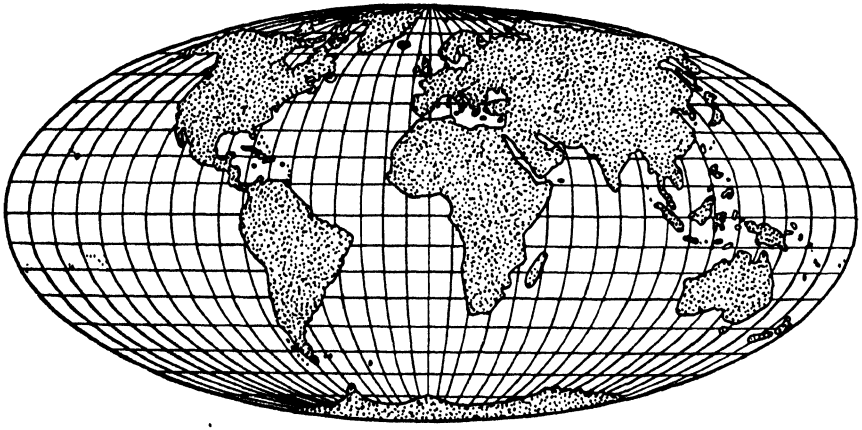
FIG. 10. SINUSOIDAL PROJECTION OF SOUTH AMERICA.

large areas in the low latitudes and for small areas in all latitudes. The projection is one of the best for the continents of Africa and South America.

Homolographic projection

In the homolographic projection the whole sphere is represented within an ellipse; the east-west axis is twice the north-south axis. The

parallels are straight lines and parallel to the equator. The equator is divided into equal parts by the meridians, which are ellipses with the line of poles as one axis and the other axis determined by the proper



After Deetz and Adams.

FIG. 11. HOMOLOGRAPHIC PROJECTION OF THE WORLD.

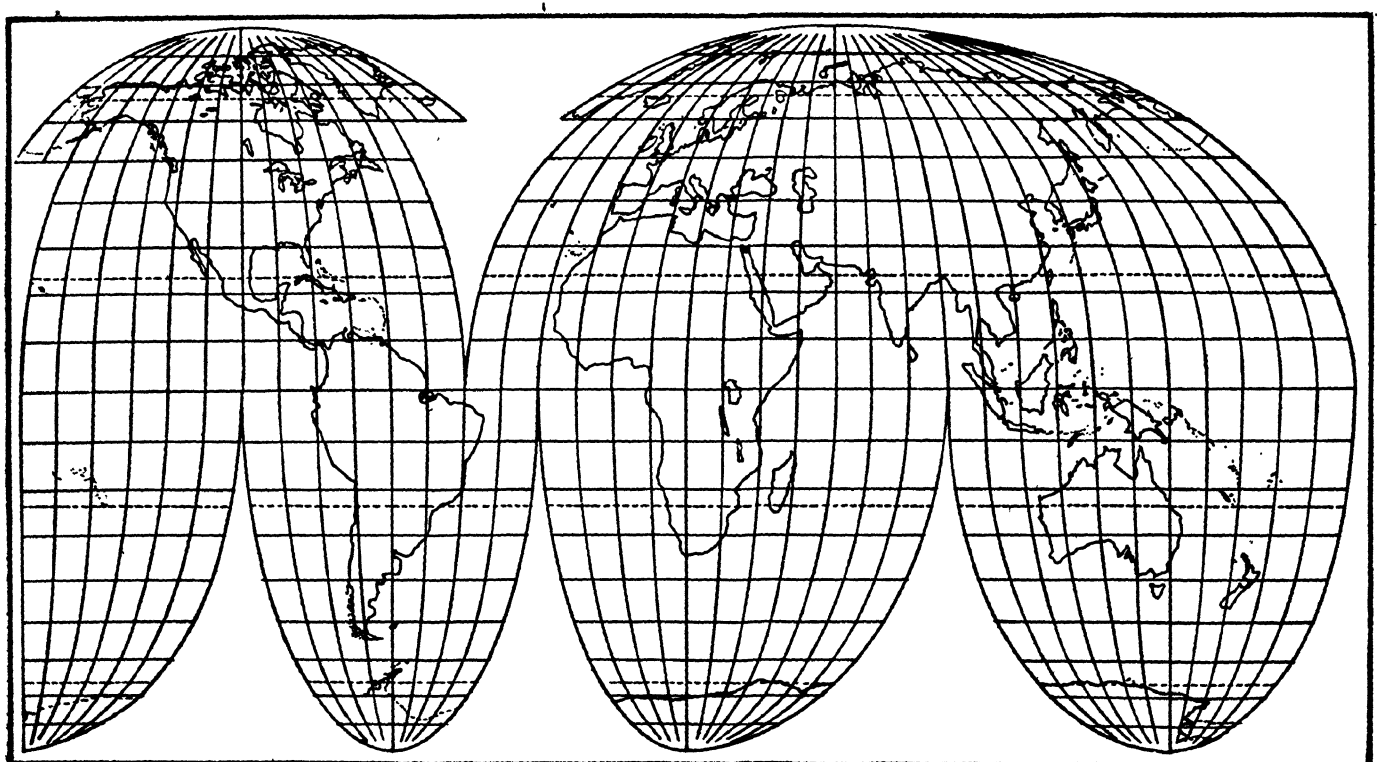
intersection of the meridian with the equator. Shapes are badly distorted in the far octants, but are good near the middle meridian.

Interrupted homolographic projection

Through the kind permission of the University of Chicago Press, we are able to include in this discussion a projection of the world devised by Doctor J. Paul Goode and copyrighted by the University of Chicago Press. It is an adaptation of the homolographic projection and is illustrated on opposite page (Figure 12).

The homolographic projection which provides the base for the new modification is an equal-area representation of the entire surface of the earth within an ellipse. The homolographic projection of the hemisphere offers advantages for studies in comparative latitudes, but shapes become badly distorted when the projection is extended to the whole sphere and becomes ellipsoidal.

In Doctor Goode's adaptation each continent is drawn on a separate central meridian, so that no important land area lies far enough from a center to be seriously distorted. The use of several centers for the map is made possible by interrupting the continuity of the projection in mid-ocean. Instead of greatly stretching the spherical surface, the pro-



After Goode. Copyright by the University of Chicago Press.

FIG. 12. THE WORLD ON HOMOLOGRAPHIC PROJECTION (INTERRUPTED) FOR CONTINENTS.

jection cuts through it. Thus North America is best presented in the meridian 100° west, while Eurasia is well taken care of in the choice of 60° east; the other continents are balanced as follows: South America, 60° west; Africa, 20° east; and Australia, 150° east.

Besides the advantage of equal area, each continent and ocean is thus balanced on its own axis of strength, and world relations are, in a way, better shown than one may see them on a globe, since they are all seen at one glance on a flat surface. As a study in world maps on an equal-area representation, this projection is a noteworthy contribution to geography and modern cartography.

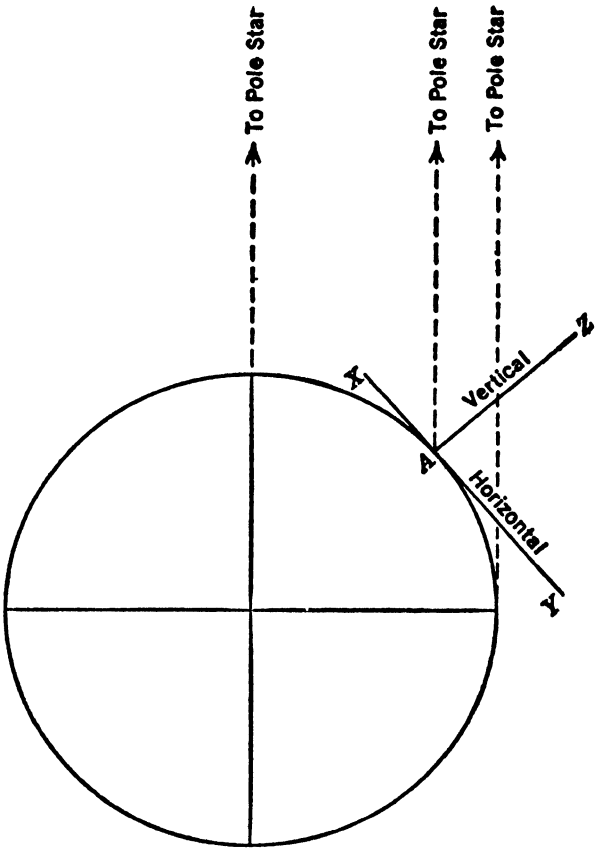
Summary of projections

In addition to the projections discussed, there are many slight modifications of these types; some are of a rather different nature. No one projection is fitted for all purposes, but usually there is a best projection for any particular use. Which projection will be selected for a given map depends upon the size of the area to be represented, its latitude, and the purposes for which the map is to be used.

Determination of latitude

The latitude of a place is determined by reckonings made on the polestar; the polestar is nearly in line with the prolongation of the earth's axis to the north. At the North Pole this star is directly overhead, while at the equator it appears to be on the horizon. All lines to the star from different points on the earth appear to be parallel. If a person were at position *A* (see Figure 13), one third of the distance between the equator and the north pole, he would determine his latitude as follows: The line *xy* appears horizontal to the observer and is at right angles to *Az*. The polestar then, at position *A*, is one third of the way up from the horizon to the point in the heavens directly overhead. In the Southern Hemisphere the Southern Cross is used as a basis for determining latitudes.

At sea the latitude may be determined every noon by an observation of the sun. The simplified diagram in Figure 14 illustrates the principles for determining positions. The distance of the sun from the poles varies throughout the year; this variation is tabulated in the *Nautical Almanac*.



After Deetz and Adams.

FIG. 13. DETERMINATION OF LATITUDE OF A PLACE.

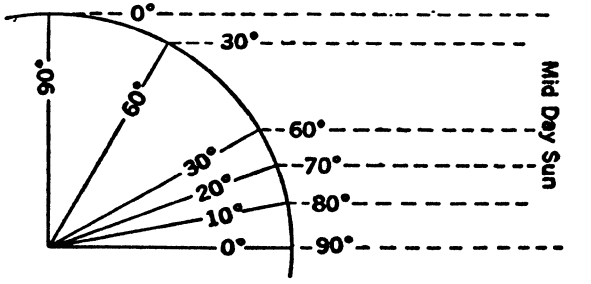


FIG. 14. DETERMINATION OF LATITUDE AT NOON.

Determination of longitude

A pole erected at any place will cast a shadow north of that pole at noon, and this phenomenon would occur at the same time at all points exactly north and south of the place. A line passing through the poles and through the given place is called a *meridian.* A clock set at noon at this given place and carried to another place east or west of that point will have a different time at noon at the new position; the difference in time will be proportionate to the difference in distance. Since any place may be used as a starting point, or zero degrees, an arbitrary point was selected. The meridian which has been adopted by most countries is the one which passes through the observatory at Greenwich in England.

By setting the clock to Greenwich time and observing the hour at noon, one can determine the longitude by allowing 15° to each hour of time; there are 360° in the entire circumference, and the earth turns on its axis once in 24 hours. This description is only a rough outline of the way in which longitude can be determined. The exact determination of a difference in longitude is a work of considerable difficulty.

Standard time

Standard time is the time in common use and is derived from the sun. When the sun is on the meridian of any place, we call the time at that place *noon,* or twelve o'clock. It follows that when it is noon at any given place it is similarly noon at all other places having the same meridian, and at places having different meridians it is either afternoon or forenoon.

Prior to 1883 the railroads regulated their train schedules on their own systems of time. Each road took the local time of the principal city on its line. There were some 75 different kinds of railroad time. To add to the confusion, each community had its own peculiar variety of time (regulated presumably by the sun), which differed from that of its neighbors to the east or west, a difference in which there was often much local pride.

In order to avoid the necessity of changing time a few minutes for distances traveled in an east or west direction, an arbitrary time scheme

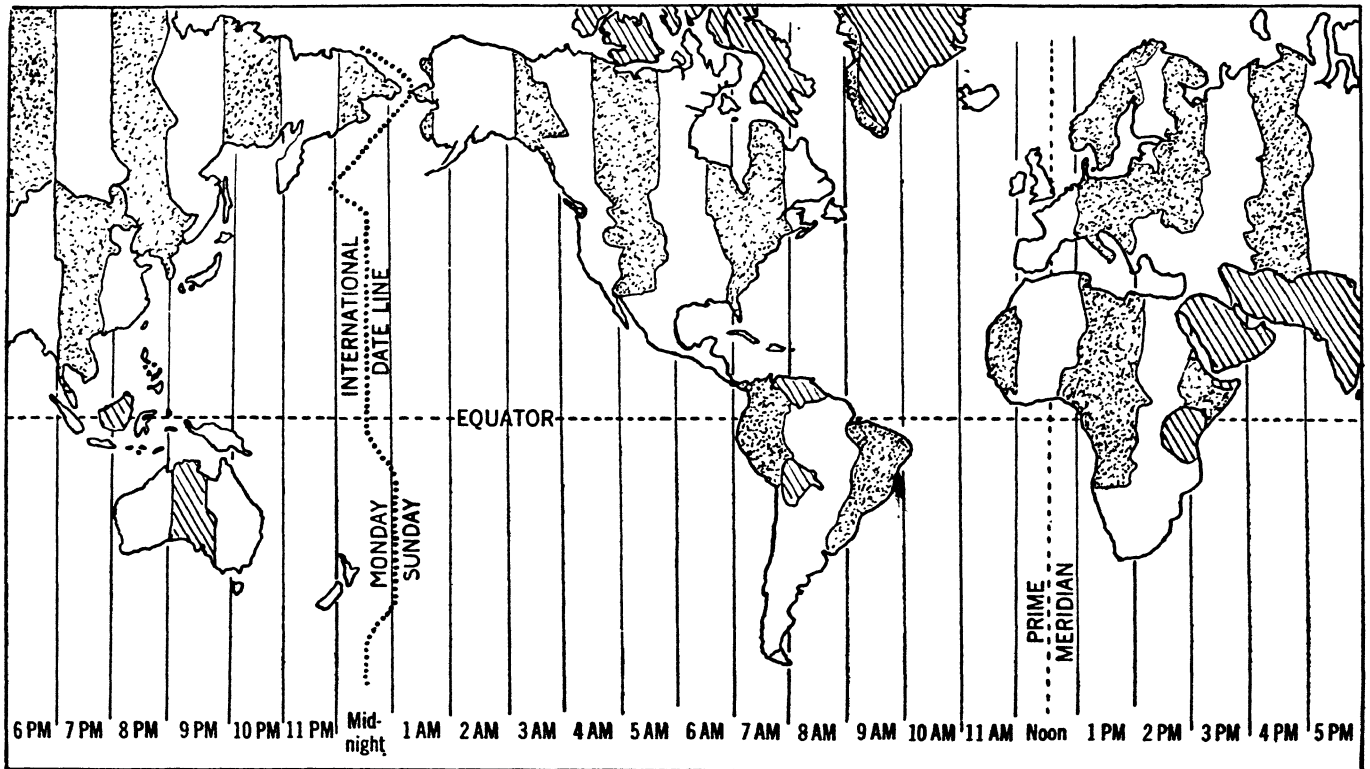


FIG. 15. STANDARD TIME ZONES AND INTERNATIONAL DATE LINE. The map shows the 24 time zones, with figures to show time in each zone when it is noon at Greenwich. The zones are irregular on the land and even bands over the oceans. Russia runs one hour ahead of standard time in each zone. Areas with diagonal lines do not conform to the standard time zone system.

was adopted in 1883 called *Standard Time Belts.* All places within a belt use the sun time of a chosen meridian. In the United States there are four time belts, each varying from the next belt to the east or west by one hour. The 75th, 90th, 105th, and 120th meridians are the basal meridians for the Eastern, Central, Mountain, and Pacific time belts. The whole world has been divided into time zones, and the meridian of Greenwich has been used as the starting line. The division of the world into time zones is shown in Figure 15.

On the whole earth there are 24 standard time zones, extending from pole to pole and differing from Greenwich time by an integral number of hours. In practice, some countries have employed their own standard meridians which do not differ from Greenwich time by exact hours.

International date line

If a traveler were to start from New York City on a Monday at noon and travel westward as fast as the earth turns on its axis, he would have noon all of the time. When he arrived at New York City 24 hours later, after traveling all the way around the world, it would be Tuesday noon there, although he had not had any night. When did Monday become Tuesday? In order to have agreement about dates, it was decided to make the change of date at the 180th meridian. When this line is crossed going westward, one day is dropped from the calendar. Going eastward, one day is added, or a day is counted twice. This line is known as the *international date line.* The map on page 25 shows several deviations from that meridian; these deviations are to prevent a change in date for areas which have a heavy population, or so as not to separate islands that belong to the same nation. Since the line is entirely in the Pacific Ocean, no land mass has to change its date for opposite sides of the line.

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3

The Function of the Map in Relation to Geography

THE function of the map is to serve as a symbolic summary in miniature of sections of the earth's surface. Acquiring the ability to read and interpret maps will give the student a richer understanding in many fields and a much greater retention of facts. As the ability to read and interpret maps increases, the map will prove to be a time-saving tool in geographical learning, for, as Doctor J. Paul Goode once declared, it is the true shorthand of geography. The following article[1] presents the function of maps and some of the problems involved in their construction.

As long as geography was regarded primarily as the accumulation of earth-knowledge, the map served as a graphic medium for organizing and recording that knowledge. When geography advanced to the level of earth-description, the map became an illustrative aid to the visualization of location, area, shape, and so forth, with respect to the region described. However, as geography entered into its present stage of earth-interpretation, the map developed a more functional relation to geographical science. In order to appreciate the position and possibilities of the map as a functional tool in geography, it is necessary to analyze in some detail the essential nature of the modern map and its relation to the content and methods of geography.

A *map* in its modern sense may be defined as a graphic representation

[1] Carl H. Mapes, *History and Function of Maps in Relation to the Science of Geography.* University of Washington Library, 1931.

on a plane of certain selected features of a portion or the whole of the earth's surface according to some definite scale. It is apparent at once that several problems are involved in the construction of any map. These may be roughly classified under two headings: (1) technical problems, and (2) editorial problems. The technical problems of map construction are mathematical and cartographical in character. They involve the representation of the surface of a sphere upon a plane, or the problem of projection; the determination of the ratio to be used between measurements on the map and distances on the earth, or the problem of scale; the accurate entry upon the map of all data according to position and distribution upon the earth's surface, or the problem of location; and the indication of direction upon the map, or the problem of orientation. Each of these problems is important in connection with the relation of the map to the science of geography.

As we have seen, the technical problems of the map are derived from the fact that it is a miniature representation of the earth's surface or a section thereof. The surface features of the earth, however, are far too numerous and complex to be faithfully reproduced on a small scale. There must be both selection and generalization. These are two of the editorial problems of map making; a third is the problem of arrangement, so that the data selected is legible and informatory. Of these three problems, that of the selection of surface features to be represented on a map is the most important. Naturally, it is determined by the purpose for which the map is intended. A geological map should represent a selection of surface features which will be of greatest aid in understanding the geological structure and formations of the area under consideration. A military map must reveal those features which would be of offensive or defensive aid to military forces in time of war. Each special type of map requires its own selection of content according to its purpose. What, then, are the criteria for selection of surface features to be represented on the geographical map? To answer this question we must analyze more carefully the function of the map in relation to the science of geography.

Geography, as we have said, has passed from the stage of earth-description to earth-interpretation. Perhaps it is well to explain just what is involved in this statement. The subject matter of geography consists of the surface features or phenomena of the earth. As a science,

geography can trace its beginnings to the earliest efforts of human beings to organize their knowledge of earth phenomena. The maps of early peoples, we have noticed, are one expression of such efforts; the map below is an illustration of such efforts. But the entire field of the earth's surface phenomena is too inclusive and complex for any one science. Geography becomes more and more restrictive in its selection of surface phenomena to be investigated. Later geography apparently accepted the study of the distribution of phenomena on the surface of the earth as its special field, and this viewpoint is still held by some geographers. But man is himself one of the distributive features of the earth's surface, and it is only natural that the human element in geography should gradually have increased in emphasis. In other words, the place of man among the surface features of the earth has become the focal point in geographical science. At first geography was content with a mere description of man amid his surroundings, and in much geographical writing this is apparently still the case. Scientifically minded geographers, however, realized that if geography were to be a science it must deal with cause and effect relations between sets of facts. Hence it was that geography in its effort to become more scientific selected as one set of facts, those surface features of the earth directly due to the existence of man and his activities, and sought to discover and analyze the causal relations between man (and his works as surface phenomena) and the non-human surface phenomena of the earth. Geography thus became earth-interpretation as the home of man.

The concept of geography as "the science of the present day distribution phenomena on the surface of the earth" greatly stimulated the use of the map as a vehicle for the expression of geographical data. The accurate mapping of all available data—each kind by itself—became the first step in the geographical analysis of any area. As a result, a vast amount of information in map form could be accumulated. The weakness of geography as a science of distribution, however, lies in the fact that the map is regarded as an end in itself. The viewpoint of geography as the study of causal relationships, on the other hand, raised the map to a new level. It became a scientific source for geographical deduction and a methodical tool in geographical analysis.

The primary source in geographical investigation is, of course, the actual surface of the land and the phenomena, both natural and cultural,

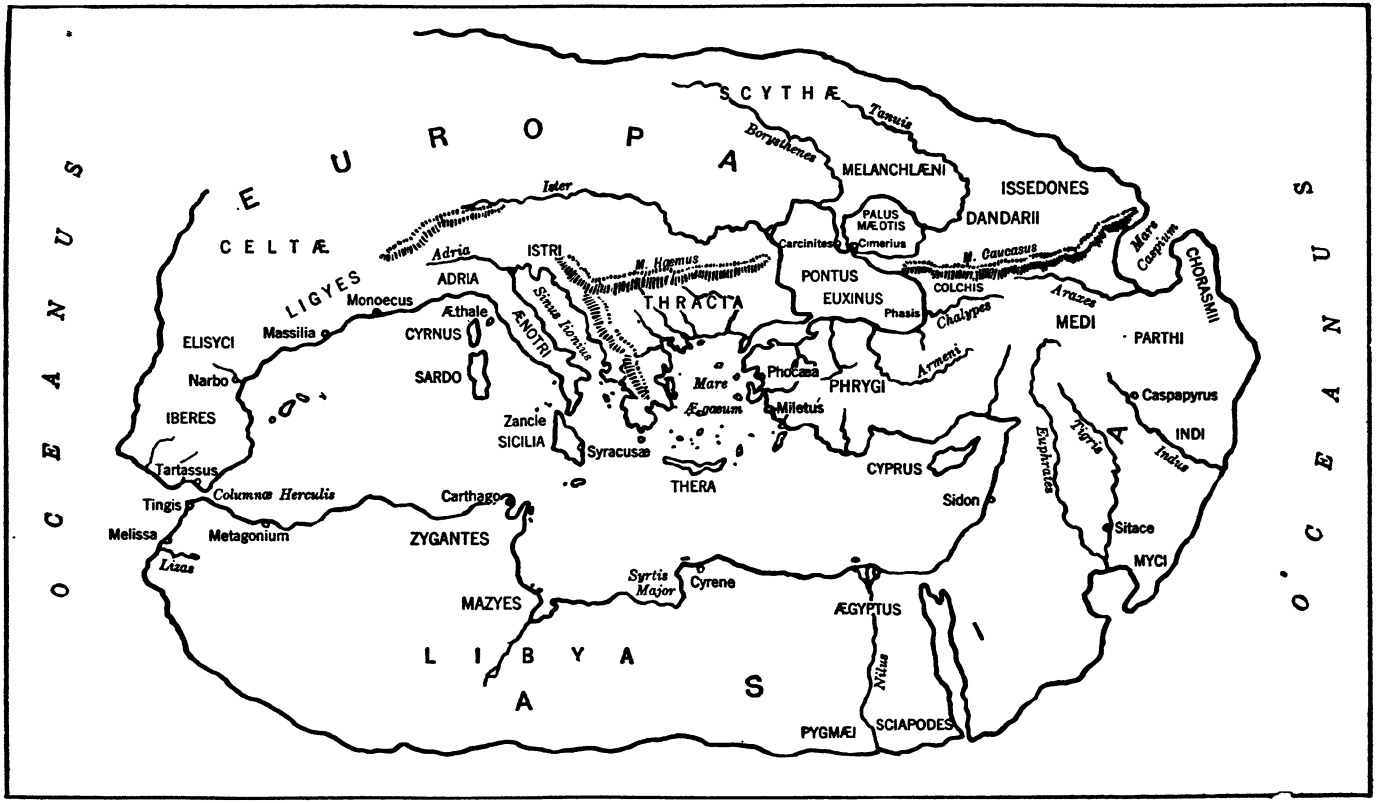


FIG. 16. WORLD ACCORDING TO HECATAEUS (B.C. 500).

which may be observed there. But it is not always possible, nor is it necessary, for the geographer personally to observe and identify the actual surface phenomena which must be considered in his interpretation of human adjustments to environmental conditions. If he has access to maps of a dependable scientific nature, large enough in scale and rich enough in content to depict the distributional relations of the works of man and the natural surface features of the region, he may save the time and labor by using the map as a source to replace, or at least supplement, personal observation. Not only does the map reduce nature to the size of man and hence make it more comprehensible, but it also makes the geographical work of generations available, and preserves and accumulates it graphically.

Geographical source maps have been classified by Doctor Max Eckert into two groups, geographically concrete maps and geographically abstract maps. The former represent large scale reproductions of facts as they exist in nature such as the distribution of land and water, heights and depressions, roads and buildings. The best examples of such maps are the detailed topographic and survey maps prepared by various governments for geological and military purposes. The geographer, however, finds them of great value in his interpretation of geographical relations. Geographically abstract maps are generalized rather than specific representations of surface phenomena; that is, maps showing the distribution of environmental features such as population, political divisions, transportation lines, areas of cultivation, and so forth. Both types of maps provide source material of inestimable value in geography.

The data to be shown on a geographical map, therefore, must be selected with the objective in mind of showing causal relations between the works of man and the features of his environment. Sometimes, as in political and economic maps, cultural features will predominate, a mere background being provided of the land and water areas, drainage features, configuration of coast lines, and so on. In the case of relief and climatic maps, environmental features predominate, associated human adjustments having to be brought into the picture through geographical interpretation. The ideal geographical map is one which shows only related cultural and environmental features, and future progress in geographical map making will consist of efforts along this line. As yet too little attention has been given to the classi-

fication of those features, cultural and environmental, which should appear together on the same map.

There is considerable evidence in recent geographical literature that the map as a working geographical tool is receiving increasing attention. Map studies are not only being prepared to accompany descriptive and analytical articles; they are regarded more and more as worth-while contributions to geographical science in themselves. Eventually the map as a source and a tool in geography may outrank the printed word.

4

Elements of Weather

IN THE discussion of the elements of weather it is necessary for the student constantly to keep in mind the fact that nature never works first with one element, say climate, then another, land forms, and then the third. In nature many of the elements are operative concomitantly. For classroom purposes and for the beginning student it becomes necessary to discuss one element at a time. Climate has a profound effect upon human activities and upon land forms, surface waters, and the other elements. In turn, the type of climate is influenced by such factors as mountains, oceans, and continental position. While the various elements are classified and catalogued in this book, it must be kept in mind that in geography or in the analysis of any area no such segregation is possible.

Composition of the atmosphere

The atmosphere is a collection of gases which are mixed but not chemically combined. While it surrounds the solid and liquid parts of the earth, it is an integral part of this planet, extending outward to a height of several hundred miles. The gases that form our atmosphere have different properties and different atomic weights. Some are active and others are inactive. Some are abundant and some are rare. Other planets have atmospheres that are quite different in composition from ours, and the sun itself has a very complex atmosphere.

Ignoring water vapor, which varies in quantity, and some of the minor variable constituents, the composition of the lower atmosphere, in volume percentages, is as listed in the table at the top of the following page.

Nitrogen	78.03
Oxygen	20.99
Argon	0.9323
Carbon dioxide	0.03
Hydrogen	0.01

The more abundant constituents of the atmosphere are nitrogen and oxygen, in the ratio of about 78 to 21. They differ strikingly from each other in that oxygen has a strong chemical affinity for nearly all other elements, while nitrogen is chemically inert and has little tendency to unite with other elements. However, by indirect processes and chiefly through the agency of plants and animals, a large number of nitrogen compounds are produced.

Carbon dioxide, commonly known as carbonic acid gas, occurs in the atmosphere in the almost constant ratio of three parts in 10,000 by volume. Over cities and towns it is more abundant than in the open country or over oceans. It is continually being added to and subtracted from the air by many agencies that have no dependence upon one another. Volcanoes, mineral springs, the combustion of fuel, respiration of plants and animals, and the decay of organic matter add carbon dioxide to the air. It is withdrawn from the atmosphere by green growing plants, by chemical combination with certain rocks, and by absorption in sea water.

Water vapor varies more than any other constituent of the atmosphere. The amount of water vapor that space can hold increases rapidly with an increase of temperature; the temperature limits the amount of water vapor that can be held. A decrease of temperature may cause the vapor to condense in visible forms as cloud, fog, hail, dew, rain, or snow. The movement of vapor in the atmosphere is part of the hydrologic cycle of the evaporation of moisture from a body of water, passing then as vapor, condensing in clouds, and falling as precipitation.

The solid impurities of the atmosphere are of manifold nature. While the coarser particles will fall to the earth in a short time, the finer ones may remain suspended for months or even years. These particles play an important part in determining temperatures and sky colors, in forming clouds and fogs, and in precipitation.

The essential properties of the gases in the atmosphere are mobility, capacity for expansion, compressibility, little friction, low viscosity, and

no definite shape or size. Because of its great mobility the atmosphere tends to be uniform. But exact uniformity cannot be attained because of compression by the weight of the air above. Since gas is a substance and therefore has density, it exerts pressure. The pressure is proportionate to the density and is exerted in all directions. Air being compressible, the volume is decreased and the density increased when pressure is applied. Since air expands readily, the volume is increased and the density decreased when pressure is released; in the atmosphere a change of temperature is the primary cause of changes in density and pressure.

The force of gravity holds the atmosphere to the earth; this weight is expressed as pressure. The weight or pressure of the atmosphere at sea level is approximately 14.7 pounds per square inch in all directions. The weight of the atmosphere decreases with altitude.

The atmosphere has no very definite upper limit, but it becomes gradually thinner and thinner until it is imperceptible. It has been estimated that there is no perceptible pressure above 50 miles. The compressibility of the air restricts the atmosphere so much that 50 per cent of the entire mass is below 3½ miles, and 95 per cent is below 18 miles.

Planetary relations

The earth is held in space by the gravitational attraction of other heavenly bodies. Its motions are also controlled by them. The two principal motions are *rotation* and *revolution*. The earth rotates in an easterly direction on an imaginary axis every 24 hours.

The earth not only rotates on its own axis but at the same time revolves in a slightly elliptical orbit about the sun. The time required for the earth to rotate determines the length of the day; the time required to revolve about the sun, nearly 365¼ days, determines the length of the year. The average distance of the earth from the sun is about 93 million miles.

The axis of the earth is inclined toward the plane of revolution about 23½ degrees. This inclination is constant, and therefore the axis is always parallel to a position that it occupied at any previous time.

One half of the earth's surface is always illuminated. If the axis about which the earth rotates were perpendicular to the plane in which the earth revolves about the sun, the illuminated half would be from

pole to pole as well as half of every parallel. If half of every parallel were always illuminated, the days and nights would be of equal duration everywhere. Furthermore, if the earth rotated on an axis perpendicular to the plane of its orbit, the sun would be equally high at any given place at the same hour of every day. However, at any place in the middle latitude zone the sun is much higher above the horizon at noon in summer than in winter. The variation of the angle at which the sun's rays strike the same place at different times and the unequal lengths of days and nights in most places are the result of the inclination of the axis on which the earth rotates as it revolves about the sun (Figure 17).

The effect of the inclination of the axis is illustrated by Figure 17,

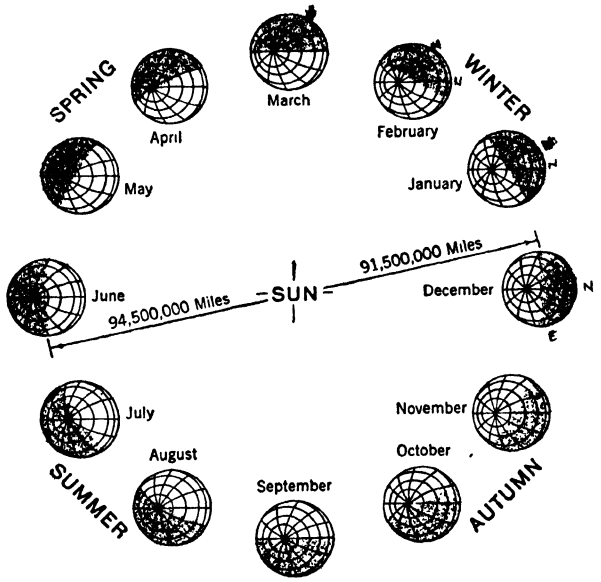


FIG. 17. REVOLUTION OF EARTH ABOUT SUN.

which represents the earth in its various positions on its orbit. It should be noted that the position of the axis is constant throughout the year. In the position for September 21st, the days and nights are equal everywhere; one half of every parallel is illuminated. For December 21st more than half of each parallel in the Southern Hemisphere is illuminated and the days are longer than the nights; in the Northern Hemisphere the nights are longer than the days and less than half of each

parallel is illuminated. In the position marked March 21st half of each parallel is again illuminated and the days and nights are equal. For June 21st more than half of every parallel in the Northern Hemisphere is illuminated and the days are more than 12 hours long. In the Southern Hemisphere the nights are longer than the days.

Twice during the year, on March 21st and September 21st, the days and nights are equal everywhere, and these times are known as the *equinoxes.* The equinox in September is the *autumnal equinox;* that in March is the *vernal equinox.*[1] On December 21st the days are longer in the Southern Hemisphere and the sun's rays at noon fall perpendicularly on the surface of the earth at approximately 23½ degrees south. This time is the *winter solstice.* The *summer solstice* occurs six months later, when the sun's rays are perpendicular at approximately 23½ degrees north and the days are longer than the nights in the Northern Hemisphere.

The angle at which the sun's rays strike the earth and the relative duration of day and night are the chief causes of seasons. Most of our methods of reckoning days and years, positions, directions, and distances depend upon these various earth relations.

The earth's shape, its rotation and revolution, together with its inclination and the fact that the inclined position is constant, combine to produce the underlying principles in our study of the atmosphere.

Atmospheric temperatures

For practical purposes, all of the heat received on the surface of the earth comes from the sun. The sun has a diameter of about 880,000 miles; the surface temperature of the sun has been estimated at 10,000 degrees F.

In physics *heat* is defined as the energy of molecular motion. The radiation sent out by the sun is known as *insolation.* The energy from the sun, which becomes heat when received by the earth, travels in straight lines in every direction. Eight minutes are required for this energy to reach the earth. This energy travels at this tremendous speed in short wave lengths of from 1/10,000 to 1/100,000 of an inch. The waves, on striking an object, spend energy on it. The waves set up a

[1] The exact days of equinoxes and solstices vary slightly from year to year.

vibration in the same way that a note on the piano may cause a vibration on a wire some distance from the piano. As long as these waves pass through the upper atmosphere, they move unimpeded and they spend no energy. As these waves strike some tangible matter, undulations are imparted to that mass, and the molecules of which that mass is composed are set in motion. The increased motion of the molecules causes the object to be heated.

Of the total amount of heat sent out by the sun, only a very small fraction, 1/2,000,000,000 part, is received by the earth. Yet all activity on the earth is dependent on this small fraction of heat emitted by the sun. This energy is the parent of all energy on the earth, and it is the starting point for all discussions in meteorology and climatology.

Radiant energy on its way from the sun to the earth is not heat. It was excited by heat and will produce heat when absorbed by the earth, but until it is so absorbed it must be considered as a special form of energy.

The upper atmosphere, being extremely rare and having little or no dust, water vapor, or carbon dioxide, is a poor absorber of insolation and therefore a poor radiator. Insolation passes through it with little depletion. The few observations that have been made show that the range of temperatures is slight and that temperatures are nearly constant. In the lower atmosphere the air is more dense and has more dust, water vapor, and carbon dioxide, and thus becomes a better absorber and radiator. The nearer we approach the earth, the greater the range in temperature for air of ordinary cleanness. Air that has much dust or water vapor has less range in temperature.

The surface layer of the ocean is like the atmosphere in being slow to change its temperature, but for different reasons. The greater part of the sun's radiation is reflected from the surface of the ocean and is not effective in raising the temperature of the water. The fraction which is absorbed by the surface layers is expended in changing the water into vapor, and some is transmitted to lower layers of water. The part that is used to change the liquid to a gas (vapor) does not increase the temperature. The same conditions which retard an increase in the temperature also retard a decrease in water temperatures. The lower layers of water change but slightly from day to night or from season to season.

Land surfaces, in contrast to water surfaces, are relatively poor reflectors. Also, the land, being opaque and a solid, concentrates the solar energy close to the surface. The sun's rays are thus absorbed by day by a thin layer of the earth's surface, and there can be no mixing as there was in the case of ocean water. Furthermore, the land is easily warmed, for its specific heat is only one fifth to one half that of water. In contrast to the atmosphere or the ocean, the surface of the land reaches a high temperature by day. For the same reasons it is a good radiator; thus temperatures fall at night.

Land, water, and atmosphere are not separated from each other but rather influence the temperatures of one another. The atmosphere over land is heated, or cooled, by absorption and radiation by the earth, and that over water is more constant. Air moving from one area to another transports temperatures. Thus air moving from the ocean in summer or in the daytime transports cooler temperatures to the land, while air moving to the ocean from land in those same periods transports warmer temperatures. The reverse is true at night and in winter.

The change of the position of the earth in relation to the sun at various times of the year was shown in Figure 17. This variation causes a fluctuation in the amount of radiant energy received by the earth at various places and at various times.

At the time of the equinoxes the day is twelve hours long over the entire surface of the earth. The greatest amount of insolation is received at the equator. Progressing to and through the middle latitudes, the amount of insolation decreases, for the sun does not reach the zenith, or the sun's rays reach the surface of the earth at an angle. At the poles the rays pass tangent to the surface of the earth, except for a slight bending by atmospheric refraction, and no insolation is received. At the summer solstice the equator still has a twelve-hour day, but the sun reaches the zenith at latitude 23½ degrees north instead of zero degrees, as at the time of the equinox. In the Northern Hemisphere the amount of insolation for all latitudes is greater at the summer solstice than at the time of the equinox or the winter solstice. This is due to the increased length of day, together with the relation of the earth to the sun's rays. Beyond latitude 40 degrees north, the increased length of day is offset by the increased angle of the sun's rays, and the

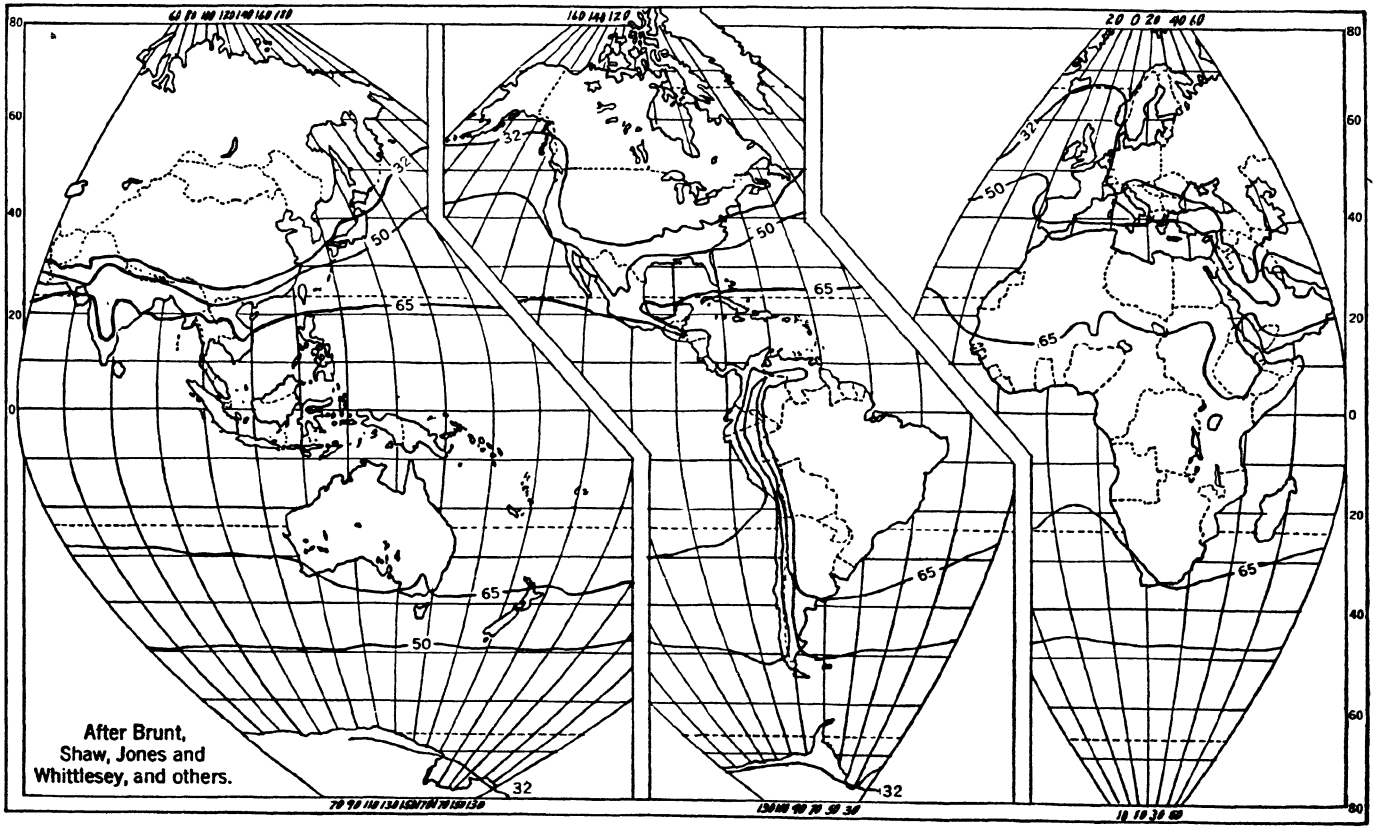


FIG. 18. ISOTHERMAL MAP FOR JANUARY.

insolation again decreases. In the polar regions the sun is never very high above the horizon, and direct sunlight is consequently weak; the scattering and reflecting of sun's rays weakens insolation, and probably not more than 18 per cent of the total solar radiation that reaches the earth reaches the ground level at the poles. In the Southern Hemisphere the conditions are similar to those found in the Northern Hemisphere during the winter solstice. During the winter solstice, the Northern Hemisphere has oblique sunshine and a shorter and shorter day, until beyond 66½ degrees the night is 24 hours long. As a consequence, the amount of insolation received decreases. At the south pole, because the earth is near the perhelion at the winter solstice, the amount of insolation is greater than that received at the north pole. The distribution of insolation, then, depends largely on the length of the day and the angle of the sun's rays.

Distribution of Temperature Over the Earth. The isothermal maps for January and July (Figures 18 and 19) illustrate the high temperatures around the equator and the low temperatures around the poles. The greatest amount of annual insolation is found near the equator and decreases poleward. The *heat equator,* the line of highest mean annual temperature, is higher by about five degrees over the lands than over the oceans for the same latitudes. The cause of this is the interchange of waters from cooler and warmer regions, which equalizes the temperatures. Over the land such an interchange is not possible. The result is higher land temperatures near the equator and higher water temperatures near the poles. The oceans tend to equalize their temperatures, while the lands have temperatures corresponding to their latitude.

The isotherms, lines connecting places of equal temperatures, show no similarity of arrangement in the hemispheres on the two sides of the equator. In the Southern Hemisphere the lines are more regular, especially over the oceans. In the Northern Hemisphere they are more irregular. Over the lands the isotherms trend poleward, while over the oceans the trend is equatorward. The isothermal maps for January and July, Figures 18 and 19, give the seasonal extremes. In generalizing from the three maps (Figures 18, 19, and 20) we conclude the following: (1) There is a latitudinal shifting of the isotherms between January and July following the migration of the sun's rays. (2) The

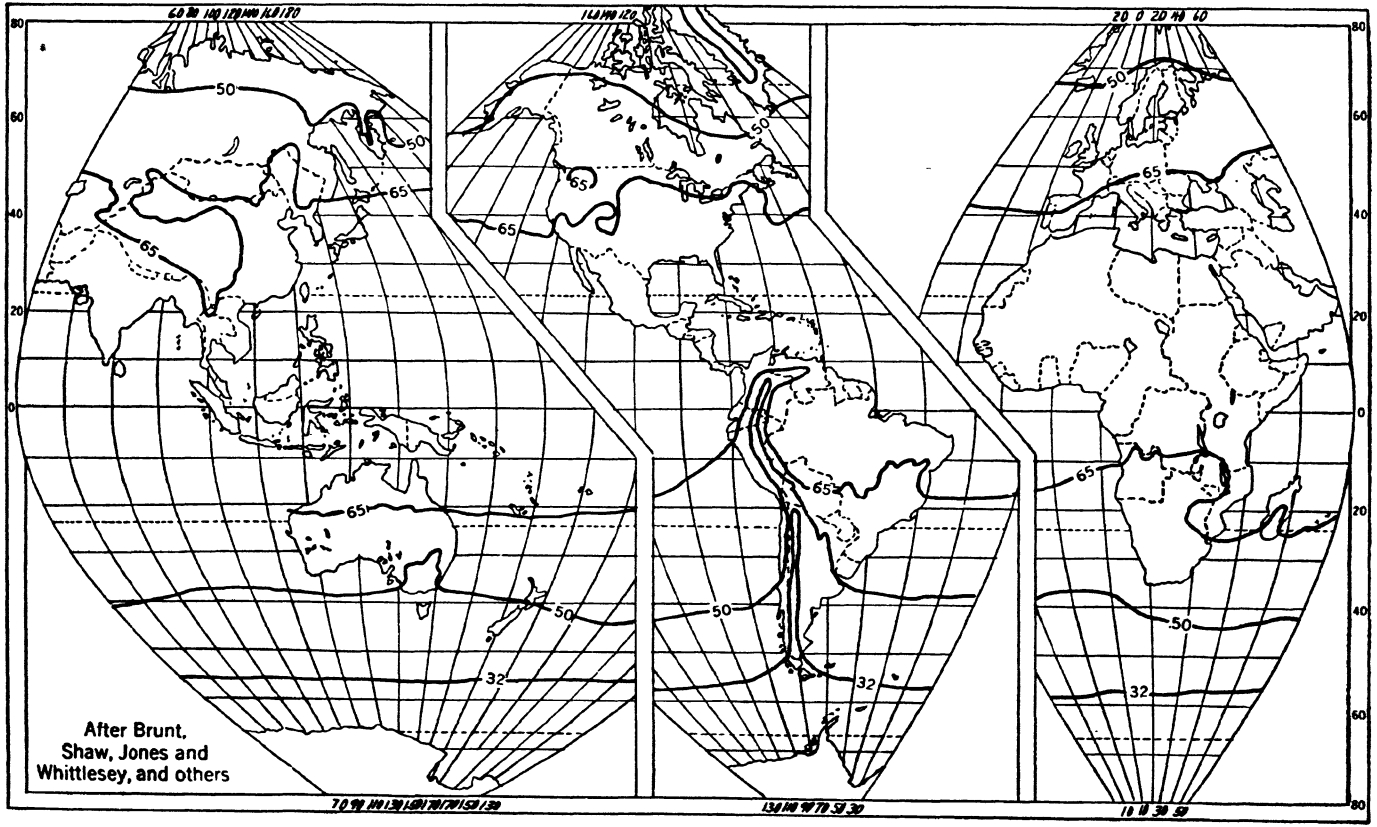


FIG. 19. ISOTHERMAL MAP FOR JULY.

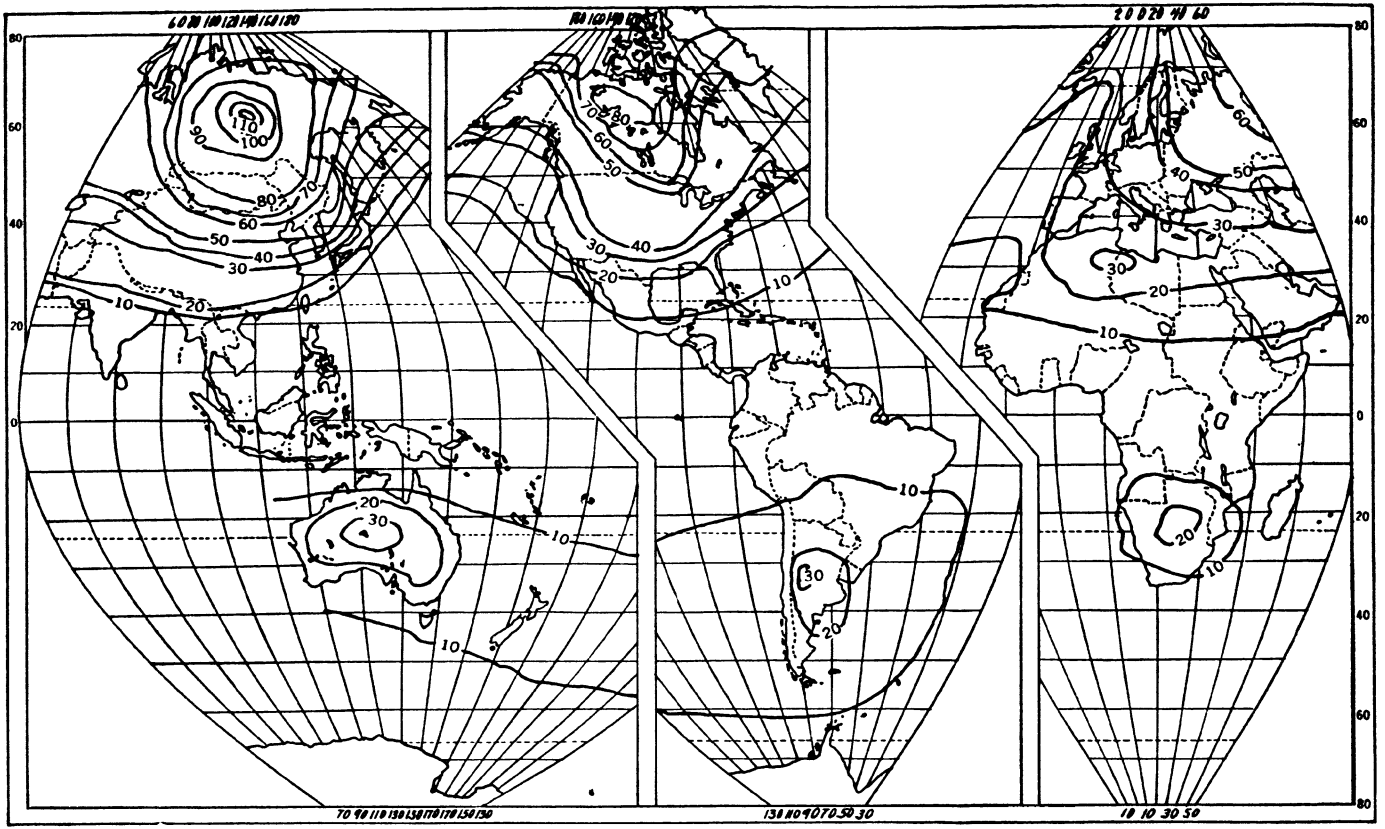


FIG. 20. AVERAGE ANNUAL TEMPERATURE RANGE.

migrations are less over the oceans than over the continents. (3) The highest temperatures as well as the lowest are over the lands. (4) The rate of change of temperature, known as *temperature gradient,* is greater in winter than in summer. (5) Nearness to the sun, *perihelion,* has less effect than amount of land mass. (6) In the Northern Hemisphere the thermal north is located some distance from the mathematical North Pole. In the Southern Hemisphere the two corresponding points may be more nearly the same; more observations are needed before this can be definitely stated. (7) Temperature ranges are less near the equator, and less over the oceans than over land masses.

Atmospheric pressure and circulation

Since the temperatures of the atmosphere are continuously and periodically higher in one region than another, there is a systematic movement of air from one place to another. Uniformity of temperature over the earth's surface at all times would produce a stagnant atmosphere.

The pressure of the atmosphere varies from time to time at the same place, and from place to place. Some of the reasons for this variation are: (a) Variation in temperature causes variation in pressure. An increase in temperature makes the air lighter and thereby reduces the pressure. (b) The changing amounts of water vapor change the pressure. Water vapor displaces some oxygen and nitrogen and other constituents which are heavier than the vapor. Thus an increase in water vapor decreases the air pressure.

Lines drawn on a map through places of equal pressure show the pressure distribution. Such a map is known as an *isobaric map,* and the lines connecting places of equal pressure are called *isobars.* Such a map may be drawn for any period desired.

The isobaric map for January, Figure 21, shows that the high-pressure belt is very wide in the Northern Hemisphere, especially on the land, which is cooler in winter than the oceans. This high-pressure area is especially marked over Eurasia. Low pressures over the north Atlantic and north Pacific are strongly marked, contrasted with the pressures over the land. In the Southern Hemisphere for the same period, temperatures are higher over the land than over the oceans and the pressures are higher over the oceans than over the land.

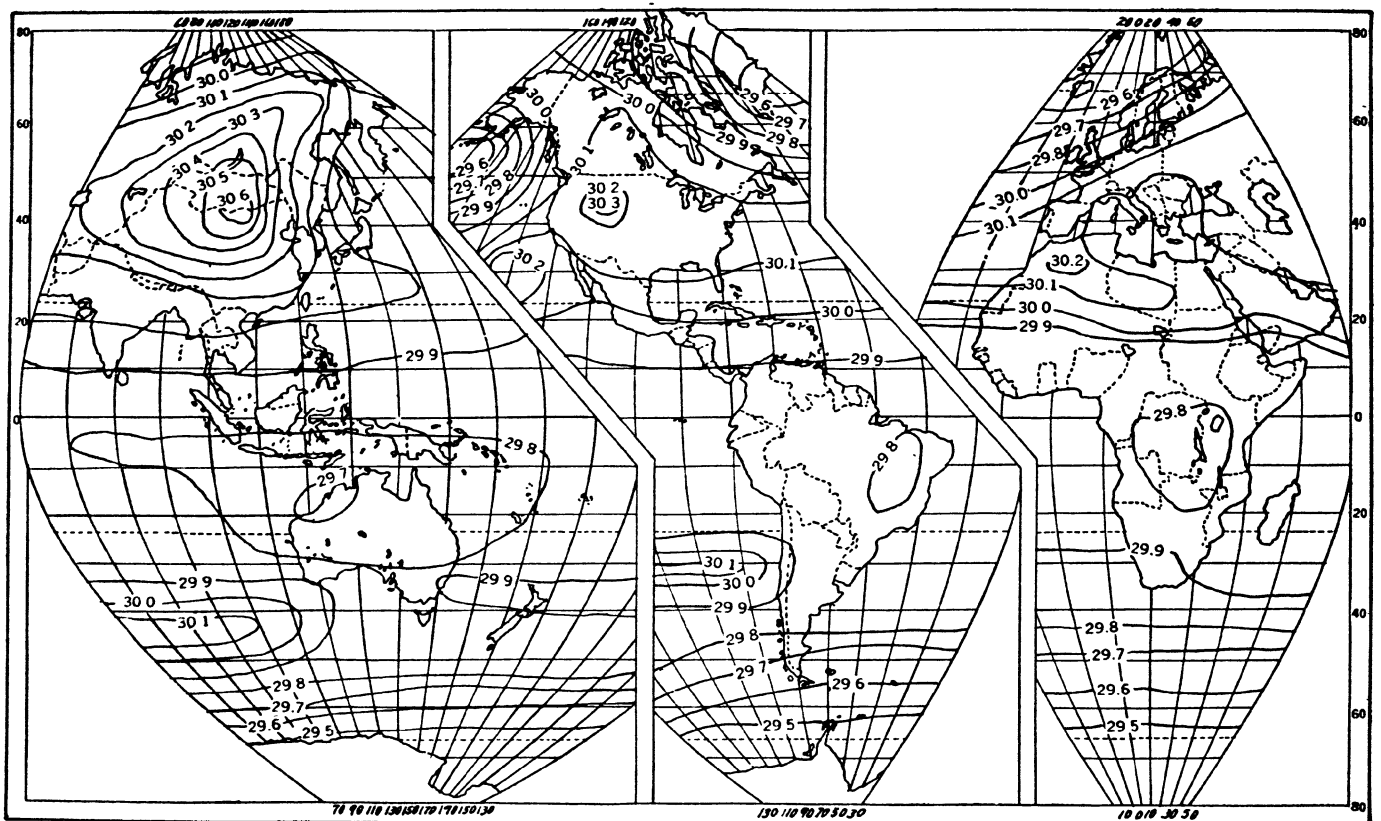


FIG. 21. MAP OF ISOBARS FOR JANUARY (MEAN SEA LEVEL PRESSURE).

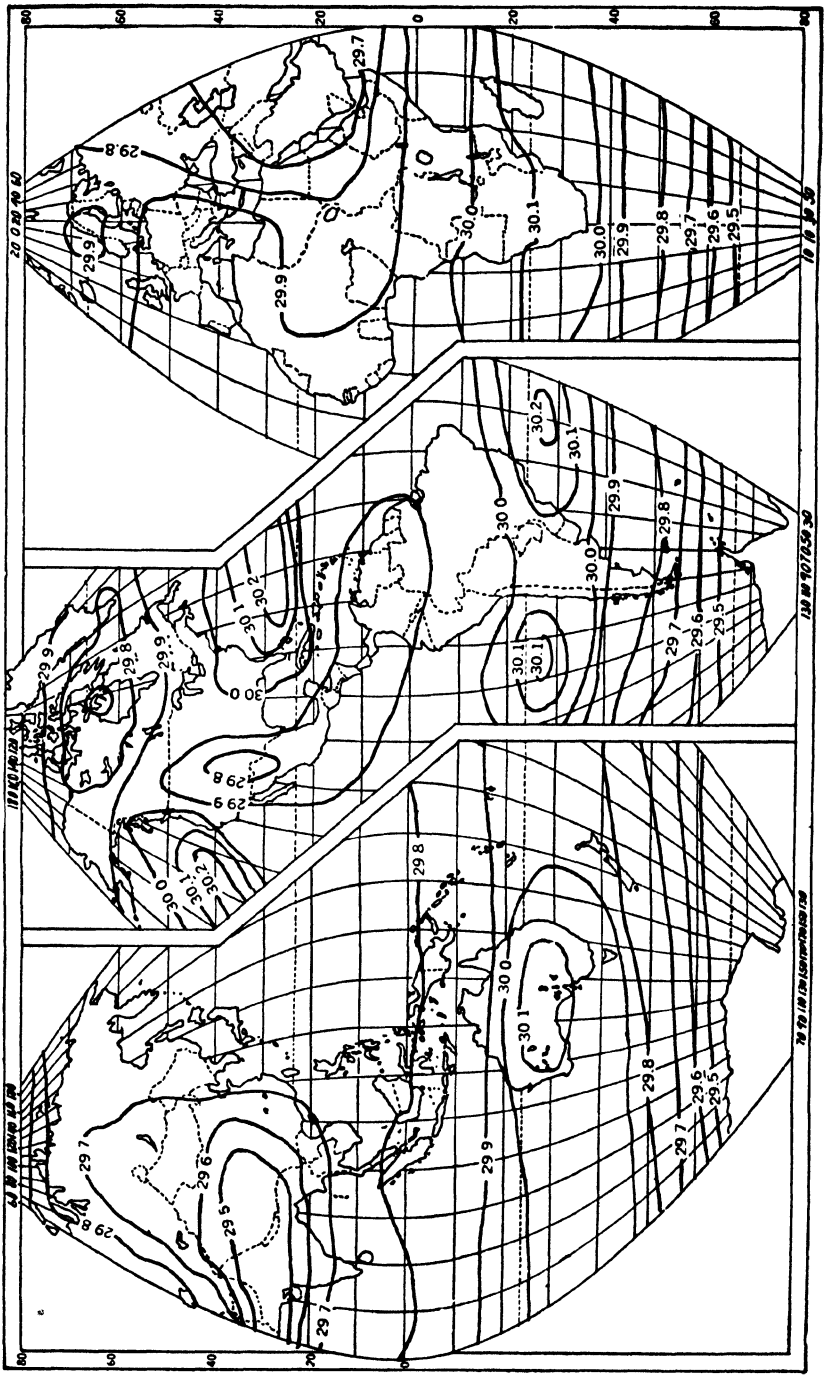


FIG. 22. MAP OF ISOBARS FOR JULY.

A study of the isobaric map for July brings out conclusions similar to those made from the January map. Pressures in the Southern Hemisphere over the land are higher than for January, and are lower than over the water, owing to the differences in temperatures. In the Northern Hemisphere the pressure is less in January than in July.

A summary of the two isobaric maps shows that (a) the isobars have a general east-west trend, (b) low pressures are found in low latitudes, (c) higher pressures are found in the latitudes just outside the equatorial belt, (d) isobars are more regular in the Southern Hemisphere than in the Northern, and (e) isobars are more regular over the oceans than over the land.

As a general rule, regions with high temperatures have lower air pressures than regions where temperatures are not so high. The ultimate cause of pressure differences is regional contrasts in temperatures, yet it must not be inferred that this direct relationship is always obvious. There are many apparent exceptions, some of which will be included in the discussion following.

Winds

Winds are horizontal movements of air. Winds are important in eroding land, increasing evaporation, distributing moisture, furnishing power, and keeping the air from becoming stagnant. In addition, they lower the sensible temperature and make atmospheric conditions more invigorating for human activities. Winds are produced by inequalities of pressure at the same level. These inequalities are produced by unequal heating. Since, as pointed out before, these inequalities constantly exist, winds are always blowing.

Winds blow from areas of high pressure towards areas of low pressure, and they blow faster on steeper barometric gradients than on fainter gradients. *Barometric gradient* is the rate of decrease from one isobar to another. Winds should follow the line of gradient, according to the general principles of convectional circulation. Instead, we find that the winds in the Northern Hemisphere are deflected to the right, while the winds in the Southern Hemisphere are deflected to the left (Ferrel's Law). The cause of this deflection from the gradients is to be found in the earth's rotation.

Winds, as well as all objects moving over the earth's surface, are

deflected by earth rotation. Gravitation and centrifugal force are the two forces affecting such motion. Winds tend to move in a straight line from the high pressure to the low pressure. Directions on the earth are fixed by meridians and parallels rather than by a point in space. These meridians and parallels are constantly changing their position with respect to any point in space as the earth rotates. Thus, as a wind moves across the surface of the earth along a meridian, the earth rotates away from under it so that the wind apparently changes its directions, whereas actually the meridians have changed their position. The meridians and parallels rotate to the left in the Northern Hemisphere, which gives the winds in that hemisphere an apparent deflection to the right. In the Southern Hemisphere the reverse is the case. Thus, the rotation of the earth produces the deflection from the straight line from a high pressure to a low pressure.

The arrangement of the planetary winds is shown in a diagram on an idealized sketch, Figure 23. The variations from the ideal are

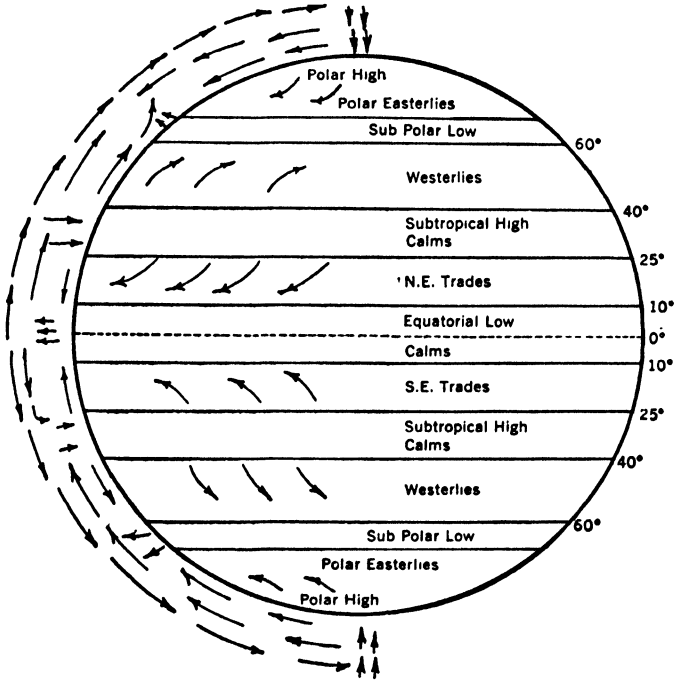


FIG. 23. IDEALIZED SKETCH OF WORLD WIND SYSTEMS.

shown on the January and July wind maps, Figures 24 and 25, and will be discussed in a later section.

A *wind belt* is a region over which air moves in the same general direction at least more than half the time. These belts are of two types: *Calms* are belts in which air moves upward or downward as currents, and *belts of prevailing winds* are areas in which air is moving parallel to the earth's surface.

The *belt of equatorial calms,* or *doldrums,* in the equatorial region encircles the globe in a belt about 10 degrees wide. The air is calm and sultry, with light and variable winds. The ocean may be glassy smooth, and it reflects the gray or leaden color of the sky.

The *trade winds* blow toward the equator from the northeast in the Northern Hemisphere and the southeast in the Southern. These winds hold their courses steadily over wide areas and are the most regular winds in the world. The current of air is about two miles or more in depth, so that only the highest mountains in the belt escape the effect of these winds. The winds may blow for days or even weeks with slight variation in strength or direction. The oceans are, in this belt, roughened and of clear, dark-blue color.

The vague *tropical belts of high pressure* on the poleward margin of the trades are characterized by light variable winds and occasional calms. The weather, unlike that of the doldrums, is clear.

Beyond the tropical belts of high pressure are the *prevailing westerly winds.* They blow west-southwest in the Northern Hemisphere and west-northwest in the Southern. The upper air current is in the same general direction as the westerlies, and thus these winds are of greater depth than the trade winds. Frequent storms are found in this belt, in contrast to the trade wind area.

Poleward from the prevailing westerlies are the subpolar low-pressure belts, which are belts of calm. At each of the poles is a high pressure belt, and between the high-pressure and low-pressure belts are the *polar easterlies.*

Migration of Wind Belts. The temperature belts of the earth migrate northward and southward with the steeper rays of the sun and the lengthening days of sunshine. The pressure belts migrate with temperature belts, and the wind belts migrate with the temperature and pressure belts. In general, wind belts lag a month or possibly two behind the sun. The migration is greater over continents than over

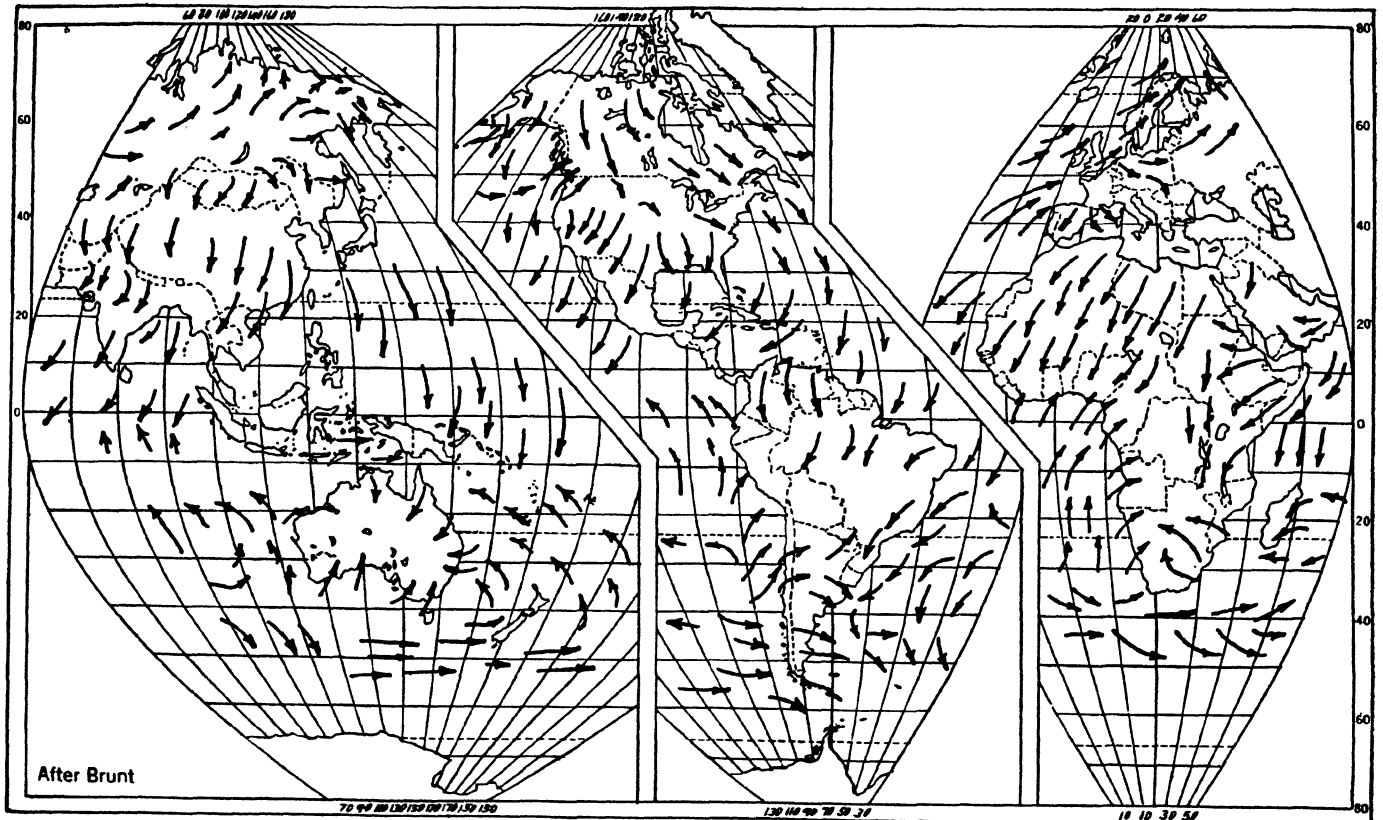


FIG. 24. MAP SHOWING WINDS OF THE WORLD FOR JANUARY.

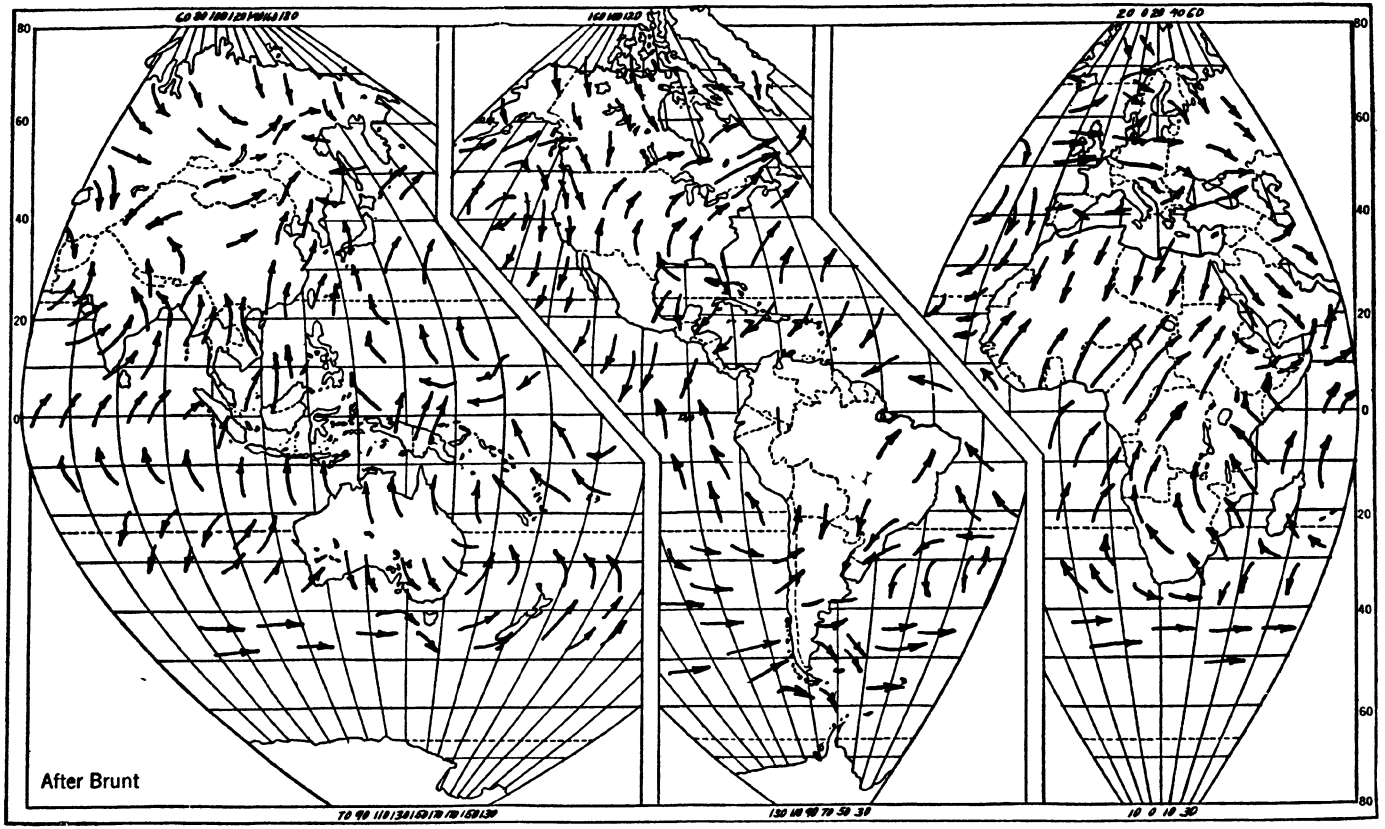
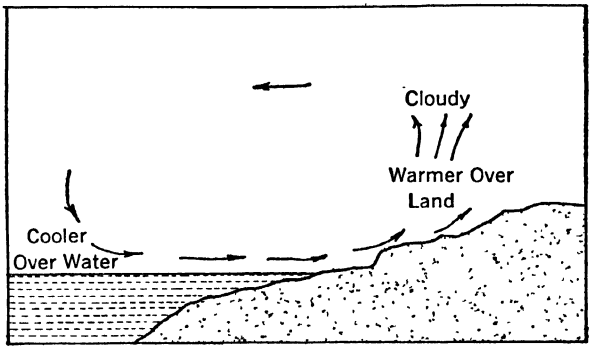


FIG. 25. MAP SHOWING WINDS OF THE WORLD FOR JULY.

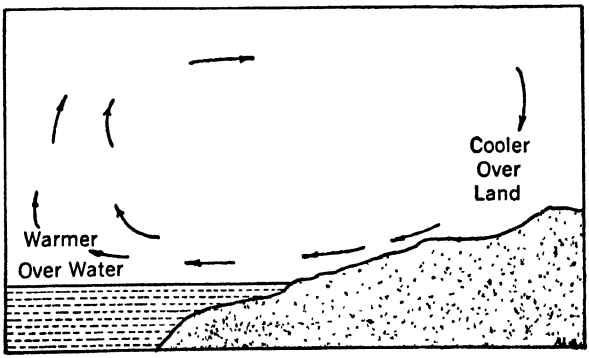
oceans, and the lag over land is less than that over large bodies of water.

This migration of wind belts becomes significant when we discuss climates, for there are areas which have an intermediate position between two unlike wind belts. The two maps showing winds for January and July should be studied carefully to see the migrations. The intermediate areas take the characteristics of opposite wind systems at different times of the year. In the Northern Hemisphere three such transitional areas exist. Latitudes 5 to 15 north and south are affected by the doldrums and the trade winds. Latitudes 30 to 40 are between and in the subtropical highs and westerlies. Latitudes 60 to 70 are in the third intermediate position. These are not well-defined lines of latitude, but are frequently vague and irregular boundaries influenced by land masses and land forms.

Land and Sea Breezes. Land and sea breezes develop because of differences of pressure, which have been produced because of the differ-



Sea Breeze (Day Time).



Land Breeze (Night Time).

FIG. 26. DIAGRAMS OF LAND AND SEA BREEZES.

ence in temperatures between land and water. As the land is heated during the daytime, it becomes warmer than the body of water, and thus a lower pressure is established than over the ocean. The air moves in from the ocean. At night the direction is reversed, since the body of water is warmer than the land and therefore has a lower pressure.

Mountain and Valley Breezes. Mountain and valley breezes depend upon surface irregularities. At night the breeze blows down the valley, and it is particularly strong where a large valley emerges on an open plain. By day the breeze blows up the slope, but with less velocity than the nocturnal wind. The cause for these winds is similar to that given for land and sea breezes, namely, unequal heating and cooling. At night, the colder and therefore heavier air lies along the slope of the mountain, and gravity forces the air to descend. By day, the lower air warms and expands, causing a reversal of air flow. This wind makes the nocturnal inversion of temperature in hilly and mountain regions more apparent. At the higher level the temperature may be many degrees higher than in the valley.

Monsoon Winds. Land masses heat and cool at rates different from those of bodies of water. These differences in rate, as well as the actual temperatures reached, produce differences in pressure and in turn determine wind direction. The monsoons of Asia are winds that are produced chiefly by a huge land mass being heated in summer and cooled in winter. A belt of low pressure, which reaches huge proportions (see Figure 22), becomes centered over central Asia in summer. Winds moving toward the center of that low belt cross the Indian Ocean and Arabian Sea and move across India. In winter, a high pressure is established over the same area (see Figure 21), and the winds move from that center outward and cross India from the opposite direction. Thus, there is established a wind system with reversal in direction, caused by unequal heating of land and water.

Moisture of the atmosphere

Water vapor is found in the atmosphere in varying amounts. Since about three fourths of the earth's surface is water, a continuous supply of water vapor is ensured. The water in the ocean must first be changed to a gas through evaporation; this process requires a vast

amount of energy in the form of heat. The large share of insolation required to change a liquid mass to a gas is one of the reasons for the small diurnal change in temperature for large bodies of water.

Humidity is the state of the air with respect to the moisture that it contains. When the air is damp, the humidity is high, and when the air is dry, humidity is low. A decrease in temperature reduces the capacity of the air to hold moisture which is in the form of vapor. Thus, on a cool night the air near the surface of the ground is frequently saturated. That is not because more water vapor has been added, but is due to a change in temperature. The amount of water vapor actually present in the air is called the *absolute humidity*. The absolute humidity divided by the amount of vapor that might exist if the air were saturated is the *relative humidity,* and is expressed as a ratio. The temperature at which saturation of the air takes place is known as the *dew point*. The cooling from noon to evening may bring about a condition of saturation without a change in the absolute humidity.

The absolute humidity is high over the belt of doldrums because of the intensity of insolation and the quietness of the air. It is especially high over the oceans. In the trade wind belt the water vapor decreases because the air is being moved equatorward and thus warmed. In the subtropic highs the absolute humidity is again low because the air is moving downward, and therefore the temperature is increasing because of compression of the air (see Figure 23). In the belt of westerlies the water vapor is low as compared with the low latitude zone, for the temperature is lower. The same conditions apply as one goes poleward. On the land the absolute humidity varies with the prevailing temperatures, with the distance from the oceans, with the degree of enclosure by mountains, and with altitude. The water vapor diminishes as one ascends to higher and higher altitudes. The relative humidity is continually varying with changes in temperature either diurnally or seasonally.

A decrease in the temperature tends to condense the water vapor in the atmosphere. When the temperature of air has been reduced to a point at which the water vapor present reaches the stage of saturation, the temperature has reached the dew point. Any further cooling will cause condensation and produce cloud, dew, fog, or frost. If condensa-

tion occurs at temperatures above freezing, the product will be water; if the temperature is lower, there will be ice in the form of frost, snow, hail, or ice crystals in the air.

In the formation of *dew* the water vapor comes from the air as well as from the ground and plants. The amount of water from each depends upon the territory under consideration. Where a large number of plants are present, more water comes from plants than where fewer are present. *Frost* is formed in the same way as dew, but at temperatures below the freezing point. Dew and frost are common on clear nights when radiation is greatest, when no wind is blowing; they are greatest in valleys, and greater at higher elevations.

Formation of Clouds and Cloud Forms. Cloud, including fog, is the normal form of condensation. The condensing of water vapor in the air into droplets makes fog if the condensation takes place in the lower part of the atmosphere at a temperature above 32° F. It makes ice particles, or frost, if the temperature is below 32° F. The lowest clouds are ground fogs, which result from the cooling by radiation of the lowest layers of air at night. The difference between fog and cloud is the difference in the height above the ground. Clouds are formed by the condensation of vapor into droplets at some height above the ground. They are usually the result of mechanical cooling of air below its dew point through lifting. The three main types of clouds are *cumulus, cirrus,* and *stratus.* All the other types are modifications or combinations of these three.

Cumulus clouds are thick, and their upper surfaces tend to be dome-shaped, with irregular and fleecy projections. Their bases are nearly horizontal. They are formed from vertically ascending air currents, and their level bottoms mark the altitude at which condensation takes place as the air rises. They appear especially in clear, hot weather, in mid- or late afternoon, after insolation has established convectional currents.

Cirrus clouds consist of slender fibers, sometimes in long parallel lines, sometimes in feathery, curled, or tangled arrangement. Their form slowly changes. Their altitude varies between five and ten miles above sea level. They are never thick enough to produce shadows, so that they always appear white.

Stratus clouds are horizontal sheets of cloud, often not more than 1,000 feet above the earth. They form a dull, gray sky, often stretching from horizon to horizon. They are most common in winter.

Any extended clouds from which precipitation is falling are called *nimbus* clouds. Usually they are thick masses of cloud without definite shape, and with ragged edges, and are barely more than half a mile above the earth's surface.

Forms of Precipitation. When vapor is condensed in sufficient quantity, the droplets coalesce and fall. The processes which produce clouds, if carried far enough, bring rain or its winter equivalent, snow. Every cloud particle is a center for additional condensation in the cooling, saturated air. The particles must be of slightly unequal size; unequal movements of particles in the cloud occur, since the particles do not weigh the same, and collisions result in larger drops. In time they reach such a size that they can no longer be carried, but must fall as *rain.* If the temperatures are below 32° F. during the process of condensation, the vapor sublimates as it condenses and forms *snow* flakes. When precipitation occurs, as in the polar regions, at temperatures lower than –5° F. or –10° F., small *ice needles* are formed. *Hail* consists of compacted ice and snow taking the form of pellets or balls.

The distribution of precipitation according to regions is shown for the periods from November to April and from May to September, as well as the average annual precipitation, on the maps, Figures 27, 28, and 29. Only a brief analysis of these maps will be made at this point, since they will be discussed in the next section on climates. A comparison of the various maps in this chapter shows that precipitation is produced by some wind movements and there is a close correlation between the amount and seasonal distribution of precipitation and the general and local circulation of the atmosphere. The maps showing wind directions should be compared with the precipitation maps.

Winds blow toward the belt of equatorial calms from both sides. In this belt of low pressure, high temperatures are reached at all times of the year. The air rises, owing to heat and low pressure; the moist air, brought by the trade winds and high evaporation, cools as it ascends, causing condensation. Toward noon the clouds are already well formed, and heavy precipitation occurs in the afternoon. Toward

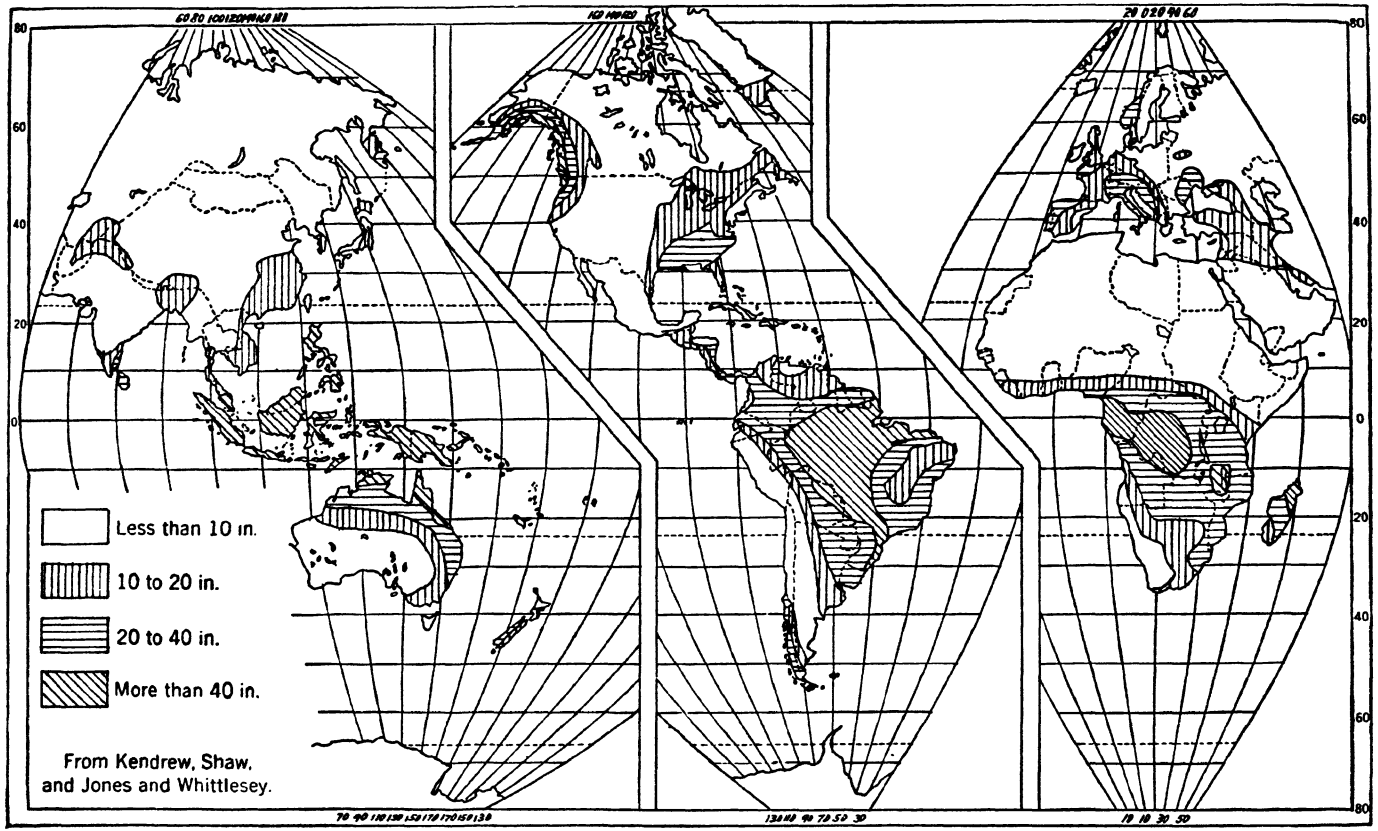


FIG. 27. MAP OF PRECIPITATION FOR NOVEMBER TO APRIL.

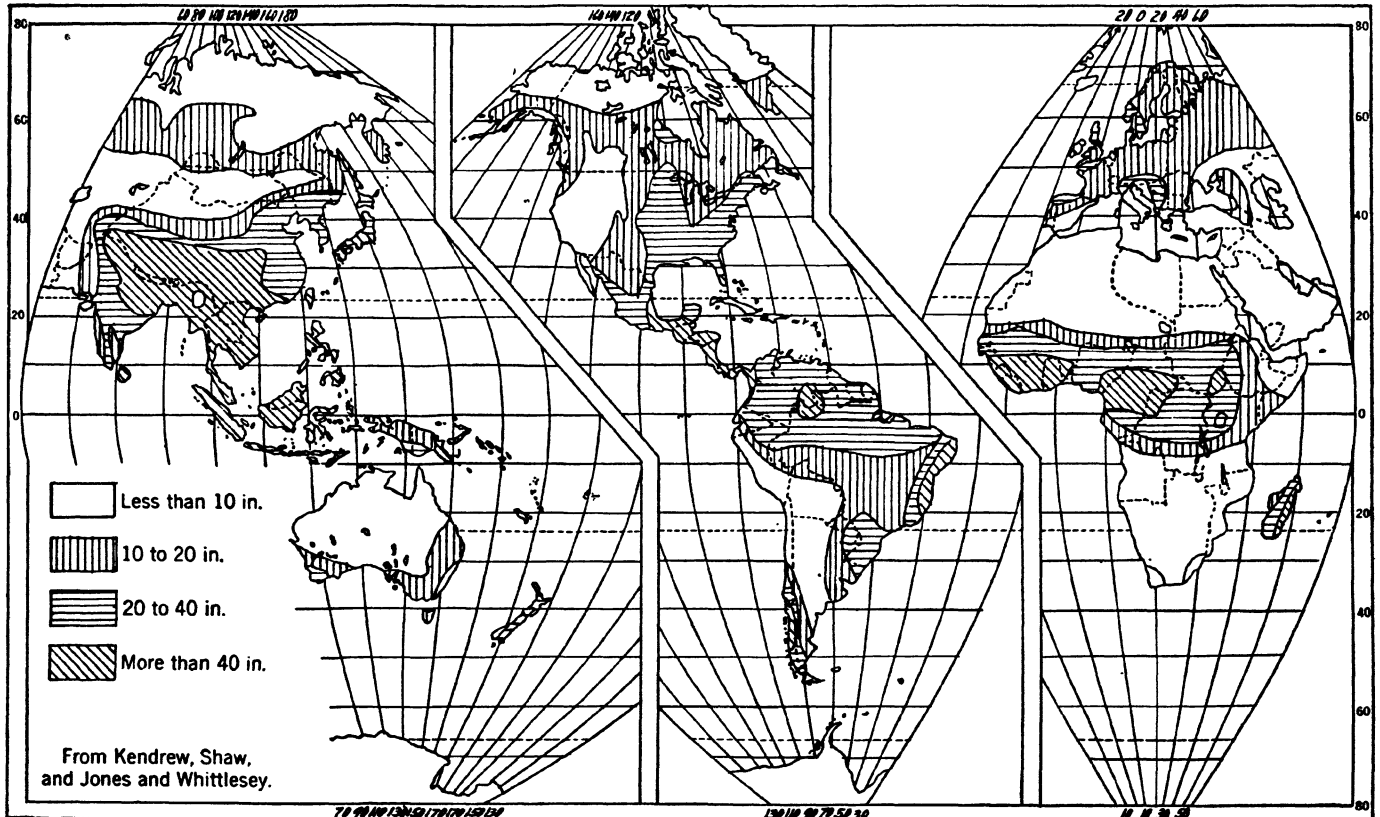


FIG. 28. MAP OF PRECIPITATION FOR MAY TO OCTOBER.

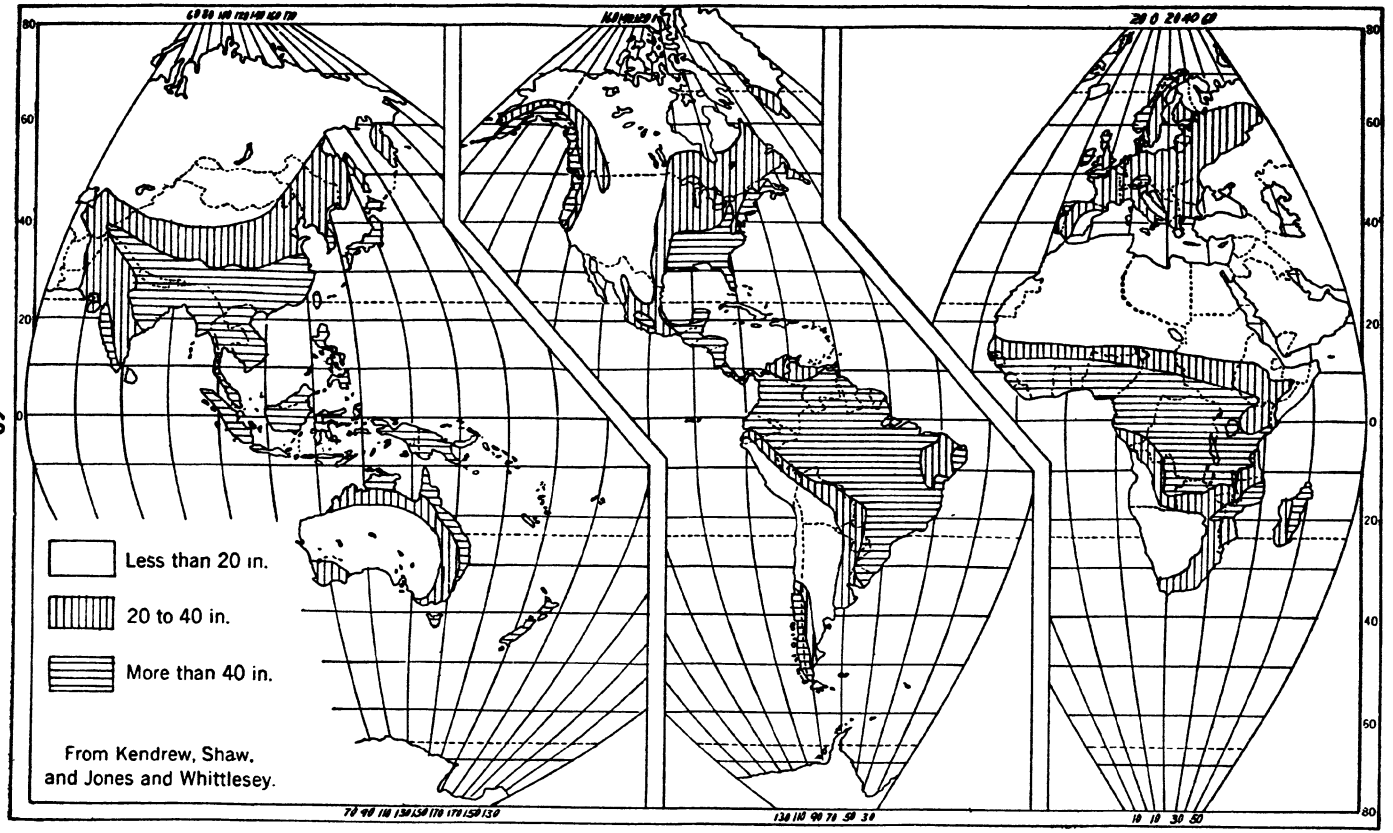


FIG. 29. MAP OF ANNUAL PRECIPITATION DISTRIBUTION.

night the clouds dissolve, and in the morning the sky is clear. The precipitation comes in the form of convectional showers. When the surface air is heated, it expands and is forced to rise by the cooler, heavier air above and around it. The air in rising is cooled. On a hot summer day, when surface heating is intense and condensation abundant, precipitation may be copious. There is essentially a vertical movement of warm, humid air, with rapid cooling, and the rainfall resulting is likely to be in the form of heavy showers. Convectional precipitation is usually associated with the warm season of the year and the warm hours of the day. In the middle and higher latitudes, convectional rain, occurring in the season of the year when plant growth is most active, is extremely important. Precipitation comes throughout the year, and the quantity is great.

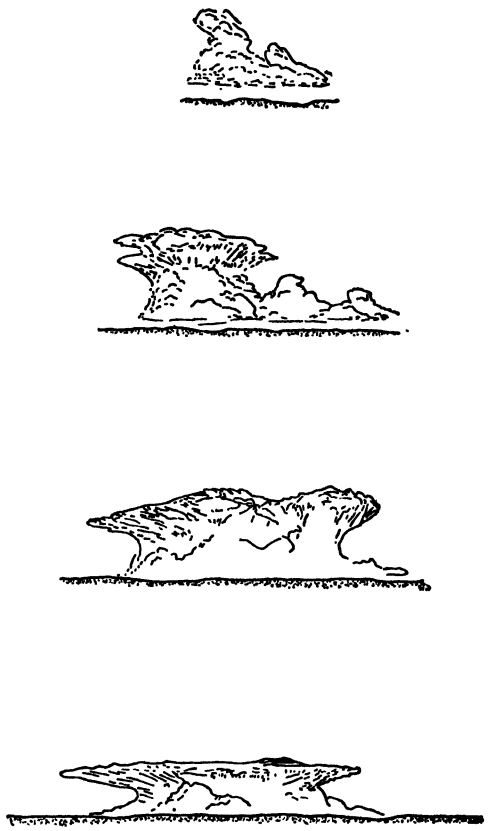


FIG. 30. PROCESS OF CONVECTIONAL SHOWER. Development from cumulus cloud to nimbus cloud.

In the trade wind zone the winds are being warmed as they blow equatorward, thus increasing their capacity for the water vapor. It is only where the trade winds blow against mountains and are cooled that precipitation occurs in this belt. Where these winds blow over land areas of slight to moderate elevation, they are picking up moisture rather than dropping it. Thus low latitude deserts are found in areas which have trade winds throughout the year.

In the belt of subtropical highs the air is descending. This air is

warmed by compression and becomes dry. In this region the sky is clear and the air is drier than in the trade wind belt.

The westerly winds, blowing on the poleward side of the belt of subtropical highs, are being cooled rather than warmed. It is in this belt that the cyclones and anticyclones, discussed in a later paragraph, are found. Abundant precipitation is found in the region except on leeward sides of mountains and in the interiors of larger continents. In the latter two cases less precipitation occurs because of the heating effect of the land mass or descending air currents.

In the polar regions precipitation is comparatively moderate. The annual amount is 10 to 15 inches. This is by reason of the small amount of water vapor in the air at the low temperatures of the region. The same number of degrees of cooling in a lower latitude would yield more moisture. A mass of air in the equatorial region cooled from 90° to 80° will yield about twenty times as much precipitation as air cooled from 0° to −10°. Much of the precipitation comes in the form of ice needles and snow.

Water vapor is in constant circulation in the air. The circuit which it makes is somewhat as follows: (a) It is evaporated from the ocean (and all moist surfaces); (b) as vapor it is diffused over the land, where some of it (c) is condensed and falls as rain or snow. Hence, the amount and distribution of precipitation bears a connection with some movement of the winds. The shift in the wind belt, as described in a previous paragraph, produces seasonal variations in many regions of the earth. The amount and seasonal distribution depends upon (a) the opportunity for moisture-bearing air to reach a place without serious loss of its moisture content and (b) the existence at a given time and place of the conditions for condensation. The facilities for the arrival of moisture-bearing air depend upon (a) the wind direction, (b) distance from the source of the water vapor, and (c) the relief of the land, for water vapor is limited to the lower layers of the air and decreases rapidly with elevation.

Cyclones and anticyclones

In the belt of westerlies there are frequent and irregular changes of weather. These changes are accounted for by the succession of traveling cyclones and anticyclones.

Cyclones are low-pressure areas, while *anticyclones* are high-pressure areas. Both are present throughout the entire belt of westerlies, and are shown on the daily weather maps by a series of enclosed concentric isobars. In the cyclone, the pressure increases outward from the center, while in an anticyclone the pressure decreases outward from the center. No definite pressure, in terms of barometric readings, distinguishes a cyclone from an anticyclone. They vary in size from those of thousands of miles in area, the largest, to those of a hundred miles in area

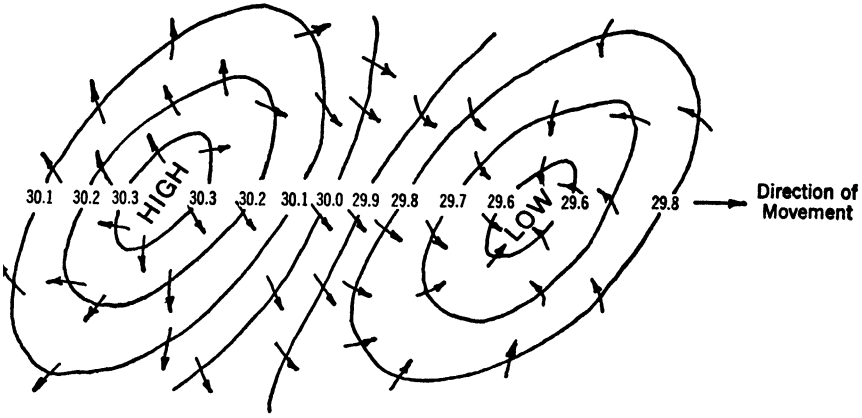


FIG. 31. SKETCH OF ANTICYCLONE AND CYCLONE.

or smaller. Generally anticyclones are larger by about one fourth than cyclones. They move in a general eastward direction with the westerly winds. Their rate of movement is variable, but they average about 20 miles an hour in summer and about 30 miles an hour in winter.

The wind direction, as in the general wind systems already discussed, is from high pressures to low pressures. The wind directions are given in Figure 31.

The air at the center of the low pressure area rises gradually, rather than rapidly, as in the tropics. The temperatures of cyclones and anticyclones are affected by the winds which blow from either warmer or cooler areas. The winds having a temperature acquired in a lower or higher latitude affect the temperature at a given place.

Thus far the cyclones and anticyclones have been discussed only from a pressure, temperature, and wind viewpoint, and that only at the surface. In the period since 1930, it has been recognized that cyclones

and anticyclones have vertical structure which may be of significance as great as or greater than the surface characteristics. A general discussion of the vertical structure will be given in the following paragraphs.

Air masses

The term *air mass* is applied to an extensive portion of the earth's atmosphere which approximates horizontal homogeneity. Whenever masses of air remain for some time over particular regions of considerable extent, they develop properties that are characteristic of the region, especially with regard to temperature and moisture. Over the Gulf of Mexico, for example, temperatures are high and the moisture content is large. A mass of air overlying this region will gradually acquire high temperatures and large moisture content; this change will take place first at and near the surface and then gradually in the intermediate and finally the upper levels, owing mainly to convection. On the other hand, in northwestern Canada in the winter season temperatures are low and humidity is low. These characteristics will be transmitted by turbulence to a mass of air overlying such a region. In the middle latitude zone, generally speaking, the uniformity of conditions and light air movement which must characterize a source region are lacking. Thus the basis of air mass classification must be the polar and tropical source types.

As a result there are polar and tropical air masses, and each of these may be classified according to the type of surface that gives it its characteristics. A brief classification affecting North America, and in the main the other continents as well, is:

Polar Continental ..... source area in region of ice and snow.
characteristics—dry and cold.

Polar Pacific ..... source area over open water.
characteristics—cool and saturated.

Tropical Marine ..... source area over region warm and moist (Gulf of Mexico and Atlantic Ocean).
characteristics—warm and saturated.

Tropical Pacific ..... source area in high altitudes over Pacific.
characteristics—cool to warm for its latitude; thin lower layer; fairly moist and dry in upper layers.

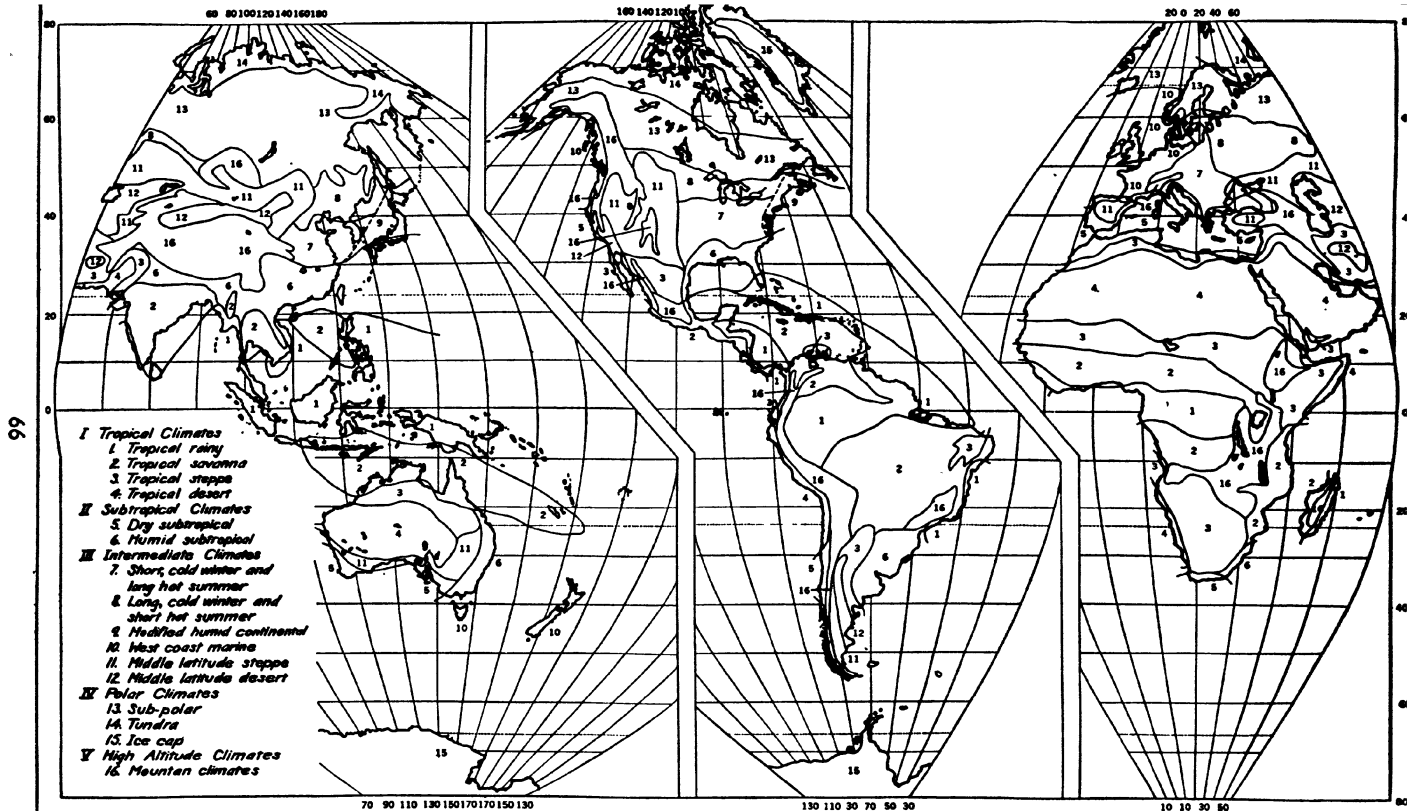
5

Types of Climates

THE average values of atmospheric conditions of a region constitute its *climate*. In the preceding chapter the elements out of which climates are composed were analyzed, and their distribution over the earth's surface described. Variations in the amount, intensity, and seasonal distribution of these elements result in varying combinations and give the reason for the different climates.

The most important climatic elements are temperature, precipitation, and wind. As it is impossible to describe the climate of every locality in the world, even if it were known, it is customary to class together certain large areas over which the climatic conditions are broadly similar. The earliest attempts of this kind, originating with the Greeks, considered only the divisions of the earth as theoretically determined by the distribution of sunshine. They divided the hemispheres into three broad belts or zones, which are commonly used today. The equatorial region or low latitude zone, the polar zone or the high latitude zone, and the middle latitude zone lying between the two are the divisions used here. Within each zone are types of climates. The zones consider only the element of temperature, while the types of climate include other climatic elements as well.

Within each of these three broad zones there is marked variation from place to place in seasonal temperatures, in the amount and distribution of precipitation, the direction and velocity of the wind, the relative humidity, and cloudiness. In the low latitude zone the variations are primarily in the amount and seasonal distribution of precipitation. In the middle latitude zone the differences in temperature are as significant as the contrasts in precipitation. In the high latitude



After Bengtson and Van Roye

FIG. 32. TYPES OF CLIMATES OF THE WORLD.

zone the difference in temperature from place to place is the important variant. Any portion of the earth over which climatic elements and the broad climatic characteristics are similar, not necessarily identical, is called a *climatic region*. These climatic regions are shown on the map, Figure 32.

Low latitude types of climate

The most striking thing about the climate of the low latitude zone is its uniformity of temperature. The weather does not change frequently, as in the middle latitudes. The uniformity of atmospheric conditions day after day, month after month, is so great that weather and climate are almost the same. Conclusions based on observations for a very few years are nearly as good as conclusions drawn from observations spread over many years.

The lack of great variation is due to the fact that, first, the sun is always nearly overhead, and, second, the length of day and night is always nearly the same. Consequently the amount of insolation never varies much from season to season. The diurnal range is greater, in many places, than the seasonal range. The highest temperatures, however, are not so great as are those experienced every summer in the middle latitudes. It is the monotonously high temperatures throughout which characterize the low latitude zone.

Rainfall and its effects are the basis on which different types of climates are determined in the low latitudes. There are four principal types: (1) tropical rainy, (2) tropical savanna, (3) tropical steppe, and (4) tropical desert. The modifications due to altitude give another type which may be called mountain climate.

Tropical rainy type of climate

The tropical rainy type of climate is a belt, irregular and somewhat interrupted, lying on both sides of the equator. The region is distinguished by its absence of seasonal variation, either in precipitation or temperature. Over most of the area the sun is nearly overhead throughout the year, and days and nights are nearly equal at all times. The interruptions in the boundaries are caused by mountains and plateaus, where the temperatures are lower. While the temperatures are high throughout the year, they do not reach the extremes found

in many other places. The average seasonal temperatures for the entire region are from 75° to 90°; in a given place the seasonal temperature range may not be more than five degrees. The slight average range is due in part to the position of the sun, and in part to cloudiness and precipitation. The diurnal range (the difference between the warmest and coolest part of the day) is usually 10° to 25°. Sensible temperatures are high; "sensible temperature" refers to the degree of heat or cold felt by the human body. Low temperatures seem lower and high

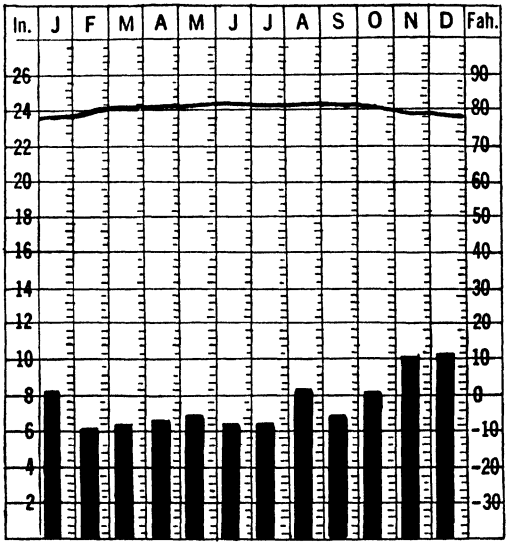


FIG. 33. CLIMATE GRAPH FOR SINGAPORE, STRAITS SETTLEMENT. For all climate graphs the curve represents the mean temperature and the vertical bars, rainfall.

temperatures seem higher when the relative humidity is high; moist air is a better conductor of heat than dry air. In the tropical rainy type of climate, the high sensible temperature is uncomfortable and debilitating. The graph, Figure 33, shows the seasonal range in temperature. The temperature-range graphs, showing not only temperature but precipitation as well, should be studied carefully. They represent a station within the type of climate and are considered typical; graphs from other stations, removed some distance, will show a variation but should be similar.

As the name, tropical rainy, indicates, the rainfall occurs throughout

all or most of the year, although some seasons may be rainier than others. The tropical rainy type of climate should be compared with the precipitation maps. Convectional showers occur almost daily during the warmer hours of the day. While there is no dry season in this type of climate, it must not be inferred that the rainfall is evenly distributed throughout the year. The climate graphs show the amount of precipitation as well as the distribution. At some places there may be two or four seasons: a wet season and a less wet season.

Such winds as occur are very light. Along some coasts of continents and on certain islands sea breezes make the areas more liveable than the continental interiors.

The combination of abundant rainfall, much sunshine, and persistent high temperatures promotes a dense growth of vegetation. There is no common period of flowering and fruitage for the flora, and no distinct season of leaf fall. In this region there is a complex aggregate of plants both as to species and as to forms. There are no solid stands of any one species of tree, typical of forests in higher latitudes; instead there are mixtures of many species of trees. In addition there is a variation in the forest itself. In some places the tree growth is so dense that there is little room for other vegetation, and in other places there is a maze of trees, vines, and shrubs. The vines are both epiphytes and parasites.

Change is rapid and continuous in both organic and inorganic substances, owing to the great amount of precipitation and high temperatures. Rock weathers rapidly, regardless of kind, and plant material undergoes rapid decomposition. The mineral plant food of one generation of plants is quickly available for the next generation of living plants. The roots of the trees are shallow and thus afford less protection for the underlying rock than in the higher and drier latitudes. Thus another factor is added to the rapid decomposition of rock material. The thin mud, always present under the root mass, moves down the slope under the force of gravity. These slides produce sharp ridges which are a characteristic feature of the landscape in the tropical rainy type of climate. The sliding of the surface and the leaching due to high precipitation leave a soil which generally is not high in mineral plant food.

Tropical savanna type of climate

The tropical savanna type of climate is similar to the previous type of climate in temperature, but differs in that it has marked seasonal alteration of rain and drought, and it usually has less total annual rainfall. Figure 34 shows these differences.

The tropical savanna climate lies on each side of the tropical rainy type, or, in general, between latitudes 5 and 15 degrees in both the

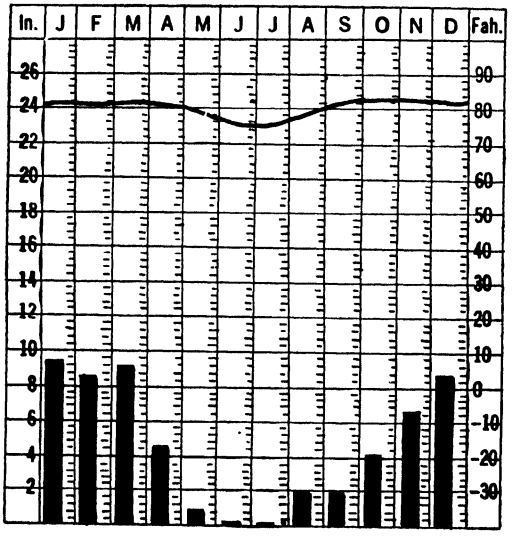


FIG. 34. CLIMATE GRAPH FOR CUYABA, BRAZIL.

Northern and Southern Hemispheres. This location is in the belt of doldrums part of the year and in the belt of trade winds the other part of the year. The student should examine the two graphs showing the winds over these areas, Figures 23 and 24. On the poleward margins the trade winds blow for a longer period than on the equatorward side.

High temperatures are the rule, as in the tropical rainy region, for the sun is nearly in the vertical position throughout the year. The difference in temperatures between the coolest month and the warmest month is generally a little greater than in the tropical rainy region; the difference is from 5 to 15°. The sensible temperature varies with

the seasons of rain; during the rainy season it may be as high as in the tropical rainy region.

Since the tropical savanna is a transitional zone, the amount of precipitation varies on its two margins, and the rainy season decreases progressively toward the poleward margin. The amount of precipitation is between 40 and 60 inches. The shifting of the doldrums and the trade winds determines the length of the rainy season. On the equatorward margin the season will be but slightly shorter than in the tropical rainy region. On the poleward margin the trade winds blow for a longer period of time, and, since the trade winds are drying winds, the amount of precipitation greatly decreases. It should be kept in mind that these boundaries are never lines but rather transitional zones. The beginning of the rainy season follows the high sun and the doldrums. The fluctuation in the amount of rainfall from year to year is greater toward the poleward margin; this fluctuation increases the hazards of getting a living. A year of too much rainfall may be followed by too little rainfall; excess and deficiency are common.

The flora reflects the amount of precipitation. On the rainy tropical side the flora is chiefly forest type; the trees are smaller and the stands less dense than in the rainy tropics. Beyond that will be found the mixed trees and tall grass. The trees are deciduous, losing their leaves during the dry season. On the poleward side, the flora is tall grass, which becomes withered during the dry season. The grassland with open, parklike deciduous trees (collectively called *savanna*) is, however, the characteristic vegetation of the region.

Since the region is exposed to variation in seasonal distribution and amount of precipitation, the weathering is different from that found in the tropical rainy type of climate. When exposed to the air, rocks crumble and fall apart in the same manner that wood rots and iron rusts. This decay and disintegration is called *weathering*. All changes that, like oxidation and carbonation, lead to the breaking up of the rock are phases of the general process of weathering, which include most of the natural, unobtrusive processes by which rock at or near the surface is caused to crumble. Weathering is the work of disintegration, decomposition, and solution, accomplished by rain and associated processes. *Erosion* is a comprehensive term denoting the sum of the processes of mechanical and chemical action by which rocks

are decomposed or worn away. By this process of wasting and washing, the land surface is slowly worn down and the deeper structures of the earth's surface are attacked. The chief eroding agents are rain, running water, wind, glaciers, wave action, and certain physical and organic processes. The topics of weathering and erosion are treated in greater detail in later chapters. In the tropical savanna region the ground dries out during the drought period and permits oxygen to penetrate deeply. Changes in temperature during the dry season permit mechanical weathering. When the first rains come, the ground is generally bare, so that a great amount of surface erosion takes place. The transportation of weathered rock by surface rills is more important in reducing the land surface than in the tropical rainy region. As the rains increase, the rivers become flooded; the surface waters carry large quantities of silt to these streams. As the streams overflow their banks, they deposit silt on the sides, or wherever the stream velocity is checked. As the rains decrease, the volume of the streams decreases, until they may become completely dry; that is especially true of the smaller streams.

Tropical steppe type of climate

The tropical steppes lie in a narrow belt just poleward from the tropical savanna type of climate. The tropical steppe region differs from the tropical desert in that it is encroached upon for a short period of the year by the doldrums. In that period, the seasonal rains make the region similar to that of the tropical rainy type, and differentiate it from the desert. The average monthly temperature for the warmest month and for the coolest month is about the same as that in the tropical savanna; the hottest season is just before the rains, and the coolest season comes when the sun's rays are most oblique.

During the high sun period, the tropical steppe region is characterized by light rains, mostly of the convectional type. The rains may be quite heavy while they last, but are meager in amount. The rainfall is variable and undependable, which makes the region more hazardous for human occupation than the desert region. In the desert there is never enough rainfall to tempt settlers to make an agricultural adjustment, except in the oases; in the steppe an occasional wet year may be sufficient to tempt inexperienced farmers. The graph shows the aver-

age rainfall for several years but does not give the variation from year to year.

The flora consists of low shrubs and grasses, with much bare ground showing. The grasses are mostly of the bunchy species, coarse stemmed, and of the varieties that grow quickly during the short rainy season. The shrubs are thorny, with small, leathery leaves, and adapted

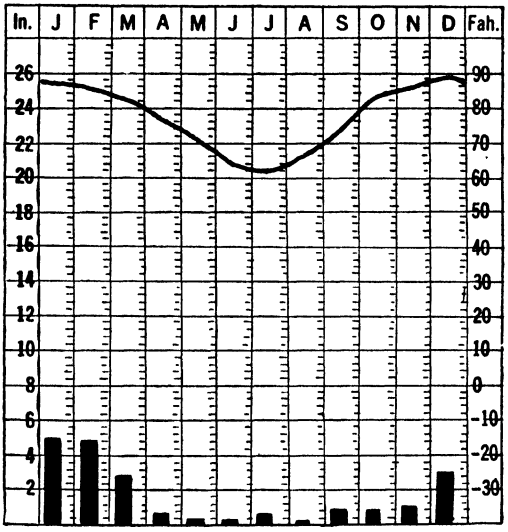


FIG. 35. CLIMATE GRAPH FOR CLONCURRY, AUSTRALIA.

to conserve moisture. The trees are found near water courses, where the water table is nearer the surface.

The steppe region has, usually, a cover of wind-laid material, since the steppes lie on the margin of still drier regions. The grass and shrubs act as a trap for the material that has been deposited. Thus a grass-covered region tends to have a smooth surface, because of the grass cover which can replace itself quickly if the surface is broken, and because of the deposits of wind-borne material.

Tropical desert

The climate map shows that large portions of the low latitude zone have deserts. These deserts lie on the poleward side of the low latitudes in the belt of trade winds throughout the year, and too far from the east coasts of the continents to receive any moisture which might

be dropped by the trade winds. The trade winds blowing toward the equator from a northerly and easterly direction drop some moisture on some eastern coasts where land elevations cause air to ascend and cool, but, in general, they are drying winds.

The difference in temperature between the average for the coolest and the average for the warmest month is 20° to 40° in the tropical desert, and greater than for any other type of climate in the low latitude zone. The diurnal range is usually larger, averaging 30° to 45°, and

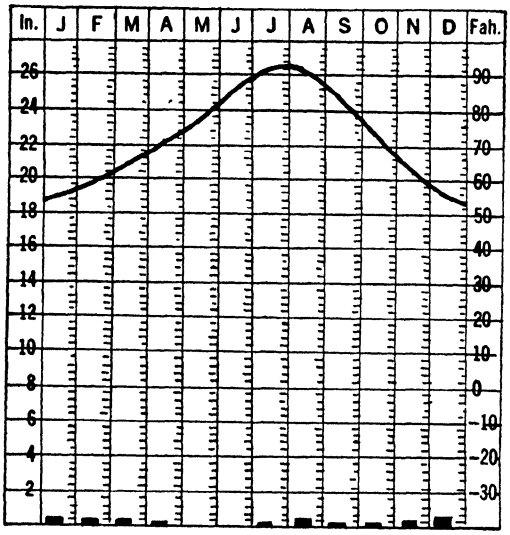


FIG. 36. CLIMATE GRAPH FOR YUMA, ARIZONA.

in some cases reaching 60° or 70°. These extremes—seasonal and diurnal—result from dry air, dry earth, and cloudless sky. Light frosts frequently occur, especially at moderate altitudes, 2,500 feet and higher.

The amount of precipitation is usually somewhere between 10 and 20 inches, and many deserts receive less than 5 inches. In the Atacama Desert, rain may not fall for five or ten years in succession. The rainfall is irregular and torrential in occurrence. The violence with which the rainfall comes often causes considerable damage to transportation routes, settlements, and irrigation systems. The precipitation which reaches the earth is quickly evaporated, and the run off is rapid, owing to the lack of vegetation. Some does sink into the ground and becomes a source of water for springs and wells.

All flora in the tropical deserts must be able to conserve and utilize moisture when it is available. The vegetation is sparse, leaving much bare ground between plants. The leaves are small, or thick skinned, so as to reduce evaporation. The root systems either are wide spreading, in order to reach out for water, or are of the tap root variety so as to go deep for water. Other species are able to store water within the plant itself. Some plants grow only after the showers; these ephemeral plants may be dormant for months and then after the shower they grow quickly to maturity, carpeting the desert with bright colored flowers.

Chemical weathering is not so important as in humid regions. Extremes in temperature within a short period of time are the most effective agents of mechanical weathering. The scant vegetation facilitates the movement of weathered particles by whatever forces are present. These forces are running water after the sudden and intense rains and wind which blows more freely than where vegetation hinders its movement. The temporary streams carry the debris into the nearest depression and deposit these weathered particles. Wind, being the principal agent, carries materials great distances and may leave deposits of considerable depth.

Middle latitude types of climates

The two middle latitude zones lie on either side of the low latitude zone. Variability is the distinguishing feature of the types of climate in these zones. In general, the variability is less in the Southern Hemisphere than in the Northern, because of the greater amount of ocean in comparison with land masses. The fundamental cause of variability lies in the fact that the sun is never overhead, and during at least part of the year it is many degrees below the zenith at noon. Accordingly, there are marked differences in the amount of heat received at different times, and the year is divided into seasons which vary in temperature. The westerly winds are not so regular in direction or velocity as the trade winds of the low latitudes, and the westerlies are frequently interrupted or modified by cyclonic storms.

In the middle latitude zone, weather and climate are entirely different. In summer the weather is frequently like that of the low latitudes. The temperature may show a regular rise and fall day after day,

and convectional showers may appear in the afternoons. In winter diurnal changes are frequently abrupt, for in winter the chief control of weather is the movement of cyclones and anticyclones and the greater movement of warm air masses from lower latitudes and of cold air masses from polar areas. Temperatures, accordingly, vary from day to day, from season to season, from year to year, and from place to place.

The variations in temperature are accompanied by variations in precipitation. There are two general types of seasonal precipitation in the middle latitude zones, the marine or winter type and the continental or summer type. In general, windward coasts have the winter type of rainfall, while interiors and leeward coasts have the summer type.

As already noted, the middle latitude zones have various types of climate. They are: (1) subtropical with rainy winters, (2) humid subtropical, (3) long hot summer, (4) short hot summer, (5) modified humid continental, (6) west coast marine, (7) middle latitude steppe, and (8) middle latitude desert.

Subtropical with rainy winter type of climate

The subtropical with rainy winter type of climate, which is often called "Mediterranean" because of its extensive development about the Mediterranean Sea, is located just poleward from the tropical zone and on the western sides of continents, and roughly between latitudes 30 and 40 degrees. The symmetrical arrangement of the climate types, so apparent in the low latitude zone, is equally characteristic in the middle and high latitude zones (see climatic map, Figure 32).

The summer average temperatures are between 70° and 80°, and usually the winter temperatures are between 40° and 50°. The diurnal range, in summer, is 30° or more; many places have a range of more than 60°. Clear skies and dry atmosphere are ideal for rapid and strong diurnal change. In winter, frosts may occur during the three months, but they rarely are severe. The diurnal range, in winter, is about 15° to 20°. The prevalence of cyclones and anticyclones in winter causes the temperatures, during that season, to be less regular than in summer.

The annual rainfall varies considerably in different places in the region, but 15 to 25 inches is a fair average. The amount varies considerably with latitude, altitude, and proximity to the ocean. All or

nearly all of the rain falls in the cool season, generally in the form of short, heavy showers. Except on the northern borders, snow is almost unknown and remains on the ground only a few hours on the rare occasions when it does fall.

During the summer there is a definite period of drought. The seasonal alternation of drought and rain results from the latitudinal shifting of the wind belts with the sun's rays.

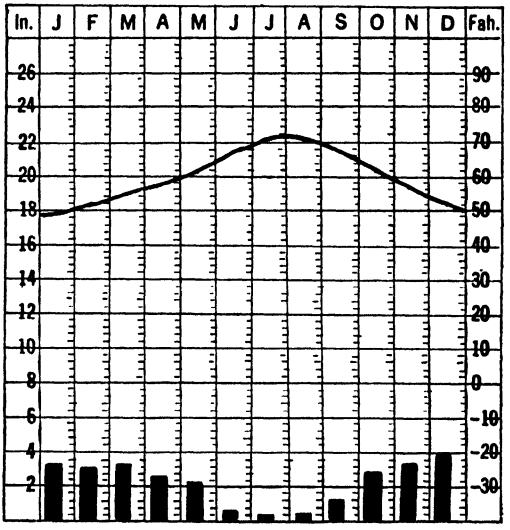


FIG. 37. CLIMATE GRAPH FOR LISBON, PORTUGAL.

During the winter months the westerlies blow from the oceans over the regions which have lower temperatures than the waters. The influence of the westerlies is stronger on the poleward side of the region; thus the poleward sides receive more precipitation than the equatorward margins. During the summer months the sun's rays have shifted poleward; the belt of westerly winds also shifts with, but lags behind, the sun's rays; and the belt of calms or trade winds replaces the belt of westerlies (see maps of wind directions, Figures 23 and 24). The result is the drought of the summer months.

The native vegetation must be able to withstand the drought of the summer months and be able to grow when the temperature is lowest for the year. Spring and fall are the periods of greatest plant growth; in the spring the plants grow before the soil has lost its moisture, and

in the fall they grow before the temperatures get too low. Annuals grow during the rainy season only. The perennials have adapted themselves to withstand the summer drought. Their characteristics are similar to those of plants found in arid and semiarid regions. During the mild winter, a certain amount of plant growth is possible. Trees grow in depressions in which water is within reach of their roots. On the uplands the typical vegetation is *scrub,* known in California as the *chaparral.*

Alternate drought and moisture permit chemical and, to a more limited extent, mechanical weathering. During the summer, the air is able to penetrate deeply, and during the winter the moisture penetrates to a corresponding depth. Chemical action is active to considerable depths. The heavy rains carry the weathered particles to lower slopes, leaving the harder and more resistant rocks standing out as prominent features.

Humid subtropical type of climate

The humid subtropical type of climate shares the same latitudes as the dry subtropics but lies on the east sides of the continents. The continental influence becomes noticeable. The climate differs from the region just described: the precipitation is heavier, the precipitation is greater in summer than in winter, and there is no dry season.

While the average temperatures of the two subtropical regions are similar, the humid subtropics have more extreme and sudden changes than the west coasts. The temperature on the eastern side is not affected to the same extent by winds from the oceans. The average summer temperatures are about 75° to 80°, while winter temperatures average between 40° and 55°. The diurnal range in summer is about 15° to 20°, about half that on the west coast. This difference in diurnal range is due more to the cooler nights on the west coast than to temperatures in the daytime. The winter diurnal range is usually a few degrees greater. In both winter and summer, but especially in summer, the relative humidity is high. The relative humidity in conjunction with high temperatures gives a higher sensible temperature in the humid subtropics than the subtropics on the west coast. In winter the lowest temperatures occur during the rainy days; the lower temperatures accompanied by the higher relative humidity give a low sen-

sible temperature. Freezing temperatures may occur throughout the entire region and many times during the winter. This greater frequency of freezing weather is due to cold air masses that descend into the middle latitudes, where they are swept on as a phase of the westerlies. The eastern coasts of the Southern Hemisphere do not have frosts as frquently as those of the Northern. In the Southern Hemisphere there are no broad land masses in the higher latitudes from which cold winds blow to lower latitudes.

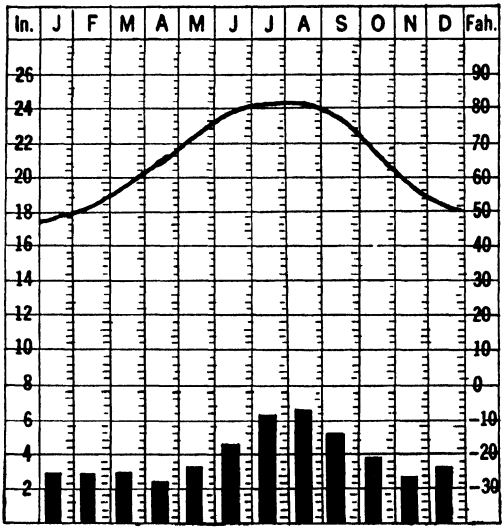


FIG. 38. CLIMATE GRAPH FOR CHARLESTON, SOUTH CAROLINA.

The amount of precipitation varies between 25 and 65 inches, depending upon the location within the region; the amount is well distributed throughout the year. Snowfall may occur every winter away from the coast; along the coast the snow generally melts before reaching the ground, and it falls then as rain. In winter, this region is in the belt of westerlies and cyclones and anticyclones. The passing of the cyclones brings the winter quota of rain. In summer, the latitudinal shifting of the belt of westerlies, as explained for the previous region, brings monsoon-like conditions. The region, especially in the northern continents, becomes a large low-pressure area into which the winds blow. These winds are moisture laden, since they blow from large bodies of water. The result is convectional rain in place of the cyclonic

drizzles in winter. The rainfall, in summer, is torrential, and as much as an inch or more may fall in an hour. While the summer is the rainier season, the high evaporation rate reduces the amount of effective precipitation. Effective precipitation is the difference between precipitation and evaporation. The streams have their period of high water in winter or spring rather than in summer. During the latter part of the summer, tropical hurricanes occasionally reach the coasts, causing considerable damage. In winter the "norther" brings sharp temperature drops of as much as 30 or more degrees in a few hours.

The natural vegetation consists, mainly, of broad-leafed evergreen, broad-leafed deciduous, coniferous trees, and tall grass. The variety of trees, while great, is not so large as that found in the tropical rainy region, for the trees must adapt themselves to the winter period. On the other hand, stands of particular species are common, in contrast to the tropical forests.

Weathering, while similar to that in the tropical rainy regions, differs largely because of the differences in temperature in winter. The vegetable matter on and in the soil, while not so great in quantity as in the tropical forests, is decomposed rapidly. The torrential rains remove much decomposed rock and vegetable matter, especially in areas that have been cleared. Chemical weathering prevails because of high temperatures together with high precipitation in summer. The trees, having deeper root systems than in the tropical forests, protect the underlying rock to a greater extent, thus giving greater selective weathering. The result is that the land is not so monotonous as in the tropical rainy regions, but instead conforms more to the relative resistance of the rocks to weathering.

The long hot summer type of climate

The types of climate in the middle latitude zone which are to be described differ from those discussed in that they have longer frost seasons, colder winters, and greater annual ranges in temperature. The first, the long hot summer type, is located poleward from the humid subtropics and limited to the Northern Hemisphere. The smaller land areas in the latitudes occupied by this type of climate give a greater oceanic influence in the Southern Hemisphere. A similar situation is found in the Northern Hemisphere in Iceland.

The average summer temperatures are about 75° to 80°. Much higher daily temperatures are recorded; the daily maximum may reach 105° or more. The high relative humidity in the daytime gives sultry, oppressive days, and with high absolute humidity at night, cooling is very slow, so that the nights are often uncomfortably warm. The summers are long, the frost-free period being 150 to 200 days. The winters have relatively cold weather, the average monthly temperatures being

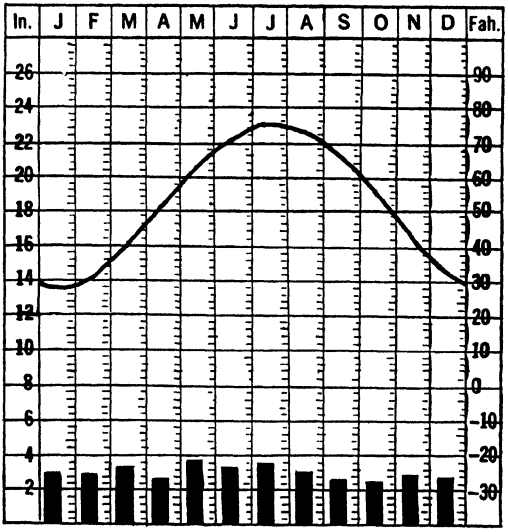


FIG. 39. CLIMATE GRAPH FOR COLUMBUS, OHIO.

about 20° to 25°. But the average monthly temperature for winter is of little value, for changes of weather are sudden and emphatic. For periods of days or weeks the winters may be as cold as those in the high latitudes; temperatures of –20° or lower may be recorded. A fall of ten or more degrees may take place within an hour. Rises in temperature may be as sudden and as great. Diurnal changes in winter are greater than in summer, and the seasonal range is greater than the daily normal range in temperature. The average diurnal range for July is from 10° to 15°, while for January it is from 20° to 30°.

The precipitation comes chiefly in the summer months, but the winter months are not dry. The amount, while not great, varies from place to place within the region. On the drier margin the amount is about 20 inches and increases from that to about 45 inches. The

amount also varies considerably from year to year. Since most of the precipitation falls during the warmer months, the amount is more effective for crop production than if it occurred chiefly in the cooler months. In winter, most of the precipitation takes the form of snow; nevertheless, rain is likely to fall every month of the year. In summer, much of the precipitation may be of the convectional type, and is frequently accompanied by thunderstorms.

This type of climate is continental and lies in the belt of westerlies throughout the year. Continental types of climate, in general, are characterized by marked differences in temperature from winter to summer and by changeable weather from day to day. These peculiarities are due partly to the rapidity with which land masses become heated and lose their heat, and partly to the influence of cyclonic storms and polar and tropical air masses. Land masses tend to be more extreme than sea expanses in seasonal range of temperature. Therefore continental interiors are likely to have greater range in temperature than the sea borders of the continents. Continental types of climate are found especially in the interiors of North America and Eurasia. With the movement of the cyclones and anticyclones, the wind directions are extremely variable. Velocities are greater in winter than in summer, and weather changes are more frequent in winter. Each change in wind direction, owing to the cyclones and anticyclones, brings its own distinctive weather conditions. The most violent wind storm in the United States is the tornado, which, while covering only a narrow area, causes considerable property damage.

The flora varies from open grassland in the drier parts to deciduous forests in the sections with more rain. Many solid stands of species are found, for the increased severity of temperature eliminates many varieties. The deciduous trees shed their leaves during the winter, which is the drier period, and thus are able to conserve moisture, for the naked branches can transpire very little water. In the coniferous forests, the large crowns prevent sunlight from passing through to the ground, and in such areas little ground vegetation is able to grow. In the deciduous forests, the herbaceous plants are able to grow in that short period in the spring before the leaves of the trees exclude the light.

The weathering process is nearly negligible in winter, because of the low temperatures and the correspondingly low evaporation rate.

Where drainage is poor, as in depressions, vegetable matter may accumulate from year to year, and, becoming saturated with water, form bogs. In places where the evaporation rate is low, the bogs may extend up the slopes. In the forested areas, the humus accumulates and the solutions from the humus carry chemical decomposition into the lower strata. The chemical weathering reduces the lime and other soluble contents.

The short hot summer type of climate

The short hot summer type of climate lies just poleward of the previous region. While this type of climate resembles the long hot summer type, it represents the more severe phase and makes human adjustments unlike for the two climatic regions.

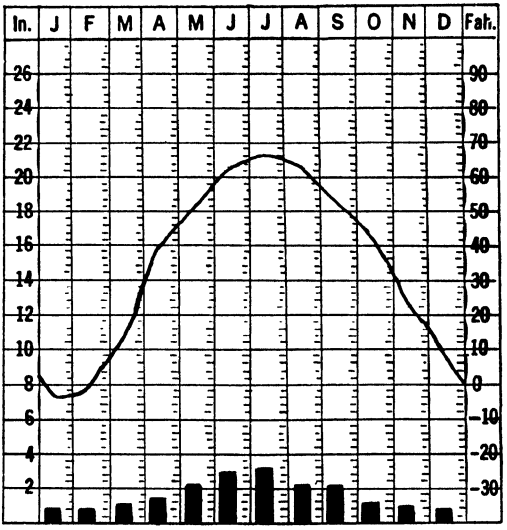


FIG. 40. CLIMATE GRAPH FOR WINNIPEG, CANADA.

The temperatures are lower in the northern region, and the growing season is about 120 days. While extremely hot days may be as high as those of the long summer type, duration of the hot period is much shorter; the cold waves in winter are of a longer period, and temperatures may drop to -40°. The summer average temperatures range from 65° to 70°, and the minimum average temperatures of winter range from a -2° to 15°.

As in the previous region, the precipitation occurs throughout the year, with the minimum amount in the winter months. The total amount is less. With lower temperatures and therefore a lower evaporation rate, a greater amount of this precipitation is available for crops and flora. Also, a greater amount comes during the growing season than in the longer summer climate. In winter, the precipitation occurs as snow. While the total amount of snow is not great, most of it remains on the ground until spring, thus adding to the amount available for plants. The low relative humidity keeps the sensible temperature from falling as low as might be expected.

The winds are similar to the previous type of climate. Tornadoes are rare, and blizzards are frequent.

The flora resembles that of the long summer type of climate, since climatic conditions are similar. The arrangement of forests and grasslands is similar. In the forested areas, the trees are a coniferous type instead of being mixed deciduous. The trees are slow growing, and their size is smaller than in the forested areas to the south.

Modified humid continental type of climate

The modified humid continental type of climate lies on the eastern sides of the continents between latitudes 35 and 50 degrees in North America and Asia. This type of climate is a modification of the two climates just discussed, for there is a marine influence not felt in the first two types. Since the marine influence is great in the next two types to be described, it is well to review at this time the marine-influenced climates.

The fundamental reason for the marine influence is that land heats and cools more rapidly than water. There are several reasons for this: (a) the specific heat of water is higher than that of the land, (b) water reflects more heat than land, (c) water, being transparent, is heated to greater depths, (d) there is a continuous motion of the various layers of the water, transferring the heat from one part to another, and (e) the greater evaporation on water produces a cooling effect. As the winds blow from water bodies, they transfer the temperatures over the water to the land.

The seasonal range of temperatures is much less in the modified humid continental climate than in the long summer and short summer

types. While winters are about as cold, the summers are greatly modified. The springs as well as the autumns are later. The average January temperature is approximately 21°, and the average July temperature is about 60°.

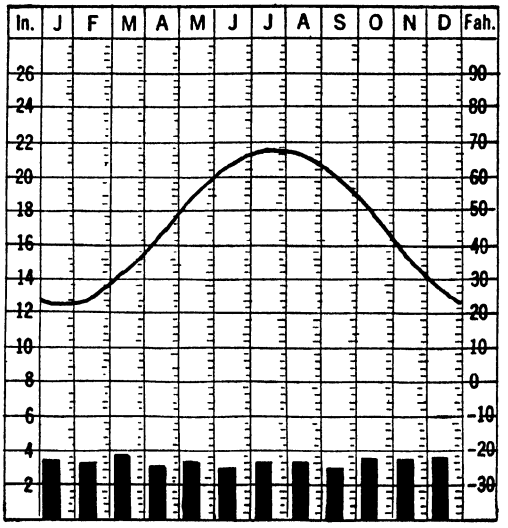


FIG. 41. CLIMATE GRAPH FOR PORTLAND, MAINE.

Precipitation is considerably heavier than that in the long summer and short summer types of climate. In winter, the precipitation takes the form of snow; snowfall may be 80 or more inches and may remain on the ground throughout the winter. Generally the seasonal distribution of precipitation is more even throughout the year than in the continental types of climate. Cloudiness is common throughout the year.

The region lies in the belt of westerlies and is crossed by cyclones and anticyclones. In summer, many of the winds blow from the ocean, thereby modifying summer temperatures. The summer rains usually fall in gentle showers. Tornadoes are rare, and blizzards are unknown (*blizzards* are snow driven by high winds). While temperatures do not reach the same height as in the interior of the continent, the sensible temperatures are relatively high in summer and low in winter.

The flora responds to the lower temperature and the large amount of precipitation. The natural vegetation is similar to that of the short

summer type in the more humid parts; it is of the forest type, with coniferous trees and some deciduous broad-leaved trees along the southern margin. The original forest cover is heavy, and the trees are slow-growing varieties.

The west coast marine type of climate

The west coast marine type of climate is confined to the windward coasts above the 40th parallel. These regions are influenced by pre-

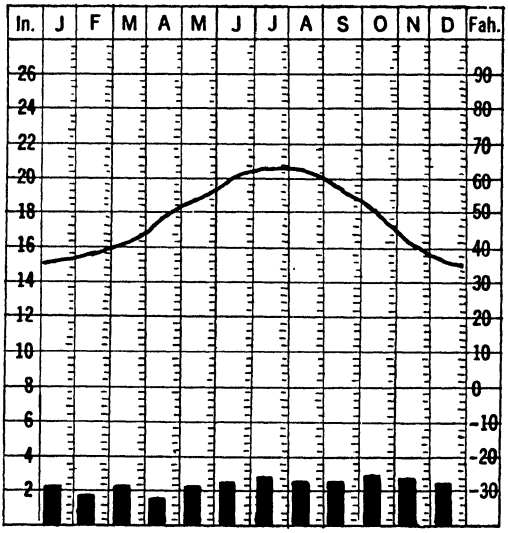


FIG. 42. CLIMATE GRAPH FOR LILLE, FRANCE

vailing westerly winds blowing continuously from ocean to land. The transition from the subtropical climate, lying equatorward, is very gradual. The transition to the continental climates, lying eastward, is gradual or abrupt, depending upon the absence or presence of mountain barriers.

Seasonal variations in temperature are less than for places lying in the same latitude. A comparison of climatic graphs clearly reveals this point. The average July temperature ranges from 60° to 65°, while the January average ranges from 35° to 45°. The summer diurnal range is about 20°, while the winter diurnal range is 10°. Prevailing cloudy skies in winter reduce the day-to-night range of temperature.

Precipitation varies considerably from place to place within the region. Those places which are more exposed to the westerly winds, with higher latitude, or with higher altitude, receive a greater amount of precipitation. The amount of precipitation varies from 33 to 120 inches per year. The precipitation occurs at all months of the year; while the amount varies from month to month, there is no season of the year in which rain does not fall. The maximum amount falls in the winter months. Snowfall, while common on the near-by mountains, is extremely rare in the lowlands. When snow does fall, it melts in a day or two. Humidity is high throughout the year, and it is cloudy 60 to 70 per cent of the time. Fog and mist are other characteristics. Along some of these coasts, fogs may prevail for days or even weeks continuously.

The region is influenced by the westerlies; the passing of the lows causes a continual shift in wind direction and velocity. Changeable weather is the rule.

The flora consists or consisted of heavy stands of timber. In Europe the trees have been cut to clear the land for farms, while in the Western Hemisphere and New Zealand much of the original forest still remains. In the United States, large tracts have been cleared, while in Canada and Alaska little of the timber has been cut. While the forested areas are extensive, the variety of trees is not great.

Owing to the continuous supply of water in the soil and in the surface rocks there is a constant store of ground water. Chemical weathering is the rule, and the movement of the ground water into the streams carries with it the soluble particles. The roots of the trees are deep, and the decomposed surface layers of organic and inorganic material are not removed by erosion; consequently chemical weathering is deep.

Middle latitude steppe type of climate

The steppe type of climate in the middle latitudes lies on the leeward sides of mountains and adjacent to the humid regions. This type of climate has very irregular boundaries, owing to the arrangement and position of the mountains on the continent.

Temperatures vary with latitude and with altitude, and because of the extent of the type of climate, it is difficult to give a general average figure for the region. Temperature averages for January range from

12° to 44°, and those for July range from 60° to 80°. The frost-free period ranges from about four to eight months. The diurnal range is extreme. The winds, as given in the discussion for cyclones and anticyclones, blow from all directions in a relatively short period of time. Wind velocities are high as compared with most humid regions. Blizzards, chinook winds, and "northers" are usual winter occurrences.

In precipitation, these lands are intermediate between the humid areas and deserts. In some years the precipitation may be as high as

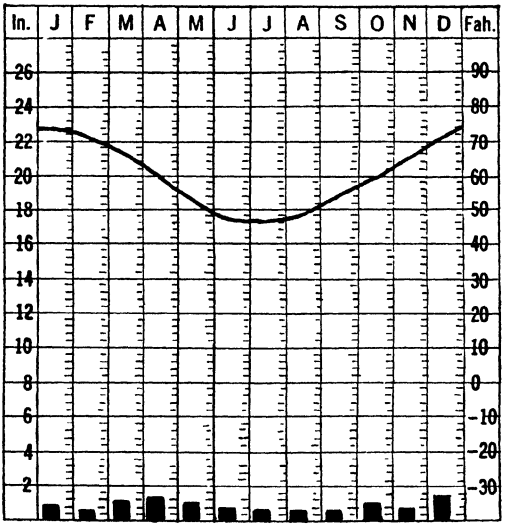


FIG. 43. CLIMATE GRAPH FOR PATAGONES, ARGENTINA.

in parts of the humid regions, and in others it may be as low as that in the deserts. The rainfall is favorably distributed, for the maximum comes in the late spring and early summer, just when vegetation needs it most. The winter precipitation comes in the form of snow, which protects and furnishes moisture for the vegetation cover. The annual precipitation varies from 6 to 20 inches. The variability in the amount of the precipitation is most critical for crops, and is the rule rather than the exception.

The lands which have the middle latitude steppe type of climate are grasslands. Where streams cut through grassy regions, the water table, both in the bottoms of valleys and on their sides, stands nearer the surface, and thereby provides opportunity for tree growth. Toward the

drier parts, the sod breaks up into bunch-grass cover. The transition in amount of precipitation determines the vegetation type, from short grass to bunch grass.

The erosion varies with the amount of precipitation received. In areas where there is more grass cover, the roots tend to hold the soil in place. Since grass grows quickly, and since roots are shallow, the erosion which does take place is quickly covered over by the growth of grass cover. Therefore, there is a monotony of surface. In those sections where the grass is further apart, the surface is more exposed to washing and blowing. Much of the steppe region is the recipient of materials blown from more arid regions; this wind-blown material is called *loess*. Some areas in the steppe region have a thick mantle of loess. Winds which blow over the steppe region are less interrupted than those in any other section of the world.

Middle latitude desert region

The middle latitude deserts are similar to the tropical deserts but not identical. They lie on the drier margins of the middle latitude steppe

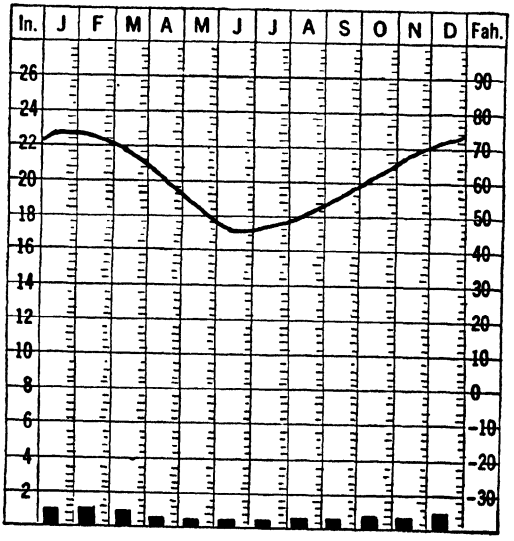


FIG. 44. CLIMATE GRAPH FOR MENDOZA, ARGENTINA.

region; generally their location is on the immediate leeward sides of mountains and in the interior of continents.

The temperature conditions are similar to those discussed for the steppe region. Their lower relative humidity gives them more clear days than occur in the steppe region. The amount of precipitation varies from less than 6 inches to 10 inches. The rain comes in the form of thundershowers, infrequent, and erratic in distribution.

The streams which flow through the region have received their water from humid country, for the streams which arise within the region are intermittent and disappear by evaporation or by sinking below the surface. Many streams lose much of their volume by evaporation in flowing through. The evaporation rate is always high because of the sparse vegetation. The movement of ground water from below the surface to the surface brings with it many soluble minerals, which are deposited on the surface; since the run off is negligible, these minerals accumulate. The strong heating of the ground by day and strong cooling at night weather materials at a rapid rate. The wind, being unimpeded by vegetation, picks up the weathered materials; together the temperature changes and wind continue the weathering process. Mechanical weathering becomes particularly significant in all desert regions.

High latitude zone

In the high latitude zone the sun is above the horizon for more than 24 consecutive hours, and below the horizon for a similar period, once each year. The period of continuous sun is shorter near the equatorward margins of this zone than near the poles. During the period of continuous light, insolation is greater in polar regions than in low latitudes, but the temperatures of the air are not raised accordingly, because (a) the sun's rays are very oblique, and (b) much of the heat which reaches the surface melts the ice and snow and is not effective in warming the air. The result is low temperatures for the year. There are three types of climate within this zone. They are (1) subpolar, (2) tundra, and (3) ice cap.

Subpolar type of climate

In the Northern Hemisphere, the subpolar type of climate extends in a long irregular shape and lies in a nonlittoral position. This type is the extreme in continental climates. The summer period is less than

three months, and for a few weeks during the summer the daylight is almost continuous.

The mean July temperature is about 60°; temperature averages above 50° occur for only about three or four months. Light frosts may occur any night even during these summer months. During the winter, for at least four months, the mean temperatures are below freezing; the average for January is about 10° below. The extremes in temperature range from 90° to -60°. Spring and autumn are of very short

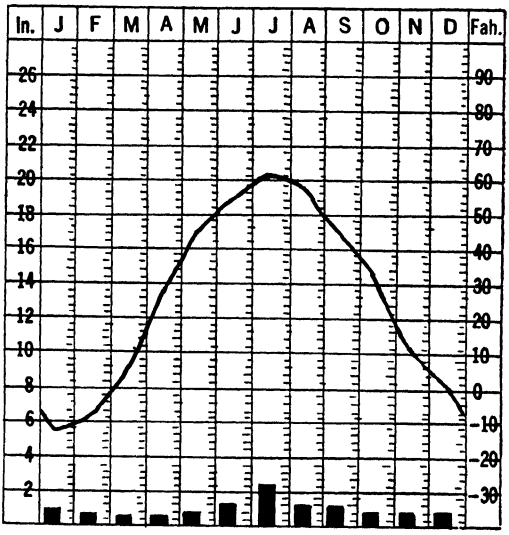


FIG. 45. CLIMATE GRAPH FOR FORT CHIPEWYAN, CANADA.

duration. Since the air is dry, the sensible temperature is not so low as might be expected, even with a low thermometer reading. Greater extremes in temperature occur in Siberia than in Canada, for the land mass is greater in the Eastern than the Western Hemisphere.

The maximum precipitation occurs during the summer months; the amount is 20 inches or slightly less. While the amount is not great, it is sufficient for vegetation, for the greater amount of the rain comes during the summer months, the evaporation rate is low, and the melting snows from the previous winter add to the amount available for plants.

The flora is generally the coniferous forest type. The forest stand varies from north to south; in the southern part the trees are larger and

fairly dense, whereas at the northern margin they are small and scattered. The chief commercial use of these trees at present is for pulp.

The tundra type of climate

The tundra type of climate lies along the borders of the Arctic Ocean of North America and Eurasia. In the Southern Hemisphere, only the fringe of the continent of Antarctica and some of the small islands have this type of climate.

The average temperature for July is only slightly above 40°, and the January average is about -20°. The summer period is short, with

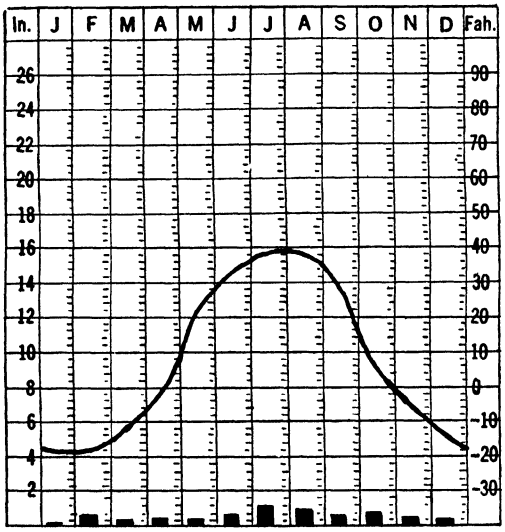


FIG. 46. CLIMATE GRAPH FOR POINT BARROW, ALASKA.

almost continuous sunshine. The autumns and springs are extremely short. In winter, in the northern parts, the sun does not shine for weeks. The precipitation is not more than 10 or 12 inches. While the amount is low, it is effective, since the rate of evaporation is also low.

The ground is frozen most of the year. During the short summer, the surface thaws out; the depth to which it thaws varies with latitude. In the Aleutian Islands it may thaw to a depth of 12 to 16 inches, while at Point Barrow it is only 4 to 6 inches. Below the surface layers, the ground is frozen at all times. Mosses, lichens, and flowering plants are

the predominant type of flora. The dry cold air of the region greatly increases the evaporation of water from plants. Plants, even though dormant, are killed by this excessive evaporation. The height to which perennial plants grow depends, in this region, upon the depth of snow to protect them from evaporation of water.

Chemical weathering is reduced to a minimum, except where the water is able to drain in the summertime and the sun is able to raise the temperature of the dry soil. Mechanical weathering, on the other hand, is more excessive than in any other climatic region in the world. Water fills all the available cracks, and the freezing action permits weathering throughout a large part of the year. Rocks are broken down into fragments and are only slightly changed by chemical weathering. With the lower layers frozen at all times of the year, and with the upper layers thawed out in summer, there is a considerable amount of movement of the upper layers down the slope. The lower frozen layers provide a smooth surface for the sliding. The alternate freezing and thawing of water in the weathered material, saturated when above the freezing point, produces mass movement of the rock waste down slopes under gravity. Such movement is called *solifluction.* The frozen earth at a slight depth prevents the escape of water below and provides a smooth gliding surface. The roots of plants are never deep in the tundra, and thus there is no binding effect to retard the sliding of the upper layers.

The ice cap type of climate

The ice cap type of climate is located where the temperatures are never above freezing. The actual amount of precipitation is not known; such observations as have been made indicate that all falls in the form of snow. The amount that falls accumulates from year to year, since the evaporation rate is low and the runoff is negligible. The snow accumulates into snow fields, and they in turn become ice fields and glaciers. The glaciers move into warmer areas or into the sea, where they melt, and thereby dispose of the surplus moisture. The glaciers, in their progress, carry rock fragments and perform the work normally accomplished by streams and wind in other climate regions. Frost weathering disintegrates such rock surfaces as project above the snow.

Influence of weather and climate

The importance of climate as an element of the natural environment is evident. Plants, animals, and human activities may be roughly subdivided into classes in accordance with the climate of the place they occupy. The trees of the tropics are unlike those of the polar zone or even of the middle latitudes. The topography of various areas is different, the soil and water supply are different, and the social and economic activities are not the same. In some types of climate it is easier for human beings to make a living than in others. The easier it is to make a living, the more *favorable* the climate. The favorableness depends upon temperature, rainfall, growing season, amount of sunshine, and wind. In some cases, an unfavorable factor may be remedied, as, for instance, irrigation is used to overcome aridity.

One fundamental cause of trade is difference in production. An inability to produce certain commodities creates a demand, and the ability to produce certain other products creates a surplus. This production is determined, in the case of agriculture, by weather and climate. Thus the largest amount of trade, national and international, is fundamentally dependent upon climate.

It is not to be assumed that climate is the only factor in influencing the economic and social adjustments of a region. While it is important and can be more readily seen than some of the others, it is only one factor. Others will be discussed in the succeeding chapters.

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6

Introduction to Major Land Forms

LAND forms have been an important factor in determining the history and development of the human race. They permit man to engage in certain activities, and they forbid his successfully undertaking others. By influencing the type and extent of human pursuits they constitute a factor in the distribution and density of population.

Land forms were among the earliest elements of the environment to be noted as having an influence on human activities. It was observed that people living in different land forms had different economic occupations, social structures, and political organizations. The plainsman had his distinctive customs, and the mountaineer his. Primitive man, in seeking to explain these differences, took little account of differing conditions of environment and frequently formulated myths and legends as an explanation.

Economic pressure produced by population density has long and often caused man to seek new regions which offered greater opportunities. When some region could no longer supply the demands of the whole group, it became necessary for a part of the group to migrate to new fields. New opportunities were sought in places the topography of which was similar to the one they had left; the mountaineer attempted a new start in a mountain region, the plainsman in a plains area, and the man from the hills in a hill country. Only occasionally was a new start made in a different type of land form. Adjustment to an entirely new environment involves experimentation with unfamiliar conditions. The possibility of success in an environment not tested is less than in one similar to that already known.

Such a change to a new locality, motivated by social, political, or

economic pressure, might be made by small groups or whole tribes. Once the migration was set in motion, the direction as well as the immediate route that was taken was influenced by the nature of the land surface.

The features of the earth's surface not only directed the course of the migration but also were instrumental in determining the ultimate distribution of the population. High elevations, steep slopes, and rough terrain form natural barriers that hinder the progress of a migration or deflect its course. These barriers, or the absence of them, influence the extent and the pattern of settlement in any area.

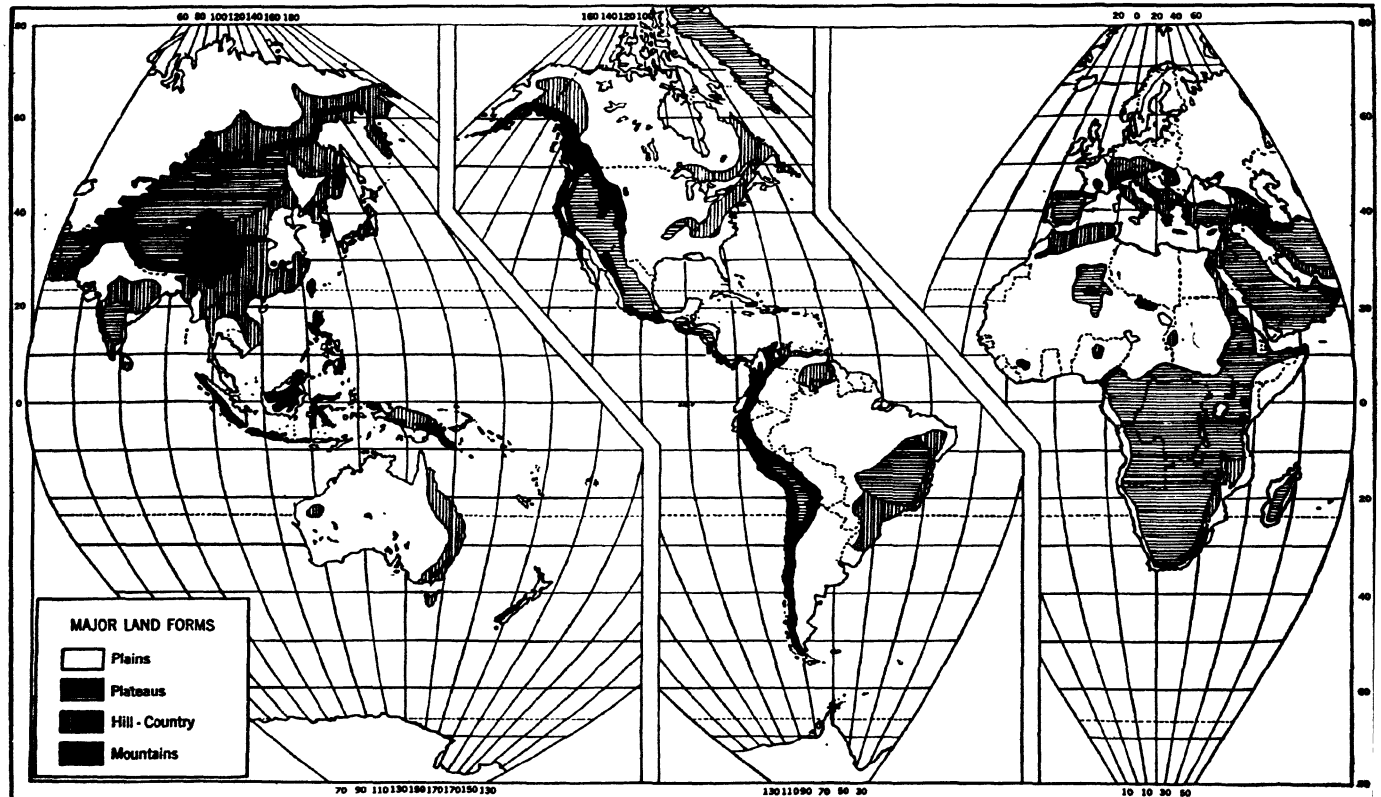
Extremes in land forms are effective means of segregating groups of people. The effect of such segregation is the development of strongly marked national characteristics; Nepal and Afghanistan are specific illustrations of this effect. An area that is isolated because of restrictive land forms produces a more homogeneous population than an area having no such natural barriers. As long as these barriers are not changed by improved means of transportation, they retain their power of isolation; examples are to be found in Andorra and in the Kentucky mountains. Any large plain facilitates the influx of new peoples and produces a mixed population.

The four types of major land forms are (a) mountains, (b) hill-country, (c) plains, and (d) plateaus.

From the viewpoint of geography the basis for classifying these four types of land forms is (1) the proportion of slope and (2) the relief. *Relief* is the difference in elevation between high and low altitudes of an area. These two factors in turn determine the use which can be made of each of the land forms. The combination of relief and proportion of slope determines, also, the type of land form into which a given area may be classified.

Mountains

The term *mountain* is used in regard to a region that has more slope than flat land and of which the relief is a thousand feet or more. Gorges, peaks, ridges, steep slopes, cliffs, and a variety of other scenic features characterize the mountains. Such land forms impose severe handicaps upon human use as well as restrict communication between people living on either side of the mountains. Mountains produce ex-



From Jones and Whittlesey and others

FIG. 47. MAJOR LAND FORMS OF THE WORLD.

tremes in climate on the windward and leeward sides and bring great climatic changes within the mountains as compared with the surrounding lowlands. Because of the difficulty of transportation, the passes assume an importance in directing the routes of communication. The greater the mountain barrier, the greater the significance of mountain passes. Cirques, water gaps, wind gaps, snow fields, and glaciers are all features to be found in mountains.

Plateaus

Plateaus are those regions which have relief similar to that of mountains but which have more flat land than steep slope. Plateaus, like mountains, impose many restrictions upon human occupance and on communication between areas lying on either side of such land forms. In contrast, these restrictions are less severe for communication on the plateau itself than on the mountain itself. In many cases the climate is different on the leeward from that on the windward side. Extremes of climate are not so pronounced as those found in mountains. Human activities may be similar to those of the mountain areas.

Hill-country

Hill-country includes areas which have a relief of five to six hundred feet or less, with more slope than flat land. The population pattern will be similar to that found in mountains, with most of the people living in valleys. The roads and railroads generally follow river beds and declivities. The human use varies with the population density in the immediate plains; the denser such population, the greater the use which will be made of the hill-country. The problems of communication and of getting a livelihood are less severe than in mountains and not so easy as in plains. The type of cultural features found in mountains may predominate.

Plains

Low relief with more flat than slope characterizes *plains.* Restrictions on communication and utilization are not imposed by this land form. Such restrictions as are found are produced by other elements—climate, soil, rivers, or something other than the land form. Most of the world's population is located on plains, and most development has

taken place there. Most of the large urban settlements are found on this type of land form. Nearly all forms of economic activities can be found on plains. However, there are but few inorganic minerals and little water power.

7

Mountains

MOUNTAINS are those major land forms which have slight summit area and considerable relief. The term "considerable relief" has been variously defined by writers on the subject in geography, but the one which meets with most approval is 600 to 1,000 feet or more. Such a definition immediately removes those minor land forms which are conspicuous in an otherwise featureless region and are called "mountains" by local people. Thus the term "mountain" is general and includes a great many phrases which are frequently loosely used. Some of the more common phrases are cordillera, system, ridge, peak, range, interior basin, park, pass, and alp.

Mountains consist of an uninterrupted series of elevations and depressions. If these elevations are rounded or dome shaped, they are called *domes.* If they are conical, they are commonly called *mountain peaks* or *mounts;* examples include Pikes Peak and Mount Rainier. Such single elevations may represent harder rock which is more resistant to the forces of erosion. When elevations, instead of being more or less isolated, are elongated, they are referred to as *ridges.* Between the ridges may be many depressions called *valleys,* and in the ridge may be a low place known as a *pass.*

A group of mountain forms including ridges, valleys, and peaks is known as a *mountain range.* At times the term *mountain chain* is used as synonymous with "mountain range." A *mountain system* consists of a series of mountain ranges. A *cordillera* is a group of mountain systems. To illustrate: Provo Peak and Clayton Peak, together with other peaks, ridges, and valleys, make up the Wasatch Mountain Range (Salt Lake, Utah, Topographic Quadrangle). San Pitch Moun-

tains, Wasatch Mountains, and various other ranges form the Rocky Mountain System. The cordillera of western United States includes the following systems: Rocky Mountains, Sierra Nevada, Cascades, Basin Ranges, and Coast Range. Many other illustrations can be given.

There are many types of valleys and variations within the types. Some of these variations have been classified and given specific names. The areas between ridges may be so extensive that they have become a major land form—plateaus. Or they may be smaller than plateaus, and, if they have no drainage outlet to the sea, they are called *interior basins.* Small interior basins are known as *parks. Alps* are grass-covered slopes above the tree line or pastures on mountain spurs or in hanging valleys.

Areal distribution

The map, Figure 47, on page 98 gives the areal distribution of mountains on the various continents.

In Asia the mountains have a latitudinal trend. The highest of these, the Himalayas, have also the greatest elevation in the world. The southern slopes of the Himalayas rise abruptly from the plains; to the north there are many branch ranges in this mountain system. The Himalayas have such famous peaks as Everest (29,002 feet), Kinchinjunga (28,826 feet), and Dhaulagiri (26,826 feet). The Karakorum chain, reinforcing the Himalayas on the northwest, extends in a southwestern direction. This continuous wall of mountain and plateaus makes a complete break with the lowlands of southern Asia. The only passes are from 3,373 feet in altitude, as the Khyber Pass, to 18,000 feet, as the Karakorum Pass. All of the passes have had a significant part in the migrations of peoples throughout all history. In the northern part of Asia are the Khingan Mountains and a series of short ranges along the Manchurian border; the Thian Shan, Great Altai, and Sayan Mountains are the most important in the Manchurian border series.

In Europe the mountains at present are interrupted. At one time they were continuous and presented an uninterrupted barrier between north and south Europe, but, chiefly as a result of erosion, they have

become a series of shorter and discontinuous ranges. In northern Spain are the Pyrenees, rising to an elevation of over 11,000 feet and forming a barrier between Spain and the rest of Europe. To the east are the Alps, which rise near the Mediterranean Sea; they curve northward and then eastward and consist of slightly broken mountain chains. The highest peak is Mount Blanc, 15,781 feet. Near Vienna the system divides into two branches encircling the Hungarian Plains; the two branches form the Carpathian Mountains, the Dinaric Alps, the Balkan Range, and the Transylvania Alps. The Caucasus Mountains on the

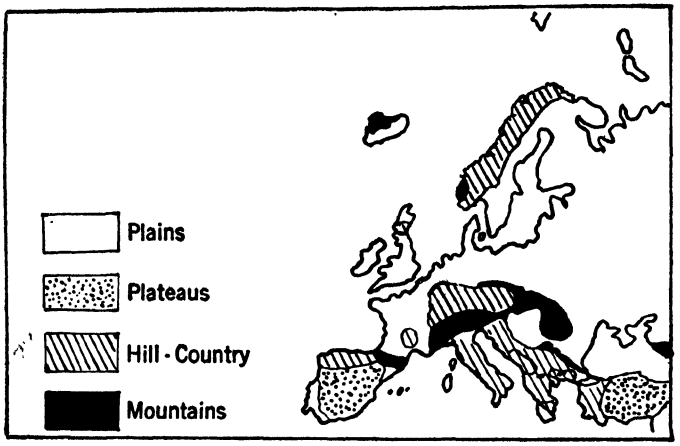


FIG. 48. LAND FORMS OF EUROPE.

southern boundary of Europe are higher than any of the interior systems; Mt. Elbruz and twelve other peaks are over 16,000 feet.

In Africa the mountains are superimposed on the rim of the plateau. They are of irregular height and size, and the ranges are short and discontinuous. In the north are the Atlas Mountains bordering the Sahara Desert; Jebel Ayashin rises to an elevation of 14,000 feet. Along the eastern side of Africa is a discontinuous chain of mountains of volcanic origin. In this group are the Ruwenzori Mountains, a snow-clad range lying across the equator. In South Africa the plateau is rimmed by the Drakensburg Mountains and the Lebombo Mountains. Other smaller ranges rise along the edge of the plateau in central Africa.

The main mountain feature of Australia is the Great Dividing Range, which runs close to and parallel with the eastern coast in the south. The greatest altitude reached by this range is Mount Kosciusko, which has an elevation of 7,323 feet.

In South America the gigantic Andes front the western side of the continent for a distance of 4,000 miles. At the north they consist of

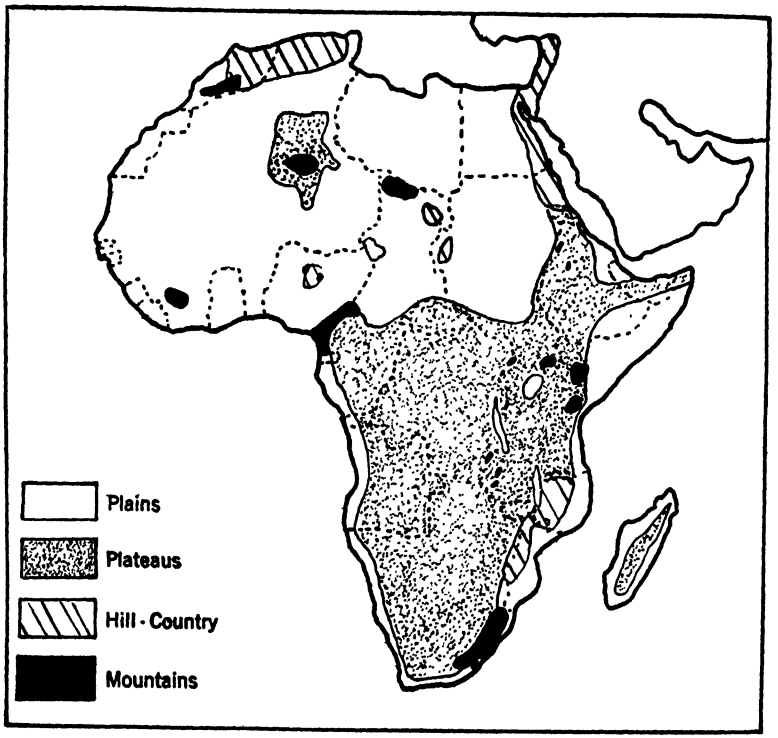


FIG. 49. LAND FORMS OF AFRICA.

three ranges and narrow to a single chain to the south and decline in elevation toward the southern end of the continent. Their loftiest peaks include Mt. Aconcagua (22,867 feet), Mt. Sajama (22,349 feet), Mercedario (22,302 feet), and Huascarán (21,812 feet). These peaks are surpassed only by the Himalayas. Other peaks are volcanic cones such as Chimborazo (20,702 feet), Cotopaxi (19,550 feet), and Misti (20,013 feet).

The main mountain system of North America parallels the western side of the continent. This western cordillera includes the Rocky Mountains, the Selkirks, Cascades, Sierra Nevada, and Sierra Madre. The highest point is Mount McKinley in Alaska, with 20,300 feet.

The mountains on various islands which are on a continental shelf near the continents may be considered as extensions of the mountain system on the mainland. Those mountainous islands lying off the continental shelf are usually volcanic cones.

Classification of mountains

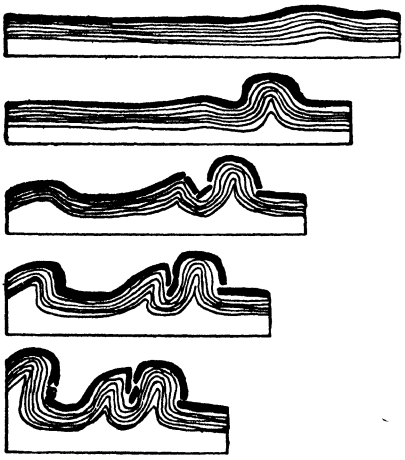
Figure 47 shows mountains and other irregularities on the land surface. Generally speaking, these irregularities were probably caused by loss of heat from the interior of the earth and have been formed during geological time. The loss of heat has caused the outer surface of the earth to go through many contractions and expansions, thereby causing irregularities, including mountains. The various changes in and below the earth's surface have resulted in different kinds of mountains and may be used as a basis for classifying mountains. Any classification is subject to dispute, but the simpler and generally accepted classification includes (1) tectonic and (2) subsequent groups. *Tectonic* mountains are those which have resulted from the action of forces within the earth that have had a notable influence on the surface itself. Under the tectonic group are deformation—folded, faulted, and laccolith—and the accumulation mountains. *Subsequent* mountains are the result of erosion of other major land forms into mountains. We can make the following outline of types of mountains:

I. Tectonic.
    1. deformation.
        a. folded.
        b. faulted.
        c. laccolith.
    2. accumulation.
II. Subsequent.

Folded Mountains. Folded mountains are the most common and therefore the most important. Mountains of this type vary among themselves; some are highly complicated by many faults while others

are simple and symmetrical. In most cases, though, the present topography is the result of erosion on the original folding. The Jura Mountains are examples of folded mountains. (Folding can be illustrated by Figure 50.)

If moldable material is placed in a vice and then laterally compressed, the result is an excellent imitation of rock folds. If, instead of pressure from only two sides, pressure should be applied to four sides, or if additional compression were applied after the initial folding, then complexly folded mountains could be illustrated. Figures 51 and 52 show examples of simple and complex folded mountains.



After U. S. Geol. Survey.

FIG. 50. EXPERIMENT TO SHOW FOLDING IN MOUNTAIN RANGES.

Block Mountains. Block mountains or faulted mountains are the result of faulting on the earth's surface. A plain or a plateau may develop great vertical cracks, producing a series of great blocks which are displaced upward or downward. The edges of these blocks may then form the ridges of mountains. These ridges may result from the



After U. S. Geol. Survey.

FIG. 51. OPEN SYMMETRICAL FOLDS IN THE APPALACHIAN MOUNTAINS.

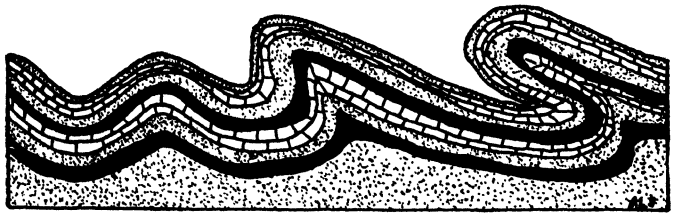
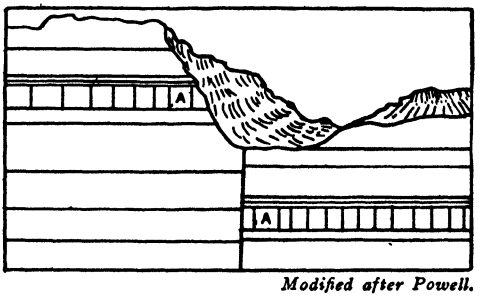


FIG. 52. COMPLEX FOLDING.

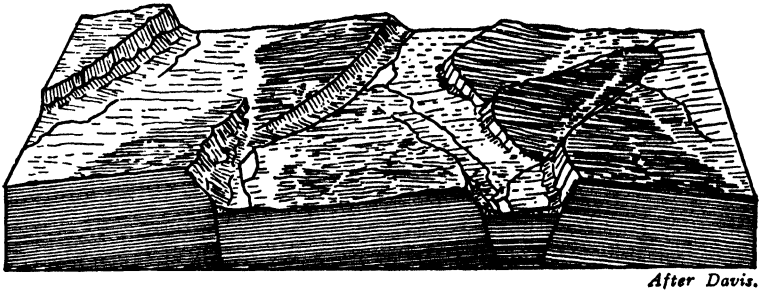
sinking of the land adjacent to the edge of the block or to an uplift of the block itself, or both. Oregon and Nevada have many block mountains.



Modified after Powell.

FIG. 53. DIAGRAM OF A NORMAL FAULT. Layer A–A shows the amount of displacement on the two sides of the fault plane.

Laccolith Mountains. A third type of tectonic deformation is the laccolith mountain. Most of the lava (liquid rock) which has been forced up from great depths probably never reaches the surface but instead solidifies underground. If a large mass of magma is intruded between strata, it may raise a part of the overlying layers to form a dome called a *laccolith,* a lake of rock. The molten rock rising toward the surface came in contact with strata of such a nature that, instead of breaking through, the lava lifted the overlying rock, producing intrusion instead of volcanic overflow. Thus,



After Davis.

FIG. 54. BLOCK MOUNTAINS.

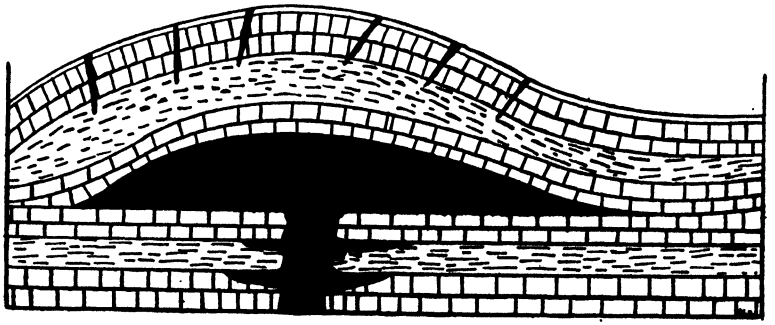
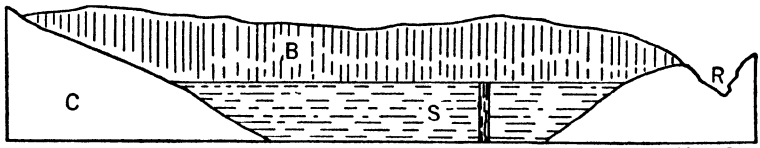


FIG. 55. DIAGRAM OF A LACCOLITH.

instead of material being added on the surface, a great reservoir o lava was thrust into the strata. The Uinta and the Henry Mountain in Utah are examples of this type.

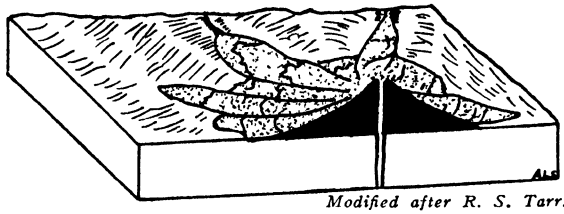
Accumulation Mountains. The second type of tectonic mountain are those formed by accumulation. The lava may flow out on th surface or at times solid rock may be thrown on the surface. The roc material usually is built into mounds or cones or even high mountains



After Lee.

FIG. 56. CROSS-SECTION OF A THICK FISSURE ERUPTION OF BASALT AT WILLIAMS CANYON ARIZONA. The lava is 800 feet thick in the middle. C, crystalline rocks; S, sand and grave B, basalt; R, river.

These cones resulting from volcanic activity are called *volcanoes,* an the hollow from which the rock material comes is known as a *crater.*



Modified after R. S. Tarr.

FIG. 57. DIAGRAM OF VOLCANO AND ITS LAVA FLOW.

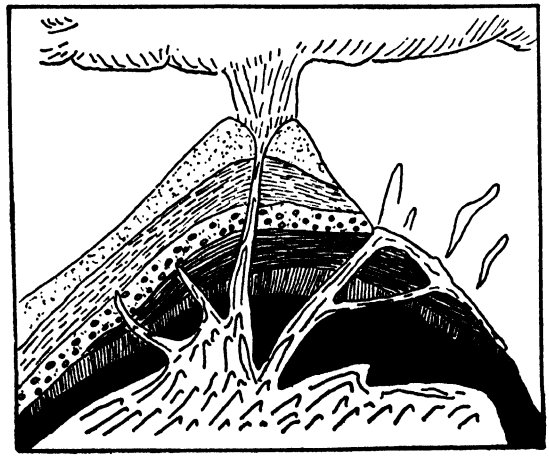


FIG. 58. DIAGRAMMATIC CROSS-SECTION OF A VOLCANO.

If the material is lava, the slopes are generally more gradual; solid rock produces steeper slopes. The solid material may have been liquid in the beginning of its eruption but was solidified either before it was shot out or during its flight in the air. If the materials are minute particles of dust, commonly called volcanic ash, they may be carried considerable distances, since they are light enough to be carried by the wind. The heavier particles and liquid, on the other hand, will come to rest near the vent. All rocks formed by the consolidation of lavas are *igneous* rocks.

Some volcanic cones make mountains of great size, such as Mount Rainier, Mount Shasta, Orizaba, Fujiyama, and others. Volcanic cones

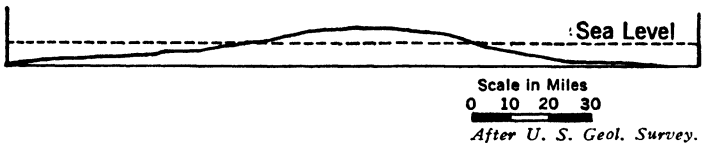


FIG. 59. PROFILE OF THE CONE OF MAUNA LOA. Vertical scale same as horizontal scale.

are more numerous than active cones. The Hawaiian Islands were formed from the accumulation of lava on the surface.

Subsequent Mountains. No portion of the earth's surface can escape erosion. Erosion is always greatest along stream courses, and, as the streams cut their way downward, larger and larger rock surfaces are exposed. This material is either worn down into smaller particles in the river itself or else carried away by the river, or both. Gradually valleys are formed which become deeper and broader as erosion continues. The erosional process takes place during the period of uplift, or accumulation of material on the surface, as well as later.

Thus what was formerly a plateau may be so modified by erosion that a new major land form, a mountain, may be created. That is, the work

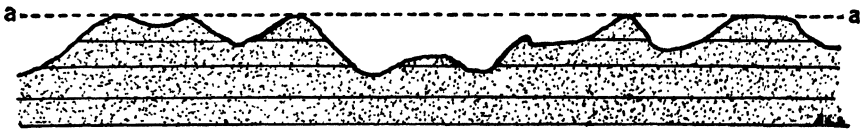


FIG. 60. SUBSEQUENT MOUNTAINS CARVED OUT OF A PLATEAU OF ACCUMULATION. a–a, original surface of plateau.

of stream erosion may so deeply carve the former plateau that it loses its plateau characteristics and becomes instead a mountain area. This change is wholly the result of denudation. This type of mountain is

not the result of tectonic forces but is subsequent to the former land form. Subsequent mountains depend upon characteristics and arrangement of the materials out of which they have been formed and the eroding agent.

Life history of mountains

Mountains are formed, in one way or another, by tectonic forces. During the formative period they rise faster than the agents of erosion can act. Some parts are elevated higher than others, and the result is the formation of ridges and ranges with valleys in between. During this same period there may be a general uplift without disturbing the folding or faulting or other processes of mountain building. If the latter occurs, it may produce a plateau with mountains superimposed upon it.

The various agents of degradation are more effective in mountains than on land surfaces, which are less rugged and have less elevation. Erosion by mechanical processes is more rapid in mountains than on plains, because of their steep slopes. Streams in mountains are, as a rule, more rapid and make deep valleys. Rapid erosion promptly removes the weathered rock; accumulation of mantle rock is not so great as where erosion is less rapid. Bare rock is common. Low temperatures restrict vegetation growth, and absence of flora allows running water and wind to remove weathered rock. Extreme diurnal changes make rock breaking most effective.

In general there is a great amount of precipitation in mountains; the larger proportion is in the form of snow. The running water from the melting snow has the same effect as heavy rainfall. On the whole, erosion is more rapid in mountains than in other land forms.

However, the deposition of sediment is relatively less in mountains than on plains, because of the steep slopes and swift streams. Much of the debris which falls or is carried down steep slopes is temporarily lodged at the base. The material that accumulates at the bases of cliffs by the fall of rock fragments loosened by weathering is known as *talus*. Talus consists of angular pieces of rock, varying in size from minute bits to larger blocks, which have broken off from the cliff above.

Young mountains are characterized by steep slopes, gorge-like valleys, peaks, and rugged ridges. In time the forces of denudation become

more active than the forces of construction. Denudation operates here, as on all other land forms, to broaden the valleys, lessen the slopes of the valley walls, reduce the slopes of the valley bottoms, and remove the interstream areas. Thus the elevation of the mountain is diminished and the ridges and peaks are lowered. The lowering may continue until the former mountain is reduced to the level condition of a plain. A land form, whether a mountain or any other, worn down to the moderate slopes of the old-age stage is a *peneplain.* The surface of the former mountain reduced to a peneplain swings up and down, and

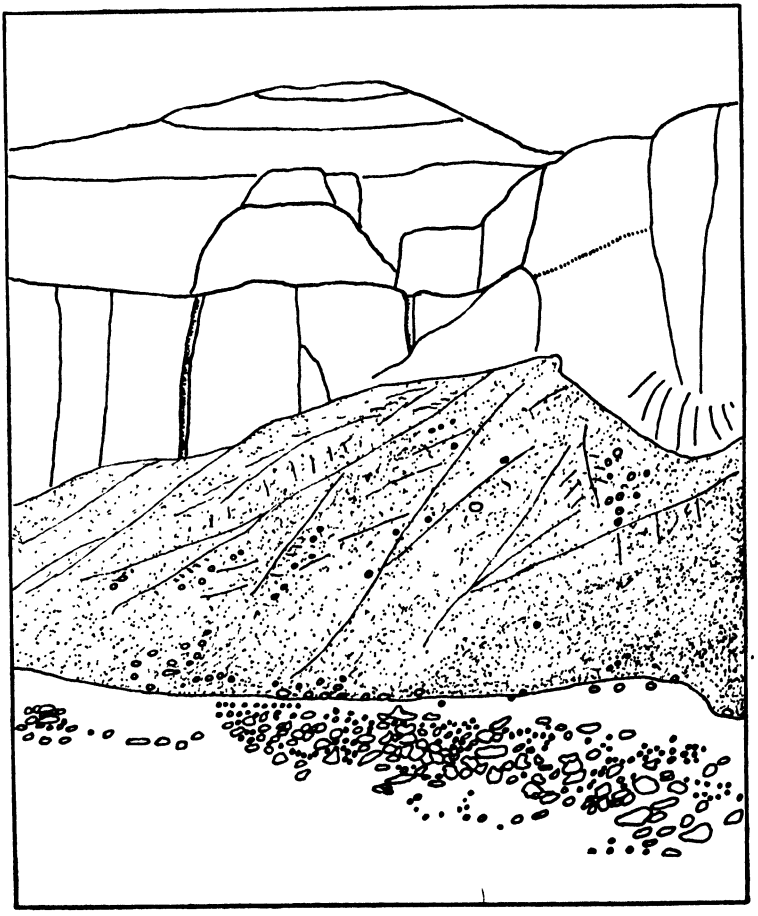


FIG. 61. SKETCH OF TALUS SLOPE.

the more resistant layers mark the low swells. Examples in the United States of the peneplain stage are in the Lake Superior region and the Piedmont section from Washington, D. C., to Boston, Massachusetts. The Appalachian Mountains are an example of a peneplain which again went through an uplift and is now in the second stage of being reduced to a peneplain.

In summary, during the uplift stage of mountains, denudation is most active and young mountains are rugged. Mature mountains have been lowered and valleys broadened; old mountains are lowered still further, and may in time be reduced to a peneplain. Then a mountain region may be rejuvenated and start on a new cycle.

Climate in mountains

Mountains have a profound effect upon climate and especially the climatic elements of temperature and precipitation. Temperature in mountains is a direct reflection of latitude and altitude. When air rises, it expands and cools. The ascending current is moving from a lower altitude, where the atmospheric pressure is greater, to a higher altitude, where the pressure is less. The cooling resulting from expansion of the air in rising is known as *adiabatic cooling*. The rising air continues to expand as the weight of the atmosphere upon it becomes less. As it pushes aside other air in order to make room for itself, it does work. This work performed by the rising and expanding air consumes energy, which expresses itself in the loss of heat and results in the lowering of temperature. Conversely, when a mass of air descends from higher to lower altitudes, it is being transferred into regions of higher atmospheric pressure, and the descending air mass is being compressed in volume. Work is being done upon it, and as a result of compression its temperature is increased. The heating resulting from compression of the air in descending air currents is known as *adiabatic heating*. The rate of cooling or heating resulting from a vertical movement of dry air is 5.5° per 1,000 foot change in altitude.

As was brought out in the chapter on elements of weather, the cooling tends to increase precipitation. Thus the windward sides have a cooler, cloudier, and wetter climate than the leeward sides. On the leeward sides air is descending. As the air is warmed, the capacity for holding water is increased. This makes the leeward sides have a drier, warmer,

and sunnier climate than the windward sides. Figure 62 shows the amount of precipitation on opposite sides of the mountain.

The rarity of the air in higher altitudes allows the sun's heat to pass through readily; consequently the earth's surface is quickly warmed. The same condition allows the heat of the earth to radiate readily at night. The result is extremes in temperature from day to night. Diurnal change is important in erosion and human activities.

High mountains may deflect wind direction. As the wind blows across the mountain range, it may be deflected as much as 90 degrees. Thus many valleys in the belt of prevailing westerlies may get most of their winds from the south or the north. A *foehn* or *chinook* wind is one blowing on the lee sides of mountains, increasing the temperature and rapidly melting and evaporating the snow (see previous paragraph

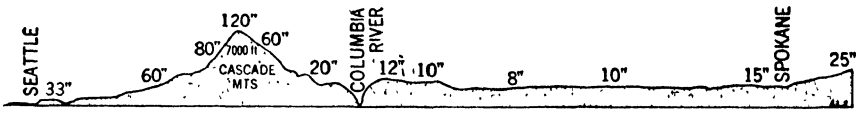


FIG. 62. CROSS-SECTION THROUGH PART OF STATE OF WASHINGTON TO SHOW INFLUENCE OF MOUNTAINS ON AMOUNT OF PRECIPITATION.

on adiabatic change). Within a few hours the temperature may be increased 50° and as much as 12 inches of snow may be removed.

A good many mountains are so high that there is perpetual snow on their summits, and there may be glaciers in the valleys. The line above which perpetual snow is found is called the *snow line*. Below this is an area the climate of which is too cold for tree growth. The line above which trees cannot grow is the *timber line*. These lines are lower on the north slopes than on the sunnier slopes. Above the timber line and below the snow line is a belt in which some of the slopes may have grass.

Agriculture in mountains

The extent of agriculture in a mountain region depends upon the amount of flat land and the altitude. While no two farmers in mountains have exactly the same problems, they all have similar problems. These problems include (a) rapid erosion, (b) level space, and (c) thin rocky soil. The soil is being carried away with almost every rain.

Rains that would have no serious effects in plains regions do considerable damage in mountains, owing to the increased runoff. Ground which is tilled is subject to greater erosion than non-tilled land, and poor tilling increases the erosion. Frequently the areas of deposition are temporarily ruined.

With the greater erosion in mountains, only a thin soil may be found in most of the sloping areas, and, owing to greater denudation, the soil will be rocky. Thus, even such soil as is present may be poorer than most soil found in areas having more flat land.

The third great difficulty is the lack of level land. As the population increases in the mountain area, the slopes may be terraced to provide more level areas to raise crops. The large amount of labor required to construct and maintain these terraces compels the farmers to raise crops that yield high returns.

Tree crops are commonly found in mountains, since they help reduce erosion and can withstand the rigors of the climate. Trees are grown for lumber and to provide food. In sparsely populated areas lumber is the principal reason for tree crops, while in densely populated regions food supply is paramount.

The agricultural development in mountainous areas varies considerably from place to place. This variation is the result of population density in and near the mountains, the type of mountain, climate, and many other factors. An illustration of the economic use of mountains is found in the succeeding reading on Andorra by Roderick Peattie. Similar discussions could be given for other places, but Andorra may be taken as a type study. For other mountainous areas variations will be found; these variations will be a reflection of the factors given above.

Lumbering

Usually mountains are among the last places to be settled and thus the last places to be cleared of forests; in mountain areas the steeper slopes are left after the valleys have been cleared. Forests are denser and have larger trees on the windward side and below the timber line. In the United States the steeper slopes are still forested, because they are more difficult and more costly to log than are the gentler slopes. Many mountain areas are being set aside for forest reserves in the United States and in other countries. They will not only increase the supply

of lumber but also regulate the streams that drain those mountains, diminish floods in the lowlands, and decrease soil erosion.

Mining

In every part of the world there is a close relation between mountains and mining. All inorganic minerals are found in mountains or in worn-down mountain areas. The same earth forces that created the mountains created the minerals. Throughout the world the great mining centers are located in mountains.

One of the chief reasons for the settlement of many mountains and many towns and cities is the mining industry and the refining of ores. The different kinds of minerals and their uses will be discussed in Chapter 36.

Resorts

Mountain scenery is an asset which has been capitalized upon in many parts of the world. This is particularly true of those mountains most accessible to population centers. In Europe and America in summer and in winter many persons are enjoying vacations in mountain areas.

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8

Andorra: A Study in Mountain Geography

THERE is no form of environment about which it is more difficult to generalize than the environment of mountains. The economic opportunities for the inhabitants of mountains are more restricted than for people living in plains. Each mountain should be studied separately to get the variations in adjustments. The following article[1] is a type study of human activities in one mountain area.

The geographic factors back of the anomalous independence of Andorra, lying between two great countries, are Pyrenean rather than purely Andorran. The summit of the eastern portion of the Pyrenees range is an uplifted and youthful plain. Here are vast pastures known by the Catalan as *plas*. With pastoral life as a prime element in the existences of both the Spanish and French mountaineers, these pastures are, in summer, the true focus of the local economies. The extent of pasture rights held by the people is as important a measure of the prosperity of the valley communes as is the amount of cultivated land. Indeed the communes frequently hold privileges upon the *pla* land in disregard of the national boundaries. The flocks and herds of the two peoples mix here. A bond, born of long contact with each other and a common set of economic problems, is established by people of two nations. Though more particularly so in the past, even today the Pyrenees

[1] Adapted from Roderick Peattie, from the *Geographical Review*, Vol. 19, No. 2, published by the American Geographical Society of New York.

are a zone of transition rather than a sharp boundary between governments and cultures.

Legend has it variously that Andorra owes its origin to the liberality of Charlemagne and to Louis I (le Débonnaire). The fact is that until the thirteenth century it was merely a mountain fief of a certain degree of independence under various seigniories and that at one time or another it owed allegiance to overlords on each side of the mountains.

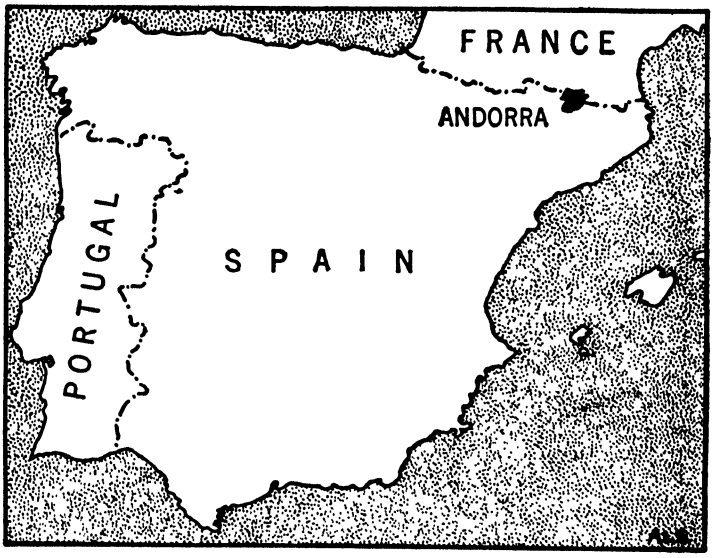


FIG. 63. SKETCH MAP SHOWING LOCATION OF ANDORRA.

In feudal days rights frequently extended across the range. Thus the counts of Toulouse held Spanish Catalonia, and again the kings of Aragon held French Béarn and Foix. The quarrels between the Spanish bishops of Urgel and the French counts of Foix as to rights in Andorra led to the *Paréage* of 1278. *Paréage* is a feudal term implying equal rights of two lords to a seigniorage. That such a neutral situation should have lasted into the twentieth century may be explained in part by the definite geographic isolation of the little country.

Physical circumstance

Andorra is officially known, in English, as the Valleys and Sovereignty of Andorra. Its 495 square kilometers (190 square miles) lie

largely in one drainage basin, but its main stream, the Riu Valira, has two distinct branches, and, in all, six open basins. Hence the term "valleys." These basins are due to unequal resistance of the metamorphic rocks found in the southern part of the country. The north-

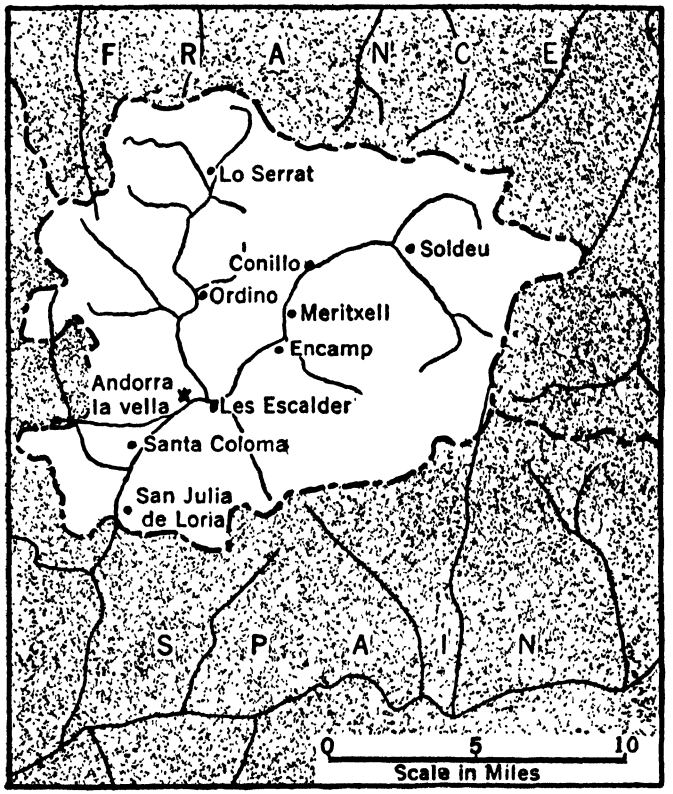


FIG. 64. SKETCH MAP OF ANDORRA.

ern portion, referred to previously as the *pla* country, represents the granitic core of the range. There is also much high-level land represented in the southern portion, differing in character, however, for glaciation has been much more severe in the more easily eroded rocks. Cirques, compound cirques, glacial lakes, and hanging valleys are common. Both the northern and southern portions of the upland contain summer pastures, but the organization of the industry is different in the two cases. On the *plas* large droves of sheep and goats,

largely transhumance from France and Spain, feed in the summer time. The increased precipitation due to the altitude combined with levelness and the impermeability of the granite rocks provides excellent pasture for small stock. The highlands of the dissected southern portion consist of peaks and serrated ridges with steep cirque walls which separate cirque bottoms and high-level valleys. Here the steep slopes have only enough soil and ground water for the mountain pine. The pasture lands are excellent but small areas of valley-bottom soil, *comas.* There are, then, two topographic levels of life in the country—the pastoral and the agricultural. The difference in relief between these two levels is 1,000 to 1,500 meters. In distinction to mountain nomadism represented in many higher groups of mountains, such as the Alps, here only a few shepherds take part in the seasonal movement.

The valleys are distinctly glaciated. The forms of erosion are much more dramatic than in most parts of the Pyrenees, and the general aspect of the landscape is savage. The basin of Andorra la vella is a little Yosemite. Since glacial times there have been canyons cut, which are still so youthful as to offer serious barriers to communication between the basins. Thus the gorge of Sant Antoine between the basin of Andorra and La Massana has today but a mule path hewn from the rocks. The gorge from Andorra to Encamp has a road along its wall considerably above the stream, but from Encamp to Conillo the trail is forced up 320 meters over the shoulder of the mountain to pass the gorge of Meritxell. The climb is an arduous one for man or mule. The villagers of Mare de Deu and Prats along the route are a half hour above their valley-bottom grasslands. The last-named villages are on terraces which are lateral moraines. Whereas the glacial terraces in places offer high-level agricultural land, elsewhere the morainic deposits are so rough and strewn with huge boulders as to be impossible for use except for pasturage between the rocks. The French call such an area a "chaos," and indeed it looks as if it were a portion of the earth unfinished on the day of creation. On the whole, glaciation has improved the Andorran valleys as a place of habitation. The greatest contribution made by the ice was the terminal moraine on which Santa Coloma stands. A lake of short duration existed in the valley upstream, upon whose lacustrine soils deposits from the side walls have since encroached.

Character of the farming

In lieu of climatic statistics, which are totally lacking, the climate is best discussed in terms of natural vegetation and agriculture. The olive stops at the Spanish gate of Andorra. The chestnut and walnut are found only in the neighborhood of the lowest village, Sant Julia (950 meters). The live oak occupies sunny slopes in the basin of Andorra la vella. The climate, always rude, increases in severity very quickly with altitude. Many valleys are entirely subalpine and alpine in character. In less than three hours of thalweg road one may pass from harvest rye to green rye. On the plain of Andorra (1,000 meters) grain is harvested from July first to the tenth. At Encamp (1,300 meters) the harvest is nine days later. At Lo Serrat (1,600 meters) harvest is not until the twentieth of August, when some plowing of fields for the next season's crop has already begun.

The region is to be classed as of a mediterranean climate in distinction to the dry mediterranean climate to be found in Spain just outside the borders of the country. Farming is both of the irrigated and normal type. Hay, tobacco, and vegetables are grown by irrigation; the cereals are a dry-land crop. All land that is level and the slopes that lie adjacent to and below canals on the valley walls are irrigated. These slopes are usually unterraced and devoted to grass. As in all regions where beasts are pastured in the high mountains in summer, the greatest part of the cropped land is devoted to hay production for feed for animals during the winter stabling. Andorra has an excess of high pasture. Therefore economic pressure for hay land as against field crops is great. The more hay, the more beasts of Andorran ownership on the uplands. The number of cuttings of grass varies from one in the natural prairies at the edge of the *plas* to four on the irrigated fields. There is in Andorra, considering the mediterranean type of climate, a remarkable flow in the streams. That the uplands have a significant duration of snow cover is an element in this condition, but the relative levelness of the uplands as well as the number of lakes plays a part. There is always an excess of water for the amount of land to which it can be easily conveyed.

The cereals are largely rye and barley. The people eat black bread. Where there are gentler breaks in the valley walls and farmable slopes

extend up to the *pla* level, rye occupies the top fields. Elsewhere rye is grown on the shoulders of the canyon walls. These highest fields in Andorra lie at 1,850 meters and are not infrequently an hour's tramp from the nearest house. The isolated position of the fields represents largely a search for sunlight.

The question of sunny slope and shady slope is of utmost importance in mountain climates, the more so because at high altitudes air temperatures in the shade are critically low. Each group of peoples has a set of names to correspond to the two slopes. The Catalan calls the sunny slope the *sola, solana,* or *solane,* and the shady slope the *ubaga, obaga,* or *ubach.* Every inch of the *solana* is cultivated, but the *ubaga* almost literally belongs to anyone who wants it. Insofar as production goes, the *ubaga* is almost negligible. And yet the *ubaga* is farmed, and the condition of slopes may be so favorable that it is farmed as high as the *solana;* indeed, frequently the greater the altitude on the *ubaga,* the greater the percentage of sunlight. But the crops on the shady side are commonly so slight or even precarious as to have relative unimportance. It may be stated as a principle of mountain geography that the shady slope can be farmed as extensively as the sunny, but the two vary greatly in economy. Also, the higher the altitude, the less the difference in the economy of the two slopes. However, I do not think that the climatic limit of agriculture of one sort or another has been reached by the Andorrans. Matters of accessibility, distance, difficulty of carrying manure to the fields and crops to the granges, and unwillingness to encroach upon pasture lands, as well as unfavorable soils on the *plas,* are factors which all obviously play a part. It would almost be easier to determine a lower climatic limit for grain in the gorges than an upper limit. In the valleys the sunlight duration is so short that the season necessary for maturing grain is lengthened. In places men may sow one grain crop in the autumn before the grain of that year is harvested from an adjacent field. The land must then either lie fallow a year or be put into field crops.

Tobacco is the most distinctive crop of Andorra. It had its start when smuggling was a recognized profession. Today smuggling is no longer what it was, partly because of the unfavorable exchange since the First World War. Andorra uses Spanish currency, and the peseta is much more nearly normal than the franc. But the amount of tobacco grown in Andorra is far in excess of national needs. I have no

confidence that this tobacco pays duties when it is exported, and it would have been a breach of hospitality to have made inquiries. Climatically, the interesting thing regarding tobacco is that the highest cultivated fields in the basins of Andorra and the valley end of high Arinsal are devoted to it. Tobacco is everywhere given the country's best lands.

Other agricultural products of Andorra are potatoes, garden vegetables, buckwheat, rye, and barley. A few vines exist near Sant Julia, the lowest community.

Pastoral activities

As with the mountain communities, the true basis of Andorran economy is pastoral. They have much more pasture land than they themselves can use. Hence great numbers of beasts, largely sheep, with a sprinkling of goats, come into the country annually from Spain and France. Spain alone will rent privileges for 30,000 head. The revenue from the rents amounts to many thousands of pesetas each year. The least desirable lands and the most remote are allotted to the foreign animals. They are in the country from June 24, the fête of St. Jean, to September 28, the fête of St. Michel. Other than that the shepherds keep their flocks to the proper pastures and that they be out of the country by a definite date, there is but one requirement. It may be demanded that for three nights the beasts be quartered on the higher fields for the sake of the manure. It is a custom in the Pyrenees to quarter animals on fields at night, the smaller groups being enclosed in a movable stockade. Thus the animals are forced to cover the field systematically with droppings.

Herding involves only a small number of men. The French sheep are guarded by Frenchmen. The Spaniards are inclined to bunch their herds and turn them over to Andorran shepherds. These men live aloft for three to four months in a crude stone shelter with a single blanket against the night. A certain number of the beasts are locally owned. The communes of Encamp and Conillo have little farm land and much *pla* pasture and own most of the 16,000 to 17,000 sheep of Andorra. The local people keep their goats in the villages the year around, so as to profit from the milk. A small amount of sheep's and goat's cheese is made at a definite period in the summer, the cheese being divided between the shepherd and the owner.

Another phase of the transhumance is the migration of beasts of the Andorran villages to the better and usually less distant pastures. This involves mostly beef cattle, mares, and their mule offspring. Andorra is too isolated for dairying, and in any case the tradition of the Pyrenees favors beef cattle rather than milch cows. The raising of mules is one of the chief sources of local income. These animals usually descend earlier than the other animals from the *pla.* They come down in time to profit from the grass growth on the valley meadows after the last cutting of the hay and to fertilize the fields before the autumn plowing.

Industry

There is little industry in Andorra. An exception in the past was the contraband industry and today is the lumbering industry. Some of the well-to-do men of the country today are the smugglers of a few years ago. The government took halfhearted steps from time to time to reduce smuggling, but one imagines that such legislation was merely a diplomatic gesture. It is more than likely that mules and tobacco are still smuggled through the lonely ports of the frontier.

That Andorra was heavily forested at one time seems beyond doubt. The name of the country is reputed to have come from a Moorish word, *Aldarra,* meaning "place thick with trees." There are iron ores of value in the country, and a very heavy drain was put upon the timber by the early Catalan forges, whose numerous ruins are still to be seen. Today fuel is an important item, but lumbering is carried on in every permanent community. The construction of a sawmill is an easy matter, for there are power streams everywhere; and large quantities of logs are shipped out of Andorra la vella by motor trucks into Spain. The communes have complete freedom to cut their forests. There is, I should judge, a greater subtraction of trees than is supplied by the annual increase. If this is so, it is especially unfortunate, for water resources constitute the outstanding asset of the country, and the stream flow may well be damaged by future excessive deforestation.

The manufacturing industry is very slight. Cigarettes and cigars are produced there by a tobacco factory as well as by cottage industry. Matches for local use are made. There is a factory at Escaldes for woolen blankets and scarfs, chiefly for Andorran use as wraps and capes.

9

Plateaus

PLATEAUS are those larger land features which have considerable relief, and, at the same time, a surface more flat than sloping. They are the result of uplift of the earth's surface, of denudation, or of deposition. While plateaus, on the whole, have greater elevation than plains, the distinction between them is not one of elevation but rather of relief. Frequently they grade into each other so completely that it is hard to draw an arbitrary boundary.

Origin

Plateaus have attained their form and elevation in various ways. (1) Some have been formed by the accumulation of material on the surface of the earth either as lava deposits or as deposits from other land forms. (2) Some are the result of tectonic forces causing an uplift of the earth's surface. (3) Some are the result of adjacent areas having been worn down or warped down. (4) Many are the result of a combination of two or three of these processes.

Plateaus of Accumulation. In volcanic action the lava rises to or near the surface; hot lava is known as *magmum* and has a temperature of about 1,100° F. The magma rise to the surface of the earth and freeze in the form of new *igneous* rock. The eruption of the magma may come from a central point, a crack known as a *fissure,* or from areal eruptions, in which a considerable part of the earth's surface emits the lava. The largest number of lava plateaus have been formed by magma issuing from fissures.

The fissures may be very short or they may be forty or more miles long. The lava may issue from the fissures and reach out on both sides

thirty or more miles. If there be a succession of fissures from which lava is emitting at various times, the area covered may be extensive and the depth of lava considerable. The fissures may be formed by pressure from the inside. If the fissure is forty miles long, the pressure from below will amount to 270,000 pounds to the square inch. With this pressure the surface is torn open, and a more or less vertical crack is formed.

The most extensive lava plateau in North America covers parts of the states of Washington, Idaho, and Oregon, or about 200,000 square miles.

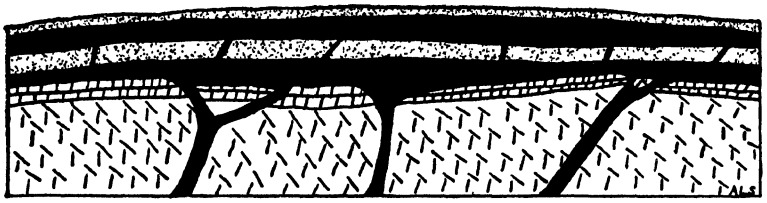


FIG. 65. SIMPLIFIED SKETCH OF FISSURE ERUPTION FORMING COLUMBIA PLATEAU.

Other large lava plateaus are the Deccan Plateau of India and those in Scotland, Argentina, and Brazil.

Plateaus of smaller size may be formed by accumulation in mountainous regions where there is excessive erosion. In such areas the



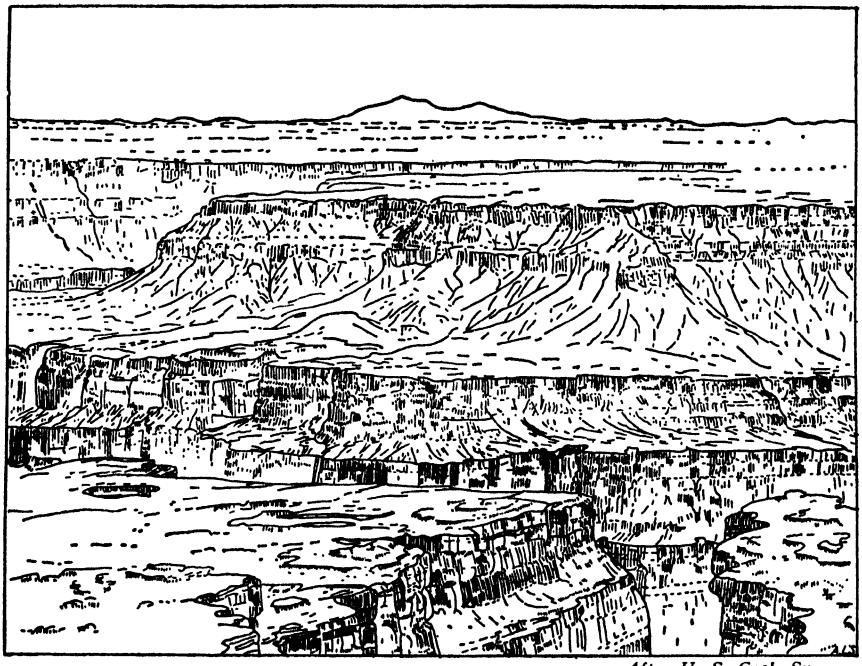
FIG. 66. SIMPLIFIED SKETCH OF MEXICAN PLATEAU. Stippled area is deposited debris from mountains.

material eroded from the mountains accumulates at the bases of the mountains. In time, enough material has collected to form a new major land form, a plateau. Such a plateau may have extremely deep regolith, and the surrounding mountains may be only a little higher than the plateau. The *regolith* is the disintegrated material, also called *mantle rock*, overlying solid rock. The distinction between regolith and soil is discussed in a later chapter. The plateau of Mexico is an example of this type.

Plateaus of Uplift. Plateaus of uplift are associated with mountainous areas and are formed with the surrounding mountains. When a

definite uplift occurs, a part of such an area may result in mountains, and another part will have but slight disturbance of its strata. The Colorado Plateau has been formed in this way. Upon the general plateau there may be local disturbances such as folding or faulting, causing minor mountains on the plateau.

Subsequent to the uplift the Colorado River and its tributaries have cut deep canyons. The Grand Canyon covers about 200 miles of the



After U. S. Geol. Survey.

FIG. 67. GRAND CANYON.

total length of the Colorado River Canyon. A great many minor canyons have added to the general dissection of the region. In his report of the Colorado plateau, Major Powell says,[1] "every river entering these (canyons) has cut another cañon; every lateral creek has cut a cañon; every brook rises in a cañon; every rill born of a shower, and born again of a shower, and living only during the showers, has cut

[1] J. W. Powell, *Exploration of the Colorado River of the West*, U. S. Geography and Geology Survey, 1875, 291 pages.

for itself a canõn; so that the whole upper portion of the basin of the Colorado is traversed by a labyrinth of these deep gorges."

Plateau of Erosion or Warping. As rapidly as dry land appears, various agents of erosion are at work. Eventually the period of upbuilding is followed by the time when the tearing down forces are greater than the forces of construction. The degradational forces, or agents of erosion, are chiefly running water and climatic elements such as wind, precipitation, and variations in temperature. The greatest erosion will take place on the ridges, because they are more exposed. Since the rock material is of varying hardness, the softer parts will be eroded more quickly. The result is erosion of smaller sections as well as of the entire land form at varying rates. This plateau has been formed by the eroding of a mountain, and there are many flat-topped segments. These segments may be bounded by steep faces; the steepness will vary with the nature of the rock strata and the nature of the climate. In an arid region the face will be sharper than in a humid region. If, in addition, the strata are alternately hard and soft, then, in an arid region, the face may be approximately vertical. In a humid region the face will be rounded. In addition to the lowering of the surrounding area by erosion, the adjacent land may have been warped down, leaving a plateau.

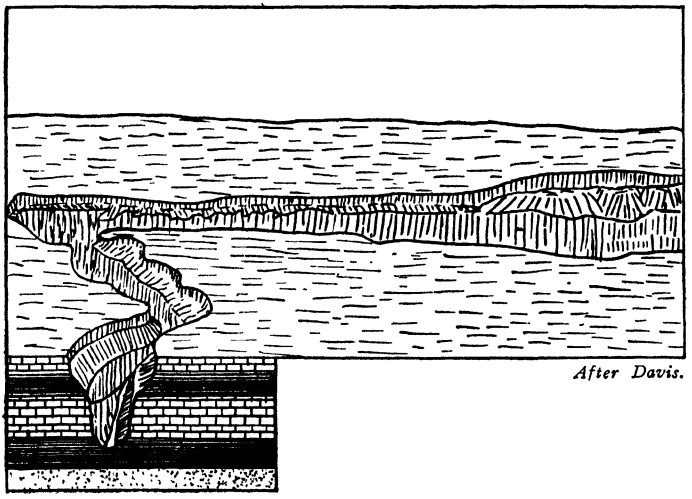
Polygenic Plateaus. The plateaus described above are monogenic. Most plateaus, however, have been formed not by a single force but by a combination of factors. Thus a plateau may be the result of uplift and lava deposits or uplift and the deposition of material from the enclosing mountains, or any other combination. In polygenic plateaus one force may have been more pronounced than others, but it was the combination of forces that produced the present land form.

Denudation of plateaus

The agents of erosion disintegrate a plateau in a manner similar to that already discussed in the section on mountains. The elevation, rock structure, and agents of denudation will determine the rate and form of erosion.

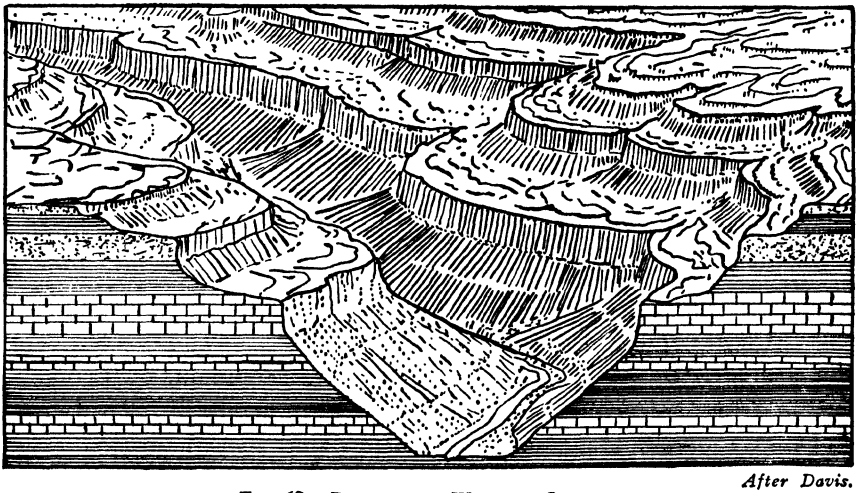
Plateaus, in the early stages of erosion, are dissected by a few deeply cut rivers. In arid and semiarid regions the valleys are steep walled, with bare rock exposed. At the heads of the streams the ravines are not

sharp pointed as they are in humid areas. The ravine has been formed by weathering rather than by stream erosion; the weathering is equal in



After Davis.

FIG. 68. PLATEAU IN ARIZONA.



After Davis.

FIG. 69. DIAGRAM OF WIDENED CANYON

all directions, and circular forms prevail. In humid areas, the valleys of the plateau have rounded rather than precipitous walls such as occur in arid regions. There is more talus and more soil. The ravines cut by the tributaries are narrow because of the continuous stream erosion.

As erosion continues, the main stream tends to widen the channel. The sections of the river bed composed of harder rock will be narrow, with falls and rapids. Gradually cliffs will be undermined. Wherever a harder strata is underlaid with softer material, erosion will produce overhanging cliffs. Later these will break, and new overhanging cliffs will start. At the same time the interstream areas are dissected more and more. Ridges and pyramidal or round-topped hills are produced, and another major land form—hill-country—has come into existence. If the plateau is not sufficiently high, or if the rock strata are of such a character that sharp downcutting is not possible, then that plateau may take another form and a plain will be formed.

In the course of erosion harder materials may resist the wearing down process more than the surrounding softer material. *Mesas* and *buttes* represent all that remain of a plateau that was formerly widespread

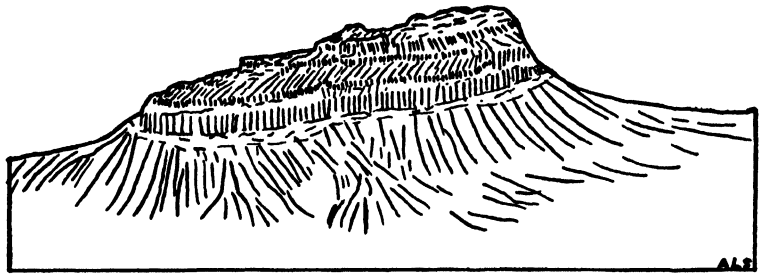


FIG. 70. DIAGRAM OF A BUTTE.

over the region. The space between the mesas was produced by the valleys widening to such an extent that their floors now occupy a great part of the surface. The level of the former plateau was higher than the top of the butte or mesa, for the uppermost strata have eroded to some extent. Buttes and mesas, usually, are the remnants of the interstream areas as developed in dry climates. An area which has buttes and mesas represents a plateau approaching old age, for in time even they will be completely worn down. In youth the plateau has broad stretches of upland and the valleys are narrow canyons. Western New Mexico has many isolated mesas and buttes rising several hundred feet above the surrounding area. Enchanted Mesa, rising 400 feet above the plateau, is one of the better known of these mesas. The original Indians used many of them as places of refuge.

Areal distribution

The areal distribution of plateaus on the different continents is shown on the map, Figure 47.

In Asia the plateaus, occupying a large proportion of the total area, extend from east to west in the southern part across the continent. Between the mountain chains (described in the chapter on mountains) in central Asia are the high plateaus which are wider in the east than in the west. The highest and greatest of these is the plateau of Tibet, which is adjacent to the world's highest mountains, has a mean elevation of 11,000 feet, and consequently is deserving of its title "Roof of the World." The plateau of Tibet is not only the highest in Asia but also the highest in the world, the elevation varying from 9,000 to 17,000 feet. Immediately west are the plateaus of Iran, Afghanistan, and Baluchistan. Almost the entire peninsula of Arabia is a plateau. The Deccan Plateau of India completes the southern extension of the central plateau reach.

The only plateau of any extent in Europe is on the Iberian Peninsula, where it occupies the larger part of the countries of Spain and Portugal; the highest part of the Iberian Plateau is 4,000 to 5,000 feet. The other plateaus of Europe are so small that they cannot be shown on small-scale maps.

All of southern, much of eastern, and isolated parts of central Africa are plateaus. The mountains, such as there are in Africa, are on the edges of the plateaus. The mean elevation of these plateaus is 3,000 feet. One of the unique features is the system of terraces between the plateau and the coastal plain; these terraces are a series of hills, locally known as "mountains" and by various names.

There are no real plateau areas in Australia. Such places as are called plateaus locally do not come within the strict definition of the term.

In the tropics of eastern South America is the Brazilian plateau, with a mean elevation of 5,000 to 6,000 feet. Located as it is in the low latitudes, it assumes great significance in the economic life of Brazil. The intermontane plateaus of the Andes reach a much higher elevation, and because of their latitudinal position also have great economic significance.

In North America nearly the whole of Greenland may be a plateau. Between the mountains of the western cordilleras is another extensive plateau system. In Middle America the plateaus are again associated with the mountains.

Climate on plateaus

The climate on plateaus varies with latitude and altitude but is similar to that of mountains. The plateaus with lower elevations are not affected so adversely as are those with higher elevations. The climate of the latter is distinctly colder than that of lowlands with similar latitudes; generally the precipitation is less. The climate of the low latitude plateaus may be desirable for human occupation because of higher altitude.

As with mountains, climates on plateaus have (a) lower temperatures, (b) greater diurnal and seasonal range in temperature, and (c) less absolute humidity than lowlands. The differences between plateau climates and mountain climates are caused by the mountain ridges and valleys which produce wind deflections and ascending and descending air currents with their resulting changes. These changes bring variations in amount of precipitation within the mountains. On plateaus the only changes in amount of rainfall or snowfall will be at the edges of the plateau. This change will depend upon whether the plateau is intermontane or completely isolated from the mountains, and similar factors. But there will tend to be a uniformity in the amount of precipitation over an entire plateau, whereas in mountains the amount varies from locality to locality.

Human use of plateaus

Climate and land form are the two chief environmental controls in human adjustments. One of the factors influencing the temperature of a given area is its altitude, and plateaus have high altitudes. Consequently the temperature (as brought out in the previous section) is cooler than that of plains. Thus the human adjustments on plateaus differ from those on most plains in similar latitudes, and the activities vary with the latitude of the plateau.

In the low latitudes we find that, because of the lower temperature, the population is denser and more economic activities are carried on

than in the surrounding plains. In Middle America and South America the denser population is found at altitudes between 3,000 and 10,000 feet. In Mexico the more energetic peoples are found on the plateau rather than on the hot, moist lowlands. In Mexico the plateau area has most of the manufacturing, most of the agricultural production, a denser population, and more social and political progress. The lowlands have a sparse, backward Indian population who have only a subsistence type of agriculture. Illustrations could be repeated for Ecuador, Bolivia, Colombia, and all the other countries lying in the low latitudes which have plateaus. The amount of soil erosion from place to place on the plateau and the type of plateau will determine the exact population distribution. Only a detailed analysis can give all the variations.

However, in the middle latitudes just the reverse is true. The population for all plateaus is less dense than in the immediately surrounding plains. In places such as the British Isles, where the population density is great, and the United States the plateaus will have relatively fewer people and a less progressive population than the plains. The western plateaus in the United States have but few people, and the eastern plateaus have fewer people than the immediately surrounding lowlands; the less favorable climate is part of the explanation.

In the polar regions we find but few people, and only an occasional nomad on the plateaus. The climate for the entire region is severe, and worse on the higher elevations.

Conclusion

The human use of plateaus depends largely upon (a) the climate, (b) the kind of material from which the plateau has been formed, and (c) the amount of dissection that the plateau has undergone.

The plateaus located in the polar zone cannot at present be used for human occupation. Those in the middle latitude zone are used in part. In the low latitudes the plateaus are at a premium. If a plateau has been severely dissected so that the surface is greatly broken up, it will be used in a manner similar to mountains. If, on the other hand, such a surface has not undergone the changes brought about by severe erosion, the terrain may be used in the same way as a plain with a similar climate.

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10

Economic Importance of Plateaus in Tropical America

THE human use of plateaus varies with the amount of dissection, the amount of precipitation, the temperature, and various other factors. Plateaus have a cooler climate than the neighboring lowlands, and, as a result, are the main areas of human habitation and agricultural production in the low latitudes. The following article [1] summarizes the human activities in the tropics.

The mathematical limits of the low latitude zone cause the tropical regions to receive much undue credit, because high altitude extends the middle latitude zone in the form of mountain and plateau islands which rise above the surrounding tropics. Thus far-flung outliers of the north are too often counted in with regions of their latitude which thus get unmerited credit in many economic considerations.

If those parts of the tropic latitudes that do not possess tropic climate or yield tropic products were excluded from our consideration of that zone, our ideas of it would be materially modified. This is especially the case in America.

The plateaus and plains of tropic America offer an interesting paradox in their relation to the foreign commerce of those regions. The highlands are the chief seats of population; the lowlands are the nat-

[1] Adapted from J. Russell Smith, from the *Bulletin of the American Geographical Society*, Vol. 37, No. 8, published by the American Geographical Society of New York.

ural and, indeed, the only place for the production of most of the large and increasingly important list of staples for which the nontropical regions depend upon the tropical. Here is a vast field for ethnic and industrial readjustment by which the people should re-locate themselves where they can have access to the best resources and those fitted to produce the most universally desired products.

A survey of that half of the American continent lying between the Rio Grande and the Rio de la Plata shows a topographic distribution of dominant population groups, population that is the exact opposite of that prevailing in the temperate parts of the Americas, of Europe, and of Asia.

In North America the early colonists established themselves on the Atlantic plain, gradually worked up the valleys of the Atlantic rivers, and thence westward into the basin of the Great Lakes, to the valley of the Mississippi and its northern extension, which is fast becoming the seat of empire upon the continent. Along the Pacific coast similar conditions were repeated. The valleys of California, Oregon, and Washington contain nearly all the population of those States, leaving large areas outside with very scanty population.

In Europe the dense populations are on the good lands of the great low plain extending from the Pyrenees to the Urals, and in the valleys of the Po, the Danube, and the British rivers. In Asia the great majority of the people, possibly nine tenths of the population of the whole continent—half the people of the world—are crowded into the lowlands of the monsoon countries between the Indus and Manchuria and northern Japan. Upon these lands the summer monsoon rains make possible the growth of heavy summer crops. In over-populated Japan agriculture is practically limited to a paltry 15 per cent of the land, a mere fringe around the edge of the mountainous isles, where irrigation water can be secured from the mountain streams which flow across the narrow plains to the sea.

Throughout tropical America the centers of population are, with few exceptions, upon the interior highlands, and 99 per cent of the vast area of lowlands skirting the two oceans, and sometimes reaching the interior of the continent, is unsettled, unused land. Instead of being the home of peoples, as in the temperate zone, it has always been a bar to settlement, and is to this day a hindrance or a prohibition to com-

merce and a vast land reserve of great but unknown possibilities for a more resourceful future to utilize.

In Mexico the geographers usually classify three zones—the cold, the temperate, and the hot, corresponding to the plateau, the slopes, and the low plains. Upon the first two are centered nine tenths of the people. The plateau has in some sections a population as dense as that of France, and, considering its aridity, is really overpopulated, and the pressure of people upon subsistence is causing an alarming denudation of the rather scanty forest growth. Aside from the small seaports, the lowlands have a sparse population of planters, wild Indians, lumbermen, and other forest workers. A few new plantations have also been started there, and this new work, in conjunction with recent railroad building, has created a demand for labor that can be met only by importing laborers from the plateau; one of the needed reforms of the government is to stop the carrying away of the highland dwellers to involuntary servitude in the lowland forests. The profound climatic difference between the temperate Mexican plateau and the tropic lowland is evidenced by the dread that the highlander has of the lowland, where he so often perishes like any newcomer from a cool climate.

Central America is still more pronouncedly a plateau country. The heavy rains from the trade winds give dense forests to the slopes and reduce much of the coastal plain to swampy jungle. The Atlantic plain being wider than the Pacific, the plateau between the double mountain ranges to the west was more easily reached from the latter ocean, from which it was settled and through whose ports its commerce was for more than three centuries almost exclusively carried on. In recent years coastal settlements along the Caribbean have grown through the rise of the banana industry, and Costa Rica and Guatemala have shifted a part of their commerce to the east through the opening of railroads to Caribbean ports; but for the majority of its population Central America is still, economically speaking, a Pacific country, because the centers of population, being upon the plateau, lie nearer to that ocean and use it as their highway to the outside world.

The Pacific coast of South America shows in the main the same plateau predominance. The marine plain from Panama to central Ecuador is wet, forest clad, and, except in some unwholesome ports, is populated only by a few wandering Indians. Ecuador consists of a

fertile low plain, containing one fourth colored population. In British Guiana this coastal characteristic is more pointedly brought to attention, because nearly all the exports of this large colony are grown on a strip of alluvium diked and reclaimed from the sea after the manner of Holland. Furthermore, the coast settlements and cities from Rio de Janeiro to Guiana are largely populated by Negroes or mulattoes, or, as in Guiana, by imported East Indian coolies.

The economic effect of this predominance of the plateau is that the population is located on the least productive lands, and commerce is handicapped by the great difficulty of reaching the sea. This difficulty at times borders upon prohibition, and it is prohibition for commerce in any modern sense of the word. The upland dwellers of Ecuador, for example, numbering hundreds of thousands, possibly a million, and including the residents of the capital of the country, were, until the beginning of railroad work recently completed, dependent for connection with the outside world entirely upon mule trail, where life and property were often threatened with destruction by slipping from narrow rocks to abysses below. Another part of this same trail crossed the lowlands, which the rainy season often made impassable even for pack animals. This case is extreme in the number of people dependent upon a single route, but it is fairly typical of the conditions that separate a large proportion of the people of tropical America from the world's highway, the ocean. As a natural result of this isolation many of these people have almost no foreign commerce whatever. The statement is not made that any single country has no foreign trade, for they all have; but each contains a considerable share of people who have almost no part in this trade and who live in houses of local construction, some without an iron nail in them, eat home-grown food entirely, and wear clothing of the meagerest pattern, possibly of homespun, possibly of imported cloth.

11

Hill-Country

HILL-COUNTRY is the third major land form. It is classed as a major land form because it is extensive in area and is not the result of recent (geologically speaking) formation and because human adjustments are definitely different from those found on other land forms. It must be kept in mind that hill-country is a subsequent land form formed where forces of erosion have modified either mountains, plateaus, or plains. The geologist does not recognize this type of major land form; however, since the geographer is interested primarily in the human use rather than in tectonic forces, he has a fourfold classification. Before discussing the general human use it is necessary (1) to define hill-country, (2) to locate the areas of the world that have this type of land form, and (3) to explain the ways in which hill-country is formed.

Hill-country is that major land form which has slight summit area and slight relief. Thus hill-country is somewhat similar to mountains, but it differs considerably in relief. The consequence of this is that while human use may be somewhat similar in the two regions, the adjustments are not alike because of the difference in relief.

There is, obviously, within a given area no sharp boundary *line* between plains on the one hand and mountains on the other. The terms are relative and to different people may, for a given place, refer to another classification. The same thing is true for all major land forms. Our surroundings determine our attitude toward a familiar as well as a new environment. The inhabitants of Eastern Kentucky, for example, refer to their region as mountainous, but persons from the State of Washington would not. People of Kansas refer to a knoll 15 to 25 feet high as a "hill" and give it a special name, whereas people from the Sierra Nevadas would hardly recognize such a minute change from the

continuous flatness of the area. Similar illustrations can be given for every other region. However, if the difference in relief is three to five hundred feet and if more than one half of the area is slope, then the term *hill-country* is applied. In any atlas many areas are designated as mountains, whereas the map for Major Land Forms, Figure 47, shows those areas to be hill-country; this apparent inconsistency is due to the fact that the map in this text uses the above definition in plotting hill-country.

Areal distribution

The world map of Major Land Forms shows the areal distribution of hill-country on the various continents.

In North America there are two continuous areas that have hill-country. The one extends along the eastern part of the United States and Canada, and the second lies along the Canadian-Alaska boundary and north of the Rocky Mountains.

Hill-country in South America is adjacent to the eastern and southern sides of the plateau in Brazil. Two small areas in Venezuela have this same major land form.

In Europe the western and northern fringes of the continent are hill-country; this includes Norway and western Sweden, the western and northern part of Great Britain, and the northern part of Spain. The second great region is the area surrounding the Alps Mountains and includes all or parts of France, Germany, Italy, Yugoslavia, Bulgaria, and Greece.

In Asia the hill-country continues southward from Europe uninterruptedly into Turkey, Syria, and Arabia. The other fork of this extension reaches eastward into Persia and on to India. The high plateaus and mountains bring an interruption. Immediately adjacent to the plateau on the west and north in southern India is hill-country. Throughout eastern Asia, from north to south, is the same major land form, extending into Siberia through China and Japan and to Indo-China, Siam, and Burma.

The entire eastern fringe of Australia is hill-country and is only slightly broken by mountains toward the southern side. Another small area in western Australia is hill-country.

In Africa there are only small areas of hill-country. They are found near the northern coast of the continent, along the coast of the Red

Sea, in the southern and eastern part, and there are two in the central section.

In addition many of the islands of the world, especially the East Indies, have this type of land form.

Formation of hill-country

Hill-country, as was pointed out above, is the result of erosion rather than the direct effect of tectonic forces. Dissimilar kinds of rock subjected to similar kinds of erosion and similar kinds of rocks under dissimilar climatic erosion and many other variables and differences in the stage of erosion all produce various kinds of hill-country. Consequently hill-country may retain some of the features of the land form from which it came, or it may be so maturely dissected that on casual inspection the previous land form will be hard to distinguish. The differences in hill-country are, as a result, extremely great. Examples will serve to illustrate these.

Plateaus with nearly horizontal strata in humid regions will become maturely dissected in time by streams and their tributaries. In the dissection the plateau will become a series of uplands and valleys, and the larger proportion of the surface will be cut into slopes. No comparison is possible between the deeply eroded present surface and the former land form. An examination of the stream pattern reveals an interlacing of the tributaries; such a pattern is known as *dendritic*. The same horizontal strata in an arid region would remain undissected and retain their original characteristics for a longer period. In a humid region, however, the hill-country is the remnant. Locally the area might be called "mountains"; the geologists would refer to it as a "plateau"; the geographer describes it as "hill-country" because of the

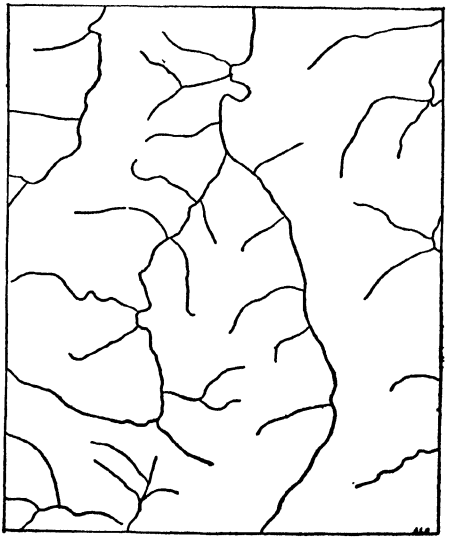
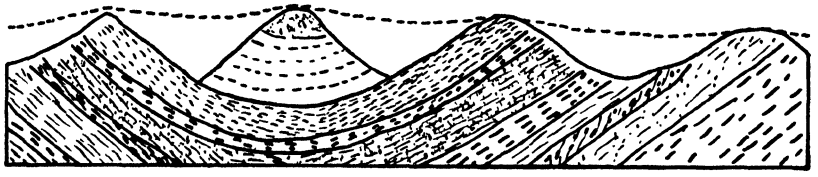


FIG. 71. DENDRITIC STREAM PATTERN IN MATURELY DISSECTED HILL-COUNTRY (PAINTSVILLE, KENTUCKY).

human use. Examples of this type of hill-country in the United States are found in the Appalachian section and the Ozarks.

Hill-country may be formed by mature dissection of plains, which produces very rough surfaces. The Bad Lands extending from South Dakota into Nebraska are an example of this type. The name "Bad Lands" came from the French trappers and traders, who applied the term "Mauvaises Terres." The rainfall in this area comes as heavy thunderstorm showers which last but a short time. Such precipitation is an extremely great eroding agent. Also, the clays expand greatly when wet and contract when dry, so that their surfaces form an easily eroded mass of material. Frost produces the same effect. In addition the horizontal strata are of varying degrees of resistance. Terraces, undercutting, cave-like formations, gulches, and steep ravines are produced.

In some hill-country are found roughly parallel linear ridges and valleys. Examples are Ouachita Mountains, Appalachian ridge and



After U. S. Geol. Survey.

FIG. 72. CROSS-SECTION OF APPALACHIAN SYSTEM. Dotted line is supposed level of the peneplain.

valley region, Jura Mountains, and the Appennine Mountains. In the Appalachians the ridges are nearly parallel to one another, have steep slopes, and their summits extend for miles with but slight change in elevation. Not only does each ridge preserve approximately the same altitude, but all of the ridges are about the same elevation. The valleys between the ridges are undulating and appear to be built in two stories, the streams having cut a narrow secondary valley within and below the main valley. The explanation is found in the diagram (Figure 72). The entire peneplain was raised, and the valley, or softer rock, was worn away, leaving the harder rock as ridges. In brief, this region was folded and faulted, after which it was reduced to a peneplain, subsequently elevated, and renewed erosion exposed the harder

beds as ridges, while the softer beds have been carried away, leaving valleys.

Hill-country is also formed where polygenic mountains are eroded. That is, mountains have been formed by repeated folding, faulting, and igneous intrusion. These are then eroded to hill-country. The result is a complicated land form varying with the original materials and eroding agents. Such complex hill-country is found in the Blue Ridge Mountains, eastern Asia, and eastern Australia.

Human use of hill-country

Because hill-country is similar in slope to mountains, the human use is similar, but, since the relief is less, the activities are much more intensive. The diversity in the physical characteristics in hill-country from place to place makes generalization difficult. The population density is determined at least partially by the density in the areas immediately surrounding the hill-country. The population density in these areas, as well as their economic activities, to a large extent will determine the type and the degree of the economic and social adjustments of hill-country life. The chief economic activities include farming, lumbering, mining, and manufacturing.

Small-scale farming is dominant in most hill-country. The size of the farms is limited by physical conditions and generally results in low incomes. Because of the rough topography a large proportion of the tilled land is in forage crops. On the farms but little machinery can be used. These conditions are similar to those in mountain regions, yet by contrast a larger proportion of the land is farmed, since the relief is less. Likewise the population density will be greater because it is less difficult to migrate from one part of the region to another. Dairying, also, may be important, especially where markets for the products are readily accessible.

Where rainfall is sufficient, a large part of hill-country may be in forest, especially in the more rugged parts not suited to agriculture. The cutting of trees is frequently a winter activity. In the more remote areas of hill-country forest exploitation may be the cutting of the better trees for ties, mine props, or lumber for immediate use, and the other trees may be ruined by burning to clear the land for pasture purposes.

Where minerals exist in hill-country, they may be exploited. This topic will be discussed in the chapter on minerals.

In more densely populated hill-country manufacturing will be processing such products as have high value and require much hand labor. Examples are wood carving, furniture making, basketry, hand weaving, and similar crafts.

Summary

In general, the term *hill-country* is used if the differences in relief within short distances are more than three to five hundred feet and if more than half the area is in hill slopes rather than upland or lowland flats. The population is usually confined either to the crests or to the valleys, depending upon which offers the larger amount of tillable land. The proportion of occupied to unoccupied land determines the character of the cultural landscape. However, combinations of valley, upland, and slope culture occur in nearly every hill region.

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12

The Changing Role of the Kentucky Mountains and the Passing of the Kentucky Mountaineer

THE following article[1] provides information as to the major economic and social conditions and problems which characterize the "Kentucky Mountaineer" and reveals the underlying basis for the conditions and problems. As a type study it gives the fundamentals for other areas of hill-country. Furthermore, contrasts can be made with areas lying on either side. Climatically and historically the areas on either side are similar to those within the "Kentucky Mountains." The difference in economic and social adjustments must be related to some other factor, which in this case is partly the land form.

The Kentucky Mountains during the colonial period

French and English colonial occupation of the North American continent differed greatly in character. The English settlements, confined to the seaboard, were primarily agricultural; fur trading and other pursuits were incidental, carried on to supplement agriculture, largely in areas where soils were thin or poor. French occupation was very different; settlement early spread over a vast area, fur trading rather than agriculture being the dominant interest. The voyageur replaced the isolated farmer; the fur trading post, the village of the English colonists.

[1] Adapted from D. H. Davis, from the *Journal of Geography*, Vol. 24, No. 2, published by the National Council of Geography Teachers.

It is not sufficient to explain this difference in the character of occupation on the basis of difference in racial aptitude. Doubtless the French voyageur was able to maintain more friendly relations with the Indians than was the English colonist. His habits of life and his practice of intermarriage cemented Indian friendships. In addition, his method of obtaining a livelihood did not threaten the economy of the Indians. The English farmer, by his clearing and cultivation of the land, deprived the Indian of a means of support, which engendered hostility. This difference in occupation, which in large part explains the strained relations between the English colonists and the Indians, was not, however, related to differences in the racial aptitudes of the French and English colonists. It would be difficult, if not impossible, to prove that the Frenchman is an adventurer, an explorer, and a lover of the wilderness, whereas the Englishman is a tiller of the soil. Differences in the character of the settlements were the result of the physical build of the North American continent. First obtaining a foothold in rather high latitudes, where the soils are comparatively thin and for the most part poor, with long cold winters, with ease of penetration and communication afforded by the waterways, the French virtually assured the destiny of their colonial enterprise. The English colonies, on the other hand, were hemmed in on the west by a topographic barrier, the heavily forested parallel ridges of the Appalachians and the maze of ridges and valleys of the dissected Allegheny-Cumberland plateau, a barrier which has proven difficult down to the present and which was, in colonial days, virtually impassable. The Kentucky Mountains comprise a portion of this barrier which imposed itself between the Atlantic seaboard and the fertile areas of the Mississippi Valley.

Topography and soils of the Kentucky Mountains

Physiographically, the Kentucky Mountains represent a maturely dissected plateau, with the crests of the ridges which represent the remnants of the former even plateau surface rising from an average altitude of about 1,000 feet above sea level at the Ohio River to an average elevation of 2,000 feet above the same datum plane at the Tennessee border. Five large rivers, the Big and Little Sandy, the Licking, the Kentucky, and the Cumberland, rise in the plateau. Many of these streams have tributaries of considerable size. The region is covered with a network

of rivers, creeks, and forks which head against one another on opposite sides of the ridges and constitute the divides between the drainage basins.

The ridges in general have rather an even sky line, form a complex network over the major portion of the area except in the southeast, where the Cumberland and Pine mountains parallel one another in a N.E.-S.W. direction, ten to twelve miles apart. Whereas over most of the area the strata are practically horizontal, with only a slight dip to the southeast, in both these ranges the strata are highly inclined. The Cumberland Range presents a steep face, broken in few places, to the Virginia side; the steep face of the Pine Mountains is to the northwest. Between these two parallel ridges, the Black Mountains, a mass of ridges and spurs, reach a maximum elevation of slightly over 4,000 feet.

The character of the valleys is determined by the geological formation. Where hard conglomerate ledges interspersed with shales outcrop, castellated forms are numerous and the valley sides often rise sheer from the valley floor several hundred feet, frequently making communication from valley to valley across the ridge almost impossible. Such a topography is well developed in Rockcastle County, in the area drained by the Rockcastle River, both the county and the river deriving their names from the castellated forms which abound. Along such valleys, the conglomerate layers frequently overhang and form rock houses, and waterfalls occur in the stream courses. Recent investigations have shown that these caves were utilized by prehistoric man as dwelling places.

Over the greater portion of the area, the rivers and creeks are bordered by alluvial deposits of considerable width and the valley walls rise steeply but not precipitously. The bottoms, which lie on alternate sides of the rivers as the stream swings from side to side of the valley, usually afford a considerable amount of level land along the larger streams. Along the smaller creeks, the bottoms are limited in extent and decrease rapidly in width upstream.

The widths of the ridges vary greatly. In the areas of conglomeritic outcrop, ridges are frequently of considerable width, but wherever stream dissection has progressed far, the ridges are narrow and the stream valleys expand in width.

Soils on the ridges are derived from the conglomerates and are, as a rule, thin and sandy. They are not retentive of moisture, and their content of plant food is low, as shown by chemical analysis and crop yield. These ridge lands form very poor agricultural areas. Soils are thin, and rock outcrops are not uncommon. Crops suffer severely during dry weather on the thin, sandy, infertile soils.

Soils in the valleys and on the adjacent slopes vary considerably in character. Where derived from shales, they are clays; the soils on the slopes are thin and wash badly, so that the life of a field under cultivation seldom exceeds three or four years.

In the valleys, the soils are alluvial in character and highly desirable, particularly where the rivers have cut through to limestone, but these areas are not numerous.

Movement of population into the mountains

The area has always been difficult of access. Until the last decade of the eighteenth century, there was no settlement in the mountains, which were viewed only as a barrier to be passed on the way to the West.

The Wilderness Road, by way of Cumberland Gap and the break in Pine Mountain at Pineville, where the Cumberland River cuts through, served as the principal highway over which poured the early flood of settlement into the agriculturally more desirable areas of central Kentucky. From this incoming tide of population a few settlers detached themselves and occupied the more desirable and larger creek bottoms, but the majority pushed on, as the area in general did not appeal to them. The larger number of settlers moving down the Ohio River or coming in by the northern overland routes also passed by the eastern portion of Kentucky, as did those coming in by the southern route. Though girt by roads leading to the West, the mountains were sparcely settled, settlers representing, for the most part, those who dropped out on their way to areas farther to the west.

At a later date, when the wave of transmontane immigration had spent itself, settlement pushed in from the west, but here also penetration of the mountains was difficult. Only where the rivers had frayed the west-fronting conglomerate escarpment was access possible. Until late in the history of the state, no railroads penetrated this western

barrier, and almost without exception, the wagon roads east of it were poor. Even today, railroads and roads enter only where main drainage lines have breached the barrier. The consequence of this topographic condition has been that at both an early and a late date, movement into and through the mountains and communication with the outside world have been hampered. This has been the cause of the retardation which is disappearing so rapidly.

Distribution and increase of population

From the beginning, population was widely diffused, occupying the bottoms of the larger creeks. At an early period, and to the pioneer, there was much that was attractive. The slopes were heavily timbered, and game was abundant; the alluvial soils of the bottoms afforded sufficient level land to raise abundant crops of corn. With the increase in population between 1840 and 1900, which was almost entirely genetic, population began to press heavily on the limits of sustenance of the area. As the population increased and movement up the creeks occurred, even the exceedingly rough country of the Upper Cumberland and Kentucky basins was occupied. By 1900 the density of population was everywhere from 18 to 45 to the square mile, virtually all a rural population. For a period of one hundred years, the isolation of the area was accompanied by the agricultural occupation of the land. The exploitation of the timber resource was possible in only a very limited way, and of the coal, in even lesser degree. Every farmer was practically self-sufficient. The population was of fair density, and the density increased with each decade, but development was retarded by isolation.

Character of the population

Early settlers in the mountains were virtually all of American birth and American parentage, and mostly from southern states. The stock is in all probability in large part the same as that of the Blue Grass, but it has been modified by long isolation in an area of lesser desirability. The transmontane settlers grew in wealth and culture, but in the mountains deterioration began as soon as population commenced to press upon the limits of sustenance. In addition, the lawless flocked to the mountains and reproduced their kind. Relief was not afforded by

emigration because, since the people were shut in by the mountains, ignorance of opportunity elsewhere prevailed. In addition, the mountaineer is strongly attached to home and kindred; poverty prevented escape from the area.

Although genealogical records are lacking, names and survivals in language and customs indicate an English and Scotch ancestry with a certain admixture of Germans and Hugenots. In consequence of the genetic increase of the population and the absence of immigration, the ethnic type has been preserved and the population is of extraordinary homogeneity. Even the physical characteristics are common. Since the mountaineers came from the same stock, intermarried to a degree almost unknown in any other part of America, and led the same type of life, this homogeneity is no way remarkable. The average mountaineer is lean and lank with rather high cheek bones and an inexpressive face, which effectually conceals whatever he may feel or think.

Adjustments of the population to the physical equipment of the area

Thrown entirely on their own resources by isolation, the settlers adjusted their living conditions to the limited opportunities of the area; consequently pioneer conditions prevailed for a much longer period than elsewhere in North America. The older homes are of roughly squared and fitted logs with fireplace and chimney of sandstone slabs, quite often laid with mud in place of mortar. Roofs are of hand-split shingles or "boards." In many cases, windows are lacking, ample ventilation being secured through the chinks between the logs.

Outbuildings are commonly few or lacking; hay is stacked in the field; corn is kept in a small crib or fed directly from the field; stock runs in the open except for a very limited portion of the year. Outbuildings other than a few sheds are, therefore, unnecessary.

Domestic conveniences are still few in the mountains. Up to a few years ago, furniture was largely of local manufacture. Kitchen utensils were limited to a frying pan, an iron pot, a bucket, a coffee pot, and a few tins supplemented by gourds of various sizes and shapes. Though the day has passed when the women "battle the clothes in the stream," washing is still a laborious process, carried on out of doors by the side of the creek in the summer.

On the farm, little machinery is used. Scythes, cradles, flails, and wooden harrows with locust wood teeth still are in common use. In the preparation of the land, the bull-tongue plow is ordinarily used, though sometimes the ground is simply "drug" with the branch of a tree. The hominy block and the handmill have practically disappeared, and the old water mills are likewise being displaced.

Not only has the mountain environment left its impress on the activities of the community, but it has left as well its stamp on the nature and mental processes of the mountaineer. The self-reliance made necessary by isolation has developed an independence which manifests itself in a disregard of revenue laws and a disposition to avenge wrongs without recourse to processes of law. The average mountaineer is unable to appreciate the binding force of a contract and is almost unaware of the value of time. In the monotony of their lives, small events assume great importance. Strangers excite curiosity, even today, in all areas far from the beaten trail.

It was literally true a few years ago that the Mountains were "a backwoods where the civilization is that of the eighteenth century—where money is as scarce as in colonial days, and all trade is by barter" and that in 1878, Shaler, of the Kentucky Geological Survey, saw men hunting squirrels with old English "short bows," but these are things of the past, not of the present. Most of the literature extant on the mountains conveys an entirely erroneous impression of present-day conditions.

Change in the Kentucky Mountains

The development of the coal resources has resulted in the superimposition of twentieth-century industrialism upon the community of self-sufficing households. This has been accompanied by profound changes, the amount and character of the change being determined by the extent to which the coal resource has been developed and the type of coal mining operation. Where development has been extensive, the land has in many cases passed completely out of agricultural use. In almost all parts of the mountains, the influence of the mines has penetrated; only in the remotest coves at the headwaters of the Kentucky are conditions essentially static.

Few foreigners entered the mountains prior to railroad construction,

and up to 1900 there were relatively few Negroes in the mountains. The small mountain farm did not require slave labor, and the hard conditions of life and lack of opportunity for domestic service made the area unattractive to free Negroes. In addition, the mountaineer has never taken kindly to Negroes in the community. At present, however, both foreigners and Negroes have appeared in all areas where extensive mining operations are carried on and in the urban centers which are springing up in response to the needs of the mining communities.

The future of the mountains and the passing of the mountaineer

The Kentucky Mountains, although settled at an early date, constitute the largest and only undeveloped area in Kentucky that holds forth great promise for the future. In no other portion of Kentucky is change occurring with more rapidity, yet the metamorphosis which the next half century will witness has as yet only begun.

For nearly one hundred years the mountaineers have been immured in their mountains, shut in on the east by the Pine and Cumberland mountain barrier and separated from the Blue Grass on the west by the frowning escarpment of the Basal Coal Measure Conglomerate. Amid the mountain surroundings, the mountain people have multiplied in numbers, meanwhile wringing a bare existence from the narrow bottoms and unfriendly slopes. Cut off from the outside world, they changed slowly or not at all, so that this group of people perpetuated the customs and expressions of a by-gone day. In the mountains, up to 1890, lived "our contemporaneous ancestors."

The interesting characteristics of the population, with their eighteenth-century customs and peculiarities of speech, have long intrigued the imagination of the outside world to such an extent that it has been difficult to dissociate the mountaineers from the mountains. It has come to be accepted almost as a truism by many people that this is a country of little opportunity because of its past performances, whereas the reality is far different. Few areas are more highly endowed by nature than the Kentucky Mountains. To the individual who must have level farm land with black prairie soils, who cannot appreciate any area which will not grow bumper crops of corn, the mountains promise little, but though in an agricultural way the area holds forth but slight

promise, the great mineral wealth and its possibilities as a reservoir upon which the prairies may draw for lumber, make up for the agricultural deficiencies.

This area has not as yet been despoiled, except in small part; it still possesses resources of great value. Old in point of time of settlement, the area is young in the stage of development. The problems which confront it are those which face every young and rapidly developing area, the problems of conserving the assets with which the region is endowed, which implies a wise utilization of the resources.

The old order passes and with the passing goes one of the most picturesque figures in the field of American fiction, the Kentucky Mountaineer. Adjustment to new conditions must be made, and with this adjustment, all the romance attached by fiction to the person of the Kentucky Mountaineer disappears and he becomes only another member of the modern industrial world.

13

Plains

PLAINS are the fourth of the major land forms, the most important from the standpoint of human use, the largest in area, and the simplest in formation. Plains differ widely among themselves in elevation, fertility, origin, size, and other respects. Because of these differences various names are applied to plains for the purpose of directing attention to some distinctive feature. The types of plains will be discussed later.

Economic importance of plains

From the definition given for "geography" it is the business of the geographer to consider the population distribution on the earth's surface, the activities of man, and problems incident to these, in relation to the environment. Generally speaking, the denser the population, the greater the human activities. If a map of the world showing population density is compared with the map showing major land forms, it will be found that the denser population areas in the middle latitude zone are on plains regions. Since greater economic activities are found in the middle latitude zone than in the low latitude zone, the statement can be made that the plains of the world have the greatest economic activities. This does not mean that land form is the only control. Other factors must be considered; otherwise it would not be possible to explain the differences in population density on plains throughout the world. Plains of low relief in the middle latitude zone, with favorable precipitation, near good transportation, with supplies of coal and iron available, do have a dense population, and the people will be engaged in industry. In China we find the denser population on plains,

and the people are engaged in agriculture rather than in some more advanced economic activity. The specific uses of plains will be treated separately.

Plains cannot be defined in terms of elevation, as is shown by the diagram. Some plains may be higher than plateaus or even than mountains. Plains have low relief and have more flat land than slope.

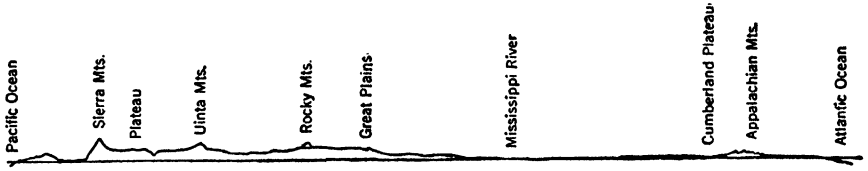


FIG. 73. DIAGRAM ACROSS NORTH AMERICA. The Great Plains are higher than the Cumberland plateau and parts of the Appalachian Mountains.

Plains are not flat; they may range from rather flattish to undulating land. Because of their low relief they have, generally, low angles of slope.

Areal distribution

The plains of Europe extend from the British Isles across the northern part of the continent. In addition there are smaller areas of this major land form in France and northern Italy.

In Asia the plain continues eastward from Europe uninterrupted across the entire northern part of the continent, narrowing as it extends eastward; at the eastern coast it becomes a narrow strip. The coastal strip of eastern Arabia, northern India and the eastern coast of India, the Malay Peninsula and immediately adjoining territory, parts of eastern China, a small section of eastern Japan, and small parts of the East Indies have the same major land form.

The larger part of Australia has plains. The only parts of that continent not having this land form are the eastern coastal section and a small area of hill-country in western Australia.

The northern part of Africa has plains interrupted by mountains and plateaus in the central part and along the northern and eastern coasts. In addition there are plains along the eastern and western coasts in southern Africa.

While the coastal parts of South America, except in the south, have other types of land form, the remainder of the continent is a long north-

south trend of plains. This plain extends without a break from near the northern coast to Tierra del Fuego.

In North America the plain begins at the most northerly part, including the northern part of Alaska, and extends southward to the Gulf of Mexico and along the coastal section of Mexico and the countries of

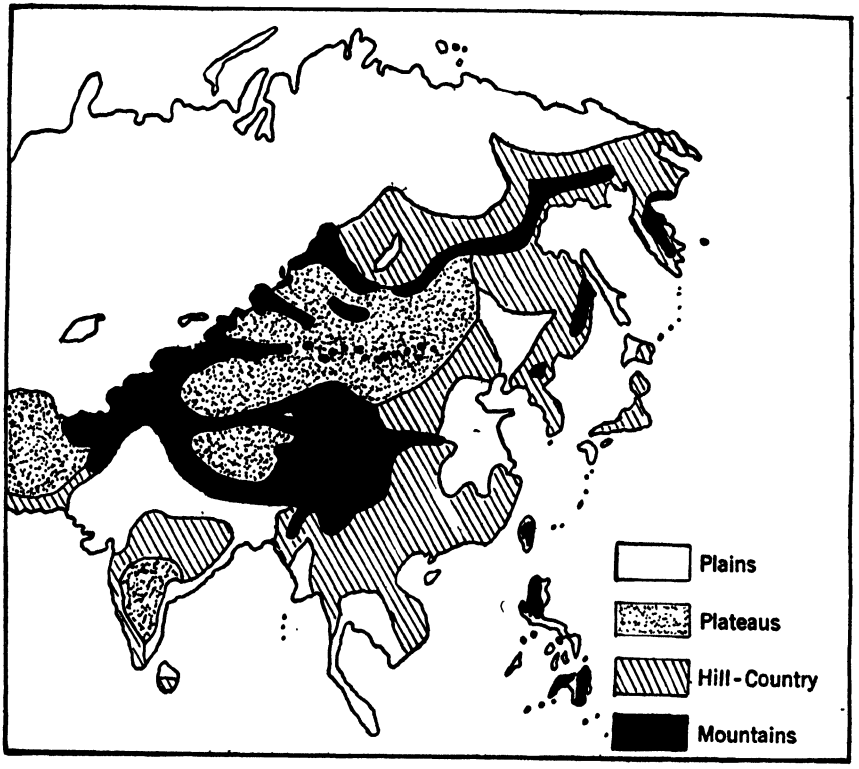


FIG. 74. LAND FORMS OF ASIA.

Central America. The hill-country and mountains of eastern North America produce an irregularity of outline along the eastern boundary, while the western boundary is extremely regular. In the western part of the continent small areas have plains, as well as the peninsula of Lower California and the western coast of Mexico.

Some of the islands of the world are entirely plains, while others may have a small area of this land form.

To summarize: most of the extensive plains are located in the

Northern Hemisphere. In the Southern Hemisphere the greatest plains are near the equator, and thus on this land form there is little human progress. In the Northern Hemisphere the plains which border the Arctic Ocean are, at present, of little significance. From the standpoint of human activities, the plains in the middle latitude zone are of greater importance than any other major land form.

Origin of plains

Plains differ from the standpoint of origin. They may be formed by exposure of the former continental shelf, by lava deposits, by agents such as river, lake, glacier, and ocean, and by denudation of a higher land form.

River Plains. The chief plains resulting from river action are flood-plains, terraces, deltas, and alluvial fans. Perhaps to these might be added the outwash gravel plains built up by streams issuing from glaciers.

Glacial Plains. Where glaciers have spread out over gently undulating surfaces, their deposits have sometimes filled valleys and made the land more level. Large tracts of country in the northern Central States have been leveled up in this way; in places the deposits are several hundred feet in depth. A detailed discussion of glaciation and its results is given in a later chapter.

Lava Plains. Lava flows, spreading out at the base of a volcano, or still more notably when flowing from fissures, may give rise to plains. Volcanic ash, falling upon the country round a volcanic vent, may also level up the surface, though wind and running water are aids in the building of such a plain.

Lacustrine Plains. Sediment settling upon a lake bottom tends to smooth over irregularities and gradually to form a level bottom. If such a lake disappears, a plain is left at its site. If a lake persists, it will in time become completely filled and its site will then be occupied by a filled lake plain. Thousands of instances of this are found in the regions of former glaciation, where filled lake plains are still so level that they are swamps.

During the stages of lake filling, smaller plains are also formed around the shores. In some cases a narrow plain is cut by the waves as they cut into the land; in others the shore is built outward, forming

a swampy plain strip at or near lake level. Larger plains are formed by the filling of bays, and by the growth of deltas into the lake.

Marine Plains. Plains along coasts have been formed by deposition and the elevation of the continental shelf. Rivers or other agents carry materials from the continent and fill in bays and inlets. Remains of organic life in the ocean have had a similar effect. When a part of the ocean bottom is raised above sea level, new land—which becomes a coastal plain—is added to the continent.

Plains of Denudation. As a land surface is worn down by denudation, plains are caused not only by deposit but also by the direct attack of the agents of erosion. Instances of this are the result of wave work along lake and seacoasts. The latteral cutting by a river in terrace formation is another.

Plains also develop as denudation lowers a land surface. This is best illustrated in areas of nearly horizontal strata as a result of the fact that resistant beds are removed less readily than weaker ones. The original land may have been mountain, plateau, or hill-country.

Dissection of plains

Plains with the same origin will differ in the stage of the erosion cycle, for plains, like other land forms, undergo a cycle of dissection. In this cycle of dissection the level area may be sculptured into a very rough surface which may be followed by leveling.

The coastal plain from Florida to southern Texas is an example of a young plain. A young plain has a level surface from which the water does not drain freely. Large areas of these plains are not suited for human occupance although they may have luxuriant plant growth. Precipitation is not so necessary for heavy vegetation on low coastal areas as on the higher, better drained plains. Ground water level is near the surface in the former instance.

A young plain, however, may be elevated so that streams will cut along their banks, and, if that occurs, dissection begins. In the beginning the stream beds are narrow and the divides flat topped and broad. If the soil and climate permit, such areas may be used extensively for agriculture. Examples of such plains are the Red River valley in North Dakota and Minnesota. The successive stages of dissection depend primarily on elevation, precipitation, and rock structure.

Elevation is a primary factor, since a surface with higher elevation offers greater possibilities for deep dissection than a plain with lower altitude. A plain of high elevation may be so dissected that the entire landscape has been changed into hills and valleys, producing a very irregular surface. In regions of lower elevation there is less possibility for such variation and the features are less striking and less numerous.

In regions where humidity is high and rainfall heavy the tops of ridges caused by water dissection are rounded. In arid regions mechan-

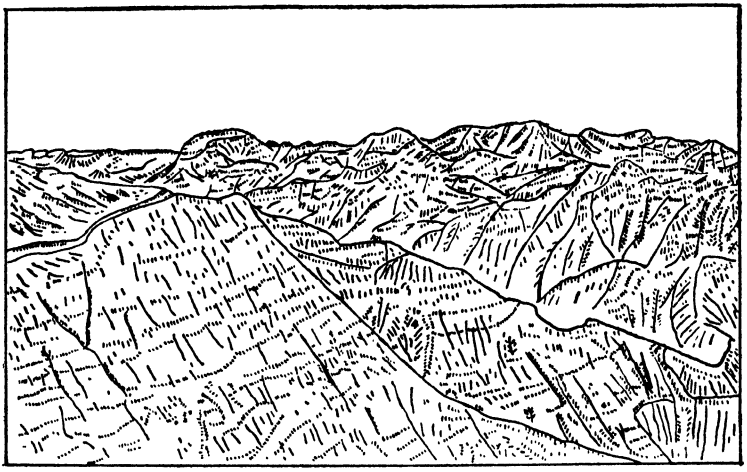


FIG. 75. BAD LANDS. Result of Rain Water Erosion.

ical disintegration increases angular forms and more rock is exposed, since wind removes disintegrated fragments and the lack of vegetation cover increases erosion. Thunderstorm showers are a common type of rainfall, especially in arid regions. This shower falls very rapidly, and a large amount of water may fall in a short period of time. Bare ground, especially when consisting of clay, is sculptured by rainwash into innumerable close-spaced, steep-sided ridges and valleys of small size, producing a type of country called "badlands."

The rock structure varies in plains, as in other land forms, and this variation produces changes in the stage of dissection. In areas where there is uniform rock structure, the cycle produces first a few gorge-like valleys with divides which are flat topped. Later the cutting action of the headwaters of the streams widens the valleys and narrows the divides. This condition continues until the area is again reduced to a

level plain. If a plain has been produced by the erosion of a former mountain, the rock structure may be extremely complex and the rocks at different angles offer various degrees of resistance. This produces valleys and intervalley areas which are nonsymmetrical. The arrangement of the valleys will be determined by the rock structure. As dissection advances, the valleys and ridges may have produced mountainous topography. As the influence of the rock is lessened by increased dissection, a plain may again appear. Many combinations of rock structure from the simplest to the most complex might be cited, and each would result in a different dissection. Thus for a given area the rock structure (from simple to complex), the precipitation (from arid to humid conditions), and the elevation (from sea level to high altitudes), all determine the process and degree of dissection.

Human use of plains

In the middle latitude zone the largest proportion of the population is found on plains. Isolation, such as was discussed for mountains, is lacking in plains. Extreme isolation is always unfavorable for the development of civilization. It is out of conflict, comparison, exchange, and accumulation of ideas of the many that civilization is produced. While it is possible to find interchange of culture in mountains within small areas, on plains interchange over wide areas may be found. Another advantage of plains is that they may have a climate which has less extremes in temperatures than any other land form. Thus from the standpoint of climate, soil, and topography plains are the great agricultural regions of the world. Climate is the most important factor affecting life on extensive plains. The form of the human adjustments will vary with the different types of climates, as suggested in the chapter on climate.

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14

Land Economy of Warren County, Kentucky

THE two regions in Warren County, Kentucky, have economic and social adjustments strikingly unlike. One part of the county has plains, and the other is hill-country. Climate is similar; the hill-country is not sufficiently elevated to differ significantly from the lowland. The racial stock and the cultural background of the pioneers of both areas are identical, and settlement occurred about the same time. In land forms these regions differ conspicuously, and Doctor Gibson, in the following article,[1] shows that there is a causal relation between land forms and modes of life.

Kentucky belongs to the South, which, by virtue of a common tradition derived from the pre-Civil War period, a similar ancestry of population, and common economic interests, is perhaps the most distinctive cultural division of the United States. Abundant, tillable soil of varying arability and productivity, under a humid mesothermal climate of mild, open winters, and warm, rainy summers promotes a culture chiefly rural, and industries chiefly agricultural. The plantation system of ante-bellum time has, in a major sense, crumbled. Subdivision of farming land and opening up a new territory have kept pace with rural population growth, and in post-war years subsistence agriculture has gained predominence over the plantation system.

[1] Adapted from J. Sullivan Gibson, from *Economic Geography*, Vol. 10, Nos. 1 and 3, published by Clark University, Worcester, Massachusetts.

The place of Warren County in Kentucky and the South

Climatically, racially, and culturally Kentucky represents and typifies the Old South. Its present culture, a result of present and past en-

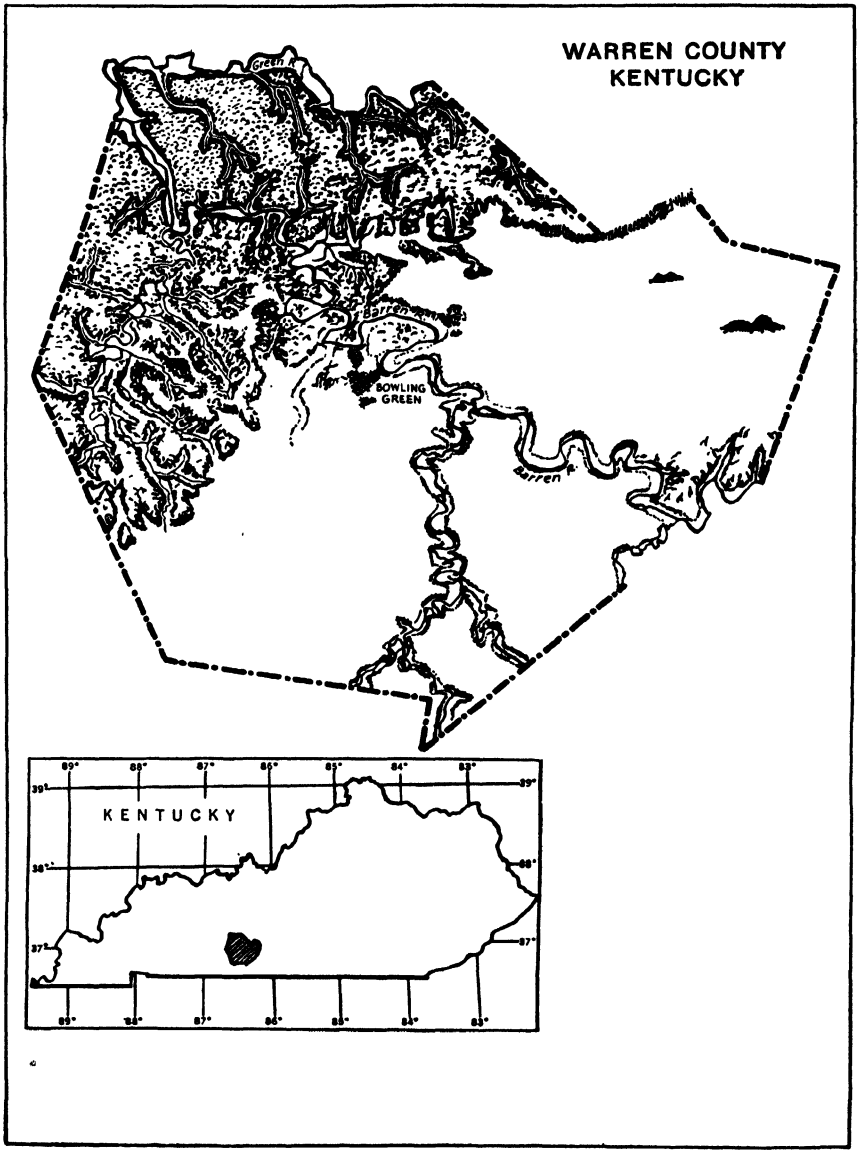


FIG. 76. SKETCH MAP OF WARREN COUNTY, KENTUCKY.

vironments, portrays the qualities of both the courageous, resourceful frontiersman of colonial days and the present-day semiaristocrat of the Atlantic slope. Pride of home and state is regarded as one of the strongest attributes of Kentucky citizenship, while inventiveness and ingenuity, held in high regard, characterize a people ambitious to keep the activities of their commonwealth abreast the times. Although the state is relatively rich in minerals, particularly coal and petroleum, Kentuckians have long realized that the basis of their civilization is the agricultural land. The million or more people actively engaged in agriculture, by consistent use of this one great resource, are promoting an industry of livestock raising, tobacco farming, and general agriculture in keeping with the potentialities and needs of the state.

Location

Warren County in southwestern Kentucky lies somewhat in line between two southern metropolitan centers, Louisville, Kentucky, and Nashville, Tennessee. From the standpoint of land utilization it is typical of a rather extensive part of both Kentucky and Tennessee. Its location as the second county north of the boundary between the two states places it well within the state in a physical and cultural environment typically Kentuckian. Louisville, 125 miles north of Bowling Green, the Warren County seat, is the recognized metropolitan center to which all western Kentucky is in a measure tributary, although Nashville, 67 miles south, shares somewhat with Louisville in this respect. Neither of these centers is highly significant in Warren County, however, for Bowling Green constitutes a trade and cultural center to which this part of the state is significantly tributary.

Type of the Pennyroyal

Warren County lies near the center of the Pennyroyal, a well-recognized though ill-defined regional subdivision of the Interior Low Plateau (Fenneman classification). This rather large region, embracing a considerable part of eastern Kentucky and northern Tennessee, is the most transitional in character of all the major natural regions of Kentucky. Surface and soils exemplify almost the entire range of

conditions found elsewhere in the state. Broad belts of rich limestone soil compare well with soils of the Bluegrass, while sections of thin, sandy soil and rugged relief are quite suggestive of the mountain topography. Cultural conditions within the Pennyroyal likewise have a wide range, from those of the poor farmer of the more remote hilly section to those of the wealthy tobacco and livestock farm owners of the fertile limestone country.

Similarly, Warren County displays a range and variety of conditions typical of the Pennyroyal at large. Within a distance of only a few miles from north to south are represented the extreme physical and cultural conditions of the entire region.

Physical and economic background

The northern and southern parts of Warren County stand in direct contrast to each other, both physically and economically. The Pennyroyal contains no better land than the deep, fertile, undulating, limestone plain of the southern part of the county; while in the northern part, rugged hill-country with thin, infertile, sandy soil has perhaps as low agricultural potentialities as any part of the region.

Northern part of the county

The northern part of Warren County is characterized by hilly relief. The Chester sandstone, which once underlay the entire area, has been dissected by tributaries to Barren and Green rivers. In the more hilly sections only the ridge tops are capped with this sandstone. Both limestone and sandstone, interbedded along most slopes, are exposed, while in the valley bottoms limestone underlies the thin, depleted soil covering. On the more level section of the higher divides sandstone and sandy soil continue uninterrupted.

A surprisingly high percentage of this hill-country has been cleared. Only a small part of the timber left is of merchantable quality, and farmers make little use of it except for firewood and for small amounts of lumber for home purposes. The development of the oil industry a few years ago was of material significance to many of the hill people; but at present production is low and landowners realize very little from

the industry. Most of them look directly to their farms for their income.

Infertility of soil and steepness of slope limit cultivation and restrict production. Land holdings vary little in average size for this section of the state. Cultivation is on a small scale and follows a patchy pattern. Roads, as a rule, follow the ridge tops, and the farm pattern is irregular. Frontage on a road passable in wet weather is more significant in this day of the automobile than it was a generation ago.

Average farm values are low, and both investments and returns have always been small for the hill farmer. Owing to small per capita wealth and, therefore, inability to furnish security for loans, the average farmer has not been considered a safe risk on heavy loans; he has consequently been forced to live within his income. Self-reliance and hardihood characterize the hill people. The degree to which they produce the food they consume is remarkable. Their purchasing power is low; their needs beyond the commodities they can produce at home are few. Although the hill folk lead rather simple, frugal lives and follow standards of living that would be considered low in comparison with those of the people living on the Pennyroyal Plain or in the Bluegrass, the majority are respectable, religious, patriotic citizens, playing well the role in which they are placed by the inexorable conditions of their land.

Southern part of the county

The hills of the northern part of Warren County terminate, for the most part, rather abruptly along the contact zone of the St. Louis and St. Genevieve limestones and the Chester sandstone. In the east this contact follows the Dripping Springs escarpment, a steep, south-facing scarp that rises almost vertically for a hundred feet or more above the limestone plain to the south. Farther west, however, the escarpment gives way to a dovetailing of deep canyon-like valleys with steep sandstone-capped ridges and knobs.

The southern part of the county, which belongs to the Pennyroyal Plain, is characterized by level or slightly undulating relief, except in a few karst areas and in the vicinity of the drainage channels. The Clarksville soil, developed from the St. Louis limestone that underlies

most of the area, is in most places a deep, fertile, red silt loam with high productive capacities.

The tobacco plantation of slavery days flourished here, and some of the present-day holdings are remnants of the pre-Civil War estates. Land holdings are much larger than in the hill-country, and average investments are several times as great.

Road construction is easy, and a rather high taxable wealth warrants a relatively good road system. Both roads and farms follow a rectangular pattern. Frontage on a gravel road is one of the essentials of every farm, and the automobile has become a necessity.

The farmers of this section have always been heavy investors, and many of them have been heavy borrowers. In practicing large-scale farming they have invested heavily in land, equipment, and labor. In times of good yields and high prices they make money and the communities prosper; but in times of economic depression heavy operating expenses, high taxes, and high interest rates have piled up debts that have broken many of them.

The average farmer in south Warren County does not practice the strict economy necessary in subsistence agriculture; but, prompted by a motive to make money by investing heavily in cash crops of tobacco, grain, and livestock, he has developed a rather extravagant system of living. Standards are high; homes, as a rule, have all the luxuries of the well-to-do city dwellers.

Typical of the Pennyroyal, which in turn is average for Kentucky, Warren County can best be understood from a land use viewpoint by recognizing two distinct types of physical and cultural landscapes, the hills and the plain, with a transition belt grading from one to the other.

Relationship of the physical environment to Warren County agriculture

Every civilization, old or new, depends directly upon its physical environment for existence and progress. But the extent to which a people may recognize the dominance of their physical surroundings may vary according to (1) the state of culture attained by the people, (2) the degree to which the population has crowded the region toward the saturation point, and (3) the abundance and permanence of resources.

The pioneer settler in a land of abundant resources has all he wants and needs merely for the taking. But it is in the old settled regions where generation after generation ekes out an existence from the land of limited wealth, pressed on all sides by a crowded population, that man recognizes and respects the dominance of his physical environment to the extent that he acts with nature in a wise and conservative use of the resources with which she supplies him.

The present culture of this part of the Old South is, to a certain extent, a heritage of the past. Farmers grow corn and tobacco because their fathers before them grew the same crops, and either created a demand for them or supplied the wants already in existence. In the hills, farm land rests from the plow about three years in four; this again has been the practice for ages in hill-countries. If a farmer plunges in without regard for the physical restrictions about him, he loses; if he succeeds, he follows, perhaps, the plan acquired generations ago through the trial and error method.

The land use program in Warren County, Kentucky, is so definitely related to the physical background of the region as to warrant and necessitate a careful consideration of the various physical elements, to determine their definite relations to the ways farmers use their land.

The hill-country

The hill-country serves as an excellent example of a region where both physiography and soil favor low productive capacities. Although much of the upland tableland remains almost level, the work of surface and underground water has reduced the level tracts in many places to mere patches, through the headward erosion of hollows and the collapsing of caverns developed in the limestone below. Both the sides and the narrow bottoms of these hollows and sinks are covered with sand and fragmentary sandstone that have worked downward from the Chester sandstone beds above. In many instances, large slabs of this sandstone have gravitated down the slope below the level of the ledges. Thus, much of this soil, although resting on a limestone base, is derived chiefly from disintegrated sandstone and is very low in calcium content.

There is a concentration of these hollows along and near the escarpment. Numerous valleys penetrate it from the south, while many

hollows with steep-wooded slopes which drop abruptly a hundred feet or more to ramifying bottoms covered with thin stony soil cut the uplands into patches connected by narrow, flat ridges.

The upland is not everywhere dissected. In places on the divides it appears as a continuous tableland for a considerable distance, broken only by minor irregularities. Such sections permit a rectangular road and field pattern and favor farming on a larger scale than farmers can follow in the rougher sections. In the extreme eastern part of the county and extending into the western part of Edmonson County, such a section of continuous upland covers several square miles and constitutes one of the best farming sections of the entire upland region.

Originally the valley bottoms offered better advantages for farming than did the upland areas, and they were the first lands of the hill-country to be cultivated. The soil covering, though much inferior to soils of the Pennyroyal Plain, derived considerable advantage from its mixture of sandstone and limestone debris. It stood up poorly under cultivation, however, and farmers early extended their clearings up the slopes, beginning cultivation on hillsides with, at best, only thin sandy coverings. With slope-wash thus augmented, the steep land lost its soil mantle and the bottom fields soon became strewn with sand from the upper slopes. Cultivation migrated back to the valley bottoms, leaving the cleared, gullied hillsides abandoned.

Soils of the more nearly level upland are extremely sandy. Although the surface is relatively smooth and the land not subject to rapid erosion, their period of usefulness under cultivation is relatively brief. They were put under cultivation later than the valley soils, but in spite of the absence of slope-wash, much of the upland has already been abandoned because of the exhaustion of fertility.

Level upland, steep slope, and narrow valley bottom succeed each other in rapid order throughout the northern part of Warren County. No community is without all three types of topography, and many individual farms include the entire range. Soils vary in composition, texture, and depth with each variation in relief, and a consequent variation in productivity gives, indeed, a mottled appearance to the farm income map of any hill community.

For the most part the hill-country has an air of poverty. Thin, depleted, sandy fields are returning, one by one, to nature for the fertility

that weeds and sassafras bushes slowly restore, while new clearings on even steeper slopes are replacing the abandoned fields for only a brief span of years at best.

The whole hill-country depends upon the Pennyroyal Plain for its political and commercial connections. This is true not only for Warren County but for the hilly parts of neighboring counties as well. There is not a single market or court center in this area, but the whole region is strictly dependent upon and tributary to Bowling Green, Russellville, Hopkinsville, and other Pennyroyal market and political centers.

The future

The hill-country of northern Warren County appears destined to remain a land of small farms of low productivity and small monetary worth. The soil, naturally of low productivity, can scarcely be rebuilt by any economical means, when once it is depleted; hence its value for agricultural use continues to depreciate. Subsistence agriculture is as nearly attained here as anywhere in the South; it will probably remain the system of the future. The hill people have little opportunity ever to rise much above their present level of living. They very probably will roll away the debts brought on by the present depression period sooner than will farmers of the better farming sections; many of them will rebuild their bank accounts, but one cannot expect many of them to accumulate much beyond the necessities of life. The hill people fit remarkably well into their physical setting; in the future they doubtless will continue to play the role of hardy, contented, patriotic citizens, making the best of what is offered by their environment of limited opportunities.

The limestone plain

In the southern part of Warren County optimum Pennyroyal conditions are developed. The region, usually referred to as the "Pennyroyal Plain," has very slight relief and a rather simple physical landscape resulting from the weathering of broad masses of St. Genevieve and St. Louis limestones. The region is truly a plain with a remarkably smooth surface, for the most part, and relatively few rock outcrops except in the foothill area near the upland border. Soils vary considerably in depth, and, consequently, in productivity. Bedrock, as a

rule, lies from 2 to 15 feet beneath the surface; but in some places it outcrops or lies within a few inches of the surface, thus rendering the land unfit for cultivation and of only low quality for pasture.

In other places, on the other hand, the limestone bed is buried beneath 30 or 40 feet of unconsolidated soil material. This variation in soil depth is remarkably significant in the vicinity of Rich Pond. Just north of the village, bedrock outcrops over a considerable area, while about a half mile to the southward the driller of an oil well encountered limestone only after drilling through more than 40 feet of soil and clay. The deep soils are highly productive, and, where properly cared for, are perhaps as fertile as any of the soils of the Pennyroyal.

Surface streams are not significant in the southern part of the county. Tracts of many square miles in extent are without streams or valleys. Much of the Pennyroyal has underground channels; but in sections, as in the extreme southern part of the county, sinkhole drainage is inadequate, and large areas become sites of extensive marshes and lakes in rainy seasons. In the Matlock section, such a marsh covers several hundred acres, while additional adjacent areas of considerable extent are sometimes water logged for several months in late winter and spring. The few small surface streams found in this region have poorly developed courses and are quite irregular in their flow; in the dry season they appear merely as indefinite, dry channels. During the times of heavy rains, however, the cavernous earth does not take up the water as fast as it falls, and mudladen streams flow brimful through ill-defined, flat valleys.

The development of the present surface and soil of this plains area is chiefly the work of solution and underground drainage. Surface streams produce little erosion, and much of the weathered material is washed down into cavernous passages and carried out of the area. Such drainage, for the most part, is effective and would serve adequately for a rainfall much in excess of the 50 inches which the region receives annually. The soils, although sticky when wet, soon dry out after a rain. Farmers can cultivate their fields here much sooner after a rain than can those of the Illinois and Iowa prairies, where there is little or no subsurface drainage. The solution work is so evenly distributed in this region by water percolating through the sieve-like rock mass, that the surface is slowly being lowered very uniformly.

A typical community on the limestone plain

About the village of Rich Pond spreads the gently undulating limestone plain on which Pennyroyal agriculture finds its optimum development. Stretching for miles in broad, billow-like swells, uninterrupted by surface streams and only slightly broken by occasional solution sinks and ponds, the plain displays large, well-kept farms producing abundant crops of corn, wheat, and tobacco, and supporting a farm economy and culture that compares well with the best in the South. The physical and cultural landscapes harmonize remarkably. Farms and roads conform to the rectangular pattern, while the layout of fields and the arrangement of buildings and grounds show careful planning. A remarkably high percentage of the land is cleared and cultivated; timber, although not altogether lacking, is restricted to small woodlots and to permanently pastured patches where trees serve as shade for stock. Very little waste land mars the area; practically every acre is utilized in some profitable way or seeded to legumes or other soil-improving plants, thus insuring continued productivity of soils that might otherwise become depleted under constant cropping.

Farms range in size from 50 to 60 acres to more than 1,000 acres, with relatively few of the smallest or largest types. The nine farms which were carefully surveyed collectively typify the entire region, averaging 164 acres, approximately twice the size of the average hill farm in the northern part of the county. The high productivity of the reddish-brown soil, a large percentage of which produces a crop every year, insures an average income several times as great as that of the hill farm.

In this section most farmers practice large-scale methods. The tractor is used on practically every farm for plowing and for harvesting grain, while a few farmers use teams of two to six mules each for this work. Two-row planters and cultivators contrast strikingly with the one-mule plow of the hill-country, while the power hay press and the grain combine used in this section are likewise impractical in the hills. This method of farming naturally calls for an orderly layout of relatively large fields, in rectangular pattern, conveniently arranged for rotation practices.

A considerable variation in type and quality of dwellings reveals itself in the section. The farmstead home, however, is usually large,

comfortable, and in good repair. Some are large, expensive buildings, equipped with running water, gas, electrical appliances, radio, and other modern conveniences. A few of the old colonial mansions, built a half century ago, remain as landmarks of the pre-Civil War plantation system. The newer homes, however, are frame or brick bungalows, modern and well equipped but more conservative in size and cost. Tenant homes, as a rule, are small box houses, poorly constructed and uncomfortable.

Barns and other buildings suggest the large-scale methods which farmers practice. On most farms, at least one large barn supplies storage for corn and hay and for housing work stock and milk cows. Most barns (usually unpainted or painted red) are in good repair; however, a few dilapidated barns are still in use. The number and size of barns are usually in keeping with the size of the farm, the number of livestock kept, and the amount of feed stored for winter feeding. On the larger farms three or four fair-sized barns are needed, besides a tobacco barn, a granary, a garage, a smokehouse, and possibly other buildings. Some farmers store hay in the open, but much more of it is housed than in the hill-country.

The Dixie Highway passes through the northeastern edge of the community and gives excellent connection with Bowling Green, Franklin, and Nashville. County gravel roads serve all parts of the community and connect them with other neighborhoods of the southern part of the county and with Bowling Green via Greenwood. The gravel roads are well graded and graveled, follow a rectangular pattern, and serve practically every farm. Transportation presents no problem in this community. Most farmers own one or more automobiles, and the good system of gravel roads serves them excellently at all seasons.

Property ownership

The per capita wealth of this region rises considerably higher than that of the hill-country. According to the agricultural census of 1930, the farms and farm buildings of Hickory Flat Magisterial district, which lies entirely south of the hills, represent a value of $1,194 per farm inhabitant; this is two and one half times that for Greencastle district, which is entirely hills. For the best farming districts, such as the Rich Pond section discussed above, the per capita valuation is probably five

times as great as the Greencastle average, while farms have an average value of about $90 per acre, or $15,000 each. This is about eight times the value of the average hill farm. Thus the ratio of average farm values of the Hickory Flat and the Greencastle districts is eight to one, while the ratio of the per capita wealth of the two districts is only five to one. This shows that a smaller percentage of the people own farms in the limestone region. The high cost of land makes it difficult for the farmer with little capital to become a home owner.

People of this region who do not own homes fall into two classes: the tenant or share cropper and the "hired hand." Most of the larger farms have one or more tenants who live in a tenant house on the farm and work a crop for themselves. The farm owner usually furnishes his tenant with seed, teams, and tools, sharing with him the proceeds, usually on a fifty-fifty basis. Frequently the tenant works part time for the land owner, from whom he receives daily wages. Many farmers do not keep tenants but employ hired help instead. Ordinarily, after a farmer provides the necessary machinery and other equipment it is more economical to hire laborers and operate his entire farm than to rent part of it to a share cropper. Tenant and hired hand alike frequently become permanently attached to the land and remain year after year. They never accumulate much property and most of them barely make a living, yet in prosperous times many may have substantial bank accounts. With little or no investments they have few responsibilities. They have little opportunity to contract debts; as a rule they live "from hand to mouth," and in depressing times maintain their financial level much better than do the land owners. Negroes are numerous; but very few own land. They function well as tenants and hired hands, for they are more content with their lot than are the white people in the same role, and as a rule are more satisfactory for the lower classes of work. Negroes constitute 20 to 25 per cent of the population of the section. Some farm owners live in town, leaving their farms entirely in charge of tenants, who look after the affairs of the farm for the best interests of all concerned and usually make money for the owner and themselves. As a rule, these tenants rank considerably above the average tenant and wage worker, socially and culturally.

Conclusion

The cultures of the hilly northern part of Warren County and of the limestone plain differ as widely as their physical character. The chief cultural differences between the two regions, one may say, have resulted very greatly from physical differences and, therefore, are highly environmental. Both cultures, however, are products of the past as well as the present; in both regions nature has set up physical limitations that have determined largely the activities of men; likewise they have also determined those characteristic customs that past generations have handed down to the present.

15

Minor Land Forms

THE major land forms are those strongly marked features of the continents that have been constructed in geological time. Upon the major land forms changes are gradually and continually taking place, altering the major land form so that variations are produced which are called *minor land forms.* The minor land forms are the smaller features on the major land form. The agents producing these changes are many, but the chief ones are (1) sun, (2) rain, (3) frost, (4) wind, (5) running water, (6) ice, and (7) the sea. While each agent acts separately or in combination with others to effect a change, it performs its work differently from any other agent.

The sun

As the sun's rays heat the surface of rocks, or the earth's surface, the heating produces expansion. If the rock were composed of a single mineral, the expansion would be uniform for the surface heated. But, since the rock is composed of many and varied minerals, expansion occurs at different rates, causing cracks to form in the rock. Also the entire surface of the rock is not heated to the same extent. Where rock has little or no covering of loose material, as is the case on steep slopes, it is heated by day and cooled by night. In mountains the daily changes in temperature of the surface of the rock are great. The surface of the rock may become very warm while the sun shines. Rock is a poor conductor of heat and thus only the surface is heated notably. As the rock is heated, it expands. The heated part may scale off from the cooler part beneath. At night the surface cools and contracts. The outer film of rock cools first and most, and tends to break.

The changes in temperature involved in this process of rock breaking

are changes of temperature of the rock and not of the air. During the day the temperature of the rock may be higher than that of the air above it. The air affects the process only because it has some effect on the amount of temperature change which the surface of the rock undergoes. This process of rock breaking is very common and important. In high mountain regions where changes of temperature of the rock are great and sudden, the exposed rock is usually much broken. The surface may be covered with cracked and broken rock. Quantities of such debris are found at the bases of many mountains of western United States. The pieces range in size from tiny bits to masses which may be a ton or more in weight.

Rain

The rain, especially where there is very heavy rainfall, has a powerful action in loosening and carrying away the earth's surface. Where soil is held by roots of trees or grasses, this action is more difficult; cultivated hillsides are often completely washed away by heavy rains. When rains, especially downpours, fall on softer beds of sand or clay in which there are large stones, the soft material around the stone may be washed away, but the soft material below the big stone is protected and stands up as an earth pillar. Also, rain, in falling through the air, absorbs a considerable amount of carbon dioxide gas. Rain water, with this gas in solution, dissolves certain rocks, such as limestone. The water which sinks into the ground is able to carry on its work of solution there, forming underground caves. Some substances, such as salt, are dissolved by pure water.

Frost

In regions of high latitude or high altitude frost is an important agent of distintegration. In regions where there is a deep cover of soil or mantle rock the water near the upper layers freezes in winter so that the surface becomes a solid. When the ice melts, the water runs off the surface much as rain water would; if the lower layers are still frozen, as in the tundra climate, the action of running water is slight, as discussed in a previous chapter.

In regions where the loose material on the surface is thin or absent, some of the rain water sinks into the cracks of the rock. When the

water freezes, it expands about one tenth of its volume. The ice acts as a powerful wedge, widening the cracks, and in time breaks the rock. This process is particularly important where there is abundant moisture and where changes of temperature above and below the freezing point of water are frequent. The blocks and stones produced by frost action are angular and sharp edged. Since frost action is a powerful agent in rock breaking in high mountains, it results in many rugged and sharp-edged ridges and peaks.

Wind

The agents just discussed are only agents of denudation. The remaining agents not only break down rock and land forms, but also transport these weathered materials and deposit them in a new area.

The wind acting alone or with millions of small particles which it may be carrying is able to wear down even the hardest of rocks. Wind erosion is greatest at the base of a cliff or rock; because of it, undercutting takes place. In time, the undercutting progresses to the point where the rock topples over or the cliff breaks off. The finer particles that have been broken off by the wind or some other agent may be carried away by the wind. These particles may be carried many hundreds of miles. In central Asia a thick mantle of dust, known as *loess,* has been deposited by the wind. Sand deposited by the wind usually takes a crescent shape.

Running water

Some of the precipitation which falls collects on the surface and forms brooks, streams, and rivers. Each rivulet begins to cut for itself a channel, and this is continued until the water reaches the sea. The channel tends to be at first shallow and narrow, and becomes broader and broader as it reaches the mature stage. This denudation takes place in all parts of the world except where the ground is constantly frozen, and it is greatest in the upper courses of the rivers. The particles that are carried by the stream are broken down by chemical action of the water, and by the rocks being thrown against other rocks. The rivers carry materials in suspension, in solution, and by rolling them along the bed of the stream. In time the stream velocity is checked,

and the materials being carried are dropped, forming a deposit which may be temporary or which becomes a minor land form.

Ice

In higher altitudes and in polar regions ice accumulates and moves into warmer regions. As it proceeds, it erodes the land along the sides and bottom of the glacier. Some of the material is picked up and carried in and on the glacier. As the glacier melts, the carried material is deposited either at the sides, front, or bottom of the glacier. The process of ice formation and the work of glaciers in erosion is discussed in detail in Chapter 24.

The sea

The sea changes much of the coastline. The waves which are hurled against the land wash away the softer parts. The more resistant rock may be left behind as headlands, capes, or islands. The sea hurls boulders with the waves; when they come into contact with other rock, they are broken into finer particles. The sea, instead of cutting the surface irregularly, wears the land into a nearly flat surface. Materials broken down by the sea or carried into the sea are moved laterally along the coast or into deeper water. Sufficient material may be broken down from the coast by the sea or carried into it by running water for land to be added to the edges of the continent or the island.

Summary

On the whole the tendency of the work of the sun, rain, frost, wind, running water, ice, and the sea is to loosen materials of the surface of the land and lower the surface. These materials are then carried away. There comes a time when the material which has been broken down from one part of the earth and carried to another is deposited.

These modifications, by whatever agent, bring changes in the major land form and produce for a small area a new land form. This new land form, being a modification on the larger, and occupying but a part of it, is known as a "minor land form." Minor land forms are the result of continual and gradual changes by forces acting in historical time rather than in geological time. The next chapters will discuss the principal minor land forms.

16

Floodplains

FLOODPLAINS are those minor land forms built by river deposits, which, under normal conditions, are within the control of the river. Before discussing floodplains and their use, it is necessary to see how and why rivers are formed, to examine the source of the deposits, and to review the work of a river in erosion.

When precipitation falls, a part is taken immediately by plants, a part evaporates, a portion sinks into the ground and may return later to the surface, and part collects on the surface and runs off. The part which runs off is the chief source of the water supply for rivers. Rivers are the means whereby surplus water is removed from the land. Every permanent stream and many temporary ones flow in depressions called *valleys.* The very small depressions are called *gullies;* if somewhat larger, *ravines.* Gullies and ravines are but small valleys. During a rain the water falls on the ground, and that which remains on the surface flows down the slope. Almost immediately little rills are formed in which the water collects as tiny streams; these streamlets unite with one another to form creeks, and they unite to form rivers.

Erosion

Streams are an effective agent in changing the surface of the earth, for streams are numerous in most lands. They have been active for a long period of time (geological time), and much of their work is concentrated in valleys. As the water flows down the slope, it picks up and carries particles of materials. Thus, almost from the time that surface water begins to flow it begins the work of erosion. This is especially true if the runoff flows over cultivated fields, or where loose

particles are available. *Erosion* is the wearing away of the land. In general it consists of three stages: degradation, transportation, and deposition.

Valleys become deeper, wider, and longer year by year. This process continues until something interrupts it.

When rain or melting snow flows from the surface, it first moves into the lower depressions; in but very small areas will the surface of the land be so smooth that no lower places occur. In a short time a rill has been formed which may become a gully; continued wearing deepens the gully to a ravine, and then it becomes a valley. The valley may become deepened so that it is below the ground-water surface; the

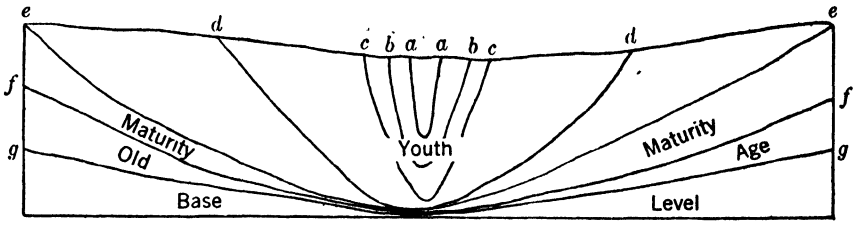


FIG. 77. DEVELOPMENT OF STREAM VALLEY THROUGH YOUTH TO OLD AGE.

ground water then seeps into the stream and feeds water into it. This is an important source of water for the stream during the dry period.

Swift streams remove material and make the valleys deeper. In the larger river basins the deepening of valleys may occur only in the upper courses. A *river basin* is the region drained by a river. As a stream deepens its valley, the gradient becomes less and the stream flows more and more slowly. In time every stream will cut its channel until its current is sluggish. The lowest level to which a stream can reduce its basin is *base level.*

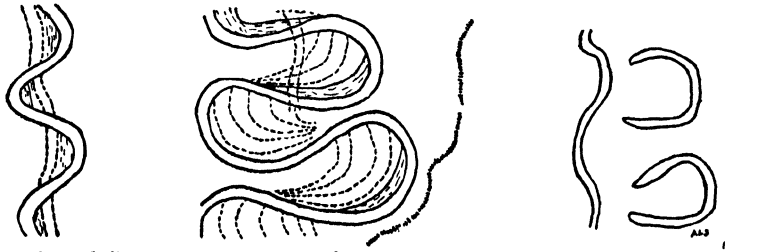
Development of valley from youth to old age

Not only are valleys deepened, but they are also widened. While valleys are widened in many ways, the following are the more common methods: The loose material which lies on the slopes of the valleys creeps slowly downward, especially if it is wet. Rain water flowing down the slopes carries material with it and slowly wears back the slope.

A stream flows against one side of the channel with sufficient force to undercut the slope above. A slow river widens its valley, in this way, more than a swift one, for the former is more easily deflected against the banks by obstacles in the channels. By the methods listed, as well as in other ways, valleys grow in size as they advance in years. When a valley is young, it is narrow and its slopes are steep. If the land has a high elevation, the valley may have a steep gradient and it soon becomes deep. Tributaries are short, and the cross section of the valley is somewhat V-shaped. A mature valley is wider, slopes more gently, and the tributaries are longer. An old valley is wide and has a low gradient. The terms *youth, maturity,* and *old age* may be applied to river systems as well as to a single river. Every river system, aided by weathering, is carrying to the sea the land of its basin which is above base level. Little of this work has been done while the river system is *young.* When the main valleys are wide and deep and the upland areas well dissected by valleys, the river system has reached *maturity.* When the drainage basin is reaching base level, the river system has reached *old age.* The main stream reaches the characteristics of old age sooner than its tributaries, and in its lower course sooner than in its upper.

Meanders

No river flows in a perfectly straight line. On the contrary, there are always irregularities in the course; the current flows first against one



Early stage. Dotted lines show former stream bed. Second stage. Later stage. Oxbow lakes in floodplain.

FIG. 78. DEVELOPMENT OF MEANDERS.

bank and then the other. Thus starts a curving of the river known as a *meander,* named after a river in Asia Minor whose lower course is very winding. The banks are less resistant at some places than at

others, and the stream will cut at those places. Once a curve in a bank is started, it is increased by the current that is directed against it. As the current swings from the bank into which it is cutting, it encroaches on the opposite bank and develops another curve, and so on. The meanders become more and more pronounced. The curves vary in size with the volume of the river. As meandering continues, in time of high water, or even at other times, the river may cut across the neck of the curve and then abandon the curve in favor of the new course,

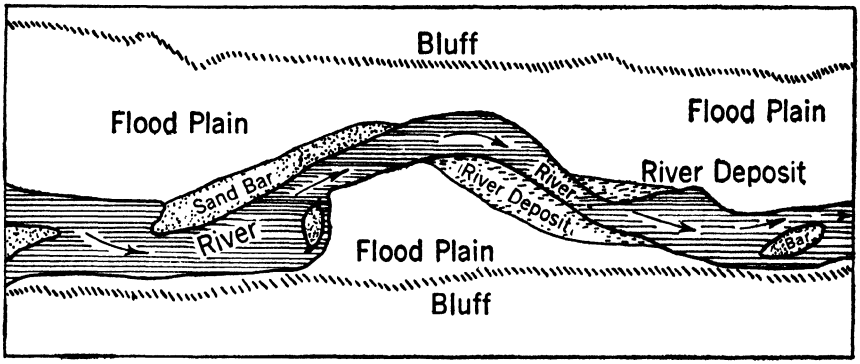


FIG. 79. MEANDERING RIVER CUTTING AGAINST BLUFF ON ONE SIDE AND DEPOSITING ON OPPOSITE SIDE.

which is shorter and steeper. The lake which is formed is known as an *ox-bow lake*. Sediment deposited by the river will cut off the lake from the river.

Human occupation of river valleys

When a young river is deepening its valley, the valley sides are steep and the valley bottom is wider than the river channel. Such a valley floor prevents settlement, and the roads are perched on the side slopes. Highways will be constructed through a young river valley only if there are highly productive regions on either side. In some cases, as of the Colorado River, an effective barrier is created between the areas on either side. In time of flood the water can rise only in the valley. Water confined in a steep-sided valley will rise rapidly, sweeping away all obstacles, and, as the supply of water decreases, it will subside gradually. In an area of sparse population in a young valley,

transportation within the region is difficult. Highways tend to follow the river bed during low-water season and are obliterated during high water. It is only by extreme population pressure from the outside that the region becomes more densely populated.

The continued action of the stream widens the valley floor by cutting first on one side and then on the other. At the same time, the sides of the valley are worn back to gentler slopes and the valley floor becomes more accessible. The valley is more available for human occupancy than when it is young, steep walled, and narrow. Agriculture is established, communities are built, and roads are constructed along the river and throughout the valley. The former barriers are removed and isolation is no longer an obstacle as in the young valley.

On the valley floor, where meanders are present, the cultural pattern and location of cities along the river may continually be shifting. Even political boundaries are changed where a river is the boundary line between political units. A farm may slowly be eaten away; the boundary of a political unit such as a state, county, or country may be changed, and a town site may be destroyed or left some distance from the river.

Degradation

Degradation is the reducing of the height of any part of the earth's surface by wearing action of natural agents, as by river action. The wearing action takes place by mechanical and chemical processes. The rate of erosion by running water depends chiefly on (a) its velocity, (b) its volume, (c) the character of the material of the stream bed over which it flows, and (d) the amount and character of the load it carries. The velocity of the stream is the most important factor.

Transportation

Rivers are the most important agent in transporting materials. Rivers may be many hundred miles long and so carry mud and sand enormous distances. They carry materials (a) in solution, (b) in suspension, and (c) by rolling them. Many substances are dissolved by water, and these are carried downstream in solution. Other fine particles are moved in suspension; if water from a river at flood time is left for some time without moving, the mud will settle to the bottom.

Along the bed of the river large stones can be rolled; as they are rolled along they knock against one another and are gradually made smaller.

Deposition

Streams on their way to the sea are constantly cutting and eroding material from the sides of their banks as well as from their valley floors and transporting it downstream. This sediment must in time be deposited; some is deposited in the channel and some along the sides. This deposition occurs wherever the current, for some reason or other, is checked. The decreased velocity may occur where the floods have subsided, or on the downstream side of some obstruction, as a rock or tree, or in an eddy in the current. These deposits result in bars, floodplains, alluvial fans, levees, or deltas.

Sand Bars. In low-water period many streams deposit materials in the inner curve of the stream until sand bars are formed. During high-water period many of these bars may be removed, since the stream is swifter during flood stage than at low water. Frequently the sand bars may become more or less permanent islands. If they become covered with tree growth, they are less easily eroded and become permanent islands in the river.

Alluvial Fans. Alluvial fans are formed when young streams descend from mountains or hill-country onto a flat area. The abrupt checking of the river causes the stream to drop its material in a fan-shaped deposit which may be many miles wide. Many such alluvial fans are found at the base of the Sierra Nevadas in California and along the rivers descending from the Rocky Mountains onto the Great Plains. Alluvial fans vary in size from little deposits but a few square inches in area up to extensive fans which may have a radius of thirty or forty miles.

Levees. Natural levees are the low ridges on stream flats along the banks of the channel. At flood time, the current in the main channel is swift, and, as the water escapes its channel and spreads over the adjacent plain, the velocity is immediately checked. As the velocity is checked, much of the load is deposited at the edge of the channel. The continual deposition at the same position produces the levees. The levees serve as a partial protection to the floodplain against floods. Since these levees are better drained than the surrounding areas, they

were settled first. Today, many cities and a dense population are to be found on the levees of the lower Mississippi River.

At times the natural levees are not high enough or strong enough to check the floods; then artificial levees must be constructed. By the construction of artificial levees, large tracts of land not otherwise usable are rendered habitable, and dense populations may be located in such regions. In Italy, the Po River has been confined between artificial

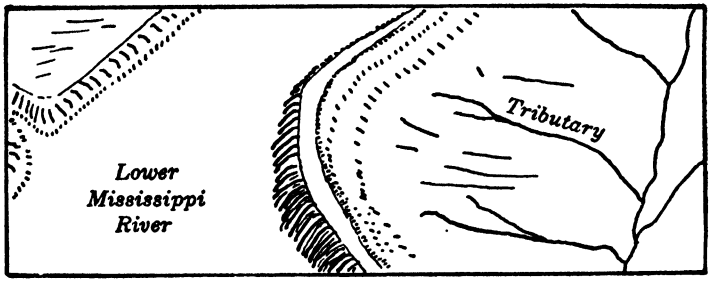


FIG. 80. SKETCH OF A LEVEE.

banks, and in Holland dikes have been built along the lower Rhine; many other examples can be cited.

Floodplains. The banks of most rivers confine the water in ordinary stages of flow, but are so low that in times of flood the water overflows them and spreads beyond. The stream, as has been pointed out, is carrying sediment throughout most of its course, but at flood time it will be most heavily laden. As the water spreads beyond the banks, the current is checked. The water leaving the swifter channel is unable to carry its load of sediment, and the material is deposited on the land.

As a result of this process, strips of land are built up along the sides of the river. Such a plain is a *floodplain,* for it is created during the floods. The width of the floodplain will vary with the width of the meander belt; the wider the meander belt the wider will be the floodplain. With each flood the floodplain is raised and gradually built up on both sides of the river. The sediment may accumulate to a depth of hundreds of feet.

To form extensive floodplains there must be frequent flooding and an abundance of sediment. Frequent overflows depend on variation in

runoff, which is normal in the lower courses of large streams, where the slope is so gentle that the channel is unable to dispose of any great addition to the volume. At the same time, the greater the tributaries the greater the amount of sediment brought into the streams. For

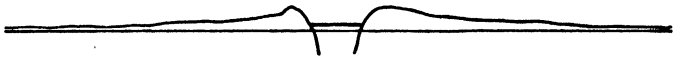


FIG. 81. PROFILE OF MISSISSIPPI RIVER NORTH OF DONALDSONVILLE, LOUISIANA.

these two reasons, floodplains are typical phenomena of the lower courses of large streams.

Man's use of floodplains

Floodplains are often very fertile and are among the areas most desired for agricultural purposes. This was as true in ancient times as now, for the valleys of the Nile, the Po, and the rivers of southern Asia were the centers of ancient civilizations. The frequent deposits of sediment on these plains continually renewed the soil and made it fertile. The earlier civilizations were so confined to such valley plains that the period before 800 B.C. has been called the "fluvial period" of history.

One of the most famous rivers of this kind is the Nile, which flows a thousand miles through the desert. Its floodplain is several hundred feet below the desert upland, is about 500 miles long and from 5 to 15 miles wide. Here most of the Egyptians live, and their chief occupation is agriculture. They depend on the annual inundation of the Nile, which begins in June. For thousands of years the fertility of the floodplain has been maintained by the annual additions of river deposits; the addition has been estimated to amount to four and a half inches in a century.

Floodplains, today, are extensively used because of the rich, fine-textured soil and the ease of near-by transportation. However, where climate is unfavorable, such areas may be sparsely settled; the floodplains of the Mackenzie, the Ob, and the Lena, with polar climates, or the river valleys of Lower California, with a climate too arid for ordinary agriculture, have a sparse population.

As the population density increases in any country, the floodplains assume greater and greater importance. It becomes increasingly a

greater problem to control floods so that cities and farms may continue to prosper. Frequently artificial dikes are constructed along wider floodplains to reclaim the land for agriculture. An example of this is found in the State of Iowa, where recently the Maquoketa River was confined by the construction of levees. Behind these levees, intensive farming is now practiced where formerly the land was used only for pasturing and hay crops. These farms are one fourth the size of average Iowa farms, and the yields are about four times or more greater than in the immediately surrounding areas. Land reclamation of this type will proceed as population densities increase.

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17

The Yazoo Basin in Mississippi

THE use of floodplains varies with the climate, type of material deposited, drainage, and many other factors. The Yazoo Basin is a type study of the cultivation of a floodplain and the high returns resulting from its use. The map, Figure 82, also shows the *Yazoo tributaries,* a term which applies to all stream tributaries of similar formation. When rivers raise their channels above the level of the floodplains, their tributaries cannot join the main stream. They then flow along the side of the floodplain until they reach some point further downstream. Tributaries which flow for some distance parallel to the main stream are called *Yazoo rivers.*

History, character, and size of the Yazoo Basin [1]

The Yazoo River basin extends from Chickasaw Bluffs at Memphis, Tennessee, two hundred miles southward to Walnut Hills near Vicksburg, Mississippi. The western border is the Mississippi River, and the eastern is a chain of two-hundred-foot bluffs. The area of the Yazoo Basin is 7,110 square miles, drained entirely by the Yazoo River.

Geographically and topographically this area is a distinct contrast to the remainder of the state. It is a low-lying expanse without prominent features. The altitude at the Tennessee line is barely 200 feet

[1] Adapted from Fern E. Dorris, from the *Journal of Geography,* Vol. 28, No. 2, published by the National Council of Geography Teachers.

above sea level, while that of Vicksburg is only 100 feet. In its primeval state it was a land of low ridges, flats, cypress swamps, cane brakes, sloughs, and bayous, covered everywhere with a great hardwood forest of sweet gum, sycamore, oaks, tulip, poplar, pecan, maple, hickory, walnut, ash, hackberry, and cypress, festooned with creepers and clinging vines of grape, Virginia creeper, and muscadine, and under which grew thick growths of cane and shrubs. Through this forest roamed the manifold wild life indigenous to the section. What a rendezvous it must have been for the Indian tribes—the Chickasaws and the Choctaws—who inhabited this hunting ground!

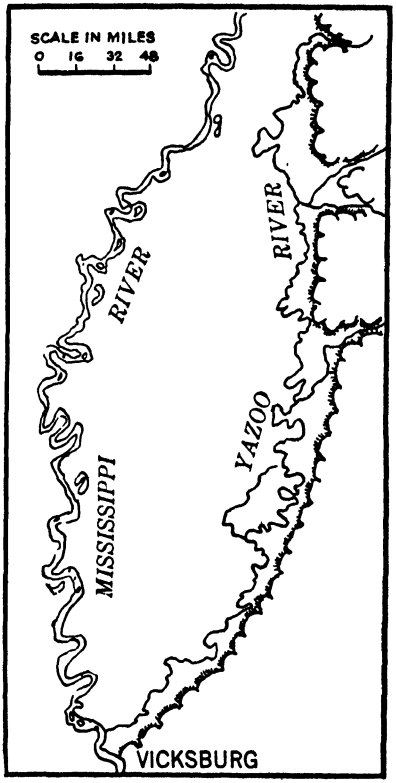


FIG. 82. SKETCH MAP OF YAZOO BASIN.

Origin of the Basin

The Yazoo Basin is an extension of the floodplain of the Mississippi River. The interior is intersected by a veritable maze of streams as winding in their course as the Mississippi itself. The Mississippi in time of flood, before the advent of the levees, often discharged some of its waters into these streams, which finally regained the main river lower down by way of the Yazoo River. If the flood was serious enough to overtax these channels, the waters would gradually spread out over the lower lands, filling the lagoons, sloughs, and brakes, in the end to inundate the entire Basin, with the exception of the highest ridges. These were seldom covered.

Soils

The depth of the alluvial soil of the Basin varies. In general it tends to become less toward the highlands on the east. Some estimates place

the average depth at two to three hundred feet; by many authorities it is given as much more. Everywhere it is of surpassing richness. The humus has been added as regularly as the minerals, since each overflow would place a coating over the plant life, which was augmented by the leaves from the trees and the undergrowth.

Land ownership and labor

From the very earliest settlement the Basin tended to be a region of large plantations. Cotton planters, with their slaves, came, in the years between 1825 and 1860, from the worn-out lands of Maryland, Virginia, North and South Carolina, Georgia, Tennessee, Kentucky, Alabama, Louisiana, and Mississippi itself to establish in this new country the counterpart of their former homes. This they did to the extent that was possible on wild lands. Mr. E. N. Lowe, State Geologist of Mississippi, says of present conditions, "Nowhere in Mississippi have antebellum conditions of land holding been so nearly preserved as in the Basin. The land is held in large plantations, several hundred to several thousand acres in extent, which are devoted almost entirely to cotton growing and are worked entirely with Negro labor."

Cotton culture

The first settlers in the Yazoo Basin in 1828 were actuated by the desire to open up cotton lands; one century later, in 1928, new ground was still being hastily and earnestly redeemed from the wild state for the very same purpose. The planters early became cognizant of the fact that the soil and climate would produce a superior fiber. Phillips, in his *American Negro Slavery,*[2] says, "Cotton tended to have a longer fiber, ranging particularly in the districts of the 'bends' of the Mississippi north of Vicksburg as much as an inch and a quarter in length and commanding a premium in the market." Cotton from these bends came to be known in the cotton trade. Today the Basin is the center of the long-staple acreage of the entire nation.

This section from the very first has produced cotton as its sole commercial crop. The soil and climate suit the plant admirably. The soil

[2] Phillips, Ulrich B., *American Negro Slavery.* New York: D. Appleton-Century Company, 1918.

is proverbially productive, and some of it has been under cultivation for more than half of a century without rest or fertilizer, yet renders excellent returns.

Climatic factors in this region seem to be extremely favorable for the production of cotton, as judged from a comparison with the yield in other cotton-producing areas of the world. These factors in general are sunshine, temperature, wind, amount and distribution of rainfall, and humidity. Separately and collectively they are conceded to have a profound influence upon the growth and production of the cotton plant.

This section is wedded to cotton culture: a union so natural that it is doubtful whether it can ever be dissolved in spite of the warnings given and the low price of the staple. Recommendations for a limitation of cotton acreage together with an increased production of foodstuffs were being made as early as 1848. Throughout the succeeding years the same "tocsin" has been sounded to no avail. The Basin is still a one-crop section. Experiments carried on at Stoneville Experiment Station in Washington County show that practically all temperate zone crops may be grown in the Yazoo Basin, but as long as cotton will produce so abundantly to the acre, and as long as Negroes constitute the available labor, it is going to be difficult to convince the average planter that it is worth his while to engage, to any great extent, in the attempt to produce any crop besides cotton on a large scale.

Corn has always been grown in this region, yet has never been raised for commercial purposes. As the slave's diet consisted mainly of corn bread, bacon, and molasses, probably corn at first was introduced mainly as food for him. Yielding fairly well, it continued to be planted for grain for the livestock; however, never in sufficient quantities to take care of the need. The early planter regularly received shipments from the old Northwest of corn, as well as bacon, on the steamboats of the Mississippi. Today his corn arrives via the railroad. In spite of the fact that the Negro, as it were, has been brought up on corn, he has never understood corn culture. He does not show a natural affiliation for corn as he does for cotton. It may be that corn growing requires more scientific methods than cotton. The condition remains that as a general rule the Negro is more successful with his cotton crop than any other that he attempts to plant.

Markets of the region

The question of markets has been, from the beginning, a simple one. Since the planter had only one staple—cotton—to dispose of, and his crop being produced on the credit system, he had usually very little choice as to where to ship. At first all cotton went down the river by boat to New Orleans, where it landed on the wharf at Levee Street.

Cotton today is marketed principally in Memphis. The steamboats still carry much of that grown in the river counties. The railroads carry the major portion, although there is an increasing tendency to truck the bales direct to the city. Sales are made also to local buyers, local merchants, cotton shippers, and sometimes to local bankers. There is some indication that the cotton factor, *per se,* is passing to give way to the local merchant or banker who advances the capital to the planter.

The future of the Yazoo Basin

One hundred years ago the Yazoo Basin was a wilderness, covered with a dense forest, traversed by many winding, tortuous streams, subject to almost annual overflow by the Mississippi River, without roads or even trails, peopled only with wild beasts and fowls. Three generations of inhabitants have wrested from nature a domain which approximates an empire in extent and constitutes a national asset in its producing ability. The area is covered with a network of railroad lines and is dotted with towns. Excellent highways of gravel and concrete cross the region, while the principal centers are connected by both bus lines and railways. The civilization that is here represented is dependent for its existence, prosperity, and advancement upon the wealth gathered from the soil, principally in the form of cotton.

Other nations seek abroad for possible cotton areas, while we have lands as yet untouched. The Yazoo Basin contains 2,000,000 acres listed as uncropped, which are as fruitful as those now under cultivation. Perhaps it will be many years before the Basin reaches the maximum of production and attains the zenith of development, yet it is certain to contribute much to the world from its great wealth, surpassingly fertile soil, together with unparalleled climatic factors, augmented by an intelligent, industrious, and progressive population. The future is exceptionally promising.

18

Deltas

THE sediment of rivers is in large measure deposited along their courses as floodplains and sandbars, but much also reaches the sea or inland bodies of water and accumulates at the river mouths in the form of deltas, which are submerged or partly exposed above the level of the water. While many streams have deltas, the proportion of rivers of the world having this land form is small. The conditions favoring delta formation are (a) sufficient supply of sediment carried by the river, (b) a checking of the current, (c) lack of strong tidal currents to prevent the sediment from being carried away, and (d) sufficient time for the deposit to accumulate.

While deltas are common, they are not universal. An absence of one or more of the above-named conditions prevents their formation. Some streams carry so little sediment that deltas are absent. This is due either to the fact that the rivers flow through hard, resistant rock and are unable to pick up much material or that they emerge from lakes, into which they have deposited their materials, and then in the ocean or sea no delta appears. In the latter case a delta may be formed in the lake. In other cases of deltaless river mouths the sediment is distributed by waves and currents of the open ocean. A recent subsidence of the land is an important cause for the absence of deltas; even a moderate subsidence may exceed the rate of accumulation of the sediment. In general, the coasts along northeastern North America and northwestern Europe have no deltas, for there has not been sufficient time for sediment to accumulate since the subsidence. Whatever deltas these rivers previously built are now beneath the sea.

Deltas are more numerous and better developed at the mouths of streams entering into lakes than along the open coast. Waves in lakes are less effective in distributing the sediment over a wide area and thereby permit greater concentration.

Process of formation

The chief cause of delta formation is a sudden checking of the velocity of the stream. The bulk of the deposit is concentrated at the point where the velocity is checked, which is at the forward edge of the old deposits. The result is a steep slope on the forward edge beyond which sediment cannot be carried. As the delta grows outward, it maintains the steep slope, upon which the abundant sediment settles.

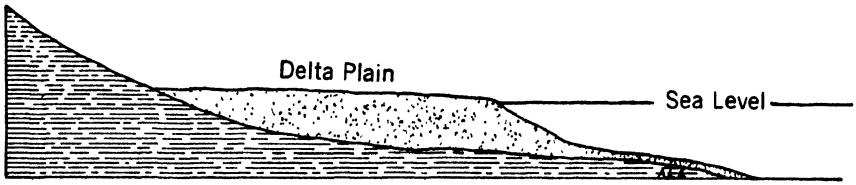


FIG. 83. CROSS SECTION OF A DELTA.

The diagram, Figure 83, gives a cross section of a delta. The delta is started below the surface of the water, and later the surface may be built to and above the level of the water. Deposition back of the steep front, however, continues at a less rapid rate. As the delta is built up to sea level, the waves push back sediment before them and throw some of the sediment up in beaches or bars. In time of flood the river overflows the delta and deposits sediments as in the formation of flood-plains. Thus the upper deposits are horizontal, while the lower ones are inclined. The form, consequently, is a flat-topped plain at or above the level of the water in which it is built, and extending beneath the water is a steep front. The normal form of a delta on an open coast, seen from above, is somewhat semicircular.

Because of the levelness of the delta plain, the water of the stream that forms the delta may flow through several mouths or *distributaries,* which divide the stream near the head of the delta and spread out fan-wise. The delta, in such cases, instead of being formed by the one

channel, is made by many, and its front is broad, so that the form of the delta plain, between its sea margin and the two outer distributaries, is triangular, like the Greek letter delta (Δ) from which it receives its name. The number and position of the distributaries vary with each delta.

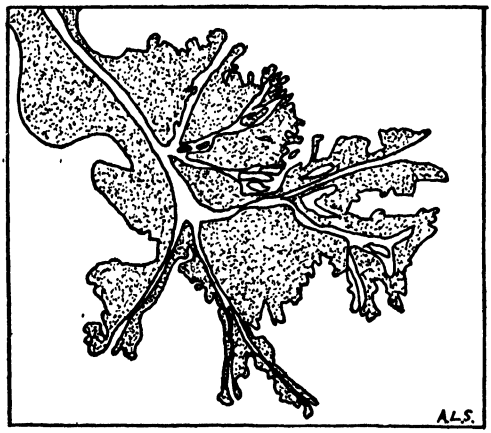


FIG. 84. MISSISSIPPI RIVER DELTA.

The form and composition of deltas vary considerably. The chief reason for variation in delta forms is the interference by one or more of the four factors named above. Deltas are more common in lakes than in the open sea mainly because lakes are shallower and less sediment is required to raise the bed to the surface of the water. Extreme depth is one of the chief reasons for the absence of deltas from many streams which empty into open seas. Any stream that carries sediment will build a delta in time if there is no interference by waves or subsidence.

In the larger deltas of the world streams flow in uncertain courses, so that a slight disturbance is sufficient to make the stream abandon one of its former channels. Such rivers, as the Huang Ho of China, change their courses frequently. The delta of the Huang Ho extends 400 miles along the coast and 300 miles inland. The first complete abandonment of its channel is supposed to have been in 2293 B.C. and the second in 602 B.C. The reason for this abandonment is that the slope is so slight that the river deposits sediment and builds its bed higher, in time abandoning its old course to find a newer and lower channel.

The seaward growth of deltas ordinarily proceeds at a fairly rapid rate. The Mississippi River delta is normally advancing at a rate of 340 feet a year. The Orinoco delta has an area of 8,000 square miles, the Nile delta 20,000 square miles, and the Ganges delta 50,000 square miles. The deposits at Calcutta are at least 500 feet deep, while at New Orleans they are over 1,000 feet deep. The city of Ravenna, in

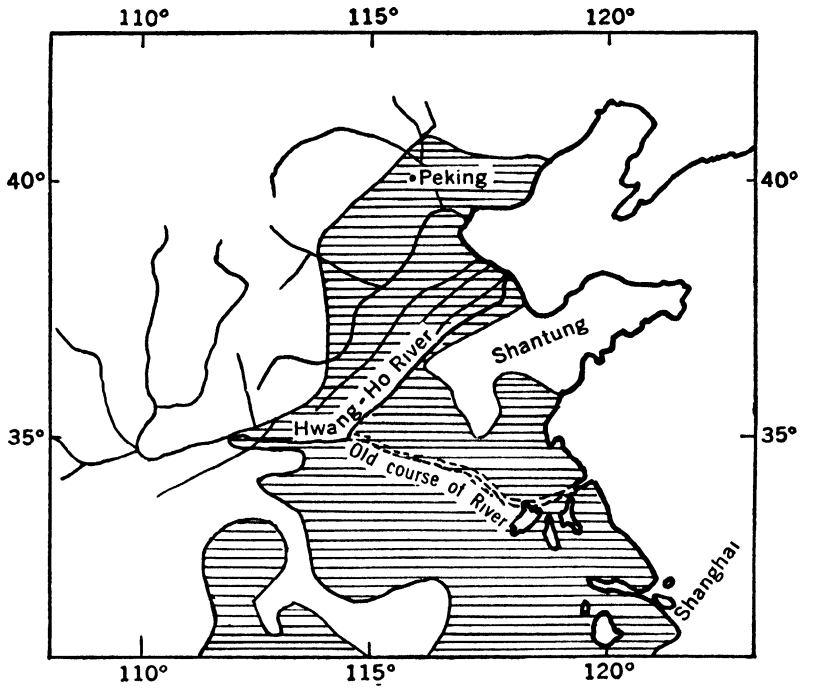


FIG. 85. DELTA OF THE HUANG HO. Shaded portion is area of delta.

Italy, at the time of Augustus was on a lagoon; today it is some five miles inland. Scores of similar cases are known. The Colorado River carries annually sediment which would cover 53 square miles one foot deep. At one time the mouth of the Colorado was approximately at the present site of Yuma, Arizona. On the east side of the Gulf of California the river built up a delta and gradually extended the deposits to the opposite side. A salt water lake was left completely detached from the Gulf; subsequent evaporation has reduced the lake to the small Salton Sink.

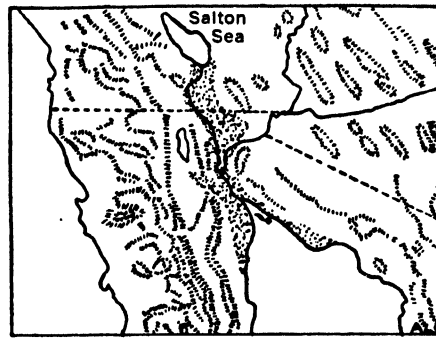


FIG. 86. COLORADO RIVER DELTA. Stippled area shows delta fan.

Since deltas may have a depth of several hundred feet or more and

cover the areas indicated above, the vast amount of sediment that the rivers carry to the sea is readily appreciated. The deposition of this sediment produces new land; deltas are additions to the land, and the materials have been obtained by lowering the land through which the river systems flow.

Soils on deltas

The soil of river-mouth deltas is deep, rich in mineral plant food, well mixed, and fine. However, because of the low elevation the land is wet and diking and drainage are necessary before agriculture can be practiced. In many countries where populations are dense the deltas have been diked and drained and there they support a very great population; the Huang Ho delta of China is an example. In spite of all precautions floods may be an ever-present menace.

Human use

Most delta land away from levees is low and wet. The soil of most of the larger deltas is deep and fertile, as given above; the small deltas in mountain lakes may have been built of coarse materials. Wet ground may be so serious a problem as to prevent use. However, many deltas have a dense agricultural population. The reading, Chapter 19, *The Fenghsien Landscape: A Fragment of the Yangtze Delta,* describes one delta with a dense agricultural population.

Occasionally large cities may be found on or near the delta; Shanghai, Rotterdam, Calcutta, and New Orleans may be selected as typical. These cities have many problems in common and some of them include: Inundations may be of almost yearly occurrence or an annual threat. Street improvements are difficult because building stone must be brought from outside regions. The problem of domestic water supply is among the first to be faced by the inhabitants and frequently remains serious; the problem is sometimes partially met by catching rain water and storing it in cisterns. Sewage cannot be disposed in the river, for the water may flow at a level above the houses. The disposal of heavy rain water is usually a real problem on account of the low elevation and the constantly saturated soil. Communication with the outside world may be confined to river transportation until railroads

are constructed along the levees; bringing products from the hinterland to the city may be difficult.

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19

The Fenghsien Landscape: A Fragment of the Yangtze Delta

THE population density, except for urban areas, in many cases is less on deltas than on floodplains or older lands. However, some deltas have an agricultural population of several hundred or more to the square mile. The population on deltas with a humid climate always faces serious problems, and these are increased with successive increases in population density. Doctor Cressey describes a delta with a population of 2,000 to the square mile and pursuing an agricultural adjustment.[1]

Twenty miles south of Shanghai, near the edge of the growing Yangtze delta, lies the crowded county of Fenghsien. On one side is the ocean, from which the land has persistently been snatched. On the other is the exotic metropolis of Shanghai, singularly out of harmony with this ancient agricultural countryside.

Above Fenghsien fly the planes of the air service from Shanghai to Canton. As viewed from the air, the most striking features of the flat, green landscape are the micropattern of the fields and the net of closely spaced canals. Other areas may have an equal intensity of agriculture, but in few parts of the world is there a similar development of canals and ponds. In one measured square mile there are no less than 27.8 linear miles of these waterways, and the average spacing is only 380

[1] Adapted from George B. Cressey, from the *Geographical Review*, Vol. 26, No. 3, published by the American Geographical Society of New York.

feet. It is these that give the area its distinctive stamp and make the *geo*graphy essentially *hydro*graphy.

From the air one may see the lines of maritime dikes bordering the silt-laden sea, which protect the land from high tides. These barriers enclose successively reclaimed areas similar to the Dutch *polders*. Within the newer dikes the canals are laid out in rectilinear plan, in contrast with the irregular pattern in the older land, west of the innermost, and older, dikes. Scattered clusters of broad-leaf trees and bamboo surround groups of farmhouses, and the traveler is seldom out of sight of a market town.

Flagstone trails take the place of roads, for there are no carts and few

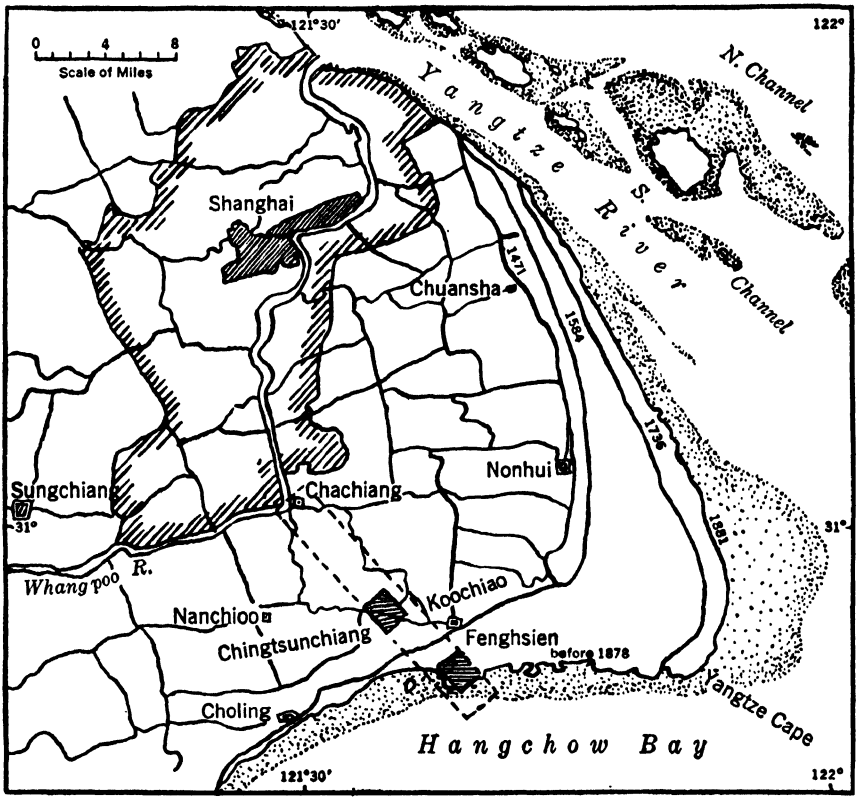


FIG. 87. SITUATION OF FENGHSIEN IN YANGTZE DELTA AND IN RELATION TO SHANGHAI. The International Settlement, French Concession, and the old walled city are closely ruled; the shaded border marks the limits of Greater Shanghi. The main maritime dikes are shown with date of construction.

wheelbarrows. Passenger and freight boats move slowly along the larger waterways; smaller farm boats carry fertilizer or produce over the smaller canals. Outside the dikes, along the shore, are numerous salterns, where thousands of evaporating trays are spread out.

But the full intensity of land use is not to be understood from the air. Tall reeds hide many of the canals; but on all sides there are gardenlike fields, covered in summer with cotton and rice and in winter with wheat and broad beans. There are no fences, and field boundaries are mere ridges among the flooded fields. Farmsteads and canals cover as much as a quarter of the area; grave mounds occupy from five to ten per cent of the arable land.

Even from the highest graves there are few broad vistas because of the trees and bamboo which half hide the scattered farmsteads. Along the canals are thatched shelters for irrigation pumps. The innumerable grave mounds betray the long past; the numberless cheerful children suggest problems for the future. With a rural population of 2,000 to a square mile there can be little idle land and but infrequent cessation in man's supreme occupation—the quest for food.

The fundament

If we could sweep aside the cover of vegetation and the structures of man, the vicinity of Fenghsien would present a monotonously flat sky line. No part of the area is now more than twelve feet above sea level. But for the intervention of man, the delta would be crisscrossed by random drainage ways, most of them tidal thoroughfares. Well borings at Shanghai have penetrated 920 feet without reaching the bottom of the delta. The Yangtze today carries an annual burden of silt and clay amounting to 494,000,000 tons, which is spread out over the floor of the East China Sea. Measurements in Hangchow Bay by the Whangpoo Conservancy Board show an average silt content of 1,000 parts in 1,000,000 by weight. Changing shore currents influence the areas and rate of accretion, so that the boundary between land and sea varies with the size and slope of the submarine delta. It has been estimated that the shore line advances one mile in 60 years, but it is clear that the distribution of land and sea has been and is influenced by both erosion and deposition. Man has reclaimed this foundation so completely that there are no longer natural drainage ways.

Fenghsien is a humid subtropical land with monsoonal tendencies, somewhat similar to the southeastern United States. The winter brings occasional freezing temperatures and a flurry of snow, but the ponds rarely have more than a paper-thin coating of ice. Most of the rain falls during the summer, but every month has at least 2 inches of precipitation; the yearly average is 45 inches. The growing season is more than 300 days. Summer temperatures are high, and there is much humidity. Statistics for near-by Shanghai from 1873 to 1930 show that during July the mean temperature is 98° F. and the relative humidity 84 per cent; in January the mean temperature is 21° F., and in December the relative humidity is 76 per cent. During the summer of 1934 Shanghai experienced 21 consecutive days during which the daily maximum was more than 100° F., and for 60 days the daily maximum averaged 97° F.

Two thousand people to the square mile

People are inescapable in Fenghsien—old scholars giving their birds an airing, children tending the buffaloes, women weeding the crops, boatmen punting their shallow skiffs, groups of men and boys operating an irrigation pump. From dawn till dusk people are busy in the fields, and one can rarely find a secluded spot out of sight of humanity.

The average population density of the Yangtze plain, which includes all the level land below Ichang, is 1,277 to a square mile. In many parts of the delta this figure is doubled, as in the island of Tsungming in the Yangtze estuary, where there are 2,873 people for each square mile. A recent estimate credits Fenghsien with a population of 304,400 and gives the area as 474.3 square miles. A census in 1865 reported 140,215 persons. Across the canal from Chachiang a partial house-to-house census was taken of 1 square mile of farm land. This incomplete enumeration indicates a density of about 2,050 to a square mile in a purely agricultural area. Individual house groups, sometimes of a clan, reported 2 to 30 families and 3 to 120 persons. There are no resident foreigners in the area, and the only mission station is a Jesuit church and orphanage at Chingtsunchiang. The Southern Methodist Mission at Sunkiang has had several outstations in the county.

Except for the few urban centers, the population inside the main dike is evenly distributed. The surveys of the Whangpoo Conservancy

Board locate practically all farmhouses and show no localization of the systematic pattern of distribution. Canal junctions and trail intersections have not produced concentrated settlements. Roadside teahouses, isolated stores, and country temples are uncommon and have not resulted in settlement nucleuses. Almost without exception houses are on waterways, but the waterways are so closely spaced that there is no linear arrangement. Access to water is not needed so much for transportation as for domestic use.

There is little circulation on the part of the farm population. Each family group lives a practically self-contained life in the midst of the fields it cultivates. Only a few times a year is it necessary to visit the city for supplies or for temple festivals. There are few wants that call for frequent purchases at near-by shops, nor is there the ready money with which to satisfy such wants if they did exist. The few needs and the low rate of circulation probably account for the absence of focuses of rural settlement. In Fenghsien near neighbors are unavoidable, and there is no necessity to group farmhouses for sociability, as there would be in a more sparsely populated land.

Most buildings are made either of poorly burned gray brick, pounded earth, or woven reeds. There may be a veneer or plaster, usually whitewashed. The better buildings are roofed with tile; the others are thatched. The floors are made of brick or pounded earth. Farm buildings invariably are one storied; only in parts of the larger towns are two-storied buildings to be seen. There are neither cellars nor attics. Windows, sometimes made of translucent sea shells, are few and small. Wood is expensive, and its use is restricted to doors, windows, and roof beams.

Every farmhouse has its courtyard for threshing grain and domestic uses. Unlike those of North China, these courtyards are unwalled except for a possible hedge. The houses have from two to ten rooms, arranged in a row, not more than three being connected. The usual arrangement is a combined kitchen and living room with a bedroom on each side. Simple chairs and tables, bedframes of woven fiber supported on stools, and chests for extra clothing make up the furniture. Instead of a barn, an extra room houses tools and supplies. The water buffaloes and yellow cows may have a shed to protect them from the rain, but pigs, chickens, and dogs find shelter for themselves. Each

farm has a privy, in which all human wastes are collected in large jars until needed on the fields. Threshing is done either with a flail or by driving the farm animals over the grain. In each courtyard are large piles of straw, to be used for fuel or perhaps for weaving cheap rope or making straw sandals.

The most elaborate structures are the temples, but most of the buildings are in need of repairs. Their roofs are made of uncolored tile. There is a nunnery at the north gate of the city of Fenghsien and another east of Kaochiao. The more pretentious grave plots may have an encircling wall and an ancestral hall for family tablets. Despite the antiquity of the area, there are surprisingly few material souvenirs of the past. There are no pagodas and only a few dilapidated pailous, or stone archways. Even the more important family graves are usually without stone markers. The stone bridges are probably among the oldest structures.

Economic activities

Three primary occupations furnish a livelihood to these people: agriculture, fishing, and salt production. The agricultural harvest consists of cotton and rice in the summer and wheat and broad beans in the winter. During the winter there is some fallow land, but in summer the whole countryside is under cultivation. Few fields exceed 100 yards in length; many are only 100 feet long by 50 feet wide. A crop such as soybeans may be planted in two or three rows along a path, and much corn is grown in odd patches less than 10 feet in diameter. Where an entire area is in the same crop, it is often impossible to determine field boundaries. There are no fences and few stone corner markers. Muddy ridges a foot high and a foot wide separate flooded fields but are invisible amidst the standing crops. Maps of land ultilization thus fail to show the tiny size of farm units, which through inheritance subdivisions have been reduced to small fractions of an acre.

Water buffaloes, yellow cows, and a few oxen are available for plowing, but a large amount of work must be done by hand. To ensure better drainage the farmers plant sweet potatoes, beans, and, often winter wheat in ridges some ten inches high, which are spaded up by hand. Planting, weeding, and harvesting bring all members of the family into the fields.

Cotton has been raised around the sandy margins of the Yangtze delta for centuries. By July, 1936, it was the dominant cash crop, and the development of modern mills in Shanghai has made the area the most important cotton-producing region in China. A small amount of cloth and braid is made in the homes, but most of the cotton is exported through *hong* (an establishment for foreign trade in China) merchants in the towns, where it is usually ginned before shipment.

Rotation is practiced rather generally, two years of cotton and wheat being followed by one of rice and beans. Some fields are kept almost continuously in cotton because of its cash return. In the newer *polders,* especially those that are saline, cotton covers as much as 80 per cent of the arable land. The rest of the area is in corn and soybeans, but not rice. There is considerable winter fallow, along with some soybeans, but no wheat. No mulberry is grown, though silk culture is an important industry some tens of miles to the south and west.

Fish largely replaces meat in the Fenghsien diet. There is some fishing in Hangchow Bay, but there are no harbors along the Fenghsien shore in which to land a catch. The fishing of Fenghsien is done in canals and ponds. Where there is a noticeable tidal movement, bamboo weirs with bottleneck enclosures have been built across the canals to trap the fish; elsewhere large, square nets, eight feet and more on a side, are let down from a bamboo framework. Trained cormorants also are commonly used, and fishermen usually have about a dozen of these birds to a boat. Most of the fishing is only a part-time occupation.

The ever-industrious farmer harvests aquatic plants and bottom mud to fertilize the fields. With scythes attached to long poles he cuts the vegetation growing in the ponds, and with a long-handled scoop shovel drags up the rich mud from the canal bottom.

The production of salt from sea water along the Fenghsien foreshore dates back many centuries. The official records refer to salt boilers, but all the production today is by solar evaporation. Directly east of the city of Fenghsien dikes have been built out to the high-water mark, but farther south is a large unreclaimed area that is covered with salterns. Twice monthly, on the first and the fifteenth of the Chinese month, this area is flooded at high tide. The tide leaves behind a veneer of salt-impregnated silt. As needed, the top quarter inch of this

silt is scraped from an area 100 feet or more in radius and is heaped into pyramids 10 feet high.

In front of each pyramid are two percolating basins. A few bushels of silt are placed in these basins, and water from near-by ponds or tidal thoroughfares is poured over them. This water dissolves the salt and slowly seeps into a cistern. Workers carry the brine from the cistern to wooden trays, into which it is poured half an inch deep and allowed to evaporate. Each day or two a layer of crystal salt accumulates and is scraped up ready to be sold. The process continues throughout the year, but with lessened activity during the winter.

20

Lacustrine Plains

LACUSTRINE PLAINS are old lake bottoms. The lakes have disappeared in various ways, leaving plains the use of which depends on their location and their present and former climate. Before describing the use of the plains it is necessary to discuss lakes, their formation and disappearance, and to give a résumé of types of ancient lakes.

Origin of lakes

Lakes are a phase of drainage. Their basins are local depressions and serve as storage places for some water and reservoirs for sediment carried by rivers. The distinction between lakes and similar bodies of water which are not called lakes is rather arbitrary. A *pond* is usually understood to mean a body of water smaller or shallower than a lake, but this usage is not universal. Ponds and lakes differ from inland seas and bays in that they are more completely, or, as in most cases, are altogether, shut off from the ocean.

Thus a *lake* is a body of water occupying a closed depression, or basin, in the surface of the land. Lakes vary greatly in size, depth, and form; most lakes are long because they occupy parts of river valleys, and their long axis is in the direction of the valley. Lakes form parts of river systems, but their basins usually are not made by the rivers. In their action of valley cutting, rivers tend to establish regular slopes and develop only small basins, such as potholes and ox-bow lakes. Lake basins owe their origin to many factors, but their causes may be generalized into four classes. They are (1) damming of rivers by slides and various types of deposits by animals and by man, (2) newly made land, (3) glaciation, and (4) volcanoes. Close observation often re-

veals that a particular basin has had a complicated history and that several causes may be responsible for its existence.

Interference with drainage, usually by some kind of dam, is a common feature. Many examples may be found in various parts of the world. Man is now one of the most important agents in the making of lake basins to store water for power, irrigation, domestic water supply, and other uses.

There are many lakes in the southern part of Florida, where new land surface has recently been raised above sea level to form the coastal plain and there are many depressions in which standing water gathers. When the drainage lines are established, the lakes will disappear. Many of these lakes are small in area, and most of them are shallow.

Many lakes are found in northern United States and eastern Canada. The relation between the distribution of these lakes and the area covered by the ice sheet (see Chapter 24) is so close that it cannot be considered as accidental. Glaciers give rise to lake basins in various ways. The basins may be due to uneven erosion by the glacier or deposition of debris carried by the ice and left on the surface, forming a barrier of one type or another. Many of the lake basins within the glaciated

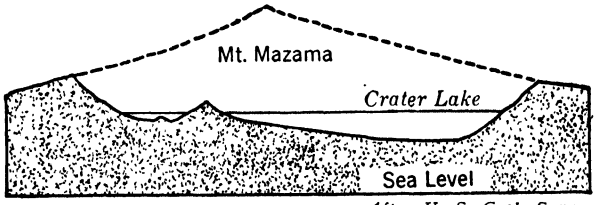


FIG. 88. CRATER LAKE, OREGON.

area of North America and on the other continents, however, owe their origin to a combination of conditions. The Great Lakes are an example to illustrate this point. Their basins are probably due to (1) glacial excavation, (2) deposition about the rim of the basins, and (3) down-warping of the surface.

Volcanoes, directly or indirectly, have given origin to many lake basins. The craters of extinct volcanoes are sometimes occupied by lakes of great depth. Crater lake, in the Cascades of southern Oregon, is an excellent example. This body of water is 5 to 6 miles in diame-

ter and some 2,000 feet deep at an elevation of 6,239 feet. The lake has no tributaries and no visible outlet.

Origin of lacustrine plains

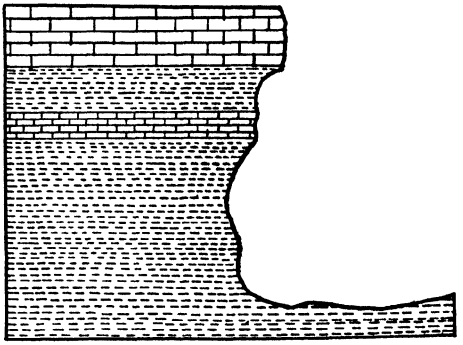
Whatever the origin or setting of a lake, it is a relatively short lived hydrographic feature, for forces are immediately and constantly at work to destroy it. These forces are vegetation, rivers, and evaporation in arid regions.

After a lake is formed, various types of water plants begin to grow and very shortly encroach on the lake, thereby narrowing it year by year. The process, for a lake of any type, is somewhat as follows: the water plants begin to grow and crowd the lake into a smaller space; around the margin small plant life of nonaquatic species takes root and in turn compresses the waters still more; then shrubs and trees in time surround the lake; with each season the old plants or branches are dropped into the water and along the edge, causing the lake to become shallower and narrower, until it finally disappears. Peat bogs, which are the remnants of lakes destroyed by vegetation, occupy about one tenth of Ireland, and large areas of eastern United States are filled-in lakes. Organic processes thus convert clear bodies of water into swamps, then bogs, and finally into lacustrine plains with rich soil high in humus content. Artificial drainage may hasten the process and is used particularly in densely populated regions.

Rivers may destroy a lake by dumping sediment in the upper part and draining the water at the lower. These two processes are sometimes carried on simultaneously. Stream deltas are found in the first stages of filling; then the sediment is spread out from the place where the river enters the lake. More and more sediment fills the lake, thereby making it narrower and shallower. In many cases the stream begins to cut back, as is the case with the Niagara River and at Lake Tahoe in the Sierras. At the latter the Truckee River is cutting the canyon farther and farther back and in time will completely drain the lake. The cutting process is delayed, in all such processes, by the fact that the river constantly loses its effective cutting tools—sand, gravel, and silt—by deposition.

During the ice age in North America Lake Agassiz came into existence, and it disappeared after the ice. Extinct lakes of this sort were formed by the great ice dam across north-flowing streams obstructing

the natural drainage, and the water rose in the basin until it overflowed to the south. Lake Agassiz covered a maximum area of 110,000 square miles, or about 20 per cent more area than the combined area of the Great Lakes. The water, however, was shallow. Lake Winnipeg and the many other smaller lakes are remnants of Lake Agassiz, for they occupy the deepest depressions in the former lake. The fine-grained

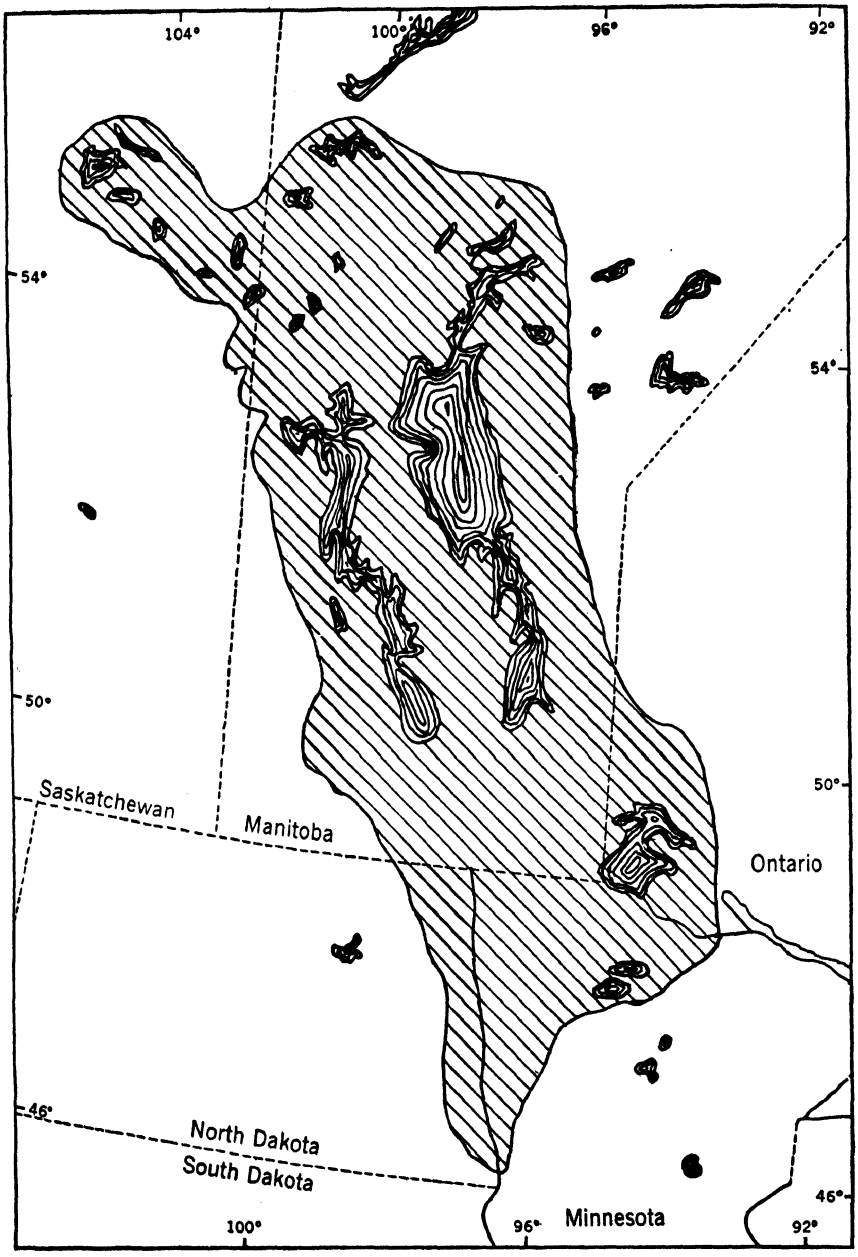


After Gilbert.

FIG. 89. NIAGARA WATERFALLS.

sediment that was deposited on the bottom of this extinct lake has made a fertile lacustrine plain. Its surface is so level that, after a rain, water stands on the ground in sheets. This flatness, however, makes it possible to use labor-saving machinery extensively. After agriculture was started in 1872, population increased rapidly. Today this plain is one of the best agricultural regions in the United States.

Lacustrine plains similar to the Lake Agassiz plain are numerous within and bordering on the glaciated areas. These plains are much alike in land form, but their soils vary widely in fertility and their areas in most cases are much smaller than that of Lake Agassiz. Many relatively small lacustrine plains, of a rather different type, are to be found within the glaciated areas of North America and Europe. They are the result of the disappearance of small lakes similar to those found in depressions in moraine plains. These former lakes were converted into lacustrine plains by filling with sediment, by accumulation of remains of bog vegetation, and by artificial drainage. The soils of many of these plains are peaty; if so, they may have little or no agricultural value.



After U. S. Geol. Survey.

FIG. 90. LAKE AGASSIZ PLAIN.

In arid regions lakes have a different life history, for there they are controlled by climate rather than vegetation or river action. If the rainfall is sufficient, the lakes may increase or overflow, but, if evaporation equals or exceeds precipitation, the lakes will be lowered below the level of their outlet and each succeeding year there will be a decrease in the volume of water. The size of a given lake varies from month to month. The size reflects the amount of precipitation and evaporation; these two factors constantly at work determine the volume of water. An increase in precipitation increases the size, while greater evaporation decreases the volume. While the above generalizations are true for most lakes, the fluctuation tends to be greater in arid than humid regions, where precipitation is usually less dependable and evaporation is greater. Lakes in arid regions may even dry up during the dry part of the year, in many cases leaving alkali flats or salt marshes. The alkali and salt are brought in small quantities, dissolved in the water, and left when it evaporates. In times of heavy precipitation the flats may become shallow, muddy lakes; evaporation changes them to hardened mud crusted over with alkali and salt.

Along the sides of the Wasatch Mountains, some 900 feet above the present Great Salt Lake, can be plainly seen the shores of a former lake. The former and larger lake has been called Lake Bonneville, and the present lake is merely a relic. The size of Great Salt Lake relative to that of old Lake Bonneville is shown on the map, Figure 91. The old shore line on the mountains is revealed by cliffs and beaches formed during the existence of the ancient lake. The channel of the old outlet was northward across a pass to the basin of Snake River, and through that outlet fresh water flowed. With the reduction in size the ancient lake deltas were trenched by the streams that deposited the materials forming those deltas. A complete change in climate from one that was decidedly wetter to the present desert conditions increased the rate of evaporation and reduced the amount of intake water. That change in climate reduced the old fresh-water Lake Bonneville to the present brackish Great Salt Lake. In some years the present lake increases slightly in area, but, if the history of the lake over a long period of time is examined, it can be seen to be getting smaller. Perhaps in time the entire lake will disappear as have smaller lakes in the general vicinity.

Use of lacustrine plains

The use of plains formed by the drying up of former lake basins depends upon (1) the factors which caused the removal of water and (2) the present climate. The evaporation of water from former saline

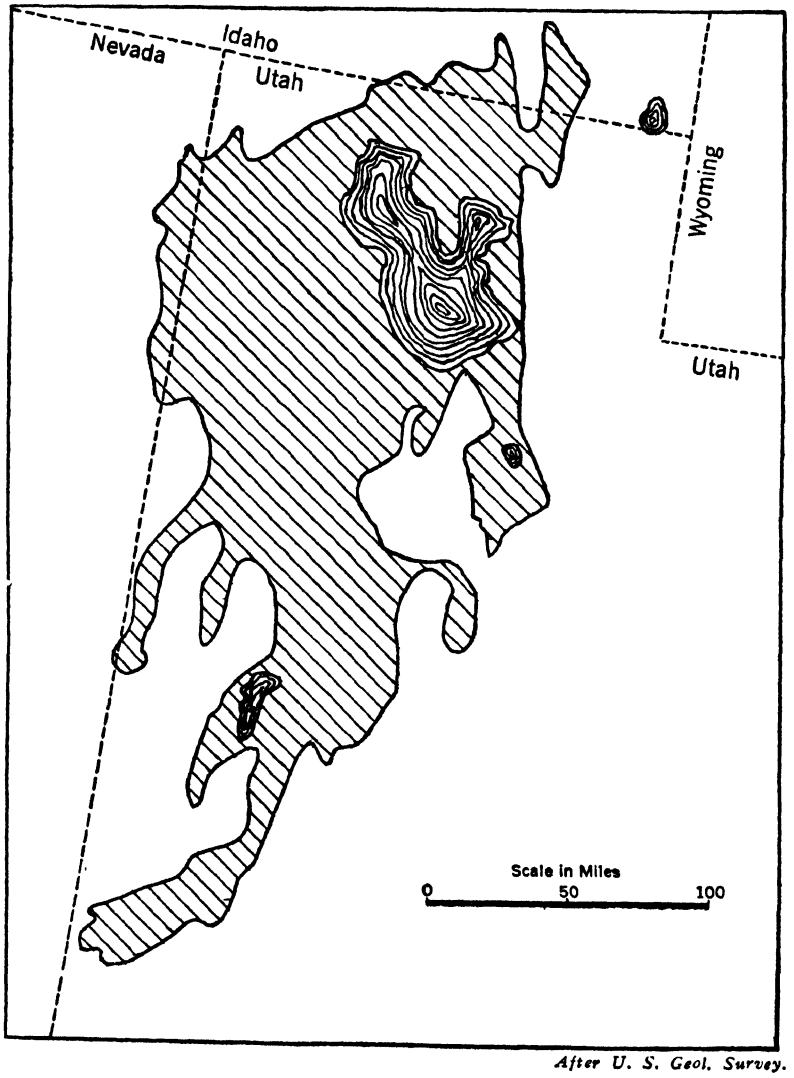


FIG. 91. ANCIENT LAKE BONNEVILLE WITH ITS MODERN REPRESENTATIVES, GREAT SALT LAKE AND SEVIER LAKE.

lakes leaves salt, soda, borax, and other salts. Many commercial deposits of salt throughout the world are in areas of this type. The agricultural use of lacustrine plains formed by evaporation is confined to those sections in which salts are in such limited quantities as not to prevent ordinary plant growth. The situation may be improved by planting salt-tolerant flora to neutralize the saline effect, and this flora, in addition, builds up the humus content, which is usually deficient in this type of lacustrine plain.

In humid regions the use of lacustrine plains, for a time, may be restricted by the presence of many swamps and marshes. In time these swampy areas will be drained; the draining may be hastened by artificial methods. After they are drained, these areas are included in the world's best farming regions, for the land is level and the soil is well mixed and fine grained. If the climate is suitable for growing crops, the yields will be high and the area may have a dense population.

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21

Reclamation of Tidal Marshes

SECOND-RATE land, that is, land on which man can make a less good living than on first-rate land, may remain unused or partially used for many years in the history of a country. It creates no problem demanding a solution until the population density reaches a point where the best lands, that is, those on which it is easier to make a living, are used up. When that point is reached, man attempts to remedy the situation and, through one means or another, make it possible for greater settlement on the second-rate land. In the following article[1] George M. Warren considers some of the factors in reclaiming marsh land.

The embanking of tidal marshes and their use for agricultural purposes date back to antiquity. For upward of three centuries the coastal countries of Europe, particularly those bordering on the North Sea, have been engaged in this practice and have developed in the polders of the Netherlands and the fen lands of England the finest agricultural lands in Europe and drainage works of greater magnitude than elsewhere in the world.

In this country the reclaiming of tidal marshes extends back about 150 years, but the results obtained have not been wholly satisfactory. The comparatively few permanent successes have been accompanied by so many failures that a large number of people have become discouraged and skeptical as to the practicability of such reclamation.

[1] Adapted from George M. Warren, *Tidal Marshes and Their Reclamation*, U. S. Department of Agriculture, Bull. 240, 1921.

The population of the United States is increasing. Owing to this increase, there is a growing scarcity of good upland farms and a widespread inquiry for detailed information on various phases of marsh-reclamation work.

Some marshes are old river or lake bottoms filled with the partially decomposed vegetable accumulation of ages. These peat marshes, when decomposition is more advanced, become the muck beds so frequently seen along our coasts. The reclamation of such lands should be undertaken with caution. If possessed of sufficient earthy material, they may become fertile, especially adapted to the growing of potatoes, celery, cabbage, and onions, but their shrinkage and consolidation when drained and aerated is very large, and as a foundation for sluices and embankments they are unstable.

Another type of marsh exists as a barren waste of sand, almost devoid of vegetation. The reclamation of such land is not likely to be financially successful, as the expense of putting the land in a productive condition is very great, and sand as an embanking material is most treacherous.

Still another type of marsh is that found behind barrier beaches along outer coasts and in other locations subject to violent wave action. Through long-continued mechanical action of the waves on an exposed coast the boulders, pebbles, and sand are ground into exceedingly fine particles, of which the greater portion is carried by the undertow into the sea, but an appreciable quantity remains to be swept by waves and currents into the indentations and inlets of the shore. Moreover, such inlets or estuaries have a tendency to become closed by ridges or barriers of sand heaped by the sea and the action of winds. The tidal marshes formed in this way are very extensive, but their reclamation is often difficult, because free outfall channels are not easily constructed and maintained.

Soil formation is in progress everywhere through various chemical and mechanical agencies. From the spot of its origin, perhaps hundreds of miles inland, moving water is the vehicle which is ceaselessly conveying the soil to its resting place to form the fourth and, to the agriculturist, the most important type of marsh. Without the instrumentality of the tides, the fine sand, silt, and clay which is constantly being brought down by rivers would be carried out to sea and lost to

man's use forever. The descending fresh water, with its accumulation of detritus, is met and forced back by the comparatively clear water of the flood tide; before the next ebb occurs, the silt-laden water has been forced to spread out over the low marshes, and a portion of the suspended matter is deposited. The heavier particles deposit first, thus building up most rapidly the marsh adjacent to the river; the finer, lighter particles are carried farther toward the uplands, and here the marsh-building process is much slower. With the lapse of time enormous areas have in this way been raised, so that they are submerged only by storm tides, and in this condition they offer inviting prospects for reclamation and development.

The rate of tidal deposits varies greatly. A heavily wooded watershed or one in which the agricultural development has been small will generally be drained by a comparatively clear river, and the marshes will, in consequence, build up very slowly.

Most soils shrink when deprived of their water. Experience, both in this country and abroad, has shown that where marshes have been drained there is a long-continued shrinkage or subsidence of the land; the amount varies with the depth and character of the soil, being more in those of a peaty or mucky nature and less in clay, silt, or sand. Approximate subsidences noted in several reclamations are as follows: Green Harbor, Mass., between 1872 and 1908, about 2 feet; Hackensack Meadows, N. J., between 1869 and 1887, from 3 to 3.5 feet; Cohansey Creek, Cumberland County, N. J., from 2.5 to 3 feet; Mays Landing, N. J., about 1 foot; Salem, N. J., 3.5 feet to 4.5 feet; Whittlesey, England, 7 feet in 18 years, and it is said that the subsidence is still going on in the old reclamations at the rate of an inch per year. The drainage of the fen lands has, with the lapse of time, been accomplished only through an ever increased use of pumps. In planning drainage works the tendency to subsidence must be fully appreciated, since if long continued, it results in the ditches becoming more and more ineffective, and after a while the water can be removed only by pumping. Failure to discern the shrinkage of marsh soils has caused many to believe that the tides rise higher than in former years, but there is no evidence that such is the case.

Marshes composed of a deep soil that contains sufficient clay to render it when moist somewhat slippery under foot are most likely to prove

agriculturally profitable, to be subject to only moderate settlement and subsidence, and to be best adapted to the building and sustaining of levees and sluices or to the digging of ditches.

Marsh soils generally show an acid reaction, owing to the decomposition of vegetable matter, and require lime as a corrective. The beneficial effects of lime do not continue so long as on upland soils, for it unites with the chlorine of the sea water, forming chloride of lime, which is soluble in water. Hence applications of lime may be needed on some soils every three or four years. The presence of marl, shells, or other calcareous matter is a favorable sign.

Draining marsh land should be done gradually, as otherwise the mechanical condition of the soil may be injuriously affected, its capillary power destroyed, and decomposition of the organic matter retarded. Where fresh water is available and can be promptly removed, much of the saline matter can be washed from the soil. The usual method of subduing a rank sod is by burning, and is to be recommended, despite criticisms which have been made. If the burning does not extend deeper than a foot, comparatively little available plant food is destroyed and the ashes and charred matter improve the texture of the soil, correct acidity, and hasten nitrification. Every facility should be offered for air, rain, sunlight, and frost to enter and act upon the soil. Many marsh soils, in common with clay soils, bake when exposed to sun and drought. Plowing should be done in the fall or winter and when the land is neither very wet nor very dry; otherwise a baked or lumpy surface will result, and proper preparation of the land will be rendered difficult, if not impossible. The land should be plowed when gentle rains have brought it to its most friable condition. The furrow-slice should be shallow the first year and increase in depth in subsequent years.

Corn is a favorite crop on newly reclaimed marshes, as it withstands considerable acidity. Red top, bent grass, meadow grass, and alsike clover grow well on damp, sour land; and timothy, rye, oats, buckwheat, potatoes, tomatoes, strawberries, celery, melons, and rice have all shown adaptability to marsh soils. Asparagus, onions, beets, and sorghum are crops that resist considerable salt.

Unreclaimed, the marsh lands have a value of from $1 to $20 per acre, depending upon their location, elevation, and capability of grow-

ing salt hay. In general, the values are greater in the more thickly populated North Atlantic States than in the sparsely settled South Atlantic States. Reclaimed, the marsh lands are worth from $20 to $100 or more per acre, varying with the elevation of the land, the character of the soil, and the thoroughness of the development. Probably $50 to $60 per acre would be a fair average value at the present time.

The acre cost of a projected reclamation will of course vary widely with the extent of the land to be protected, the amount of upland drainage, and the length and height of the levee. Under average conditions it may run from $50 to $60 per acre.

Marshes that are daily submerged by the tide or are so little above high tide as to be frequently covered through moon, wind, or storm influences are not considered prejudicial to health or dangerous as mosquito-breeding territory. When the marsh becomes so high or its contour is such that flooding is infrequent, the deleterious effects become manifest in malaria, chills, fevers, the mosquito pest, and, in certain localities, anthrax. Reclamation of land of this character and its utilization for agricultural purposes has seldom failed to abate the harmful influences and to destroy the mosquito nuisance. . . .

In considering a proposed reclamation, the all-important questions to be decided are:

1. What is the character of the soil, especially its fertility and depth?
2. What is the elevation of the land with respect to low tide, and the range of the tide?
3. What is the area and slope of the land?
4. How is the land situated with reference to shelter from storm tides?
5. Is the shore line advancing or receding?
6. What is the amount and character of the upland drainage?
7. Can intersecting streams be diverted?
8. What is the market for the products of the land?

Especial emphasis should be placed on the importance of carefully considered plans for and thorough construction of levees, sluices, ditches, and pumping plants, since much money has been squandered in the past through hasty, ill-advised, and poorly constructed works.

22

Coastal Plains

COMPARATIVELY level surface in an area which was previously very uneven ground may be due either to denudation or to deposition or to a combination of the two processes; by these processes many minor land forms are made. This is true of coastal plains. *Coastal plains* are those plains which border the coast line.

The ocean is the great receptacle of deposits, and frequently the deposited material is elevated above the surface of the water and a coastal plain is formed. Some of the most important plains of the earth have been produced by uplift of marine sediments. Such plains have all of the characteristics associated with continental shelves, namely, a fairly uniform surface with seaward slope and surface material consisting of silts, sands, and gravels. The map for the United States shows coastal plains on both the Atlantic and Pacific sides, but these plains are considerably varied. They may be classified into (1) narrow coastal plains and (2) broad coastal plains.

Narrow coastal plains

In a region with a narrow coastal plain the foothills of the mountains may descend to a lowland and the lowland slope gently toward the sea. The gentle slope is continued in the gradually deepening sea floor. Frequently the plain is so level that a great part of the rainfall enters the open soil instead of running off in streams. Streams crossing the plain cut deeply in the side slopes bordering the plain and then carve their way slowly across the plain on their way to the ocean. In the first stages the plain is a continuous, even surface but it becomes more dissected as time passes. The dissection is lateral rather than vertical,

for the stream cannot wear the valleys deeper than the surface of the sea at their mouth.

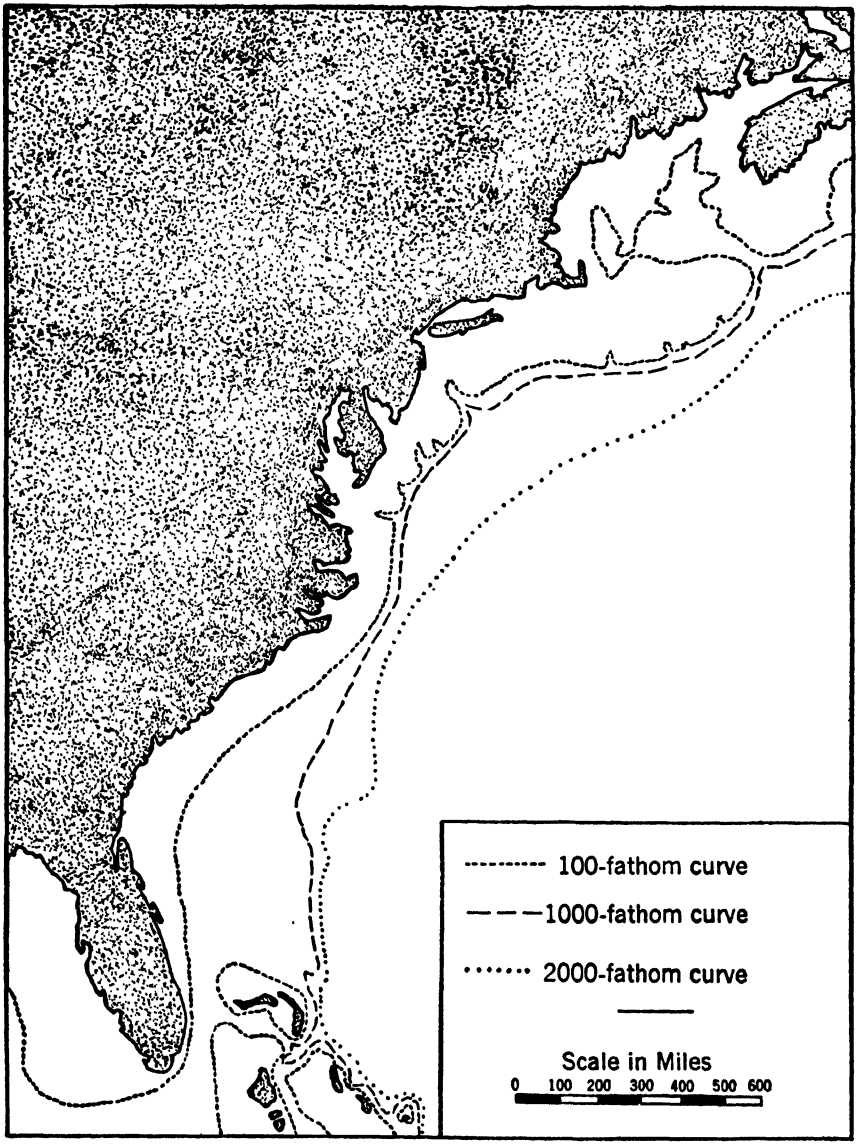


FIG. 92. THE CONTINENTAL SHELF OF EASTERN UNITED STATES. The 100-fathom line marks the boundary of the continental shelf. Note the sharp drop beyond the 100-fathom curve.

Along the Oregon coasts many narrow coastal plains occur. They may be a mile or two wide and twenty or more miles long. The forested mountains rise in the background, thus confining habitation to the narrow strip of land near the ocean. Similar coastal plains are found along all the rest of the western side of the United States and Mexico, and near Veracruz on the Atlantic side of Mexico. Many other parts of the world have similar plains.

Broad coastal plains

The outer part of the broad coastal plains resembles the narrow coastal plain, but the inner part is more cut up by branching valleys and ravines and the large river valleys are broader. Relief increases with the distance from the shore line, for the rivers are able to cut their valleys deeper.

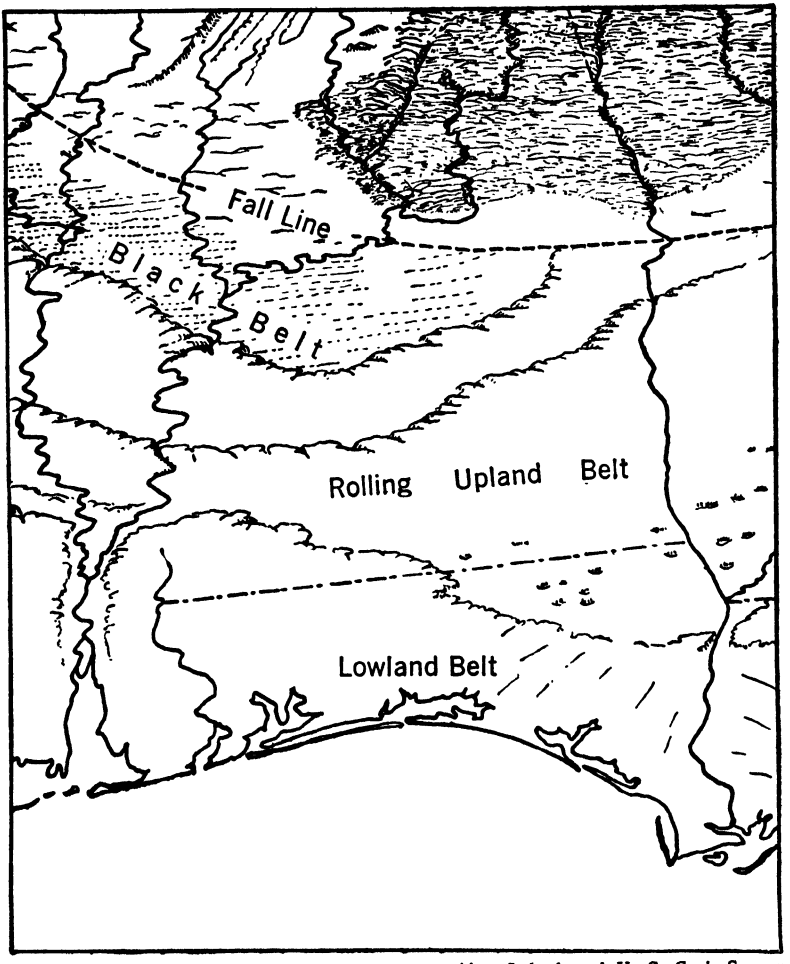
Different kinds of sediment are deposited during the gradual uplift of the region. The soils can be arranged into three belts which are roughly parallel to the length of the plain. The Atlantic coastal plain of the Southern States is a characteristic broad coastal plain and illustrates the arrangement of soils. The diagram, Figure 93, is an illustration of a broad coastal plain. The outer belt is a smooth plain with sandy deposits rising gradually from the ocean; the deposits for the area illustrated are coarse, but in other areas they may be fine materials. The belt is poorly drained. Farther inland the soil is much better and the surface is gently rolling. On the inner belt the surface is more hilly and sandy and the slope is steepest of the three belts. Beyond the coastal plain is the piedmont, or older, land form, the source of much of the sediment.

In general, the soil belts of broad coastal plains determine their specific uses. The less sandy soils of the middle belt are used for cotton production, while the inner belt has extensive pine forests from which timber and naval stores are secured. The outer belt, the one nearest the ocean, is swampy and little used at present; where this belt has been drained, truck gardening may be extensively carried on.

Beyond the coast is a belt of shallow salt-water lagoons with extensive marshes bordering the mainland. Then come the sand reefs, half a mile or more wide, enclosing the lagoons. These reefs are interrupted by inlets connecting the lagoons with the sea.

Embayed coastal plains

Embayed coastal plains are another type of coastal plain. In such plains the region has been submerged and the valley floors are drowned beneath the sea. Long shallow arms of the sea divide the low hilly arms of land. The stream pattern has been interrupted so that the former tributaries become main rivers and drop their waters immediately into the bay; the bay may have been formerly the master stream.



After Lobeck and U. S. Geol. Survey.

FIG. 93. BELTED COASTAL PLAIN.

The former regular shore line has given way to one which is very irregular. The situation mentioned above has been reversed, for the sea now occupies former land areas. The land is being cut back by the waves, and the bays are being filled with river sediments which in



FIG. 94. SKETCH OF EMBAYED COASTAL PLAIN.

time may become deltas. The drowning of the land took place recently (recent geological time), for the changes in the land heads and bay heads are of moderate amount. The Atlantic coastal plain from Delaware Bay to Pamlico Sound presents many examples of embayed coastal plains.

Embayed coastal plains greatly restrict human occupance and occupations. Road patterns and village sites are determined by the hilly land arms. Farm land is restricted by topography instead of by soil as in the previous case. The shallow bays may be important as fishing centers, and the upper reaches of the bays may become important commercial centers as described in the chapter on oceans and coasts. In the colonial history of the United States embayed coastal plains were of greater importance than at present, for the drowned valleys offered easier communication between settlements than was found overland. In "tide water" Virginia the many drowned valleys offered easier communication between settlements than the forests of the coastal plains.

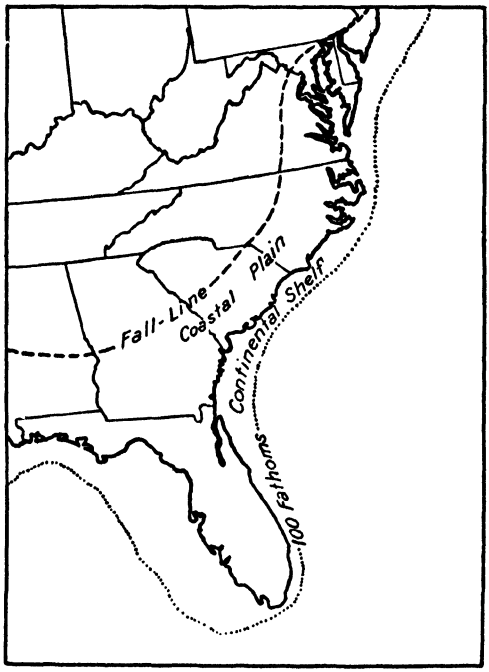
Fall line

The *fall line* marks the inner boundary of the coastal plain of eastern United States. The fall line is a belt rather than a line and is a slope steeper than the plain itself. It is this steep slope, rather than any particular elevation, which limits the coastal plain to the landward side. On this fall line the streams are marked by many falls and rapids. The rapids and falls are due to the fact that streams have been able to

cut more rapidly into the unconsolidated sediment of the coastal plain than into the resistant rocks of the piedmont. Many cities are located along the fall line, for here river navigation is interrupted and water power can be developed.

Summary

Coastal plains are common but not universal features of continental borders. If the oceans were withdrawn from the submerged parts of



After Loomis.

FIG. 95. EXTENT OF COASTAL PLAIN AND CONTINENTAL SHELF.

the continental platforms, it would be seen that the coastal plains are topographically continuous with the continental shelves. Thus the continental shelves, or submerged coastal plains, are more nearly continuous than the emerged coastal plains. Many of the coastal plains have emerged in late geological time.

Some coastal plains offer special advantages for settlement. They have a large extent of arable land which is easily tilled, transportation

is not difficult, access to harbors is ready, and artesian water may usually be found. On the other hand many coastal plains have soils deficient in plant food and the harbors are poor. In the aggregate the coastal plain population of the world is large; this may be due to the fact that the acreage of coastal plains is extensive rather than to the fact that unusually favorable conditions are found for supporting a large population.

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23

Zuider Zee Project

THROUGHOUT the course of history the story of the Netherlands has been of man's unceasing struggle against the sea. There is a saying current amongst the people of the Low Countries that "God made the land, but the Dutch made Holland," and it is true that the most fertile and productive portions of the country are those which have been reclaimed from the ocean by man. The largest and most recent undertaking is presented in the following article.[1]

Reclamation through drainage is one of the best understood and most scientific types of engineering practiced in the Netherlands. The Hollander lives in a region much of which has been built up from river alluviums and which has been awash with fresh or salt water for centuries. Beemster, Purmer, and Shermer lakes, great shallow sheets of water between Amsterdam and Alkmaar, were drained as early as the seventh century. Bit by bit the coastal lowlands were diked off and the water pumped out by batteries of slow-moving windmills. Between 1540 and 1920 the Dutch diked and turned into *polders*—the local term for a basin-like field below sea level—some 1,500 square miles of swamp and sea bottom. The clumsy dikes of early years have been greatly strengthened and improved, new drainage canals dug, and steam or diesel pumping plants gradually installed to take the place of the long-armed windmills. These things have been accomplished so

[1] An unpublished article by Howard H. Martin.

quietly that the world has remained almost unaware of Holland's superior skill in this type of engineering.

One of the best examples of profitable reclamation is Haarlem polder, which was formerly a large but shallow lake. Systematic drainage operations were begun in 1848 and completed in 1852. By the use of power machinery and large steam pumps the entire lake was drawn

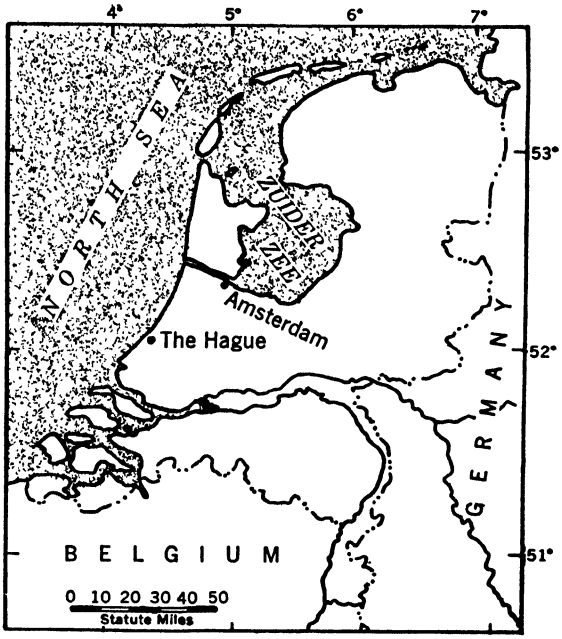


FIG. 96. SKETCH MAP OF HOLLAND.

off, laying bare a broad expanse of rich alluviums. The resulting polder contained 42,000 acres, no small addition to the agricultural economy of any country, and especially welcome in this overcrowded land. Haarlemmeer is now the recognized center of the Dutch bulb business. In addition to a profitable trade in cut flowers, this area exports millions of dollars worth of bulbs annually. Haarlem land which at the time of reclamation in the 1850's sold for $100 an acre is now often worth $1,000 per acre. Intensive horticulture of this type provides employment for many men per acre, but makes heavy demands on the natural fertility of the soil. As a result of this, the district is one of the largest known users of commercial fertilizers.

While Haarlemmeer is probably the most spectacular and profitable of all the Dutch drainage operations, there are many smaller polders. Some have been reclaimed so long ago that the Dutch have almost forgotten they were once lake or salt sea bottom. Polders which were taken out from under the sea have required years of continuous pump-

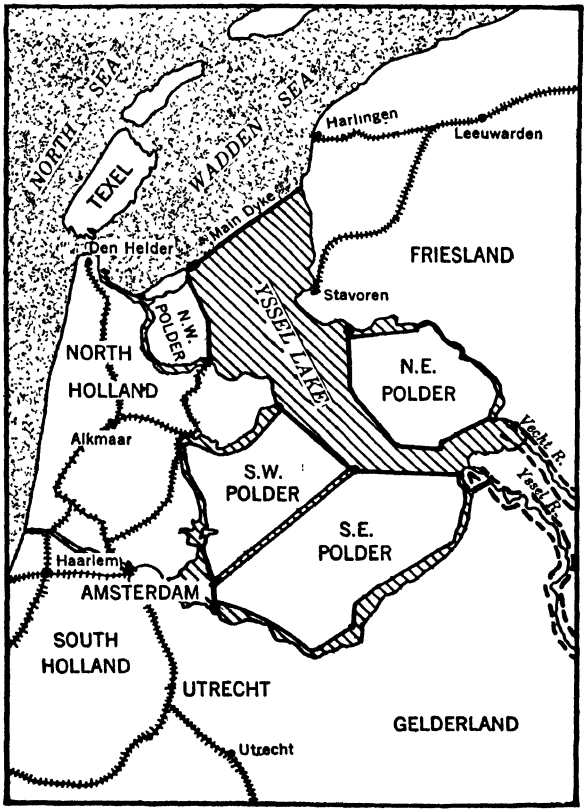


FIG. 97. SKETCH MAP OF ZUIDER ZEE PROJECT.

ing and freshening before the salinity decreased sufficiently to permit the growth of plow crops. Large areas will never be used for intensive bulb and market gardening of the Haarlem type, but are excellent for use as meadows. In all of them the water table is naturally near the surface, and constant pumping is necessary to keep the water in check. These pastures, kept green the year round by steady and persistent rains, form part of the great dairy economy of Holland.

In the last twenty years the enterprising Dutch have embarked upon a still more ambitious project—the drainage and reclamation of the larger part of the Zuider Zee. This great arm of the North Sea is approximately 85 miles long, varies from 10 to 45 in width, and has an average depth of only about 14 feet. For centuries the Dutch nibbled away at its margins, but, finding this process too slow, they began large-scale engineering, which included the construction of a great sea dike across the entrance to the Zee, and pumping out most of the water behind it a section at a time.

The original Zuider Zee plan was drawn in 1891 by the famous hydraulic engineer, Dr. Cornelius Lely, but it was not until 1918 that a final plan was adopted and work started. With the venerable Dr. Lely as chief engineer of the Zuider-Zee Werken, a long-scale program was arranged, with the final completion date set for 1960. The estimated recovery of this program is 867 square miles of cultivable land, which means, roughly, an addition of 10 per cent to the farmable area of Holland. The estimated cost to date is about $250,000,000. The final cost will probably be over $500,000,000.

After surveying various routes for the main dike, the engineers finally decided to take advantage of Wieringen Island. This island, lying off the coast of North Holland, forms a convenient natural barrier about 7 miles in length. The damming of the Zuider Zee began with the construction of a short 1½ mile sea wall from the North Holland coast to the southwestern tip of the island. This first section was finished in 1926.

The main dike, 18½ miles in length, connects the northeastern tip of Wieringen with Kornwerd on the coast of Friesland. Most of the construction was in relatively shallow water (10 to 15 feet), but there were a few places where powerful tidal currents had scoured out channels over 40 feet deep. Beginning in 1920 the work was pushed from both ends. To withstand the force of the North Sea storms this great sea wall had to be of massive construction—250 feet wide at sea level, and 23 feet above high tide. Giant dredgers brought up sticky boulder clay which was mixed with sand and pumped into the core of the structure. As the two ends approached each other, the engineering difficulties increased. Tidal currents swept back and forth through the gap with such force that the fill was frequently torn out as fast as it was dumped into place. To close the last gap it was necessary to

weave huge mattresses of brush and willows, and import great blocks of stone from Germany. The mats, weighted with stone, were sunk in the narrowing channel. By using alternate layers of mats and boulder clay the gap was finally closed in 1932. The seaward side of the barrier was faced with tightly fitted pentagonal blocks of black basalt, to protect it from the erosive effect of wind and wave. Cobblestones and concrete were also used. The finished dike has a transportation as well as a drainage function. Its top is wide enough for both a railway and a motor highway; North Holland and Friesland are now brought within easy reach of each other by this viaduct across the mouth of the Zuider Zee.

Too large to be handled as a single drainage project, the Zuider Zee was divided into four units, each with its own separate dikes, each to be constructed independently of the others. As finally planned, these four great basins or polders were:

The Northwest Polder	50,000 acres
The Northeast Polder	135,000 acres
The Southwest Polder	135,000 acres
The Southeast Polder	230,000 acres
Total area	550,000 acres

The first and smallest of these basins, officially known as the Northwest Polder, but commonly called the Wieringenmeer Polder, lay in a natural embayment formed by the peninsula of North Holland on the south and west, the island of Wierengen on the north. The main seadike from Wieringen across to Friesland was scarcely started when the engineers began work on the Northwest Polder. With headquarters at Den Oeuver and Medemblik, they built the great inner dike between the island and Medemblik, completing it in 1929. This dike, while broad and constructed with great care, was not subject to the pounding of wave and tide like the main barrier across the Zuider Zee mouth, so it was not necessary to face it so expensively.

Actual drainage operations for the Northwest Polder began early in 1930. Two giant pumping stations, one electric, the other diesel-powered, were installed at opposite ends of the enclosure—one on the mainland side of the basin at Medemblik, the other at Den Oeuver on the north side. Throughout 1930 the pumps worked steadily, pouring

a daily total of some 4½ million tons of water over the dikes into the open Zuider Zee. The level dropped at the rate of an inch a day, and by January, 1931, the bottom was in sight. Before it was entirely laid bare, powerful trenching machinery began plowing through the sludge to dredge out the main ditches, the ensuing channels being used to divert the last water in the direction of the pumps. The uneven surface also needed considerable leveling, so the polder was divided into three sections, each with its own water level and all three draining finally to the pumping stations. Between levels there was a difference of two or three feet. Cross laterals were dug from the main ditches across the newly exposed bottom. The entire polder was at first little more than a slippery waste of sediments, sands, and clays, with many low spots still filled with water. No one except an experienced drainage man or a land-hungry Hollander would have considered it inviting at this stage.

By the time Wieringen was drained, many years of experimentation had taught the Dutch how to handle new sea lands. Using some of the lighter and sandier soils, a cover crop of mixed grains was grown the first year, on about one per cent of the total drained area. In spite of salinity, the grain made a fair return and helped to freshen the soil. In 1932 twenty per cent of the polder was sown, and year by year the acreage was increased. A systematic soil analysis was made. Much of the soil is heavy clay which will take several years of drainage work and constant freshening before becoming really productive. The steady rainfall is of great assistance, soaking up considerable salt; seepage has a similar effect. Many millions of tons of brackish water must be pumped out before the soil loses its salinity. It takes from five to ten years before sea bottom becomes good pasture or grain land.

The Netherlands government resolutely refused to sell any of the new polder to capitalists or speculators. The Zuider Zee land is regarded as a national project where landless sons may settle and develop farms of their own, similar to those now found in the mature polders such as Haarlemmeer or Anna Paulowna. The unit of settlement in the Wieringenmeer was set at 20 hectares, or about 50 acres per colonist.

Lying as it does 15 to 20 feet below sea level, the safety of this polder depends entirely upon the strength of the dikes and the efficiency of the pumping stations. To provide the new colonists with additional

security, as well as to insure homesites free from undue dampness, the engineers threw up broad mounds or safety islands of clay. After these raised townsites had been allowed to settle, the actual erection of buildings was begun in 1932. Glootdorp was laid out in June of that year, Middenmeer the following spring, and De-Terp early in 1936. The three towns were carefully located within the polder to provide colonists with the most favorable access to their individual farms. About 100 dwellings for workers were first erected in each town by the state authorities; all dwellings were of substantial construction, neat in design, with brick walls and red tile roofs. As a result, each town has an air of quality and permanence not usually associated with pioneer ventures. Only the flat and practically treeless landscape stretching away to the distant horizon reveals the secret of a seabottom recently laid bare.

A partial innovation in the Wieringenmeer culture pattern is the greater attention paid to roads. The older drained areas had many permanent canals, broad enough and deep enough to provide the farmers with barge haulage for their produce. The modern Dutch farmer, however, is using the motor truck for greater speed and efficiency. The Wieringen polder has been laid out with fewer barge canals, but with a greatly expanded highway net. The major arteries have narrow strips of hard-surfaced roads, flanked by dirt strips for the use of farm machinery which might damage the brick pavement. This combination of roads and drainage ditches has necessitated more bridge building, the district containing between 50 and 60 bridges.

Work on the other three polders was not begun until some time after the Zuider Zee was shut off from the North Sea. The dike to enclose the Northeast Polder is not under construction (1940), and but little has so far been done on the other two polders. When the last of these areas is finally enclosed and drained, all that will remain of the former sea will be a long, narrow lake called the Ysselmeer. Like the Zuider Zee, the future lake will receive a constant flow of fresh water from the Yssel River, one of the delta outlets of the Rhine, and from the smaller Vecht River, which rises in Westphalia.

At high tide the present enclosed lake is one meter below the North Sea; at low tide it is one meter higher than sea level, so the locks can be opened to let surplus water run into the North Sea. Even before

the reclamation of the three other polders the enclosed Zuider Zee received a sufficient supply of fresh water at the east end, and had been able to spill out enough salt water at the west end to become virtually a fresh-water lake. This change in salinity has already affected the biology of the enclosed waters; salt-water flora and fauna have been dying out and are being gradually replaced by certain fresh-water types.

The future Ysselmeer will be connected to Amsterdam by a canal of sufficient depth to permit the entrance of small ocean-going vessels, and there will be lesser canals emptying into it for drainage purposes. Ocean shipping will not be affected by the disappearance of the Zuider Zee. Large ocean-going vessels have not used it for many years; Amsterdam has a deep-water outlet to the west, the North Sea Canal, which carries the bulk of its ocean shipping.

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Glaciers and Glaciation

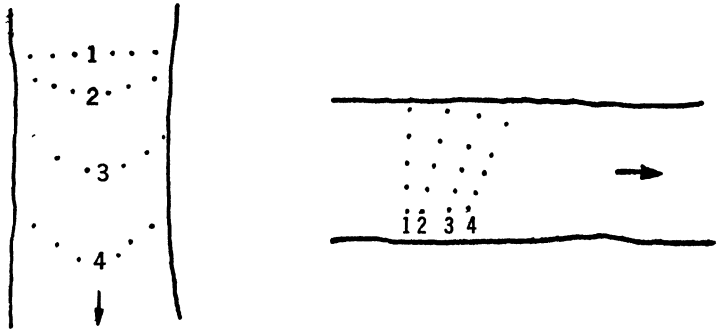
GLACIERS are found in practically all latitudes; the greater number are found in the higher latitudes and on the windward sides of continents on high mountains. Within the tropics glaciers are found only on the highest mountains. If the quantity of snow that falls is greater than the amount that melts and evaporates, the difference remains from year to year and gathers as *snow fields.* During the summer, part of the snow melts by day and freezes at night, and occasionally rain falls on it. Through this process the snow field changes from loose snow to a coherent mass. Part of the mass will be snow and part ice; this mass is known as *névé.* The pressure of the upper layers consolidates the névé into ice. The ice, lying on a mountain slope, will move downward of its own weight and become a *glacier,* or moving ice.

Glacier movement

Since glaciers are composed of ice, they move not as a liquid but as a solid. As the glacier moves, it thaws, rolls, freezes, and slips—all at the same time. The thawing permits many ice granules to move as separate particles, to grow and alter in shape as they change position. Thawing also permits the water to sink into the glacier, where it then freezes and expands and pushes down the slope. Slipping permits various layers of ice to pass each other. The consolidation of snow into ice and the movements of ice are accounted for by the fact that breaking, pressure melting, and regelation (freezing again) are constantly taking place.

A glacier moves faster in the daytime than at night, in summer than winter, and near the lower end than the upper. A glacier moves in response to many intricate and interacting forces. The principal ones are gravity, heat, and regelation. It is impossible to determine just how much each factor contributes to the result.

The movement is not only complicated but also slow. The glaciers in the Alps were the first to be studied, and they were found to travel from one to three feet a day. Some of the glaciers of the Rocky and



Movement on Surface of Glacier. Movement on Side of Glacier.

FIG. 98. MOVEMENT OF GLACIERS.

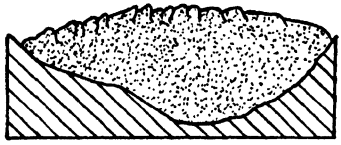
Cascade Mountains move eight to fifteen inches, while some in Alaska move four to twelve feet a day.

Stakes driven into the surface of a glacier in a straight line reveal that the glacial movement varies with its different parts. The line of stakes —beginning as a straight line—becomes more convex as the glacier proceeds downward. The motion is more rapid toward the center than at the sides. Stakes driven into the sides of the glacier in a straight vertical line reveal that the movement is greater at the top than at the bottom.

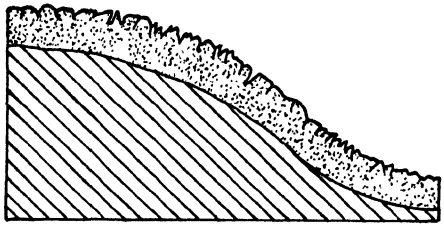
Crevasses

The surface of a glacier is usually rough and irregular. The roughness is due partly to water melted from the ice which cuts channels on the glacier, and partly to rock debris carried on and in the ice. The surface has many cracks and fissures known as *crevasses.*

Crevasses result from ice movement even where that movement is slow. Strains are produced partly by the unequal movement of the ice itself and partly by the uneven surface over which it is moving. Thus crevasses are found where there is a change in the slope over which the ice is moving (*transverse crevasses*), when the glacier is retarded by the valley wall (*marginal crevasses*), and when the glacier spreads out on the piedmont (*longitudinal crevasses*). However, the first crevasse appears where the glacier starts moving, pulling away from the parent ice field. This fissure or series of fissures is curved and called *bergschrund*.



Cross Section of Glacier and Crevasses.



Longitudinal View of Crevasses in Glacier.

FIG. 99. CREVASSES IN GLACIERS.

The movement of the ice often causes the crevasses to become closed, and later no trace may be found of them. However, if the fissure remains open for some time, much melting takes place, and the sides, when they come together again, do not fit; hence the surface will be uneven.

Location of glaciers

Many parts of the earth are covered by glaciers, which range in size from thousands of square miles to a fraction of a square mile. The largest existing glaciers cover Greenland and Antarctica. The mountains of Europe—the Alps, Pyrenees, Caucasus, Carpathian, and those of Norway—have many glaciers. The Himalayas of southern Asia have many high-latitude valley glaciers. The Andes of South America, because of their high elevation, have many glaciers, some of which are on the equator. The Rocky and Cascade Mountains have hundreds of glaciers. Alaska has more valley glaciers than any similar area in the world.

Types of glaciers

Glaciers perform their principal work by erosion of the land and by transporting and depositing materials. While the areas glaciated are

small and the time in which the work has been done is relatively short, the work is of great importance.

According to size, position, and form, glaciers may be classified as follows: (1) valley glaciers, (2) piedmont glaciers, (3) ice caps, and (4) ice sheets.

Valley Glaciers. In some high mountains the precipitation comes in the form of snow, which may accumulate year by year and form snow fields. In the high elevation the wind whirls the snow about, bringing some of it to rest in valleys between the peaks. Since the steep slopes cannot retain much of the falling snow, it slides down into the valleys. Avalanches, or snow slides, bring additional material when the snow becomes too deep. By these three means, in addition to the precipitation itself, the snow reaches great depths in the mountain valleys.

By melting and freezing and by pressure the snow is compacted into ice and then it slowly moves down the valley as a glacier. This downward movement continues as long as the supply exceeds the melting.

As the glacier moves down the valley, it cuts its own valley, as a river, but instead of cutting down to form a V-shaped valley, it cuts along the sides to form a U-shaped valley. Material is dropped on the glacier by wind and from avalanches. As the glacier advances, some of the material will be dropped. Rock fragments dropped mainly from the valley sides near the margin give rise to *lateral moraines.* When two glaciers come together, two of the lateral moraines coalesce and become a *medial moraine.* Through the crevasses some of the surface material falls to the bottom, where it obtains more material rasped from the bed. Material deposited along the bottom of the glacier is called *ground moraine.* In time, the glacier reaches the place where the supply of snow and ice is no longer sufficient to permit it to advance, and a moraine is formed at the terminus—a *terminal moraine.* If the ice remains at one place for a long time, the terminal moraine may be built to a considerable height; this mound is made of gravel and boulders brought and dumped by the ice.

The erosion of a glacier is unlike that of a river, for it accomplishes much of its work under the heavy pressure of ice above it; it acts like a powerful rasp, grooving and polishing the surface over which it passes, and it may grind some fragments to a fine clay. These rock fragments become frozen into the ice, and large boulders and small particles are

carried together side by side. River deposits are assorted according to the size that can be carried with a given velocity. Deposits of a glacier vary from fine clay to large boulders; many of the boulders are scratched, since they were once part of the rasping surface at the bottom of the ice.

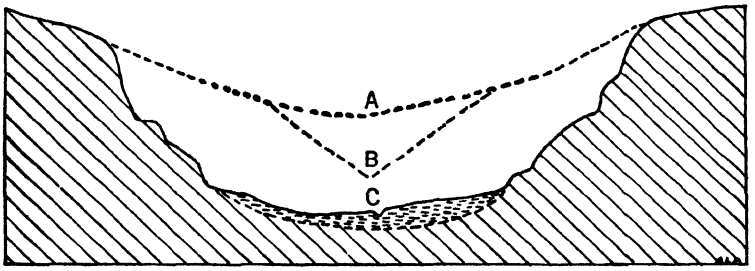
Even while glaciers are growing, their ice is melting to some extent, and when they disappear, it is chiefly by melting. Drainage is vigorous at the edge of an ice sheet and below the ends of valley glaciers much of the time. Water work, therefore, accompanies ice work in all cases. The stream emerges with considerable velocity and carries much sediment, which makes it milky white in color. This debris, carried down the valleys, is deposited in the channel, over the floodplains, or in lakes. These *fluvio-glacial deposits* take many forms.

The material deposited by the stream in the valley below a glacier is a *valley train.* The deposits may be miles beyond the front of the



FIG. 100. PROFILE OF VALLEY TRAIN.

glacier. The material deposited by water is stratified. An *outwash plain* is formed when the glacier pauses for a considerable time upon



After U. S. Geol. Survey.

FIG. 101. PROFILE SECTION OF GLACIAL EROSION, YOSEMITE VALLEY, CALIFORNIA. A, original profile; B, stream-eroded valley; C, glacial-eroded valley.

a rather flat surface. A network of streams emerges and deposits materials more or less uniformly over the surface. *Kames* are formed at the margins of glaciers by debris-laden streams which heap up sand and gravel as they emerge from the ice. They have rounded outlines and are from 50 to 150 feet high. Kames may be stratified or un

stratified. *Eskers* are long, usually winding, low ridges of stratified sand and gravel. Their crests are narrow and rather even, 75 to 100 feet high, and they often look like artificial railroad embankments.

Piedmont Glaciers. When two or more valley glaciers emerge upon relatively level ground, they may coalesce and form a single glacier. Malaspina Glacier in Alaska is a piedmont glacier and covers some 1,500 square miles. The valley glaciers are the feeders, while the piedmont glacier is a low-lying ice plateau. The amount of its movement will depend upon the topography and the amount of ice moving in from the valley glaciers.

Ice Caps. In the northern high latitudes on relatively level plains or plateaus, ice fields are formed from the accumulation of snow. This process is similar to that discussed previously. These ice fields move radially and, in addition, may send out tongues of ice. Such ice fields are known as *ice caps.* They vary in size from a square mile or two in area to several hundred square miles. The lower temperatures in the high latitudes permit the accumulation of snow from year to year. In lower latitudes the sun would thaw the snow on the flat surfaces.

Continental Glaciers. In Greenland and Antarctica are glaciers which are like ice caps but much larger and therefore called *continental* glaciers. They move outward in all directions, sending many tongues of ice into the sea. During the Glacial Period similar continental glaciers existed in Europe and North America.

Summary of Types of Glaciers. Valley glaciers are of moderate size, are confined by valleys, fed by precipitation from ascending air currents, have internal movement throughout, and change the topography into a rugged type. Continental glaciers are of vast size, have a flatly domed surface, have a movement apparently restricted to the margins, and produce monotonously flatly undulating topography. Ice caps are an intermediate stage from which continental ice sheets may evolve. In size they are nearer the valley glaciers, but in form they more nearly resemble continental ice sheets, except that the dome is much less flat.

Continental glaciation

About two million years ago in the Northern Hemisphere the climate became cooler. The average drop in temperature amounted to ten or twelve degrees, which is less than the drop between summer and winter. Sufficient ice accumulated in the northern part of Europe and North

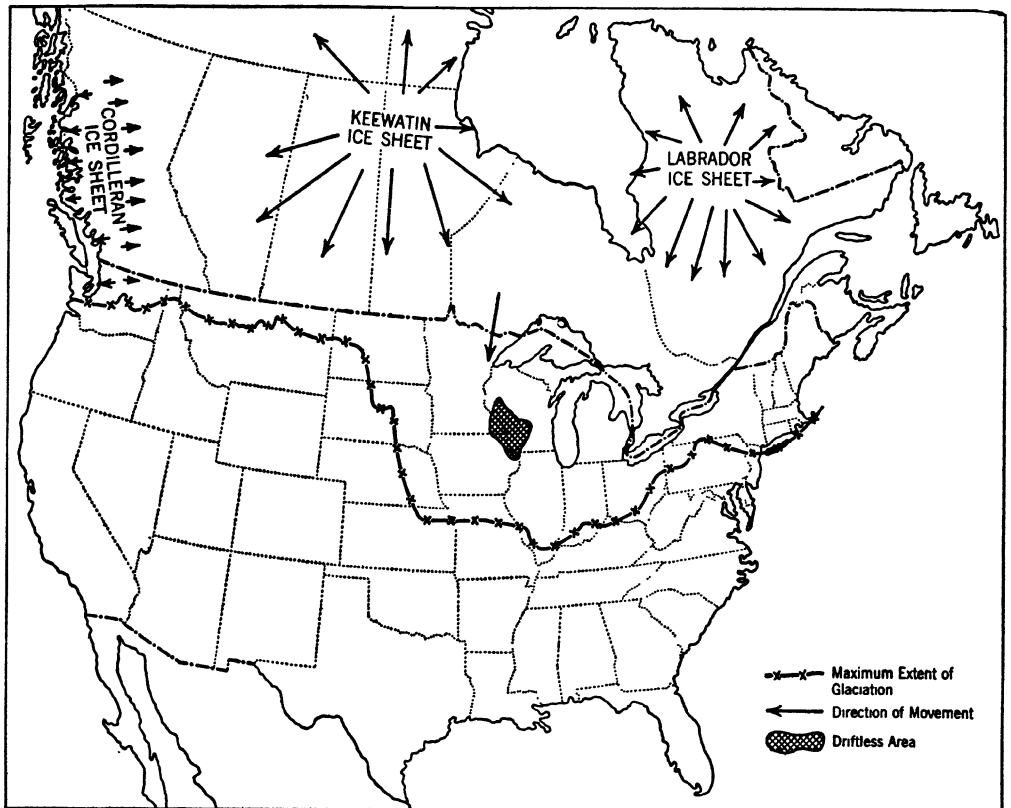


FIG. 102. GREAT ICE AGE IN NORTH AMERICA.

America to begin the *Ice Age*. South America, Africa, and Australia went through the Ice Age without continental glaciation. On the North American continent proper, the Keewatin ice sheet formed west of Hudson Bay and extended from the Arctic to Montana and moved southward into Missouri. The Labrador ice sheet formed in Labrador and moved south into Ohio. In the west, the valley glaciers united and covered all but the high peaks from Alaska to central Washington. The combined area covered was some four million square miles.

In Europe the ice spread across Ireland, central Europe, and southeast of Moscow, covering an area of seven hundred thousand square miles. In Asia the ice sheet formed along the mountains and covered parts of Siberia.

During the Ice Age the glaciers advanced in North America into Kentucky and Kansas. A change in climate brought warmer conditions, a melting of the ice, and a reappearance of flora and fauna.

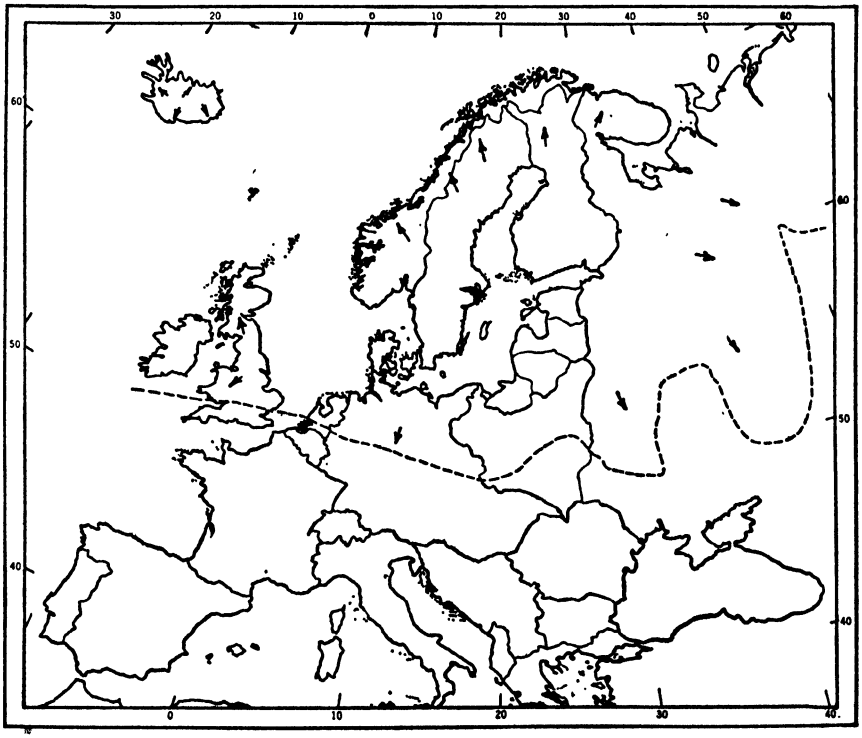


FIG. 103. GREAT ICE AGE IN EUROPE. Dotted line is maximum extent of continental glaciation. Arrows indicate direction of ice movement.

Colder climates again brought glaciers; they advanced nearly as far as the first glaciers. Another interglacial epoch was produced with warmer climates. A fourth and fifth ice sheet crossed Canada and advanced into the United States. From the deductions that have been made from certain waterfalls, particularly Niagara, it appears that 25,000 to 50,000 years is somewhere near the correct period for the postglacial era.

As the ice sheet moved southward, it crossed plains and high elevations. Each climb was made by successive layers of ice at the margin; a layer of ice moved a short distance, and then the next layer went a bit farther, and so to the top of the glacier. High elevations, such as the Catskills, were crossed by the Labrador Ice Sheet, and other elevations of 8,850 feet were covered. Since the surface of the ice was dome shaped, the glacier must have been 10,000 feet thick. The Keewatin sheet has been estimated at 10,000 to 15,000 feet thick.

Some of the evidences of the Ice Age are (1) rocks with polished and striated surfaces which could have been produced by no other eroding agent, (2) boulders which have been transported many miles from their parent material, (3) deposited materials over the area which are stratified and unstratified, (4) terminal moraines along the southern edge of the Ice Sheet, and (5) recessional moraines. Since the Ice Sheet had no sides, lateral moraines are absent.

Results of continental glaciation

The continental glaciers moved much material from one place to another; they replaced by new soil the old which was removed; they

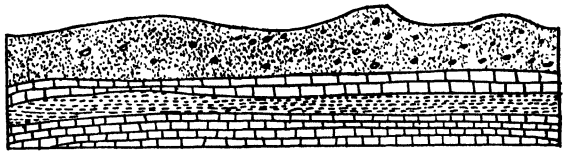


FIG. 104. UNEVEN DEPOSITION OF GLACIAL DRIFT. Former nearly level surface changed to rough outline.

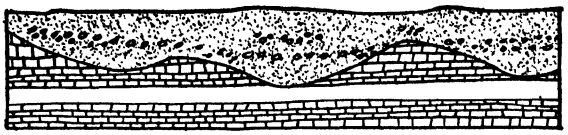


FIG. 105. EVEN DEPOSITION OF GLACIAL DRIFT. Former hilly land changed to comparatively flat surface.

lowered many hills; they dug new valleys and filled others; they modified the drainage pattern; and, in general, they left a changed land surface.

The effect on the topography was a minor consequence, with but slight lowering of higher elevations and rounding of their tops. Valleys were filled with debris, and some were carved in softer rock parallel to the direction of the ice movement. In general, owing to deposition in the preglacial depressions, the country was left somewhat less rugged than it was before the Ice Age.

Soils were affected tremendously throughout the four million square miles covered by the glacier. Residual soils were picked up, mixed with other soils, transported, and deposited in new places. In some places, as eastern Canada, only thin soils or bare rocks are found, with little or no agricultural possibility. In areas of glacial deposition, as in most of eastern United States, deep soil permits extensive agriculture. In areas of deposition, some places have deep soil rich in soluble plant food, while in others, boulders are numerous and sand and gravel are abundant.

Another important effect of glaciers was upon the drainage systems. As the ice advanced equatorward, it became a barrier for the north-flowing streams. Such streams were first changed into lakes with no outlet, and, fed by water increasing in depth, the temporary lake was forced to find a new outlet in the only direction possible, to the south. This new stream, the outlet for the lake, cut down barriers and established a new river channel. After the ice disappeared, many streams continued in their new course to the south. One of the best examples of such a change is found in the Allegheny River, which, in the preglacial period, flowed northward to the St. Lawrence, but at the present time flows southward to the Ohio.

During the period of the Ice Age streams could not exist under the glacier. With the retreat of the ice, the rivers came into existence again. The old valleys had been obliterated, and new valleys had to be carved by the rivers. Frequently the streams were forced to carve gorges, a characteristic of young streams, in the rock or till deposited by the glacier. As a consequence, waterfalls are found in many glaciated areas.

Lakes are another characteristic feature of regions which have been glaciated. Frequently moraines, deposited by the retreating glacier,

became a dam for the postglacier stream, behind which the water collected into a lake. The lakes of northern United States and of Canada are the result of glacial action; the glacier either left the dams of moraine or dotted the surface with saucer-shaped depressions. The Great Lakes are due partly to the digging action of the glacier, partly to the moraine dams, partly to the glacial deposits which choked the old preglacial valleys and forced the change in the drainage pattern, and partly to down-warping of the earth's surface, especially in the area around Lake Superior.

Extensive changes in plant and animal life occurred during the Glacial Period. Plant life was killed, but seeds of those plants were transported to areas much farther south. Animals, being able to migrate, moved southward, causing a biological crowding equatorward. With the melting of the ice the former glacier-covered area was again slowly populated with flora and fauna. The redistribution of species for both flora and fauna over the area was slow—perhaps tens of thousands of years. Many Arctic plants migrated up the mountains instead of northward, which explains, perhaps, the distribution of many Arctic species of plants in mountains of the middle latitude. Thus the Glacial Period produced important changes in plant and animal distribution as well as in species.

Summary

Ice, while not now so important as the major agents discussed, is an agent in modifying land forms. It wears down the land and moves the waste to the sea, modifies the soil, changes the drainage pattern, and influences the distribution of plants and animals. While ancient ice sheets are more important than the glaciers of today, yet existing glaciers are of economic value chiefly in connection with the development of power from streams that flow from the glaciers.

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25

A Case of Geographic Influence Upon Human Affairs

THE continental ice sheets left conditions far from uniform over the area which they covered. In the ice-scoured regions bare rock makes agriculture almost impossible except for the small-scale subsistence type. In the areas of deposition variation is the rule. Some places were left hilly and rough, while others are comparatively smooth. A contrast between two areas which are juxtaposed where the ice deposited materials is presented in the following article.[1]

Among the geologic questions presented within the bounds of Illinois perhaps none has a greater economic bearing than the glacial problem. It is the purpose of this paper to look at glaciation and its results in a limited portion of Illinois, from the point of view of geographic influence upon plants, crops, and animals, and upon man's distribution, occupations, successes, and failures.

From the studies of the glacialist we may learn that during a not very remote period most of the state was invaded by some of the southern lobes of a continental glacier. An early invasion from the north or northeast advanced almost to the southern limits and retreated, leaving a sheet of rock waste spread over the surface. The drift sheet is known as the Illinoian. Another much more recent invasion covered approxi-

[1] Adapted from George D. Hubbard, from the *Bulletin of the American Geographical Society*, Vol. 36, No. 3, published by the American Geographical Society of New York.

mately one third of the state in the northeast corner. During a prolonged halt, at its farthest advance, the melting ice freed quantities of material, which formed a large terminal moraine somewhat concentric with the southern shoreline of Lake Michigan.

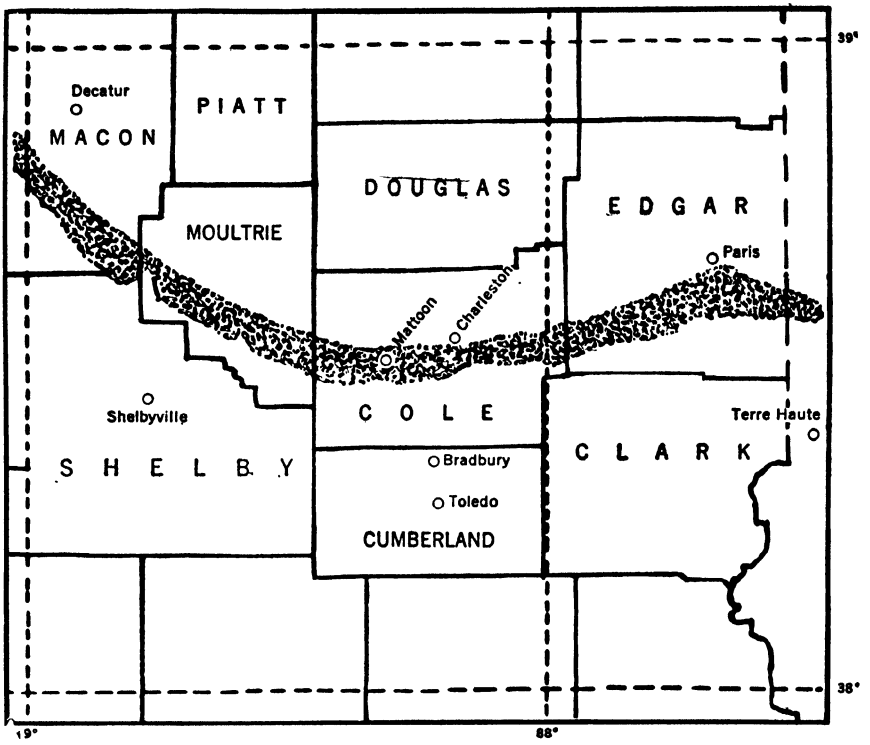


FIG. 106. SKETCH MAP TO SHOW SHELBYVILLE MORAINE.

After entering the state from Indiana west of Terre Haute, the moraine sweeps westward and then northward along a belt south of Paris, Charleston, and Mattoon, north of Shelbyville, west of Decatur and Clinton, and, after crossing the Illinois River at Peoria, runs northward, then northeastward, blending with others at several points before reaching the Wisconsin line. Upon the completion of this great moraine, called, in its southern portion, the Shelbyville system, the lobe of ice, with many halts, retreated northward and deposited over the surface of drift laid down in earlier invasions a very heavy sheet of waste

called, near the moraine, "the Shelbyville till sheet of the early Wisconsin." Thus there were spread over the area within the encircling terminal moraine two layers of drift, differing in age as much as the time between the two retreats of the ice which deposited them. The lower of these sheets continued beyond the moraine to the farthest limit of the greatest advance of the ice.

The studies embodied in this paper deal with the terminal moraine and a strip on either side of it wide enough to show the characteristics both of the old and of the new drift; and, while the discussion centers in two adjacent counties, the main features of it are applicable to the region near the great terminal moraine from the point at which it enters the state from Indiana well toward Wisconsin. In a number of localities the influence of the drift on human affairs has been partly obscured by that of other factors, sometimes geographic, sometimes not.

Many questions of interest have arisen in connection with the work, among which three may be singled out as most fruitful.

1. What was the relief and what were the forms when the ice withdrew and the streams began?
2. What are the present differences between the old and the new drift and drift forms?
3. What influence may these geographic differences be said to have upon human affairs?

For the present the first question must be passed over. The second and third have an intimate relation, and, since the latter cannot be discussed without at least a statement of the facts of the former, these last questions will determine the succeeding sections of the article.

Characteristics of the old and the new drift

The great moraine has been crossed in a number of places, ranging from Amboy in the north to Paris in the southeast, and salient points noted, but the investigations have centered around the region from Shelbyville to Paris.

Throughout all this region very marked differences exist between the new and the old drift forms. Although only twenty years ago geologists had not recognized the relations existing here, there are many farmers who have known for a score of years that adjoining counties were quite different in soil, relief, drainage, and crops.

Soil and subsoil

Probably the transition from old to new drift is most easily recognized from the change in the color of the soil. That of the older drift is light gray and contains but little organic matter. The subsoil is of a grayish color, owing to the state of oxidation of the iron. The soil of the moraine and later drift sheet is dark to black, especially if damp; humus is almost universally abundant. The subsoil is a yellow, gravelly, or sandy clay, passing into blue till below the oxidized zone. The particles of both soil and subsoil are smaller on the south side of the boundary line on similar slopes, presumably owing to the greater amount of weathering in the longer period of exposure. The greater degree of fineness is attested on dry, windy days; then the air over the older drift is thick with suspended matter, which may float for a day or more unless forced down by a shower. There are fully twice as many pebbles and boulders in the drift of Cumberland county as in the other counties on similarly situated areas, which means that there were even more when the ice first retreated. Those in the moraine and new till sheet are of both igneous and sedimentary origin, but the old drift shows a marked decrease in sedimentary fragments, although both regions are underlain with coal measure rocks. However numerous the sedimentary pebbles when the ice retreated, they have had ample time to become disintegrated, for even the igneous rocks are often "rotten" and crumbling. In the new drift most of the specimens of both classes are still sound. These facts largely explain the physical condition of the soil. That of the older or Illinoian drift is a heavy, rather compact clay, passing below into partially cemented layers of hardpan; that of the more recent Shelbyville sheet is a loose, light loam, and much richer in sand.

Dissection. North of the moraine and upon it, and increasing northward, may be noticed marshes or fresh-water swamps, locally known as *sloughs,* but outside the looping moraine they are almost entirely wanting. Outside, the streams have pushed their headwaters back, and have thus claimed nearly all the territory; while within the loop there is much undisputed surface, where water does not run off freely. Many of the marshes have been drained by underground tiling, so that, although the surface waterways are still in a very immature stage, the number of swamps is much reduced. These drained swamps, rich in

humus, become within a few years the most valued farming land. Tiling would be useless in the old drift, because the heavy clay soils are so impervious to the water, and it is not much needed, because of the development of natural drainage. But for crops all through the gravelly soil of the new drift tiling is beneficial.

A further comparison of the valleys on opposite sides of the moraine shows that the little valleys have been pushed back two to four or five times as far from the master streams on one side as on the other. Again, the little valleys are more mature on the old drift than on the new. The comparison must be made at similar distances from the master streams and between streams similar in size. Observations are best made from unfrequented by-roads or fields, because they have not avoided the rough country so completely as have the best roads. From a commanding point one can easily see that the country is more dissected in the area of exposed old drift. The increased number of lines for streams south and west of the margin of the new drift gave that portion a darker appearance, and the position of the terminal moraine could thus be traced with ease.

Along the Rivers. Embarras River, where it crosses the new drift, usually flows in a postglacial gorge. This gorge is about one hundred feet deep across the moraine, less deep farther north, and is cut in boulder clay nearly all the way; but occasionally the stream, missing the old channel, has cut down into bedrock. This narrow valley has a correspondingly narrow and elongated basin in the region north of the moraine, in part because other streams are near and in part because the headwaters have not claimed all possible territory. Southward, in the region of the old drift, the wider valley formed before the Wisconsin drift sheet and partly filled with overwash materials of Wisconsin age can easily be traced.

This overwash or valley train partially filling the old valley with drift, usually pretty well sorted, has been cut into by the stream to a depth of about thirty feet, leaving a series of terraces.

The old valley is often a mile in width, and from its crest to the bottom of the inner channel more than fifty feet deep; but the stream has not yet cut through the filling, except where it crowds close underneath the bluffs of the old channel. The postglacial channel varies in width from a half to one mile, and very rarely lies at all beyond the

confines of the older valley. The river, in swinging from side to side, has reached the east bluff in several places, but has not yet disturbed the west bluff. Hence remnants of the surface of the glacial filling are quite continuous for miles on the west side; while they are very fragmentary on the east side. These terrace tops are locally known as the "second bottoms," here as in many places in Illinois, in order to distinguish them from the lower present bottoms, or "first bottoms." They are considered superior to the uplands for farm crops, but inferior to the lower bottoms. Practically all of this terrace seen in the Embarras, and it extends eight or ten miles beyond the moraine, has in front one step dropping down to the present floodplain. There are similar terraces in gravel trains along many streams in Illinois, where they have just emerged from the terminal moraine into the older drift; and, since they do not, and from the nature of the case cannot, occur within the moraine loop, they furnish one more characteristic feature of the old drift. It is unfortunate that so little study has been made of these terrace forms, for they are really common along the streams leading outward across the terminal moraine of the early Wisconsin sheet.

Influence on economic conditions

The people dwelling within the loop of the great moraine speak of the southern portion of the State as *Egypt,* and of their own portion as *God's Country*. So characteristic are the features of the regions on the two sides of the boundary that all classes of men recognize their unlikeness.

A land agent is authority for the statement that the northern three rows of sections of Cumberland county are worth more than all the rest of the county. These three rows of sections constitute all the land in the county which is not of the older drift, except patches of bottom lands. Real estate men and landholders recognize the geographic boundaries between good and poor land. Geographic influence is a reality which may be expressed in standard terms of value. The records of land transfers, except in the river bottoms, show the average price of land south and west of the great Shelbyville moraine to be not more than $30 per acre; many farms sell for as low as $15; a few for $40. North and east of the moraine through many counties the land

brings from $75 to $125 per acre, rarely less than the lower figure, and occasionally more than the higher. But to the cultivator geographic influence is as real a thing as to the taxpayer. Crops are not the same on opposite sides of the moraine, and on account of the nature of the soil the plows used are of different quality. On the south, in Cumberland and adjoining counties, lies a region producing timothy hay. Possibly a third of the land is mowed annually. Owing to the large acreage and the smoothness of the country, machinery is extensively used. Straight, round haystacks, in groups or scattered, dot the meadows; rarely is there a hay barn to be seen. Next to hay, stock—cattle, sheep—is the most important product, but many of the cattle are driven a few miles north to be fattened, or are fed with grain from across the moraine. Again, timber is not so scarce in "Egypt," because the soil is not considered worth clearing for cultivation, and the trees are left in possession. Corn and oats are grown, but are very poor crops compared with those on the new drift. Broomcorn is often tried, with poor success. On the other hand, within the moraine loop is found a characteristically different group of crops. Hay for commerce is rarely grown. Most farms produce enough for their own use, and usually the local markets are supplied from the neighboring farms. Because of the limited acreage hay-harvesting machinery is little used. Clover hay is more common than timothy. The haystock is rarely seen, because the crop is stored in barns. Corn and oats are the dominant crops, with good and occasionally prodigious yields. The stock is fat and well fed with the output of the farm. Timber is rarer because the rich soil is worth more for cultivation. Broomcorn in Coles and Douglas counties is a leading crop, and these two counties produce a very large percentage of the total output of the United States. The difference in the quality on opposite sides of the moraine is probably more conspicuous in the case of broomcorn than in that of any other crop. Why such differences in the quality of similar crops? According to the Department of Agriculture Bureau of Soils (Bulletin 22), the economic distribution of crops is influenced mainly by the climate and the physical characteristics of the soil. If, as the experiments of the Bureau seem to show, there are but two chief factors, then the physical characteristics are the determining causes of these noted crop dissimilarities, because in two small, adjacent, similar areas the climate is essentially the same.

A table of facts, concerning yield and value of crops in two adjacent counties, has been compiled from the Statistical Atlas of the Twelfth Census and is inserted here to show the relative strength of Coles and Cumberland counties.

According to the same authority, Coles also outranks Cumberland in cattle and swine, but they are similar in horses and sheep.

County	Corn in Bu. per Acre under Corn	Wheat in Bu. per Acre under Wheat	Oats in Bu. per Acre under Oats	Hay in Tons per Sq. Mile for Entire County	Total Value of Farm Crops per Sq. Mile for Entire County	Value of Crops per Acre of Improved Land
Coles	30–40	7–14	36 and over	75–100	$5,000 and over	$10–15
Cumberland	20–30	less than 7	20–28	100–150	$2,500–5,000	$6–10

One is struck with the comparative degree of thrift apparent in each of the two regions. Outside of the moraine many log houses are still in use; while on the inside they have, almost without exception, been replaced by commodious modern dwellings. Buildings are in much better condition—are larger, more convenient, and more numerous—within the moraine loop. Abandoned houses are occasionally seen through this district, but they are much less numerous than in the district floored with the older drift. The reasons for abandoned houses are at least two: (1) The owner of the farm has built a new dwelling and has left the old one standing. (2) The partial abandonment of poor farms and the consequent consolidation of two or more under one management. The resident displaced by this means usually leaves the region. In that case the division of farms near towns and their intensive cultivation, together with some centralization of population in the towns, maintains the total population of the entire region from census to census; but the unproductiveness of the farms is an important factor in the partial abandonment and consolidation of farms.

The density of population differs remarkably in adjoining counties lying on opposite sides of the outer boundary of the moraine, as is seen in the case of Coles and Cumberland counties. In 1890, Coles had thirty per cent more people to the square mile than Cumberland; and in 1900 forty-two per cent more. If a similar comparison be instituted

in the adjacent counties to the east, Edgar and Clark, it will not be found to work so well, because the moraine, whose area belongs with the newer drift, covers much of Clark county. Furthermore, Clark has productive bottomlands along the Wabash River. These two advantages place Clark almost on a par with Edgar as to density of population. In 1890 the difference was well marked, but greater development of the bottoms since has balanced up the population. Probably, if the census were sufficiently refined as to minor districts, a comparison of adjacent areas on opposite sides of the moraine might show results tallying with those in the Coles-Cumberland case.

The influence of environment is clearly felt in road and railroad construction, and is so different in its results as to admit of easy comparison. The abundance of gravel in the hills of the moraine reduces the cost of roads, and there are, accordingly, many miles of well-graveled roads in Coles county, especially in the southern half. In Cumberland there is very little available road material, and the heavy clay makes good roads possible without gravel. Away from the moraines of the new drift there is little gravel, and the roads, over the black, sticky, rich earth, become in rainy weather almost impassable. North and east of the moraine railroads cost less for grading, cutting, and bridging than they do south and west of it. The greatest expense for these items is where the road is laid among the morainic hills.

Conclusion

Well does Professor Davis say: "The vanished ice sheets are of greater importance in American geography than are the Indians in American history." We cannot accurately tell what would have been the condition of the country had a glacier not visited it, but upon the glaciated parts we can see that the effects vary greatly even within narrow territorial limits. Whatever the origin of the so-called Illinoian drift and whenever it came with reference to the Wisconsin sheet, the present geographic conditions on opposite sides of their common boundary have given rise to differences in crops and in values, in the cost and facility of road and railroad construction, in the occupations and thrift of the inhabitants, and even in the distribution and density of the population.

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Soil

SOIL is one of the most important elements of the natural environment and is essential to man's occupancy of the earth. Food is of prime importance, and plants get their living from the soil; animals are supplied their sustenance by consuming plants. Soil is a fundamental factor in determining the amount and kind of man's food supply.

Early man, in getting his living from hunting animals and plants, was obliged to migrate from place to place, since no one area could supply him with sufficient food. The beginning of agriculture marked the change to a sedentary occupation and adaptation to the soil. With this change humans could begin to live on a well-balanced diet rather than exist on that which nature provided in a particular area. If nature was generous in an area, in the nomadic period of man's history, then food supply—plant and animal—was abundant, but not necessarily varied. Agriculture brought about a change, so that food was more abundant and more varied than it had been. With the development of agriculture and trade variety in diet increased. At the present time in areas where trade is restricted and agriculture backward, the diet is restricted and the general physical welfare of the population is impaired.

With the change from a nomadic to an agricultural adjustment man began to assist nature with the supplying of his needs. Generation by generation he accumulated experience and knowledge to aid in reducing the hazards of life. Primarily man had learned to adjust himself more positively to his environment and to use and force nature to his advantage. In compelling nature to reward him more generously, he

began to make a direct use of the various factors of the environment. The first of these elements compelled to work for man was soil.

The change from the direct method of securing food to one which was indirect and planned was a slow evolutionary process. Each stage of this advancement was brought about by an improvement in agriculture. North America presents an example of the evolution of agriculture. Many of the colonists came to the new world to engage in agriculture. They found the American Indian raising many crops, and these crops, together with plants from the home land, became the basis of their agriculture. The Indian grew some of his plants for his own subsistence and gave to the whites information regarding the raising and care of these products. The white farmers were self-sufficing, with the exception of a few dollars' worth of salt and iron. Their standard of living was much lower than that of the farmers of today. With the development of industry and the increase in trade the subsistence farming changed to commercial farming. The change in agricultural emphasis brought with it a greater demand for information on soil and an attempt to secure greater returns. Each step in the development of agriculture in North America, as well as in other places, brought a greater dependence on the soil; each step required greater knowledge and a more careful use of the soil.

Today the needs of the individual and of society are greater than nature can furnish unassisted. From accumulated experience man has learned to produce his particular necessities. This evolutionary process has changed the simple and direct method which supplied man a mere subsistence to a complex method of production which gives surplus commodities for trade and offers the farmer and society a higher standard of living. This change has brought a demand for more information about the natural environment.

Soil formation

Soils are a mixture of weathered rocks and minerals, organic matter, air, and water, in proportions which vary greatly. They have been produced by the action of climate and living organisms on parent material and are constantly undergoing further change. The change is slow, historically, unless there is a change in the environment. The chief factors in the formation of soil are (1) rock material, (2) climate,

(3) action of living organisms, (4) slope of the land, and (5) time. These factors act not singly but in combination and on each other, so that there are very complex interrelationships. The complexity must be kept in mind while considering the formative factor separately.

Soils pass through cycles of development; there are young, mature, and old soils. This statement does not imply that all soils will pass through the complete cycle, but that when conditions favorable to the completion of the cycle are present, the particular young soil will become mature and then old.

Young soils have profiles not completely developed and have the characteristics of their parent material to a greater or less degree. To a large extent they are found in areas where erosion is great and the underlying undeveloped formations are brought to the surface. The evolution of the soil is constantly retarded as the new materials repeat the changes of youth. Floodplains may also have young soils, and the evolution, in this case, is set back by deposition of new sediments.

Mature soils have normally developed profiles. They occupy relatively level surfaces and are formed under good drainage conditions. They have reached a stage of development marked by the absence, more or less complete, of geologic features. They have the profile features characteristic of most of the soils within the general climatic and biologic region in which they are found.

Old soils have passed maturity. They have lost some of the essential characteristics of normal soils, and have acquired abnormal features such as hardpans. Most of them occupy old, flat land surfaces, where they have been undisturbed for long periods of time. The time required for a soil to pass through a complete cycle is not known, but it is at least many generations of human life. It varies with the material from which the soil has been formed and with the forming agents.

Parent material

Rocks are the source from which soil is formed. "Rocks," in our discussion, include consolidated and unconsolidated deposits of the earth. They supply soils with the bulk, but not all, of their material. The three principal kinds of rocks are (1) igneous, (2) sedimentary, and (3) metamorphic. Igneous rocks are formed by the hardening of various kinds of lava and are composed of different minerals in various

proportions. Igneous rocks may also come from volcanoes. Volcanic materials may be blown from craters and spread over the earth's surface by wind or water. Volcanic materials, which are porous and fine textured, are easily weathered into soil. Sedimentary rocks are either consolidated or unconsolidated rock materials deposited by water, wind, or glaciers. Metamorphic rocks are igneous or sedimentary rock exposed to intense heat or pressure, or both, which have changed the original structure and composition.

The character of the ultimate soil derived from any given rock will depend in a large degree on the activity of the other factors of soil formation. Rocks, within each of the three groups, and between the groups, vary in their mineral composition. But a given rock may be rich in the minerals which are essential to plant growth and still produce a very poor soil. Or, under favorable conditions of climate and vegetation, a productive soil may be produced from parent material relatively poor in plant-producing minerals. Before soil is formed, various agents must break down the rock. Unconsolidated rocks such as clays and sands are easily changed by chemical weathering into soils, whereas consolidated rocks need to go through much greater disintegration. Thus the rock material may be resistant to change, or may be subject to rapid alteration, under the action of the environment. Nevertheless, soils subject for a long period of time to the effect of soil-forming processes tend to lose the character of the parent materials and become homogeneous in a given area. That area will be defined primarily by climatic factors.

Influence of climate

The influence of climate on soil is both direct and indirect. Directly it affects the type of weathering of rocks and the removal and redepositing of materials by such agents as wind and water; it is also directly responsible for the establishment of percolation of water through the soil. Highly leached soils are found in regions of high humidity, and thus the chemical nature of these soils is different from that of soils in regions that are located in arid and semiarid climates. Soils in humid regions are more or less acid in reaction and, with few exceptions, have very little free lime. Soils in arid or semiarid regions are leached but little, are usually high in lime content, and contain some

soluble salts. In Arctic regions the substrata are frozen throughout the year, the upper strata freeze and thaw during the summer, and there is a considerable mechanical mixing of the soil horizons; such soils are poorly drained most of the time. The most important direct effect of climate is on the disintegration of rock and mantle rock.

The carbon dioxide content is considerably higher in soil air than in the air above the soil, since it is continuously being produced by plant roots and other living organisms. Soils are saturated with water vapor except at the immediate surface or in areas which are exceedingly dry. If the soil is covered with wild vegetation, the surface will contain more water vapor than if it were cultivated. The removal of vegetation cover, especially in the low latitude zone, reduces the activity of micro-organisms.

The average relative humidity of the atmosphere affects water vapor of the surface soils very profoundly. If the average relative humidity is 90 to 100 per cent, the soil is more moist than if the average is 60 per cent or less. On the Kweichow Plateau of China the relative humidity for the year averages approximately 95 per cent, and the soils are in almost continuously moist condition in spite of the fact that the rainfall is less than in other places. This higher humidity produces soils very similar to those found in southern United States, where the precipitation is heavy (see the chapter on climate). In the Province of Yunnan, China, the relative humidity averages 60 to 70 per cent for the year and the rainfall is greater than on the Kweichow Plateau. The water content of the soil is less in Yunnan Province, and the dominant soils belong to another group. Poorly drained areas increase the water content of soils. Topographic conditions may produce the same effect as differences in relative humidity.

The total annual precipitation of a given region is not the only consideration in determining the effectiveness of water in soil formation. Other factors to consider are the type and form of precipitation. Torrential rains tend to puddle the surface soil and prevent the penetration of the water, whereas, if the rain comes as a gentle shower, it percolates into the soil without great runoff, except where the parent materials are entirely impervious. A vegetation cover will check the runoff and permit more moisture to seep into the soil.

High average annual temperatures increase the rate of weathering of

rocks. In general, the speed of chemical reactions approximately doubles for each increase in temperature of 20° F. This chemical reaction is greater in humid regions than in arid regions. In hot arid regions the chemical processes take place only in the deeper horizons, where the soils are more moist. In the high latitude zone the frozen ground prevents the percolation of water through the soil, and soil-forming processes are reduced to a minimum.

Wind acts as an agent of erosion and also as a drying agent. In windy regions the soils dry out more rapidly than where there is quiet air; if the relative humidity is low, the effect is accentuated. Wind erosion is more rapid in arid regions, for there is no vegetation cover to hold the soil in place.

There exists a particular equilibrium between the soil and the life upon it. The differences in types of vegetation—grassland, woodland, and shrub—and in the rate and nature of decomposition of organic residue have a close correlation with the particular soil types that have developed. This was discussed in some detail in the chapter on types of climate.

Organic materials

Plant and animal life furnish the soil with organic matter and bring plant nutrients from the lower to the upper layers. While all soil contains organic matter, the amount varies with different types of soil and with different layers of soil. The roots of plants penetrate the soil, making it more or less porous. Some plant roots penetrate deeply and bring up water from lower depths; with this water there is always a certain amount of dissolved mineral material. The type of vegetation —grasses, or trees, and so forth—will determine the penetration, and thereby the effect on the substrata. As the plants die or drop their leaves, they furnish organic material to the soil. The organic material from grass or tree leaves is eaten by worms and mixed by them with the soil. The decay of forest debris causes the formation of organic acids and produces strongly acid soils in forested regions. Animals aid in soil formation in various ways. Animals feeding on plants leave their excreta, which transforms the soil on which it is left. Burrowing animals aid in soil formation by mixing the various layers of soil and adding fresh material to the upper layers. Earthworms are especially important in this process. Micro-organisms play an important role in

changing raw vegetable waste into organic matter for the soil. Putrefactive bacteria and various kinds of fungi cause the decay of dead material and aid in its incorporation into the soil as organic matter.

Slope

Slope is an influence in soil formation in its control of drainage, run-off, and erosion. Perfectly flat surfaces and uniformly permeable soils are unknown; rain water collects in depressions and penetrates some soils more than others. Soils on slopes are less well developed than those on more level surfaces, because of the increased erosion and the fact that plant life, because of less water, may not be so great, to aid in soil formation. Slopes which have greater precipitation or less evaporation will have more plant life and better soils than those where the amount of water is less. In many mountain regions it is possible to find a succession of soils similar to that found in going from the arid part of the Great Plains to humid forest soils of the Atlantic States.

Time

Time is necessary for the development of soils from parent materials. The length of time required for the formation of a given type of soil depends very largely on the other factors involved. One cannot make any useful statement in terms of years regarding the rate of soil formation in general. However, measured in years, all soils involve long periods of time in their development. Some soils have formed rapidly and others exceedingly slowly. There is no direct relationship between the age or maturity of soils and the age of the rocks underneath.

Characteristics of soils

Under the influence of the changing forces already discussed, soil is a complex substance, constantly undergoing change and never reaching a static condition. Soils began their history with the accumulation and exposure of finely divided, weathered rock materials. The next step, and often coincidental with the first, is the introduction of living organisms and the beginning of soil-forming processes. As the process develops, changes are brought about in the surface layers that will in time make those layers very different from the parent material. This changed portion, or *soil,* may vary in thickness from a mere film to several feet. The character and thickness of the soil formed depends

upon the intensity of the soil-forming processes, the time during which they have acted, and the resistance of the parent material to change.

At any stage of its history the soil may be wholly or partly removed by erosions, exposing the material beneath. Then the soil-forming process must begin anew on the material brought under its influence. While normal erosion may be beneficial, accelerated erosion is always destructive. Normal erosion is the removal of soil from the surface at the same rate as soil-forming processes penetrate downward, so that a constant depth of soil is maintained and new soil added.

Horizons

If a hole is dug in any well-drained soil, along the walls will be found a series of horizontal layers of soil of varying thicknesses. The layers are called *horizons,* and they differ in color, texture, and structure. The separate horizons of the soil profile are given letters *A, B,* and *C*. The *A* horizon includes the upper part of the profile and is that horizon in which life is most abundant and active. The larger part or all of the organic material is found in this horizon, and the plowed layer lies in the *A* horizon. The *B* horizon is marked by deeper colors and heavier texture in normal soils of humid regions. The *A* and *B* horizons constitute the true soil. The *C* horizon is the unconsolidated material below the true soil and is referred to as parent material.

Color

The color of soil is perhaps the most obvious characteristic. While in itself of minor importance, it often serves as an indicator of other soil conditions that are extremely important. In general, dark-colored to black soils are regarded as being the most productive. These darker colors are usually due to the high humus content. In general, red or reddish-brown soils are less fertile than dark ones, and they owe their color largely to compounds of iron. Yellow soils are due to hydrated iron oxides and have low inherent productiveness. Gray colors in soils may be due to lack of sufficient oxygen or to low contents of organic matter and iron.

Texture

The mineral particles of soil are classified according to size into three principal groups, which are called *sand, silt,* and *clay.* Varying proportions of different sizes of these particles determine our classes of soils, or what is known as *soil texture.* Texture influences plant growth through its effect on the physical condition of the soil and its influence on the supply of mineral elements.

Structure

While texture refers to the individual soil grains, *structure* refers to the arrangement of those grains within the soil mass. The individual grains are commonly held together in aggregates of different sizes and shapes, although soils do occur in which there is no structure. The structure of the soil horizons largely determines the ease with which plant roots can penetrate, the rates of absorption and movement of water, the tilth and mellowness at any time, and the resistance of the soil to erosion by wind and water. The maintenance of favorable structure in cultivated soils is just as important to the farmer as is the preservation of soil fertility.

Structure is the physical feature which is the most striking of the characteristics of soil. Soils with good structure form smooth crumbly beds and break down readily when plowed. If the structural particles are well developed and resistive to disintegration, they are classed among the best soils for growing crops. Such soils have good internal drainage, as the water penetrates the interstructural air spaces. On the other hand, heavy-textured soils of poor or imperfect structure are hard and refractory when dry, plastic when wet, and cloddy when turned in plowing. Their natural drainage is poor. Roots and air penetrate them with difficulty. The relationship of good structure to fertilization is of great significance. Infertile soils with favorable structure are favorable for plant growth. Soils with poor structure are unresponsive and cannot be made productive by the mere addition of proper fertilizers.

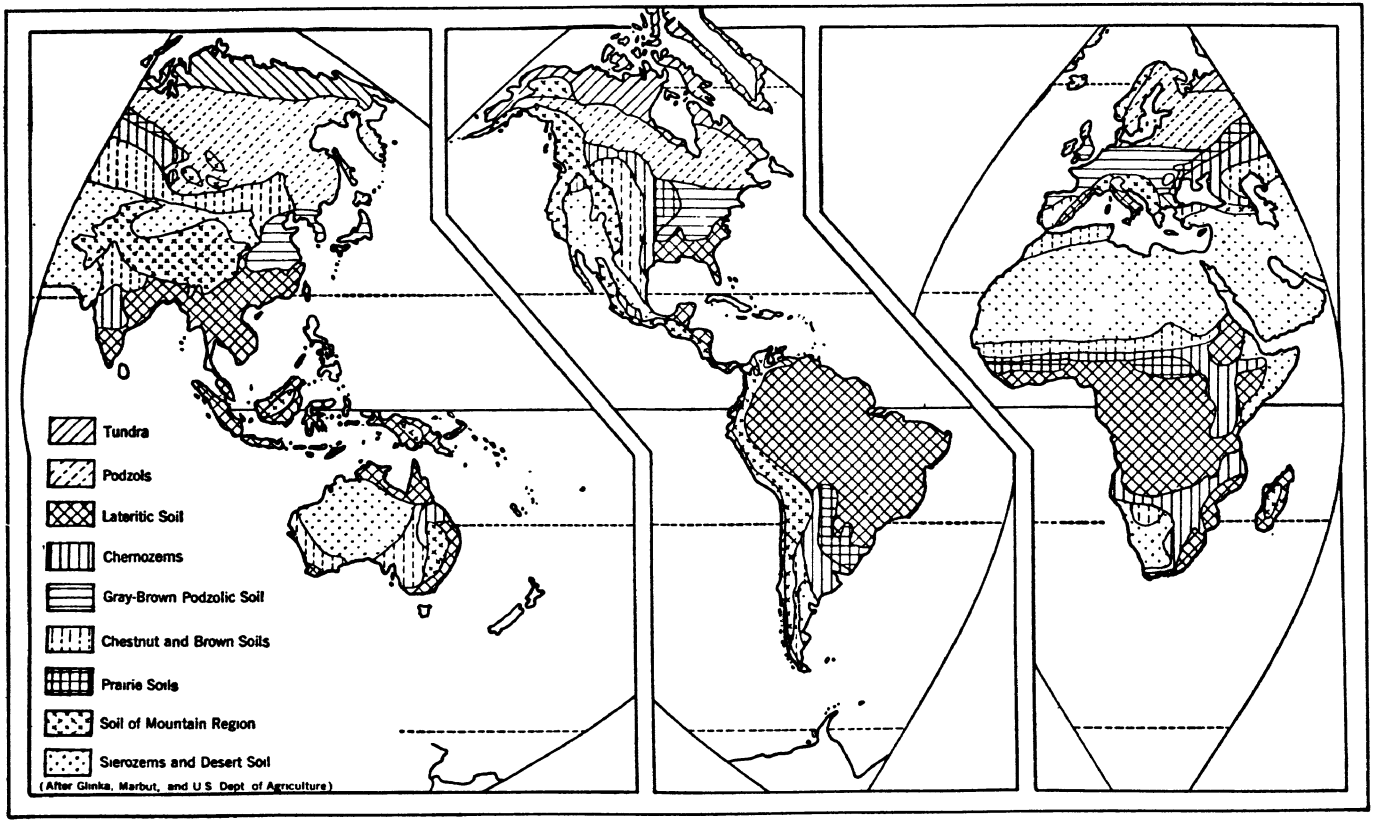


FIG. 107. SOIL MAP OF THE WORLD.

Soil classification

During the course of history, the human race has interested itself in the problem of agriculture, and slowly there has been built up a certain body of knowledge regarding it. Much of this knowledge was gained by direct observation and experience. From the concept that each soil had its individual character as a soil, and that it was the product of a particular environment, it has been possible to construct a system of soil classification in which different kinds of soil may be placed.

Curtis F. Marbut was for many years the chief of the Soil Survey Division in the United States Department of Agriculture. His researches in soil classification and geography laid the foundation for our modern concepts of soil. He classified soil types into two great groups which he called *Pedocals* and *Pedalfers*. These names were coined by combining the Greek word *pedo* (ground) with an abbreviation of the Latin word *calcis* or *calx* (lime) and with the abbreviations of the Latin words *alumen* and *ferrum* (aluminum and iron). Pedocals have accumulations of calcium in all or part of the soil profile. Pedalfers lack lime accumulation and usually have iron and aluminum compounds. C. F. Marbut showed the relationship of these soil groups to the climatic zones of the country. His general classification for the United States is given in the readings which follow this discussion. A map of the world with its chief types of soils is given, and the characteristics of those types are shown in tabular form below.

GENERAL CHARACTERISTICS OF SOILS AND THEIR ENVIRONS [1]

Soils	Profile	Native Vegetation	Climate	Natural Drainage	Productivity (Crop Plants)
Tundra	Dark-brown peaty layers over grayish horizons mottled with rust. Substrata of ever-frozen material.	Lichens, moss, flowering plants, and shrubs.	Frigid humid.	Poor	...
Podzol	A few inches of leaf mat and acid humus. A very thin dark-gray *A* horizon, a dark-brown *B* horizon. Strongly acid.	Coniferous or mixed coniferous and deciduous forest.	Cool temperate and humid.	Good	Unusually low. Medium under good practices.

[1] Adapted from *Agricultural Yearbook*, 1938, pp. 996–999. United States Department of Agriculture.

GENERAL CHARACTERISTICS OF SOILS AND THEIR ENVIRONS (*Cont.*)

Soils	Profile	Native Vegetation	Climate	Natural Drainage	Productivity (Crop Plants)
Gray-Brown	Thin leaf litter over mild humus over dark-colored surface soil 2 to 4 inches thick over grayish-brown leached horizon over heavy *B* horizon. Less acid than Podzols.	Mostly deciduous forest with mixture of conifers in places.	Temperate humid.	Good	Medium. High where well fertilized and managed.
Laterites	Red-brown surface soil. Red deep *B* horizon. Red parent material.	Tropical savanna vegetation.	Tropical wet-and-dry.	Good externally. Good or excessive internally.	Low. Medium to high with heavy irrigation and fertilization.
Prairie	Very dark brown or grayish-brown soil grading through brown to lighter colored parent material at depth 2 to 5 feet.	Tall-grass prairie.	Temperate humid.	Good	High
Chernozems	Black or very dark grayish-brown friable soil to a depth ranging up to 3 or 4 feet grading through lighter color to whitish lime accumulation.	Tall-and-mixed-grass prairie.	Temperate subhumid.	Good	Medium to high. High to very high where irrigated.
Chestnut	Dark-brown friable and platy soil with lime accumulation at a depth of 1 to 4 feet.	Mixed tall-and-grass prairie.	Temperate to cool. Semiarid.	Good to imperfect.	Medium. High where irrigated.
Sierozems	Pale grayish soil grading into calcareous material at a depth of 1 foot or less.	Desert plants, scattered short grass, and brush.	Temperate to cool. Arid.	Good to imperfect.	Medium to high if irrigated.

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Soils of the United States[1]

SOILS are the products of the environmental conditions under which they have developed or are developing. These conditions in turn are the products of geologic, topographic, physiographic, climatic, and biologic factors.

The range of differences in environmental conditions within the United States is wide. This is owing not only to the great area included, but also to the large number of possible combinations of environmental factors. Of the factors named, the climatic and biologic are active or dynamic and constitute the forces operating in any given spot in developing the soil. The others are passive and accelerate, retard, or modify in some other way the action of the dynamic factors. Any given association of environmental factors producing an environment would occupy, theoretically, only a point on the earth's surface, since in general each factor has a different strength of expression or a slight difference in character in different localities. In the practical consideration of environments as soil-building agents, however, a range in strength of expression or of character of each factor is accepted as a unit rather than a single absolute value. An association of these value-ranging units, producing an environment, will occupy an area rather than a point.

Although the number of possible environmental unit areas is large, many individual units extend over large areas. This is fortunate, since the expression of these conditions in terms of organic life and of that group of bodies, the soils, which are neither wholly organic nor wholly

[1] Adapted from C. F. Marbut, *Soils of the United States.* Atlas of American Agriculture, Part III. U. S. Department of Agriculture, Bureau of Chemistry and Soils. 1935.

inorganic, may therefore be studied over large areas. The occurrence of similar physical conditions over large areas facilitates the study of the relationship of these conditions to the character of the soils, plants, and animals existing and developing under their influences. The physical conditions in the United States offer unusual advantages for the study of the relation of organic life and of soils to the physical environment.

Notwithstanding this inviting condition, soils as such were not studied in the United States until about the beginning of the twentieth century. The study of soils refers to the study of the genesis, the morphology, the characteristics in general of soils in the situations in which they are developing or have developed, along with a study of their relation to the environment in which the development is taking place. Reference is not made to the collection of material from the soil without a study of its characteristics in place and the subjection of this material to various tests under controlled conditions in the laboratory.

History of soil unit definition and classification in the United States

When the work of differentiation of natural soils was begun in the United States, there were no established criteria to serve as a basis for doing it. All that had been done was to define in a very crude way certain units which were recognized, not as individual units but really as groups, and their definition was not based on their individual characteristics but on an assumed relation to other bodies. Broad soil units, recognized as groups subject to further separation into smaller units, had been established in eastern Europe many years before the beginning of the twentieth century, but western Europe and eastern North America had at that time no knowledge of the results. This work in the United States, therefore, necessarily started from the bottom, except as far as our knowledge of the geologic formations of the country supplied a temporary basis.

Prior to the beginning of the twentieth century and subsequent to the middle of the nineteenth century, the science of geology attained an advanced stage of development. Since the materials of soils lie on the surface of the earth and constitute part of its crust, and since they have been derived from geologic formations, it was but natural and

seemingly logical and reasonable to conclude that the characteristics of soils were determined by the characteristics of the rocks from which the soil material originated. No suggestion that the characteristics of soils were due to other agencies had received recognition in the United States. Such studies as had been made on the soil were of the chemistry of soil materials mainly, with little or no reference to the character of the soil as it occurs in nature.

The study of the genesis, morphology, and evolution of soils, made necessary over a wide area by the work of the Soil Survey, has shown that soils are to a much greater extent the product of those factors which influence and in a measure control the development of organic life, the physical environment taken as a whole, than of the single factor of the character of rock material from which the soils have developed. It has also been determined that the characteristics of the soil at any given time and in any given spot are of two kinds—those that may be defined as inherited and those that have been acquired. The quantitative relationship of the two differs from time to time. The inherited characteristics are those derived from the parent material or the geologic formation from which the material came, and they are dominant in the early stages of soil development. As the soil becomes older, these characteristics become less and less dominant through the development of acquired characteristics impressed on the soil by the dynamic soil-building factors. By the time a stage of development that may be defined as maturity has been attained, these acquired characteristics become entirely dominant. This conception is, for the United States, an entirely new one and has been developed, so far as the details and their application to particular soils are concerned, through soil investigation within the United States.

When soil investigation in the field, designated in this country usually by the expression, "soil survey investigations," was begun in the United States, the soil characteristic considered most important was the texture of the surface layer, and, in the earliest work, differentiations were made mainly on this basis. On the basis of his studies, Milton Whitney came to the conclusion that the adaptability of the soil for a given crop and the success with which a crop could be grown on any given soil were dependent primarily, if not exclusively, on its texture. Thus the use of the texture of the surface soil as a basis for defining soil units auto-

matically gave such units agricultural significance. The soil was thought of as a crop-producing body rather than as a natural body worthy of investigation to increase human knowledge, and its study was justified on the ground that the information furnished was valuable in the promotion of crops.

That the dominant reason for doing the work was practical rather than scientific is further shown by the limitation (during the first two decades) of the depth of soil examination to about three feet. This limitation was arbitrarily based on the idea that the average farm crop extended its roots into the soil to about that depth.

The first work was done in the summer of 1899. This work, and that of the following year or two, was entirely local in character. A number of soil units were identified and separated, but they were differentiated on the basis of texture mainly and with little reference to their interrelationships. Differentiation of soils on so simple a basis made any relationships among the several units equally simple and limited. While this simple definition prevailed in the central office in Washington, the men in the field in actual contact with soils soon discovered that characteristics other than the texture of the surface layer were important features.

The number of texture units in soils the use of which is practical or convenient is small, fifteen in all, and work in the field soon revealed the existence of many other soil characteristics seemingly as important as the texture of the surface horizon. Before much knowledge of these characteristics had accumulated, except for restricted areas mainly in the eastern part of the United States, there arose the concept of a group of soils which would include a wide range of textures, possibly all known textures, but whose characteristics other than texture of the surface horizon were uniform. Such a group was designated as a *soil series*.

As the work of the Soil Survey extended, experience was gained with soils over a wide range of territory and developed under a wide range of conditions. Gradually, as a result of this accumulated experience, the definition of soil series was modified, and by almost imperceptible stages became more and more pedologic and less and less geologic. It finally became based on soil characteristics entirely, not necessarily the characteristics of a mature soil and therefore pedological entirely; but,

in the case of young soils, where the soil itself is, to a considerable extent, a geological body, some geological characteristics were retained. The soil series became, therefore, a group of soil bodies essentially alike in all soil characteristics except the single characteristic of the texture of the surface horizon, which, in the original definition, referred to the plowed zone.

Apparently there was no intention, at the time, of constructing a classification similar to that of plants and animals in which the soil series would correspond to the genus and the texture to the species. Since then classification has developed into such a similarity to the extent that each soil unit, like each plant or animal, is described by two terms, one designating a group characteristic other than texture of the surface soil common to all the members, the other designating the texture of the surface layer. Similarly a plant is designated by a generic term connoting all its characteristics except one, which is called its "specific" characteristic.

The work during the first decade or more after inauguration of the Soil Survey gradually, and, it may be said, inevitably accumulated information about soil characteristics; yet, because of the predominance of the geological rather than the pedological point of view, attention was directed, even by field men, to the geology of the soil material rather than to the soil itself. The recognition of the soil as a body with entirely different chemical, physical, mechanical, biological, and morphological characteristics from the parent material beneath it did not become well established in the Bureau of Soils until the second decade of Soil Survey work was well begun.

The breaking up of a soil series into its various textural members has always been done for the purpose of giving the soil type a practical value. As the work has progressed, however, during the past years, the expression "texture of the surface soil," originally applying to the plowed layer, has gradually shifted to apply to the "texture of the *A* horizon."

The soil at a given spot with a given *A* horizon texture and with other characteristics designated as series characteristics constitutes a soil *type*.

All the soil types within a given area of country contain all the soil characteristics found within the soils of that area, and the differentiation

of the soils of a region into soil types, as shown on the detailed soil maps and described in the reports of the United States Soil Survey, cover all the characteristics of all the soils in that region possible of recognition by the stage of development of the science at the time the studies were carried on.

Soil Province. Soon after the series and type definitions had been rather well established, it became desirable to group soil series into larger groups, establishing thereby a classification scheme of more than two categories. An attempt was made to found it on a basis of distribution of soil series, rather than more accurately on the character and relationship of the series in the various groups. Such a category in the scheme of classification was called a *soil province* and was more or less unconsciously recognized as a grouping comparable to series grouping. Soil grouping must be done on the basis of soil characteristics only.

Mature soils are the product of their environment. In a region like the United States, environments, including not only the dynamic factors but also the conditions with which these factors must operate to produce soils, are uniform over large areas. Hence the soils produced under the influence of each of these environments, constituting members of a given category of soils when placed on a map, will each occupy the whole of such an area. Such a map may legitimately be called a "soil-province map."

The development of the classification up to the present time of the great soil groups is given in the following pages.

The Podzols

Podzols are dominant in the northern part of the Great Lakes region, east of the boundary between the pedalferic and pedocalic soils, and in sandy areas of New York, New England, New Jersey, and to a slight extent farther southward along the coast. Their general distribution is shown on the map (Figure 108). The main areas may be defined as those of the Great Lakes region, those of New England and northern New York, and those of New Jersey. Small areas lie in the Allegheny Plateau where the elevation is sufficient for a climate like that of the northern lake region or northern New England. These soils occupy regions of high rainfall and low temperature, as compared with the rest of the United States, or areas where the soil material consists mainly

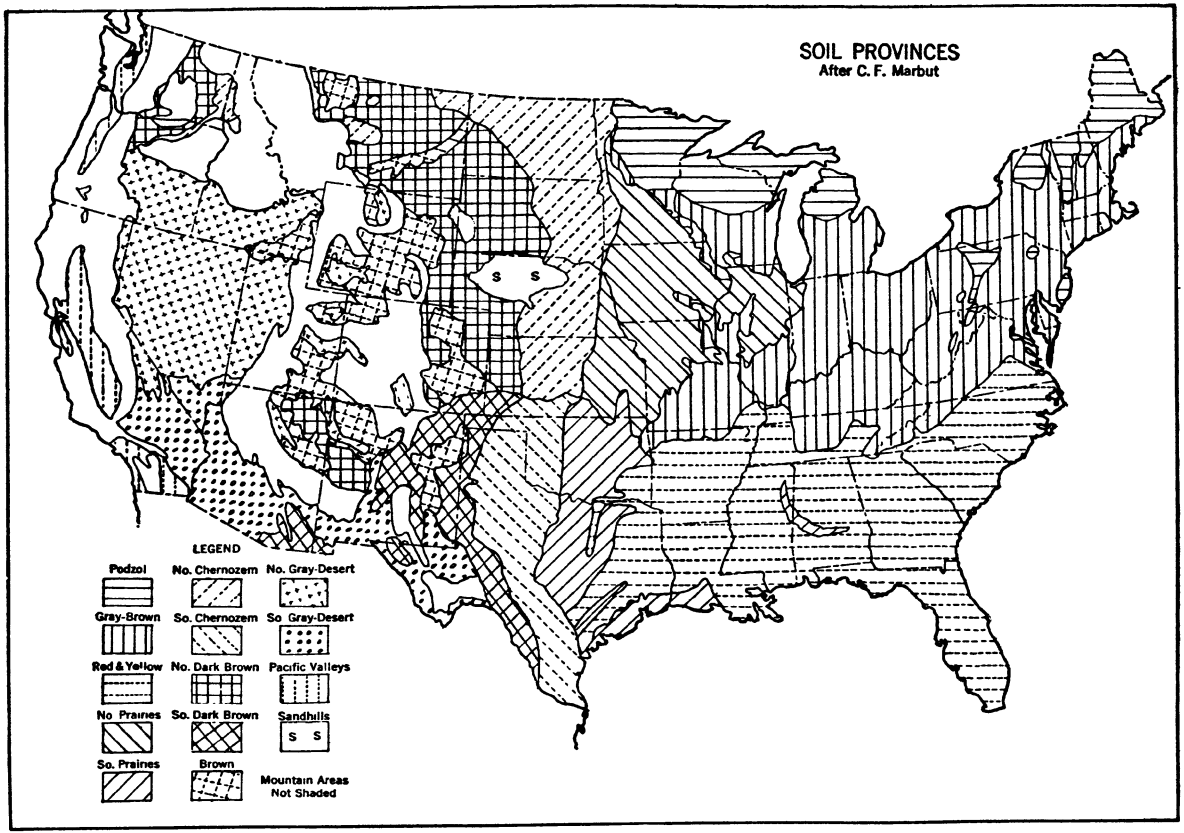


FIG. 108. SOIL PROVINCES OF THE UNITED STATES.

of sand, which is readily attacked by the forces of leaching. Because of the low temperature and high rainfall, the soils remain in a more moist condition throughout a greater part of the year than soils in any other part of the United States. Like all the groups of pedalferic soils, except the Prairie soils, the Podzols have developed under forest cover, but for the most part under a cover containing a somewhat larger percentage of conifers and of plants which flourish on acid soil than is the case with other members of the pedalferic group. Although the Red and Yellow soils in the southeastern part of the United States were covered with a vegetation consisting mainly of conifers, when the region was first visited by white men, they do not support an undergrowth of acid-loving vegetation similar to that on a large part of the area of the Podzols.

The dominant vegetation on the extremely developed Podzols of Europe, most of which are very sandy soils, consists of the common heath plant (Calluna vulgaris). That plant is not the characteristic Podzol plant in the United States or apparently anywhere in North America. The very sandy Podzols in the United States are covered with pine or hardwoods, with an undercover mainly of blueberry bushes (Vaccinium). The large area of sandy heaths, or *heide,* which covers large areas in northern Germany and Denmark, has no exact duplicate in this country or in North America.

In general the Podzol profile is as follows:

1. Covering the surface is a layer of accumulated organic matter consisting of leaves of forest trees and other forest debris ranging in thickness from an inch or two to a foot or, in extreme cases, even more.[2] This material is brown, only partly decayed, acid in reaction, and wholly without structure. In an extremely developed Podzol profile it overlies the mineral soil abruptly, there being a sharp boundary between the layer of organic material, or raw humus as it is called, and the mineral soil. In the United States, however, in most cases, the upper part of the mineral soil contains more or less partly decomposed matter. In an extreme profile, the raw humus layer will continue as

[2] It is doubtful whether a layer of organic matter as thick as a foot overlies any of the Podzols in the United States, since these soils occupy the southern part of the Podzol region on the North American Continent. Soils representing the extremes of podzolic development are not present in the United States, or they occur in small areas only. They seem to be better developed north of the international boundary, in Canada.

raw humus to the bottom of the layer, but in the United States there is generally a layer, immediately above the mineral soil, of somewhat better decomposed material.

2. The upper part of the mineral soil consists of a gray layer, the *bleicherde*. This may be gray or white from the top downward, or it may contain an admixture of organic matter in the upper part. The lower part is always gray, and it ranges in thickness from a mere film to a foot or more. It is structureless but may have a laminated arrangement. In chemical composition it has a high content of silica and a content of iron, alumina, alkalies, and alkaline earths lower than that in the horizon below. The upper part, with an admixture of organic matter, where such is present, is usually designated as the *A-1* horizon, and the lower part as the *A*-2 horizon.

The bleicherde is underlain by a brown, dark-brown, or coffee-brown horizon which may or may not be indurated. The induration usually varies with the texture, being highest in sandy material and less in clay. The brown, dark-brown, or coffee-brown color is more intense at the top of the horizon than below, the thickness of the deeply colored layer varying from a mere film to several inches. The material gradually becomes lighter in color with depth, grading through rich brown and yellowish brown, and finally passing into the underlying parent geologic material, whatever that may be. This horizon, or layer, is designated as the *B* horizon and is a zone of enrichment, including organic matter, hydrated iron oxide, compounds of alumina, and occasionally some of the alkalies and alkaline earths. The enrichment in any given case does not necessarily consist of all these constituents, but may consist of hydrated iron oxide in one case, compounds of alumina in another, and organic matter in another, though usually where the enrichment involves a great deal of organic matter, it also involves a great deal of alumina. Where the enrichment consists mainly of iron oxide, the alumina may or may not be important. The material is usually structureless and has an acid reaction.

The Gray-Brown Podzolic soils

The Gray-Brown Podzolic soils are those in which the podzolic process has been the dominant one in development. In these soils, as in the true Podzols, the process is primarily one of leaching, which

develops eventually an acid reaction in the soil and a *solum* in which readily soluble salts and a considerable percentage of the bases (alkalies and alkaline earths) have been removed. The profile is not identical with that of the Podzols, but the difference is one due to the degree of the operation of the podzolic process mainly. But recent work by Anderson and Byers has confirmed a former brief statement by Gedroiz that in the Podzols a breaking up of the silicates by soil-developing processes has taken place. No such silicate decomposition has been shown to have taken place in the Gray-Brown Podzolic soils region. The virgin profile in no case includes a thick layer of raw humus. There is always an accumulation of organic matter on the surface, but it rarely amounts, in the United States at least, to more than an inch or two and is better decomposed than is the true raw humus overlying the well-developed Podzols. It is apparent that in the United States this humus rarely becomes completely decomposed. It is not usually thoroughly decomposed into black granular colloidal material but is somewhat more closely related to raw humus in its inherent characteristics. The bleicherde, or *A-2* horizon, is not white or light gray as in the Podzols but is grayish brown or pale yellow and is usually not so thoroughly eluviated. A thin layer, impregnated with organic matter (horizon *A-1*), constituting the upper part of the mineral soil is thicker than the corresponding layer in the Podzols, and it may have a faintly developed granular structure. The rest of the *A* horizon is structureless but has a laminated arrangement in the undisturbed soil.

The *B* horizon is heavier in texture than horizon *A*, with an apparent accumulation of iron oxide and alumina but none of organic matter. In no case in the United States has the *B* horizon been indurated to a hardpan. It is apparent that in this country we have no humous Podzols, such as are described by Frosterus, or, if so, they have a limited distribution in the neighborhood of swamps and lakes in the Podzol region. The true Podzols of the United States are well-drained soils in which iron oxides, alumina, and organic matter are present in higher percentages in horizon *B* than in *A* or *C*, whereas in the Gray-Brown Podzolic soils iron oxide and alumina have been involved in apparent accumulation only in the *B* horizon.

The Gray-Brown Podzolic soils are defined on the basis of soil characteristics only and without reference to geographic distribution, yet they

occupy a well-defined region of the United States, one much larger than that occupied by the Podzols. The region includes the mid-latitude belt of the United States extending from the Atlantic coast westward to the prairies in western Indiana, with a narrow tongue extending northwestward across Wisconsin into Minnesota, and another stretching across western Kentucky and Tennessee into the Ozark region of southern Missouri. A great many small areas, originally covered with forest, scattered through the prairie region of the Middle West, always in areas of uneven relief, are covered by members of this group also. The northern boundary is also the southern boundary of the Podzol region, but, as in nature generally, no sharp boundary line exists. The true boundary is a zone of gradation in which, from north to south, the dominant Podzols become the dominant Gray-Brown Podzolic soils. On its south side the region is bounded by the common boundary between it and the Red and Yellow soils. This line runs, in general, from the mouth of Chesapeake Bay southwestward across the Appalachian region in western North Carolina, across Tennessee and the Ozark region, and thence curves northward with the eastern boundary of the prairies to northwestern Minnesota.

This area was occupied, before it was cleared for agricultural use, by deciduous forest, with practically no admixture of conifers. The precipitation is essentially the same as in the Podzol region.

The environmental conditions prevailing in the Podzol and the Gray-Brown Podzolic regions are not widely different. In both, the rainfall is high, ranging from 30 to 40 inches; both were forested, the former with conifers and deciduous species, the latter with deciduous species, mainly oak. The prevailing temperatures are considerably higher in the Gray-Brown Podzolic region than in the Podzol region. This is probably the most important difference between them. The higher temperatures have operated directly as a soil-developing factor and indirectly through their influence on air humidity and evaporation. The existence of the Podzol profile beneath deciduous forests and the presumption that it developed under temperature influence suggests that the difference of forest character has not been all powerful. The same kinds of parent materials occur in both regions, but the Podzol profile, as shown by its occurrence in full development in New Jersey and Maryland, extends farther southward into the general region of

the Gray-Brown Podzolic profile. The difference is in the extent of development of a single process.

The average summer temperature in a belt running across the central part of the Podzol region in the United States is about 65° F., and the average winter temperature is about 15°. The average summer temperature across the central part of the area of Gray-Brown Podzolic soils is about 73°, and the average winter temperature is about 32°, except east of the Appalachians, where it is about 35°.

In addition to the main region, already described, in which the Gray-Brown Podzolic soils are dominant, and the smaller areas within the prairies, large areas of soils in the Pacific northwest seem to belong to the group. Smaller and less continuous areas lie in the Rocky Mountain region. In all parts of the West and Northwest the soils, although belonging apparently to this and the next group to be described, are not identical with their eastern relatives. In general the degree of podzolization, measured by the development of a light-colored *A* horizon, is not so complete. The *A* horizons are brown rather than decidedly gray or yellow as in the East, and the *B* horizon is not so well marked. These soils seem to belong, in stage of podzolic development, nearer to the stage occupied by the Brown soils of Ramann than do the true Gray-Brown Podzolic soils. The Brown soils, among students who have given most attention to them, are not defined as still in a stage of practically complete saturation by bases. They have developed under forest cover but have not yet been podzolized, or, if so, at least very faintly. The soils of the Northwest seem to have passed the podzolized stage but have not yet reached that occupied by the Gray-Brown Podzolic soils.

Red and Yellow soils

The southeastern part of the United States is occupied by a group of soils covering about the same number of square miles as the Gray-Brown Podzolic soils. They are designated here as Red and Yellow soils. The color of the dominant mature soils of the region is red or reddish, but yellowish soils cover large areas. These, however, seem to differ in color from the dominant soils because of local rather than regional conditions, so that the regional profile color is red. It is not yet known, however, whether the red color of the soil is permanent or

merely an expression of relative youth or early maturity. Whatever may be the reason for the red color and whether the red is permanent or temporary, the fact is that the most abundant maturely developed soils of the region at the present time are red or reddish. The red or reddish soils occupy regions where drainage is good and where the water table lies many feet below the surface. Yellow soils occur predominantly on smooth relief, where ground water stands at a depth of a few feet, usually immediately below the *solum,* or has stood at that position until a very recent geological date. Yellow soils also occur locally in situations where the ground water lies far below the solum, but such soils are dominantly if not exclusively derived from sandy material, usually sands or loamy sands. The dominant Yellow soils throughout the region are sandy but not sands, and there are large areas of sandy materials which have developed into reddish and red soils. The grouping of the soils into Red and Yellow cannot be done entirely on the basis of the texture of the parent materials.

Although these soils are designated as "red," or "reddish," and although that color characterizes the greater part of the total thickness of the soil layer, in the fully or maturely developed soil the surface layer is invariably yellowish or grayish. Where the red color extends to the surface, the soil is either immature or the light-colored surface horizon has been removed. This removal has taken place over large areas.

On the basis of existing knowledge, which is by no means complete and decisive, the boundary between the region occupied by the Red and Yellow soils and that occupied by the Gray-Brown Podzolic soils extends from the mouth of Chesapeake Bay westward and southwestward through Virginia, across western North Carolina, gradually rising southward into the Blue Ridge in southern North Carolina, thence westward to the valley of east Tennessee, northward along the eastern side of the valley to the northern part of the state, westward and southward, as shown on the map (Figure 108), into east-central Texas, and southward into the Gulf. The region includes all or parts of the Southeastern States, Louisiana, southern Arkansas, and the western part of Texas.

In this region the soils have developed under a cover partly of conifers and partly of deciduous trees, mainly oak. In the sandy part of the

region, pine is dominant. In that part where the soil is derived from less sandy material, oak constitutes an important element in the forest vegetation, but pine is present. The rainfall is high, ranging from 30 to nearly 60 inches a year, and the average summer temperature ranges from about 75° F. in the eastern part of the region to 80° in the western part. The average winter temperature ranges from 40° around Chesapeake Bay to about 47° in eastern Texas.

The Red and Yellow soils differ from those of the Gray-Brown Podzolic group not only in their dominant red or yellow color, but also in a lower percentage of alkalies and alkaline earths and of silicate silica and in a higher percentage, where textures are comparable, of iron and alumina. They differ also in the more thorough eluviation of the profiles of Red and Yellow soils and a wider difference of textures between the *A* and *B* horizons. This textural difference is especially true of those soils derived from rocks containing a considerable quantity of sand, and such rocks are more abundant in the region of the Red and Yellow soils than in that of Gray-Brown Podzolic soils. The more thorough leaching and eluviation of these soils expresses in part the results of a higher rainfall and in part the results of prevailing higher temperatures. As the prevailing temperature is higher than in the Gray-Brown Podzolic soils, the same amount of percolating water will be more effective in the decomposition of soil minerals and in the leaching of the constituents, especially of the bases and silica, than where the temperature is lower. The more extensive eluviation and the much wider occurrence of soils derived from sandy material in the Southeastern States become readily explainable. The color is an expression of the relatively high temperatures and possibly of the effect of long summers, the latter parts of which are dry.

In general the region may be divided into two parts on the basis of the character of the parent material from which the soils are developing. One of these regions is of the dominant sandy material, and the other of heavier materials, although sandy materials are not entirely lacking. In geologic age the sandy material is young, the other old. The sandy material consists of unconsolidated sands and clays, mainly of tertiary age, constituting what is known as the *coastal plain.* The other differs widely in age but is predominantly Paleozoic and older.

The older rocks range from crystalline gneisses and schists to limestones, shales, and sandstones. The regions with old rocks are known as the piedmont plateau and the Appalachian regions.

The Prairie soils

The soils of the prairies of the United States have been separated into a group comparable to the Gray-Brown Podzolic and the other great soil groups. Whether these soils will finally be recognized as such a group is not yet known. The soils are so entirely different from those of any of the other great groups that, for the present, it seems very unwise to attempt to include them. The area in which Prairie soils are shown on the soil map is defined not on the basis of the character of the soils. While the extent coincides, on the north, east, and south, with the grassland boundary, on the west grassland extends far beyond what is recognized as the Prairie boundary. The Prairie soils are grassland soils, but were developed under a high rainfall. In this respect they seem to be unique, not occurring elsewhere in the world, except possibly in small areas.

East of the general boundary of the Prairie soils, small areas of similar soils occur; they also were developed under grass cover. These areas are scattered here and there, through Michigan, Indiana, and Ohio, and apparently also in Kentucky. In detailed mapping they have been differentiated from the normal soils of the Gray-Brown Podzolic groups surrounding them. They are all degraded and are approaching in character the normal podzolic soils surrounding them. On Figure 108 they are not shown separately because of the small area covered by each of them.

The general distribution of the soils included in this group is shown on the map. As for the other areas on this map, the boundaries are those of the region throughout which well-developed soils having the characteristics of the group occupy important areas, though they are not necessarily dominant. Within the area designated as that of the Prairie soils a rather large proportional part is occupied by soils whose characteristics are different from those typical of the group. It is probable that the proportion of such soils is greater in the Prairie region than in any other group, because the fundamental characteristics of

the typical Prairie soils are entirely different from those of any of the groups described on the preceding pages.

Typical Prairie soils are not podzolic, but soils of all the groups previously discussed are podzolic. Although development seems to have taken place under the influence of a rainfall high enough to have podzolized them, Prairie soils do not have the podzolic profile. The surface horizon of the somewhat theoretically typical Prairie soil has not been leached of its bases to such an extent as to make it acid in reaction, deflocculate its colloids, or produce an eluviated horizon.

The typical Prairie soil profile has a very dark brown or black surface horizon, or layer, the blackness being caused by the presence of much organic matter. The structure is granular, with rather fine grains. This layer is underlain by a brown horizon which is little if any heavier in texture than the surface horizon but differs in the brown color and in having a much lower percentage of organic matter. Upon exposure, the material in this layer usually falls, in the upper part, into rather large roundish grains, and in the lower part into angular particles ranging up to about half an inch in diameter, larger than the round granules. This layer, in turn, is underlain by parent material ranging widely in character.

The profile just described is the ideal and somewhat theoretical profile. Over most of the area the soil is less dark than the typical soil and is slightly acid at the surface; the colloids in the surface are slightly deflocculated, and very slight eluviation has taken place. The soil is in the earliest stages of podzolic development. In soil survey work a soil in the prairies is accepted as a member of the Prairie group if the surface horizon has a well-defined dark color and is eight or more inches thick. Most of the Prairie soils are slightly degraded.

Considerable areas of Gray-Brown Podzolic soils occur in the northern part and of Red and Yellow soils in the southern part of the prairie region. So far as is now known, the Prairie soils are the original soils within the region. Either the Gray-Brown Podzolic soils have been developed in recent geological time in areas where original Prairie soils have been changed, or new soil has developed in places where Prairie soils have been removed by erosion, the new soils not being Prairie soils. Prairie soils occupy the smooth uplands, which have not yet been

thoroughly dissected, while the streams within the area are bordered by belts, varying in width approximately according to the size of the streams, in which Gray-Brown Podzolic soils occur.

It is generally considered by botanists that the prairie region is potentially a forest region. By that is meant that this region would have been occupied by forest except for what may be considered an accident. The persistence of grass vegetation through a long period of time is considered to be the result of an accident and is not an expression of the natural environment of the region.

The light-colored Gray-Brown Podzolic soils lying within the belts along the streams of the region are soils which have a more complete adjustment to the climatic conditions of the region than the Prairie soils. However, the climate is only one of the dynamic factors which develop soils, natural vegetation being another and apparently a very strong one. Since the character of the Prairie soils seems to have been determined by the grass vegetation, it is apparent that these soils may be considered not as without normal development, but as an expression of the operation of both the dynamic factors of soil development in which the particular combination of forces has been somewhat unusual. They are the product of an association of natural grassland with a humid climate. The usual association is with a semiarid climate. In this case the natural vegetation has, up to the present time, overcome the normal effect of the climate. It has proved to be, so far, the stronger factor.

In the forested areas along the streams where Gray-Brown Podzolic soils have developed, the two dynamic factors have operated in harmony to produce the Gray-Brown Podzolic soils; or, if not, the influence of the prevailing forest vegetation has been relatively less effective than the grass vegetation in the Prairie soils.

Since the grass in this region is not what botanists call *climax* vegetation, its presence must be described as accidental. It is not necessary to discuss the reason for this, as it is an ecological matter.

The Pedocals

The soils described up to this point have belonged to the Pedalfers, one of the two great soil groups into which all soils of the United States have been divided. The two groups may be approximately designated

as humid soils (the Pedalfers) and subhumid and arid soils (the Pedocals). The terms "humid," "subhumid," and "arid," when applied to soils, are merely general designations without significance in scientific soil nomenclature. They are climatic terms that have been used in soil literature for many years merely as general terms, without exact meaning, before pedological terms had come into use.

The respective areas of distribution of the soils of these two groups in that part of the United States east of the Rocky Mountains are essentially continuous. Within the Pedalfer area all the soils are either maturely developed Pedalfer; young soils whose characteristics are still imperfectly developed but insofar as they have developed are Pedalfer; or soils in a still more primitive stage where, owing to local conditions, the normal course of Pedalfer development has not yet begun, but which, because of their association in identical environment with mature Pedalfers, cannot be considered as any other than potential Pedalfers.

Within the Pedocal area the same statement is true in general and practically in detail. The only area of Pedalfer soils within the Great Plains area of Pedocal soils consists of the Black Hills. In addition to the Great Plains area of Pedocals, another large, approximately continuous area (but less continuous than the preceding) is the Great Basin, lying between the western foot of the Rocky Mountain belt, taken as a whole, and the eastern foot of the Pacific ranges. Within the Rocky Mountain and Pacific range belts both groups of soils occur in a great many areas varying widely in size. The higher lying areas throughout the region are Pedalfers. In the Pacific northwest, in the Pacific coast ranges, and in the northern part of the Rocky Mountain belt considerable areas of Pedalfers lie at moderate elevations. Elsewhere the lower areas are mainly covered by Pedocals.

It is well known, of course, that climate has been an important factor in the determination of the characteristics of the soils of this great group, the natural vegetation being the other of the two great dynamic factors, but the soils have not been differentiated on the theoretical basis of having been developed by factors of any kind but on the basis of actual characteristics.

The basis of differentiation of the two great groups is the presence in the Pedocals of a zone of carbonate accumulation and its absence in the

Pedalfers. Since this zone is one of accumulation and is therefore a product of development, it is evident that it cannot exist in the soil until at least a considerable advance in stage of development has been attained. The differentiation, therefore, of the soils of the United States into these two great groups is based entirely on the characteristics of the mature soils and not of the undeveloped or immature soils. Immature soils associated with the mature soils will in time develop the characteristics of mature soils. They are grouped therefore with the soils which contain the characteristics toward which they are developing.

The Pedocals have been differentiated into four subgroups designated as the Chernozem, Dark-Brown, Brown, and Gray groups, according to the color of the surface layer to a depth ranging from 6 to 15 inches. The soils of each group occupy a series of north-south belts succeeding each other from east to west, the first two extending practically unbroken from the northern to the southern boundaries of the United States. The other two occupy less continuous belts.

It will be remembered that the soils of the several groups of Pedalfers, Podzols, Gray-Brown Podzolic, and others occupy ill-defined east-west belts.

The soils of the Pedocal groups range in color from black to gray, the subgroup with blackest soils occupying the most easterly belt, that with the gray soils the most westerly. The two other subgroups occupy intermediate positions and have soils of intermediate colors. The soils of any given belt are lighter in color than those of any belt east of it and darker than those of any belt west of it. The darkness of the soils is an expression of the density of grass cover under which they developed. Other things being equal, the density is the result of rainfall, the higher rainfall supporting the most dense grass cover, the lowest the least. The Pedocal groups are distributed, therefore, in belts which correspond to the distribution of belts of rainfall, the westwardly decreasing soil color coinciding with westwardly decreasing rainfall. Each belt may be broken up into two stretches, a northern and a southern, corresponding to differences in temperature.

The Chernozems

The most easterly of the Pedocal belts is that of the Chernozems, a modified form of a Russian word meaning "black earth." This is the

belt containing the darkest colored soils. Westward, even within the belt and also beyond it, the soils become gradually lighter in color than along the eastern margin, corresponding to differences in rainfall and also, as a mere matter of observation, to differences in density of grass growth. All of these dark colored soils, though not all of the Pedocals, are grassland soils, and, as is the case with the Prairie soils, their dark color is caused by the accumulation of organic matter through the growth and decay of grasses. The grasses of the United States are grouped into two great groups known as tall grasses and short grasses. The Prairie soils lie wholly within the tall grass region. The greater part also of the Chernozem belt is in the tall grass region, though the short grasses become dominant in the extreme western part of the belt, especially in Kansas and Texas, whereas the tall grasses, though of different species from those in the prairies, extend over practically all the belt in the Dakotas.

All the belts of great soil groups of the Pedocals extend northward from the United States into Canada, and it is apparent that most of them extend southward into Mexico. Practically nothing, however, is known of their extension in the latter country. In the United States they occupy belts which extend almost due north and south, but in the Canadian northwest they assume a northwest-southeast course. The first and second Pedocal belts are broken into two parts, a northern and a southern, and, in addition to this, the Chernozem belt is interrupted by the sand hills of Nebraska.

The Dark-Brown and Brown soils

The soils of a belt lying immediately west of the Chernozem belt constitute the Dark-Brown soils.

The belt of Dark-Brown soils includes the eastern part of the Great Plains west of the western boundary of the Chernozem belt. On account of the gradual decrease westward of the dark color of the soil, considerable areas of the Great Plains are occupied by soils of the Pedocal group too light in color to be included in the Dark-Brown soils. Theoretically these lighter soils should occupy a continuous belt, stretching, like the Dark-Brown soils, from north to south entirely across the country, and it is easily possible to establish such a belt. On the soil map, however, the belt of Dark-Brown soils extends westward

to the mountains, except for a few large areas, notwithstanding the well-known fact that the color of the soils in the western part of the belt is lighter than that in the eastern part.

In a narrow belt lying along the mountain front, except in those places where the mountains are low, and extending eastward a few miles, usually less than 10, the soils are darker than farther eastward; in some cases, especially in Montana, they are black. This belt is too narrow to be shown on the soil map and is included, therefore, in the belt of Dark-Brown soils.

In a large area of the Great Plains of Montana, with the town of Shelby occupying approximately the center, the soils are brown. This is an area in which the rainfall is low, amounting to only about 14 inches, and the grass cover has not been sufficiently dense to give the soil a dark-brown color. The zone of carbonate accumulation lies at less depth, usually very little more than a foot, than in the Dark-Brown belt.

Another large area of Brown soils lies along South Platte River in Colorado, a third along Arkansas River in southern Colorado, and a fourth in New Mexico and in the Trans-Pecos country of Texas.

Within the Rocky Mountain belt, most of which is shown on the map as rough land, there are many areas typical of all the great soil groups found in the Great Plains and eastward to the Atlantic. Many of these are shown on the soil map with approximate accuracy as to general location.

The Gray soils

Because of the fact that the Gray soils, except in the small areas where irrigation is possible, are practically nonagricultural, little work has been done on them. A few areas have been mapped in the western part of the desert in California, in the eastern part of Utah, small areas in Arizona and New Mexico, and a considerable area in western Idaho. Some work has been done in central Washington and central Oregon. The soils placed, tentatively at least, in the Gray group, or, in Russian terminology, the Gray Desert soils, occupy the Great Basin region extending from the foot of the Wasatch Range in Utah to the Sierra Nevadas. They extend northward into Washington, but their extension into Canada has not yet been demonstrated. The greater part of

north-central Washington is occupied by low mountains in which the rainfall is a little too high for the development of Desert soils. For all practical purposes, the northern boundary of the large area of Desert soils may be considered the Columbia River in Washington.

Southward from the great Nevada-Utah area of the Great Basin these soils extend to the Mexican boundary and thence east through southern Arizona and New Mexico into southwestern Texas, the main body being interrupted by mountains a few miles east of El Paso. Other small isolated areas occur in intermountain basins in the Trans-Pecos region of Texas. Three areas occur in western Wyoming, one west of the Big Horn Mountains, one north, and another northeast of the Uinta Mountains.

That part of the Great Basin region extending approximately from the northern boundary of Nevada southward or southeastward as far as the Desert soils are known to occur consists topographically of a series of isolated, short, north-south mountain ranges separated by long alluvial fans stretching from the mountains outward, the fans from adjacent ranges meeting along the axial line of the lowland belt separating the mountains. In places where the fans do not actually meet along the axial line of the lowland, they are separated along this line by a flat area which is usually subject to flooding and known as a *playa.* The playas constitute, however, a very unimportant part of the whole region. The mountains are either entirely bare or are covered with a very thin cover of brush, except for a few ranges much higher than the average on which open forests are growing on podzolic but immature soils. The mountains, as a rule, contain no soils or an extremely thin layer of soil, much thinner than is present in the Rocky Mountain region.

Practically all the soils of the region, except narrow belts of river alluvium, lie on the alluvial fans and playas and have developed or are developing from the materials of which the fans and playas are composed. The alluvial fans are in process of development, but deposition of material from which they develop does not take place over the whole surface of the fan at any one time. The streams which carry material from the mountains, during the occasional desert thunderstorms, onto the alluvial fans, shift from time to time and eventually distribute the material over the whole fan. In some part of every fan, therefore, the

material is now accumulating or has accumulated so recently that no soil profile development has taken place. In other parts of the fans, accumulation took place a long time ago.

Almost all the Desert soils, aside from color, have closely similar profiles. They differ, of course, in texture and in those characteristics which express the character of the parent material.

The typical desert profile consists of a desert pavement at the surface. The pavement is a layer of gravel and small stones, lying practically bare and kept bare of fine material by the wind. It usually forms a rather firm crust capable of bearing some weight, but in most places not sufficiently strong to bear the weight of a man. When one walks over it, the crust breaks and the gravel forming it sinks half an inch or more, making a well-defined track in the pavement. The gravels of the pavement are embedded in a gray, almost white, fine-grained material which is usually extremely porous or vesicular. When removed, however, the material is so delicate that it falls to pieces easily in the hand. This material lies in the lower part of the desert pavement and extends downward for an inch or two. It constitutes the material into which the pavement is pressed when trod upon. It contains within it some gravel materials also. This layer is underlain by a firm structureless brown or reddish-brown layer, forming the important part of the soil, the horizon in which lie most of the plant roots. This layer ranges from five to eight inches in thickness and may contain some pores and in extreme cases may be firmly cemented. It is underlain by the zone of calcium-carbonate accumulation when the soil is well developed or by alluvial-fan material if immature. Locally the zone of carbonate accumulation is indurated, especially on the old fans around the mountain bases and in the neighborhood of river bluffs. The material is usually reddish below the carbonate zone except in northern areas. The character of the alluvial-fan deposits depends on the character of the rocks in the mountains and the strength of the currents depositing them. The third horizon is reddish brown, and the parent material also is reddish brown.

Soils of the Pacific coast

As has been given above, the distribution of soils exists because of the corresponding distribution of the dynamic factors producing the soils of the great groups. When we come to the Pacific coast, however,

the dynamic factors of climate and natural vegetation are not distributed uniformly over large areas because of the rapid changes in relief from place to place. All gradations or combinations of climate and natural vegetation occur within a comparatively short distance. The Pacific coast region is mountainous, and within any mountainous region conditions differ widely within short distances. All the great soil groups which occur in the eastern part of the United States occur also in the Pacific coast region, but in no case do these great groups occur in such large areas as to make it possible to show their distribution in the soil province map. The Pacific coast region constitutes a region of its own, one may almost say a world of its own, and it is more convenient to discuss it as a separate geographic region than to discuss its soils as members of the great soil groups.

Physiographically the Pacific coast region consists of two mountain ranges with a lowland belt between. Each feature extends more or less continuously from Mexico across the United States and into Canada. The Coast Range lies between the lowland belt and the Pacific coast; the Sierra-Cascade Range between the lowland belt and the Great Basin. The soils within the two mountain ranges consist to a considerable extent of freshly disintegrated material, differing widely from place to place according to the character of the underlying rock. Since soil studies have not been carried on in the mountainous region east of the lowland, nothing is known of the general character of its soils except that they are similar to the soils of the Rocky Mountain region and also to those of the humid region of the eastern part of the United States. Such development as has taken place, considered as a whole, is similar to that going on in the Pedalfers. The mountain ranges, however, for which soil mapping has not differentiated the soils, are shown on the soil map as rough, stony land. The soils which have so far been defined, identified, and mapped in this region lie mainly within the lowland belt, but considerable areas lie within the Coast Range and some on the western slope of the Sierras.

The northern end of the Pacific coast lowland consists of the low hilly region around Puget Sound. In the soil mapping, done several years ago in this end of the lowland, a number of soil series were differentiated. All of these soils, however, belong to the Pedalfer group. They are Brown soils, and they constitute faintly podzolized members of the Gray-Brown Podzolic group.

In the vicinity of Puget Sound the soil material has been accumulated by glacial processes. It has developed under a dense forest cover, and although a great deal of organic matter is dropped to the soil from the trees, none of the soils has developed the Podzol profile except locally in the highest parts of the mountains. The organic-matter layer is thin, except where masses of decaying tree trunks and woody materials have accumulated, but much of it is made up of material from conifers, mainly fir. In few places is this layer more than two or three inches thick, and it is not underlain by a bleicherde, or gray layer. The *A* horizon of the mineral soils is brown, not so light in color as is the corresponding horizon in the Gray-Brown Podzolic soils. The *B* horizon is a little heavier and somewhat lighter brown than the *A* horizon, eluviation not being noticeably developed. This layer, in turn, is underlain by the parent glacial material derived from crystalline metamorphic and volcanic rocks, mainly the latter.

The Coast Range in Oregon, Washington, and northern California contains considerable areas underlain by soft brown sandstone. This sandstone, with its associated shales, occurs also in the interior lowland belt, especially in the Willamette Valley in Oregon. In the latter region the soils developed from material accumulated by the decay of this sandstone are similar in general characteristics to the Everett soils, but differ from the Everett in their darker color. The soils immediately along the Pacific coast developed under a dense forest cover and therefore are somewhat different from the soils in the other lowland regions of the Pacific Northwest. In the Willamette Valley the soils have a distinct dark color, owing to their development under an open forest in which a grass cover was present. They are characterized by rather dark brown surface soils very slightly podzolized, with yellowish-brown, somewhat heavier, subsoils.

The soils on the west side of Sacramento Valley, south of Willow, consist mainly of young alluvium derived from the eastern part of the Coast Range, where the rainfall is relatively high and where the material is moderately well leached. Being young, they have not lain in place long enough to develop a profile characteristic of the region in which the material has been laid down. Practically all the development that has taken place is the accumulation of some organic matter. They are brown soils without soil profile.

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Rivers

A RIVER is more than an amenity, it is a treasure," said Justice Holmes in the Delaware water case. In the United States, as in every country of the world, rivers have played an important role in the history of their particular country and continent. Their part has varied with the other conditions of the region, but always they have been of incalculable value in the national wealth.

The rivers of America have been highways of exploration and settlement. The city of New York at the mouth of the Hudson was the terminus for traffic up and down the river, and for the trade area to the north. The Erie Canal was but a short cut for the route from Manhattan to the Great Lakes. The rivers of New England, though not navigable rivers, were an important source of power for the mills which soon were established along their courses. The St. Lawrence River was the imperial highway which sustained the old French empire in North America. The rivers to the south—the Shenandoah, the James, the Savannah, the Chattahoochee, the Alabama, and others—had been used by the Indians and were means of ingress by the first settlers. The Mississippi River, draining the interior of the continent, was one of the chief reasons for visioning the Louisiana Purchase. Traders and settlers used the Mississippi and its tributaries, first to the east and then to the west, and saw the possibilities of forming the entire drainage system into one nation. The Colorado for many years was merely an obstacle to westward migration. Now it is making possible settlement in much of the area through which it flows. Rivers were the attraction for the early development of California; they were used first by the gold miners and later by the farmers for irrigation.

The Columbia tributaries were the route of migration in the Northwest and later the source of water for irrigation and power.

While it may be possible in law to separate the amenities and treasures of each river and treat separately the topics of transportation, power, and irrigation, in actuality that becomes impossible. In reality these functions are interwoven. For classification purposes, it is necessary to segregate the functions of rivers and treat each function separately.

A *river* is a stream of water carrying the surplus water which falls as rain or snow and the waste of the land from higher to lower ground, as a rule to the sea. A river system involves not only the familiar river flowing in its channel, but, in addition, the innumerable little rills that have their birth with rain and flow down each slope. In one sense it may be said to include the full surface of the country. The water supply of a river comes partly from the rainfall directly, partly from the surface runoff of either rain or melted snow or ice, and partly from water that comes to the surface from underground. A trunk stream and all the branches that join it constitute a *river system*. *Stream* is a general term with little relation to size, while the terms *rill, brook,* and *creek* apply to streams of small size or moderate size. The area of land from which a river gathers its water and its load of rock waste is called its *basin*. The crest line between basins of neighboring streams or rivers is known as a *divide*. Certain crest lines in the Rocky Mountains separate basins of rivers which discharge into the Atlantic and Pacific oceans; these crests constitute the *continental divide*.

Many of the ways in which rivers and lakes affect human activities have been noted in preceding pages. In this chapter rivers will be discussed from the standpoint of transportation, power, irrigation, and flood control.

Transportation

Primitive man was a natural rover. If he went by land, he had to clear the way, and so he first traveled extensively by water, for nature furnished him the course. Drifting with the current or the wind conserved his energy, and the waterway idea was impressed on him at the very beginning of his ascent. Rapid progress came only when man

learned to build transportation equipment that increased his ease of migration.

Transportation has been a factor of outstanding importance in our national growth and prosperity. Spreading westward from a thin fringe of scattered settlements along the Atlantic seaboard, the American population extended the frontiers of the nation in a relatively short time. Westward migration was confined closely to the rivers, which provided the easiest means of transportation. With the settlement of the interior, the Mississippi River, with its several important tributaries, was for many years the main transportation route west of the Alleghenies. One of the earliest means of water transportation was the canoe, later followed by the bateau. Later, the barge and the flatboat were used. Because of the difficulty of going against the current, most of the goods moved downstream. Many towns developed along the Ohio and Mississippi rivers to aid in the movement of goods. The year 1811 marked the beginning of steamboat use on rivers, and the movement of goods upstream as well as downstream. In 1855 there were about 750 steamboats in service on American rivers.

The physical improvement of our rivers for transportation began soon after the advent of the steamboat. At first the work consisted of removing obstructions such as rocks, snags, and sandbars and deepening the channel.

The period from 1840 to 1860 was the beginning of railway construction in the West. During that period the railroads were considered supplementary to the waterways and were built as feeders for the rivers. By the beginning of the present century river traffic had nearly disappeared. The railroads not only absorbed the ever-increasing traffic but also took the business that had formerly been carried by the rivers.

Shortly before 1907 there developed a new interest in river transportation which culminated in the appointment of the Inland Waterways Commission. The President of the United States asked the newly appointed commission to study and prepare a report on the river systems of the nation. After making his selection, the President summarized his views in a letter to the Commission by stating:

> In creating this Commission, I am influenced by broad considerations of national policy. The control of our navigable waterways lies with the Federal

Government, and carries with it corresponding responsibilities and obligations. . . . Our inland waterways as a whole have thus far received scant attention. It is becoming clear that our streams should be considered as great natural resources.

The opening of the Panama Canal in 1914 had a far-reaching effect upon river navigation. The benefits of the canal accrued to the coastal regions, for it brought the east coast in closer touch with the west coast, to the detriment of the Middle West. Again, the necessarily large advance in railroad freight rates during and after the First World War

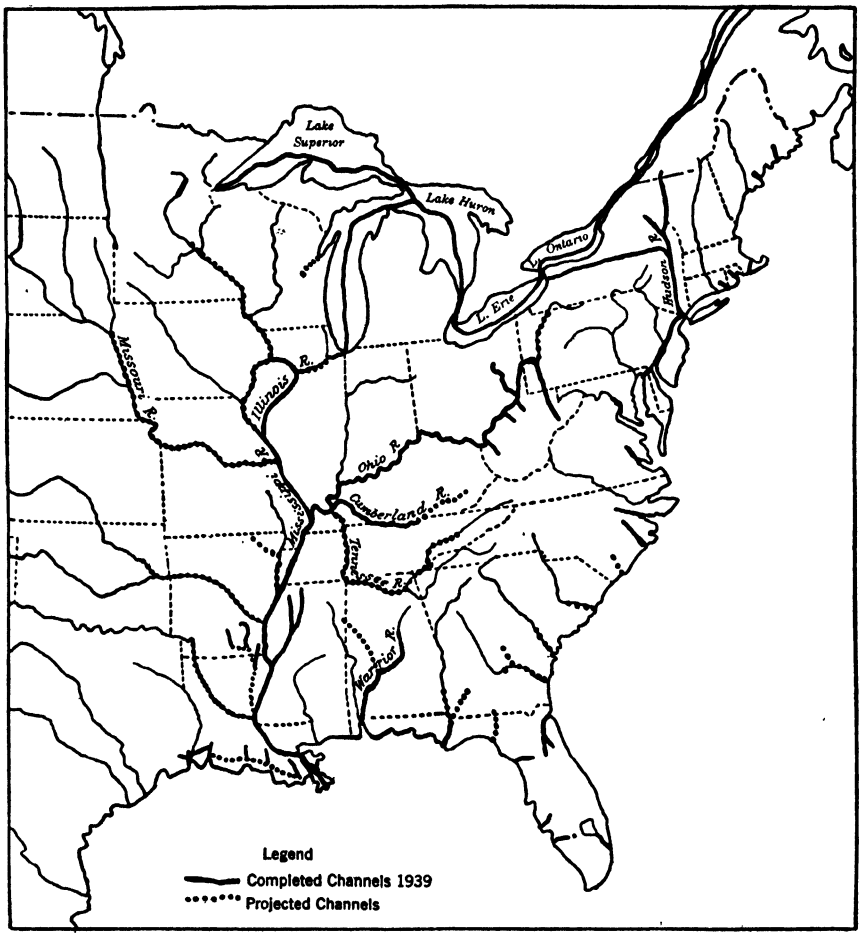


Fig. 109. Waterways of Eastern United States.

worked another hardship on that section of the country. The combined effect has been to make it doubly urgent to take advantage of our rivers for transportation.

Pursuant to the provisions of the Transportation Act of February 28, 1920, the Secretary of War organized and put into operation the Inland Waterways Corporation, whose objective was the promotion of navigation on our inland waterways. The Corporation, through the operation of the Federal Barge Line, reestablished commerce on the rivers. The act provides that as soon as the Corporation has fulfilled its purpose and private carriers have established successful operation, the former will cease operations as a Government agency.

The development of the national waterways plan has been coincident with the development of our national policy. The entire plan has been a matter of growth. With changing conditions, the character and method of improvements have been changed.

The United States Engineers, War Department, have charge of all river and harbor work. Until the middle of the nineteenth century the Federal Government had to rely upon the army engineers to carry out all its technical work. For many years West Point was the only engineering school in the country. The Corps of Engineers of the United States Army is charged not only with improvements and maintenance of our harbors and waterways, but also with the enforcement of our Federal laws designed to protect and preserve the navigable waters of the United States and its territories.

River transportation on other continents

The rivers of South America with commercial significance are the Amazon, the Rio de la Plata, the Orinoco, and the Magdalena. The Magdalena has been important to Colombia throughout its entire history, and, were it not for the river, much of interior Colombia would be undeveloped. The cost of constructing highways through the mountainous territory would be prohibitive. The Rio de la Plata and its tributaries, the Paraña and Uruguay, are navigable for considerable distances with smaller boats. The Amazon is the largest river in the world, having a length of about 4,000 miles. Shallow-draft ocean steamers can ascend as far as Iquitos, a distance of 2,600 miles. Its commercial significance is reduced because of the lack of economic

development in that part of South America through which the river flows. The Orinoco River is navigable nearly to the Colombia border, and it likewise flows through an area that has not been developed.

In Europe nearly all of the rivers have been and are important commercially. Many rivers have been canalized to increase their use for transportation. The Rhine, Elbe, Danube, Rhone, and Volga are the more important of these rivers. The Danube River has been an important highway since early times, and its use has been increased by the construction of jetties at the delta mouth. The Rhone, the natural highway into France from the south, is the largest river in the country. The Volga is the most important river of Russia and the largest river of Europe. It affords over 7,000 miles of navigation if the tributaries are included. Its usefulness is lessened by the fact that it flows through a semiarid region in its lower course and into a land-locked sea. The rivers of northern Russia are impeded for navigation, since

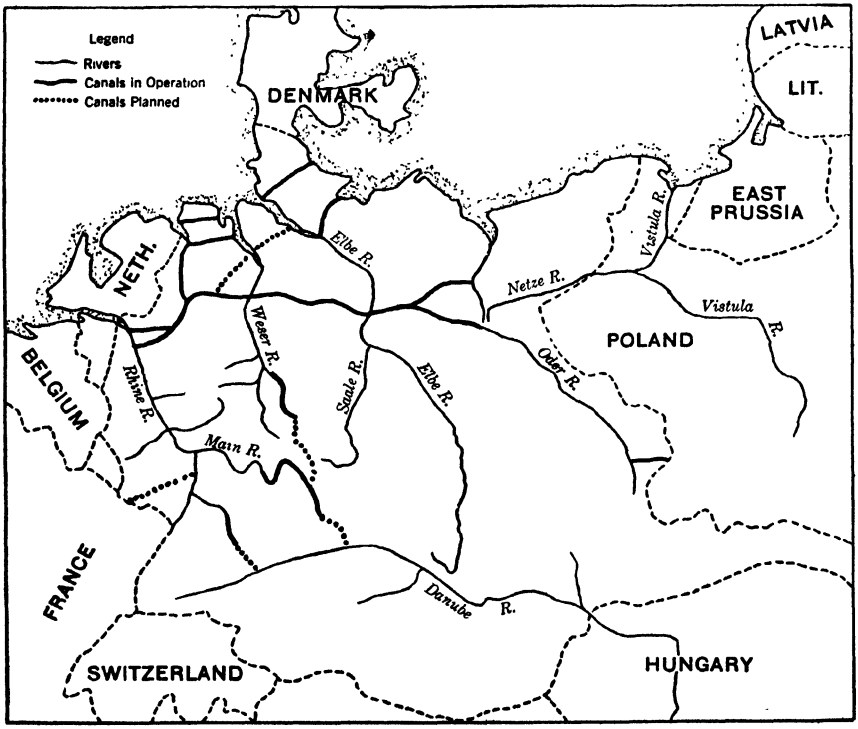


FIG. 110. GERMANY'S NETWORK OF INLAND WATERWAYS.

they are ice locked in winter, subject to severe flooding in early spring, and are tributaries to inland seas. The Rhine has influenced the history of Germany and central Europe more than any other river, and is today the most important commercial river of the continent. The valley of the Rhine is settled densely, and there are more important cities on its banks than on an equal length of any other river. The Elbe is commercially the second river of Germany. The traffic on the

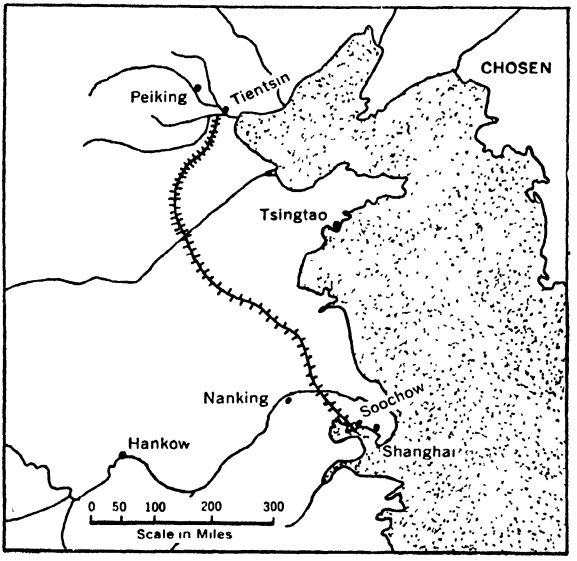


FIG. 111. GRAND CANAL OF CHINA.

last two rivers is largely heavy freight, such as coal and grain. The opening of the Mittelland-Kanal in 1938 gave a new navigable waterway from the mouth of the Rhine to Berlin and the Oder, thus extending the possibilities for water transport across north Germany from east to west. The new canal, which is nearly 300 miles long, completes a network of waterways which link some of Germany's most important industrial centers. This new canal that links the rivers of the Rhine, Ems, Weser, and Elbe is no new project. It was contemplated more than 300 years ago, and work has been progressing—though intermittently—for the past 50 years.

Few of the rivers of Asia are important for transportation because of the relief of the continent. The Yangtze-Kiang is the greatest high-

way between eastern and western China, and large ocean steamers ascend to Hankow, a distance of some 600 miles. Smaller steamers navigate another 500 miles. The Hwang-Ho (Yellow) River, while flowing through a densely settled region, is nearly useless for navigation because of the shifting and silt-choked channel. To increase their waterways for commerce the Chinese constructed a canal from Hangchow to Tientsin, a distance of over 1,000 miles. The canal was started before 500 B.C. in the vicinity of Yangchow, and gradually through the centuries it was extended north and south until it provided an artery of commerce for about 50 per cent of China's internal trade. The canal is known to the Chinese as Yun Ho and shown on the maps as the Grand Canal. In India the Ganges and the Indus are similar to the two rivers cited above. The Ganges has been important throughout the history of India; ocean vessels are able to reach Calcutta. The river is used for navigation for over 1,000 miles by smaller boats. The Indus River is seldom used for transportation because of frequent channel changes and the sandbars.

In Africa the relief limits navigation to short distances from the coast. On the Nile, navigation is impeded by the delta, while in the upper reaches smaller craft navigate the river throughout the year.

Water power

Power—material power—to most people today means more and more electricity and less and less steam or water power, even though man must have steam power or water power before he can have electrical power. Prior to the age of steam, man used for power such scraps as he was able to acquire, including his own brawn. The age of steam converted the energy of mineral fuels into mechanical energy and thereby introduced the industrial age. Prior to the age of steam, water power had been utilized by harnessing a waterfall directly to the wheels of a mill located along the bank. That process demanded small mills, for only small waterfalls could be harnessed; it restricted the use of water power to the immediate location, for that power could not be transported any distance. Then water, because of its restrictions, was replaced with mineral fuels. After the development of electrical energy in the latter part of the eighteenth century, water power became a competitor of mineral fuels. Today they are considered as complementary rather than as competing sources of power.

Water and fuels (coal, oil, and gas) compete for supremacy in cheapness of development, yet they supplement each other to give the most perfect and cheapest service when combined in extensive systems. In

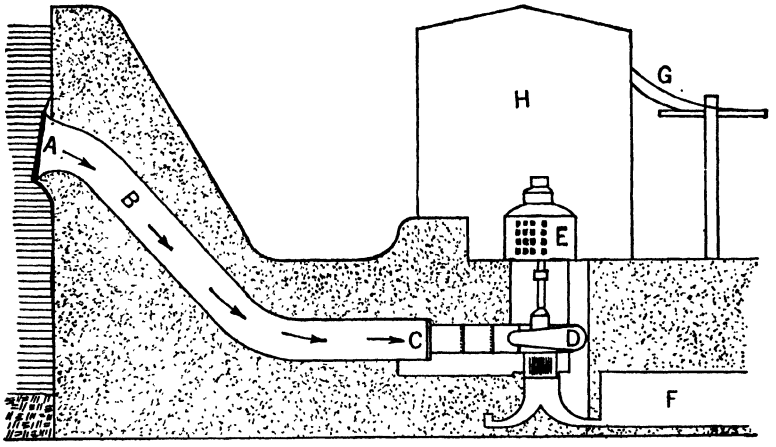


FIG. 112. SIMPLIFIED SKETCH OF HYDROELECTRIC POWER PLANT.

A, grid to keep out debris.
B, water intake to turbine.
C, valve for regulating water flow.
D, water turbine.
E, electric generator.
F, tailrace where water returns to stream.
G, outgoing feeder line.
H, generator room.

INSTALLED CAPACITY OF ELECTRIC GENERATING PLANTS [1]

Year	Total Kilowatts (in 000's)	Hydro as Per Cent of Total
1925	23,512	26.2
1926	25,392	26.2
1927	27,020	26.4
1928	29,714	27.1
1929	31,622	25.8
1930	34,055	26.3
1931	35,369	26.7
1932	35,991	26.6
1933	36,242	26.9
1934	35,791	27.2
1935	36,074	27.2
1936	36,564	28.5
1937	37,134	28.5
1938	39,042	28.3
1939	40,317	28.3
1940	41,638	27.8

[1] Electric Power Statistics, Federal Power Commission.

areas where water power is abundant and can be developed economically, fuels are held as a reserve and to supply peak loads. In other areas, fuel power dominates the field, and water power, if developed at all, is used for feeding the power line but is not relied upon for the base load. The table on page 303 shows the installed capacity of electric generating plants in the United States and the percentage of that capacity developed by water power.

It will be noted in the above table that the ratio of hydroelectric capacity to installed capacity has varied but little during the period since 1925.

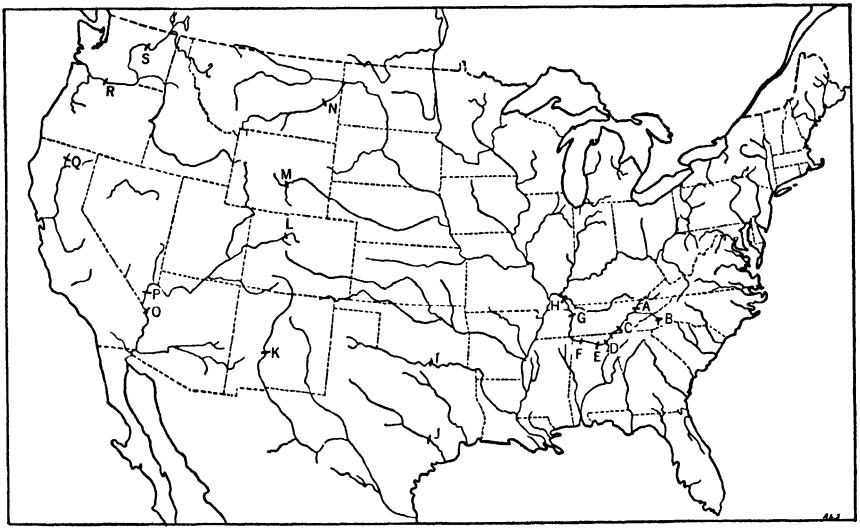


FIG. 113. FEDERAL GOVERNMENT POWER PROJECTS.

	K.W. Hrs.		K.W. Hrs.
A, Norris (Tenn.)	100,000	K, Elephant Butte (N. Mex.)	24,500
B, Hiwassee (N. C.)	120,000	L, Big Thompson (Col.)	142,500
C, Chickamauga (Tenn.)	108,000	M, Kendrick (Wyo.)	36,000
D, Guntersville (Ala.)	97,200	N, Fort Peck (Mont.)	105,000
E, Wheeler (Ala.)	259,200	O, Parker (Cal.-Ariz.)	82,500
F, Wilson (Ala.)	444,000	P, Boulder (Nev.-Ariz.)	1,380,000
G, Pickwick Landing (Tenn.)	216,000	Q, Shasta (Cal.)	350,000
H, Gilbertsville (Ky.)	160,000	R, Bonneville (Wash.-Ore.)	504,000
I, Denison (Tex.-Okl.)	125,000	S, Grand Coulee (Wash.)	1,900,000
J, Marshall Ford (Tex.)	51,000		

The total capacity of water wheels installed in water-power plants in the United States on January 1, 1935, was 16,075,307 horse power, an increase of 161,856 horse power, or one per cent, during 1934. Based on the present practice in the installation of water wheels for the utilization of water power sites, it is estimated that water wheels having a

WATER POWER IN THE UNITED STATES [2]

States	Developed Water Power [a]	Per Cent of United States [b]	Potential Water Power Resources Available 90 Per Cent of the Time [a]
Total	16,075	100.0	41,701
Alabama	867	5.4	820
Arizona	137		2,759
Arkansas	94		200
California	2,450	15.2	4,120
Colorado	101		873
Connecticut	172		65
Delaware	1		5
Dist. of Columbia	5		[c]
Florida	20		20
Georgia	569	3.5	572
Idaho	341		2,550
Illinois	87		189
Indiana	55		45
Iowa	182		169
Kansas	15		104
Kentucky	144		245
Louisiana	00		9
Maine	615	3.8	536
Maryland	403		106
Massachusetts	421		107
Michigan	476		184
Minnesota	272		212
Mississippi	00		72
Missouri	235		84
Montana	427		2,410
Nebraska	23		183
Nevada	13		300
New Hampshire	574	3.6	186
New Jersey	17		50
New Mexico	1		116
New York	1,884	11.7	4,034
North Carolina	980		916
North Dakota	[d]		82
Ohio	22		55
Oklahoma	2		70
Oregon	362		4,400
Pennsylvania	562	3.5	313
Rhode Island	29		25
South Carolina	811	5.0	555
South Dakota	19		206
Tennessee	291		1,340
Texas	52		288
Utah	144		1,420
Vermont	191		103
Virginia	154		459
Washington	1,037	6.5	8,800
West Virginia	226		355
Wisconsin	545		285
Wyoming	22		704

[a] In 000's horse power.
[b] For 10 leading states only.
[c] Listed as part of Maryland.
[d] Less than 1,000 horse power.

2 For January 1, 1935.

capacity of about 80,000,000 horse power would be required to utilize all of the water power in the United States. Therefore, 20 per cent of the nation's water power is developed at the present time.

Since 1928, when the latest revised estimate of potential water power in the United States was made, many surveys and investigations have been made by bureaus of the Federal government, by states, by corporations, and by private engineers. So far as the results of these surveys are available, they have been incorporated in the estimate on the preceding page. Extensive surveys of possible storage sites in the upper Columbia River basin and in the Tennessee River basin show that the potential power of these rivers and some of their tributaries is considerably above the old estimates.

The figures given in the estimate above show the 24-hour horse power available 90 per cent of the time at an over-all efficiency of 70 per cent at all developed and undeveloped sites. The estimate includes half of the potential power of Niagara River and of the international section of the St. Lawrence River, though an international agreement is necessary to permit the full use of these resources.

An examination of the above table shows that the Western States have the greatest potential water power in the United States. The conditions underlying the larger possibilities in these states include the following factors: (a) precipitation is abundant on the windward side in the higher altitudes, (b) mountains increase the stream velocity, (c) natural reservoirs are provided by glaciers, snowfields, lakes, and marshes, (d) bedrock is impervious and near the surface and provides a good foundation for dams, (e) the large size of the states and the presence of much unappropriated land reduce the legal problems found in many eastern states, and (f) the absence of coal produces a non-competitive situation. The combined effect of these factors is increasing the developed water power, so that the Western States may in time lead not only in potential but also in developed water power.

Floods and flood control

Floods are a natural occurrence which mankind is constantly opposing. Every spring and early summer floods cause the loss of hundreds of lives and force thousands of persons to leave their homes, abandoning possessions and often losing the accumulations of a lifetime.

Can floods be predicted? Have they always occurred? What can be done to protect people and their possessions against them? Are floods increasing in severity?

Records, to be of value for planning protection and forecasting floods, should cover a long period of time and be accurate. There are two types of data concerning river conditions: First, those of river heights read from river gauges. These gauges are posts sunk in midstream with graduations in feet and tenths marked on them. The zero mark is arbitrarily taken, generally below a level ever likely to be reached by the river. The second type of data is determination of the rate of flow. The United States Weather Bureau has charge of the river gauges and river forecasting throughout this country, and it has made an enviable reputation in accurately forecasting river stages.

It is necessary to review some of the characteristics of river basins and of the weather to realize the problems of floods and flood control.

Watersheds vary considerably one from another. A hilly watershed is more conducive to flood than a flat watershed. In hilly basins, the water runs off quickly, concentrating in the main stream and causing it to rise rapidly. A more or less flat watershed detains the water because of the slower runoff and because there are more lakes, swamps, and small pools which act as reservoirs. If a watershed is narrow, floods are less likely to occur than in the case of a circular watershed. The character of the ground is another important factor. A basin underlaid with rock or clay gives a quick runoff, while sand absorbs considerable water.

A forested area with a good layer of humus and leaf litter has a deterrent effect on the runoff. Water falling over a forested region has its speed broken, and the rain water trickles down the branches slowly and thus reduces erosion. Furthermore, it is soaked up by the humus and litter, and considerable amount of water is retained, to seep out at some future time. But floods cannot be attributed to deforestation. Forests are of use in flood control only to the extent of detaining some water. After the ground is soaked in a forested region, about 90 per cent of the rain becomes runoff. The great floods recorded by the early explorers had little to do with deforestation. Various hydraulic engineers have made a thorough study of the question, and the conclusion which they reach is that deforestation has little effect

on floods. Rivers do not rise higher or fall lower now than when there were forests.

Rain, snow, and temperature are the weather elements most important in producing floods. The antecedent weather conditions are also of considerable importance. Most floods are caused by continuously heavy rains. If the soil has been previously soaked or if the ground is frozen or has a layer of hardpan, the percentage of runoff immediately becomes high. If there is a layer of snow, some of the rain will be absorbed; but, if the temperature remains high, there will be the combined effect of the melting snow and the release of the soaked-up water to add to the runoff of the falling water. If the river flows to the north, ice, at or near the mouth, may act as a dam to hold back the water. Thus floods usually occur in the late winter and spring.

The volume of a flood depends upon the intensity of the weather factors coupled with watershed conditions. In addition, a variety of minor details must be considered, and these vary with the different watersheds.

Immense destruction accompanies every major flood. A river flowing along in its normal way does some eroding and transporting. A river in flood erodes and transports with much greater power than normally. The destruction caused by floods need not be discussed here. Millions of dollars are lost in property and hundreds of lives may be lost in a single flood.

Flood prevention includes all means to prevent the overflowing of land employed for habitation or economic use. The more important methods of prevention include dams and levees, deepening and straightening the channels, and diverting the flood waters to other streams or unused or less valuable land. The best example of protection by dams is that of the Dayton detention basin. This group of five basins is used only for the impounding of flood waters. This system will take care of a flood 45 per cent greater than that of 1913. Levees are used along the Mississippi River. Much excess water may be disposed of by diversion. The Babylonians used this method of diverting the Euphrates into a depression in the desert.

There is at present no method of forecasting floods any period of time in advance of the coming of the high water. Floods come at uneven intervals. A major flood of one year may be followed by one

equally great the succeeding year. However, in the long run, the larger the flood the less frequently it occurs, although there is no regularity of flood frequency.

Floods, formerly a problem of immediate localities and states, have now become a concern of the Federal Government. The welfare

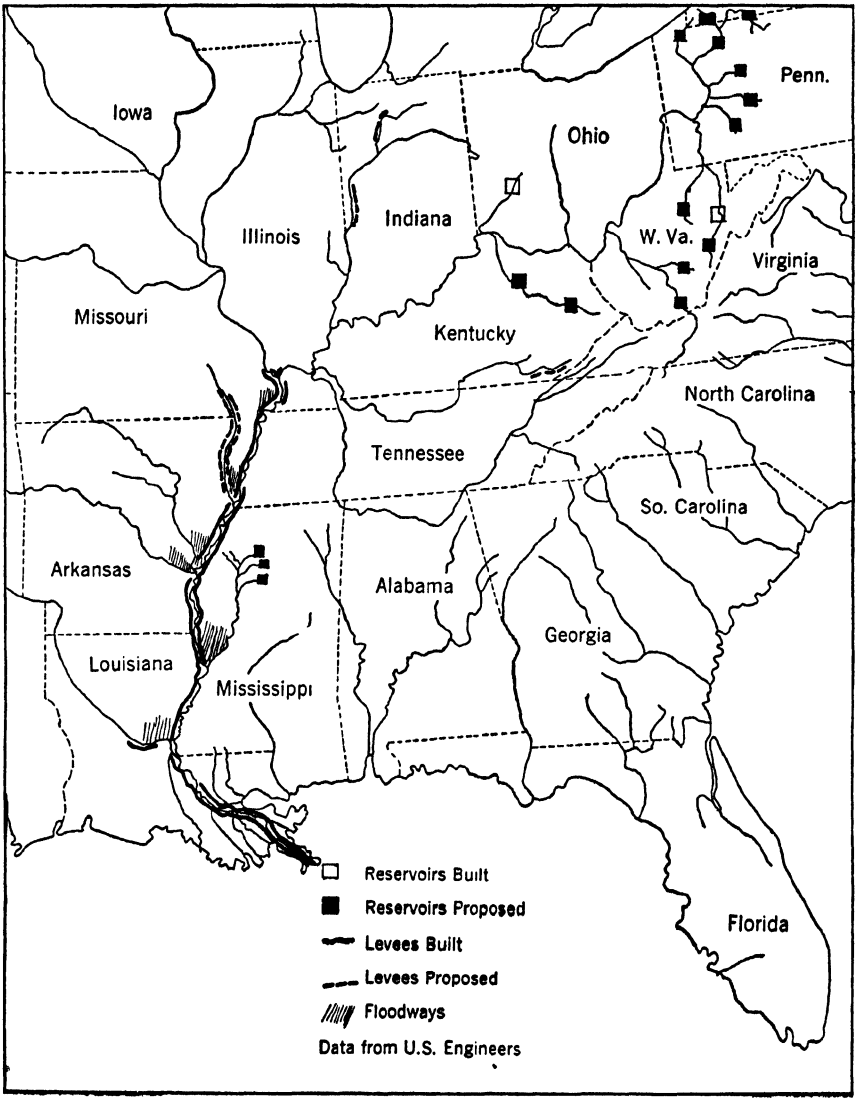


FIG. 114. MISSISSIPPI BASIN FLOOD CONTROL PROGRAM.

clause of the United States Constitution is used as authority for many activities, and flood control can be authorized by acts of Congress. River surveys, including flood control, have been authorized by Congress, and are carried out by the United States Engineers. As a result of much concentrated effort, a complete plan is now being worked out for the entire nation.

Irrigation

Irrigation is the artificial application of water to land for the growing of crops. Streams are the chief source of this water supply but not the only one. Irrigation is necessary in arid and semiarid regions, but it is also practiced in humid regions to increase crop production. Dry farming is carried on in many areas where the annual precipitation is slight, but the yields are low, production is uncertain, and crops are not obtained every year. The distribution of the precipitation is also an important factor, as well as the rapidity of evaporation and the type of soil, which partly determine the effectiveness of precipitation.

About one third of the total land surface of the earth needs irrigation before crops can be grown successfully. Of that one third only a small percentage can ever be irrigated. The factors which make for non-irrigable land include the lack of a suitable reservoir site, rough topography, alkaline or otherwise infertile soil, and the lack of available water. Most soil in arid regions is fertile and needs only water to make it productive.

Over 90 per cent of the water used for irrigation comes from streams. Arid and semiarid regions frequently lie near mountains, and streams rising in those mountains are fed by melting snows. The snows melt in the early summer and raise the water level at that time; during the months of July and August the rivers have but little water. In order to conserve the large amount of water available in the early summer reservoirs must be constructed to hold the surplus. The size of the reservoirs varies from those large enough to hold the entire flow of the stream which they dam to those so small as to hold only enough water for a day or so.

The water is taken from the reservoir to the canals, and from there to smaller ditches, which carry it to the fields to be flooded. In the

more primitive projects the main canals may be mere ditches. In areas where evaporation is great it may be necessary to line and cover the ditches.

As the lands are irrigated, some of the water sinks into the ground and seeps through the soil to the natural drainage channels, reappearing in the streams as an addition to the stream flow, which is again diverted to the irrigation canals. This water may be used three or four times.

Ground waters collected from springs and wells are an additional source of water and may be used for smaller fields. Springs are particularly important in mountain areas. Wells, artesian and pumped, are used in some states, such as California and New Mexico, and also in humid regions. Again, the projects are small as compared with those using water stored in reservoirs.

Irrigation has been practiced since ancient times. The history of Egypt is largely an account of irrigation. The annual overflow of the Nile irrigated a small acreage of floodplain, in addition to leaving a rich deposit of new soil. To supplement the water added by nature, the early people carried water in buckets. Later, labor-saving devices, such as wheels and sweeps, were installed, usually propelled by animals. With the decline of the Egyptian state there was a decline in the care given to irrigation projects. In later years the great Aswan Dam was built (1898 to 1908), and now two or three crops per year are grown.

The ancient civilizations of Mesopotamia were based largely on the extensive irrigation systems. Again, with the decline of that civilization came the neglect of the irrigation ditches, until they could no longer be used.

India has the largest irrigated acreage in the world, about 50 per cent of the total world area. The Indus and Ganges Rivers are the source of the water, and they are fed by the snows from the Himalayas. On the Deccan Plateau, the source of water for irrigation is from wells and kanats. *Kanats* are underground channels constructed by the native Persians.

In China, irrigation is practiced extensively both in the humid and arid regions. In the humid regions rice fields are watered, making flooding a conspicuous feature of the agricultural system. Most of

the arid areas of China are watered in small projects rather than from extensive and costly systems.

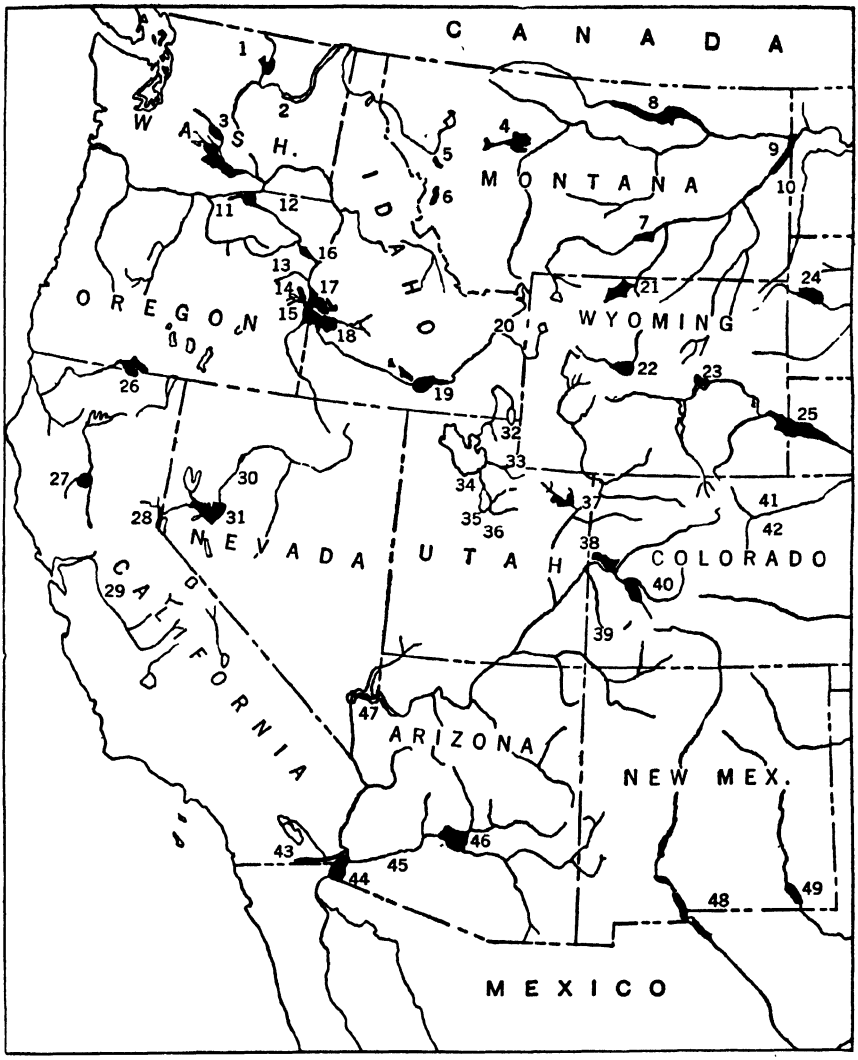
In the southwestern part of the United States the Indians practiced irrigation long before the coming of the Spaniards. They utilized the streams to augment the meager rainfall for the production of such crops as maize and pumpkins. The Spanish colonists, having had experience with irrigation, supplemented the experience of the Indians. The first organized effort in the United States in irrigation was by the Mormons, when they established their colony in the Salt Lake basin. Their efforts were cooperative and formed the basis for their agriculture and their later industrial development. Other projects followed in later years.

As the western states were settled it became necessary to invest more capital, and companies were organized to carry out the work. In 1894, the Carey Act was passed, under which the states were permitted to assist in irrigation. This act served an immediate need and aided in providing additional capital for a short time. Greater sums of money were needed because of the increasing difficulty of the construction work, and then the Federal Government took over the irrigation projects.

The Reclamation Act was passed on June 17, 1902; it gave the Secretary of Interior authority to "make examinations and surveys for and to locate and construct irrigation works for the storage, diversion, and development of streams and rivers" for irrigation (32 Stat. 388). This act marked the beginning in the United States of soundly planned irrigation works with public funds on a self-liquidating basis.

Since the Bureau of Reclamation was organized within the Department of Interior, 34 irrigation projects have been constructed, and by 1939, 3,067,495 acres of land had been reclaimed. Of the total seven hundred million acres of arid land in the West, twenty millions now are irrigated.

Before an irrigation project can be approved, certain investigations must be made by the various agencies of the Federal Government. The United States Geological Survey furnishes much needed material before any project can be considered. The topography is one of the first considerations to determine whether a given area is irrigable. Geological surveys must be made to determine suitable reservoir sites



After Bureau of Reclamation.

FIG. 115. FEDERAL IRRIGATION PROJECTS.

1. Okanogan
2. Columbia Basin
3. Yakima-Roza
4. Sun River
5. Frenchtown
6. Bitter Root
7. Huntley
8. Milk River
9. Lower Yellowstone
10. Buffalo Rapids
11. Umatilla
12. Stanfield
13. Burnt River
14. Vale
15. Owyhee
16. Baker
17. Payette
18. Boise
19. Minidoka
20. Upper Snake Riv.
21. Shoshone
22. Riverton
23. Kendrick
24. Belle Fourche
25. North Platte
26. Klamath
27. Orland
28. Truckee Storage
29. Central Valley
30. Humboldt
31. Newlands
32. Hyrum
33. Ogden River
34. Provo River
35. Strawberry Valley
36. Sanpete
37. Moon Lake
38. Grand Valley
39. Pine River
40. Uncompahgre
41. Colorado
42. Big Thompson
43. All-Amer. Canal
44. Yuma
45. Gila
46. Salt River
47. Boulder Canyon
48. Rio Grande
49. Carlsbad

for storing water without excessive seepage losses. Records of stream flow must be examined for the stream in question as well as for the neighboring streams. Drainage data must be determined; the subsoil must permit the drainage of water in order to prevent the water table from rising too close to the surface and damaging crops. Careful soil studies are included; while most soils of desert regions are fertile, yet many small areas of infertile soil may ruin a project economically. Power requirements for pumping or for commercial development require studies of power possibilities at existing sites. These studies must always be supplemented with economic studies to determine whether or not the settlers on the project can make a living and then repay the Federal Government for its investment.

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The Rise and Fall of River Navigation

THROUGHOUT the course of this text the influence of the environment upon human activities has been considered. Different factors of the physical environment have been presented, and their influence has been suggested. In general, man works constantly along what he conceives to be lines of least resistance; it is thus that trade routes have been and are determined. The following article[1] shows the influence and the changes in use of rivers in transportation in the United States.

As our savage ancestor found it necessary, in the search for food or better hunting grounds, to move himself and his scanty belongings from one place to another, he soon learned that it required less labor to carry a load in a canoe than on his back. As man became more civilized, his necessities increased, and he became a tiller of the soil to satisfy them. As he often produced more than he personally needed, an exchange of commodities became desirable, and he sought the cheapest means to transport them. This was afforded by a raft or a barge wherever a river lane was available for the movement.

Since cheap transportation was provided by the river, meeting places for the exchange of goods were naturally established along its banks, and these grew into towns. When the sea also came to be utilized for transportation, the seagoing ship penetrated the river as far as it could conveniently sail. At this point of transfer from the sea to the land a city arose, but, even above that point, the river was still the easiest

[1] Adapted from C. McD. Townsend, from *The Military Engineer,* Vol. 28, No. 157, published by the Society of American Military Engineers, Washington, D. C.

road for distribution, and river navigation became paramount. It was recognized as such and has been protected by the laws of all civilized nations.

Influence of river navigation on the settlement of the United States

When the United States was colonized, the new settlers were usually forced to debark from a ship on a navigable river and to develop the country along it. River navigation was the essential element in this development.

There were three main lines for these penetrations of the country: the Mississippi Valley, the St. Lawrence Valley, and the numerous rivers along the Atlantic coast. The Spaniards, by right of discovery, obtained possession of the Mississippi River; the French had control of the St. Lawrence, and various other European nations sailed into the mouths of the rivers on the Atlantic coast.

As a result of European wars, France acquired control of the Mississippi River and established trading posts as far north as St. Louis, and on the Ohio River to Pittsburgh. England conquered Canada from the French, but the conquerors, fortunately for the United States, became more interested in early days in the development of the fur trade of the Hudson Bay Company than in colonization, and, owing to obstructions in the St. Lawrence system, its river navigation retrograded to the Indian and his canoe. England also obtained possession of the rivers north of Georgia and colonized their banks.

Canals

A river, of necessity, occupies the *thalweg* of a valley, and its use for navigation becomes limited by the cost of land transportation to it. The Allegheny Mountains, therefore, formed an obstacle impossible of passage by water and seriously menaced the development of the country from the east.

River navigation can, however, be extended by the canalization of the tributaries, and canals were constructed for this purpose.

Prior to the War of the Revolution, the numerous rivers south of the Potomac made Virginia the leading colony, and General Washington foresaw the necessity of piercing the Allegheny barrier by canals, ex-

tending the navigation of the Potomac or the James River to the Ohio River, if Virginia was to maintain its supremacy by becoming an outlet for the products of the West. Although he failed in his efforts, numerous canals were constructed, particularly to the coal fields of Maryland and Pennsylvania; by the construction of the Erie Canal, which flanked the obstacle, commerce was diverted to New York City.

Other canals extended river navigation to the Mississippi River, but New Orleans still maintained its supremacy over the Mississippi Valley. Pittsburgh, Cincinnati, and St. Louis became thriving towns, while Chicago, Detroit, and Cleveland were mere villages.

If the development of the country had remained dependent on river navigation, a large part of the United States west of the Mississippi would have remained the Great American Desert, and the states east of it would have been only partially developed. New Orleans, as the great port of entry at the mouth of the Mississippi, would have rivaled New York in importance. The iron ore of Minnesota might have floated down the Mississippi to a union with coal from Illinois and the Ohio River, instead of following the Lakes to the coal of Pittsburgh and Ohio.

The steam engine

When the canal was attaining its maximum development for extending river navigation, the steam engine came into use. This instrument revolutionized the means of overcoming frictional resistance on land. When the locomotive was placed on rails, the distance that materials could be transported economically was enormously increased.

The steam engine also benefited the river boat and produced the cheapest navigation per ton-mile that ever existed in the United States in the transportation of coal from Pittsburgh to New Orleans by the steamer *Sprague* and of lumber and logs from the State of Minnesota to St. Louis. This was due principally to the utilization of the river currents for propulsion while the steamboat merely aided them.

Nearly all this traffic except that of the Government barge lines has practically disappeared. Large expenditures for river improvement have been accompanied by a diminution in river commerce, which has been absorbed by the railroads.

The advantage of the railroad

It is therefore evident that elements other than cost per ton-mile of the transporting vehicle seriously affect the movement of freight. Of these, probably the most vital is rapidity of transit. A train in motion displaces air, while a boat displaces water. At low velocities the rail friction may equal water friction, but, as the speed increases, a head is created in the waterway that a train does not have to combat. In addition, a boat moving upstream has to overcome the river currents. A large part of the cost in the transportation of coal on the Mississippi River was due to returning the empty barges to Pittsburgh. Prior to the steam engine it was not attempted.

A second cause of the decline of river navigation was due to the unsatisfactory terminal facilities. Animal traction was necessary to assemble material for either car or barge, and manual labor had to be used to transfer it from the cart. A railroad parallel to a river or canal intercepted the source of supply or the point of delivery of freight. At a certain distance from the waterway, depending on the material handled and the length of the railway, the extra cost of assemblage and delivery on the river bank counterbalanced the cheaper cost of water transportation.

As the railroad permeated all sections of the country while the waterway was confined to the thalweg of streams, the amount of freight that used the car, even at a greater cost, rapidly increased. Every town and village on the rail line had its depository, even if it was merely the railway station, while the warehouses for waterways were limited to the large towns. These terminal facilities increased the variety of traffic which sought the railroad, and soon practically reduced river navigation to crude products such as iron ore, coal, and lumber. This change is illustrated by the absorption of the traffic of the Erie Canal by the railroads of New York State.

A third and important cause of diversion of freight to the railroads has resulted from a change in business methods by merchants. Barges, to be operated economically, require large cargoes; the railroad operates in cars of relatively small capacity and will handle less than car lots. The merchant in former times had to expend a large amount of capital in storing a season's supply of material, necessitating a corresponding

increase in the interest on his investment. Today, this investment is reduced to a minimum. If his coal supply becomes low, he telegraphs and promptly receives a car load. He can also replenish by less than car lots or by express any shortage in his merchandise.

Another factor is the greater distance between points by river than by rail. This is intensified by the fact that the railroads can seek new markets unconnected with the river valleys. As examples, coal is diverted to Cleveland and other lake ports from the mines in the vicinity of Pittsburgh which formerly sought New Orleans, and Chicago has absorbed the lumber industry from St. Louis.

The only law which originally governed the cost of transportation by rail and water appeared to be to charge what the traffic would bear. The competitive function of both river and rail was thus an important one in any valley. The competitive value of potential river navigation inspired river improvements in order to bring freight rates down, even though the amount transported by barge was relatively small.

The Interstate Commerce Commission

The creation of the Interstate Commerce Commission introduced the conception that charges must be reasonable on railroads, but did not disturb water rates. Today conditions are reversed, and the railroad determines the traffic rates that are charged by the waterways in the Mississippi Valley. The Interstate Commerce Commission determines the railway charges, and the Government-owned barge line charges what the traffic will bear. It attracts freight by allowing a rebate of from 15 per cent to 20 per cent on these charges to shippers by water to a comparatively few river points to enable them to overcome the disadvantages that are inherent in water transportation.

The public, to be sure, is permitted and invited to utilize the river lanes, but the only persons on the Mississippi River who find it economically profitable to take advantage of the invitation are the owners of ferry boats; the operators of afternoon excursion steamers at large cities; the dredgers of sand and gravel from the river bed, who haul their product by river to the nearest economical point for shipment; and an oil company which owes its success not to reduced cost of river navigation but to its terminal facilities.

If the decline in river commerce which has accompanied the large

expenditures that have been made in the improvement of our rivers is any criterion, it indicates that the large commercial interests along our rivers prefer other means of transportation. This was emphasized during the First World War, when two barge lines were subsidized by the government to provide river navigation as a war measure regardless of cost. They were both economic failures.

Lake navigation

A comparison of the successful navigation of the Great Lakes with the deplorable results on our rivers is illuminating. Colonel N. Y. Du Hamel states that:[2]

"the Great Lakes with their connecting waterways provide a water transportation system on which, on a ton-mileage basis, is carried over 10 per cent of the commercial traffic handled by all transportation agencies, including railroad, pipeline, truck, and airplane, operating in the United States. This fact alone well illustrates the tremendous importance of the Great Lakes in the industrial and commercial development of the United States. Coal, grain, iron ore, and stone comprise more than 80 per cent of the commerce of the lakes."

The essential elements of success in any method of transportation are to have something to move and a cheap way to move it. In the early days on the Great Lakes, the Indian canoe solved the problem of transportation. When, however, iron ore was discovered in Minnesota, the necessity of joining that ore with Pittsburgh coal forced an enormously rapid development of the harbors and channels of the Great Lakes. There was something of value to be moved, and the waters of the lakes furnished the road for moving it.

Motor trucks

There is arising a third method of transportation which merits attention, that is, the automobile truck. It has the terminal facilities and the other advantages of the railroad. Its facilities not only greatly exceed those of the barge but rival those of the freight car.

Conclusion

Man has utilized rivers not only for navigation but also for creating water power and for irrigation. He is also protecting their banks from

[2] From a recent article in *The Military Engineer*, Vol. XXXIII, No. 188, 1941.

overflow. They are all worthy purposes and deserve support by the government. They should be carefully studied and government expenditures made so as to produce the greatest good to the majority of the people.

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Geographical Conditions of Water-Power Development

THE existence of water power rests on the two environmental elements of surface waters and land forms. The maximum potential water power of the world is found in rugged highlands where precipitation is heavy, in glaciated mountains on the west sides of continents, on rough glaciated plateaus and plains, and in ice-scoured areas.

The student should apply the principles given in the following article[1] to various countries of the world and especially to the various sections of the United States.

The modern use of water for its motive force depends not only on its weight as in the old mill wheels but on pressure of water conveyed by conduit. This use is very recent. It was only in 1869 that the first hydraulic power plant was installed in the northern French Alps near Grenoble; and from this usage of waters arising in Alpine glaciers and snows originated the picturesque term "white coal"—*houille blanche.* In 1883 the experiments of Mercel Desprez on the electrical transmission of water power, also conducted in the neighborhood of Grenoble, opened up the present varied possibilities of the utilization of white coal. This was the beginning of the hydroelectric industry, which thus dates back scarcely more than 40 years. In this short space of time it has, however, taken on a prodigious development and has become one

[1] Adapted from Raoul Blanchard, from the *Geographical Review,* Vol. 14, No. 1, published by the American Geographical Society of New York.

of the great economic facts of the modern world. We shall here examine the geographical conditions involved—the physical and economic circumstances which have influenced the establishment and expansion of the industry—and shall take in specific illustrations of various countries.

The physical conditions

What are the prime factors in the exploitation of hydroelectric force? From the physical standpoint there are two, susceptible of combination in a variety of ways—water and slope. The pressure of a certain quantity of water falling down a slope puts in motion a turbine. The greater the quantity of water available, and the steeper or longer the slope, the more energy is generated. Nothing simpler could be imagined. The most favorable conditions for the hydroelectric industry will then be realized in countries of pronounced slopes; that is, in mountainous regions which at the same time are well watered, regions of humid climate. On this basis the Bengal slopes of the Himalayas and the flanks of the Cameroon Mountains should be the most favored parts of the world in respect of water-power resources.

But this simple concept needs some elaboration. In the first place, if the *quantity* of water is a factor of prime importance, so also is what one might term the *quality*. By it we mean regularity of flow. A river with marked variation in flow is of inferior value; for utilization must be based on minimum flow, or power production will be irregular. Obviously it is possible to correct irregularity of flow by the creation of storage reservoirs, and the building of these has become a prominent feature of the industry. However, such works may prove too expensive for an enterprise in which the high cost of installation is already a handicap.

The two essential factors, water and slope, may be considered as mutually compensatory in a large measure. If in the one instance a small quantity of water falls from a great height, it will yet be capable of generating considerable force. Inversely, on a slight slope a great volume of water can effect the same result. Thus there are two well-defined types of power-producing streams—of high fall and small discharge, of low fall and large discharge. It should, however, be noted that if the power generated in the two cases is equal, the cost of pro-

duction will not be the same; for the high fall can be equipped and maintained at less expense. Advantage thus rests with slope over volume, and in hydroelectric development it may be said that slope is a factor of more decisive importance than water. Let us now see in what parts of the world the required conditions are best realized.

Advantage offered by glaciated regions

On the whole it would appear that glaciated regions best respond to the requirements, and this is confirmed by detailed study. Such places are usually rich in water. Glaciation calls not only for a low temperature but more imperatively for abundant precipitation. In Quaternary times central and eastern Siberia, where precipitation then as now was scant, was unoccupied by glaciers, while they capped the mountains of the equatorial zone. In America glaciation profoundly affected Labrador and eastern Canada, while in the same latitude of the southwestern prairies its effects are lacking, because of the difference in precipitation. Now the distribution of precipitation today is similar to that of Quaternary times. Regions which were occupied by the great Pleistocene glaciers today receive abundant precipitation and are characterized by well-filled water courses.

As regards the other factor, slope, glaciated regions are likewise well suited for hydroelectric development. Glaciation has contributed to this end in a variety of ways. In the mountains tributary hanging valleys offer abrupt descents to the major valleys, a condition which reduces the labor of installation to a minimum. To this specific cause may be attributed the precocious development of water power in the French Alps. Many alpine valleys are also characterized by *verrous,* transverse rock barriers over which the streams descend by cascades. Moraines may also constitute an obstacle, less durable without doubt but long capable of sustaining a break in slope. But the chief influence of morainic deposits is indirect. By obstructing river beds they have turned streams out of their former channels; the new superimposed courses in a youthful stage almost always exhibit stretches of steep gradient and broken slope. These are present, for instance, in many sections of the Drac in the French Alps; in North America moraines were operative in the origin of Niagara Falls.

At the same time the streams of glaciated regions are likely to be of

uniform or easily regulated flow. This advantage arises in the first place out of the character of the water supply. Regions where temperature was low enough for glaciation in the Quaternary still receive a part of their precipitation in the form of snow. Melting of the snow, or even better of the ice if accumulation takes this form, contributes to the maintenance of stream flow in the warm season, when it would otherwise tend to be irregular and scant. Thus in France the alpine torrents, largely fed by melting of the snows, have a more regular regimen than the rivers of the central Massif, where the heavy rains of summer do not prevent this season from being a period of extreme low water. But the uniform flow of the rivers of a glaciated country is primarily due to the character of the topography. The creation of natural dams, as we have noted, tends to the accumulation of water in natural reservoirs. Glaciated countries are *par excellence* countries of lacustrine hydrography. This is the case with northern Russia, Finland, Scandinavia, Scotland, Ireland, the Alps and Pyrenees, New England, Canada, the Cascade Mountains, the southern Andes, and the New Zealand Alps. Now lakes act as remarkably efficient regulators of flow; rivers emerging from them have a constancy of discharge that renders them well adapted to hydroelectric development. It will suffice to instance the Rhone issuing from Lake Geneva or the St. Lawrence from the Great Lakes. These natural conditions can be improved upon artificially by heightening the barrier impounding the waters and thus increasing the storage capacity.

Glaciated regions thus offer all the favorable physical circumstances for hydroelectric development—water in abundance, slopes abrupt and broken, uniform and easily regulated flow. If economic conditions permit, they will become producers of white coal.

Circumstances in nonglaciated regions

The favorableness of glaciated regions does not mean that hydroelectric industry cannot flourish save in them. It can, but in general only through qualification by some exceptional circumstance. Almost always one of the important factors that we have enumerated will be lacking. Nonglaciated mountains usually suffer from insufficiency of precipitation or too great seasonal variation in distribution. This is the case with the greater part of the Mediterranean chains and the lower

slopes of tropical mountains, where division of the year into wet and dry periods imposes such irregularity on stream flow as to render it difficult of utilization. Rivers of the equatorial regions, on the contrary, have much water well maintained throughout the year; but the very volume of water has permitted them rapidly to approach base level, while the amount of alluvial material carried further militates against utilization. In temperate regions rivers rising in nonglaciated mountains are also marked by lack of uniform flow; almost always they are very low in summer. As we have said, there are exceptions. The most remarkable is that of some of the equatorial rivers, where to already favorable circumstances of abundant and steady flow some tectonic accident has added steepness of gradient. Thus the great river Congo, whose entire middle course is in the equatorial zone, is characterized in its lower course, between Stanley Pool and Matadi, by a series of rapids of total fall of 800 feet capable of generating a force estimated at 100,000,000 horse power. Then there is the case of the Upper Nile, which shortly after its emergence from the regulating reservoir of Lake Victoria forms the Murchison rapids, uniting three favorable factors—slope, volume of water, uniformity of flow. The height of the Victoria Falls on the Upper Zambezi creates great hydroelectric potentialities on a tropical river of irregular flow. Similarly the steep western slopes of the Deccan invite development in spite of the irregularity of stream flow dependent on monsoonal rains. The eastern Andes of Peru and northern Bolivia have a heavy rainfall through the year and offer physical conditions of a high order counteracted at present by the extreme isolation of the region, which has been the main factor in retarding economic development. The rivers on the southeastern flank of the Appalachians offer the advantages of the fall line. The *porogs,* or rapids of the Dnieper in the Ukraine, representing an abrupt break of slope in the Russian plain, are capable of furnishing more than 100,000 horse power, although the stream flow is far from uniform.

But it is apparent that these are exceptional cases; the general conditions where they obtain are entirely otherwise. While the Congo is utilizable, thanks to the Yellala rapids, that other great equatorial river, the Amazon, is unutilizable for lack of slope. On the eastern slope of the Deccan the gradient is insufficient to compensate irregu-

larity of flow. The Zambezi below the Victoria Falls is of no interest hydroelectrically. In the southern Russian plain only the Dnieper rapids are useful; no other sections of this river or of the Don or Volga offer opportunities for power development.

This rapid survey of hydroelectric conditions in various parts of the world brings us to the conclusion that, save for exceptional cases, favorable factors are to be found much more generally in glaciated regions. Here the industry has developed. It remains to be seen if the economic factor is in accord with this distribution.

The economic factor

The economic factor has as great weight in the geographical distribution of the hydroelectric industry as the physical factor. The first problem encountered is that of means of access. The labor of installation in its many elaborate details demands sufficiently good means of access to the chosen location. Some fine natural sites in the heart of the mountains have been passed over for others less advantageous in themselves but more accessibly situated. Climate may exert an influence to the same end. Some sites otherwise favorable are blocked by snow six months of the year. The short season of accessibility means that work must be carried on over a greater length of time for capital to gain returns; and labor demands more remuneration, for working conditions are harder. Here enters in a psychological factor that cannot be ignored—the effect of living in a remote place in a region of wild and hostile nature. We know of a large plant in the French Alps where strikes are of very frequent occurrence, the attitude of the workers being largely due to the unfavorable location of the plant—in a deep, narrow, shut-in valley where the sun disappears for three months during the winter. In some instances the problem of ways of access is truly insoluble.

Significance of power transmission

Closely connected is the question of utilization on the spot of the power generated. It is advantageous that the energy obtained should be used as near the generating plant as possible. This also calls for ease of transportation for the introduction of raw materials of manufacturing and expedition of the elaborated products. Early in the his-

tory of hydroelectric development, when technical achievement was little advanced, it was necessary to take every possible advantage of favorable physical circumstances, and establishments using water power were installed in the interior of the mountains in situations not too well placed as regards communications. But progressive improvement has been made in this respect. Now the tendency is to place the manufactories on the periphery of the mountains. In glaciated mountains the industry has best scope for development if extensive plains are adjacent. In glaciated lowlands, such as the Laurentian region, where favorable sites abound, the problem of communications enters in only in detail. In the French Alps it has long been clear that the disposition of the hydroelectric plants is intimately connected with the railroads. Yet a tendency toward modification is in progress in virtue of the possibility of power transmission.

The possibilities of power transmission modify somewhat the earlier controls over location of the industry. It is now possible to transmit power to great distances in the form of currents of high voltage and low intensity through the use of transformers. A current of over 100,000 volts can, for instance, be carried a distance of over 500 kilometers. But power cannot be transported beyond a certain limit—as yet scarcely beyond 500 kilometers. The problem is chiefly one of cost. Transmission involves a loss of 10 to 20 per cent; erection and maintenance of the lines is also expensive; hence a point is reached where costs of transmission exceed the value of the power transmitted. In the great project for harnessing the Rhine conceived in 1917 the cost of carrying the power 400 kilometers to feed the great plant of Genissi at Paris proved nearly as great as the operation of the plant itself. To improve the transmission of power between the northern Alps and the Lyons region new lines were constructed, the cost of which was so great that it could be borne only by a combination of the several hydroelectric associations. Thus advantage evidently lies with those industries situated near the central power station.

More general in nature, common indeed to all industries, is the problem of labor. A region admirably dowered from the physical point of view but economically inactive is likely to remain unexploited. The glaciated regions of the far north, where conditions of life are hard and highways of transportation are far removed, are "empty of

men." Northern Canada is in this case, and so is northern Europe; to a less degree the same is true of the Andes of southern Chile. Outside the glaciated regions in the favorable exceptions we have noted, similar economic handicaps may obtain. Along the lower Congo not only are formidable technical difficulties encountered, but, even if the potential 100,000,000 horse power could be developed, one would not know what to do with it in this new country, where industry of all kinds could scarcely make use of 10,000 horse power. In a less degree the falls of the Upper Zambezi suffer similar disabilities. The great falls of the Paraña and the Iguassu have remained undeveloped in part because of their remote situation.

Competition with coal

Another aspect of the problem of the economic utilization of hydroelectric force is competition with coal. Countries which possess abundant resources of coal or even of lignite, capable of producing cheap electric power, are hardly interested in developing their water-power potentialities even if these are considerable and favorably disposed. The northwest of Great Britain with its glaciated topography, its lakes, falls, and heavy precipitation offers most favorable physical conditions. The existence of the coal basins has discouraged hydroelectric development, and the British Isles produce only 200,000 horse power from water power. As a recent analyst of the situation has said, "It would appear, therefore, that there is sufficient water power in the Scottish Highlands to meet a large part of the demands of industrial and municipal requirements in Scotland, but, on the other hand, it is doubtful if the cost after development and transmission to existing industrial areas would be less than the cost of power generated there at the pithead." Conversely the absence of coal is an incentive to development of hydroelectric resources. This absence is one of the reasons for progress of the industry in the French Alps and in Italy. In eastern Brazil, in spite of the irregular regimen of the streams, about 150,000 horse power is already developed, because of lack of fuel.

Thus for hydraulic electricity to be exploited on a large scale it is necessary that the producing stations be situated accessibly and that the power generated be utilized as near the stations as possible.

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Irrigation in Western United States

IRRIGATION is essential to habitation of large sections of western United States. As the western area became populated and irrigation became more important, it was found that individuals and cooperative efforts of individuals could not finance or build the larger projects necessary to irrigate lands located some distance from the rivers or at higher elevations. In order to make a beneficial use of land and water and to aid in settling the West, the Reclamation Act was passed in 1902. The results of this act are summarized in the following article[1] by the Commissioner of the Bureau of Reclamation.

One June 17, 1902, when President Theodore Roosevelt signed the Federal Reclamation Act, high hopes were held that important and lasting benefits would be derived from the conservation of the arid soils and the scant waters of the West. It was hoped that new opportunities to gain an American standard of living could be made available to large numbers of people who might find homes on the reclaimed land; that the natural handicaps of these big western states could, in part, be overcome through the construction of soundly planned irrigation works with public funds on a self-liquidating basis; and that through building homes and communities the United States could be made a better and richer country.

Let us look at the Federal Reclamation program from the vantage

[1] Adapted from "Reclamation Fulfills Its Mission," by John C. Page, Commissioner, Bureau of Reclamation, United States Department of the Interior. From the *Reclamation Era*, Vol. 28, No. 7.

point of the years that have passed and ask ourselves: "Have events justified the expectations of 1902?"

Since the Bureau of Reclamation was organized, 40 irrigation projects have been constructed to serve more than 5 million acres of land which recently were desert.

On the projects which have been put in operation, more than 1,000,000 people make their homes and find their livelihood on nearly 70,000 irrigated farms and in 257 towns and cities which serve and are dependent upon them. These people have built communities which support public schools and churches.

These are normal American communities where men live and work, where they earn and achieve a measure of prosperity. These are the permanent improvements of reclamation. Before analyzing these results and attempting to determine their significance, let us see what the peculiar western conditions were which made this program necessary.

Need gave rise to reclamation

Here lay 700 millions of acres which were arid or semiarid, or which were mountainous. Most of the water supply was received during winter months, and, with the coming of spring, it collected into a few streams and ran off, without benefit to mankind, to the sea. Only through the damming of streams, the storage of spring floods, and their distribution through canals could a little of the land be made productive and be made to support a considerable population.

As the receding frontier drew the American people westward, they came upon the arid and semiarid region, trapped its waters for fur, explored its mountains for metals, and cut into its forests, but they passed rapidly over its deserts. They crossed miles upon miles of arid land, hoping to find fresh fields; they pressed onward until they realized that it was upon the foundation of this desert that the permanent civilization in the West must be built. Then they began the easy stream diversions and irrigated the low-lying valleys and the benches near the big rivers. Gradually the irrigation systems became more complicated. Finally the unregulated flow of streams became insufficient to the needs of developments relying upon them, and storage works were required.

It was at about this time that the Government adopted its reclamation

policy. Summarized, this policy was to invest funds received from the sale of public lands in the Western States in irrigation. These funds were not to be expended as gifts, but were to be placed in a revolving fund into which the settlers upon the lands reclaimed must repay the cost of the construction of their projects. It was a simple and business-like arrangement, and, although the Reclamation Act has been amended, the principle remains unchanged.

Look at a map of the West now. The populous areas, the cities and the farms, are gathered together in spots where irrigation can be practiced, where water can be taken from the rivers or from the ground and applied to the arid land.

Of the 700 million acres in the West, 20 millions now are irrigated, and this small fraction forms the major support for 13 millions of people. Surveys show that some unused water remains available—sufficient in the estimation of the Bureau of Reclamation to irrigate, with projects which now can be considered feasible, an additional 10 millions of acres. Beyond the boundaries of these projects as yet unbuilt stretch the untracked desert and the short-grass plateaus, and above them rise peaks of a maze of mountain ranges. Hundreds of millions of acres must remain forever uncultivated.

The growth of the West since the shaking down process which followed the gold rush to California has been keyed to its irrigation development. This relationship must be retained in the future. The Bureau of Reclamation has played an increasingly important part since 1902 in the widening of the agricultural base for this growing section. For 15 years it has been the principal agency in the field of irrigation construction. It is likely to remain such in the future because the remaining developments generally are large and costly, involving too many complications to attract private finances and being too difficult to be undertaken cooperatively by irrigation districts.

What has been done under the Federal Reclamation Act, then, assumes a greater importance. In 1938 the Bureau of Reclamation had built 138 storage and diversion dams, 20,000 miles of large canals, and had expended 237 millions of dollars on projects which have gone into operation and are settled. With the expenditure of these funds it contributed 15 per cent of the total of irrigated land in all of the arid and semiarid region.

Let us analyze these figures a little more carefully. The construction of the irrigation systems for these projects has cost less than $263 for each person who has been provided a home, and, moreover, this expenditure is to be repaid. Of the $263 per capita outlay for construction, about $55 already has been repaid, and that represents within 2 per cent of all the money that has become due and payable. The provision of homes and new opportunities was the fundamental objective of the Reclamation Act. They have been provided for 900,000 persons, and for each of these, products of a cash value of more than $2,500 have been harvested from lands which recently were useless. In addition, taxable values have been created in the states exceeding $400 for every one of the persons living on the Federal Reclamation projects—on farms and in the cities and towns which the farms have created.

What does this mean to the public welfare? Here are a few facts. During the severe drought of the Great Plains in 1936, the Great Plains Committee found that in counties where adequate irrigation systems had been built and were in operation only 5 per cent of the taxes were delinquent; while in many counties adjacent or near by where there were no irrigated lands, tax delinquencies amounted to 95 per cent. And this difference resulted despite the fact that the appraised value of irrigated land generally was more than 10 times as high as that of dry farming and grazing lands. The support provided by irrigation for established government and institutions in this semiarid region becomes more obvious under such conditions. Irrigation lends a stability without which the very governmental structure of the West, as we know it today, could not exist.

Findings of repayment commission

Another bit of evidence: The Repayment Commission, in its recent report in the chapter devoted to general observations, said that its survey of relief conditions on Federal Reclamation projects revealed that bona fide farm operators in these areas were forced on relief only in a few areas. These isolated cases, it added, resulted from the fact that the farmer was a new settler who had not had the opportunity to bring his land into production, or who had been subjected to a condition over which he had no control. The records of the Bureau of Reclamation show that the average gross return per acre on its projects

is more than 2.5 times that received by the farmer the country over. It is realized that the overhead costs of the irrigation farmer are necessarily higher than those of farmers who do not have to buy and handle their water, but in the light of the observations of the Repayment Commission it can be stated that these projects have brought a measure of prosperity to those who sought the opportunities they offered.

The provision of homes and new opportunities, the support of Government and institutions, and the stabilization of the economy of a wide area are contributions to the social welfare not only of the project areas, the counties, and states in which they lie, but also of the whole United States.

Remember, too, that the social value of a reclamation project does not depreciate. These projects are permanent improvements which will continue to provide homes, employment, and a decent living for their people.

The agriculture of the irrigated sections of the West complements that of other regions of the country.

Livestock is a major western industry. Half of the feed which supports this industry is produced on the 20,000,000 acres of irrigated land, and the other half is obtained from the public ranges, hundreds of millions of acres in extent. These Western States provide the feeder stock for the pens of the midwestern farmer.

Specialty crops produced under irrigation

General farming and the production of specialty crops which can be shipped to distant markets for a cash return occupy the irrigation farmer. The big staple crops, of which other areas produce exportable surpluses, are not grown in appreciable quantities on irrigated land. For example, no tobacco is grown in the West. The Federal reclamation projects do not produce sufficient wheat, generally, for their own needs. The large western cities, which are the nearest markets for the products of irrigation, buy large quantities of pork and pork products from the Mississippi River Valley. Some cotton is grown, but most of it is of the long-staple variety not produced elsewhere in the United States.

Every project has its specialty crop, and they are of wide variety. They range from citrus fruits to sugar beets. Winter truck is an im-

portant crop of these projects. On first thought it might be believed that the production of cherries in Idaho, or lettuce in California, or cantaloupes in Colorado, and their shipment throughout the country might provide a source of competition with gardeners and orchardists near the large cities of the East and Middle West. The products of California, Colorado, and Idaho can be sold in Boston, New York, and Chicago, however, only after being freighted from 1,000 to 3,000 miles. To bear the freight charge they must be produced out of season so far as eastern markets are concerned. They cannot compete with locally grown produce in season, and they never attempt to do so.

The growth of the West has not been made at the expense of other sections. It has, on the other hand, reflected the growth of the country. There are insufficient opportunities now in the West to take care of more than a small fraction of those seeking them. In 1938, 69 farm units were opened for settlement on the Tule Lake division of the Klamath project in the extreme northern section of California. More than 3,000 home seekers applied on the first day for consideration in connection with the assignment of these farms. At this time there are, in the West, more than 50,000 farm families which have been driven by drought from their homes in the Great Plains alone. Few of them can hope to find permanent lodgment on farms.

Economic results of construction program

The Bureau of Reclamation is now engaged in the greatest construction program in its history. Projects under construction will, upon their completion, add an additional 2,500,000 acres to the watered area of these states. This construction program also will provide supplemental water for about as much more land, now irrigated but with insufficient water to produce good crops.

When these projects are completed, opportunities will be provided, according to estimates, for a total of 825,000 people on 41,600 farms and in cities and towns, as yet unlocated.

Some of the new projects will make settlement opportunities within a year or two, but some will take much longer. There is no possibility that all of the new lands could be thrown open at once, even though it might be desirable to do so. On the contrary, they will be made available in steady progression, and the last of those to be

irrigated by the Grand Coulee Dam may not be ready for 20 years. Such a large and complicated development cannot be completed quickly. If it were possible by some engineering legerdemain to complete overnight the network of canals in order that we might deliver water to each farm in the 1,200,000 acres to be served by Grand Coulee Dam, we would not be able to provide farms for more than three fifths of the families which are now refugees from the Great Plains drought alone.

One function of the Bureau has been to investigate the water and soil resources of the West and to plan for their development. The program growing out of this work is of long range. No effort has been made to keep the construction abreast of the demand for farm homes. Ultimately any such attempt must fail. As we have seen with respect to the Grand Coulee Dam, the largest unit possible of inclusion in any such program, the development must proceed slowly, while the needs may become quickly urgent. The best that can be done is to provide a sound plan and to spread the opportunities as intelligently and as widely as can be done.

Benefits of reclamation

No review of the contributions made by Federal Reclamation can be complete without the mention of hydroelectric power.

More than a score of power plants are being operated on federal projects. Several of them are important; and one of them, that at Boulder Dam, is very large. In connection with five additional projects now being built, important power developments are being made. These are at Grand Coulee Dam in Washington, at Shasta Dam on the Central Valley project in California, on the Colorado-Big Thompson project in Colorado, at Seminoe Dam on the Kendrick project in Wyoming, and at the Elephant Butte Dam on the Rio Grande project in New Mexico and Texas.

The output from these plants, like that at Boulder Dam, will be used in industries, in mining and smelting, in the lighting of city homes, and in rural electrification.

It is believed that this by-product of irrigation should be made available for widespread use in order that the benefit derived from the investment of public funds in the projects may be shared by the largest

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Ground Water

THE water supplied by rain and snow is disposed of in part by evaporation from the surface, in part by running down the slopes, and in part by sinking underground. The last is called *underground water,* or simply *ground water.* All the water below the surface of the earth is called *subsurface water,* to distinguish it from surface water and

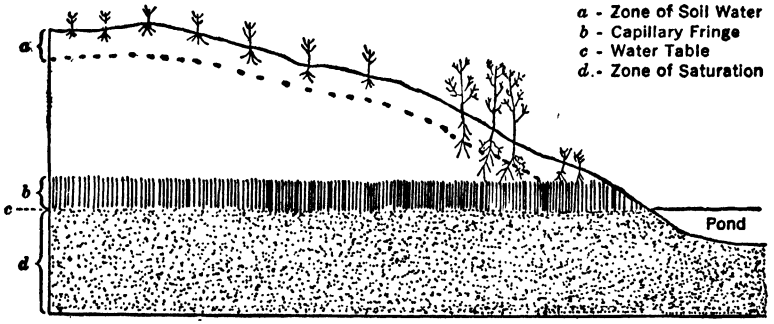


FIG. 116. SKETCH TO SHOW WATER UNDERGROUND.

atmospheric water. That part of the subsurface water which is in the zone of saturation is the ground water. The subsurface water above the zone of saturation is called *suspended water.* The suspended water is held up against gravity by molecular forces and is literally suspended. The water that supplies springs and wells is the ground water and comes from the zone of saturation. If a well is sunk, its walls may be moist at various levels above the water table, but not until the well enters the zone of saturation does water flow into it and become available for use as a water supply.

The proportion which percolates into the ground varies greatly, depending upon the amount and the rate of the rainfall, the steepness of the slope, the dryness of the air and of the ground, the porosity of the soil and rock, and the amount and type of vegetation.

Considering each of these factors, we find that if the rainfall comes as long-continued light precipitation, more water will pass underground than if there is heavy rainfall. The percolating process is always slow; if the precipitation comes as a downpour, less will have a chance to soak through the soil and rocks.

Precipitation falling on a surface which has a steep slope will run off in greater proportion than the amount which evaporates or sinks into the ground. Rapid runoff gives little time for percolation or for evaporation.

If the air is dry, a larger proportion of rain will evaporate than run off or sink in. This is particularly conspicuous in an arid region, for the evaporation rate may at times almost equal the precipitation. Snowfall may disappear in such regions by evaporation, even though the temperature is below the freezing point of water.

Compact soils or rocks can take water less readily than open or loose materials. Furthermore, porous materials have greater space between the constituent parts in which to hold water. When the ground is frozen, there is less porous space, and surface water, even though it is not frozen, is able to penetrate but slightly.

Vegetation retards the flow of the surface water and holds it longer on the surface. As a result there is more time for the water to sink in. These factors separately and in combination determine the amount of ground water.

Movement of water underground

In its underground journey water sinks through all pores and cracks. Since the cracks may go in all directions, water descends not only vertically but in oblique directions as well. This descent continues as long as there are pores or cracks not already filled with water. The smaller these cracks or pores become, the more difficult it is for water to seep through, for, if these openings diminish by one half, the difficulty is more than doubled. The greater the distance from the surface, the smaller are the openings through which the water can pass. The

absolute limit to which an appreciable amount of ground water (in the usual definition of the term) can descend is about six miles. The pressure of the overlying rocks makes it impossible for appreciable openings to exist beyond that depth. However, most of the ground water occurs within a few thousand feet of the surface. This latter statement has been verified by the fact that in deep mines little or no water is found below a few thousand feet.

Ground water movement

Ground water is in constant but very slow movement. When wells are pumped dry, they will fill up again. When mines are pumped dry, they will refill again, and constantly flowing springs are seen.

There are many reasons for the movement of ground water. The two principal forces are gravity and molecular attraction. Gravity is the force that causes water to percolate from the surface into the earth. It is also the principal force that causes water to seep out of the earth in low places, to enter wells, and to flow from springs. Water moves in a system of rocks with interstices very much as it does in a system of waterworks. In rocks with large openings, comparable to the mains of a waterworks system, gravity is the controlling force. In rocks with small or very small interstices the force of molecular attraction becomes effective. The attraction of the walls of the interstices for adjacent molecules of water and the attraction of molecules of water for one another is most significant in the latter type of rocks. These two forces continuously operate to cause a movement of ground water.

In addition there are many other forces. Rainfall is not evenly distributed. A heavy shower in one area fills the soil and rock interstices more or less completely with water. In that area the water surface is raised temporarily. The water then will tend to flow in all directions to places where the water surface is lower. The principle is similar to that of water flowing along the surface, but the rate of flow is much slower. In a region of uniform precipitation but of uneven land surface, other things being equal, the water surface is somewhat higher beneath high land and somewhat lower in the case of low land. Ultimately the water surface will become level if there is no rain; in humid regions rain is frequent, so that the water surface under the higher land rarely or never sinks to the level of the surface water under

the lower land, before it is raised again by additional rains. As a result of inequalities of rainfall and of topography, ground water constantly is moving from areas where the water surface is higher to areas where it is lower. Capillary action is continually bringing water from lower to higher levels. Some of this upward movement is aided by roots of plants.

In summary, the movement of ground water is caused by gravity, capillary action, plants, and pressure.

What becomes of water that sinks into the ground and moves about? Some returns to the surface through springs and seepages; some returns by capillary to the surface and evaporates; some is used by plants; a considerable amount is removed through wells; some enters into chemical composition with various minerals and rocks, to be held there; and some remains underground in crevices and pores.

Occurrence of ground water

The rocks which form the surface of the earth are rarely solid throughout. They have many open spaces, and these spaces are the places where ground water occurs and are the receptacles from which springs and seepage draw their supply.

There are many kinds of rocks, and their open spaces differ greatly in size, number, and arrangement, and, consequently in their ability to hold water. Most rocks have open spaces which are very small; these spaces are usually connected, so that water can move through the rock by percolating from one space to the next.

Rocks of the earth can be divided into two large classes: (1) the consolidated rock or bedrock and (2) the unconsolidated materials. The differences in these two classes of rocks are of fundamental importance in the occurrence of ground water.

Materials deposited during recent geologic time contain more water than the older formations, partly because of their position on the surface and partly because they contain more pore space, since they are uncemented or only slightly consolidated. Gravel is the best kind of formation to yield water. A coarse clean gravel has a high porosity and high permeability. It absorbs water readily, stores it in large quantities, and yields it to wells freely. Sand and sandstone rank next to gravel as water bearers. As a rule sand and sandstone formations are

more continuous and widespread than beds of gravel. They are not so favorable as gravel, for they consist of smaller particles and smaller interstices and therefore conduct water less readily and give up a smaller proportion to wells. Loess has interstices of such a size that it has a high water-retaining capacity but permits slow percolation and therefore yields its water slowly. Clay consists of exceedingly minute particles and is among the poorest as a source of water supply. Clay is so soft and plastic when wet that any openings in it are closed under even slight pressure. Shale is formed by the induration of clay or one of the clayey mixtures and is a poor kind of formation from which to get water. Glacial till, because of its heterogeneous textures, varies widely as a water bearer.

The consolidated rocks are of two kinds—those produced by solidification of molten magmas and those developed from unconsolidated sedimentary deposits through pressure, cementation, and recrystallization. Both kinds are generally broken into blocks and yield most of their water from the cracks or joints between the blocks or from porous zones and open passages developed by the decay and solution of the rocks where the water penetrates these cracks. The less thoroughly cemented sandstones yield most of their water from the original spaces between the grains; they are the most important water bearers among the consolidated rocks. Limestones yield most of their water from the openings produced by the solution of the rock. Most of the other hard rocks, such as granite, shale, quartzite, and schist, yield small amounts from joints or zones of decayed rock. Crystalline rock is notoriously poor in ground water. The individual crystals of which it consists fit snugly against each other, leaving little interstitial spaces. In the case of very ancient rock the cracks and joints are more or less plugged up with precipitates of solid mineral matter.

Thus rocks, as reservoirs of ground water, vary among the different classes and among themselves in a class. But regardless of the kind of rock, the percolation is always slow.

The relief of the land is another important influence on ground-water conditions. In a level, low-lying region, not bordered by higher land, the porous formations become filled with water nearly to the surface, and in those places there is little movement of ground water. In a hilly or mountainous region the water that seeps into the ground

percolates rapidly and will be discharged at a lower level, where the formation through which it percolates crops out. The rapid return of ground water to the surface brings with it much soluble material. In mountains and hill-country springs are more abundant than in other land, and wells are usually not needed.

Water table

The surface below which the soils and rocks are saturated with water is called the *water table.* Generally it is farther under the surfaces of hills than valleys; water at higher levels tends to migrate to lower

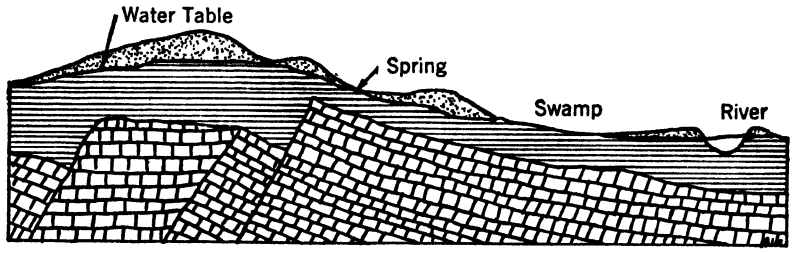


FIG. 117. PROFILE OF GROUND WATER OCCURRENCE.

levels under the action of gravity. After a heavy rain the water table rises, and in a flooded area may rise to the surface. Surface water, such as rivers and lakes, generally coincides with or passes below the water table. Drainage and drought are the two chief factors in lowering the water table in a given area.

Uses of ground water

Ground water is important in man's occupation of the earth and in his many activities connected with that occupation. (1) It is important to plants, for it dissolves certain mineral elements of plant food and then carries those elements to their roots. (2) Underground water is a source of water for springs and wells. (3) Ground water produces changes in the rocks that are unaffected by surface waters.

The amount of ground water in an area is an important factor in determining the flora. Crops depend in a large measure on the retained ground water, that is, the water that is not available for wells and springs. The depths to which roots of plants go for water vary

greatly with different kinds of plants, with different kinds of soil, and with moisture conditions. The root system of an ordinary plant includes a large number of fine rootlets that penetrate all parts of the soil from which the plant draws its water supply and dissolved mineral matter. Large trees and certain types of deep-rooted desert plants draw water from considerable depths. There is evidence that a certain type of mesquite obtains its water from depths as much as 50 feet below the surface, and other perennials may send their roots to depths of even 60 feet.

A spring occurs when water issues through a natural opening in such quantity as to make a distinct current. In the early settlement of the United States farmsites were selected near springs, while upland areas without springs remained unsettled because of the lack of a water supply. After well-drilling machinery and pumps were invented and brought into use, the necessity of springs for homesites disappeared. Many towns and villages in Europe and eastern United States owe their immediate location to the presence of large springs. Many town names carry the name "spring." Newer communities, as with farmsites, lost their dependence on springs after the introduction of well-drilling machinery.

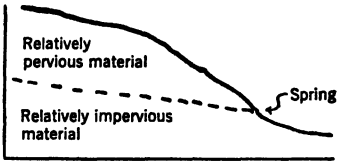


FIG. 118. CROSS SECTION OF A SPRING.

In arid and semiarid regions springs assume a great importance. Travel routes follow lines of springs, and stopping places are determined by the presence of such a water supply. These springs are commonly found at the bases of cliffs, which border the higher elevations such as mesas, plateaus, or mountains. The disappearance of a spring for a short time may cause not only inconvenience but often fatal accidents. The United States Geological Survey is now showing springs on its maps, indicating their importance.

Water may seep through rocks containing sulphur, iron, or some other minerals in soluble form, and issue out as mineral springs. With excellent advertising such springs may be commercialized and reap high returns from the waters for their supposed health benefits. At some parts of the world the waters may be heated below the surface

and issue out as "hot springs." Many world famous resorts have been built around such springs.

If the water from a well rises and overflows, the well is said to flow. Flowing wells in that respect are like springs, but they differ in that openings for springs are natural, while for artesian wells they are man made. The name *artesian* was derived from a well with such characteristics at Artois, France. At the present time the term "artesian well" is often applied whether the water overflows or not.

Artesian areas are found in many parts of the world. The artesian area covering the eastern parts of North Dakota and South Dakota illustrates the conditions essential for all such regions and the use of underground water as an important resource. The water-bearing

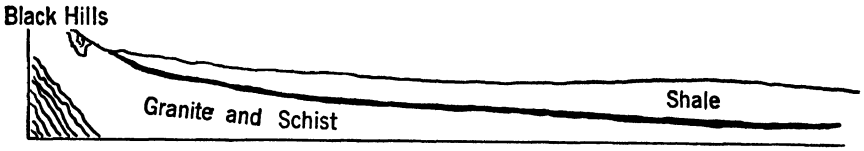


FIG. 119. CROSS SECTION SHOWING ARTESIAN WATER CONDITIONS. The solid black line is the water-bearing stratum.

stratum is the Dakota sandstone, which is a porous layer of 100 or more feet in thickness. This stratum comes to the surface at the Black Hills and at the foothills of the Rocky Mountains. Water seeps into the exposed end of the stratum and then moves underground eastward through the sandstone. The Dakota sandstone is overlaid and underlaid with impervious strata. The gradual slope of the porous stratum carries the water to the eastern part of the two states and gives pressure to the water. Wells drilled into the sandstone have had water flowing from them for many years. The farms and communities in that area receive some of their water supply from artesian wells. This supply is convenient, inexpensive, and wholesome. Until two decades ago the water was abundant, but with an increased number of wells the flow has been decreasing. Legislation has been passed to attempt some conservation. The water in the sandstone has been accumulating for centuries and will require many centuries for enough to accumulate to restore the water that has been taken from the stratum.

Wells

The presence of ground water is a source of domestic water supply to a large percentage of the world's population. A well dug below the water table insures a source of water as long as the water table is not appreciably lowered. Since the water table rises and falls with changes in rainfall, the supply of water varies with, but lags behind, the rainfall changes, for it takes some time for the water to seep through the ground. A drought will make shallow wells go dry, and a prolonged drought may affect the deepest wells.

The depth to which wells must be dug to insure a supply of water depends upon the climate, the topography, and the porosity of the rock strata. In humid regions shallow wells are adequate, while in arid regions even the deepest holes may produce no water. Wells must be deeper on hilltops than in valleys. If a porous layer rests on an impervious stratum, the water supply is more constant than in many other places.

Care should be taken to keep the wells from becoming polluted. Surface water may run into the well, or a source of pollution may readily drain into the well. Even if a well is located on a hilltop, the subsurface stratum may slope downward to the water table and carry pollution into the water. Pollution of wells, carelessly or ignorantly located, has been the cause of much difficulty.

Underground solution

The movement of water underground is accompanied by a slow decomposition and, to some extent, disintegration of the rocks through which the water passes. Carbonic acid gas and other substances carried by the rock aid in rock solution. All water that enters into the ground and comes out again carries a varying amount of dissolved mineral. While ground water tends to make rocks porous where it dissolves mineral matter, it tends to make them compact where it deposits the mineral matter which it holds in solution; this deposition may be in pores or cracks. In some places dissolution may be more effective, and in other places there will be deposition. In general, ground water probably increases porosity of rock near the surface and especially above the ground water surface and increases its compactness at greater depths.

The effect of deposition is in some cases to cement loose parts of rock together. Thus sand may be cemented into sandstone, and gravel into conglomerates. Rocks vary in their content of soluble minerals; limestone is the most soluble of all rocks. In a limestone country, such as that part of Kentucky near Mammoth Cave, much of the water sinks into the earth; there are few streams because the drainage is mostly underground. The surface water runs into depressions, where it sinks into the ground, and it may emerge as a spring some distance from where it submerged. In such areas caves are common, for erosion is taking place under the surface rather than above the ground. Gradually the surface of the land is worn down, and in time the caverns may become partly exposed. Later the underground water becomes a surface stream as the roof of the cave disappears. Natural bridges then occur, for a part of the wall and roof of the cave is firmer than the rest and remains standing as a bridge across the valley, the last remnant of the old cavern. Every particle that the underground water carries away in solution weakens the entire mass, and in time the whole structure may fall. As the water moves, it comes in contact with many minerals which combine with the water or with carbonic acid gas, oxygen, or other elements carried by the water, and a change is produced in the mineral. The changes that take place are complex. Minerals which before the change were not soluble may become so, and the water is then able to carry them off in solution.

Summary

Ground water is essential to plant life; it determines, in part, the character and density of flora. Since domestic water supply is always necessary, ground water affects human occupation by supplying springs, artesian wells, and wells. Ground water slowly, over millions of years, has removed soluble minerals, replaced old constituents with new, and favored chemical combinations in the rock.

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Man and Water Supply[1]

THERE are many factors in the physical environment of man, and, while some of them, such as land surface, location, and climate, must be given a large place in the study of geography, there are many others with which mankind has to cope that ought not to be neglected. This paper discusses briefly one of these, the domestic water supply.

Water is one of the most important natural resources in the world. In the humid regions it has always been made so easy for the householder to obtain water that he gives little thought to its value; waste frequently marks the daily use of this commodity. It is almost axiomatic to say that in the early history of the race mankind's first care when he founded a settlement was to have a water supply. Towns and villages were built around springs and water courses, and a common engineering feat among ancient peoples was the construction of aqueducts. Today mankind occasionally builds villages and cities far from any visible supply of water, and increases city population first, seeking water afterwards, because he feels confident that water can be brought to him.

A few centuries ago no one would have dared to found a colony in northern Chile or in central Australia, but now Iquique, a city of 45,000, flourishes on the arid Atacama, and Kalgoorlie and Coolgardie are located in the very center of the Australian desert. Iquique brings its water from Pica, a distance of 88 miles.

When gold was discovered in the Australian desert in 1892 and the towns of Kalgoorlie and Coolgardie were founded, the district was

[1] Adapted from Robert M. Brown, from the *Journal of Geography*, Vol. 32, No. 6, published by the National Council of Geography Teachers.

practically waterless. For a while the railway transported water at a cost of $5,000 per day. In 1903, a water line was completed from the Darling range, 350 miles away. The water had to be elevated 2,000 feet, but all engineering difficulties were surmounted and a delivery of 8,000,000 gallons daily resulted. So long are the pipes that they contain

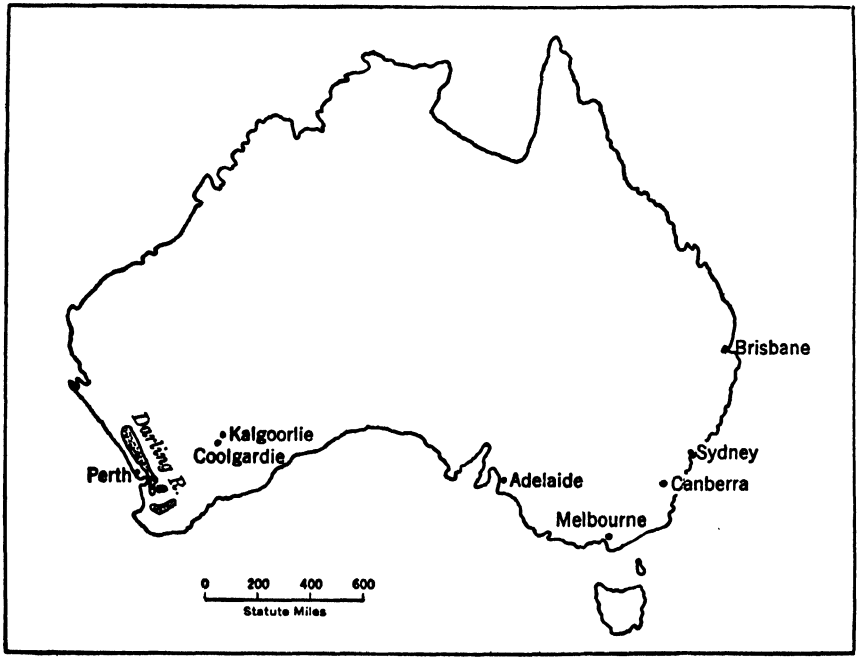


FIG. 120. SKETCH MAP OF AUSTRALIA.

a month's supply of water; in other words, the water takes one month in traveling from Mundaring to Kalgoorlie.

Water as a means of transportation and as a source of power has been the chief concern of humid-area people. It is generally known, although somewhat academically, that in arid and semiarid areas water is useful and even essential for irrigation. But as a prime necessity for domestic purposes, the use of water is generally accepted as a gift of nature which is constant, abundant, and never failing. The struggle of densely settled areas to get water enough is rarely appreciated by the householder, although reports of plans to increase the supply are constantly before him and large sums of money are voted for water systems.

Nevertheless, the acquisition of enough suitable water to serve our large cities is in many cases a struggle of considerable magnitude, and any defection of the regular supply would result in a serious calamity.

Water supply in humid areas

New York City consumes on the average 126 gallons of water a day per capita, and her 6,900,000 people use approximately 936 million gallons a day. The New York system is able to yield about one billion gallons of water daily, so that the demand for water seems to be somewhat less than the supply. But if one considers that the city has increased in population in the decade ending in 1930 by 1,300,000, and in the decade ending in 1940 by 480,000, with a new demand for water of nearly 20,000,000 gallons daily, he will see that in a few years the entire available supply may be used up. The city is already facing the problem of increasing the watershed, and the new Delaware River system is scheduled for completion in 1942. Nearly all large cities in the area between Boston and Washington face similar conditions, generally of less magnitude, but nevertheless of supreme importance to increasing urban populations.

Most of these cities use surface drainage from small streams, and so nearly do the cities and towns in this region use all the water provided by the Boards of Water Supply that an extended period of drought as in the summer of 1930 causes a scarcity of water. One may recall the orders to discontinue watering lawns and washing automobiles. In places schools have been closed, Monday washing banned, and tub baths limited, while in many country places water had to be carted from distances. Such contingencies teach us that our water supply is a resource that should be conserved.

If, however, we turn to another type of city, those whose water supply environment includes the Great Lakes or a large river, we find an ample supply of water. Cities in this class include Detroit, Cleveland, St. Louis, Chicago, and New Orleans.

Water supply in arid areas

Farther west is the arid and semiarid zone, and the water supply problem becomes acute again. Los Angeles had a population in 1930 of over 1,238,000; in 1920 of over 576,000. The city had increased 114

per cent in ten years, growing four times as fast as New York City, which increased in the same period by 23 per cent. In 1940 the population was about 1,496,000. Los Angeles outgrew its local supply of water in 1914, when the city's population was about 250,000, and it tapped the Owens River, 250 miles away, approximately the distance from Boston to Lake Ontario. Then the Owens River became inadequate, and Los Angeles obtained water from the Colorado River by a 392-mile aqueduct. This was completed in 1941 at a cost of over $220,000,000.

The use of water is a big question in all the Southwest, and the Colorado River appears to be the normal source of supply for many communities. However, a rather serious problem arises. Irrigation is necessary for all the land of the lower and upper basins of the river, and any diversion of water must necessarily limit the extent of irrigable lands. Here the use of water for domestic supply conflicts with other uses of the water, and controversies have arisen and will arise in the face of growing populations which will not be easy to solve.

The purification of the water supply

A few years ago the water supplies of many localities were subject to pollution and thus became the carriers of disease. Cities such as Philadelphia, St. Louis, New Orleans, Jersey City, and many others suffered from scourges of typhoid fever. Process treatments, settling, filtering, and sterilizing have been inaugurated and have overcome this defect of the water supply environment, and now water from nearly every source is rendered palatable and safe. In general, water supplies in the United States can be practically absolved as carriers of diseases today, and one great danger in traveling and segregation has been eradicated.

Another characteristic, the hardness of the water supply, affects certain industries. Water is hard if it contains such salts of the earth as sulphate of lime, carbonates of calcium, and the like, and, while hard water may occur anywhere, it is common in limestone areas and in close proximity to the sea. Hard water demands a softening process before the proper detergent action of soap can be brought into play. The advantages of soft water are as follows: it reduces the use of soap in laundries and in silk dyeing; it is favorable to operations of power houses, breweries, and photographic establishments; and it lessens scale

in boilers and the corrosion of boiler tubes. The Water Supply Board of New York City states that the Catskill water is well suited for business and household purposes, and this means the aggregate savings of hundreds of thousands of dollars affecting many classes of consumers in Greater New York.

34

Oceans and Coasts

OCEAN basins form one of the two divisions of the relief features of the first order of the earth, the other being continents. The total water area of the globe is about 140 million square miles, or 71 per cent of the total surface of the earth. Of this 71 per cent, 43 per cent lies north of the equator, the rest south.

The oceans lie in the great depressions in the surface of the lithosphere. The diagram below suggests the real shape of an ocean basin, which is, in general, of slightly convex curvature. The surface of the

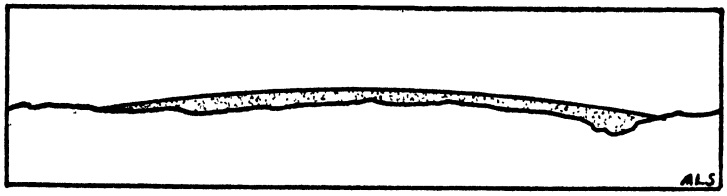


FIG. 121. FORM OF OCEAN BASIN (EXAGGERATED).

water in these basins is even and is usually spoken of as level. In reality it is a curved surface, with its curvature nearly that of a sphere.

Topography of the bottom

The surface of the land is made rough and uneven in various ways, especially by running water and winds. Most of the sea bottom is comparatively flat and unlike the land; the difference between the topography of the land and that of the sea bottom is due largely to the fact that the agents of erosion do not affect the latter.

In spite of the general flatness of the sea bottom, it has many irregu-

larities consisting of rises and basins; these irregularities are much larger than is usually thought. The great rises, such as the Mid-Atlantic Rise and the Easter Island Rise, are as large as whole continents, such as South America or Africa. The basins which flank these elevations are of continental extent. In addition, there are other features of the sea bottom, such as volcanic cones, valley-like depressions, steep slopes, and great ridges.

Some attempt has been made to work out the contours of the sea bottom in the same way that the land elevations are surveyed; these contours are called *isobathic contours.* The areas enclosed between the successive isobathic contours are now estimated as follows:[1]

Between shore and 200 meters[a]	30.60 mill. sq. km.,[b]	or	8.4%
Between 200 and 1,000 meters	16.40 mill. sq. km.,	or	4.4%
Between 1,000 and 2,000 meters	18.05 mill. sq. km.,	or	4.9%
Between 2,000 and 3,000 meters	36.45 mill. sq. km.,	or	9.9%
Between 3,000 and 4,000 meters	79.01 mill. sq. km.,	or	21.7%
Between 4,000 and 5,000 meters	112.72 mill. sq. km.,	or	30.8%
Between 5,000 and 6,000 meters	66.88 mill. sq. km.,	or	18.4%
Beyond 6,000 meters	5.38 mill. sq. km.,	or	1.5%

[a] One meter equals 1.0936 yards.
[b] One square kilometer equals 0.3861 square miles.

The ocean basin is not a succession of isobathic contours of increasing depth, as is sometimes supposed, with the center of the ocean having the greatest depth. It is impossible to draw up a principle stating that all mountains are to be found in the center of a continent. The same thing is true for ocean depths. The greatest depths are to be found far removed from the middle part of the great oceanic basins and by contrast are located near the bordering lands. In the North Atlantic Ocean the greatest depths are associated with the Great Antillean Arc; in the South Atlantic with the Patagonian Arc; in the Indian Ocean with the Java-Sumatra Arc; and in the Pacific Ocean they are along the island-studded ridges of the continental borders of the ocean. In general the isobaric contours have a steeper gradient on the continent side and a more gradual slope on the oceanward side.

Temperatures of oceans

The temperatures of the ocean are due to the intensity of the sun's rays, to volcanic disturbances, and to adiabatic cooling and heating.

[1] Taken from the National Research Council, Bull. 85, p. 15.

The surface temperatures vary considerably with the seasons. During the summer months there may be a very warm layer floating over the deeper colder water, while in winter there may be a layer of cold water floating on warm water of great density; below this warm layer the temperature gradually decreases with the depth. The waters in the tropics may have a surface temperature as high as 80° F., and at the bottom it may be 30° F. In the northern part of the Pacific Ocean the extreme variation will be less than 35° F. throughout the entire mass.

The ocean has been referred to as a great regulator of climates and weather. The lands which lie near oceans, and especially those on the west sides of continents in the westerly wind zone, do not have the extremes of heat and cold which characterize continental interiors. Since the surface waters of the oceans contain enormous amounts of available heat, they exert a steadying and moderating effect on the climate of the world. It takes more than 3,000 times as much heat to warm a given volume of sea water one degree as to warm the same volume of air at sea level one degree.[2] The oceans take in and give off heat slowly and regularly.

Inorganic substances found in the oceans

One hundred pounds of average sea water contain nearly three and one half pounds of dissolved mineral matter. More than 75 per cent of this is common salt, but nearly all other substances found in the earth's surface are present, most of them in very small quantities.

The sea is the greatest potential source of raw material known to man. Many things necessary for his material existence come from the sea, and further experimental work which will reduce the cost of production will greatly increase the present and potential use of products from the ocean.

A good many speculators have from time to time proposed that the sea be forced to give up its gold. It has been calculated that a cubic mile of sea water contains more than 93 million dollars in gold and 8½ millions in silver. However, it has been estimated that it would cost four to five thousand dollars to obtain five dollars worth of this gold and silver from the sea.

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[2] C. E. P. Brooks, *Monthly Weather Review*, U. S. Department of Agriculture, 54: 241–253.

THE APPROXIMATE COMPOSITION OF SEA WATER[8]

Constituent	Concentration—Milligram Atoms per Kilogram of Sea Water
Chlorine	535.0
Sodium	454.0
Sulfate	82.88
Magnesium	52.29
Calcium	10.19
Potassium	9.6
Carbon dioxide	2.25
Bromine	0.81
Strontium	0.15
Aluminum	0.07
Fluorine	0.043
Silicon	0.04
Boron	0.037
Lithium	0.015
Nitrate	0.014
Iron	0.0036
Manganese	0.003
Phosphorus	0.002
Copper	0.002
Barium	0.0015
Iodine	0.00035
Silver	0.0002
Nitrite	0.0001
Arsenic	0.00004
Zinc	0.00003
Hydrogen ion	0.00001
Gold	0.00000025

The chief mineral now taken from the sea is salt. On many islands, such as Turks and Caicos in the West Indies, salt production is the chief industry. Weather permitting, some islands produce from 50,000 to 60,000 tons a year. Rain means delay or ruin for the islanders if it comes when the salt is in the evaporating ponds. The salt-making process is primitive. Sea water is let into large lakes by gravity. As evaporation progresses, the water, from time to time, is let off into lower ponds and basins. As the drying continues, the resultant salt is raked into glistening rows to drain and dry further until the process is completed, when the various grades of table, industrial, and fish salt are separated. The finished product usually is warehoused to protect it

[8] The above table was compiled by T. G. Thompson and R. J. Robinson, of the Oceanographic Laboratories, Univ. of Wash. Taken from the *National Research Council Bulletin*, No. 85–86, p. 114.

from absorbing moisture during the following wetter months. Shipments are made throughout the year. The salt beds which are found in many places on land are old salt lake beds which were cut off from the sea by changes in level and by the evaporation of the water. Such beds are to be found near Syracuse, New York, Salzburg, Austria, and Kraków, Poland.

Life in the sea

The oceans are very definitely connected with the problem of the origin of life. Many of the most primitive forms are found in the oceans today. When these primitive forms developed, some of them left their original homes for the fresher inland waters, the land surface, or in time the air. In contrast to the air and the land surface, the ocean contains living organisms throughout the whole extent, from the low latitudes to the high latitudes, and from the surface to a depth of six miles. These organisms are of simple structure and are not able to withstand extreme conditions.

In many ways the life of the sea is in strong contrast with that of the land. The most familiar plants are fixed in position, but many sea plants float. Most land animals are free to move about, while many of those of the sea, such as polyps and barnacles, are fixed throughout most of their lives. There are a great many varieties of plants and animals, and the largest modern animals (whales) live in the sea. Many plants, too, are of great size. Some seaweeds are six inches in diameter, and some have a length as great as that of the tallest trees. They are not so bulky as large trees, and the amount of solid matter is much less.

The temperature, the depth, the clearness, the saltiness, and the quietness of the water all influence the life which it contains. The depth of the water affects the distribution of plants and animals which live on the bottom, but it has little effect on those which float or swim near the surface. The most important influence has to do with light and oxygen.

The pressure of the water at the bottom of the ocean is very great (at a depth of one mile it is one ton to the square inch), and the animals living there can withstand it because their bodies are full of liquids under the same pressure. A deep-sea animal brought to the surface

will explode, and, even when it is brought slowly, it will frequently explode near the surface.

Fish are a universal and important food, especially to those nations which cannot afford to give up the land necessary to raise animals for food, as well as to those where religion forbids the taking of animal life. As an example, Japan leads the world in the total annual value of fisheries, and in China, while accurate figures are not available, the catch and consumption of fish is enormous. In general, fish play an important part in the diet of rice-eating peoples.

While a considerable supply of fish is obtained from some rivers and lakes for local use, they are of little significance compared with the supply from the ocean. The important fishing areas are located near the coasts on the continental shelf or submerged platforms called *banks*. In general, fishing is limited to those waters with a depth of not more than 1,000 fathoms (a fathom is 6 feet), and the greater part of it is done in much shallower depths. The shallower water conserves the microscopic algae and the plankton which are a supply of food for the larger fish. When the algae and plankton die, they gradually drop to the bottom. If the water is shallow, the algae and plankton are available for more fish, and, also, in time of storm that which has dropped to the shallower bottoms is stirred up and becomes available again for food. Cooler waters retard decay and thus help keep the food supply, whereas in warmer water it soon turns largely to gas.

The outstanding fishing areas of the world are: (1) the offshore banks from New England to Newfoundland, (2) the coasts of northwest Europe, including the North Sea, (3) the coasts of eastern Siberia and the Japanese Islands, and (4) the Pacific region from Alaska to California. In general, most marine fishing depends on the existence of extensive shallow waters offshore to serve as feeding and breeding grounds for large numbers of fish and convenient harbors for fishing boats. Nearness to large centers of population is less important than formerly, because of present-day facilities for transportation and refrigeration.

The chief problem in connection with fishing is the preservation of the catch. Probably the oldest method in use is that of salting and drying. This is applied especially to cod, haddock, hake, and other

larger fish. The amount that is canned is increasing year by year and applies especially to salmon, herring, tuna, and shellfish. More fish are preserved at the present time by freezing than by any other method. In a frozen state they can now be shipped to almost any part of the world. The quick-freezing method has greatly aided the fisherman.

Ice

The accumulation of great amounts of ice and the movement of such glaciers over the land has already been discussed in a previous chapter. We find that ice, likewise, has had certain and definite effects in oceans. As the ice is piled up on the land, there is a decrease in the amount of water in the oceans, causing an appreciable drop in the sea level. As the ice melts, that water is returned to the basins, with the corresponding rise in the sea level. It has been estimated that the melting of the Greenland ice cap alone would return to the ocean a volume of water sufficient to raise the level some 20 feet.

During the glacial periods the ocean basins were modified, and then, with the increased erosion taking place on the land there was an encroachment of the land on the sea. The material that was carried by the glacier may have modified the ocean itself by the deposition of the material in the basin, or it may have produced changes by modifying the coast line.

Ice also affects the temperature and salinity of the sea. Water near ice caps is fresher and cooler than water some distance away. Ice is furthermore a significant modifier of the world's commerce, forming impenetrable barriers. Shipping lanes in the North Atlantic change from winter to summer because of the floating ice that reaches into the northern lanes. The International Ice Patrol Service was established in 1913 after the Titanic disaster. The United States Coast Guard cutters carry out the work, and the expense is divided among the signatory powers in proportion to the amounts of their respective ship tonnages. A continuous patrol is maintained during the period of ice danger. The patrol maintains contact with the limits of the ice as it varies its position throughout the season and reports this information to all approaching ships. In addition, it makes scientific observations relating to the sea and thereby has increased our knowledge, insuring means of greater safety for life at sea.

Movements of sea water

Because of the mobility of their waters, the oceans are in a constant state of motion. These motions are caused by differences in salinity, differences in temperature, differences of level, winds, attraction of the moon and the sun, and such occasional disturbances as earthquakes and volcanic eruptions. Differences in salinity and temperature produce unequal densities and thereby set up motion tending to equalize the differences. The inequalities of level are produced by the discharge of rivers at their mouths, by unequal rainfall, by unequal evaporation, and by winds. Winds produce a drifting movement of the surface waters in one direction. This steady movement in one direction necessitates a return movement at some other place. All bodies attract each other in proportion to their masses and inversely as the squares of their distances. Thus the moon and the sun attract and disturb mobile surfaces such as water. Waters near coastal lands are frequently and severely affected by movements of landslides, volcanic eruptions, and earthquakes. The movements that result from these causes are waves, tides, and ocean currents.

Waves. The waves of the ocean, although the most obvious of its motions, are quite superficial, affecting merely the surface layers. They are chiefly important for the part they play, after they have "broken," in the actual shaping of the coast line. It is a matter of common observation that ordinary waves are due to the agitation of the sea by the wind, but any mechanical disturbance of a body of water will set up a rhythmic or wave motion. The large-scale oscillations are miscalled "tidal waves," and they are due to displacements such as earthquakes or volcanic eruptions. Occasionally the surface of the ocean is smooth and glassy, and yet it will show long, slow undulations. These are "swells" and usually represent waves caused by distant storms. The shortest waves are usually found where there is an actual movement of the water contrary to the direction of the wave impulse, giving a "choppy" sea.

Tides. Tides differ from waves in that they have a cycle of about half a day, whereas the cycles of waves are measured in seconds or minutes; waves are a surface phenomenon and affect only a relatively shallow layer of water, while tides move the whole mass of water from

top to bottom. Waves are caused by wind and weather, while tides are produced by the sun and moon. The most important difference between tidal and other movements of the ocean is in the periodicity. Tides may be predicted accurately for years in advance.

Tides are due to the combined effect of the tide-generating forces of the moon and the sun, which reinforce or partly neutralize one another

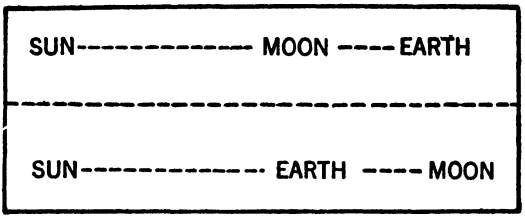


FIG. 122. POSITION OF SUN, EARTH, AND MOON AT SPRING TIDE.

according to their position. The most favorable position results in what is known as the *spring tide,* and the most unfavorable position is called a *neap tide;* each of these occurs fortnightly. The tide-raising force is at a maximum when the sun and moon are immediately oppo-

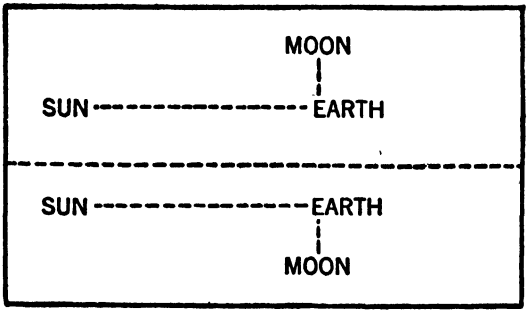


FIG. 123. POSITION OF SUN, EARTH, AND MOON AT NEAP TIDE.

site the earth, and at the antipodal of this position. The tide-raising force is at a minimum when the attracting force is on the horizon.

The attraction of any heavenly body on the earth's surface varies directly as its mass and inversely as the cube of the distance from the earth. The moon plays the leading role in bringing about the tide, since its force is about twice that of the sun.

The rise and fall of the tides at any place varies in accordance with the changing positions of sun and moon relative to the earth. The tides, in addition, vary widely from place to place in regard to time, range, and other characteristics. With a knowledge of local variations, the tides at any given place can be predicted as far in the future as may be desired. In predicting tides the times and heights of the high and low waters are given.

The possibility of utilizing the energy of the tides for the generation of power has often been discussed. There are old tide-mills which are turned directly by the ebb and flow of the tide instead of by a river. Such a direct use of the water gives feeble results. Another device is the use of a float, geared to machinery, which rises and falls vertically in a chamber to which the tide has access; air is compressed in a closed chamber entered by the tide, and work is done by the air on re-expanding. Both of these methods give very small horse power, and no power is available at slack water. In the third method a high-level basin is filled at very high tide, and this maintains a constant head of water which drives a turbine engine. Perhaps in time the energy of the tides will be used more completely than at present.

The tide is also an agent of geological change. The zone between low water and high water is the scene of continuous warfare between land and sea. The actual wearing away of the land is the work of the waves, while tides extend the area over which waves may carry that erosion. In bays and in sheltered tidal waters where tides attain a high velocity, sand and other materials are moved. Tides also assist in removing into deeper water debris that has been carried by other agents of erosion. In many rivers, the tides bring in saline water, thereby keeping open rivers that otherwise would freeze, and thus increasing the erosional work of the stream throughout the year.

Ocean Currents. Ocean currents have no relation to tides and are the most intricate of the movements of the ocean. They have far-reaching effects in determining the distribution and abundance of marine life, and in the distribution of ocean temperatures.

The problem of the causation of ocean currents has been very keenly debated. The great voyages of exploration of the fifteenth and sixteenth centuries revealed the existence of a strong westward movement around the southeast of Africa and across the tropical belt of the Atlan-

tic Ocean. This was the first knowledge of ocean currents. The same temperature contrasts between the equator and the poles that set up the planetary circulation of the atmosphere must set up a similar circulation in the ocean water, which the air movements reinforce. Just as the distribution of land and water introduces complexity into the wind system, so, and to a much more marked degree, the opposition of the land masses introduces anomalies in the ocean current circulation. The general directions of the ocean currents are shown on the accompanying map.

There will be no attempt here to discuss in detail the characteristics of all ocean currents, but it is advisable to consider the principles of these ocean movements.

The two chief causes of the circulation of ocean waters are (1) the frictional effect of the wind on the ocean surface and (2) differences in density of the water itself. The wind affects a relatively thin surface layer; the water moves in the same general direction as the wind. Differences in density may be caused by contrasts in temperature or in salinity. Not enough data have been gathered on temperatures and salinity at various depths and different places to permit conclusions as to causes of ocean currents. However, it has been assumed that differences in temperature have more to do with circulation than differences in salinity.[4]

There is a tendency for all the great oceans, except in polar seas, to have surface circulations which resemble each other. The ocean currents of the North Atlantic may be considered as a pattern for those of the other seas.

The closed elliptical whirl in the subtropical region is a most conspicuous feature, and is called the *Equatorial Current.* The Trade Winds on the equatorward sides of the subtropical highs in both hemispheres (see diagrams 23, 24, and 25 in chapter on weather elements) tend to drive the surface waters before them. The deflective force of the rotation of the earth makes this a westward-flowing current moving at an angle to the direction of the Trade Winds. The continent of South America interrupts the westward movement, and the Equatorial Current is divided; the larger part flows northwestward,

[4] *Physics of the Earth. V, Oceanography.* Nat. Research Council, Bull. 85, Washington, D. C., 1932.

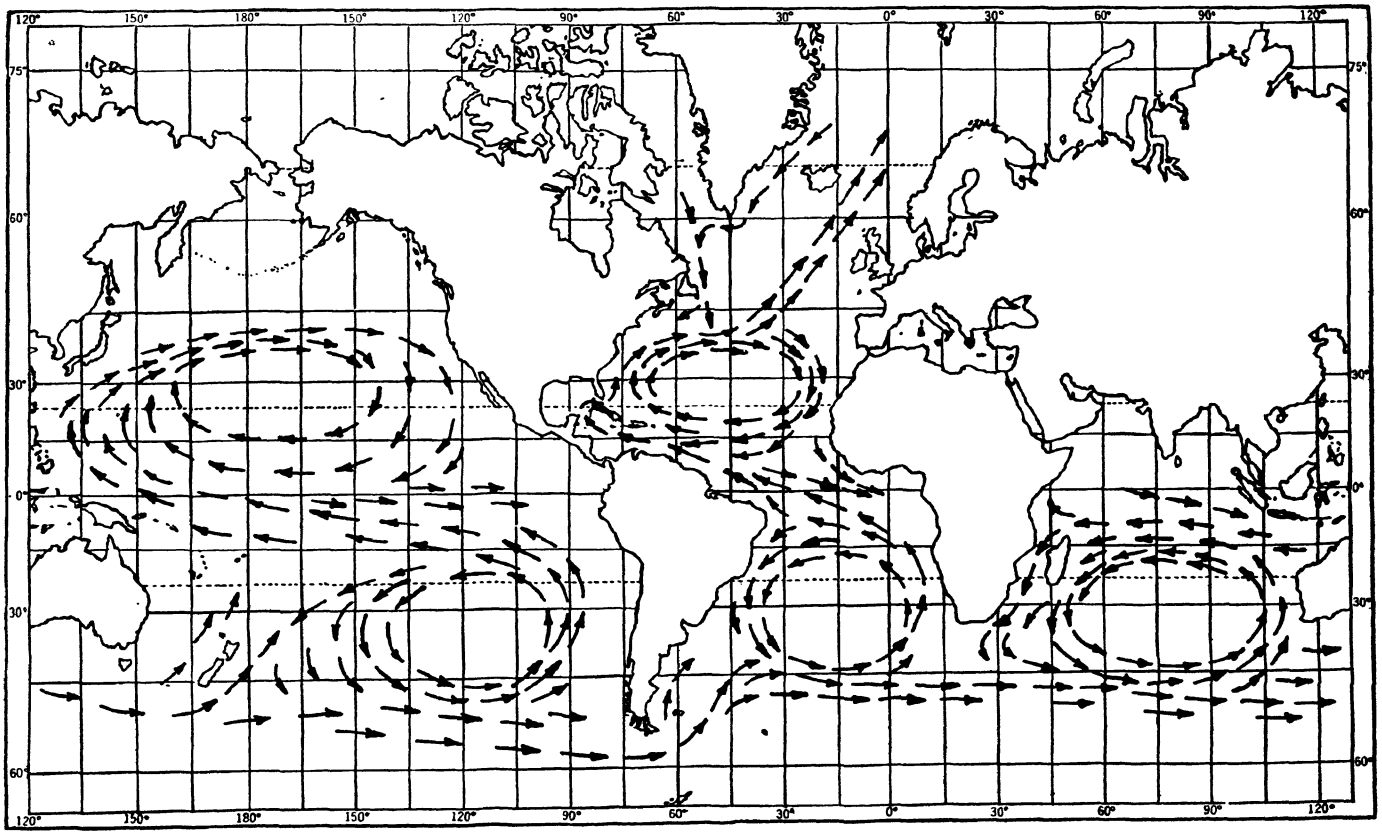


FIG. 124. PRINCIPAL OCEAN CURRENTS.

and the smaller part southwestward. A part thus enters the Caribbean Sea. The water returns to the Atlantic through the Florida Strait, and it continues eastward to form the *Gulf Stream.* In the eastern Atlantic it again divides, and part moves southward and the other part flows along the coast of southwestern Europe and forms the *North Atlantic Drift,* which flows into the Arctic Ocean. An outward surge of cold water from the Arctic Ocean compensates for the water coming from the south. The cold current from the Arctic Ocean flows along the western side of the Atlantic Ocean and is called the *Labrador Current.*

In general, relatively warm waters flow poleward and relatively cold waters flow equatorward. Cool ocean currents tend to flow along the eastern sides of continents in middle and high latitudes, while in the low latitudes the reverse is true. In certain regions, as along the coast of Peru and Chile, there may be an upwelling from depths, and this again produces cold currents.

Flotsam and jetsam of alien origin throw light on the surface circulation of the oceans. A fragment of sugar cane from the West Indies may reach the shores of Scandinavia, or a log from Siberia may be used by an Eskimo in Greenland. Such casual evidence of the direction of currents has been supplemented by the simple device of throwing bottles into the sea, with directions enclosed so that the finder will notify the experimenter as to the destination of the drift, but this method tells little as to the course of the current. Ship's captains make indirect determinations of the velocity and direction of currents that are encountered. Such rough and ready methods have been superseded by direct observation by the use of a current meter. This meter records the direction and velocity of the movement, and it can be used at any depth.

Continental shelf

The continental shelf is that part of the continent on which the shallow waters of the ocean rest. They are but slightly lower than the lowlands of many coasts and are far above the lowest parts of the oceans. They have been formed by the accumulations of sediment from the land, by the submergence of former land areas, or by the wearing down of the land by wave action.

As was stated at the beginning of the chapter, the ocean basins and the continents are the relief features of the first order. The larger part of the elevated areas is in the Northern Hemisphere, and the depressed areas are far in excess in the southern. The continental platforms are a little larger than the continents, and the ocean basins somewhat smaller than the oceans. The oceanic area is more than 143,000,000 square miles, but the area of the ocean basins proper is about 133,000,000 square miles. The discrepancy in these areas results from the fact that there is more water on the earth than the true ocean basins will hold. The excess water overflows the rims and spreads out on the continental platform. The waters which lie on the low

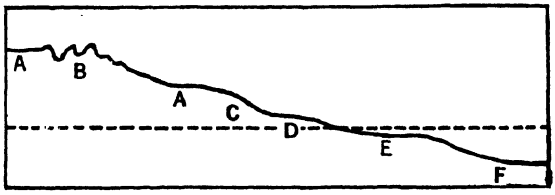


FIG. 125. DIAGRAM TO SHOW POSITION OF CONTINENTAL SHELF (GREATLY EXAGGERATED). A, plateau; B, mountain; C, fall line; D, coastal plain; E, continental shelf; F, deep.

borders of the continental platform, or continental shelf, have been called *epicontinental seas* (that is, upon the continent).

The offshore islands represent, in many cases, the higher parts of the continental shelves, while the lower parts are submerged under the water. A slight lowering of the sea or a slight elevation of the continental shelf would change the submerged part of the mainland. Such a change would not always be beneficial, as might be supposed, since it would change the economic activities of such areas and might, in many cases, even affect the climate. Such a change would most certainly affect commerce.

Coast lines

The coasts of the world present a variety of aspects. In some places are to be found an abundance of inlets, bays, and islands, and in others long stretches of unbroken coast. Some coasts are bordered by stretches of low-lying sand, and others are rock bound. Along some coasts will be found deep water, and along others very shallow water.

This variety of coast physiography is due to movements within the earth's surface; these movements have resulted in the depression or elevation of the shore line.

The land is made up of hills, valleys, plains, and other uneven features. If the land along the shore line is submerged, marked irregu-

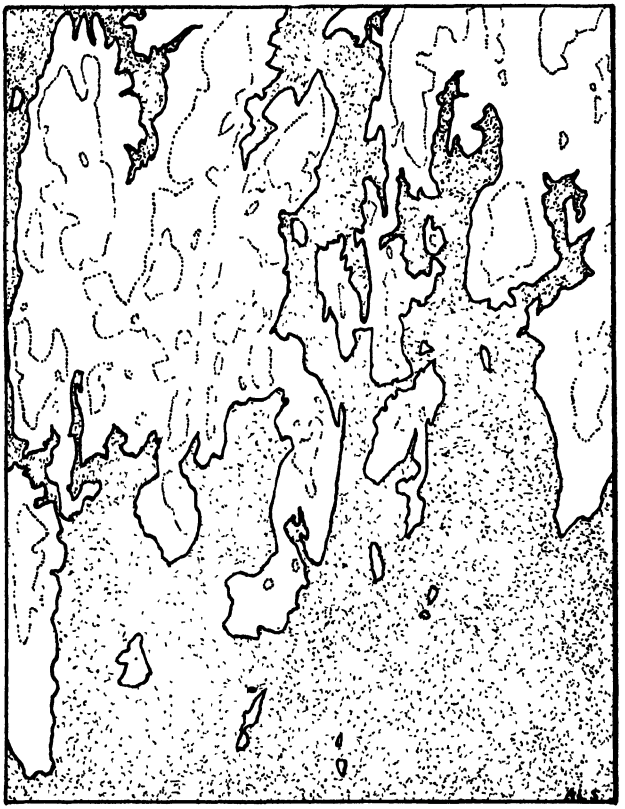


FIG. 126. SUBMERGED COAST, BOOTHBAY, MAINE, QUADRANGLE. Contour interval 100 feet.

larities are produced. When submergence occurs, the water covers the valleys, and the higher land becomes capes and promontories. Islands may be formed by the water's completely surrounding a former hilltop. If the former land were mountainous, the depressions would result in rock-bound bays. If that original shore was a plain, an entire river system might be drowned, and the former tributaries would then be independent streams and the old master stream would be an estu-

ary. An irregular coast is much better for commerce than a regular one.

When a coast is emerged, it exposes a part of the former continental shelf and results in a regular coast. Since the continental shelf is gen-

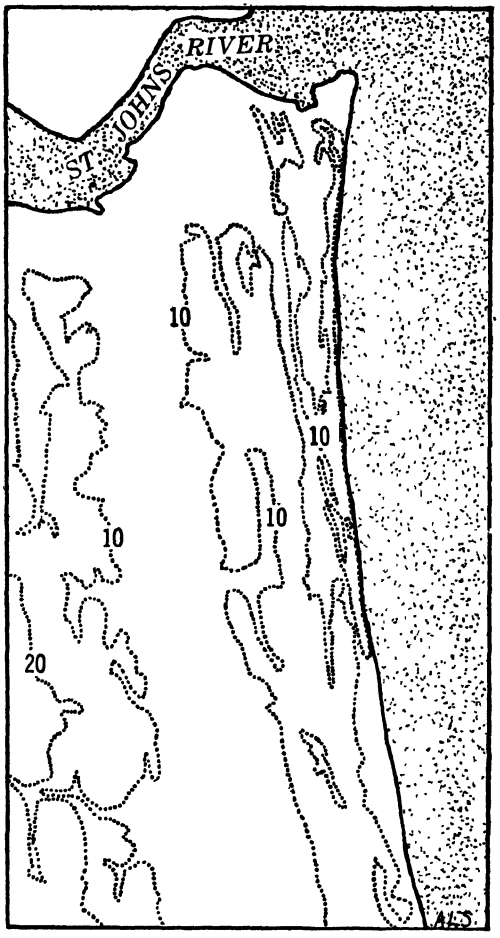


FIG. 127. EMERGED COAST, MAYPORT, FLORIDA. Contour interval 10 feet.

erally smooth and level, such a coast line tends to be regular and even, with shallow water fronting it. Such a coast has a gently sloping floor coated with clays, sands, and gravels. An emerged coast is without good harbors, except where some large river flows across the coastal plain. Large ships must anchor offshore while their cargoes are light-

ered, unless artificial harbors are provided by the construction of breakwaters or jetties.

In addition there are neutral coasts and compound shore lines. A *neutral* shore line is one that has been neither submerged nor emerged

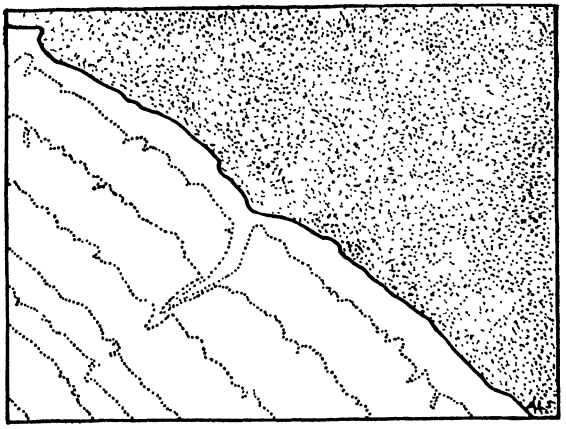


FIG. 128. NEUTRAL COAST, HONOMU, HAWAII, QUADRANGLE. Contour interval 500 feet.

but was formed in place. A *compound* shore line has traits of both emergence and submergence.

Modification of shore lines

The coast line of either submerged or emerged shores is modified by waves, shore currents, glaciers, and rivers.

Waves develop cliffs, and, with the assistance of currents to carry

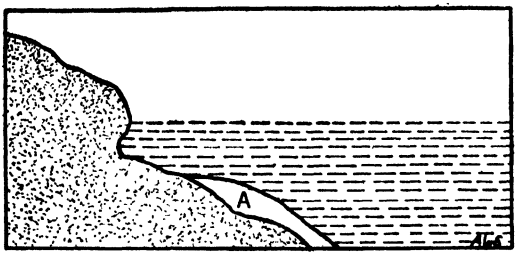


FIG. 129. CLIFF BEING ERODED BY WAVE ACTION. A, terrace built by deposition of sediment.

away debris, may remove long stretches of land. Waves are at work almost constantly on every coast line. Large waves have greater ero-

sional power than small ones; therefore wave work is influenced by the winds. Coasts exposed to stormy seas are affected more than those in quiet waters, and those of soft, loose material are eroded more effectively than those of solid rock. Also, shores which are fronted with deep water are cut more rapidly than those beside shallow water.

Shore currents, produced by waves and tides, outline the continents with long lines of barrier beaches and bars. They tend to unite promontories, to close inlets and fiords, and to replace all irregularities with curving embankments of sand. Along much of the Atlantic seaboard of the southern states of the United States are the barrier beaches formed by shore currents. These lines of sand beaches from one half mile to ten miles in width are modified by the waves on the ocean side,

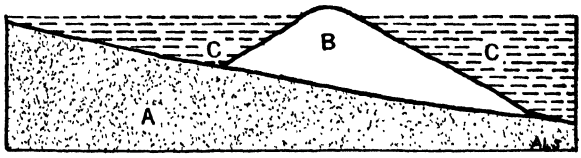


FIG. 130. PROFILE CROSS-SECTION OF A BARRIER BEACH. A, continental shelf; B, barrier beach; C, water.

and enclose lagoons back of the beach. Inlets occur through the beaches at frequent intervals. These inlets are kept open by the action of tides and rivers. Some inlets may be filled or completely obliterated by shifting mud flats.

Glaciers have had an important share in the shaping of some coasts. Glaciers are able to erode their beds even well below sea level, for their ends will not float until a depth of 600 to 800 feet is reached by an ice front 100 feet high; greater heights of glaciers require much greater depths before floating. Among the places where there is clear evidence of glacial erosion are the fiorded coasts, as Alaska, British Columbia, Norway, Greenland, and New Zealand. Here the evidence indicates that valleys whose beds were above sea level before the Glacial period were eroded below sea level by glacial sculpturing during the ice occupation. When the ice disappeared, the sea flooded the valleys and the fiorded coast came into existence. In many cases, islands front these coasts, most of them representing elevations of the old land whose surroundings have been drowned.

Winds often build sand dunes on the shore line; these may give the

land some protection from the sea, as in the case of Holland. They seldom change the shore line to any extent. Wind action in producing waves and currents is much more important.

Rivers, depositing materials that have been eroded at some distant place, may modify the shores considerably. On exposed coasts, delta building is very slow and produces few irregularities. In quiet waters of inland seas and bays the delta lands may grow rapidly. In bays,

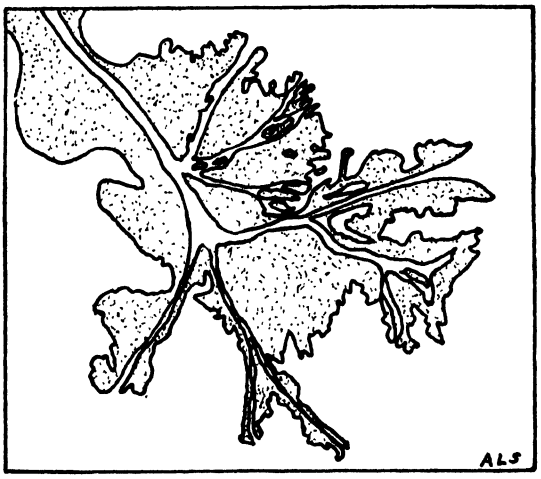


FIG. 131. MISSISSIPPI RIVER DELTA.

the rivers may lessen irregularities by filling in the indentations. The material deposited by large rivers entering bays will make such bays more shallow. The delta lands are low, marshy, and subject to annual floods; consequently their use by man is greatly restricted.

Harbors

Harbors are places where ships may lie at anchor safely and be unloaded and loaded. The value of harbors depends upon (a) protection from waves, (b) sufficient depth of water from the open sea to the anchorage, (c) freedom from ice, and (d) firm anchorage ground. Commercial harbors must have, in addition, a large and productive accessible hinterland. The above factors can be considered in evaluating and showing the significance of any harbor.

The places most suited for harbors can be classified into five groups.

They are rivers, drowned valleys, barrier beaches, atolls, and craters.

Many large harbors of the world are located at the mouths of large rivers, or some distance up such rivers. Such harbors have easy access to interior commerce, either by river navigation or by railroads, which tend to follow river valleys. Most of the conditions of harbor location given above are fulfilled in this type of harbor. However, deltas make it difficult to maintain a satisfactory depth of water to the ports. As larger vessels are built, this disadvantage becomes more and more apparent. Dredging and the building of jetties becomes necessary. In the more remote parts of the world where river transportation is the chief and frequently only means of transportation, rivers are by far the most important harbors.

Many of the most important harbors of the world have been the result of the submergence of river valleys. The Hudson, Delaware, Susquehanna, St. Lawrence, and many other considerable valleys have submerged continuation beneath the sea. The amount of sinking that the coast has undergone determines the depth of water. Such harbors are protected from waves and also have relatively easy access to the hinterland. Tides and currents may be difficult to control, and shifting sands may demand continual attention. The type of land form —plains or mountains—determines to a large extent the value of the hinterland as well as the value of the particular harbor.

Where wave and tidal action have developed barrier beaches, spits, bars, or hooks, lagoon harbors may be found. Quiet water is usually found in such harbors, and access to the hinterland is generally easy. The constant movement of sand across the entrance to the lagoon involves the expenditure of large sums of money to keep such entrances clear—frequently without success. The depth of the water is never great and may fluctuate markedly.

Atolls are rings of coral which are breached at places; coral reefs are built by polyps in warm ocean waters. While such harbors have all the satisfactory physical characteristics, they have slight commercial value, since the hinterland is never very productive.

Crater harbors are submerged volcanoes that have been breached, and they may have many natural advantages. In some cases their commercial value is very high because of the great productivity of the volcanic soil of the area in the immediate vicinity.

Artificial harbors are sometimes constructed by cities which have a great amount of ocean trade, or those that want such trade. The permanency of breakwaters which are artificially constructed is always questionable, and the cost is tremendous. Waves and tides may eliminate the efforts of man in a very short time.

Ocean trade

There is a very significant difference between ocean traffic and land traffic. The sea has a cheapness and a freedom that is unknown to large-scale land carriers. The most important difference between ocean and land transportation lies in the fact that the ocean is a highway requiring neither construction nor maintenance, and all that the navigator needs to do is to provide the vehicle. On land, roads must be built even for a pack-train. Formerly, with sailing ships even the power was provided by the winds. Because of this fundamental difference less capital is required for transporting commodities or people by sea than on land; consequently more individuals or groups of individuals can act independently than in land transportation. A single ship can be operated as a unit and have as much freedom as or more than a great line of steamers. Both the individual and the company with many ships can use the sea without any charge, can take advantage of the government surveys, and may enter any harbor. Most of these characteristics of ocean transportation are not to be found in land transportation.

Ocean trade began when the first primitive man loaded his surplus grain into a baggala and put to sea to trade with those peoples whose shores he could see on a clear day. Thus ocean trade began long after man began to travel on water.

Man's first means of water travel was perhaps on a log; then that log became a dugout canoe; and later that log was sawed into planks and a raft made of the planks. These crude means were the forerunners of modern ships. Sails soon replaced muscle power, and by the use of sails man was able to travel farther and farther. The sailing ship found its climax in the clipper ships which became famous in the early decade of the ninteenth century. In 1807, Robert Fulton put his *Clermont* into actual use, and thereby brought about the next great change in the motive power of ships. The climax of steam-propelled

ships has probably been reached in such ships as the *Queen Mary* and the *Normandie.*

By most primitive peoples the sea was considered a barrier. With the change in the mode of transportation this view changed, so that soon the ocean was thought of as a highway. The improvements in the types of ships increased commerce, and the increased commerce in turn has brought about a world community of interest. Out of this changing viewpoint has come the attitude that the ocean is an international highway for commerce and travel.

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35

Oceans and Enclosed Seas: A Study in Anthropo-Geography[1]

THE water of the earth's surface, viewed from the standpoint of anthropo-geography, is one, whether it appears as atmospheric moisture, spring, river, lake, brackish lagoon, enclosed sea basin, or open ocean. Its universal circulation, from the falling of the dews to the vast sweep of ocean current, causes this inviolable unity. Variations in the geographical forms of water are superficial and constantly changing; they pass into one another by almost imperceptible gradations, shift their unstable outlines at the bidding of the mobile, restless element. In contrast to the land, which is marked by diversity of geologic structure and geographic form, the world of water is everywhere approximately the same, excepting only the difference in the mineral composition of sea water as opposed to that of spring and stream. Therefore, wherever man has touched it, it has molded him in much the same way, given the same direction to his activities, dictated the use of the same implements and methods of navigation. As maritime trader, or as colonist, man has sailed to remote, unknown, yet familiar coasts and found himself as much at home as on his native shores. He has built up maritime empires whose dominion falls somewhere in the dividing yet uniting sea.

Man must be grouped with the air and water as part of the mobile envelope of the earth's surface. The mobility which maintains the unity of air and water has caused the unity of the human race. Abundant facilities of dispersal often give animal forms a wide or

[1] Adapted from Ellen C. Semple, from the *Bulletin of the American Geographical Society*, Vol. 40, No. 4, published by the American Geographical Society of New York.

cosmopolitan distribution. Man, by appropriating the mobile forces in the air and water to increase his own powers of locomotion, has become a cosmopolitan being and made the human race reflect the unity of atmosphere and hydrosphere.

Always the eternal unrest of the moving waters has knocked at the door of human inertia to arouse the sleeper within; always the flow of stream and the ebb of tide have sooner or later stirred the curiosity of the land-born barbarian about the unseen destination of these marching waters. Rivers by the mere force of gravity have carried him to the shores of their common ocean, and placed him on this highway of the world. Then from his sea-girt home, whether island or continent, he has timidly or involuntarily followed the track which headland-dotted coast, or ocean current, or monsoon, or trade wind marked out for him across the pathless waters, so that at the gray dawn of history he appears as a cosmopolite, occupying every part of the habitable earth.

These sporadic oversea wanderings, with intervals of centuries or millenniums between, opened to his occupancy strange and remote lands, in whose isolation and new environment he developed fresh variations of mind, body, and cultured achievements to arm him with new weapons in the struggle for existence. The sea that brought him bars him for a few ages from his old home, till the tradition of his coming even is lost. Then with higher nautical development, the sea loses its barrier nature; movements of people and trade recross its surface to unite those who have been long severed and much differentiated in their mutual remoteness. Perhaps the ensuing friction and mingling weed out the less fit variations of each and combine in the new race the qualities able to fortify a higher type of man. Not only seas and oceans, but also mountains and deserts serve to isolate the migrant people who once had crossed them; but wastes of water raise up the most effective barriers.

The transformation of the ocean into a highway by the development of navigation is a late occurrence in the history of man and is perhaps the highest phase of his adaptation to environment, because it has placed at his disposal that vast water area constituting three fourths of the earth's surface from which he had previously been excluded. Moreover, it was adaptation to an alien and hostile element, whose violent displays of power recurrently stimulated the human adjustment

between attack and defense. Because adaptation to the sea has been vastly more difficult than to the land, commensurate with the harder struggle it has brought greater intellectual and material rewards. To this conquest of the sea must be assigned a peculiarly high place in history, because it has contributed to the union of the various peoples of the world, has formed a significant part of the history of man, whether that history is economic, social, political, or intellectual. Hence history has always staged its most dramatic acts upon the margins of seas and oceans; here always the plot thickens and gives promise of striking and tremendous development. Rome of the seven hills pales before England of the seven seas.

Universal history loses half its import, remains an aggregate of parts, fails to yield its significance as a whole, if it does not constantly take into account the unifying factor of the seas. Indeed, no history is entitled to the name of "universal" unless it includes a record of human movements and activities on the ocean side by side with those on the land. For many generations our school textbooks in geography presented a deplorable hiatus, because they failed to make a definite study of the oceans over which man explores and colonizes and trades, as well as the land on which he plants and builds and sleeps.

The striking fact about the great world ocean today is the manifold relations which it has established between the dwellers on its various coasts. Marine cable, steamer, and sailing routes combine to form a dense network of paths across the vast commons of the deep. Over these the commercial, political, intellectual, or even purely migrant activities of human life move from continent to continent. The distinctive value of the sea is that it promotes many-sided relations as opposed to the one-sided relation of the land. France on her eastern frontier comes into contact with people of kindred stock, living under conditions of climate and soil similar to her own; on her maritime border she is open to intermittent intercourse with all continents and climes and races of the world. To this sea border must be ascribed the share that France has taken in the history of North and South America, the West Indies, Northern and Equatorial Africa, India, China, and the South Seas. So we find the great maritime peoples of the world, from the Phoenicians to the English, each figuring in the history of the

whole world of its day and helping weave into a web of universal history the stories of its various parts.

Man's normal contact with the sea is registered in his nautical achievements. If we enquire *where* the highest native efficiency in the art of navigation was attained before the spread of Mediterranean and European civilization, we find that this distinction belongs to the great island world of the Pacific and to the neighboring lands of the Indian Ocean. Sailing vessels and outrigger boats of native design and construction characterize the whole sea-washed area of Indo-Malaysian civilization from Hindustan to the outermost isles of the Pacific. The eastern rim of Asia also belongs to this wide domain of nautical efficiency, and the coast Indians of southern Alaska and British Columbia may possibly represent an eastern spur of the same, thrown out in very remote times and maintained by the advantageous geographic conditions of that indented, mountainous coast. Adjoining this area on the north is the long-drawn Arctic seaboard of the Eskimos, who, unaided, have developed in their sealskin kayak and bidarka seagoing craft unsurpassed for the purposes of marine hunting and fishing, and who display a fearlessness and endurance born of long and enforced intimacy with the deep. Driven by the frozen deserts of his home to seek his food chiefly in the water, the Eskimo, nevertheless, finds his access to the sea barred for long months of winter by the jagged ice pack banked up along the shore.

The highest degree of intimacy is developed in that vast island-strewn stretch of the Pacific constituting Oceania. Here, where a mild climate enables the boatman race to make a companion of the deep, where every landscape is a sea-scape, where every diplomatic visit or war campaign, every trading journey or search for new coco-palm plantation means a voyage beyond the narrow confines of the home island, there dwells a race whose splendid chest and arm muscles were developed in the gymnasium of the sea; who, living on a paltry 515,000 square miles of scattered fragments of land but roaming over an ocean area of 25 million square miles, are not more at home in their palm-wreathed islets than on the encompassing deep. Migrations, voluntary and involuntary, make up their history. Their trained sense of locality, enabling them to make voyages several hundred miles from home,

has been mentioned by various explorers in Polynesia. The Marshall Islanders set down their geographical knowledge in maps which are fairly correct as to bearings but not as to distances. The Ralick Islanders of this group make charts which include islands, routes, and currents. Captain Cook was deeply impressed by the geographical knowledge of the people of the South Seas. A native Tahitian made for him a chart containing 74 islands and gave an account of nearly 60 more. Information and directions supplied by natives have aided white explorers to many discoveries in these waters. Quiros, visiting the Duff Islands in 1606, learned the location of Ticopia, one of the New Hebrides group, 300 miles away. Not only the excellent seamanship and the related pelagic fishing of the Polynesians bear the stamp of their predominant water environment; their mythology, their conception of a future state, the germs of their astronomical science, are all born of the sea.

Though the people living on the uttermost boundaries of this island world are 6,000 miles apart, and might be expected to be differentiated by the isolation of their island habitats, nevertheless they all have the same fundamental characteristics of physique, language, and culture from New Guinea to Easter Isle, reflecting in their unity the oneness of the encompassing ocean over which they circulate.

Midway between these semiaquatic Polynesians and those Arctic tribes who are forced out upon the deep to struggle with it rather than associate with it, we find the inhabitants of the Mediterranean islands and peninsulas, who are favored by the mild climate and the tideless, fogless, fairly stormless character of their sea. While such a body of water lures to intimacy, it does not breed a hardy or bold race of navigators; it is a nursery, scarcely a severe training school. Therefore we find that, except for the far-famed Dalmatian sailors, who for centuries have faced the storms sweeping down from the Dinaric Alps over the turbulent surface of the Adriatic, Mediterranean seamanship does not command general confidence on the high seas. Therefore it is the German, English, and Dutch steamship lines that are today the chief ocean carriers from Italian ports to East Africa, Asia, Australia, North and South America, despite the presence of native lines running from Genoa to Buenos Ayres, Montevideo, and New York; just as it was the Atlantic states of Europe, and only these and all of these, except Ger-

many, who, trained to venture out into the fogs and storms and unmarked paths of the *mare tenebrosum,* participated in the early voyages to the Americas. One after the other they came—the Norwegians, Spaniards, Portuguese, English, French, Dutch, Swedes, and Danes. The anthropo-geographical principle is not invalidated by the fact that Spain and England were guided in their initial transatlantic voyages by Italian navigators, such as Columbus, Cabot, and Amerigo Vespucci. The long maritime experience of Italy and its commercial relations with the Orient, reaching back into ancient times, furnished abundant material for the researches and speculations of such practical theorists; but Italy's location fixed the shores of the Mediterranean as her natural horizon, narrowed her vision to its shorter radius. Her obvious interest in the preservation of the old routes to the Orient made her turn a deaf ear to plans aiming to divert European commerce to transatlantic routes. Italy's entrance upon the high seas was, therefore, reluctant and late, retarded by the necessity of outgrowing the old circumscribed outlook of the enclosed basin before adopting the wider vision of the open ocean. Venice and Genoa were crippled not only by the discovery of the sea route to India, but also by their adherence to old thalassic means and methods of navigation inadequate for the high seas. However, these Mediterranean sea folk are being gradually drawn out of their seclusion, as proved by the increase of Italian oceanic lines.

The size of a sea or ocean is a definite factor in the power of a body of water to lure or repel maritime ventures, especially in the earlier stages of nautical development. A broken, indented coast means not only a longer and broader zone of contact between the inhabitants and the sea; it means also the breaking up of the adjacent expanse of water into so many alcoves, in which fisherman, trader, and colonist may become at home and prepare for maritime ventures farther afield. The enclosed or marginal sea lures earlier because it can be compassed by coastwise navigation; then by the proximity of its opposite shores and its usual generous equipment with islands the next step to crosswise navigation is encouraged. For the earliest stages of maritime development, only the smaller articulations of the coast and the inshore fringe of the sea inlets count. Their use is shown by the primitive voyages of the Greeks, before they had ventured into the Euxine or west of

the forbidding Cape Malia; and in the "inside passage" navigation of the Indians of southern Alaska and British Columbia, who have never stretched their nautical ventures beyond the outermost rocks of their skerry-walled coast.

A second stage is reached when an enclosed basin is at hand to widen the maritime horizon, and when this larger field is fully exploited in all its commercial, colonial, and industrial possibilities, as was done by the Phoenicians and Greeks in the Mediterranean, the Hanse Towns in the Baltic, the Dutch and English in the North Sea. The third and final stage is reached when the nursery of the inshore estuary or gulf and the training school of the enclosed basin are in turn outgrown, and the larger maritime spirit moves on to the open ocean for its field of operation. It is a significant fact that the Norse, bred to the water in their fiords and channels behind their protecting skerry-wall, then trained in the stormy basins of the North and Irish Seas, were naturally the first people of Europe to cross the Atlantic; because the Atlantic of their shores, narrowing like all oceans and seas toward the north, assumes almost the character of an enclosed basin. The distance from Norway to Greenland is only 1,800 miles, little more than that across the Arabian Sea between Africa and India. We trace, therefore, a certain analogy between the physical subdivisions of the world of water into inlet, marginal sea, and ocean, and the anthropo-geographical gradations in maritime development.

The enclosed or marginal sea seems a necessary condition for the advance beyond coastwise navigation and the much later step to the open ocean. Continents without them (as Africa except for its northern face upon the Mediterranean and the Red Sea) have shown no native initiative in maritime enterprise. Africa was further cursed by the mockery of desert coasts along most of her scant thalassic front. In the Americas we find the native races compassing a wide maritime field only in the Arctic, where the fragmentary character of the continent breaks up the ocean into Hudson's Bay, Davis Strait, Baffin Bay, Gulf of Bootnia, Melville Sound, and Bering Sea; and in the tropical Mediterranean of the Caribbean Sea and Gulf of Mexico. Owing to the lack of a marginal sea, the excellent seamanship developed in the archipelagoes of southern Alaska and Chile remained abortive for maritime expansion, despite a paucity of local resources and the spur

of hunger; but in the Caribbean basin, the Arawaks and later the Caribs spread from the southern mainland as far as Cuba.

Enclosed or marginal seas are historically the most important subdivisions of the ocean prior to 1492. Apart from the widening of the maritime horizon which they give to their bordering people, each has the further advantage of constituting an area of close vicinal grouping and constant interchange of cultural achievements, by which the civilization of the whole basin tends to become elevated and unified. This unification frequently extends to race also, owing to the rapidity of maritime expansion and the tendency to ethnic amalgamation characteristic of all coast regions. We recognize an area of Mediterranean civilization from the Isthmus of Suez to the Sacred Promontory of Portugal, and in this area a long-headed, brunette Mediterranean race, clearly unified as to stock, despite local differentiations of culture, languages, and nations in the various islands, peninsulas, and other segregated coastal regions of this sea. The basin appears therefore as an historical whole; for in it a certain group of peoples concentrated their common efforts, which crossed and criss-crossed from shore to shore. Phoenicia's trade ranged westward to the outer coasts of Spain, and later Barcelona's maritime enterprises reached east to the Levant. Greece's commercial and colonial relations embraced the Crimea and the mouth of the Rhone, and Genoa's extended east to the Crimea again. The Saracens, on reaching the Mediterranean edge of the Arabian peninsula, swept the southern coasts and islands, swung up the western rim of the basin to the foot of the Pyrenees, and taught the sluggish Spaniards the art of irrigation practiced on the garden slopes of Yemen. The ships of the Crusaders from Venice, Genoa, and Marseilles, anchored in the ports of Mohammedanized Syria, brought the symbol of the cross back to its birthplace in Jerusalem, but carried away with them countless suggestions from the finished industries of the East. Here was give and take, expansion and counterexpansion, conquest and expulsion, all together making up a great sum of reciprocal relations embracing the whole basin, the outcome of that close geographical connection which every sharply defined sea establishes between the coasts that it washes.

The same thing has come to pass in the North Sea. Originally Celtic on its western or British side, as opposed to its eastern or Ger-

manic coast, it has been wholly Teutonized on that flank also from the Strait of Dover to the Firth of Tay, and sprinkled with Scandinavian settlers from the Firth of Tay northward to Caithness. The eleventh century saw this ethnic unification achieved, and the end of the Middle Ages witnessed the diffusion of the elements of a common civilization through the agency of commerce from Bruges to Bergen. The Baltic, originally Teutonic only on its northern and western shores, has in historical times become almost wholly Teutonic, including even the seaboard of Finland and much of the coast provinces of Russia. Unification of civilization attended this unification of race. In its period of greatest historical significance from the twelfth to the seventeenth century, the Baltic played the role of a northern Mediterranean. The countless shuttles of the Hanse ships wove a web of commercial intercourse between its remotest shores. Novgorod and Åbo were in constant communication with Lübeck and Stralsund; and Visby, on the island of Gotland at the great crossroads of the Baltic, had the focal significance of the Piraeus in ancient Aegean trade.

If we turn to Asia, we find that even the unfavorable polar location of Bering Sea has, nevertheless, been unable to rob it entirely of historical significance. This is the one spot where a native American race has transplanted itself by its own natural expansion to Asiatic shores. The circular rim and island-dotted surface have guided Eskimo settlements to the coast of the Chukchen Peninsula, where they have become partly assimilated in dress and language to the local Chukchees. The same conditions also facilitated the passage of a few Chukchees across Bering Strait to the Alaskan side. At Pak (or Peek) on East Cape and on Diomede Island, situated in the narrowest part of Bering Strait, are the great intercontinental markets of the polar tribes. Here American furs have for many decades been exchanged for the reindeer skins of northern Siberia and Russian goods from far-away Moscow. Only the enclosed character of the sea, reported by the Danish explorer Vitus Bering, tempted the land-bred Russians, who reached the northwestern coast of Siberia at the middle of the eighteenth century, to launch their leaky boats of unseasoned timber, push across to the American continent, and make this whole Bering basin a Russian sea. Just so, a few decades before, when land exploration of Kamchatka had revealed the enclosed character of the Sea of Okhotsk, the Russian pioneers took

a straighter course across the water to their Pacific outpost of Petropavlovsk near the southern end of the Peninsula. But even before the coming of the Slavs to its shores, the Sea of Okhotsk seems to have been an area of commercial and ethnic intercourse from the Amur River in Siberia in a half circle to the east, through Sakhalin, Yezo, the Kurile Islands, and southern Kamchatka, noticeably where the rim of the basin presented the scantiest supply of land and where, therefore, its meager resources had to be eked out by fisheries and trade on the sea.

The vicinal location about an enclosed basin produces more rapidly a unification of race and culture, when some ethnic relationship and affinity already exists among the peoples inhabiting its shores. As in the ancient and medieval Mediterranean, so in the Yellow Sea of Asia the working of this principle is apparent. The settlement along its coasts of divergent but kindred peoples such as the Chinese, Koreans, and Japanese allowed these to be easily assimilated to a Yellow Sea race and to absorb quickly any later infusion such as that of the Tatars and Manchus. China, by reason of its larger area, long-drawn coast, massive population, and early civilization, was the dominant factor in this basin; Korea and Japan were its culture colonies—a fact that justifies the phrase calling "China the Rome of the Far East." Historical Japan began on the island of Kiu-siu, facing the Yellow Sea. Like Korea, it derived its writing, its fantastic medical notions, its industrial methods, some features of its government administration, its Buddhism, and its religion of Confucius from the people about the lower Hwang Ho. Three centuries ago Japan had its colonies on Korean soil, and for purposes of piracy and smuggling penetrated far up the rivers of China. Korea has kept in touch with China by an active trade and diplomatic relations through the centuries.

Japan has responded most promptly and most actively to the oversea stimuli, just as England has, of all Europe, felt most strongly the reflex influences from transatlantic lands. The awakening of Japan has started, therefore, from its seaward rim. The compressed energies of Japan, stirred by oversea contact and a more aggressive government at home, have overleaped the old barriers and are following the lines of slight resistance which this land-bound sea affords.

Despite the fact that China's history has always had a decidedly

inland character, that its political expansion has been landward, that it has practiced most extensively and successfully internal colonization, and that its policy of exclusion has tended to deaden its outlook toward the Pacific, nevertheless China's direct intercourse with the west and its westward-directed influence have never, in point of significance, been comparable with that toward the east and south. Here a succession of marginal seas offered easy water paths dotted with way stations to their outermost rim in Japan, the Philippines, and remote Australia. About the South China Sea, the Gulf of Siam, the Sulu, Celebes, and Java Seas, the coastal regions of the outlying islands have for centuries received Chinese goods and culture and a blend of that obstinately assertive Chinese blood.

From the dawn of history the northern Indian Ocean, owing to its form, its location in the angle between Asia and Africa and in the latitude where, round the whole earth, "the zone of greatest historical density" begins, and especially its location just southeast of the Mediterranean as the eastern extension of that great maritime track of ancient and modern times between Europe and China, has been involved in a long series of historical events. From the historical standpoint, prior to 1492 it takes a far higher place than the Atlantic and Pacific, owing to its nature as an enclosed sea. But like all such basins, this northern Indian Ocean attained its zenith of historical importance in early times. In the sixteenth century it suffered a partial eclipse, which passed only with the opening of the Suez Canal. During this interval, however, the Portuguese, Dutch, and English had rounded the Cape of Good Hope and entered this basin on its open or oceanic side. By their trading stations, which soon traced the outlines of its coasts from Sofala in South Africa around to Java, they made this ocean an alcove of the Atlantic, and embodied its events in the Atlantic period of history. It is this open or oceanic side which differentiates the Indian Ocean physically, and therefore historically, from a genuine enclosed sea.

The limitation of every enclosed or marginal sea lies in its small area and in the relatively restricted circle of its bordering lands. Only small peninsulas and islands can break its surface and short stretches of coast combine to form its shores. It affords, therefore, only limited territories as goals for expansion and restricted resources and populations to furnish the supply and demand of trade. What lands could the

Mediterranean present to the colonial outlook of the Greeks comparable to the North America of the expanding English or the Brazil of the Portuguese? Yet the Mediterranean as a colonial field had great advantages in point of size over the Baltic, which is only one sixth as large (2,509,500 and 431,000 square kilometers respectively), and especially over the Red Sea and Persian Gulf, whose effective areas were greatly reduced by the aridity of their surrounding lands. But the precocious development and early cessation of growth marking all Mediterranean national life have given to this basin a variegated history. In every period and every geographical region of it, from ancient Phoenicia through the Roman Empire to modern Italy, the early exhaustion of resources and dwarfing of ideals which characterize small areas become more and more conspicuous. The history of Denmark and the Hanse Towns in the Baltic, and of Yemen on the Red Sea tells the same story, the story of a hothouse plant, forced in germination and growth, then stifled in the close air.

Growth demands space. Therefore, the progress of history has been attended by an advance from smaller to larger marine areas, with a constant increase in those manifold relations between peoples and lands which the water is able to establish. Every great epoch of history has had its own sea, and every succeeding epoch has enlarged its maritime field. The Greek had the Aegean; the Roman the whole Mediterranean, to which the medieval period made an addition in the North Sea and the Baltic. The modern period has had the Atlantic, and the twentieth century is now entering upon the final epoch of the World Ocean. The gradual inclusion of this World Ocean in the widened scope of history has been due to the expansion of European peoples, who, for the past twenty centuries, have been the most far-reaching agents in the making of universal history. Owing to the location and structure of their continent, they have always found the larger outlet in a western sea. In the south the field widened from the Phoenician Sea to the Aegean, then to the Mediterranean, on to the Atlantic, and across it to its western shores; in the north it moved from the quiet Baltic to the tide-swept North Sea and across the North Atlantic. Only the South Atlantic brought European ships to the great world highway of the South Sea, and gave them the choice of an eastern or western route to the Pacific. Every new voyage in the age of

discovery expanded the historical horizon; and every improvement in the technique of navigation has helped to eliminate distance and to reduce intercourse on the World Ocean to the time-scale of the ancient Mediterranean.

It would be a mistake, however, to suppose that the larger size of the oceanic horizon has meant a corresponding increase in the content and importance of history. Such an intense, concentrated national life as occurred in those little Mediterranean countries in ancient times is not duplicated now, unless we find a parallel in Japan's recent career in the Yellow Sea basin. There was something as cosmic in the colonial ventures of the Greeks to the wind-swept shores of the Crimea or barbarous wilds of Massilia, as in the establishment of English settlements on the brimming rivers of Virginia or the torrid coast of Malacca. The inner significance of Alexander's conquest of the Asiatic rim of the Mediterranean and Rome's political unification of the basin does not lose in comparison with the Russification of northern Asia and the establishment of the British Empire.

The ocean has always performed one function in the evolution of history; it has always provided the outlet for the exercise of redundant national powers. The abundance of opportunity which it presents to these disengaged energies depends upon the size, location, and other geographic conditions of the bordering lands. These opportunities are limited in an enclosed basin, larger in the oceans, and largest in the northern halves of the oceans, owing to the widening of all land-masses toward the north and the consequent contraction of the oceans and seas in the same latitudes.

A result of this grouping is the abundance of land in the Northern Hemisphere, and the vast predominance of water in the Southern, by reason of which these two hemispheres have each assumed a distinct role in history. The Northern Hemisphere offers the greatest advantages for the habitation of man, and, significantly enough, contains a population five times that of the Southern Hemisphere. The latter, on the other hand, with its vast, unbroken water areas, has been the great oceanic highway for circum-mundane exploration and trade. This great water girdle of the South Seas had to be discovered before the spherical form of the earth could be established. The wide territory of the Northern Hemisphere civilization has experienced an un-

interrupted development, first in the Old World, because this offered in its large area north of the Equator the fundamental conditions for rapid evolution. Then civilization was transplanted with greatest success to North America. The Northern Hemisphere contains, therefore, "the zone of greatest historical density," from which the track of the South Seas is inconveniently remote. Hence we find in recent decades a reversion to the old east-west path along the southern rim of Eurasia, now perfected by the Suez Canal, and to be extended in the near future around the world by the union of the Pacific with the Caribbean Sea at Panama; so that finally the Northern Hemisphere will have its own circum-mundane waterway, along the line of greatest intercontinental intercourse.

The size of the ocean as a whole is so enormous, and yet its various subdivisions are so uniform in their physical aspect, that their differences of size produce less conspicuous historical effects than their diversity of area would lead one to expect. A voyage across the 177,000 square miles (453,500 square kilometers) of the Black Sea does not differ materially from one across the 979,000 square miles (2,509,500 square kilometers) of the Mediterranean; or a voyage across the 213,000 square miles (547,600 square kilometers) of the North Sea, from one across the three-hundredfold larger area of the Pacific. The ocean does not, like the land, wear upon its surface the evidences and effects of its size; it wraps itself in the same garment of blue waves or sullen swell wherever it appears; but the outward cloak of the land varies from zone to zone. The most significant anthropo-geographical influence of the size of the oceans, as opposed to that of the smaller seas, comes from the larger circle of lands which the former open to maritime enterprise. For primitive navigation, when the sailor crept from headland to headland and from island to island, the small enclosed basin with its close-hugging shores did indeed offer the best conditions. Today, only the great tonnage of ocean-going vessels may reflect in some degree the vast areas they traverse between continent and continent. Coasting craft and ships designed for local traffic in enclosed seas are in general smaller.

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Mineral Resources

MAN, in his occupation of large parts of the earth's surface, has modified considerably the distribution and original character of many plants and animals. Certain species have been destroyed or displaced by others, for the purpose of satisfying man's many wants in the struggle for existence. The relocation and modification of species have aided man in his occupation of the earth and permitted him to exist where otherwise he might not be able to gain a livelihood.

Minerals present a striking contrast to agricultural products. Minerals cannot be transplanted from their native habitat or be produced elsewhere. Minerals have been laid down once and for all time in certain parts of the earth. While plants and animals can be increased at will, within limits, both as to number and areas, minerals are not inexhaustible or subject to quantitative increase. Furthermore, in the exploitation of minerals certain economic controls must be considered, such as proximity to market, transportation facilities, and market price of the mineral.

Conservation

There are a large number of minerals which are being used at such an accelerating rate in proportion to the known reserves, that it is a matter of simple arithmetic to determine the number of years before they will be exhausted. In this machine age minerals furnish the power and the materials from which machines are made, as well as raw materials for large numbers of industries.

In the exploitation of minerals huge losses occur; some of them are unavoidable, but many are not. The loss will run as high as 50

per cent for petroleum and 35 per cent for coal. The avoidable loss is due to carelessness and incompetent exploitation.

Particularly since the World War has the conservation problem emerged in a definite form. Until then, the rate of consumption had not reached the tremendous proportion now experienced. Minerals consumed in the United States alone since 1900 far exceed the total for all preceding history. Since 1914 especially, the rate of consumption has been greatly accelerated.

The impetuous expansion of pioneer America must give way to a less wasteful and a more orderly development. The danger is not so much the complete exhaustion of any one mineral, but, rather, greatly increased costs owing to depletion of the better and more accessible deposits. Conservation means not hoarding, as many people believe, but orderly and efficient use in the interest of national welfare, without unnecessary waste. The purpose is to insure to society the maximum present and future benefit from our mineral resources.

Stages of mineral use

From the earliest times down to the present, minerals have played an exceedingly important part in the development and progress of the human race. Primitive man made his first rude weapons and utensils from stone. The archeologists have constructed their knowledge of early man largely from their findings of these weapons and utensils. Then man became more adept in the working of stones into various shapes, and thus he entered into the neolithic age. With the discovery of methods of securing metals from their ores, man passed successively into the copper, the bronze, and the iron ages. With each successive stage minerals assumed a greater and greater importance. Then came the discovery that coal could be used as a fuel. This hastened and furthered mineral use so that at present the per capita consumption of nearly all minerals increases year by year. Under our present machine age, man's dependence on minerals is greater than ever before.

Classification of minerals

The term *mineral* is used with different meanings. In a general sense, a mineral is any organic material and includes plant and animal products which have been buried in the earth and become part of it.

The usually accepted and technical definition of a mineral is any naturally occurring substance having a definite or a definitely varying composition.

An *ore* is a material containing sufficient metal to be worth mining. Profitable use is thus an essential factor in the definition of the term "ore." A material which in one place may be a valuable ore, in another may be commercially valueless. The variability of local conditions and the influences of prices and costs are factors to be considered.

A *metal* is a heavy, lustrous substance that is capable of being drawn into a fine thread and beaten or hammered into thin plates.

There are many ways in which minerals might be classified. A very common and also useful classification is (1) mineral fuels, (2) metals, and (3) nonmetals other than mineral fuels.

No attempt will be made to discuss the complete list of minerals; only the more important minerals in world economy will be reviewed briefly.

Mineral Fuels

Coal

Coal has been formed by the decomposition of vegetation under peat-bog conditions and its subsequent submergence under deposits of sediment. Then by geological agents the whole was subjected to pressure, and the result has been the conversion of vegetation into coal. The various types of coal thus can be accounted for by the amounts of vegetable matter and the intensity and duration of the geological agents.

The various types of coal that result may be classified as lignite, sub-bituminous, bituminous, and anthracite. Anthracite coal has 92 per cent carbon, bituminous from 75 to 90 per cent, sub-bituminous from 55 to 75 per cent, and lignite less than 55 per cent.

The coal reserves of the world are estimated in the following percentages:

	Per Cent
North America	69
United States	51
Canada	17
Asia:	
China	13
Siberia	2
Europe	10
Oceania	3

At the present rate of consumption these reserves will last at most about 500 years. But before that time poorer coal, thinner seams, and poorer veins will be worked, thereby increasing the costs to the consumer. The present leading producers of coal by nations are shown below.

PRINCIPAL COAL-PRODUCING COUNTRIES [1]

Country	Per Cent of Total World Production
United States	28.4
Germany (including Czechoslovakia and Poland)	22.1
United Kingdom	16.3
Soviet Union	5.9
France	3.3
China	1.9
Belgium	1.9

PRINCIPAL COAL-PRODUCING STATES [1]

State	Per Cent of United States Production
Pennsylvania	32.7
West Virginia	23.6
Illinois	10.3
Kentucky	9.5
Ohio	4.8
Indiana	3.4
Virginia	2.3
Alabama	2.3

Petroleum

Petroleum probably originated from animal remains now buried in the rocks. It collects especially in porous sandstones with water and natural gas. Small quantities occasionally come to the surface in springs of water; these oily springs have been known for many centuries to exist in the Russian fields. Similar springs were found in western Pennsylvania at least a century before the petroleum industry began. The real beginning of the industry dates from 1859, when an oil well was dug in the Allegheny valley. Today the United States,

[1] The figures that are used here and for the other minerals are the averages for the years 1935 to 1939. The percentages are in terms of quantity and not value. The sources were the various publications of the U. S. Department of Interior, Bureau of Mines.

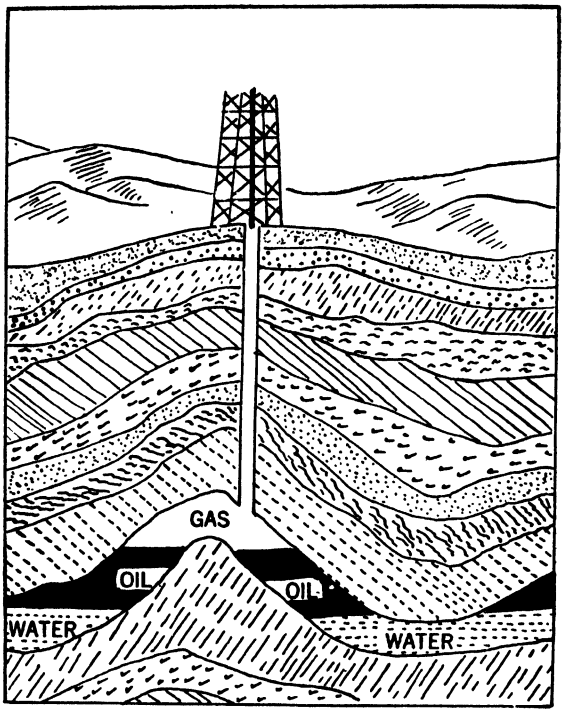


FIG. 132. PROFILE SKETCH OF AN OIL FIELD.

the Union of Socialist Soviet Republics, and Venezuela produce over 80 per cent of the output. The chief producers are shown below.

PRINCIPAL PETROLEUM-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
United States	61.0
Soviet Union	10.5
Venezuela	9.0
Persia	3.6
Rumania	3.2
Netherland Indies	2.8
Mexico	2.2
Iraq	1.4

Petroleum and all of its products play a very important part in commerce and industry. Its uses are varied and many. At one time its only uses were for crude lubrication, illumination, and medical pur-

poses. Its importance today may be gathered from the fact that the League of Nations in 1936 threatened an oil embargo against Italy, and Italy in turn threatened war against the countries that would apply that sanction. Petroleum is just as important in the affairs of nations in peace time.

PRINCIPAL PETROLEUM-PRODUCING STATES

State	Per Cent of United States Production
Texas	39.7
California	19.5
Oklahoma	17.7
Louisiana	6.3
Kansas	5.2
New Mexico	2.3
Wyoming	1.4

Natural gas

Natural gas is generally found with petroleum. In the early history of petroleum production, this gas was considered a nuisance and was allowed to escape as rapidly as possible. In 1874 it was first used for industrial purposes in Pittsburgh in making pig iron. The chief uses are for illuminating and heating. Pipe lines convey it from the petroleum fields to the near-by cities for use.

PRINCIPAL NATURAL GAS-PRODUCING STATES

State	Per Cent of United States Production
Texas	35.6
Oklahoma	14.6
California	14.1
Louisiana	12.3
West Virginia	5.5
Pennsylvania	4.2

Metals

Iron

Iron is one of the most important minerals. Its importance is constantly increasing because of the expanding list of manufactures; it is used for machines which are employed in manufacturing, as well as

general equipment in factories, offices, and homes, and, also, in the construction of buildings that house that machinery and equipment. If a nation is to assume a position as a first-class power, it must have iron ore.

Iron is extracted from the ores by smelting, and for this purpose coal and limestone are required. Until about 1840 the fuel in common use was charcoal. Until 1875 anthracite coal was commonly used, and now bituminous coking coal has surpassed all other fuels. Large amounts of labor are required for the smelting, thereby eliminating iron and steel production from frontier communities. The exact process followed in smelting depends to a large extent upon the nature of the ore. The chief types of ore used are hematite, limonite, and magnetite.

There is hardly a region of any extent in which iron ore does not occur in one form or another. There are some regions that yield it in vast quantities. The chief sections of the United States are (a) the Lake Superior district, (b) the region around Birmingham, Alabama, and (c) New York State. Some ore is imported into the United States from Central America and South America, chiefly for smelting pur-

PRINCIPAL IRON ORE-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
United States	25.3
France	20.7
Soviet Union	15.8
Great Britain	7.3
Germany	4.3
Luxemburg	2.8

PRINCIPAL IRON ORE-PRODUCING STATES

State	Per Cent of United States Production
Minnesota	17.8
Wisconsin	5.6
Michigan	5.2
Alabama	3.0
New York	1.3

poses. It has been estimated by the United States Geological Survey that if iron-ore consumption should continue at the present rate, the estimated reserves of commercial grade in the United States would probably be sufficient for 150 years. But our present rate is increasing on a per capita basis every year.

Copper

Copper was the earliest metal known and worked; it was valuable to ancient peoples in the making of bronze. Because it was very ductile, easily worked, and tenacious, it was used by these early peoples in their arts. Since it is an excellent conductor of heat and electricity, its consumption has increased enormously in the last half century. No satisfactory substitutes have been found for copper in electrical works. Bronze and brass are alloys of copper. The ores are rather widely distributed.

PRINCIPAL COPPER-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
United States	30.0
Chile	17.1
Canada	11.4
Belgian Congo	6.1
Soviet Union	4.7
Mexico	1.8
Peru	1.7
Spain	1.4

PRINCIPAL COPPER-PRODUCING STATES

State	Per Cent of United States Production
Arizona	35.3
Utah	21.1
Montana	16.6
Nevada	9.5
Michigan	7.1
Alaska	2.3
New Mexico	2.3
Colorado	1.7

Lead

Lead is used extensively as sheet lead, for piping, for munitions, alloys, and chemical compounds. It is a bluish-gray metal, heavy, soft, and fusible. Silver is frequently found with lead, and, in such cases, lead may be mined as a by-product in silver production. The proportion produced by the principal countries is shown below.

PRINCIPAL LEAD-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
United States	22.5
Australia	14.4
Mexico	13.1
Canada	10.8
Germany	9.5
Belgium	5.2
Burma	5.0
Spain	3.2

PRINCIPAL LEAD-PRODUCING STATES

State	Per Cent of United States Production
Missouri	31.5
Idaho	23.9
Utah	18.8
Oklahoma	6.2
Montana	3.8
Kansas	3.2
Arizona	2.3
Colorado	1.0

Zinc

The well-known metal zinc, or spelter, is bluish-white, brittle, and hard. Moist air will tarnish it, and then it forms a protective film of zinc oxide. Strong acids have little effect on the pure metal. It is used for roofing purposes, rods, nails, battery plates, paints protecting iron from rusting, and in various chemical industries.

PRINCIPAL ZINC-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
United States	28.9
Belgium	13.6
Canada	9.6
Germany	9.5
Poland	6.7
Australia	4.6
Soviet Union	3.8

PRINCIPAL ZINC-PRODUCING STATES

State	Per Cent of United States Production
Oklahoma	22.9
New Jersey	16.3
Kansas	12.1
Tennessee and Virginia	9.3
Idaho	7.5
Utah	6.5
New Mexico	4.4

Aluminum

The ore from which aluminum is made is the mineral bauxite. Aluminum is one of the new metals, for it did not come into prominence until 50 years ago. The expensiveness of processes formerly used in extracting it from its compounds has been greatly reduced, so that now it is coming into common use for more and more purposes. Large amounts of electricity are used in processing it. The chief aluminum-manufacturing centers in the United States are Niagara Falls and Massena, New York; Alcoa, Tennessee; Badin, North Carolina; and Vancouver, Washington. It is extremely light, white, ductile, malleable, does not tarnish easily, and readily unites with other metals. Its uses are many and include munitions, sheet tubing, rods, castings, paints, household utensils, electrical equipment, and airplane and motor car construction. Arkansas supplies 95 per cent of the total bauxite of the United States.

PRINCIPAL ALUMINUM-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
Germany	27.0
United States	24.6
Canada	8.6
Soviet Union	8.3
France	7.8
Norway	5.3
Italy	4.7
Great Britain	4.7

PRINCIPAL BAUXITE-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
France	24.7
United States	13.0
Hungary	12.2
Italy	9.9
Yugoslavia	9.8
Surinam	8.7
Soviet Union	6.7

Tin

Tin is sparsely distributed throughout the world. Its principal use is in the tin-plate industry. Tin-plates are thin sheets of iron or steel coated by an immersion in tin, which serves as a protection against rust. It is used as an alloy in making bronze, gun metal, pewter, and solder. It is a lustrous, silver-white, very malleable metal, little affected by air or water. The chief sources of supply are Malaya, Netherland Indies, and Bolivia. While the United States is the chief consumer of tin, it must depend entirely on foreign sources of supply. It is one of the few metals not mined in the United States.

PRINCIPAL TIN-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
Malay States	33.5
Netherland Indies	16.2
Bolivia	15.2
Siam	7.3
China	6.3
Nigeria	4.7
Belgian Congo	3.8
Burma	2.5

Nickel

Nickel is now considered an essential for all good steels and is especially useful in making armor plate. "Monel metal" is an alloy of nickel and copper and is used, among other things, for high-pressure steam systems. The use of nickel is increasing for household equipment. A good amount is used with copper for coinage. It is a grayish-white, lustrous metal; it is magnetic, resists organic acids, has considerable hardness, tenacity, and ductility. Canada produces about 85 per cent of the total world production, and New Caledonia (French) about 7 per cent.

Gold

The use of gold as a standard of value and as a medium of exchange is due, in large part, to its high value as compared with its bulk. Since it does not tarnish easily and because it is very pleasing to the eye, it is used extensively in the arts. The most extensive uses are in coinage, jewelry, gilding, electroplating, and dentistry. Gold can be beaten to a thickness of 1/200,000 of an inch. Owing to its softness, it is alloyed with silver or base metal for use in the arts and coinage. Gold is a widely distributed metal, but the chief sources are shown below.

PRINCIPAL GOLD-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
Union of South Africa	34.7
Soviet Union	15.1
United States	11.5
Canada	11.5
Australia	3.5
Mexico	2.3
Philippines	1.8

PRINCIPAL GOLD-PRODUCING STATES

State	Per Cent of United States Production
California	23.6
Alaska	13.0
South Dakota	11.9
Colorado	7.8
Arizona	6.3
Nevada	4.9
Utah	4.8

Silver

Silver is probably the best of all metals as a conductor of heat and electricity, and is highly malleable and ductile. It sometimes is found native, but usually the ores are combined with other metals, such as lead, copper, or zinc. It is used in coinage, silverware, jewelry, plating, making indelible inks, and photography. Mexico and the United States produce nearly one half of the total world supply.

PRINCIPAL SILVER-PRODUCING COUNTRIES

Country	Per Cent of Total World Production
Mexico	26.7
United States	19.5
Canada	6.6
Peru	5.7
Australia	4.1
Japan	3.2

PRINCIPAL SILVER-PRODUCING STATES

State	Per Cent of United States Production
Idaho	28.5
Utah	16.5
Montana	13.4
Arizona	12.5
Colorado	10.5
Nevada	6.8
California	4.0
Texas	2.0

Nonmetals

Clay products

The clay reserves of the United States, as well as those of the rest of the world, are almost illimitable and have hardly been touched. Nor have the clays been put to as many uses as their adaptabilities permit. Nevertheless, the clays of the United States form the basis of great industries. In value of annual output these products rank next to the fuels—coal and petroleum—and the metals—iron and copper. Every

state in the Union has workable deposits of clay, and nearly every variety of product is made from these deposits, from common bricks to the highest grade of china or porcelain. Brick and tile enter extensively into all kinds of structural work, especially in urban communities. In the manufacturing of pottery, in addition to kaolin, various plastic clays known as "ball clays" are used, since they have strong binding power and high tensile strength.

PRINCIPAL CLAY-PRODUCTS MANUFACTURING STATES [a]

State	Per Cent of United States Production
Georgia	19.7
Pennsylvania	13.7
Missouri	11.8
South Carolina	8.1
Kentucky	7.3
California	6.0
Ohio	5.8

[a] Based on value.

Building stone

Stone for building is an important source of this country's material wealth and is found in abundance and great variety. The principal stones quarried are limestone, granite, marble, and sandstone. Sandstone production is decreasing rapidly, since this stone is being replaced with cement. Marble is used chiefly for building monuments. Vermont is the leading producing state of marble. Granite has a variety of important uses, such as building stone and monuments. Massachusetts, Vermont, and Maine lead in granite production. Limestone constitutes about 40 per cent of the total value of the quarries of the United States. Its chief uses are for road making, railroad ballast, cement manufacturing, building stone, and chemicals. The states which rank first in its production are Pennsylvania, Indiana, and Illinois. The best limestone now comes from the Bedford district in southern Indiana. Limestone is soft and easy to saw or carve as it comes from the quarry, but upon exposure it hardens and becomes very durable. All building stone, in order to be commercially useful, must resist weathering and be strong, attractive, and not too hard to cut.

Sand and gravel

Another mineral resource of large importance is sand and gravel, particularly since the inauguration of the extensive road improvements and of concrete construction. There are but few areas in the United States where a good supply cannot be had within a reasonable distance. Production of sand and gravel is directly proportionate to the amount of road building and construction work. Other uses for sand are in glass molding and abrasives. At the present time, most of the glass sand is produced in Illinois, Pennsylvania, and West Virginia. The best glass is made from crushed pure sandstone, and cheap glass comes from water-laid deposits of sand. Cheap fuel is essential in its manufacture, and for this purpose natural gas and oil are used. Since glass is fragile, it usually is made as near to the market as possible. Molding sand is used chiefly by the iron and steel manufacturers to form molten metals. Because of the high freight costs, sand suitable for molding is produced exclusively in the areas that manufacture iron and steel. The United States has large quantities of sand that can be used for this purpose.

Sulphur

Sulphur is a yellow, brittle solid, which, when heated to 226° F., melts to an amber-colored liquid. The uses of sulphur are many and include the manufacture of gunpowder and fireworks and chemical compounds. Texas and Louisiana produce over 99 per cent of the total in the United States. The United States produces 68 per cent of the world's total, Italy 18 per cent, and Japan 4 per cent.

Salt

Common salt occurs as a mineral deposit, or it may be obtained by evaporation and crystallization from brine. Apart from the well-known domestic purposes, it is used in the manufacture of soda, hydrochloric acid, and soaps. Over 93 per cent of the salt produced in the United States comes from the states of Michigan, New York, Kansas, Louisiana, Ohio, and California.

Conclusion

Even a cursory glance at the above tables shows that the output of the world's minerals is controlled by the United States and the British Commonwealth of Nations. In the case of the United States that control is due to accidental location, while with Great Britain it is the result of a definite political policy. The United States controls more mineral resources and produces more minerals than Great Britain or any other country.

Summary

Mining, one of the most ancient of industries, has always played an important role in determining and shaping successive civilizations. Minerals have been so important that historians have named the various ages after the minerals that dominated them. We have the stone age, the bronze age, or the age of alloys.

While minerals were most important to the ancient Phoenicians, Iberians, Romans, and Greeks, they did not and could not attain great stature until the rise of modern industrialization. Whether industrialization made mining a big industry or whether the development of mining made industrialization possible is a debate to which there is no satisfactory conclusion. The two go hand in hand and are dependent upon each other. Industrialization, as understood in the present age, could not exist without the large-scale production of many minerals.

All through the long history of man's early development he found his food by hunting berries and animals. Then, by necessity, he became an agriculturalist and left his migrations for the sedentary life. While the new life became the rule for the majority, there were always those who reverted back to the nomadic period of early existence. The more venturesome left the agricultural community to find the materials out of which they might fashion their implements. They searched for gold for ornament and the other minerals for their tools and weapons. They became miners. Those who were successful attained great power. They found and furnished the minerals from which the artif-

icers made the implements for the settled community. As the community and civilization developed, the demand for the minerals increased, for the sedentary mode of life was based on minerals for machines and engines.

The miner, in order to satisfy the increasing demands, had to go into the unsettled areas to find the object of his search. He thus discovered new agricultural lands and new grazing areas. Upon his return home, the miner told the shepherds and farmers of these new lands, and frequently they migrated to the new fields. Then the miner again pioneered into the unknown land in search of mineral wealth.

Thus the miner, always searching for new mineral deposits, explored more and more of the earth's surface. In contrast to the trader, he related his experience of the new areas and presented a general description of the then unknown land. If he found minerals, he obviously kept that one bit of information as his secret. The trader, in contrast, told nothing of his new field of operation, for to do so opened the area to all comers. The miner, in many large parts of the world, explored the country, and his descriptions have led to trade and conquest.

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37

Influence of the Precious Metals on American Exploration, Discovery, Conquest, and Possession

AS discussed in the previous chapter, the distribution of mineral deposits determines the location of the mining industry, but whether or not a given mineral deposit can be worked depends on several things. Chief among these are its size, its location, its quality, the cost of working it, and market conditions. The relative importance of these factors varies greatly with different minerals.

The human factor should not be forgotten, and the influence of mining on the distribution of population varies with the different types of mining communities. The power of mineral deposits to bring large numbers of people to uninhabited regions is illustrated strikingly in the case of California. Thousands of miners and prospectors were attracted across an inhospitable region in spite of the poorest of transportation. Towns and cities developed from rude camps about mines. This type of mining community is illustrated in greater detail in this chapter. However, other mineral deposits attract no large group of people. Many minerals require large capital investments before mining can be profitable, and the prospector gives way to large companies with much available capital. The latter case is illustrated in the next chapter.

Early explorations and discoveries [1]

Beginning with the first explorer who sailed across the Atlantic, "the expectation of finding a land rich in treasures of gold and silver or in

[1] Adapted from George D. Hubbard, from the *Bulletin of the American Geographical Society*, Vol. 42, No. 8, published by the American Geographical Society of New York.

products easily sold for the metals was the prevailing motive in the minds of most of the early discoverers and explorers." The sixteenth-century travelers had little else in mind save the recompense for their toils and dangers in the rich mines of the precious metals which they were going to discover. Thus exploration was prompted by the desire for gold or for the lucrative trade in gold and spices from the Orient. The news of immensely rich empires and mines of gold and silver ceaselessly attracted Spanish exploration and conquest into new quarters and thus rapidly and extensively opened up the New World to the knowledge of mankind. The treasure was first found, in quantities, in the vaults and temples of the Indian civilizations both in Mexico and in Peru; but it was soon also discovered in the mines from which the natives derived it, and in others new even to them.

Balboa, on the Isthmus in search of precious metals in 1513, found gold in the hands of natives and traded for 500 pounds of it. Cortez on the Gulf Coast of Mexico learned of the wealth of the kingdom of Montezuma and marched successfully on his capital, destroying the natives in vast numbers in order to effect his purpose and get possession of the treasure. Pizarro is said to have extorted from the Incas $15,000,000 worth of gold and silver, partly by peaceable means, but with accompanying slaughter and pillage. These discoveries were of prime importance as revealing metals already extracted, and they soon led to the finding of the sources.

The Spaniards wanted gold, silver, or anything which would bring the precious metals easily; and by all methods they acquired about $250,000 per annum, chiefly gold, during the first thirty years (1492–1521). But during the conquests of Mexico and Peru, and for ten years thereafter, the acquisition of precious metals, now largely silver, rose rapidly to about $3,000,000 per annum. So far, essentially all the wealth obtained by the Spaniards in America was gotten by conquest, plunder, tribute, or barter. Practically no mining had been done prior to 1546, when the fabulously rich silver mines at Potosí in Bolivia were discovered, together with other mines of both silver and gold. And now, by forced native and Negro labor, the production of silver took another quick stride and rose to an average of $10,000,000 per annum until 1600.

Near the close of the sixteenth century, the Jesuits had spread across Mexico, got control of Lower California, and discovered the pearl

fisheries of the warm adjacent seas. Spanish settlers followed, and these discovered auriferous gravels, the southern end of that long line of gravel deposits extending north and south across the United States and Canada. Settlements grew, and agriculture began. The Indians harassed the settlers until their complaints brought a small army from headquarters, who pursued the Indians into the mountains and in 1771 discovered very rich placers. Some 2,000 persons rushed in, within a few months, and the deposits were extensively developed. As in the case of California later, lack of provisions hindered development. It is interesting to note how near these developments led prospectors to California, and how close they came to making discoveries that would have profoundly modified the course of history in the United States in 1846–48, and subsequently.

The two motives that impelled the Spanish

In the course of events connected with the Spanish occupation of America two motives prompted action, motives often operating in the same mind. One was the avowed purpose of the religious orders to promulgate their religion among the natives; the other, the ceaseless attraction exerted by treasure upon the military. But, unfortunately, the Jesuits were sometimes influenced by the knowledge of the occurrence of silver and gold. While the chief missionary of a party may have had pure motives, his helpers often completely forgot their specific work and went where treasure bade them go. With this double motive, exploration and conquest rapidly disclosed the New World to the Old. It is not our purpose to trace the influence of the missionary spirit in America. As for the other influence, so far as it operated through the Spanish, and aside from the above-mentioned results, its sole effects in America were the enriching of a comparatively small number of Spanish adventurers and the gorgeous maintenance of both Church and State. The commonalty suffered from two conditions, both born in part of greed for gold and silver—a cramped and restricted trade, and the tyranny, despotism, and avarice of officials.

Effects of greed for gold and silver

This very greed for the gold was one of the causes that operated to scatter the energy of the Spanish over southern North America and all

South America, and to prevent their developing cities or fixed industries. They conquered, primarily for its treasure, a territory larger than they could master and administer; and, as a result, their occupancy was irregular and short lived over a considerable portion of their possessions. The thirst for gold made the adventurers wild and led them a romantic career in the New World. They disdained agriculture, neglected singularly fertile plains, and thwarted legitimate commerce. They directed their steps wherever they heard tales of abundant treasure. And it was in these pursuits, so eagerly and mercilessly carried on, that they destroyed the native population and thus greatly lessened the value of their possessions by denuding the land of its native races. Had this industrious and rudely cultured race of Indians been conserved and properly dealt with, the Spaniards might have had a loyal colony instead of a rebellious vassalage. And, further, the Indians might have lasted some time as tillers of the soil, if given careful and wise supervision, and thus have produced abundant harvests of products desired in Europe, thereby adding extensive and lucrative commerce to Spain's advantage. And what would have been Spain's gain would also have been England's and America's.

Hypothetical cases

Whether the absence of the treasure would have made the Spanish even endurable masters or not is a question; but it is certain that, when they had once scented the precious metals, their avarice knew no bounds, and destruction and bloodshed followed in their wake. Had their course been so different as to have perpetuated their occupation of Mexico as long as they held Cuba, American history would have been quite another story. And with a loyal Spanish colony south of us as successful as the British colony north of us, our development might have been considerably different. What has been said of the Spanish in Mexico applies in principle to the Spanish in Peru and Bolivia. We might have had more valuable neighbors in these countries. What might have been is hard to tell, but it is safe to assert that the conditions assumed above would have yielded results very different from those which have passed into history. Spanish power in America was intimately connected with the output of the precious metals. When the treasure flowed freely, Spain flourished both at home and abroad; and

when it slackened, her power withered. Probably without the precious metals, her course would have been less offensive, and her influence less pernicious.

English and Spanish compared

South American mines were worked three quarters of a century before there was an English settlement on the American continent. A century of Spanish exploration, gold hunting, Christianizing, and a kind of colonizing in the South had been completed before the occupation of the northeastern seaboard began. Then followed a century of settlement and exploration along the North Atlantic. While, in individual cases, some exploration and exploitation was done by the English immigrants in the vain hope of finding wealth in gold or silver, as colonists they were actuated by other motives. Not finding gold, they were not scattered through the mountains but became much more of a solid unit than did the Spanish. Other factors, however, than the absence of gold operated against their becoming scattered. Since Spain had laid claim to so much of the South, the English, when ready to explore and settle, were restricted to the so-called less desirable parts. Had there been easily got mineral wealth discovered in the Appalachian hills and valleys in the early days, there would have been a rush of adventurers at first, with fewer fixed and staid settlements. Perhaps it would have been roving Spanish, and not English, along the Atlantic coast. Hardships under the less settled conditions would greatly have surpassed those of the early colonists as it was, or even those of California in 1849 and 1850. One might well ask, what would our history have been had there been abundance of precious metals in New England and the old Appalachians. Of course, ultimately the result would have been the development of the country; but its possession undoubtedly would have been different. Again, suppose the Spanish had not found treasure in the South. Well does Whitney suggest, "How different might have been American history had there been settlements in the Mexican and South American States instead of silver." No doubt the distribution of gold and silver found response in the distribution of the nations in America in the early days, as we can see when we imagine a profoundly different distribution.

The French

The French in America are usually thought of as a people with very slight predilections for the precious metals. They were led by other motives. But we are told that they explored extensively for gold and silver in 1719–20, about the junction of the Missouri and the Mississippi Rivers, but, of course, with no positive results. Had they found the object of their quest in the region, the story of French exploration, occupation, and possession would have needed another chapter.

Summary to 1848

Thus it becomes apparent that the desire for the precious metals was an active agent in the explorations carried on by the early voyagers; that the distribution of gold and silver led the searchers into nearly all parts of America south of the thirtieth parallel of north latitude, and aided in scattering the energy of the Spanish over too large a territory; that greed and avarice, finding a fertile soil in the acquisition of American precious metals, caused the Spanish to adopt and maintain a policy toward the natives and toward Spain's colonists both cruel and pernicious; that the lack of gold and silver in the Appalachians has had an influence for good especially on the English colonists and through them on the conquest and possession of the northeastern United States; and that the finding of treasure and the increasing production of gold and silver have stimulated geographic exploration and discovery.

The amount of production of gold and silver continued to rise, and the cost to decline from time to time by the introduction of improved processes. It is stated that the production of gold and silver in the New World in 1800 had risen to about $50,000,000 per annum. It is also known that the production of the United States at that time was scarcely one third of a million, and mostly gold, per annum; yet, indirectly, the production in other American States has aided the United States and has modified early American history perceptibly.

The California gold

Up to the discovery of gold in California the Pacific side of the continent had remained almost an uninhabited region save for the scattered

Franciscan missionary posts; and unvisited except by a few scientific expeditions that crossed the desert and mountain wastes, by whalers who occasionally touched the coast, and by trappers and fur traders who moved up and down the streams and along the coast. The interior was visited even less. Knowledge concerning the whole region was very meager. The few expeditions brought back a little information concerning strips of country actually crossed, and the trappers and fur traders knew the courses of the streams, but the real opening up of the country and the discovery of its resources, agricultural as well as mineral, had scarcely begun in 1848. Transportation was very difficult, food all but wanting, water restricted to widely scattered points, and Indians were hostile. No advantages to be gained by crossing were known. The greatness of the uninhabited region required almost prohibitive provisioning of expeditions purposing to cross; and the pressure of population from the east had not yet reached a sufficient degree to push the frontier into the deserts and mountains.

But with the discovery of the wealth buried so slightly in the sands of the Sierras was also found the incentive sufficient to induce men to brave the difficulties presented by a long land journey, or to risk the perilous voyage of six months around Cape Horn to reach the otherwise inaccessible California. Incidental to getting into California, more exploration of the interior was done in one summer than had ever been done before, and more than probably would have been done in the normal course of events in a score or two of years to come.

The fur traders had worked out many routes, but rarely did they point the way entirely across from the Mississippi to the Pacific. Frémont's report in 1845, embodying careful topographic and descriptive work, was a further contribution to the scanty fund of information concerning routes westward. The Oregon Trail was worked out and used prior to the gold discoveries by several bands who later, in part at least, figured in California. Perhaps the Santa Fé trail from St. Louis to Santa Fé, and the Gila and Spanish Trails from there to southern California were as important as any of the older trails. These routes were established almost entirely prior to 1848; hence their discovery can by no means be ascribed to the influence of gold; but they were little known and little used save by the fur traders until 1849. During that summer trails became roads, and bridle paths highways, cut-offs

were found, new watering places discovered, and in many ways the courses improved. The trail to Salt Lake City through South Pass was used; but, instead of going on northwestward to the Columbia and Oregon, the settlers worked out a new trail down the Humboldt River to Humboldt Sink, then up the back of the Sierras, and down the many ravines on the western face. The mountains seemed to fray out into many strands leading down the gulches on the western side. The American River, down which Frémont traveled, is fairly typical in the hardships presented. It is astonishing what difficulties men and even women and children will surmount when under the influence of the gold fever.

Mention must also be made of the exploration of routes mainly by water, which came into use on the advent of California gold, and led from the Atlantic ports to Mexico and Central America and then by stream or on the land across to the Pacific and thence to California. The route with the shortest land section crossed the Isthmus of Panama, and was used very early both by passengers and freight. Other routes crossed at Tehuantepec, Nicaragua, and from Tampico across northern Mexico to Matzatlan and other Pacific ports. All of the overland routes resulted in exploration of sections of the country but not in occupation or possession. The same is true for those who crossed the arid plains and mountains of the United States. Routes discovered and developed by emigrants in search of gold at the end of their journey differed from those worked out by the ordinary overland emigrant. Only the discouraged or exhausted halted on the former, while the latter soon became enlivened by settlements of those who found places "good enough for them" and turned aside to settle.

Exploration by prospectors

The pioneer exploration discussed above took place during the early days of the gold excitement in California; but as the richer deposits became exhausted, the prospector set out, impelled by a continuous vision of "nuggets." He pushed back into the interior wilderness across deserts, over ridges, into glens, gulches, parks, and traced streams from end to end. While his explorations were not scientific and his results were not recorded, his discoveries were valuable even aside from the treasure they revealed, because definite reports often got into possession

of others who made new settlements or occupied fields which he had only viewed. And even in the absence of positive statement of valuable finds of minerals, lands, forest, or game, the report that so-and-so had been through certain valleys or over certain mountains or had been exploring in a named locality or direction served to turn the attention thither, and make one feel somewhat acquainted with the places beyond his more complete knowledge. It all aided in the conquest of valley and hillside, spring and water course, to other purposes than the maintenance of wild animals and savages. Desire to find gold and the reports of gold and silver found all over the West prompted further exploration and led to discoveries, not only of precious metals, but also of many geographic features—streams, mountains, valleys, and plains, and of many other less attractive but more remunerative resources of the region. Under the powerful stimulus, exploration was very active, and the knowledge of the West extended phenomenally.

Scientific exploration of Alaska

Nor should this section be concluded without reference to the influence Alaskan gold has had upon exploration. It played no part in the discovery, or in our gaining possession of the peninsula, but since the announcement of its presence, the exploration of the country by prospectors and miners and by those who would enter the carrying trade to assist the miners has been very vigorously pushed. In a much closer way careful surveying and mapping have gone on rapidly under the supervision of the Federal Government. Of course, this work is not done alone in response to the influence of gold and silver; but the distribution of the work both in Alaska and in the states shows how influential have been the mineral deposits in determining the areas to be surveyed first. Gold and silver have played an important part, as have other minerals.

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Cultural Adjustments to the Mesabi Resources[1]

IT is difficult to strip a geographical area of its cultural superstructure in order to see it in its purely natural aspects. Once culture building begins, the setting may be radically changed, especially where the culture-building group is possessed of technological devices capable of controlling nature to a considerable degree.

The Mesabi Iron Range lies in northeastern Minnesota, some sixty miles northwest of the west end of Lake Superior. A survey of the

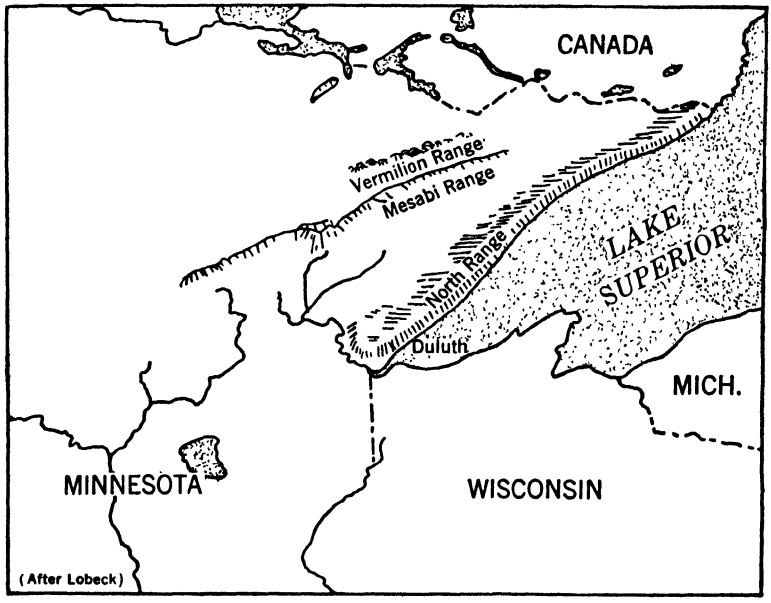


FIG. 133. SKETCH MAP OF NORTHERN MINNESOTA.

[1] Adapted from Paul H. Landis, from *Economic Geography*, Vol. 11, No. 2, published by Clark University, Worcester, Massachusetts.

history of the people who have inhabited the region indicates that different groups have utilized different natural resources. For instance, one group has sought wild game, another tillable soil, another minerals. The natural environment has been relatively constant for several centuries; consequently, all present resources have been available to previous groups. Yet each group has specialized in exploiting a selected resource. This fact merits an explanation.

Resources of the Mesabi

From our present knowledge, however, it appears that the original resources of the Mesabi Range were: (1) *Flora,* a virgin forest, principally pine; undergrowth with fruits and berries in great abundance; pin cherries, choke cherries, June berries, raspberries, strawberries, huckleberries, and blueberries; (2) *Fauna,* moose, bear, and deer, many small game animals and furbearing animals, waterfowl and freshwater fish abounding in the lakes; (3) *Soil,* a fertile and well-watered soil, but rugged and rocky, in places swampy, and everywhere so covered with trees that roots forbade tillage until they had been removed; (4) *Minerals,* vast beds of iron ore that lay near the surface in loose formation.

Early uses of the Mesabi

The Mesabi district was the possession of the Chippewa (Ojibway) Indians until January 1, 1855. The native tribes lived chiefly by hunting, using wild game and berries for food. Theirs was a hunting culture. Agriculture as they practiced it was of the most rudimentary sort. Nor did they make use of the white pine or the iron ore that has meant so much to the white man.

Missionaries seeking to Christianize the Indians and fur traders seeking pelts were the first white visitors. They did not come, as did later immigrants, to make homes or settlements or to conquer the environment.

The Range remained without permanent settlements until the development of mining. A gold rush to the Vermilion Range in 1865 took large numbers of travelers through the district, but these men sought gold—they would probably have had no interest in iron ore even though they had known of its existence.

Lumbering reached its peak on the Mesabi about 1880 to 1890. The

lumbermen saw and sought only one resource—pine. The land to them had no other meaning; timber rights were their only concern. Mineral rights were not considered in acquiring the land or in disposing of it after it was stripped of its forests.

Lumbering in the Lake Superior region was carried forward on a large scale. In the early days tremendous loads of logs were hauled in these northern forests. Massive sleds loaded with logs traversed in winter areas over which it was impossible to travel in summer by any type of vehicle. An early observer viewing the forests in what is now the Virginia district thought there was timber enough for hundreds of years, but it was gone in twenty-five or thirty years. An extensive strip of virgin timber near Hibbing, believed by early explorers to be inexhaustible, was completely gone in fifteen years after the beginning of the lumbering operations.

Long before the opening of the Mesabi, lumber had found a place in the American culture scheme. The exploiting of the Minnesota supply was only a stage in the westward quest for pine.

Lumbering had its beginnings in America in the East. New England led in the early days, New York State in 1850, and Pennsylvania in 1860. Then came Michigan, Wisconsin, and Minnesota in rapid succession, so that by 1924 only three per cent of the original timber supply of these states was left. For the last twenty years the South has been the chief source of timber supply, and now less than 20 per cent of its original supply remains. At the present time one half of the saw timber of the United States remains in the three Pacific Coast States.

Lumbermen left behind only the ruins of their exploitation—stumps, underbrush, and burned-over areas. They did not build a single city of permanence in this forest, not even a permanent dwelling. With the passing of lumber they, like the "lumber jacks," migrated to virgin supplies in the West, or turned to other enterprises in near-by cities. Many timber barons allowed the land to revert to the state to avoid taxes, or sold it for what they could get.

Discovery of Mesabi ore

Little did the lumbermen know that beneath the roots of the pine stumps they left behind lay buried treasures greater than the entire timber wealth of the nation. Some learned it to their chagrin after

having disposed of their landholdings for a pittance; others who held their land because of inability or indisposition to dispose of it learned of its value to their permanent advantage.

As early as 1850 iron ore had been discovered on the Vermilion Range (some 60 miles north of the Mesabi), by J. G. Norwood. A geological survey in 1864 led to the discovery of the Soudan Mine on the Vermilion Range. As early as 1866 Henry H. Eames, in quest of gold, located iron ore on the Mesabi Range. Peter Mitchell verified his discovery in 1869–1870. Not until 1892 did a railroad reach this range to inaugurate the shipment of ore.

Never before in the history of the world had so rich a bed of ore been located. Moreover, ore was found in a loose form, and very near the surface, so that mining by stripping with the steam shovel was first employed here. The steam shovel made possible an output without precedent.

This ore apparently had lain undisturbed for centuries. It was potentially a resource of all previous peoples that had inhabited St. Louis county. It was, however, never made an active factor in any previous culture. Why did this resource take on meaning at this time? This question is to be answered only by understanding the impact of a machine age on natural resources.

The Mesabi in an iron age

England led the world in iron production in the nineteenth century. Extensive ore discoveries brought America to the place of leadership in the twentieth century. The most important of these was the discovery of the Mesabi deposits.

In 1929 the United States produced 72,199,815 metric tons of iron ore. In the same year France produced 51,028,000 metric tons, Great Britain 13,427,043 metric tons, and Sweden 11,000,000 metric tons. The leadership of the United States not only began with the development of the Mesabi Range but has been maintained by its annual production.

Before 1820 the per capita use of iron in the United States was 40 pounds. This grew to 175 pounds by 1870, and to 400 pounds by 1900. Whitbeck and Finch state in their *Commercial Geography* that "one corporation in the United States now markets more iron and steel

yearly than all the world used in any year prior to 1880. But a century ago iron was a luxury—now it is an 'industrial commonplace.'" In 1907 twelve hundred pounds of ore were used for every person in the United States. Iron has become, in a real sense, the measure of civilization in our age. Steel-making peoples now dominate the world, and leadership among nations depends upon iron resources.

The iron ranges represent the Industrial Revolution at the raw-materials end of the process. Activities at the mines represent the first process in steel production. The other end of the process, that of manufacturing the raw material, may be seen at Pittsburgh and other cities. The range is thus tied up with the commerce and industry of the nation. The development of the Minnesota range was a step in the westward trend of the iron industry.

Charcoal was employed in the smelting of iron until about 1850, when anthracite coal came into use. This development led to a great increase in ore production in America, and the industry became centered in the anthracite district of eastern Pennsylvania. By 1875, the use of bituminous coal led to a shift of the ore-smelting district to western Pennsylvania and the upper Ohio Valley.

Railroad development during the Civil War period gave the iron industry a great impetus. Soon after (1884), the first iron ore from the Lake Superior district was shipped. Gradually the ore trade and ore smelting shifted toward the lake shores. A large steel plant was developed as far west as Duluth, and coal for smelting was shipped to the ore, replacing the usual process of shipping the ore to the coal.

The shifting areas of ore production follow the same general trends as do those for ore smelting. In 1899 New York State mined 1,247,000 tons of ore. By 1911 this output was reduced to 1,000,000, owing to the competition of the Lake Superior area more than to exhaustion of supply. In 1890 Pennsylvania led in the production of ore; by 1911 it held seventh place. The same year Michigan and Minnesota produced more than three fourths of the ore of the United States. In fact, during that year they produced more ore than the entire United States had produced in 1889. The first shipment from Michigan ranges was in 1856, from the Vermilion Range in Minnesota in 1884, and from the Mesabi in 1882. By 1900 the Mesabi Range was shipping over one

fourth of the ore of the Lake Superior district, by 1914 almost one half, and by 1916 about two thirds. It has been shipping about two thirds of the Lake Superior ore even to the present time.

The Mesabi Range came to the attention of the iron men just at the time when inventions for smelting ore with soft coal had reached the point at which ore could be profitably mined in the lake district. The time of the discovery was, then, fortuitous. It solved, to a great extent, the problem of raw materials for a rapidly expanding industrial civilization with iron as its basic material culture trait. This industrial need gave meaning to the previously unutilized ore bodies.

Location in relation to industry

The resources of the Mesabi have been of first importance to contemporary man. Next in importance, probably, has been location with reference to the heart of American industrial life. We have seen that industrial life gradually shifted westward with the development of techniques for smelting iron by the use of soft coal, until the industry was centered in the bituminous coal regions of the lower lake states. Ore is bulky, and the transportation costs are important items in determining the value of a deposit. The location of the Mesabi near the shores of one of the Great Lakes is of the greatest importance.

Ore has been profitably hauled on the Great Lakes from the Mesabi Range to Pittsburgh, a distance of approximately 1,000 miles. It is only 60 to 80 miles by rail from the various mines of the range to lake ports. From these ports ore goes to the lower lake ports by boat and is reloaded on trains and sent to the coal districts for smelting. There is a disadvantage—loading and reloading—but such efficient machinery has been developed that this handicap has been largely overcome. In fact, the ore-handling equipment of the Lake Superior district is known as the most efficient in the world.

At Duluth the ore is dumped from ore trains into dock bins and from the bins into ship holds. At the lower lake ports it is also automatically unloaded and reloaded onto the trains that carry it to the iron-smelting cities. The railroads are exceedingly economical, since they are used almost exclusively for ore and can carry the maximum traffic. The loaded trains can coast most of the way from the Mesabi Range to Duluth.

If it were not for these advantages in the way of water transportation and efficient handling, it is doubtful whether the Mesabi ore could be hauled with profit more than half the distance. The Mesabi ore no longer competes successfully with Cuban, Chilian, Newfoundland, Spanish, and Swedish ores in the eastern cities, but so far these cities have not been important competitors.

The utilization of other resources in the environment

The range cities, recognizing that ore is an exhaustible resource, have tried to plan for the utilization of other resources that will make for an enduring future.

Tourists have in recent years been attracted to the north country during the summer months. While this seasonal trade stimulates business, it cannot assure permanence to the community. The natural resources upon which it depends are also exhaustible. Fish and game, scenery and climate, are the drawing cards. Fish and game conservation measures have to be enforced increasingly to preserve wild life for the future. Cottages and clearings are already marring the landscapes in some sections. Climate will, doubtless, always be an attraction in summer months.

Probably the most permanent type of community can be built around agriculture, for the soil if properly used is inexhaustible. The range towns have recognized the importance of agriculture and have for some twenty years tried to encourage its development. Many Finnish families have turned to agriculture during periods of industrial inactivity or strife, and some have succeeded in making a fair living from the soil, despite the short growing season and the ruggedness of the surface features. One can hardly hope that agriculture will be developed sufficiently to support the towns with their present populations.

Summary

It is clear that the Mesabi, though its resources now appear to be limited largely to ore, has, in the past, provided for other types of adjustment. For the Indian it was a hunting ground; for the lumberman it was a country to exploit and abandon; for the present generation it is a land of permanent settlements where man can live by mining ore; for the Finn it is a land where agriculture is possible; for the tourist it

is a paradise of lakes, fish, scenery, and climate—a place where he can find recreation and rest.

The adjustments made by each group have depended upon its cultural possessions. The various natural resources of the Mesabi have taken on meaning to resident groups only as their culture patterns have been able to utilize them. For this reason, the resources one group has despised, another group has cherished.

There is no question that ore is the only excuse for the present cultural superstructure in the range cities, and that much of the material and nonmaterial culture is simply an adjustment technique fitted to this particular natural resource. It is also clear that upon the exhaustion of ore the present social order must disintegrate, or make adjustments that cannot now be foreseen in detail.

The effect of the cultural impact upon the range is everywhere apparent, as a testimony of man's power to dominate phases of nature and give them meaning in his mode of life. The barren landscapes stripped of timber testify to man's power to exhaust a resource and leave nature as naked and worthless to human industry as a passing hurricane or glacier could have done.

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